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Publisher Address	Sri Siddhartha Academy of Higher Education, Sri Siddhartha Institute of Technology campus , Maralur, Tumkur 572 105 Karnataka Email info@sahe.in
Cheif Editor Address	Dr. Sujatha S.R Professor, Department of Computer Science Engineering, Sri Siddhartha Institute of Technology, Sri Siddhartha Academy of Higher Education, Maralur, Tumakuru - 572105, Email: jir@sahe.in , sujathasr@ssit.edu.in

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CHIEF EDITOR

Dr. Sujatha S. R.
Chief Editor, Professor
Computer Science and Engineering
Sri Siddhartha Institute of Technology,
Maralur, Tumakuru – 572105
jir@sahe.in ,
sujathasr@ssit.edu.in
Mobile : +919986040906
Landlines : +918162200314,
+918162201073

EDITORIAL COMMITTEE

Dr. Batluri Tilak Chandra
Assistant Professor
Mechanical Engineering
Sri Siddhartha Institute of Technology,
Maralur, Tumakuru -572105
batluritilakchandra@ssit.edu.in

Dr. G. S. Sheshadri
Professor
Electrical and Electronics Engineering
Sri Siddhartha Institute of Technology,
Maralur, Tumakuru -572105
sheshadrigs@ssit.edu.in

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Professor
Mechanical Engineering
Sri Siddhartha Institute of Technology,
Maralur, Tumakuru -572105
ravikiranbs@ssit.edu.in

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Professor
Dept of Electronics and telecommunication Engineering
Sri Siddhartha Institute of Technology,
Maralur, Tumakuru -572105
savithadtorvi@ssit.edu.in

Dr. R. Suma
Professor,
Information Science and Engineering
Sri Siddhartha Institute of Technology,
Maralur, Tumakuru -572105
sumar@ssit.edu.in

Dr. S. Guruprasad
Associate Professor,
Medical Electronics
Sri Siddhartha Institute of Technology,
Maralur, Tumakuru -572105
guruprasads@ssit.edu.in

Dr. Pushpalatha K R
Associate Professor
Dept of CSE (data science)
Sri Siddhartha Institute of Technology,
Maralur, Tumakuru -572105
pushpasumukha@gmail.com

Dr. C. Manjunath
Associate Professor,
Physics
Sri Siddhartha Institute of Technology,
Maralur, Tumakuru -572105
manjunathc@ssit.edu.in

Dr. Shobha
Assistant Professor
Department of Mathematics
Sri Siddhartha Institute of Technology,
Maralur, Tumakuru -572105
shobha@ssit.edu.in

Dr. H. V. Prashanth
Professor, Microbiology
Sri Siddhartha Medical College, Agalakote,
Tumakuru – 572107
prashanth.hv@ssmctumkur.org

Dr. J. Ashok
Professor,
Community Medicine
SSIMS & RC, T Begur, Nelamangala - 562123
ashok.j@ssimrc.in

Dr. S. Srinath
Professor, Surgery
Sri Siddhartha Medical College, Agalakote,
Tumakuru – 572107
srinath.s@ssmctumkur.org

Dr. K. R. Suma
Professor, General Medicine
Sri Siddhartha Medical College, Agalakote,
Tumakuru – 572107
sumar.kr@ssmctumkur.org

Dr. K. O. Thejaswini
Professor, Physiology
Sri Siddhartha Medical College, SSIMS & RC, T Begur - 562123
thejaswini.ko@ssimrc.in

Dr. Madhusudhan V
Reader,
Orthodontics
Sri Siddhartha Dental College,Agalakote,
Tumakuru – 572107
madhusudhan.v@ssdctumkur.org

Dr. Kokila G.
Professor, Oral pathology& Microbiology
Sri Siddhartha Dental College,Agalakote,
Tumakuru – 572107
kokila.gd@ssdctumkur.org

Dr. Jagadeesh K. N.
Professor,
Prosthodontics
Sri Siddhartha Dental College,Agalakote,
Tumakuru – 572107
jagadeesh.kn@ssdctumkur.org

Dr. Preethi Bhatt
Reader,
Oral & Maxillofacial surgery
Sri Siddhartha Dental College,Agalakote,
Tumakuru – 572107
preethi.bhatt@ssdctumkur.org

Dr. Mythri H
Reader,
Public health Dentistry
Sri Siddhartha Dental College,Agalakote,
Tumakuru-572107
mythri.h@ssdctumkur.org

Graphics & Design

Dr.B.T.Muddesh
Director
Sri Siddhartha Center for Media Studies, Tumakuru, 572105.
sidharthamediastudies@gmail.com &
Shivakumar.S. Technical assistant. SSCMS.

Dr. Mallika MH
Chief Librarian, Plagiarism section

Ms. Kumudini P.L
Dept. of Humanities, SSIT, Tumakuru, 572105.
kumudinipl1972@gmail.com

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Mobile no.: 9844022363, Landline : 0816-2275516

EDITORIAL

The SSAHE Journal of Interdisciplinary of Research (JIR) serves as a vital platform for scholars, researchers, and practitioners across diverse fields to exchange knowledge and insights by bridging disciplinary boundaries.

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(i) Facilitate interdisciplinary collaboration among researchers from diverse fields; (ii) Promote innovative approaches to address complex global challenges; (iii) Publish high-quality research that integrates multiple perspectives and methodologies and (iv) TO advance understanding and knowledge across disciplinary boundaries.

JIR integrates diverse methods and theories. By addressing complex global challenges, the journal aims to advance knowledge, influence policy, and provide a valuable educational resource. It is dedicated to presenting high-quality, peer-reviewed research with broad implications and applications, ultimately contributing to comprehensive solutions and serving as a bridge between different academic disciplines.

We are pleased to bring out Vol.5, Issue 1 of SSAHE - Journal of Interdisciplinary Research. This volume comprises of 13 research articles, one each from Civil Engineering, Electrical Engineering, Medical Science, Dental Science, Master of Computer Applications, Electronic and Communication Engineering and seven research articles from the domain of Computer Science and Engineering.

Research articles are published immediately in the forthcoming issue soon after the registration. Only quality research articles with practical applicability will be accepted for publication. We extend our gratitude to everyone who has contributed so far and your efforts are greatly appreciated.

- Dr. Sujatha S. R
Chief Editor

A review on Strength and Durability Aspects of Blended Cement Concrete using Sugarcane Bagasse Ash

Gopi. K[1]✉ and B H Manjunath[2]

1. Research Scholar, Sri Siddartha Academy of Higher Education, Agalkote, B. H. Road, Tumakuru, Karnataka – 572107, India
gopiscba@gmail.com
2. Professor and Head, Department of civil Engineering, Sri Siddartha Institute of Technology, Tumakuru, Karnataka – 572105, India
Corresponding author: gopiscba@gmail.com

Abstract

Cement being the vastly used infrastructural material on earth, exhibits its prominence in the construction sector. This growing world has reached a level of saturation in pollution and non-availability of natural resources for the cement manufacturing, has knocked the exploration of many sustainable construction materials. Amongst them, SCBA is a leading material with rich pozzolanic property. The silica composition in SCBA has attracted the researchers to fit its possibilities as a construction material. The comparative study by reviewing the strength and durability properties of SCBA with different compositions and combinations, and the influence of additional parameters such as pretreatment of SCBA and the characterization of SCBA on its performance, were framed to be the main objectives of this review work. This is an attempt to clear the vision on plotting this novel material as an effective and sustainable construction material.

Key Words**:** *Sugarcane Bagasse ash, sustainable construction materials, pozzolanic properties*

1. INTRODUCTION

Currently infrastructural development around the globe is at its peak velocity and meanwhile environmental awareness has also evolved much among the population. This is mainly due to the adverse effects of these non-environmentally friendly materials and the disposal problems of environmentally friendly waste materials. In both ways keen attention is required. Henceforth, the trend towards sustainable construction materials utilizing slags and wastes from the industrial byproducts has emerge to the greater extent from couple of decades. Many of the pozzolanic and supplementary cementitious materials had even entered the codal provision with intense research activities on them. SCBA is once such novel, sustainable construction material with appreciable pozzolanic property

in line with these materials. This current trend on exploring the suitability of this material into the industrial requirements has necessitated the research on its characterization, mechanical and durability performances.

The attempts have been made through the research in all possible dimensions, majorly on its calcination temperature, fineness and the influence of this on its pozzolanic activity. These factors have the major influence on fixing the optimal percentage of SCBA replacement with cement. Now, it is required to extend the study towards strength and durability properties attained by this replacement. Thereby, confidently introducing it as an effective competitor to other available materials. The study conducted by Santhanam et al., [23] and G. Athira et al., [7] has given a confidence about the ease of accessibility of the raw material (SCBA) in India to cope up with its quantitative demand. The extent of sugarcane cultivation and the location of sugar factories has contributed to the regular availability of SCBA on which industrial demand can rely on.

A typical graph on amount of research activities happening around the globe as given in Figure 1 has surprises the researchers about its trend even in 2023. The graph also highlights the motive of replacing SCBA as a blended cement ingredient, concrete ingredient, soil stabilizer, SCBA building blocks etc. Among all, the replacement as a blended cement ingredient is a leading topic of research currently. The reason behind might be its rich silica content (approx. 70% which is greater than in cement), its particle size, ease of availability unlike other waste materials etc.

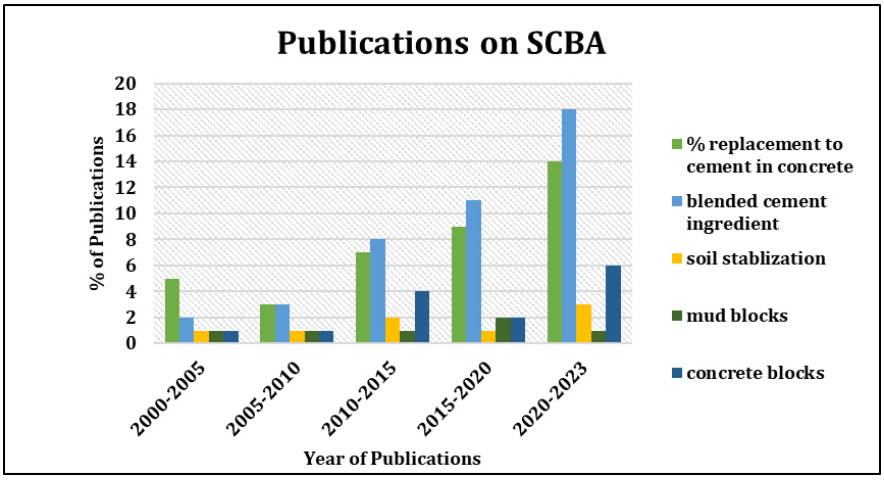

Figure-1: The research publications on SCBA in the interval of years

There are ample studies conducted on its percentage replacement and its influence on mechanical properties and to some extent the durability properties also. An in-depth study on fresh, hardened and also the durability properties is required to relay on SCBA. An overview of research articles being published on this has been plotted in Figure 2 to understand the trend around the globe about this material. In this graph the number of publications chosen were plotted in percentage vs the replacement percentages experimented by various researchers. The graph plotted above has given a clear insight into the percentage replacement range as around 20%. Beyond this the attempts are less, which might infer its optimum effective performance up to 20%. Repeated research on this optimum percentage can be seized to further explore the extended features such as high performance, high strength, fibre reinforced and self-compacting concretes for achieving growth in its application. There were few attempts even on replacement of fine aggregates with SCBA which can even act as a filler material just like quarry dust, marble dust etc.

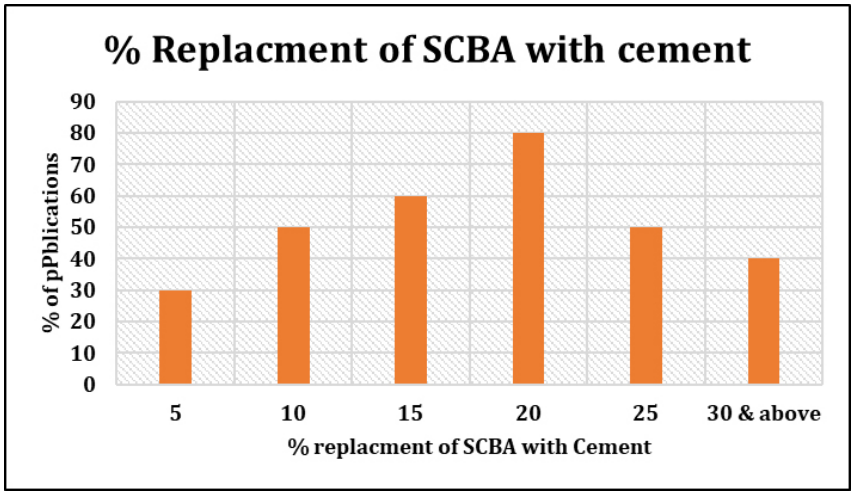

Figure-2: The percentage replacement of SCBA with cement attempted by researchers

2. FRESH PROPERTIES OF SCBA BLENDED CEMENT CONCRETE

The study on the effect of SCBA blending with cement on altering the fresh properties of concrete was less explored. The attempt on exploring the compatibility of plasticizers on slump, compaction factor properties [10] were made with 10, 15, 20% replacement of SCBA with cement. The raw SCBA sample without any preprocessing to achieve uniform particle size requirement, creates a hindrance to the flow properties of the concrete. The Raw SCBA has

the caliber to attain effective pozzolanic property by subjecting it to grinding into fine powder. The raw SCBA has fiber like particle morphology, and this might have created a locking for the other concrete ingredients to flow. Thereby indicating the necessity of applying plasticizers for this combination. The study has arrived at an inference that the poly carboxylic ether-based superplasticizer was a compatible combination with SCBA compared to sulphonated naphthalene-based superplasticizer in blended cements.

The study on flow property by slump test [1] has revealed that the increase in SCBA content can decrease the slump value of the concrete. The study on slump and compaction factor to ascertain the flow properties of the SCBA replaced cement concretes were also explored by Srinivasan et al., [24] Limited studies have been conducted on fresh properties of SCBA blended cement concretes which has noticed it as a grey area of research which needs to be explored as the mass concreting demands pumpable concrete properties, fluidity of the concrete matrix is a prominent area to be explored to assure its application.

3. HARDENED PROPERTIES OF SCBA BLENDED CEMENT CONCRETE

The hardened properties of SCBA based blended cement concrete such as compressive strength, flexural strength, split tensile strength and tensile strength properties were investigated in a vast dimension. It is indeed necessary to explore the principle behind variations in results of SCBA based concrete. Basically, the physical and chemical characterization of SCBA plays an important role in this aspect.

3.1 Influence of characterization of SCBA on Pozzolanic activity

The pozzolanic activity index of SCBA stands to be a significant parameter of concern in deciding the feasibility of sample as a supplementary cementitious material in concrete as a competitor to cement. In this view the hydration process and the hardened properties are directly influenced by physical and chemical characteristics of SCBA.

The composition of the SCBA needs a detailed study to analyze its contribution to enhanced hardened properties as a pozzolanic material. The general composition of SCBA sample gives SiO2 in the range of 60-75 %, Cao and K_2O in major percentage and Al_2O_3, Fe_2O_3, and SO_3 in minor percentage. Andreao et al., [6] has explored two samples of SCBA, one from top wash SCBA which is featured with a low quartz content, and another from bottom wash SCBA sample containing high quartz content. These ashes were investigated in comparison with the control ash where the top SCBA was concluded to be

the more active sample achieving a higher pozzolanic activity. The studies had also explored the influence of calcination temperature, duration of calcination and the contribution of particle size in packing the concrete matrix with the C-S-H formed by the pozzolanic activity of SCBA.

3.2 Influence of Pretreatment and chemical composition of SCBA on Pozzolanic activity

The studies so far have investigated in depth the role of pretreatment on SCBA on its performance as a construction material. Hence, before characterizing the available SCBA, the choice and preprocessing of the source of SCBA needs an intense focus and a preliminary attempt has been made by Mohan et al., [19]. The pretreated SCBA projects to be an effective performance by its pozzolanic activity.

The quantity of silica in SCBA is based on the bagasse burning temperature maintained in the boiler which upon subjected incomplete burning reduces the pozzolanic property indicating the significance of pretreatment of SCBA on properties of concrete. This even causes the SCBA particles courser to retain even above 45μm. It also reduces the specific gravity of the SCBA. Hence it is necessary to study the influence of burning using Chapelle test [17, 9].

The extended studies have also explored the comparative analysis on high carbon content SCBA with the controlled burnt and grinded sample. The grinding adopting closed circuit ball mill achieves a fineness of particles such that passing 10 μm be approximately 50%. The study specifies the burning temperature to be 600 ºC for 1 h using muffle furnace to achieve controlled and complete burning. This process of controlled burning and continued by grinding to obtained finer particles will enhance its reactive property as a pozzolan [12].

3.3 Significance of percentage replacement of SCBA on hardened properties of concrete

The study has focused more on the percentage replacement of 20% SCBA for this investigation [12, 5 & 2] Similar studies with respect to Inter Transition Zone was also conducted by Hussein et al., [14] and the results on 20% replacements holds good. The study from maximum research has arrived elevated compressive strength properties up to 20% replacements, 10% optimum replacement was also reported in some of the studies wwhereas the flexural and tensile strength properties are diminishing with replacement.

To explore the possibility of enhancing the percentage replacements, some of the combinations of SCBA with other sustainable materials were also

explored. As the binding property in comparison with pozzolanic property might be due to lack of free Calcium ions, the combinations with Calcium ions were explored. Some of the lime sources explored are marble dust-25% [20], quarry dust [15], quartz content [6], lime [4] etc. the mechanical properties were positively altered by these combinations to a greater extent.

The study has made by comparing the performance of SCBA based concrete with other industrial wastes such as fly ash and slags. The results were observed as the performance of SCBA based concrete in attaining the early strength is superior compared to fly ash-based concrete[18]. The hardened properties here are better than fly ash and slag-based concretes which seems to be a substantial finding in this study. Even at 3 days of curing the superiority in enhancement of strength property was noticed [12].

The hardened properties were also explored by replacement of SCBA as a sand replacement material. The results of mechanical properties and the elastic modulus were encouraging in comparison with ordinary cement [22, 1 & 24]. Similar studies were also conducted [1] to check its suitability as a fine aggregate replacement and the findings at 28 days curing were appreciable.

The flexural and tensile strengths were noticed to be reducing with the SCBA replacement has been investigated for enhancement using polypropylene fibers about 1% [2], and other fibre samples. Positive results were noticed in flexural and tensile strength properties in these investigations. It is necessary to come up with standard procedure to preprocess the SCBA sample to fit in into the industrial demand with consistent performance irrespective of the source of sugarcane bagasse ash. There were many such studies on characterizing the sample to check its influence on hardened properties as a blended cement concrete. Attempts were also made by the researchers to adapt this material for building blocks by noticing its positivity in hardened properties [16], Even mud blocks in combination with SCBA (0 to 8%) were also explored to utilize this novel material which is rich in silica [14] and soil blocks were also reported [14]. There is also an input that ambient curing will add-on to its performance enhancement especially in alkali activated combinations.

4. DURABILITY PROPERTIES OF SCBA BLENDED CEMENT CONCRETE

The durability aspects of SCBA blended cement concrete have been explored in significant dimensions by the researchers and efforts have been made to freeze the percentage replacement of SCBA based on its performance in promoting a dense microstructure, thereby enhancement the impermeable solid concrete matrix [8]. The internal mechanism is that the SCBA particles

being pozzolanic with finer particle size will have enriched pozzolanic activity in presence of $CaOH_2$ by the initial hydration process. The particle being finer will participate in hydration reaction efficiently and thereby assure an ample amount of secondary hydration products.

The influence of fine particles of SCBA subjected to fine grinding recalcination as experimented by various researchers in the enhancement of durability properties seems to be a significant point to be considered to promote it as a Supplementary cementitious material.

The acid attack test conducted by V. S. Athira et al., [8], has tried to combine SCBA with fly ash-based binders in comparison with slag-based binders and has noticed superior durability properties by bringing down the drying shrinkage and acid attack on Agro waste ash samples such as SCBA gives a positive backup for its application. Minnu et al., 2021 [18] also examined the SCBA samples comparing with established SCM's such as fly ash and GGBS in terms of resistance to chloride and water permeation. The water permeability along with resistance to chloride attack was also reported for SCBA replaced blended concrete.

The investigation proves the superior performance of SCBA blended concrete compared to fly ash and slag blended concrete. Similar results were noticed for abrasion resistance and permeability resistance in SCBA blended concrete by Murugesan et al., [20]. Mahima et al., [17] has extended the durability studies to the role cover depth in enhancing the service life of concrete structures. The rapid chloride penetration test (RCPT), chloride conductivity test, water Sorptivity test, and Torrent air permeability test were also explored on SCBA sample by Bahurudeen et al., [9] and by Amin et al., [5] to assure the suitability of SCBA in enhancing the durability of concrete. The durability studies were extended even to corrosion inhibition by Nunez-Jaquez et al., [21] using 20% SCBA replaced reinforced members. The studies have even proven the role of SCBA in densifying the microstructure. The corrosion inhibition study was also reported, and the results were promising for SCBA based combinations with lowest corrosion rates in comparison with other additives such as fly ash, rice husk ash and micro silica. Pore refinement is the main achievement to come up with this corrosion inhibition.

The studies which need an in-depth investigation by comparing the reviews articles are, the durability by Sorptivity, fire resistance test, the pozzolanic reactions at later stages are required to test the samples for longer period of curing. Water absorption and density of SCBA based samples need to be thoroughly examined. Paste, mortar, concrete studies is required.

5. DISCUSSION

It is important to understand and analyze the SCBA sample as a replacement to cement since its composition suits the pozzolanic material. SCBA being the right material to be introduced as a supplementary cementitious material because of its ease of availability with high content of amorphous silica also. The SCBA, drawing the attention of the industry by its significant features as a SCM, need an in-depth characterization. Researchers had explored through enormous methods of charactering the SCBA in all possible directions. Even then the SCBA is taking time to get introduced into the industry. The reason behind might be the optimum percentage, optimum characterizations and criteria to conclude the suitability of the available sample of SCBA. Hence it is essential to compare the characterizations undergone by the researchers in various dimensions and come up with a set of optimum characterizations to evaluate its effective performance as a pozzolanic material through systematic characterization process to achieve effective adaption as a supplementary cementitious material.

The fresh properties of SCBA based blended concrete, which were explored limitedly needs an intense focus especially for mass concrete productions. Substantial studies were conducted on hardened properties to freeze the percentage replacement of SCBA but 20% can be investigated to enhanced percentage replacements by blending with other suitable additives. Flexural and tensile strength of the SCBA based concrete needs to be explored in further stages. The durability tests such as Sorptivity as per ASTM 1585 C13, fire resistance, corrosion inhibition, resistance to permeability were indeed necessary to promote SCBA sample confidently as a sustainable industrial product. Since the pozzolanic reactions are at later stages it is required to test the samples for a longer period of curing to assure its durability properties. Water absorption and density of SCBA based samples need to be thoroughly examined into the Paste, mortar, concrete combinations. The durability enhancement has been noticed in maximum studies which project the role of particle size in pore refinement and densification of microstructure and the results were promising. This category is a need of the hour to come up with a durable blended concrete compared to other blended slag concretes.

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REFERENCES

1. Aizaz Dayo, A., Kumar Hindu, A., Shaikh, H., Kumar, A., Raja, A., Bheel, N., & Hussain Shaikh, Z. (2019), "Use of Sugarcane Bagasse Ash as a Fine Aggregate in Cement Concrete Effect of Sugarcane Bagasse Ash and Limestone Fines on the Mechanical Properties of Concrete View project Rice Husk Ash and Fly Ash Effects on the Mechanical Properties of Concrete View project In Engineering Science and Technology" *International Research. Journal, Vol. 3, Issue 3*. https://www.researchgate.net/publication/336639408

2. Akbar, A., Farooq, F., Shafique, M., Aslam, F., Alyousef, R., & Alabduljabbar, H. (2021). "Sugarcane bagasse ash-based engineered geopolymer mortar incorporating propylene fibers", *Journal of Building Engineering,* https://doi.org/10.1016/j.jobe.2020.101492.

3. Akkarapongtrakul, A., Julphunthong, P., & Nochaiya, T. (2017), "Setting time and microstructure of Portland cement-bottom ash–sugarcane bagasse ash pastes". *Monatshefte Fur Chemie*, 148(7), 1355–1362. https://doi.org/10.1007/s00706-017-1953-5.

4. Alavéz-Ramírez, R., Montes-García, P., Martínez-Reyes, J., Altamirano-Juárez, D. C., & Gochi-Ponce, Y. (2012), "The use of sugarcane bagasse ash and lime to improve the durability and mechanical properties of compacted soil blocks", *Construction and Building Materials*, 34, 296–305. https://doi.org/10.1016/j.conbuildmat.2012.02.072.

5. Amin, N. (2011), "Use of Bagasse Ash in Concrete and Its Impact on Strength and Chloride Resistivity" *Journal of Materials in Civil Engineering,* 23(5), 717–720. https://doi.org/10.1061/(asce)mt.1943-5533.0000227.

6. Andreão, P. V., Suleiman, A. R., Cordeiro, G. C., & Nehdi, M. L. (2019), "Sustainable use of sugarcane bagasse ash in cement-based materials" *Green Materials,* 7(2), 61–70. https://doi.org/10.1680/jgrma.18.00016.

7. Athira, G., Bahurudeen, A., & Vishnu, V. S. (2021), "Quantification of geographical proximity of sugarcane bagasse ash sources to ready-mix concrete plants for sustainable waste management and recycling", *Waste Management and Research,* 39(2), 279–290. https://doi.org/10.1177/0734242X20945375.

8. Athira, V. S., Charitha, V., Athira, G., & Bahurudeen, A. (2021), "Agro-waste ash-based alkali-activated binder: Cleaner production of zero cement concrete for construction" *In Journal of Cleaner Production (Vol. 286). Elsevier Ltd.* https://doi.org/10.1016/j.jclepro.2020.125429.

9. Bahurudeen, A., Kanraj, D., Gokul Dev, V., & Santhanam, M. (2015), "Performance evaluation of sugarcane bagasse ash blended cement in concrete" *Cement and Concrete Composites*, 59, 77–88. https://doi.org/10.1016/j.cemconcomp.2015.03.004.

10. Bahurudeen, A., & Santhanam, M. (2014), "Performance evaluation of sugarcane bagasse ash-based cement for durable concrete" Proceedings of the *4th International Conference on the Durability of Concrete Structures, ICDCS* 2014, 275–281. https://doi.org/10.5703/1288284315412.

11. Cordeiro, G. C., Andreão, P. V., & Tavares, L. M. (2019), "Pozzolanic properties of ultrafine sugar cane bagasse ash produced by controlled burning". *Heliyon,* 5(10). https://doi.org/10.1016/j.heliyon.2019.e02566.

12. Cordeiro, G. C., Toledo Filho, R. D., Tavares, L. M., & Fairbairn, E. de M. R. (2009), "Ultrafine grinding of sugar cane bagasse ash for application as pozzolanic admixture in concrete", *Cement and Concrete Research*, 39(2), 110–115. https://doi.org/10.1016/j.cemconres.2008.11.005.

13. Hussein, A. A. E., Shafiq, N., Nuruddin, M. F., & Memon, F. A. (2014), "Compressive strength and microstructure of sugar cane bagasse ash concrete" *Research Journal of Applied Sciences, Engineering and Technology*, 7(12), 2569–2577. https://doi.org/10.19026/rjaset.7.569.

14. Lima, S. A., Varum, H., Sales, A., & Neto, V. F. (2012), "Analysis of the mechanical properties of compressed earth block masonry using sugarcane bagasse ash", *Construction and Building Materials,* 35, 829–837. https://doi.org/10.1016/j.conbuildmat.2012.04.127.

15. Madurwar, M. V, Mandavgane, S. A., & Ralegaonkar, R. V. (2014a). "Use of sugarcane bagasse ash as brick material", *in current science* Vol. 107, Issue 6.

16. Madurwar, M. V, Mandavgane, S. A., & Ralegaonkar, R. V. (2014b). "Use of sugarcane bagasse ash as brick material", *in current science* Vol. 107, Issue 6.

17. Mahima, S., Bahurudeen, A., Santhanam, M., & Jayachandran, K. (2017), "Service Life Prediction of Bagasse ash Blended Concrete in Marine Splash Zone", *Materials Today: Proceedings,* 4(9), 9664–9672". https://doi.org/10.1016/j.matpr.2017.06.244.

18. Minnu, S. N., Bahurudeen, A., & Athira, G. (2021), "Comparison of sugarcane bagasse ash with fly ash and slag: An approach towards industrial acceptance of sugar industry waste in cleaner production of cement", *In Journal of Cleaner Production* Vol. 28, *Elsevier Ltd.* https://doi.org/10.1016/j.jclepro.2020.124836.

19. Mohan, R., Athira, G., Mali, A. K., Bahurudeen, A., & Nanthagopalan, P. (2021). "Systematic Pretreatment Process and Optimization of Sugarcane Bagasse Ash Dosage for Use in Cement-Based Products", *Journal of Materials in Civil Engineering*, 33(4). https://doi.org/10.1061/(asce)mt.1943-5533.0003650.

20. Murugesan, T., Vidjeapriya, R., & Bahurudeen, A. (2021), "Sustainable use of sugarcane bagasse ash and marble slurry dust in crusher sand-based concrete", *Structural Concrete*, 22(S1), E183–E192. https://doi.org/10.1002/suco.202000215.

21. Nunez-Jaquez, R. E., Buelna-Rodriguez, J. E., Barrios-Durstewitz, C. P., Gaona-Tiburcio, C., & Almeraya-Calderón, F. (2012), "Corrosion of modified concrete with sugar cane bagasse Ash", *International Journal of Corrosion,* https://doi.org/10.1155/2012/451864.

22. Sales, A., & Lima, S. A. (2010), "Use of Brazilian sugarcane bagasse ash in concrete as sand replacement" *Waste Management,* 30(6), 1114–1122. https://doi.org/10.1016/j.wasman.2010.01.026.

23. Santhanam, M., Bahurudeen, A., & Vaisakh, K. S. (2015), "Availability of sugarcane bagasse ash and potential for use as a supplementary cementitious material in concrete", *In Article in Indian Concrete Journal.* https://www.researchgate.net/publication/280100729.

25. Srinivasan, R., & Sathiya, K. (2010). "Experimental Study on Bagasse Ash in Concrete", *International Journal for Service Learning in Engineering*, 5(2), 60–66.

A Cost Effective Strategy for Optimizing the Positioning of Replica Servers to Improve Service Delivery in a Cloud-Based Content Delivery Network

Priyanka Dharmapal[1]✉, Channakrishnaraju[2]

[1] *Research Scholar, Department of Computer Science and Engineering, SSAHE University, Tumkuru, Karnataka, India*

[2] *Professor, Department of Computer Science and Engineering, SSIT, Tumkuur, Karnataka, India*

Email: prsh2019@gmail.com

Abstract

One of the most important considerations for a given geographic diversity connected with placement issues in Content Delivery Network (CDN) is the location of Replica Servers. Following a review of the literature, it became clear that research were focused more on traditional CDN placement issues than cloud-based CDN architectures, and the few studies that did focus on replica selection were still in their infancy. Such models are additionally not benchmarked or objectively evaluated to demonstrate their efficacy. Therefore, the suggested study provides a novel computational framework architecture that is linked to a cloud-based CDN and can make replica server management more affordable for better service delivery. The simulated study results, which were implemented utilizing analytical research methods, reveal that the proposed strategy delivers reduced cost, reduced resource dependency, and reduced resource consumption when it is implemented utilizing analytical research approach.

Key words: *Replica server, cost, content delivery network, resource, cloud*

1. INTRODUCTION

There is a need for an efficient networking technology to help in providing the smooth services regardless of traffic condition in a dedicated manner due to the increasing demands for data and service availability. One such solution is a Content Delivery Network (CDN), which uses a surrogate server and content placement to help deliver the content fast and effectively [1] through [5]. Although there are a number of stated benefits to using a CDN system to speed up data delivery, there are also a number of difficult conditions [6]. The main issue with CDN implementation is that it involves a significant financial

investment and an extremely complex deployment process [7]. Based on a number of research, it has been determined that CDN enabled technologies currently use cloud computing more [8]. This adoption offers advantageous features for resource allocation, pay-per-use, hosting service supportability, and service provisioning [9]. It should be mentioned that the role of the replica server, which is in charge of copying the original material to the content replica server, is crucial to the overall functioning of the CDN. Despite the several ways being used to improve the content placement algorithm, there is still a significant trade-off between the needs of the user and the replica server's current level of operation. The main problem with replica server placement is related to the optimization problem, which can be either of the constraint or unconstrained kind. In the current system, which considers network topology, network performance metrics, latency, the number of hops, and other factors, there is not much emphasis placed on the deployment cost of the replica server, as well as its associated delivery cost and update cost.

In addition, there are a number of theoretical models that have been given in previous research that examine the location of the facility with both capacitated and incapacitated variants while taking constraints such server capacity into account. Other methods used in previous studies include K-median, minimal K- centre, K-cache location, etc. in order to localize the replica server [10]. A detailed analysis of the current plan reveals that the bulk of methods for placing replica servers are based on traditional CDNs rather than cloud-based CDNs. The primary distinction between these two approaches is that while cloud-based CDN are extremely distributed and still have the potential to be centralized to create a vast network, conventional CDN are somewhat centralized. When a standard CDN is exposed to difficulties with greater traffic conditions as well as the unpredictable behaviour of many services and applications running over it, it will imply that there are numerous unavoidable obstacles to be confronted. In the context of the entire scenario, it should be highlighted that the cloud-based CDN system places less focus on leveraging the virtualized environment to expand the reach of replica servers [11]. Even though it is practically impossible to place the content server in several different locations, the cost can be greatly reduced if the virtualized environment (or machine) that already exists can be divided into local and global forms in order to provide connectivity on both a small- and large-scale. In order to enable better networking in a cloud-based CDN system [12], it is crucial to conduct an inquiry in this direction to understand the impact of employing local virtual machines as well as proxies [13]. Understanding how spatial variables affect the location of the replica server in the cloud-based CDN and their potential

effects on large-scale networks is also crucial. Therefore, the suggested study also conducts a deeper analysis of current literatures in order to examine these possibilities. It is discovered that studies are more focused on placing content and less on placing replica servers while installing the virtualized environment [14].

The majority of current studies have focused on the crucial QoS attribute; however, it is also crucial to take into account the user's experience, which is not often reported to be emphasized. ii) Current approaches have deployed a mechanism taking into account different types of files; however, such schemes are not very effective when deployed under a situation of non-uniform distance between content server and replica server, and iii) further, non-utilization of virtual machines Using local virtualized machines and proxies connected to a centralized content server that is further maintained in a distributed fashion, the proposed approach discussed in this research proposes a novel replica server placement. The major goal of this effort is to provide comparable user experience quality and service quality in the face of changing traffic conditions in an economical way.

The discussion of relevant literature is as follows: In our previous review, we explored various approaches and techniques aimed at enhancing the performance of Content Delivery Networks (CDNs) [15]. Currently, there are several ongoing efforts that directly or indirectly contribute to improving CDN performance.

Kalghoum et al. [16] have conducted work focusing on a probability-based model to manage stalling events in streaming services within CDNs. Their model is built upon the concept of limited storage space in caches and efficient allocation of CDN resources to enhance streaming delivery. Additionally, Ghasemi et al. [17] have presented an optimized model for content placement, employing a belief propagation system within a distributed network. This comprehensive model follows a sequential flow, involving a content helper selection mechanism, content caching, and precise content delivery to the intended destinations. Their iterative approach to modeling takes into account the states of communication channels and content popularity, with a particular emphasis on controlling energy consumption in wireless networks. Huang et al. [18] have conducted research on an allocation model for replica servers, claiming it to be both energy-efficient and reliable. Their model facilitates concurrent task processing on the primary server, which is connected to a dedicated storage point.

Cheng et al. [19] have developed a model for data replication with a primary focus on enhancing data availability within a complex, weighted network, taking

centrality factors into account. Their model also assesses graph partitioning attributes while storing data replicas in fog devices. In this model, one unit stores fog information and a single data replica, while the other unit stores all file replicas using a greedy-based approach. Goudarzi and Pejman [20] have emphasized the significance of caching mechanisms, particularly in large distributed networks. Their study underscores that there are still unresolved issues related to caching mechanisms that require attention. Fan et al. [22] have highlighted the importance of vertex markers as a means to discuss potential improvements in grid methods. Their work explores possible adjustments to scale within grid-based approaches.

The suggested document is divided into the following sections: Section 1 addresses the introduction, while Section 2 describes the approach being used, Section 3 examines the results being achieved, and Section 4 discusses the paper's conclusion.

2. METHODOLOGY

The main goal of this phase of research is to create a cutting-edge model that can execute resource provisioning to ensure better replica server placement in a dynamic distributed cloud-based CDN system. Utilizing an analytical research technique, the suggested system begins its design by taking into account a multi cloud system employing a communication model, as illustrated in Figure 1.

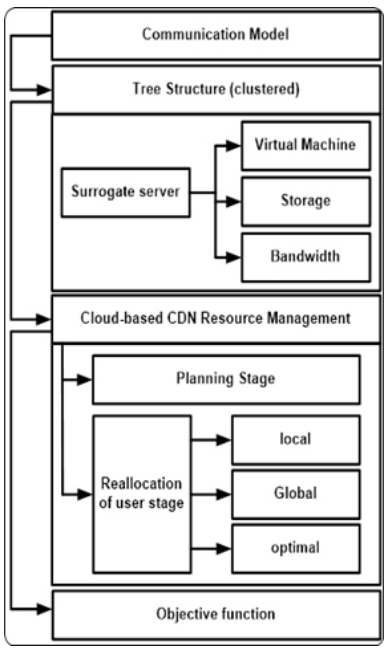


Figure-1: Communication Model

The suggested system uses a highly clustered tree structure to simplify the topology design. According to this tree structure, a dedicated cloud system using surrogate servers that are further integrated with virtual machine, storage, and bandwidth operations serves each user. The creation of a cloud-based CDN resource management system falls under the following phase of implementation, which is further divided into the planning stage and the reallocation of user stage. The cost model will be used by the proposed system to determine how much it would cost to allocate resources under the current situation. The third set of activities are carried out toward resource provisioning in the subsequent stage of user reallocation while taking formulation of realistic restrictions and obtaining maximal optimality in replica server placement into consideration. In order to effectively position replica servers in a cloud-based CDN system, an objective function will be built that can balance the resource provisioning demands with dynamic content delivery system. It is believed that this phase of implementation would result in the cloud-based CDN performing at its best. To evaluate the impact of several network parameters, such as channel capacity, cost, uncertain traffic scenario, etc. on the model, a test environment will be built. The model is expected to display less computational complexity as well. The research approach used for the implementation briefed in regard to system design and algorithm implementation is discussed in the following part.

2.1 SYSTEM DESIGN

In order to provide higher service availability via cloud networks, the main system design of the proposed method is based on the position and closeness of the replica server and the proxy cache. This plan takes into account a Centralized Content Server (CCS), which is situated uniformly close to several local virtual machines (LVM), and which stores data on replica servers and proxy cache.

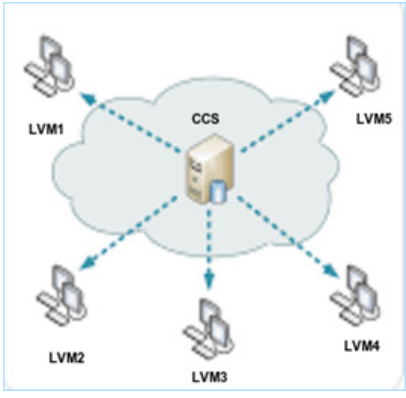


Figure-2: Scheme of Replica Server placement

The placement strategy of the replica server is highlighted in Figure 2 above where ith multiple observation zone Oz exists, i.e., Ozi=[Oz1, Oz2,...Ozi] where the deployment of LVM is done. It will imply that each Oz will contain a particular number of LVM (based on the distribution of Oz). It can be stated mathematically as follows:

$$LVM_i=[P_i, R_i]^{\alpha\beta} \quad (1)$$

Algorithm for Cost-based Replica Server Placement

Input: No, Ne, LVM, i, P
Output: ω
Start
1. Initial network [No, Ne (LVMj), P]
2. G →(No, Ne) P
3. μ = θ (G)
4. formulate matrix G=[μ, IL, OL]
5. Extract new tree= Φ (G)
6. Lt=(G, cond(probability))
7. ω =ρ(μ)
   end

In the above algorithm the input of origin node is No,last node is Ne, local virtual machine LVM, number of LVM j, and service given by the content delivery network is P that will give the final result as ω.The initial task of the above algorithm is to initialize the exact number of local virtual machine by taking the placement strategy and its connectivity with origin node and last node(line-1).the next stage of implementation consists of constructing a graphical tree G for connecting all the nodes and links in the form of a network topology in distributed and very large scale(Line-2). With the help of centrally located CCS it constructs a distributed scheme of replica server placement(Line-3).The calculation of the middle location is obtained by the score of each LVM that is divided with respect to available least quantity nodes. The output of this operation gives the score of importance attribute θ the specific function specific function μ(Line-3) After calculation of important attribute the algorithm will generate a two dimensional matrix, incoming link IL, and outgoing link OL (Line-4). This stage helps to build a distributed network links connecting all the LVMs in different places. This assessment is performed for the purpose of assessing the consistency of the new algorithm in order to acquire less delay by taking multiple locations of the LVM links with the replica server in specific Oz. After this task is accomplished, the algorithm deploys another function ω that constructs a diagraph tree structure G over the existing tree (Line-5). The system than generates a local tree Lt by

taking the newly generated tree G with the embedded condition (Line-6).When probability prob is statistically significant when the condition cond is formed with Lt .In the last step, an explicit function ρ is formed that performs final estimation of the cost ω which is linked with the placement of surrogate server at the time of transmission of data. (Line-7).

3. RESULTS AND DISCUSSION

In the preceding section, it was observed that the proposed approach introduces an innovative mechanism for placing replica servers to enhance performance within a distributed CDN system hosted in the cloud. Consequently, it is crucial to outline a definitive evaluation strategy to ensure improved data transmission performance in variable test environments within the CDN. The algorithm for the proposed system is implemented in MATLAB, with a focus on achieving a tree-like structure for server deployment, where the cost associated with replica server placement serves as the primary factor for result analysis. Table 1 presents an analysis of the costs associated with individual LVMs situated across various orientations while considering the central location of CCS (Content-Centric Storage). To evaluate the proposed scheme, a bipartite graph is constructed as part of the assessment process.

Table-1: simulation parameters

Simulation Parameter	Values Assigned
Total deployment areas of LVM	9
Total replica server	10
Bandwidth assigned for replica server	5000 mbps
Total proxy (cache)	25
Bandwidth assigned for proxy	3000 mbps

Utilizing the simulation parameters and their respective values presented in Table 1, the proposed system conducts cost estimation for individual LVMs in nine distinct circular positions, with CCS located at its centre. The comprehensive analysis is performed using variable-sized random data packets, each containing 3000 bytes, within a simulation area measuring 1000 x 1000 m^2, and it involves the presence of 500 nodes. The assessment takes into account randomly selected origin and end nodes. The individual cost outcomes for the nine different locations are displayed in Table 2, and this assessment is conducted over 50 iterations.

Table-2: Estimated Cost

Location	LVM No	ω
LVM_2	7	4
LVM_4	6	0
LVM_1	3	28
LVM_3	1	7
$LVM_2 \rightarrow LMV_1$	2	11
$LVM_2 \rightarrow LVM_3$	8	29
$LVM_4 \rightarrow LVM_1$	5	1
$LVM_4 \rightarrow LVM_3$	9	21
CCS	4	25

Figure-3:highlights the outcomes related to the estimated cost of replica server placement, demonstrating an impressive gain of approximately 45.2% compared to existing schemes such as the QoS-aware [20] and consistency-aware algorithms [20], which are commonly employed in replica server placement. The existing QoS-aware approach is known for its predefined computations, where the system determines its network topology to achieve a specified target Quality of Service (QoS) through Load Virtual Machines (LVMs) for processing generated queries. However, this static characteristic of the QoS-aware approach becomes problematic as it encounters increased traffic, leading to higher costs associated with replica server placement allocation.

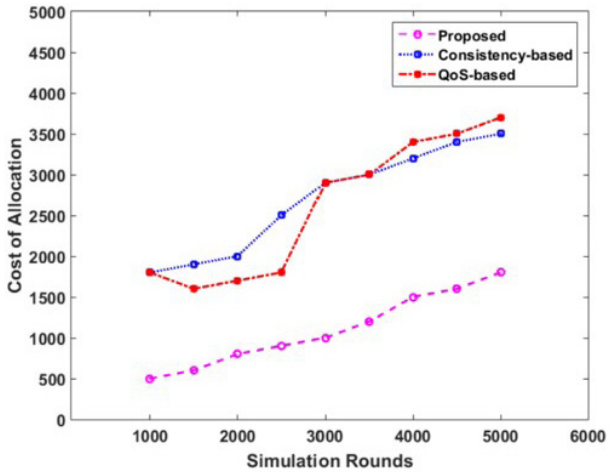


Figure - 3: Comparative Evaluation of Cost of Replica Server Placement

4. CONCLUSION

The primary contribution of the study model being proposed is the development of an innovative approach for cost-effective positioning of replica servers, specifically tailored to the use case of cloud-based CDN systems. The contributions of this proposed model can be summarized as follows: It introduces a unique method for computing costs when constructing the network's record structure, which reduces the reliance on a larger number of replica servers. This reduction in server dependency ultimately leads to cost savings in data transmission. The proposed scheme incorporates a novel concept of utilizing local virtual machines to replace traditional content servers, resulting in cost reduction. This adaptation enhances virtualization efficiency, creating an extensive chain of highly indexed structures that significantly improve data and service availability. The replica server placement strategy outlined in the proposal places equal emphasis on enhancing the user's experience and maintaining service quality. The study's findings demonstrate that the proposed system outperforms existing schemes, showcasing significantly improved performance.

REFERENCES

1. Liu, Xuan, Zhuo Li, Peng Yang, and Yongqiang Dong. "Information-centric mobile ad hoc networks and content routing: a survey." *Ad Hoc Networks* 58 (2017): 255-268

2. Stocker, Volker, Georgios Smaragdakis, William Lehr, and Steven Bauer. "The growing complexity of content delivery networks: Challenges and implications for the Internet ecosystem." *Telecommunications Policy* 41, no. 10 (2017): 1003-1016

3. Xu, Yanli, Xujie Li, and Jun Zhang. "Device-to-device content delivery in cellular networks: Multicast or unicast." *IEEE Transactions on Vehicular Technology* 67, no. 5 (2017): 4401-4414.

4. Xu, Changqiao, Wei Quan, Athanasios V. Vasilakos, Hongke Zhang, and Gabriel-Miro Muntean. "Information-centric cost-efficient optimization for multimedia content delivery in mobile vehicular networks." *Computer Communications* 99 (2017): 93-106.

5. Amadeo, Marica, Claudia Campolo, and Antonella Molinaro. "A novel hybrid forwarding strategy for content delivery in wireless information-centric networks." *Computer Communications* 109 (2017): 104-116.

6. Shuai, Qianjun, Keqin Wang, Fang Miao, and Libiao Jin. "A cost-based distributed algorithm for load balancing in content delivery network." *In 2017 9th International Conference on Intelligent Human-Machine Systems and*

Cybernetics (IHMSC), vol. 1, pp. 11-15. IEEE, 2017.
7. Bajpai, Vaibhav, Saba Ahsan, Jürgen Schönwälder, and Jörg Ott. "Measuring YouTube content delivery over IPv6." *ACM SIGCOMM Computer Communication Review* 47, no. 5 (2017): 2-11.
8. Kyryk, Maryan, Nazar Pleskanka, and Maryana Pleskanka. "Content delivery network usage monitoring." In *2017 14th International Conference The Experience of Designing and Application of CAD Systems in Microelectronics (CADSM)*, pp. 306-308. IEEE, 2017.
9. Shojafar, Mohammad, Zahra Pooranian, Paola G. Vinueza Naranjo, and Enzo Baccarelli. "FLAPS: bandwidth and delay-efficient distributed data searching in Fog-supported P2P content delivery networks." T*he journal of supercomputing* 73, no. 12 (2017): 5239-5260
10. Chu, Weibo, Mostafa Dehghan, John CS Lui, Don Towsley, and Zhi-Li Zhang. "Joint cache resource allocation and request routing for in-network caching services." *Computer Networks* 131 (2018): 1-14.
11. Poirion, Pierre-Louis, Jérémie Leguay, and Liu Ruosi. "Scalable request routing for VR-ready CDNs." *In 2018 21st Conference on Innovation in Clouds, Internet and Networks and Workshops (ICIN)*, pp. 1-6. IEEE, 2018.
12. Yang, Hui, Hewu Li, and Qian Wu. "An integrating unicast and multicast solution by extending content delivery network to satellite." I*n 2018 14th International Wireless Communications & Mobile Computing Conference (IWCMC)*, pp. 1414-1419. IEEE, 2018.
13. Sarkar, Darothi, Nitin Rakesh, and K. K. Mishra. "Population-based clustering to enhance the utilization of surrogate in Content Delivery Networks." *Intelligent Decision Technologies* 12, no. 4 (2018): 453-460.
14. Vu, Thang X., Symeon Chatzinotas, and Björn Ottersten. "Blockchain-based content delivery networks: Content transparency meets user privacy." *In 2019 IEEE Wireless Communications and Networking Conference (WCNC)*, pp. 1-6. IEEE, 2019.
15. Cui, Xin, Xiaohong Huang, Yan Ma, and Qingke Meng. "A load balancing routing mechanism based on SDWSN in smart city." *Electronics* 8, no. 3 (2019): 273.v
16. Kalghoum, Anwar, and Leila Azouz Saidane. "Fcr-ns: a novel caching and forwarding strategy for named data networking based on software-defined networking." *Cluster Computing* 22, no. 3 (2019): 981-994.
17. Ghasemi, Hamid, Mahdi Jafari Siavoshani, and Saeed Hadadan. "A Novel Communication Cost Aware Load Balancing in Content Delivery Networks using Honeybee Algorithm." a*rXiv preprint arXiv*:1902.04463 (2019).
18.Huang, Lemei, Yu Guan, Xinggong Zhang, and Zongming Guo. "Consistent

Dynamic Server Assignment in Content Delivery Network." *CoRR (2019).*
19. Cheng, Yinhang. "Routing-Independent Anycast For IPv6 Content Delivery Networks." PhD diss., Case Western Reserve University, 2019.
20. Goudarzi, Pejman, and Mahmoud Mousavinejad. "A Lyapunov optimization approach to energy-efficient content delivery networks." *Simulation* 96, no. 3 (2020): 269-280
21. Harahap, Erwin, Yusuf Fajar, Dadi Ahmadi, Abdul Kudus, and Rakhmat Ceha. "Modeling of request routing management on router for content delivery network." *International Journal of Scientific & Technology Research* 9 (2020): 308-14.
22. Q. Fan, H. Yin, L. Jiao, Y. Lyu, H. Huang and X. Zhang, "Towards Optimal Request Mapping and Response Routing for Content Delivery Networks," in *IEEE Transactions on Services Computing*, vol. 14, no. 2, pp. 606-613, 1 March-April 2021, doi: 10.1109/TSC.2018.2796567.
23. Omotunde, A. A., S. O. Okolie, Y. A. Adekunle, A. A. Izang, and O. O. Ebiesuwa. "Request-Routing for Content Delivery Networks (CDN)." I*nternational Journal of Advanced Research in Computer Science* 6, no. 6 (2021).
24. Ghaznavi, Milad, Elaheh Jalalpour, Mohammad A. Salahuddin, Raouf Boutaba, Daniel Migault, and Stere Preda. "Content Delivery Network Security: A Survey." *IEEE Communications Surveys & Tutorials* (2021).
25. Varshney, Pulkit, Sanchit Gaur, and Satya Pal. "A novel approach of Load Balancing in Content Delivery Networks by optimizing the surrogate server." In *2021 11th International Conference on Cloud Computing, Data Science & Engineering (Confluence)*, pp. 790-795. IEEE, 2021.
26 Ghaznavi, Milad, Elaheh Jalalpour, Mohammad A. Salahuddin, Raouf Boutaba, Daniel Migault, and Stere Preda. "Content Delivery Network Security: A Survey." *IEEE Communications Surveys & Tutorials* (2021).
27. H. Hu, Y. Wen, T. Chua, J. Huang, W. Zhu, and X. Li, "Joint Content Replication and Request Routing for Social Video Distribution Over Cloud CDN: A Community Clustering Method," in *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 26, no. 7, pp. 1320-1333, July 2022, doi: 10.1109/TCSVT.2015.2455712.
28. Priyanka D, Channakrishnaraju, Chethan B K "Insights on Effectiveness Towards Research Approaches Deployed in Content Delivery Network", in the Springer Series: "Software Engineering Perspectives in Systems" in the *proceedings of 11th Computer Science Online Conference* 2022, Volume 1, (CSOC2022).
29. Priyanka D, Channakrishnaraju, Chethan B K "A Novel Cost-based Replica

Server Placement for optimal service quality in cloud-based Content Delivery Network-"*International Journal of Electrical and Computer Engineering*" Scopus based Q2 Journal- ISSN 2088-8708, VOL-13-2023
30. C. Xu, C. Xu, and B. Li, "Multi-agent deep Q-network based dynamic controller placement for node variable software-defined Mobile Edge-Cloud Computing Networks," *Mathematics*, vol. 11, no. 5, p. 1247, 2023, doi: 10.3390/math11051247.

Homomorphic Cryptosystem for Protected Data Transmission for Wireless Sensor Networks

Prathibha S.B [1],✉ Supriya M.C[2]

[1]Research scholar, Sri Siddhartha Academy of Higher education, Tumkur, India . Assistant professor, Sri Siddhartha Institute of Technology, Tumkur, India

[2] Professor, Sri Siddhartha Institute of Technology, Tumkur, India.

corresponding author: prathibhasb@gmail.com

Abstract

Wireless Sensor Networks (WSNs) attain much attention in different areas due to their self- configurability, maintenance and scalability features. WSN is configured with more nodes to transfer the data inside the network. The sensor networks are generally considered based on low bandwidth, limited energy, limited power supplies and small size memory, which leads to demand for the environment to provide security. The objective is to accomplish the data security of the network by the Homomorphic Cryptosystem (HC). In this paper we have proposed a method in two level security indirection to secure data transmission over the WSN. In first phase, the secure gathering and routing procedure are achieved by means of the Multi-Objective Trust-based Bat Optimization Algorithm (MOTBOA). In later phase, the data security of the network is upgraded by the enhanced (HC) to offer secure communication in SensorNetworks. It is achieved through the HC method for the operation of encryption and encryption over the data during communication among the nodes. The detection rate, delay, throughput, routing load, and Packet Distribution Proportion are evaluated. In the implemented MOTBOA method detect the rate 62.9%, the delay is 7ms, throughput is 77.9%, the packet distribution proportion is 93.7%, and routing load is 0.46 for the network once related to the trust based DSR (TDSR), Monarch-Cat Swarm Optimization (MCSO), and secured QoS aware Energy Efficient Routing (SQEER).

Keywords: *Energy consumption, Network lifespan, Detection rate, Homomorphic cryptosystem, Network security, Trust based bat optimization algorithm.*

1. INTRODUCTION

One of the most important criteria in Wireless Sensor Network (WSN) is security. WSN security is comprised on four essential components: data privacy, honesty, certification, and accessibility [1]. The privacy and validation of data in each node is critical in the WSN network for data communication security. WSN is topic to a variety of threats. As a result, adversaries can readily alter the sensor nodes, turning theminto malicious nodes. The network's cancerous nodes stand as a source of vulnerability for the overall system. While data is being sent unauthenticated data admission may occur, resulting in the loss of critical info deposited in the nodes. As a result, a secure and energy-resourceful routing protocol is critical for extending the network's lifespan and ensuring its security [2]. The following factors must be considered while building a protocol for secure communication via WSN: honesty, onward privacy, progressive confidentiality, freshness, non-repudiation, and obtainability [3].

Homomorphic encryption is a type of encryption that allows computations to be performed on ciphertext, which encrypts data, to produce an output ciphertext that decrypts to the same value as if the computation was achieved on the plaintext [4]. This is useful in wireless sensor networks because it allows sensor nodes to share data and perform computations without first having to decrypt the data, which can save energy and computational resources. Additionally, homomorphic encryption can also provide a higher level of security for data communicated over the network by ensuring that only authorized parties can access and process the data.

A Multi-Objective Trust-based Bat Optimization Algorithm (MOTBOA) is an optimization algorithm used in WSNs to recover the presentation of the network by balancing the trade-offs between different objectives, for instance energy efficiency, reliability and security. The algorithm is created on the bio-inspired Bat Optimization (BO) algorithm, which mimics the echolocation behavior of bats to find the optimal solution to a given problem [5]. MOTBO, extends the BO algorithm by incorporating trust values in the optimization process. Confidence values remain used to evaluate the reputation or reliability of sensor nodes in the network, and this information stays used to choose the most trustworthy nodes to participate in the network's operations. In WSNs,this can help improve the network's security by preventing malicious or unreliable nodes from participating in the network and through decreasing the probabilities of a security attack.In terms of energy efficiency, the algorithm can help reduce the energy consumption of nodes by minimizing the quantity of communication rounds needed to reach a consensus among nodes. Additionally, the algorithm can similarly help to expand the reliability of the network by using the trust

values to select the most reliable nodes for data transmission.

The implementation of Multi-Objective Trust-based Bat Optimization Algorithm- Enhanced Homomorphic Cryptosystem (MOTBOA-EHC) approach expected to provide a safe clustering and routing with encrypted data transmission. The following are the main contributions of the work employing the MOTBOA-EHC approach.

• The MOTBOA is mainly aimed at for an active cluster head (CH) choice between the nodes exist in the network. Since, the bat optimization has the capacity of automatic zooming into the search space where the promising solution is found by the bat during the searching process.

• The clustering and routing are achieved bent on the multi objective fitness functions such as trust value, residual energy, communication cost, and node degree. The secured CH choice is completed through eliminating the spiteful nodes in the cluster affording to the confident rate calculation.

• The EHC method is presented in this paper for the encryption and decryption of the transmitted data to ensure its the security The rest of the article is systematized as follows. Section 2 discuss MOTBOA-EHC method and Bat optimization algorithms. The results are discussed in Section 3 and finally work conclusion and future scope is discussed in Section 4.

2. RELATED WORK

A few recent related research papers relied on wireless sensor network on secured data are described below, Yildiz, H.U et.al [1] has proposed a linear programming outline to discover the imperfect protected connectivity problem with reverence to its influence on network generation, path length, queue size, and energy indulgence. The numerical results show that if any two nodes share a key with a probability of atleast 0.3, then we should expect only a marginal drop (i.e., less than 3.0%) in lifetime as compared to a fully connected network.

Peng Zhou et.al [3] as presented the properties of bandpass memoryless nonlinear plans on OFDM signals and educate the best asymptotic presentation for both nondispersive networks and harshly time-dispersive stations. We extend the analytical methods for obtaining the Euclidean distance between two OFDM signals that are subjected to different nonlinear characteristics.

Abhishek Vashist et.al [5] as elaborated a device to classify the invader and stop the attack. We assess the planned methods on a WiNoC in the occurrence of DoS and ED attacks from both interior and exterior attackers. On a regular, 99.87% of the attack on DoS discovery was accomplished with the selected ML classifier.

Khalid Haseeb et.al [7] as explained the protocol brands the use of an artificial intelligence- created heuristic study to achieve a dependable, and intellectual

learning system. Secondly, it defends the shows in contradiction of opponent groups to reach safety with the least complication.

Lein Harn et.al [9] has described a different project to suggest a pre-distribution outline for founding group keys in WSNs. Our strategy uses a special-type multivariate polynomial in ZN , where N is a RSA modulus.
Gouramma Halidoddi et.al [11] has attained via using the EHC method for the process of encryption and decryption over the data during communication among the nodes. The performance of the proposed MOTBOA-EHC method is evaluated in terms of detection rate, delay, throughput, routing load and Packet Delivery Ratio (PDR). The existing methods namely Trust based Dynamic Source Routing (TDSR), Monarch-Cat Swarm Optimization-based routing protocol and Secured Quality of Service aware Energy Efficient Routing (SQEER) are used to evaluate the performances of the MOTBOA-EHC method. The PDR of the MOTBOA-EHC method is 92% at 100 rounds that are high when compared to the TDSR, MCSO and SQEER.

P. A. Patilet.al [13] as explained The OR in WSSs using the hybrid optimization algorithm named, Monarch-Cat Optimization(M-CSO) which is the integration of Monarch Butterfly Optimization in Cat Swarm Optimization. A framework operates on two crucial aspects: one is to select the secure nodes and the other is to choose opportunistic nodes among selected secure nodes.

3. MOTBOA-EHC METHOD

The proposed MOTBOA-EHC method has three different phases such as clustering, routing and encryption & decryption. The clustering and routing procedure are achieved through using MOTBOA and the encryption and decryption remain completed by using enhanced homomorphic cryptosystem (EHC). The CH assortment is completed are created on the fitness functions are measured in planned method. The considered fitness functions are trust value, residual energy, communication cost and node degree. The confident value of the nodes is calculated to avoid the network from denial-of-service (DoS) and blackhole attacks. Hence, the developed two-level security is used to progress the packet distribution of the MOTBOA-EHC method. The flow-chart of the projected MOTBOA-EHC method is revealed in Figure 1.

3.1 Overview of Bat Optimization Algorithm

Bat optimization algorithm (BOA), a new population-based algorithm, was inspired by the echolocation of the bat species known as micro bats for looking through target. The refreshed arrangements of BOA are built dependent on triple essential factors like echolocation, frequency and commotion. Bats are used the echolocation for finding their target, foundation frequency for

convey the variable frequency, and commotion for search the target. Solutions for the BOA are made by changing the boundaries like frequencies, pulse emission rates, and commotion of the bats, as indicated by the assessment of the detached function[12]. Equations for upgrading the locations and speeds of BOA in d-dimensional inquiry space are as per the following:

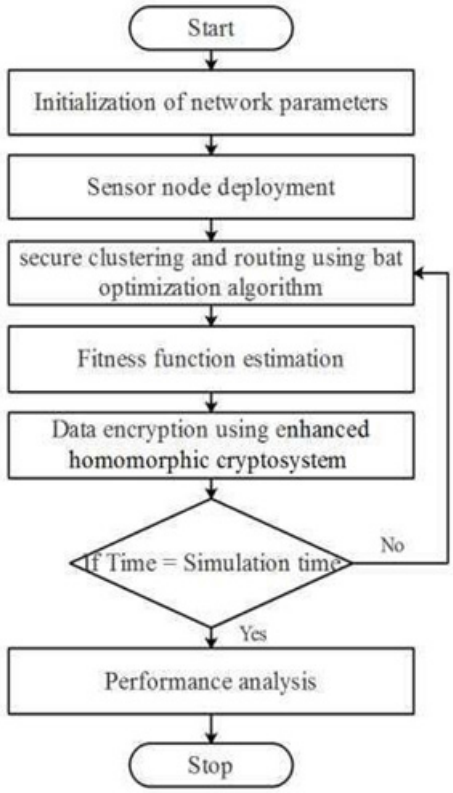


Figure-1 Flowchart of the MOTBOA-EHC method

$$f_i = f_{min} + (f_{max} - f_{min}) \times \beta \quad (1)$$

Where, the frequency for changing velocity is referred as f_i, the maximum and minimum frequency of the bats emanating the pulse is referred as $f\max$ and $f\min$ respectively and the randomly generated vector is represented as β.

3.1.1 MOTBOA Based Clustering Algorithm

The fitness functions considered for the MOTBOA based CH selection are trust value, residual energy, communication cost, and node degree. The CH selection is achieved through eliminating the malignant node in the cluster created on the confident value calculation. Hence, the DoS and black hole outbreaks are ducked in the network.

Bat representation

A bat is referenced to as a viable solution in BOA. A bat indicates a cluster of sensor nodes to be chosen as CHs in the CH selection process. Each bat has a dimension identical to the sum of CHs in the network.

Bat initialization

A random node_id between 1 and n is allotted to each bat location.

Fitness function derivation

The fitness functions for the MOTBOA based clustering algorithm is derived using the following parameters:

a. Trust value

In the projected method, the confident value of the individual node is calculated and an optimal path for secure communication is designated via using bat optimization algorithm.

b. Residual energy

The remaining energy of the nodes in the network is unique of the important factors during the selection of the CH. Since, the CH consumes huge amount of energy for data collection, processing and data communication and track assortment.

The equation to calculate the remaining energy is given below.

$$F_2 = E_0 - E_c \tag{2}$$

Where, the initial energy is represented as $E0$ and the energy employed by the node is represented as Ec.

c. Communication cost

The energy consumed by the transmitting data is directly proportionate to the square of the detachment among the candidate nodes along with the source node.

d. Node degree

In next-hop selection, the node degree is a crucial factor. If a low node degree is chosen as the next hop, the node's performance will last for a long time and it will get little data from its members. As a result, the next-hop chose low node degree.

MOTBOA Based Routing Algorithm

The fitness functions are intended for the way the assortment procedure is confident value, residual energy, communication cost, and node degree[13]. The route selection procedure is achieved based on the aforementioned fitness functions.

Bat representation

A bat is referenced to as a viable solution in BOA. A bat indicates a group of sensor nodes to be chosen as CHs in the CH assortment process. Each bat has a dimension equivalent to the number of CHs in the network.

Bat initialization

A random node_id between 1 and n is allotted to individually bat location.

3.2 Enhanced Homomorphic Cryptosystem

WSN are defenseless against the hackers exploring the wireless communication framework and its transmission nature. The energy and asset imperatives are likewise extra shortcomings on the sensor side. Generally, the sensor gadgets are arbitrarily arranged in an uncontrolled environment. Subsequently, they are effortlessly presented to actual assaults. The significant security prerequisites in WSN remain accessibility, honesty, privacy, verification and non-reputation. For that, an enhanced homomorphic cryptosystem (EHC) is projected in this research for data encryption and decryption operation. By encrypting the data in the network during data transmission, the information in the nodes are banned after the DoS attack and blackhole attack.

Homomorphic encryption (HE) is the combination of addition, multiplication, ormixed multiplication homomorphism. HE is an operation performed over the scrambled data and it provides similar results after the computation as the working straightly on the clear data. Here, the decryption performing over the amount of the two cipher texts is the same as the addition operation performing over the two plain text represented as:

$$(a + b) = E(a) + E(b) \tag{3}$$

The decryption performing over the product of two cipher texts is the same as multiplication of two plain texts represented as:

$$(a \times b) = E(a) \times E(b) \tag{4}$$

The proposed EHC is utilized as additive homomorphic encryption-based cryptographic algorithms. This cryptographic algorithm uses large number m, where $m = p \times q$. Here p and q are enormous indivisible numbers, which are kept private. q is a sharing private key. That number m is additionally a private key to scramble the information.

Tracking down an arbitrary number r is a very troublesome issue, so which is kept private. The EHC algorithm incorporates three principle cycles such as private key generation (K), the encryption algorithm (E) and the decryption algorithm (D).

Key generation (K)

i. $p, q \in P$, where P is prime, and $m = p \times$.
ii. Random number r is generated.
iii. The set of original plaintext messages $P = Z\mathrm{p} = \{x: x <= p\}$, $Z\mathrm{m} = \{x: x < m\}$ has the set of cipher text messages.
iv. Private values r, m and q.
v. Shared key $K = p$.

Encryption algorithm (E)

i. $x \in Zp$
ii. The cipher text C is calculated as $y = (x) = (x + r \times pq)(modm)$.

Decryption algorithm (D)

i. The plaintext x is recovered as $= D\mathrm{p}(y) = ymodp$.

In this MOTBOA-EHC method, two levels of security are provided for improving the data delivery of the WSN. In the first level, secure clustering and routing is accomplished

by means of the MOTBOA, where confident value is measured as a significant parameter for mitigating malicious attackers. Next, the residual energy considered in the MOTBOA is used to escape node failure. The communication cost and node grade used in the MOTBOA is used to identify the direct path by means of a smaller number of hops that helps to minimalize the delay [14]. In the second level of security, the EHC based data encryption/ decryption is used to provide the data security that helps to secure the data from the unauthorized users. Therefore, the data security over the network is obtained while minimizing the delay and routing load.

4. PERFORMANCE EVALUATION

The presentation of the MOTBOA-EHC method is examined in terms of detection rate, delay, throughput, routing load and PDR [15]. Here, three different present methods namely TDSR, MCSO and SQEER are used to evaluate the MOTBOA-EHC. This TDSR, MCSO and SQEER are intended and imitated thru using the similar conditions declared in Table 1.

Parameters	Values
Network interface type	Wireless phy
Communication radius	250mm
Number of connections	20
Number malignant nodes	10
Mac protocol	Mac/802.11
Antenna pattern	Omni antenna
Wireless propagation protocol	Two ray ground
Initial energy	50J
Queue type	Pri Queue
Speed of the data flow	448kbits/s
Size of packets	210Byte
Simulation time	Simulation time

Table-1 Specification Parameters

The presentation assessment is explained below. In the results, trust based DSR (TDSR), Monarch-Cat Swarm Optimization (MCSO), protected QoS aware Energy Effective Routing (SQEER), and MOTOBA are represented by light blue, red, green and purple color line respectively.

Detection rate

Detection rate ($Tdet$) provides the accurate rate of the correctly identified attacks in the network. The result of detection rate thru esteem to number of rounds is shown in Figure 2.

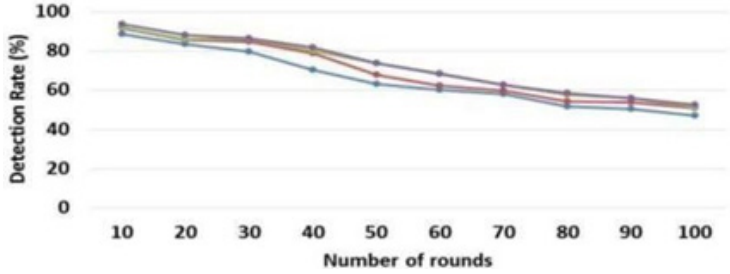


Figure-2 Detection rate

Hence, the malignant node detection increased in the network that recovers the security of the WSN network [16] .

Delay

The calculation of delay depends upon the quantity of the nodes. When the quantity of nodes rises, then the delay is increased. To obtain effective routing, the delay of the network should be low [17]. The delay is calculated from the time feasting of the nodes to respond. The result of delay with admiration to number of rounds is shown in Figure 3.

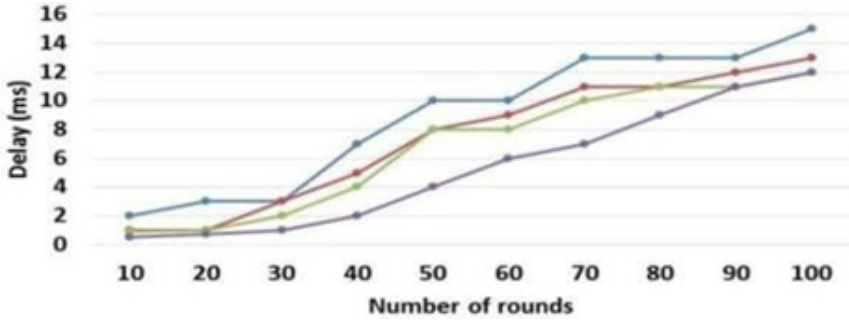


Figure-3 Delay

Throughput

The throughput is derived as the number of packets attained in a particular time and then the packet delivery is recognized. The throughput scheming is achieved via using

$$Throughput = Nr/T \times 100\%$$

where, Nr represents the aggregate sum of the nodes and T represents the simulation time. The delay is calculated from the time ingesting of the nodes to respond [18]. The outcome of throughput with respect to number of rounds is revealed in Figure 4.

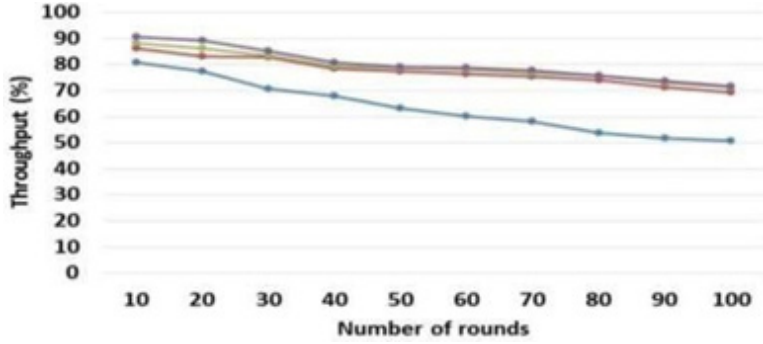


Figure-4 Throughput

Load routing

In Eq. 1, routing load is clear as the proportion of the number of routing messages generated by a node to the number of data packets successfully delivered to all destination nodes as

$Routingload = Y/X$

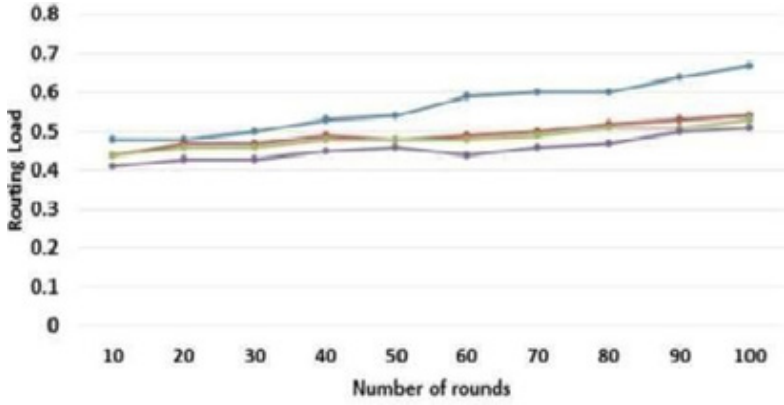


Figure-5 Routing load

The delay is calculated from the time ingesting of the nodes to respond. The outcome of routing load with respect to number of rounds is revealed in Figure 5.

Packet delivery ratio

The aggregate sum of packets received at the destination divided by the aggregate sum of packets sent by the source node is known as Packet delivery ratio (PDR) The delay is calculated from the time consumption of the nodes to respond[19]. The result of PDR with respect to number of rounds is revealed in Figure 6.

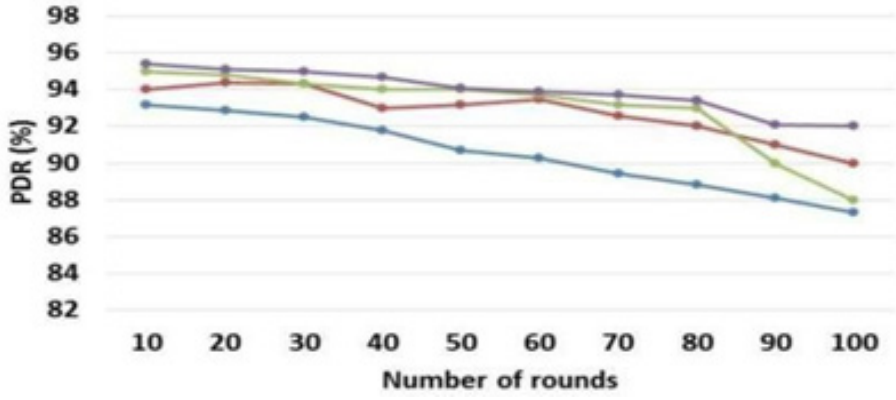


Figure-6 Packet delivery ratio

Table-2 Relative study of Routing load and PDR for MOTBOA-EHC

Number of rounds	Routing load				PDR (%)			
	TDSR [12]	MCSO [13]	SQEER [14]	MOTBOA -EHC	TDSR [12]	MCSO [13]	SQEER [14]	MOTBOA -EHC
10	0.48	0.44	0.44	0.48	93.5	94	95	95.2
20	0.48	0.47	0.47	0.48	93	94.2	94.4	95
30	0.5	0.47	0.47	0.5	92.5	94.4	94.4	94.5
40	0.53	0.49	0.49	0.53	91.9	93	94.2	94.45
50	0.54	0.48	0.48	0.54	90.5	93.4	94.1	94.1
60	0.59	0.49	0.49	0.59	90.25	93.5	94	94.1
70	0.6	0.5	0.5	0.6	89.8	92.5	93.7	93.8
80	0.6	0.52	0.52	0.6	88.8	92	93.7	93.78
90	0.64	0.53	0.53	0.64	88	91.5	90	92
100	0.67	0.54	0.54	0.67	87.5	90	88	92

The relative study of MOTBOA-EHC for 100 nodes by means of the existence of DoS attack in WSN is revealed in Table 2 and Table 3. In that, Table 2 shows the comparison data of detection rate, delay & throughput, and Table 4 shows the comparison data of routing load and PDR. From the analysis, it is determined that the MOTBOA- EHC method accomplishes improved presentation than the TDSR, MCSO and SQEER. Similarly, the MOTBOA-EHC method bounces improved presentation for the network with black hole attacks[20]. The delay of the TDSR and SQEER is high because it generates the routing path with a higher transmission distance. Next, the overhead of the MCSO is high, due to its high amount of control packets transmitted during the communication. However, the optimal fitness functions of MOTBOA-EHC such as trust value, remaining energy, announcement cost, and node degree are used to progress the presentation of the WSN. The two level securities i.e., secure clustering and routing using MOTBOA and data security using EHC improves the PDR of the MOTBOA-EHC method.

Table-3 Comparative analysis of detection rate, delay & throughput for MOTBOA-EHC

Number of rounds	Detection Rate (%)				Delay (*ms*)				Throughput (%)			
	TDSR [12]	MCSO [13]	SQEER [14]	MOTBOA-EHC	TDSR[12]	MCSO [13]	SQEER [14]	MOTBOA-EHC	TDSR [12]	MCSO [13]	SQEER [14]	MOTBOA-EHC
10	88.4	91.5	92.0	93.7	2	1	0.90	0.5	80.9	86.1	88.3	90.5
20	83.5	85.7	85.9	88.2	3	1	1	0.75	77.4	83.1	86.1	89.4
30	79.7	84.8	86.0	86.4	3	3	2	1	70.8	82.7	83.4	85.3
40	70.3	78.7	80.2	81.6	7	5	4	2	68.1	78.6	79.5	80.9
50	3.2	67.9	73.5	73.7	10	8	8	4	63.4	77.5	78.8	79.1
60	60.2	62.2	68.8	68.3	10	9	8	6	60.1	76.5	78.2	78.8
70	58.1	59.8	62.5	62.9	13	11	10	7	58.3	75.3	76.7	77.9
80	51.8	54.1	57.8	58.4	13	11	11	9	53.7	74.2	75.9	75.6
90	50.4	53.9	55.7	55.7	13	12	11	11	51.8	71.5	73.2	73.7
100	47.1	50.7	51.1	52.4	15	13	12	12	50.6	69.2	71.5	71.8

5. CONCLUSION

MOTBOA-EHC is developed by designing the secure clustering and routing using MOTBOA, and data security using EHC is used to progress the PDR of the network. The CH selection is performed conferring to the four fitness functions which are trust value, residual energy, communication cost, and node degree. The CH selection is performed by eliminating the attacker node in the cluster according to the trust value calculation. Hence, the network nodes are prevented from the DoS attack and black hole attack. The secured data transmission is obtained by encrypting the data which is conveyed through the nodes. The EHC method is employed for the successful encryption and decryption operation. Finally, the replication outcomes of the MOTBOA-EHC method is obtained by using the NS2 tool. In the implemented MOTBAT method the detection rate is 62.9%, the delay is 7ms, throughput is 77.9%, the packet delivery ratio is 93.7%, and routing load is 0.46 for the network once related to the TDSR method, MCSO method and SQEER method.

Our method has implemented by considering the node as static in nature. Same method can be implemented by considering dynamic nature of the nodes. Also it can be implemented in real time environment by considering harsh environmental conditions.

6. REFERENCES

1. Yildiz, H.U.,Ciftler, B.S., Tavli, B., Bicakci, K.,Incebacak "The impact of incomplete secureconnectivity on the lifetime of wireless sensor networks" *IEEE Systems Journal,* 2018,vol- 12(1), pp.1042-1046.

2. Feng Wang, Jiangchuan Liu "Networked Wireless Sensor Data Collection: Issues, Challenges,and Approaches" *IEEE Journal of Communications Surveys & Tutorials,* 2011,vol.13, No. 4, pp. 673 – 687.

3. Peng Zhou, Siwei Jiang, AthiraiIrissappane, Jie Zhang, Jianying Zhou, and Joseph Chee Ming Teo "Toward Energy-Efficient Trust System Through Watchdog Optimization for WSNs" *IEEE transactions on information forensics and security,* March 2015, Vol. 10, No. 3,pp. 613-625.

4. Adnan Ahmed, Kamalrulnizam Abu Bakar, Muhammad Ibrahim Channa, Khalid Haseeb, Abdul Waheed Khan "TERP: A Trust and Energy Aware Routing Protocol for Wireless Sensor Network" *IEEE Sensors journal,* Dec 2015, Vol. 15, No. 12, pp. 6962-6972.

5. Abhishek Vashist, Andrew Keats, Sai Manoj Pudukotai Dinakarrao, Amlan Ganguly "Securing a Wireless Network-on-Chip Against Jamming-Based Denial-of-Service and Eavesdropping Attacks" *IEEE Transactions on Very Large Scale Integration(VLSI) Systems,* Dec 2019, Vol. 27, No. 12,pp. 2781- 2791.

6. Mohamed M.E.A. Mahmoud, Xiaodong Lin, Xuemin (Sherman) Shen "Secure and Reliable Routing Protocols for Heterogeneous Multihop Wireless Networks" *IEEE Transactions on parallel and distributed systems,* April 2015, Vol. 26, No. 4,pp. 1140-1153.

7. Khalid Haseeb, Khaled Mohamad Almustafa, Zahoor Jan,Tanzilla Saba, Usman Tariq "Secure and Energy-Aware Heuristic Routing Protocol for Wireless Sensor Network" *IEEE Access,* Sept. 2020, Vol. 8,pp. 163962-163974.

8. Daojing He, Sammy Chan, Mohsen Guizani, Haomiao Yang, Boyang Zhou "Secure and Distributed Data Discovery and Dissemination in Wireless Sensor Networks" *IEEE Transactions on Parallel and Distributed Systems,*April 2015, Vol. 26, No. 4,pp.1129-1139.

9. Lein Harn, Ching-Fang Hsu "Predistribution Scheme for Establishing Group Keys in WirelessSensor Networks" *IEEE Sensors Journal,* Sept. 2015, Vol. 15, No. 9, pp. 5103-5108.

10. Gouramma Halidoddi, Rubini Pandu "A GOA Based Secure Routing Algorithm for Improving Packet Delivery and Energy Efficiency in Wireless Sensor Networks" *International Journal of Intelligent Engineering and Systems*,2021, vol.14, No.6,pp. 311-320.

11. Gouramma Halidoddi, Rubini Pandu "Secured Data Transmission Using

Multi- Objective Trust Based Bat Optimization Algorithm and Enhanced Homomorphic Cryptosystem for WSN" *International Journal of Intelligent Engineering and Systems,* 2022, vol.15, No.1, pp. 214-224.

12. S.S.Moghaddam, H. Taheri, and A. Karimi, "Trust based routing algorithm to improve quality of service in DSR protocol", *Wireless Personal Communications,* 2019, Vol. 109, No. 1, pp. 1-16.

13. P. A. Patil, R. S. Deshpande, and P. B. Mane, "Trust and Opportunity Based Routing Framework in Wireless Sensor Network Using Hybrid Optimization Algorithm", *Wireless Personal Communications*, 2020, Vol. 115, No. 1, pp. 415- 437.

14. T. Kalidoss, L. Rajasekaran, K. Kanagasabai, G. Sannasi, and A. Kannan, "QoS aware trust based routing algorithm for wireless sensor networks", *Wireless Personal Communications,* Vol. 110, No. 4, pp.1637-1658, 2020.

15. Yoon, Ikjune, and Dong Kun Noh. "Adaptive data collection using UAV with wireless power transfer for wireless rechargeable sensor networks." *IEEE Access* 10, 2022, 9729-9743.

16. Wang, Bin, et al. "EP-ADTA: edge prediction-based adaptive data transfer algorithm for underwater wireless sensor networks (UWSNs)." *Sensors* 22.15 2022: 5490.

17. Roy, Prasanta Kumar, and Ansuman Bhattacharya. "SDIWSN: A software-defined networking-based authentication protocol for real-time data transfer in industrial wireless sensor networks." *IEEE Transactions on Network and Service Management* , 2022: 3465-3477.

18. Swamy, Tata Jagannadha, et al. "Secure Data Dissemination in Wireless Sensor Networks with The Help of Module Based Blockchain Technology." 2023, *3rd International Conference on Intelligent Technologies (CONIT). IEEE.*

19. Sudheer, Bandlamudi Naga, and Kamepalli Sujatha. "A Brief Survey on Data Aggregation and Data Compression Models using Blockchain Model in Wireless Sensor Network."*International Conference on Innovative Data Communication Technologies and Application (ICIDCA). 2023,* IEEE.

20. Pleshkova, Snezhana, and Kostadin Panchev. "Capturing and transferring of acoustic information in a closed room via wireless acoustic sensor network." *,12th National Conference with International Participation (ELECTRONICA),* 2021*, IEEE.*

A metaheuristic algorithm based hybrid enhanced blockchain and trust management system for heterogeneous IOT systems

Pushpa R ✉

Professor, Department of Computer Science and Engineering,
Akshaya Institute of Technology, Tumkur
pushpa.aitcse@gmail.com

Abstract

Heterogeneous IoT systems provide consumers a variety of data collecting, connectivity, and integration options. This technology is intended to allow many kinds of devices to communicate and exchange data in order to build a more efficient and effective network. This study uses a Logistic regression model to offer a Hybrid Trust & Block chain-based Framework for Heterogeneous IoT System. This framework is intended to provide effective data exchange and connectivity across various IoT devices and infrastructures. Trust levels are also used to identify malicious nodes in a heterogeneous IOT system. This data is then used to build a logistic regression model that can identify malicious nodes. The suggested system's performance is tested using performance metrics (sensitivity, accuracy, and specificity), and the results display that the suggested technique can correctly detect malicious nodes. The suggested system's accuracy was determined to be much greater than that of the current systems. The results showed the proposed framework beats cutting-edge techniques in terms of security.

Key Words: *Heterogeneous IoT systems, Logistic regression, IoT devices, Hybrid Trust, Blockchain-based Framework.*

1. INTRODUCTION

The Internet of Things (IoT) has gained popularity during the last several years. The Internet of Things (IoT) is a network of physical devices (sensors, controllers, and other gadgets) that are linked to the web and may share information with one another. The term "heterogeneous IoT" refers to the networking of many IoT device types on a single network. The issue of protecting such a network becomes more complex as the number of devices rises and the kinds of devices become more diversified [1]. The difficulty with heterogeneous IoT is ensuring a secure, stable, and robust connection between

all devices, regardless of their hardware, software, or protocol. However, the complexity of IoT systems has grown dramatically, necessitating a more secure and dependable infrastructure to operate such systems. In answer to this demand, a heterogeneous IoT system based on trust and block chain technology has emerged as a possible option [2].

Blockchain technology is a system of decentralized ledgers that provides a secure and impermeable way to store and manage data. This technology was developed by Bitcoin. It is made up of a distributed network of computers, which are referred to as nodes that use cryptography to verify and record transactions. This technology is especially well- suited for IoT systems since it allows safe communication and data exchange between the different devices and also provides secure data storage. Additionally, it provides secure data storage. Although the idea of a heterogeneous Internet of Things (IoT) system that makes use of block chain technology is still in its infancy, it is rapidly gaining support [3]. This particular kind of system is an Internet of Things system, and it is made up of a wide number of various components, including sensors, actuators, and other devices. The system is intended to allow for encrypted data sharing and communication between the various devices, as well as the provision of an encrypted and immutable ledger for the data that is being stored [4].

Improved safety, scalability and dependability are among the primary advantages afforded by using a heterogeneous Internet of Things system that makes use of block chain technology. The use of this technology allows devices to securely connect with one another and exchange data without depending on a single centralized server, which lowers the probability of data being compromised [5]. The data may also be retrieved from other nodes in the network thanks to the distributed nature of the block chain technology, which allows the system to be more durable in the event of a breakdown. Last but not least, the immutable ledger of the data that is maintained on the block chain guarantees that the data is immutable, making it far more difficult for hostile actors to alter the data [6]. Many of the authors discussed about heterogeneous IOT using different methods and block chain technology. Some of them are discussed below.

In this research, [7] advised employing block chain technology as the backbone of a security framework in order to combine Internet of Things devices that had varying resource limits under one system. Ethereum may be used to develop a secure system that is resistant to Denial-of- Service attacks; it can also be used to manage device trust; it can store encryption keys; it can store encrypted data; and it can store both. [8] provided a heterogeneous Internet of Things

architecture that was composed of four layers and featured apps, networking, cloud computing, and sensors. The protection of confidentiality in large-scale heterogeneous Internet of things and the movement of huge volumes of data are two issues that the heterogeneous internet of things (IoT) will have to deal with in the future, and this research offered various possible solutions to these issues. [9] Some early research was presented on an architecture for managing heterogeneous Internet of Things systems that makes use of block chain technology. The author then proceeded to develop a framework for the management of a large-scale heterogeneous Internet of Things system. [10] A conceptual model is presented in this study with the purpose of identifying the essential factors that influence the adoption of block chain technology in IoT. Based on the findings, it seems that factors relating to data have a significant impact on the adoption of block chain technology in the internet of things as well as the willingness to use it.

2. ANALYSIS AND/OR DESIGNS

A. Blockchain

A blockchain is "an encrypted, decentralized, and ever-growing collection of records, called blocks," which are linked together. Every block contains transaction information, the digital signature of the previous block, and a time stamp. [11], which would then invalidate the network consensus[12]. The most important feature of blockchain technology is its security. With its distributed nature, blockchain technology is virtually impossible to hack or manipulate. This makes it ideal for storing information that needs to remain secure, such as financial data or medical records. The data stored on the blockchain is encrypted, making it virtually impossible to alter or delete. Blockchain technology is also extremely efficient. The blockchain allows for the speedy and safe processing of transactions as well as the quick and simple sharing of data stored there. Because it is capable of being employed to track and keep an eye on the flow of goods and amenities, it is perfect for operations like supply chain management. The information from source network to the destination network is carried out by AODV routing protocol, the terminology and the principal of working is described as presents.

B. AODV (Ad hoc On-Demand Distance Vector routing)

AODV preserves only routes in networks that satisfy a need because it is a reactive heterogeneous IOT system. The next hop for getting to destinations is maintained by AODV in a routing table. A route will ultimately time out if no packets are sent along it. Mostly since it only knows about the nodes that are nearby.

1. Terminology of AODV

The following are the three different sorts of routing communications of AODV.

i. RREQ: Route Request

A node starts the route identification procedure by sending an RREQ multicast message when it intends to send/transmit a packet but is unclear of how to get there. Prior to the message reaching the target node, adjacent nodes pass it to their neighbors while keeping track of the communication's source.

ii. RREP: Route Reply

The RREP of the destination node returned to the original node by means of RREQ. Facilitation networks create forwarding pathways as RREP travels back to the source. Intermediary nodes can respond to an RREQ through an RREP if it is aware of the destinations, enabling routers to join a pre-existing route. Once the RREP comes and the path is defined, source-to-destination communication begins.

iii. ERR: Route Error

AODV has less overhead than proactive protocols (fewer route maintenance messages). When a connection is broken and a route is no longer functioning, messages cannot be forwarded, a node sends an RERR message. Messages are recast. RERR shows an inaccessible location. Message- receiving nodes deactivate the route.

C. Key Generation

In the Advanced Encryption Standard (AES) algorithm, the key size, number of rounds, and key generation time contribute to different aspects of encryption key generation:

1. Key Size:

In AES, the key size may be anything between 128 bits and 256 bits. The greater the key size, the more keys may be used, making brute-force attacks more computationally infeasible. Generally, a larger key size provides stronger security, as it increases the complexity of the encryption process and reduces the likelihood of successful attacks. However, larger key sizes also result in increased computational requirements for both key generation and encryption/ decryption operations [13].

2. Number of Rounds:

AES has a set amount of loops, which are 10, 12, or 14 for variables of 128-bit, 192-bit, or 256-bit lengths, accordingly. The number of rounds determines the number of iterations performed during the encryption process. The security of AES improves as the number of rounds increases, thanks to the algorithm's enhanced diffusion and confusion features, making it more resistant to various attacks. However, an increased number of rounds also leads to additional computational overhead and longer encryption/decryption times.

3. Key Generation Time:

The time needed to produce a valid encryption key in AES is referred to as the key generation time. Random bits are frequently utilized during key creation to generate a safe and unique key. The produced key's quality and unpredictability have a direct impact on the encryption's security. While AES does not define a key generation technique, using a reliable and secure key creation method is critical to ensuring the strength of the produced keys. Because of its symmetric nature, the same key may be used for decryption as well as encryption with AES. As a result, the key generation procedure is typically performed only once, and the generated key is securely transmitted between the originator and recipient.

3. EXPERIMENTAL SECTION

In this study, we proposed a hybrid trust and block chain- based framework to ensure security for IOT systems with the help of trust evaluation and key strength mechanism involves several key steps. Firstly, the trust management system provides security features that enable nodes to handle the unpredictable nature of nodes, Transaction management system maintains the ledger of transaction among the nodes. Later on, these trust values are fed to the IDS to detect and remove the miscellaneous nodes from the planned path. And their corresponding details of the final secure path are pushed into transaction management system, and the Hash values of the generated blocks are transferred to the cloud for future reference. Secondly, key strength assessment phase determines the required key size, generates cryptographic keys, and evaluates their strength. The integration of trust and key strength factors guides the decision-making process.

A. Trust Model

Trust is a crucial security feature that helps nodes handle the unpredictable nature of IOT; as a result, trust calculation and maintenance in IOT are challenging. The network's performance will undoubtedly suffer from an unreliable node. Because of this, figuring out every node's trust level has a big influence on how much protection a node can offer for an encrypted connection.

The trust values of the nodes are calculated in IOT while data is transmitted ion is carried out using AODV as follows.

Trust calculation algorithm for AODV

Step 1 PR1=Count the number of packets received at each node.
PS2=Count the number of packets sent by each node
RR1=Count the number of RREQ received at each node.
RS2= Count the number of RREP sent by each node.

Step 2 Calculate the P1 from neighbor node value:

$$P1 = \frac{\text{No. of packet sent}}{\text{No. of packet Received}}$$

Calculate the P2 from neighbor node value:

$$P2 = \frac{\text{No. of Route Replay sent}}{\text{No. of Route request Received}}$$

Step 3 Calculate Trust Value = (P1 * α) + (P2 * β) where α and β = static weighting factor

Step 4 Insert Trust value into Neighbor Table

B. Key Assessment

The evaluation of the key's strength consists of determining the entropy of the cryptographic keys that were produced by using Shannon entropy.

Shannon Entropy Calculation:

The formula for computing the Shannon entropy of a cryptographic key is as follows:

$$\text{Entropy} = \sum_{i=1}^{n} p_i \cdot \log_2 (p_i) \quad (8)$$

where n is the total number of bits in the key and pi is the likelihood that each bit is 1. Shannon entropy is used to calculate the key strength of randomly generated cryptographic keys. The code computes the entropy of the keys for various key sizes (128, 192, and 256 bits) and conducts statistical analysis over a certain number of iterations. The key strength is then calculated by multiplying the likelihood of '1' and '0' bits in the key by the Shannon entropy. This study focuses on an optimization method known as PSO.

C. Particle Swam Optimization

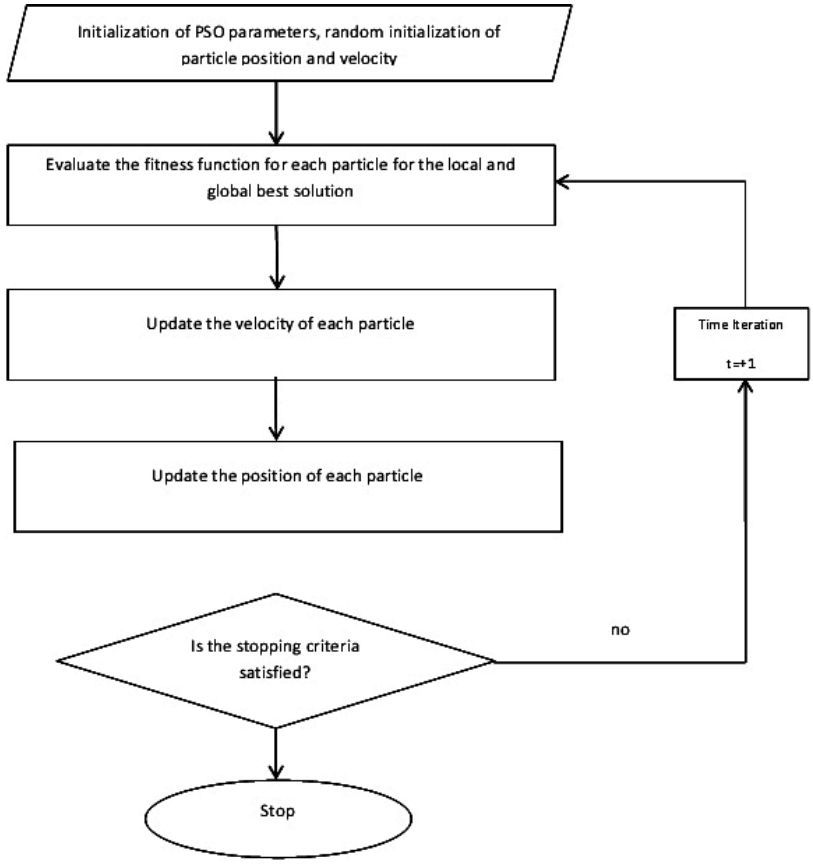
Particle swarm optimization (PSO) is a population-based search method based on the social actions of birds throughout a flock as modeled. The particle swarm concept was developed with the intention of visualizing the graceful and surprising choreographed of a flock of birds while also identifying patterns that govern a bird's capacity for synchronous flight and the ability to quickly change directions by rejoining in an optimal shape. The concept evolved into a straightforward and efficient optimization process from this fundamental objective. [14].

The formula for PSO based feature selection is as follows:

$$x^{t+1}_{id} = x^{t1}_{id} + v^{t+1}_{id}$$

$$v^{t+}_{id}{}^{1} = w * v^{t}_{id} \; c_1 * r_{1i}(p_{id} - x^{t}_{id}) + c_2 * r_{2i} * (p_{gd} - x^{t}_{id})$$

Where d, D is the d^{th} dimension of our search space. In PSO, t is the current iteration, x^{t}_{id} is the particle's current location, and v^{t}_{id} is the particle's current velocity in d in the i^{th} iteration. w is the inertia weight, which allows velocities from the previous iteration to have a controlling influence on the current one, while C_1 and C_2 are the learning rates. r_{1i} and r_{2i} are simply random numbers that are uniformly distributed in the range [0, 1], and p_{id} and p_{gd} are the p_{best} and g_{best}.



A. Logistic Regression

When it comes to ML methods, logistic regression is one that is is not a "black box" since we understand exactly how it operates. Black box models, like extremely deep neural networks (DNN), frequently undergo iterations that are more sophisticated. The outcome of a binomial logistic regression might be either 0 or 1. In the realm of ML, logistic regression is one of the few methods for which the inner workings are not a mystery. Employing black box

models, such as a very deep neural network (DNN), may lead to more fruitful iterations. The result of a binomial logistic regression might be either 0 or 1. Determine if a given event will produce a 1 or a 0 as the following step. Since 1 is as likely as not, we may express the chance that it won't happen as 1-p. Bernoulli distribution is one kind of binomial distribution, and this serves as an illustration of it. Logistic regression uses a modified linear regression model to characterize the issue at hand [16].

$\hat{y} = \beta_0 + \beta_1 x_1 + \ldots\ldots\ldots\ldots + \beta_n x_n$. Sigmoid function examples include $P = 1/\ 1+ e^{-\hat{y}}$. Continuing with this, NN with a sigmoid activation function might be employed to depict logistic regression. In additional disputes, we can calculate the weighted variables by reducing the function of cross-entropy loss generated by the common SGD approach. $l(p, y) = -y \log(p) - (1-y) \log(1-p)$ *where* $y \in [0,1]$.

As a result, the multinomial logistic regression is limited to addition new stochastic cells to the stratum. To maintain the result as the distribution of probability, we could substitute the SoftMax activation equation for the logistic function. With SoftMax, the decrease is renewed the log- likelihood loss while doing. [17]. The collected trust values are then used to train a logistic regression model that incorporates Naive Bayes, an ensemble, and a support vector machine. The performance of this suggested model will be assessed by testing at a later stage. The performance of a classifier may be measured using a number of different factors described in the literature. Whose, the formula is shown below in mathematical form.

B. Performance metrics

In terms of the performance metrics represented in the confusion matrix, we may assess the efficacy of a technique by looking Accuracy: The proportion of subjects correctly identified as part of the total no of subjects.

Accuracy =TP+TN/TP+TN + FP + FN (3)

Sensitivity: Recall, also known as sensitivity, is the percentage of true positive indicators that the system accurately recognizes.

Sensitivity=TP/TP+FN. (4)

Precision: The amount of successful predictions may be used as a measure of a viewpoint's accuracy. Another name for this idea is "predictive value."

Precision=TP/TP+FP. (5)

1-Score: A statistic that considers combined accuracy and recall is the F1-score.

F1-score=2*(Precision*Recall/Precision+Recall) (6)

Specificity: The algorithm has classified the negative as specificity appropriately.

Specificity=TN/TN+FP (7)

Whereas, FN= False Negative, FP= False Positive, TN= True Negative, and TP= True Positive.

Depending on the topic, the experimental section should include synthesis procedures, characterization techniques etc and specification of the instruments. If it is simulation, author will have to mention the type simulation software with specifications [3,7]. Write the importance of that software used relevant to research work carried out.

4. RESULTS AND DISCUSSION

Logistic Regression

Our suggested approach properly identified 348 benign nodes as benign and 149 harmful nodes as miscellaneous nodes. There are some misclassifications are also occurred, the proposed model predicts 1 miscellaneous node as normal node, and 2 normal nodes as miscellaneous nodes.

Ensemble Learning

Logistic regression model predicted 147 miscellaneous node as miscellaneous nodes and correctly predicted 342 normal nodes as normal nodes. There are some misclassifications are also occurred, the Logistic regression model predicts 3 miscellaneous nodes as normal node, and 8 normal nodes as miscellaneous nodes.

Naïve Bayes

Logistic regression model predicted 145 miscellaneous node as miscellaneous nodes and correctly predicted 341 normal nodes as normal nodes. There are some misclassifications are also occurred, the Naïve Bayes model predicts 5 miscellaneous nodes as normal node, and 9 normal nodes as miscellaneous nodes.

SVM

Logistic regression model predicted 145 miscellaneous node as miscellaneous nodes and correctly predicted 335 normal nodes as normal nodes. There are some misclassifications are also occurred, the SVM model predicts 5 miscellaneous nodes as normal node, and 15 normal nodes as miscellaneous nodes.

The following graphic depicts an accuracy examination of four algorithms, with the proposed and present approaches along the x-axis and the accuracy value along the y-axis. There is a 98% success rate in group instruction. The accuracy of the Gaussian Navies base is 97%. Logistic regression, the recommended voting classifier, achieves 99% accuracy, while the support vector machine achieves 96% accuracy. Based on comparisons with various techniques, it may be said that logistic regression yields useful results.

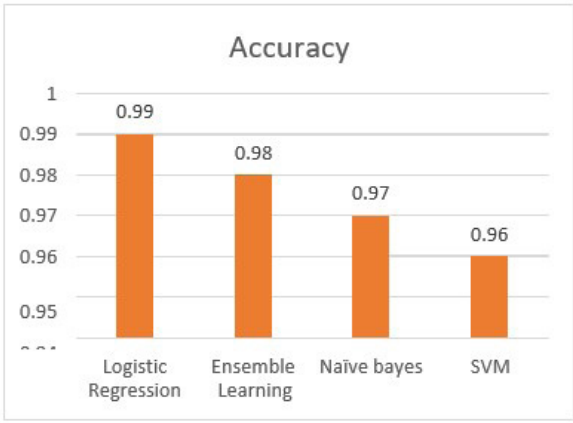


Figure-1 Accuracy study

The figure below depicts a sensitivity analysis of four algorithms, where the suggested solution and current algorithms make up the x-axis and the sensitivity value occupies the y-axis. Almost often, learning in a group requires sensitivity. The Gaussian Navies base has a 96% sensitivity. The accuracy of the recommended voting classifier logistic regression is 99%, while the support vector machine's sensitivity is 95%. One may assume that logistic regression produces successful results when compared to other techniques.

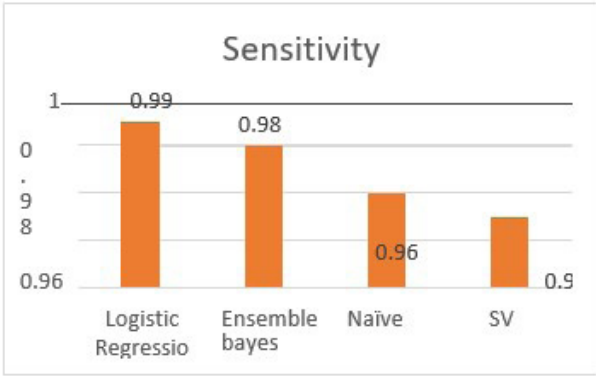


Figure-2 Sensitivity study

The following graph displays a specificity study of 4 algorithms, where the x-axis indicates the suggested and current technique and the y-axis displays the specificity value. A specificity of 97% applies to ensemble learning. A 97% specificity is included in the Gaussian Navies basis. In contrast to the support vector machine, which has a 95% specificity, the proposed voting classifier logistic regression has a 99% specificity. Logistic regression is thought to provide successful results when compared to other techniques.

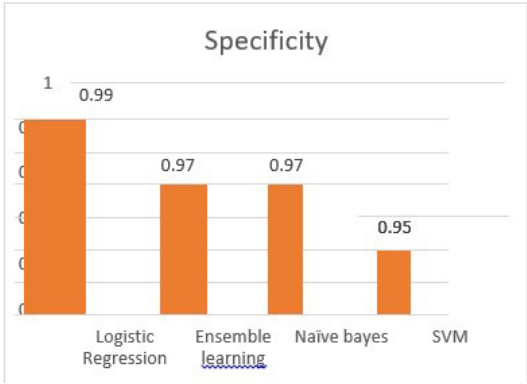


Figure-3 Specificity study

5. CONCLUSIONS

The suggested hybrid trust and blockchain-based architecture for heterogeneous IoT systems has shown promising outcomes in terms of scalability, fault tolerance, and security. The framework may be used to a variety of IoT systems and offers a trust-based foundation for safe data exchange and communication. The framework can successfully analyze data from various IoT devices and identify abnormalities or malicious actions by employing the logistic regression approach. Trust levels are also used to identify malicious nodes in a heterogeneous IOT system. This data is then used to build a logistic regression model that can identify malicious nodes. The suggested method is compared to existing algorithms based on performance metrics to demonstrate its efficiency. For proposed and current algorithms, performance principles like as specificity, sensitivity, and accuracy are compared. The suggested method has a better accuracy score of 99% than the current approach. All suggested algorithm values are greater than current algorithm values, demonstrating that the new method is very efficient. As a result, it is possible to infer that logistic regression is very accurate in detecting harmful behaviors in heterogeneous IOT systems.

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REFERENCES

1. L. Tseng, L. Wong, S. Otoum, M. Aloqaily, and J. Ben Othman, "Blockchain for Managing Heterogeneous InternetofThings: A Perspective Architecture, "*IEEENetw.,*2020, vol.34, no. 1, pp. 16–23, doi:10.1109/MNET.001.1900103.

2. B. S. Egala, A. K. Pradhan, V. Badarla, and S. P Mohanty, "Fortified-Chain: A Blockchain-Based Framework for Security and Privacy-Assured Internet of Medical Things with Effective Access Control," *IEEE Internet Things J.,* 2021, vol. 8, no. 14, pp. 11717–11731,doi: 10.1109/JIOT.2021.3058946.

3. M. A. Rahman, M. S. Abuludin, L. X. Yuan, M. S. Islam, and A. T. Asyhari, "EduChain: CIA-Compliant Blockchain for Intelligent Cyber Defense of Microservices in Education Industry 4.0, "*IEEE Trans. Ind. Informatics*, 2022, vol. 18, no. 3, pp. 1930–1938, doi: 10.1109/TII.2021.3093475.

4. W. Li and W. Meng, "BCTrustFrame: Enhancing Trust Management via Blockchain and IPFS in 6G Era," *IEEE Netw.,* 2022, vol. 36, no. 4, pp. 120–125, doi: 10.1109/MNET.013.2100768.

5. S. M. Basha, "Inter-Locking Dependency Evaluation Schema based on Block-chain Enabled," no. April 2022.

6. JOHN KENEDI, "Access to Justice for Victims of Ethnic Based Violence in Ethiopia : The Case of Oromia Region BASED VIOLENCE IN ETHIOPIA : THE CASE OF," 2021.

7. K. Yuzik and D. Makaroff, "Blockchain-Based Security for Heterogeneous IoT Systems," *Proc. 30th Annu Int. Conf. Comput. Sci. Softw. Eng.,* pp. 63–72, 2020.

8. T. Qiu, N. Chen, K. Li, M. Atiquzzaman, and W. Zhao "How can heterogeneous internet of things build our future: A survey," IEEE Commun. Surv. Tutorials, doi:10.1109/COMST.2018.2803740. vol. 20, no. 3, pp. 2011–2027, 2018,

9. J. Li, T. Liu, D. Niyato, P. Wang, J. Li, and Z. Han, "Contract-Theoretic Pricing for Security Deposits in Sharded Blockchain with Internet of Things (IoT)," IEEE Internet Things J., vol. 8, no. 12, pp. 10052–10070, 2021, doi: 10.1109/JIOT.2021.3049227.

10. Y. Liu, K. Wang, K. Qian, M. Du, and S. Guo, "Tornado: Enabling Blockchain in Heterogeneous Internet of Things Through a Space-Structured Approach," IEEE Internet Things J., vol. 7, no. 2, pp. 1273–1286, 2020, doi: 10.1109/JIOT.2019.2954128.

11. K. Fanning and D. P. Centers, "B lockchain and Its Coming," pp. 53–57, 2016, doi: 10.1002/jcaf.

12. A. Lakhan, M. Ahmad, M. Bilal, A. Jolfaei, and R. M. Mehmood, "Mobility Aware Blockchain Enabled Offloading and Scheduling in Vehicular

Fog Cloud Computing," IEEE Trans. Intell. Transp. Syst., vol. 22, no. 7, pp. 4212–4223, 2021, doi: 10.1109/TITS.2021.3056461

13. S. Kumar, "Privacy preservation and security challenges : a new frontier multimodal machine learning research September, 2022, doi: 10.1504/IJSNET.2022.10049988.

14. M. A. M. De Oca and T. St, "Université Libre de Bruxelles Frankenstein ' s PSO : An Engineered Composite Particle Swarm Optimization Algorithm," Most, no. March, 2007.

15. J. L. Fernández Martínez and E. García Gonzalo, "The Generalized PSO: A New Door to PSO Evolution," J. Artif. Evol. Appl., vol. 2008, no. 1, pp. 1–15, 2008, doi: 10.1155/2008/861275.

16. V. P. Nguyen, E. M. Ung, A. Krishna, and S. Tham, Lossless compression of topology of 3D Triangulated irregular networks. 2016. doi: 10.1109/ICICS.2015.7459974.

17. A. Field, Methods of Regression An Example Logistic Regression on SPSS Methods Residuals," Options, pp. 1– 4, 2009.

Optimizing Location Accuracy in Wireless Sensor Networks: A RSS-AMLE Approach

MohanKumar T P[1]✉, Dr. D Ramesh[2]

[1*]*Assistant Professor, Department of Master of Computer Applications, Sri Siddhartha Academy of Higher Education, Tumakuru, India-572105,*

[2]*Professor, Department of Master of Computer Applications, Sri Siddhartha Academy of Higher Education, Tumakuru, India-572105*

mohantharur@gmail.com

Abstract

Over the past decade, there has been significant growth in wireless sensor networks, particularly in the context of industrial applications. Mobile sensor networks, in particular, have garnered research interest due to their ability to facilitate communication between various devices. Still, the mobility of these nodes gives rise to challenges such as network coverage and connectivity issues. Addressing these challenges necessitates accurate estimation of sensor node locations, a critical factor in network performance. Numerous methods, such as Angle of Arrival (AOA) and Time of Arrival (TOA), have been proposed for node localization. Still, these methods are plagued by localization errors and high implementation costs. To overcome these localization errors in wireless sensor networks, we present an adaptive approach based on the Received Signal Strength (RSS) model. This model views localization as a non-convex problem and employs an adaptive maximum likelihood estimation to minimize localization errors. An extensive simulation study is carried out to measure the performance of the intended approach in minimizing the localization error. The results unequivocally demonstrate that our localization scheme achieves higher accuracy in locating sensor nodes while reducing deployment costs. Comparative analysis against existing methods further underscores the significance of our approach.

Key Words: *Wireless Sensor Networks (WSNs), Received Signal Strength (RSS) model, non-convex problem, localization errors.*

1. INTRODUCTION

A Wireless Sensor Network (WSN) consists of hundreds or even more sensory devices designed to observe the surroundings, carry out basic computations, and transmit the collected data to other sensors or a central unit for data collection. These sensor devices are characterized by their limited battery life, cost- effectiveness, compact size, and are primarily intended for a wide range of sensory applications. These applications encompass areas such as

military surveillance systems, environmental monitoring, search and rescue missions, disaster management, and wildlife habitat counting in forests, fire detection, and safety alarms, among others [1-5]. In many such applications node localization is an important criterion to report the origin of events, to query the sensor nodes, routing, and the network coverage for providing better and effective service to the end users.[6]

Over the past few years, these sensor nodes have been enhanced with wireless interfaces, enabling them to establish connections with one another, forming a wireless network infrastructure. These sensor devices gather and store relevant data in their local vicinity and then transmit this sensory data over a remote medium to central information gathering nodes, often referred to as Base stations or Sinks. At these information gathering nodes, the collected data is analyzed with the ultimate aim of determining the overall status of the sensed area.[7-10]

There are many locations-based approaches to localize the nodes. The straightforward solution is to add global positioning system (GPS) to every sensor node in the network, but it is not feasible as mountains, dense forest and other obstacles block the line-of-sight from GPS satellite. High power consumption due to the use of GPS has a negative impact on the lifetime of the entire network. Similarly, the production and implementation cost of GPS for large sensor nodes is very high [11-16]. For these reasons an alternative solution that is cost effective, easily deployable and can operate in diverse environment is required.

The localization method based on Time of Arrival (TOA) framework [Quanrui Wei et al., 2014], necessitates the use of additional devices or hardware to ensure that the transmitting and receiving devices are synchronized. Crucially, even a small error in time estimation can lead to a significant deviation in the ranging measurements. Moreover, the localization technique relying on Time Difference of Arrival (TDOA) encounters similar challenges as TOA frameworks, as they both entail considerable costs for hardware. Both TDOA and TOA methods also require the deployment of a larger number of sensor devices because their signal propagation range is limited. On the other hand, Angle of Arrival (AOA) frameworks have the potential to offer superior localization accuracy. However, they may not be well- suited for large-scale or highly dense sensor networks due to their intricate design and the associated implementation expenses.

In the realm of Wireless Sensor Networks (WSN), various localization techniques have been developed. Abbas, A. M. (2015) proposes a unique distributed and asynchronous localization model that relies on sensor devices

responding to requests from nearby peers or anchor nodes.

While it outperforms some shortest path algorithms, challenges include potential issues with malfunctioning anchor nodes and demanding computational work for localization confidence parameter calculation. Hybrid localization approaches have gained attention, accommodating both range-free and range-based methodologies. Some strategies eliminate the need for anchor nodes, relying on factors like connectivity and distances between nodes. However, challenges in error calculation time have led to the development of AI- based techniques like Genetic Algorithms (GA) and Artificial Neural Networks (ANN), which, despite enhancing precision, face issues related to NP-Hard complexity. Range-free techniques such as Convex Position Estimation (CPE), Area-Based Localization, and Monte Carlo Localization (MCL) leverage connectivity to neighboring devices, reducing the need for additional infrastructure but increasing overhead due to anchor nodes. Angle of Arrival (AOA) determines wave propagation direction, while Time of Arrival (TOA) and Time Difference of Arrival (TDOA) use transmission time and distance association for precise localization. The authors propose a combination of TDOA and AOA methodologies to improve precision and reliability by overcoming individual method limitations. TDOA calculates distances accurately, compensating for AOA's sensitivity to errors. This hybrid approach enhances location accuracy for applications like indoor tracking and navigation systems. The DV-HOP algorithm by Chen, Hongyang, et al. (2008) addresses localization challenges by using Distance Vector routing to estimate distances to anchor nodes. It offers advantages over traditional approaches, as it doesn't require precise distance measurements or expensive hardware, minimizing energy consumption in resource-constrained WSNs. Chen, Hongyang, et al. (2008) recognize a limitation in a previous study and introduce a prioritized threshold-based anchor node localization algorithm, improving accuracy. The RSS- based weighted centroid algorithm is proposed to address ranging errors in the DV- HOP framework, demonstrating effectiveness in handling unidentified devices. Overall, the DV-HOP algorithm presents a promising solution for accurate localization in WSNs[17].

This research introduces a cost-effective and highly efficient localization approach that relies on Received Signal Strength (RSS). Unlike the limitations discussed earlier, RSS-based localization methods provide effective solutions to these issues. The core concept of RSS techniques is to utilize Radio Frequency (RF) signal propagation models, which can be derived from theoretical, hypothetical, or empirical sources, to analyze RSS data and estimate distances without requiring additional ranging hardware. These systems are not only

economical but also straightforward to implement, as the majority of RF IC-chips used in wireless sensor network devices can directly furnish RSS data. Present study shows that, implementation of RSS based localization technique with error minimization and approximation methods gives better results in terms of location accuracy of sensor nodes. In this direction, we have implemented RSS based localization technique with adaptive approach for maximum likelihood estimation to increase the location accuracy of sensor nodes by reducing the localization error in wireless sensor networks.

2. PROPOSED SENSOR DEVICES LOCALIZATION MODEL FOR WSN

This section presents proposed approach for wireless sensor node localization based on Received Signal Strength (RSS) information. In order to carry out this work, we have developed a measurement model for WSN that is used for network modeling. Figure 1 depicts WSN network topology with different number of sensor nodes, paired nodes which are capable of communicating with each other directly or by using an edge. Here, node connectivity is an important parameter which affects the performance of localization. Connectivity can be defined at initial stage based on their node density or it can be assigned dynamically by adjusting communicating node's parameters.

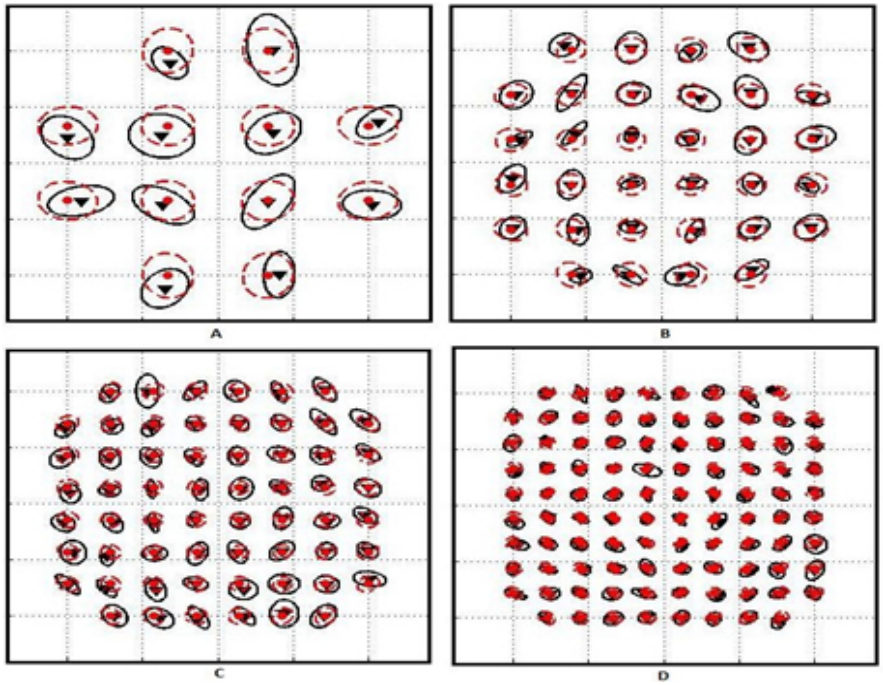


Figure-1: Network topology with different number of sensor nodes A) 4 B) 6 C) 8 D) 10

3. PROBLEM FORMULATION

Let W be a wireless sensor network which consists of anchor node and target nodes set or it can be denoted as

$W = |\square| + |P|$ (1)

Where $\square$ denotes target nodes and anchor nodes are denoted by$P$,|. | denotes fundamental parameters of a set as ($|\square| = T$, $|P| = A$). According to proposed model, location of nodes are denoted as $x1 \ldots xT, xT+1 \ldots xT+A$ where$xi \in \mathbb{R}q(q \geq 2)$. In other words, this network can be presented in the form of connected graphs which is given as $(\mathcal{V}, \mathcal{E})$ where $\mathcal{V}$ denotes vertices and $\mathcal{E}$ denotes edges of the network. In this network, every node is provided limited communication range (R) which helps to obtain improved network lifetime and energy efficient performance during communication. Using this assumption, exchange of information between node i and j is given as

$\mathcal{E} = \{(i, j): \|xi - xj\| \leq R, i \neq j\}$ (2)

Above equation (2) shows that the communication between nodes will happen if they are present in the defined communication range. For localization process, any of neighbor node are considered as anchoring node. Hence, target node set is given as$\Omega i = \{j: (i, j) \in \mathcal{E}$. Furthermore, to reduce the computational complexity, target node positions are defined as in the form of $q \times T$ assuming that$X = [x1, x2 \ldots xT]$. In this work, it is assumed that positions of anchor nodes are known from theoretical deduction whereas target nodes (i) are given an initial position estimation as

$\hat{x}$ (0), $where\ i = 1 \ldots T$ hence it can be concluded that $(X(0))$ contains initial position

i i

Estimation of all nodes.

Relationship between target node and neighboring node is established with the help of node's transmit power and received power which is given as

$$L_{ij} = 10\ log_{10} \frac{P_T}{P_{ii}} \quad (3)$$

Where PT denotes transmit power of a node, received power from jth node at ith target node is denoted byPij. Based on this relationship, RSS localization problem is formulated according to the path loss model which is represented as

$$L_{ij} = L_0 + 10\,\gamma\, log_{10}\frac{\|x_i - x_j\|}{d_0} + n_{ij}, \forall (i,j) \in \mathcal{E} \qquad (4)$$

Where $L0$ denotes path loss for a short distance $d0$, path loss exponent isγ, nij denotes log normal shadowing between node i and j node. This path loss model is modeled by considering zero-mean Gaussian random variable with variance$\sigma 2$. According to proposed approach, symmetric path loss measurement is assumed here i.e. $Lij = Lji$ for$i \neq j$.

Where L_0 denotes path loss for a short distance d_0, path loss exponent isγ, n_{ij} denotes log normal shadowing between node i and j node. This path loss model is modeled by considering zero-mean Gaussian random variable with varianceσ_{ij}^2. According to proposed approach, symmetric path loss measurement is assumed here i.e. $L_{ij} = L_{ji}$ for$i \neq j$.

With the help of path loss model presented in (4), we derive maximum likelihood estimator which is given as

$$\hat{X} = argmin_X \sum_{(i,j):(i,j)\in\mathcal{E}} \frac{1}{\sigma_{ij}^2} [L_{ij} - L_0 - 10\,\gamma\, log_{10}\frac{\|x_i - x_j\|}{d_0}]^2 \qquad (5)$$

Eq. (5) is a non-convex and non-linear problem which is formulated to obtain optimal solution by applying Maximum Likelihood Estimator.

For further evaluation in this work, it is assumed that transmit power of all nodes are identical, path loss and range are equal for all nodes and $\sigma_{ij}^2 = \sigma^2\ \forall\ (i,j) \in \mathcal{E}$

3.1 Iterative Process to Optimal Solution

Pairwise and position measurement between subsequent node are the main component of Least square problem which is presented in Eq. (5). Here it is assumed that initial position guess of target positions and true anchor nodes are known priory hence solution of least square problem is carried out independently with the help of local information, obtained from neighbors. This process is performed by each node independently. For high-density

networks, this problem is divided into sub-problems to perform localization process which helps to reduce computational complexity for localization in higher density wireless sensor networks.
Proposed iterative approach consists of two main stages of simulation: (1) communication stage and (2) computation stage.

3.1.1 Communication Stage

In communication stage, each node initiates communication or data transmission from one node to another node. This communication is defined as information sharing model which helps to estimate distance between communicating nodes. This stage of communication follows a communication pattern given as: huge amount of information exchange in network, initialization of anchor nodes. During information exchange or sharing, anchor node P has to transmit its information to other neighboring nodes. This stage helps the target nodes to transmit estimated position to other neighboring nodes.

3.1.2 Computation Stage

In previous stage, we have discussed that each node communicates with other neighboring node and shares information of position estimation. In this computation stage, position of each node is updated after estimating the target node position. This updating process is carried out by solving optimization problem, given as

$$x_i^{k+1} = \underset{x_i}{argmin} \sum_{(i,j):(i,j)\in\mathcal{E}} \frac{1}{\sigma_{ij}^2} \left| L_{ij} - L_0 - 10\gamma \log_{10} \frac{\|x_i - x_j\|}{d_0} \right|^2 \quad (6)$$

$\hat{x}$Denotes true node position or last estimated position of j^{th} which is received by i^{th} node. In next section, proposed approach is described for adaptive estimator for localization process.

4. ADAPTIVE ESTIMATOR FOR WSN LOCALIZATION

In this section, we present an adaptive modeling of Maximum Likelihood estimator which utilizes convex optimization minimization problem to obtain optimal solution. In previous section we have discussed about modeling of path loss

Computation which is presented in Eq. (4) According to this model, ML distance between node i and node j is computed as:

$$\hat{d}_{ij} = d_0 10^{\frac{L_{ij}-L_0}{10\gamma}} \quad (7)$$

Further, it can be represented as:

$$\mu_{ij}\hat{d}_{ij} = \eta d_0^2 \quad (8)$$

Where $\mu_{ij} = 10^{\frac{L_{ij}}{5\gamma}}$ and $= 10^{\frac{L_0}{5\gamma}}$. Since, already assumptions are made regarding Initial estimation of target position, from above mentioned expression in Eq. (8), position of target nodes are updated by solving Least Square problem as

$$x_i^{(k+1)} = \underset{x_i}{argmin} \sum_{(i,j)\in\mathcal{E}} (\mu_{ij} \|x_i - \hat{x}_j\|^2 - \eta d_0^2)^2 \quad (9)$$

Furthermore, adaptive nature is introduced by applying a non-convex optimization process by minimizing error. This is presented as

$$\underset{x_i, \varphi, \alpha, e}{minimize\ e}$$

$$\text{Subject to } \alpha_{ij} = \mu_{ij}(\varphi_i - 2\hat{x}_j^T x_i + \hat{x}_j^T \hat{x}_j) - \mu d^2, \forall (i,j) \in \mathcal{E}, \quad \text{i.e.} \quad (10)$$

$$\|2\alpha; e-1\| \le e+1, \qquad \|2x_i; \varphi_i - 1\| \le \varphi_i + 1$$

Where $\varphi = \|x_i\|^2, \alpha = [\alpha_{ij}]$ are defined as auxiliary variables and e denotes epigraph variable concentrating on error minimization and $\alpha = \mu_{ij}(\varphi_i - 2\hat{x}_j^T x_i + \hat{x}_j^T \hat{x}_j) - \eta d_0^2, \forall (i,j) \in \mathcal{E}$

5. SIMULATION RESULTS AND ANALYSIS:

The experimental study was carried out to localize wireless sensors using the proposed localization approach. Simulations were carried out using MATLAB tool and analysis were performed using higher configuration system. Present simulation study considers several crucial localization parameters, including the area where sensor nodes were deployed, the quantity of nodes to be deployed, the number of reference devices used, and the iterations or attempts made for localization. Received Signal Strength method was employed to assess the performance of localization error.

To demonstrate the effectiveness of our proposed model, we conducted a simulation study using the parameters outlined in Table 1. In the initial scenario,

we maintained the number of reference devices at 4 and varied the number of nodes, including 4, 6, 8, and 10, while also adjusting the localization attempts. Figure 2 illustrates the performance of our model, RSSI-AML, in terms of root mean square error when employing adaptive maximum likelihood estimation, comparing it to the existing model, RSSI-ML. Figure 3 presents the average root mean square error of RSSI-ML for different numbers of sensor devices, while Figure 4 showcases the corresponding average root mean square error of RSSI-AML. The results of our proposed localization method are further detailed in Table 2, where they are compared to the performance of the established standard localization approach.

The RSS measurement is generated by applying propagation model as presented in Eq. (4). For simulation study, a random deployment of nodes is considered where the network region is considered as $100\ m \times 100\ m$ with Monte Carlo iteration model. Initially, 500 Monte Carlo iterations are simulated to obtain the connectivity in network. Path loss exponent is considered as 3, reference distance is given as 1m and reference path loss is given as 40 dB and communication range is estimated as

$R = Network\ Length\ (100\ m)/5\ m$

Table-1: Simulation parameters considered for present study

Parameter Name	**Parameter Value Considered**
Area	100 m × 100 m
Number of Sensors	4,6,8,10
Reference Devices	4
Localization Iteration	10,15,20,25,30
Localization measurement method	RSS
Path loss exponent γ	3
Reference Distance	1 m
Reference path loss	40 dB

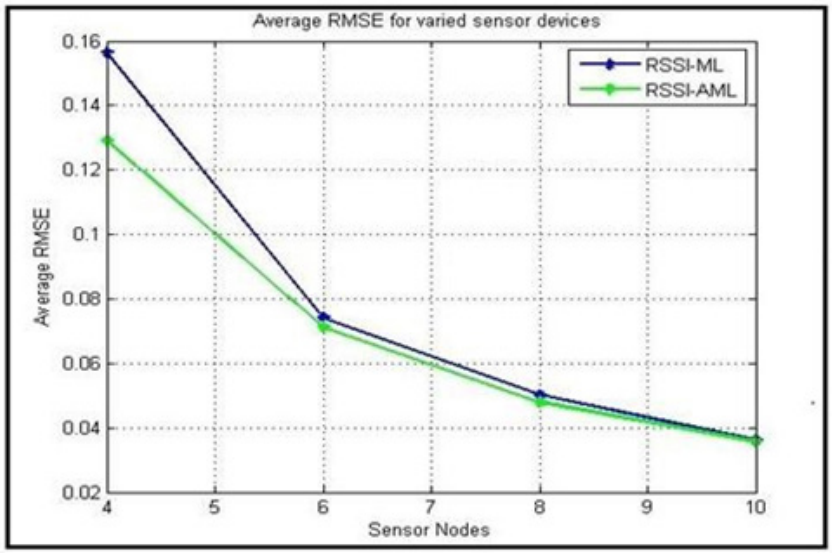


Figure-2: Varied localization attempt

In the second case, we conducted experiments in which we systematically altered the quantity of devices or nodes involved, while maintaining a consistent number of reference devices and localization attempts throughout the study. The outcomes of these experiments, which provide insights into the average performance under these specific conditions, are illustrated in both Figure 3 and Figure 4.

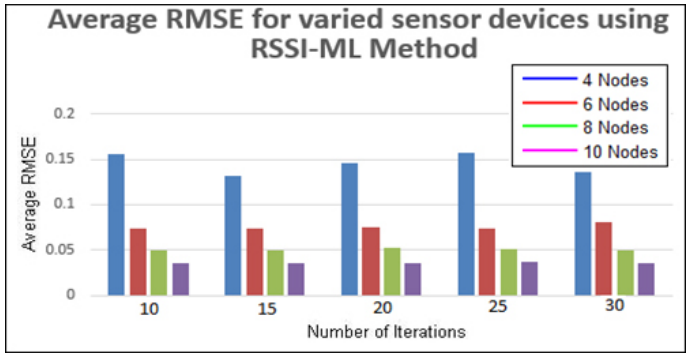


Figure-3: Average RMSE for varied sensor devices for RSSI-ML Method

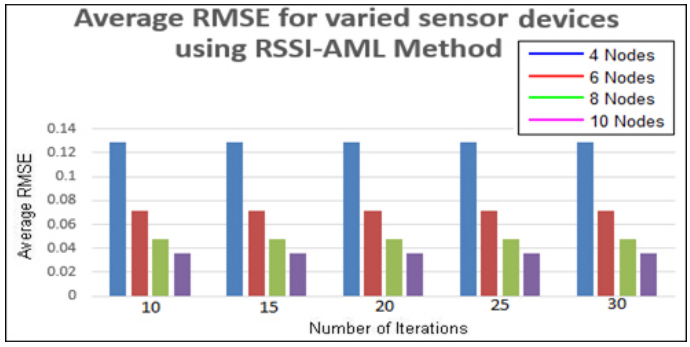


Figure-4: Average RMSE for varied sensor devices for RSSI-AML Method

In Table 2, the performance comparison of RSSI-AML with RSSI-ML is tabulated. Here we have considered varied number of sensor devices (4, 6, 8, and 10) and localization attempts (10, 15, 20, 25, and 30) by keeping the reference devices as constant (4).

Table-2: Performance comparison of RSSI-AML with RSSI-M

Number of devices	Localization attempts	RSSI-ML	RSSI-AML
4	10	0.1564	0.1291
	15	0.1312	0.1291
	20	0.1455	0.1291
	25	0.1569	0.1291
	30	0.1357	0.1291
6	10	0.0742	0.0712
	15	0.074	0.0712
	20	0.0753	0.0712
	25	0.0736	0.0712
	30	0.0813	0.0712
8	10	0.0501	0.0479
	15	0.0495	0.0479
	20	0.0529	0.0479
	25	0.051	0.0479
	30	0.0496	0.0479
10	10	0.0361	0.0356
	15	0.0356	0.0356
	20	0.0351	0.0356
	25	0.0368	0.0356
	30	0.0357	0.0356

In the provided table 2, you have a comparison of two different localization methods: RSSI-ML (Received Signal Strength Indicator with Maximum Likelihood estimation) and RSSI-AML (Received Signal Strength Indicator with Average Maximum Likelihood estimation). The data includes different configurations of the number of devices and localization attempts for each method. Let's draw some inferences and provide justifications for the results:
One notable trend is that the RSSI-AML values are consistent across different numbers of devices and localization attempts. For RSSI-AML, the value remains constant at approximately 0.1291. This suggests that RSSI-AML may be less affected by changes in the number of devices and localization attempts, indicating a stable performance regardless of the conditions. In contrast, the RSSI-ML values vary significantly across different configurations. For instance, in the "Number of devices" 4 scenario, the RSSI-ML value is 0.1564, but in the same configuration with 15 localization attempts, it decreases to 0.1312. This variation in RSSI-ML could be due to the sensitivity of the Maximum Likelihood estimation method to the number of devices and localization attempts. When we compare RSSI-ML values within the same "Localization attempts," there is a noticeable decrease in RSSI-ML as the "Number of devices" increases. For instance, with 10 localization attempts, as the number of devices goes from 4 to 10, RSSI-ML drops from 0.1564 to 0.0361. This suggests that RSSI-ML performance degrades as the network becomes more crowded with devices, potentially due to increased interference or complexity in the environment. There isn't a consistent trend with respect to the number of localization attempts for RSSI-ML. In some cases, increasing localization attempts leads to an improvement in RSSI-ML ("Number of devices" 4, 20 attempts), while in others, it leads to a decline ("Number of devices" 6, 30 attempts). The variation may be due to the complexity of the environment and the inherent noise in RSSI measurements. As mentioned earlier, the RSSI-AML values are remarkably stable across different numbers of devices and localization attempts, with values consistently around 0.1291. This suggests that RSSI-AML is less sensitive to changes in these parameters and might be a more robust choice for localization in various scenarios.

6. CONCLUSIONS

Present study shows that, implementation of RSS based localization technique with error minimization and approximation methods gives better results in terms of location accuracy of sensor nodes. In this direction, we have implemented RSS based localization technique with adaptive approach for maximum likelihood estimation to increase the location accuracy of sensor

nodes by reducing the localization error in wireless sensor networks. Based on present study the following conclusions are drawn:

1. The random deployment strategy of nodes within a 100 m × 100 m network region enhances connectivity, addressing issues associated with conventional approaches.
2. The utilization of a Monte Carlo iteration model proves effective in assessing network connectivity, offering a robust foundation for further analysis.
3. A comprehensive simulation study is conducted, systematically varying parameters such as the number of sensor devices, reference devices, and localization attempts.
4.The proposed model, RSSI-AML, leverages a Received Signal Strength based localization method.
5. An adaptive maximum likelihood estimator is incorporated to minimize or approximate the localization error within the Wireless Sensor Network (WSN).
6. RSSI-AML demonstrates superior accuracy compared to the existing RSSI-ML approach.
7. The localization scheme successfully minimizes the root mean square error, showcasing its effectiveness in achieving precise node localization.
8. Overcoming challenges associated with localization errors and high implementation costs is pivotal for providing enhanced and cost-effective services in WSNs.
9. The proposed model has significant practical implications for location- aware applications within WSNs, offering a more reliable and accurate alternative to existing methodologies.
10. The simulation results provide concrete evidence of the effectiveness of the RSSI-AML scheme, establishing its superiority in terms of accuracy and error reduction.
11. The study contributes to the advancement of WSN technology by introducing a novel localization approach that not only addresses existing issues but also outperforms established methods.
12. The success of RSSI-AML prompts further exploration of its potential applications and the possibility of refining the model for specific WSN scenarios.
13. Future research avenues may include optimizations and extensions of the proposed model to cater to evolving demands in wireless sensor network localization.

REFERENCES:

1. Abbas, A. M. (2015, May). "TrustLP: A trust-based localization protocol for wireless sensor networks". *In 2015 13th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt)* (pp. 529-536). IEEE.

2. Chen, Y., Li, X., Ding, Y., Xu, J., & Liu, Z. (2018, May). "An improved DV-Hop localization algorithm for wireless sensor networks". *13th IEEE conference on industrial electronics and applications (ICIEA)* (pp. 1831-1836). IEEE.

3. Gao, G. Q., & Lei, L. (2010, March). "An improved node localization algorithm based on DV-HOP in WSN". *2nd international conference on advanced computer control* (Vol. 4, pp. 321-324). IEEE.

4. Hui-Min Cui; Ya-Fang Wang; Jin-Xing Liu; Li-Na Liu. (2015) "Research and improvement of DV_HOP localization algorithm in wireless sensor networks", *International Conference on Machine Learning and Cybernetics (ICMLC)*, vol.2, no., pp.708-713,

5. Liu, L., Wei, Y., & Xiu, G. (2012, December). "An adaptive hybrid localization algorithm for wireless sensor network". *Second International Conference on Instrumentation, Measurement, Computer, Communication and Control* (pp. 1579-1582). IEEE.

6. Liu, L., & Manli, E. (2010, August). "Localization for wireless sensor networks by combining TFDA and FMCW". *IEEE International Conference on Mechatronics and Automation* (pp. 945-950). IEEE.

7. Magnani, A., & Leung, K. K. (2007, March). "Self-organized, scalable GPS-free localization of wireless sensors". In 2007 *IEEE Wireless Communications and Networking Conference* (pp. 3798-3803). IEEE.

8. Mohan Kumar T P, Dr. D Ramesh. "Taxonomy and comparative survey of localization techniques in WSN". *International conference on advances in engineering and technology-ICAET2023* .13th April 2023, Government Engineering College, KR Pet-Karnataka, India.

9. Nicolescu, D. (2001). "Ad-hoc positioning systems (APS)". *Proc. of IEEE Globecom,* pp 2926-2931.

10. Qingguo Zhang, Jinghua Wang, (2008, October). "Localization algorithm for wireless sensor network based on genetic simulated annealing algorithm". In 2008 *4th International Conference on Wireless Communications, Networking and Mobile Computing* (pp. 1-5). IEEE.

11. Quanrui Wei; Dexing Zhong; Jiuqiang Han, (2014). "Improved localisation method based on multi-hop distance unbiased estimation". *IET Communications,* 8(16), 2797-2804.

12. Raghava Srinivasa Nallanthighal, Veeranjaneyulu Chinta, (2014). "Improved Grid-Scan Localization Algorithm for Wireless Sensor Networks". *Hindawi Publishing Corporation Journal of Engineering*, pp. 1-5.

13. Stephan H Chagas, Joao B. Martin, Leonardo L. de Oliveira, (2012, June). "An approach to localization scheme of wireless sensor networks based on artificial neural networks and genetic algorithms". 1*0th IEEE international NEWCAS conference* (pp. 137-140). IEEE.

14. X. Wang and S. Li. (2012). "Scalable routing modeling for wireless ad hoc networks by using polychromatic sets". *IEEE Systems Journal,* 7(1), 50-58.

15. Yuan Zhang, Yuehui Chen, Yue Liu. (2012). "Towards Unique and Anchor-Free Localization for Wireless Sensor Networks". *Journal of wireless personal communications*, pp. 261-278.

16. Z Yang, Y. Liu (2010). "Quality of Trilateration: Confidence-Based Iterative Localization". I*EEE Transactions on Parallel and Distributed Systems, pp. 631– 640*, vol. 21, no. 5.

17. Zhang Xiaolong, Xie Hui-ying, Zhao Xiaojian (2007). "Wireless sensor networks in an improved DV-Hop localization algorithm". *Journal of Computer Applications*, pp.2672 -2674.

A Comprehensive Investigation On Clustering Strategies for Enhancing the Design of Cluster Head Selection in WSN.

Shruthi Bennur Mallikarjuna[1]✉, Channakrishnaraju[2]

[1] Research Scholar, Department of Computer Science and Engineering, SSAHE University, Tumkuru, Karnataka, India

[2]Professor, Department of Computer Science and Engineering, SSIT, Tumkuru, Karnataka, India

Email: shrubm@gmail.com

Abstract

In Wireless Sensor Networks (WSNs), nodes have finite and unique power resources. Clustering techniques are used to reduce energy consumption, collect data, and extend the network's operating life in order to overcome this difficulty. Despite the advantages associated with Clustering algorithms, determining the cluster head (CH), a crucial factor influencing energy efficiency, remains a significant challenge. To ensure to overcome this difficulty, clustering techniques are used to collect data, use less energy, and increase the network's lifespan. These CHs collect data obtained from WSN nodes and send it to a Base Station, which then distributes the compiled data even farther. The benefits of WSN node clustering encompass scalability, enhanced energy efficiency, and reduced routing delays. This research scrutinizes various clustering algorithms to assess their respective merits and drawbacks. A comprehensive analysis of diverse clustering strategies in WSNs is conducted, focusing on energy efficiency and power management. Finally, several concerns related to clustering are deliberated upon.

Key words: *Clustering, Nodes, Data Transmission, Energy Efficiency, Routing Delay.*

1. INTRODUCTION

New developments in wireless communications and electronics have made it possible to create Low-power sensors, small size, affordable price, and an extensive variety of applications. This development has made it possible to create wireless sensor networks, introducing a novel approach to building networks using small sensors capable of detecting environmental data, processing it, and transmitting it. The fundamental components of a Sensor networks that are wireless (WSN) are the diminutive sensor nodes. These nodes typically include a battery, a central processing unit (CPU), memory, and a radio, and the development of networked sensors has become conceivable by this advancement to fulfil a precise function [2].

1.1 Wireless Sensor Network (Wsn) Taxonomy

(i) Sensor Nodes: They are the nodes situated within the wireless network. Sensor nodes undertake various tasks, including data sensing, routing, and processing

(ii) Clusters: They are the node groups formed within the network structure. The cluster head, elected within each cluster, holds ultimate authority and is crucial for reliable data transmission

(iii) Cluster Heads: They are responsible and tasked with efficiently managing cluster operations. The key function includes data transmission, initiating and overseeing data transmission. Also they disseminate and manage the distribution of data within the cluster.

(iv) Base Station: They are regarded as a critical element in the hierarchical wireless network. It serves as a communication hub connecting the sensor network with end-users.

1.2 Challenges and Issues of WSN

In real-world applications, sensors demonstrate the capacity to grow and Work alongside with each other, which makes it easier for deployed sensors to gather a significant amount of data [3]. Sensors can be deployed in challenging environments where data collection and transmission are inherently difficult. To maximize the effectiveness of sensor networks, it is imperative to comprehend the issues and problems they confront. The protocol employed in networks addresses various challenges, and the following difficulties are notable:

(i)Data Collection in Remote Areas: Sensors placed in remote or inaccessible regions pose challenges in collecting and transmitting data

(ii)Scale of Data Accumulation: The abundance of data collected by sensors introduces challenges in efficient management and processing.

(iii)Protocols and Network Concerns: The protocols used in sensor networks must contend with various concerns to ensure optimal performance.

B A multitude of concerns and challenges are anticipated in the continued development and utilization of Wireless Sensor Networks (WSN).

Numerous concerns and other critical challenges lie ahead for Wireless Sensor Networks:

• **Energy:** In the realm of Wireless Networks, the predominant and widely encountered design challenge is power efficiency. The escalation in power consumption mandates a meticulous optimization of the three fundamental functional domains of the system: sensors, communications, and data processing. In real-world applications, sensors demonstrate mutual expansion

and cooperation, which makes it easier to gather a significant amount of data from distributed sensors. The architecture of sensor networks is inherently constrained by the finite energy resources of the sensor nodes. Furthermore, the duration of an operation is contingent on the outdoors of the software employed in the system.

• **Limited Bandwidth:** Efficient information transmission with minimal energy consumption is achievable within the range of 10 to 100 kb/s. However, the transmission of data between sensor nodes is impeded due to bandwidth limitations, as acknowledged by previous studies [4].

• **Node Cost:** Wireless communication in sensor networks employs optical, radio, or infrared communication technologies. The financial metrics of the entire system are primarily determined by the sensor nodes themselves. Achieving comprehensive metrics necessitates a substantial investment in sensors, making it a crucial factor in system planning. Sensors are selected centred on the application, considering factors such as high cost of sensors necessitates strict tolerance level management.

• **Deployment:** Reducing the complexity of a deployment can be achieved through the adoption of an efficient method. Utilizing sensor nodes at a relatively long range requires the implementation of specialized techniques. There are basically two techniques of node deployment, known as "dynamic deployment" and "static deployment."

• **Security:** Ensuring the high-level security of sensors poses one of the most significant challenges, particularly considering the sensitive data they collect. To become part of a cluster, a node must undergo authentication by the cluster head. Any unauthorized nodes are promptly isolated and segregated from the network.

1.3 Unique and Valuable Additions:

The primary objective is to offer a swift introduction to Wireless Sensor Network clustering methodologies for researchers at various levels of experience. Additionally, the paper aims to assist readers in choosing a clustering strategy that aligns with the specific requirements of their applications. To achieve this goal, an in-depth examination of the most recent clustering solutions was conducted. The subsequent sections of the paper are organized as follows:

(i) Fundamentals of Clustering Approaches in Sensor Nodes: This section introduces the foundational aspects of Clustering algorithms employed in networks of wireless sensors.

(ii) Objectives and Characteristics of Clustering: Provides a comprehensive overview, this section presents the goals and distinctive features associated with clustering methodologies in WSNs.

(iii) Challenges of Clustering Based on CH Selection and Formation: Focused on challenges, Section 4 delves into the difficulties encountered in clustering, specifically addressing the selection and formation of Cluster Heads (CH).

(iv) Description of Existing Techniques: This section elaborates on the current techniques employed in WSN clustering, offering insights into the methods currently in practice.

In essence, the paper serves as a resource for researchers, guiding them through the essentials of WSN clustering and aiding in finding an appropriate strategy tailored to their specific applications.

2. CLUSTERING METHOD

Clustering involves classifying data into unsupervised learning subsets and organizing them into clusters based on shared properties. A cluster, in this context, is a collection of entities that exhibit both similarities and differences. Distance criterion, where objects closer together form a cluster, is often employed in clustering, known as distance-based clustering.

Clustering serves as a method to identify groups of entities sharing a common characteristic. The absence of a universal standard for sample clustering highlights the user's discretion in determining the appropriateness of grouping samples. Despite this, the several requirements for optimum clustering have been proposed to guide users in achieving suitable clustering. A significant challenge in clustering is The decision-making process of the cluster number's, which are either specified by the user or specified by the algorithm itself [7].

Cluster topology necessitates dividing the network into smaller groupings termed "clusters," each serving a specific purpose. The cluster's head (CH) supervises connections among cluster members and distributes data from the cluster to the central station (BS). Nodes within a cluster architecture collaborate to send the active data to the BS collectively, enhancing efficiency and also the reducing energy consumption, thereby extending device life. Nodes may assume distinct roles in cluster protocols, functioning as either cluster members or CHs. It is typical for member nodes to provide noticed data to the CH. or to use the CH's aggregated data [8]. Fortunately, it is essential to remember that CHs often use more energy because of their higher processing loads and longer message transmission distances. Clustering algorithms play a crucial role in reducing energy usage and prolonging network lifespan.

3. DISTINCTIVE GOALS AND FEATURES

When nodes are clustered, they are more effectively organized into groups, resulting in the overall improvement of the network's performance.

3.1 Clustering algorithms pursue various objectives:

(i)Scalability: The ability of the network to grow and expand.

(ii)Node Energy Consumption: The total power consumption and energy expended by each node to fulfil its assigned task

(iii)Fault-Tolerant-Data Collection Issue: Challenges related to the data collection of nodes characterized by intermittent fault tolerance, Error-resistant and Robustness.

(iv)Lifetime: The period until all nodes exhaust their energy, marking the conclusion of the network's operation.

(v)Throughput: The volume of packets transmitted to the central station and their data transfer rate.

(vi)Data Aggregation and Analysis: The method by which data from member nodes is transmitted to the BS for further analysis, synthesis, aggregation, and compilation.

(vii)Uneven Load Distribution: If the load is distributed unevenly among cluster members, network performance may be adversely affected.

(viii)Residual Energy Reduction: Each individual node energy decreases with each round, the network's residual energy is gradually reduced.

(ix)Network Stability: The endurance of the network, Robustness and Reliability are often determined by the lifespan of the initial node.

These goals encompass various aspects of network performance and efficiency, addressing concerns such as scalability, energy consumption, data collection, and overall stability.

3.2 The Clustering Characteristics outlined include:

(i)Total Number of Clusters: The overall number of clusters can either be fixed or variable partitioning and cluster group formation, depending on the clustering procedure employed.

(ii)Hop Count in Communication: They include Jump Count and Step Count. The hop count, this displays an amount of communication steps between nodes, determines whether a communication is single-hop or multi-hop.

(iii)Clustering Strategies: Various grouping approaches and clustering strategies are available, including homogeneous/heterogeneous and single-hop/multi-hop clustering, providing different ways to organize nodes within clusters.

(iv)Upper Bound on Cluster Size: Certain algorithms may define Maximum Limit (upper bound) for the greatest total amount of nodes that can coexist in a cluster.

4. CHALLENGES OF CLUSTERING

The selection of the heads of clusters (CH) has a significant impact on the network's lifetime and the effectiveness of the clustering approach. Energy usage can be significantly decreased with the right choice of CH. The following are the most important problems with the CH assortment process:

4.1 Tasks of the CH selection

The decision about the number of Cluster Heads (CH) has a considerable impact on the clustering algorithm's efficiency and network durability. Optimized CH choosing can lead to a substantial reduced usage of energy. The primary difficulties in the CH assortment process are:

• It is feasible to centralize the process of selecting cluster head stations (CHs), with a central station performing this function. An alternative strategy is a distributed procedure in which nodes independently take on the function of CHs [9].

• The heads of the cluster (CH) may have been chosen at random or using a predefined formula. Nodes with greater amounts of energy may be more likely than nodes with a lesser amount of energy to be designated as the CH during this strategy. The amount of peers, clustering dimension, and distance characteristics are possible additional factors impacting the choice of CH.

• Extended and complex Cluster Head (CH) selection procedures could put further strain on the network's energy consumption. To reduce this expense, it is imperative to choose a CH selection procedure that is effective and ecologically friendly.

• To reduce CH congestion, a homogeneous distribution of the heads of clusters (CH) is optimum. Internal communications inside the cluster become energy-intensive in dense CH settings, where apparently is a significant distance between cluster participants and their respective CH. Consequently, the problems brought on by high internal energy consumption are lessened when CHs are distributed uniformly.

• The term "delay time" can refer to the duration it takes to select a channel. Alternatively, it might denote the time required for the formation of a cluster. This parameter is essential for clustering to be successful [10].

4.2 Cluster Formation and its Task

Now that the cluster construction step is complete, every node is updating the network with its current state. While some nodes serve as the cluster's Cluster Heads (CH), others are just normal nodes. During this stage, clustering algorithms must consider a variety of issues in their execution.

• Many contemporary probabilistic and randomized algorithms inherently

result in the generation of varying numbers of clusters. However, in several works, the set of heads of clusters (CH) may already be established, thereby predetermining the volume of clusters.

• Earlier clustering systems envisioned direct (one-hop) communications between sensors and their designated Cluster Heads (CH). However, as the number of CH and sensors is constrained, particularly in scenarios with a significant number of sensors, there is a growing need for multi-hop intra-cluster communications.

• Direct or indirect communication is possible Between the Main Station (BS) and the set of heads of cluster. When using direct mode, the CH transmits input to the central station in a single hop. In indirect mode, data is routed through a CH and transmitted via multi-hop transmission, with the data passing through a CH connected to the central station before reaching its destination.

• Clusters are distinct in regard with the quantity of nodes they contain the distance that exists between themselves and the ground station, the total number of clusters in the environment. Some clustering algorithms aim to balance elements like The amount of connected nodes, the spatial placement of each group in sequence to produce an even distribution of clusters throughout the environment. On the contrary, other techniques introduce imbalance by generating clusters randomly and without prior knowledge, leading to modifications in the total amount of neighbors distances between clusters and the BS, and other parameters [11].

4.3 Parameters of Clustering

Numerous parameters can be used in the clustering process to compare and categorize clustering approaches.

(i) Location Awareness: The calculation of distances in sensor networks requires sensors to be cognizant of their surroundings, encompassing the entire network and even the neighbors of other sensors. Achieving this awareness often involves the installation of GPS systems or the measurement of the intensity of a returning signal, both of which require energy. However, in certain algorithms, nodes may not need to know their physical geography or possibly where they were of their neighbors.

(ii) Energy Efficiency: The most significant constraint in sensor networks is the battery. Sensors are equipped with a built-in battery that has a finite lifespan and is typically non-rechargeable. Consequently, the primary principle that clustering algorithms should consider is optimizing energy consumption to prolong the network's operational life.

(iii) Clustering Objective: Several benefits come with clustering, such as

improved network scalability and lower energy usage via aggregation of data and transmission reduction. Additionally, clustering provides features including load balancing [12], fault tolerance [13], connectivity improvement [14], latency reduction, minimum cluster count [15], and maximum efficiency in resource utilization.

(iv) CH Mobility and Nodes: Clusters tend to be well-balanced and stable when nodes and Cluster Heads (CH) are immobile. This immobility facilitates easier network administration both across clusters and within them. Conversely, if all nodes and CH are movable, the cluster membership of every single node changes dynamically. Additionally, at any specific time, clusters must select a member [16].

(v) Sophistication of Algorithm: Earlier algorithm designs primarily aimed to ensure the swift termination of computations. As a result, it was expected that the temporal complexity or convergence rate would either remain constant or would vary depending upon the amount of Cluster Heads (CH) or hops in the system. Amount of nodes for sensing. may have an impact on some protocols' complexity, with older protocols placing greater emphasis on the quantity of network sensors.

(vi) Categorization: It is possible to classify broadly the clustering technique utilized to cluster information and determine Cluster Heads. Numerous clustering techniques share the randomization of the CH and cluster creation. Certain algorithms create clusters based on information from nearby nodes. Moreover, a variety of environment-segmenting techniques can be used to accomplish clustering.

5. INVESTIGATION OF CURRENT CLUSTERING APPROACHES

(i) A Wireless Sensor Network (WSN) could have a longer lifespan if a clustering protocol was implemented. This study categorizes WSNs based on algorithms, with a specific focus on convergence time, emphasizing energy efficiency, power management, and network categorization, among other factors. An energy-based protocol within the LEACH system, known as LEACH-EP [17], determines Cluster Head (CH) decisions based on data from the preceding round. The algorithm involves comparing Cluster Head Energy with Average Cluster Head Energy (Avg. CH Energy) and shares similarities in execution phases with the LEACH protocol. Additionally, the hierarchical architecture of WSN facilitates power conservation by segregating the network into clusters, each represented by a CH responsible for communication with the central station.

(ii) In [19], the author introduced a cluster-based protocol characterized by two

levels of uneven inequality. This protocol proves advantageous for large-scale and dense networks, showcasing its capability to extend the overall network lifespan. This protocol differs in that it uses two different kinds of cluster heads (CHs). The burden of each cluster is evenly distributed amongst both the primary and secondary CHs. Both the primary CH and the central station are considered to be within an acceptable distance of one another. Each cluster node is associated with two primary and two secondary CHs. The incorporation of these dual options allows for finding shorter paths and minimizing energy consumption. The protocol facilitates data transmission through multi-hop routing.

(iii) The Integrated Chaotic Logic Clustering Method (ICLCM [20]) for unbalanced clusters\ing. involves a three-step algorithmic execution. Firstly, for the proper functioning of the network, immediate information sharing is initiated. Subsequently, the network proceeds to establish clusters. Finally, The establishment of a virtual backbone for data transmission. Throughout the node-to-node communication process, nodes gain awareness of each other's locations. The heads of clusters are determined by assessing each node's radius. Each node possesses varying degrees of expertise, with competency levels determined by a set of input parameters. Distance and energy serve as the two variables for these inputs. Subsequently, each node calculates its expertise, and re-clustering takes place based on these computations.

(iv) In the work described by the author of EEFUC [22], an energy-efficient methodology is laid out to enhance communication efficiency through a distributed architecture utilizing multi-hop dispersion via Fuzzy Logic (FL). The procedure involves four main areas, employing fuzzy input parameters in conjunction with fuzzy logic. Extensive analysis reveals that these fuzzy rules have a substantial impact on performance improvement. The suggested technique is further evaluated against other standard algorithms in scenarios of varying scales, demonstrating its effectiveness for both small and large-scale applications.

(v) The GSACP (developed by Kavitha et al. [20]) is a clustering technique designed to allocate nodes with sensors are connected to a competent cluster's head (CH) with the aim of preserving energy stability within the network. GSACP, which is intended to decrease energy consumption and increase network lifetime, outperforms conventional CH selection techniques, especially when it comes to energy dissipation and the total amount of packets transferred from the central station. Nevertheless, has been noticed that there is a challenge with delayed convergence in both the krill and GSA algorithms, necessitating a shift from exploration to exploitation.

(vi) Panchal and colleagues [26] proposed algorithms focused on stabilizing

cluster formation with outstanding energy efficiency based on the LEACH protocol, known as RCH-LEACH. Cluster Heads (CHs) play a crucial role in fulfilling the primary objective of energy conservation. The CH selection method created by CHS considers a number of variables, including node capacity, Euclidean distance, and randomization. Additionally, the algorithm incorporates considerations like threshold power, residual node energy, and optimal cluster size, among other characteristics, to determine the most suitable CH to utilize. By comparing RCH-LEACH with alternative methods, the network's lifespan is increased, measured by First Node Die (FND), in comparison to the LEACH and E-LEACH algorithms. It shows a notable increase of 15 percent or 10 percent concerning FND. However, when compared to other approaches, it is shown that the network clusters stay static.

(vii) To extend the endurance of sensor networks that are wireless while reducing energy usage, researchers Ramin Yarinezhad and Seyed Naser Hashemi proposed the notion of clustering sensor nodes. The suggested strategy handles the Load-Balanced Gathering Problem. (LBGP), with a maximum known approximation factor of 1.5. Demonstrating that no polynomial-time approximation approach can achieve a better approximation factor, LBCP utilizes a Fixed Parameter Tractable (FPT) with an approximation factor of 1.2. The algorithm emphasizes the need for energy-efficient and balanced routes between Cluster Heads (CHs) and the sink. In large-scale WSNs, the suggested algorithm proves practical and outperforms similar algorithms, as indicated by simulation results [10].

(viii) Umashankar and colleagues [15] propose a self-adaptive control technique utilizing node mutation rate and crossover rate to initialize population vectors. Introducing a hybrid ideal model that incorporates the artificial annealing technique as an alternative to the constraints of traditional Low Energy Adjustable Clustering Hierarchy (LEACH), the authors combine the Equilibrium Searching Program (ESP), modified HSA, and differential evolution. By boosting the network's overall life span, hybrid strategy hopes to benefit sensor nodes as well as cluster heads. The technology also supports replacement of batteries and recharge, which promotes network reliability and effectiveness.

6. FINAL THOUGHTS AND FUTURE DIRECTIONS

The present research addresses an understudied element of wireless sensor networks (WSNs) with extensive application. Given the multitude of connected devices employed in Internet of Things (IoT) systems, an effective WSN clustering protocol becomes crucial. Techniques for clustering are essential

for maximizing energy use and prolonging the life of networks. Nodes are sorted into clusters according to predetermined criteria during clustering methods. Every cluster has a node that is in charge of gathering and sending data from all other nodes to the cluster's Centre Station (BS). The process involves considerations such as deterministic and random selection methods, distance from the BS, appropriate distribution of the heads of the cluster, and delay. The paper delves into the detailed examination of clustering methods, including the selection and formation of clusters. Clustering sensor nodes is necessary for reliable network operation and effective data distribution. While many clustering methods concentrate on either node energy or trust, to send out information, increase network lifespan, the paper recommends using an integrated energy and trust assessment-driven forecasting strategy when choosing the cluster head.

REFERENCES

1. Bala, T., Bhatia, V., Kumawat, S. and Jaglan, V., "A survey: issues and challenges in wireless sensor network", 2018, *International Conference on Advances in Computing, Communication Control and Networking* 7(2), pp.53-55.

2. Sharma, R., Prakash, S. and Roy, P., "Methodology, applications, and challenges of WSN-IoT", 2020, *International Conference on Electrical and Electronics Engineering (ICE3)* pp. 502-507. IEEE.

3. Bajaj, K., Sharma, B. and Singh, R., "Integration of WSN with IoT applications: a vision, architecture, and future challenges in Integration of WSN and IoT for Smart Cities", 2020, (pp. 79-102). Springer, Cham.

4. Devi, P. and Ravindra, W.S., "Cross layer protocol for bandwidth-hungry applications in IoT network", 2018, *Second International Conference on Inventive Communication and Computational Technologies (ICICCT)* pp. 79-83. IEEE.

5. S. Toyoda "Energy driven adaptive clustering hierarchy protocol for heterogeneous wireless sensor network", 2021, *International Journal of Recent Trends Engineering Research.,* 3(4) (2017), pp. 420-426.

6. Singh Mann P and Singh S, "Energy efficient clustering protocol based on improved metaheuristic in wireless sensor networks",2021, *J NetwComputAppl* 83:40–52.

7. Ouchitachen H, Hair A, Idrissi N, "Improved multi- objective weighted clustering algorithm in wireless sensor network", 2017, *Egypt Inform J* 18:45–54.

8. Singh, M.K., Amin, S.I., Imam, S.A., Sachan, V.K. and Choudhary, A.,

"A Survey of Wireless Sensor Network and its types", 2018, *International Conference on Advances in Computing, Communication Control and Networking (ICACCCN)*, pp. 326-330, IEEE.

9. Riaz, M.N., "Clustering algorithms of wireless sensor networks: a survey", 2018, *International Journal of Wireless and Microwave Technologies (IJWMT),*8(4), pp.40-53.

10. WohweSambo, D., Yenke, B.O., Förster, A. and Dayang, P., "Optimized clustering algorithms for large wireless sensor networks: A review" 2019, 19(2), p.322.

11. Nam, D., "Comparison Studies of Hierarchical Cluster-Based Routing Protocols in Wireless Sensor Networks In CATA", 2020, Vol. 69, pp. 334-344.

12. Rajpoot, P. and Dwivedi, P., "Optimized and load balanced clustering for wireless sensor networks to increase the lifetime of WSN using MADM approaches Wireless Networks", 2021, 26(1), pp.215-251.

13. Bhat, S.J. and Santhosh, K.V., "Fault tolerant localization based on k-means clustering in wireless sensor networks", 2020, *IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT)* pp. 1-5, IEEE.

14. Frankiewicz, A., Glos, A., Grochla, K., Łaskarzewski, Z., Miszczak, J., Połys, K., Sadowski, P. and Strzoda, A., "LP WAN gateway location selection using modified k-dominating set algorithm", 2021, *In Symposium on Modelling Analysis, and Simulation of Computer and Telecommunication Systems* pp. 209-223. Springer, Cham.

15. Al-Behadili, H.A., AlWane, S.K., Al-Yasir, Y.I., Parchin, N.O., Olley, P. and Abd-Alhameed, R.A., "Use of multiple mobile sinks in wireless sensor networks for large-scale areas" *IET Wireless Sensor Systems,* 2020, 10(4), pp.175-180.

16. Landaluce, H., Arjona, L., Perallos, A., Falcone, F., Angulo, I. and Muralter, F., "A review of IoT sensing applications and challenges using RFID and wireless sensor networks. Sensors", 2020, 20(9), p.2495.

17. L. Wu, Nie, B. Lei, Liu, J. Cui, and N. Xiong, "An energy- balanced cluster head selection method for clustering routing in WSN, 2018, *"Journal of Internet Technology,* vol. 19, pp. 115-125, 2018.

18. R. Priyadarshi, P. Rawat, V. Nath, "Three level heterogeneous clustering protocol for wireless sensor network," 2020, *MicrosystTechnoly,* 2020.

19. S. M. Amini and A. Karimi, "Two-level distributed clustering routing algorithm based on unequal clusters for large-scale Internet of Things networks,", 2020, *J Supercomput,* vol. 76, pp. 2158– 2190.

20. R. Ranganathan, B. and Somanathan, K. Kannan, "Fuzzy-Based Cluster

Head Amendment (FCHA) Approach to Prolong the Lifetime of Sensor Networks", 2020, *Wireless PersCommun,* vol. 110, pp. 1533–1549.

A Comprehensive Study of Methods Implemented in Systems for Retrieving Images Based on Content

Rajath Arakere Narayanaswamy[1], Vidyalakshmi Krishnegowda[2]

[1]*Research Scholar, Department of Computer Science & Engineering, GSSSIETW, Mysuru, Karnataka, India*

[2]*Assistant Professor, Department of Computer Science & Engineering (Data Science) SSIT, SSAHE Tumakuru, Karnataka, India*

Email: rajath191985@gmail.com

Abstract

Multimedia content analysis is widely applied in real-world computer vision applications, concentrating especially on digital photographs. Over the last many years, the intricacy of multimedia, especially images, has experienced significant growth. Platforms like Twitter, Facebook, and Instagram witness the daily upload of millions of images, presenting a difficulty in the computer vision research community to quickly obtain pertinent photos from these archives. Content-based image retrieval (CBIR) is the solution, aiming to identify similar images within large datasets through a query image. Typically, between the similarity of query image's characteristics and those image datasets is accustomed to rank images for retrieval. Early approaches involved hand-designed feature descriptors, incorporating visual cues such as shape, color, and texture. This paper offers a comprehensive survey of CBIR techniques, analyzing various retrieving images and representation models. The exploration spans from traditional low-level techniques for feature extraction to contemporary semantic deep-learning approaches. The paper delves into important concepts and key studies conducted in image representation and CBIR, bringing up some recommendations for future lines of inquiry to inspire further exploration in this domain.

Keywords: *Semantic Gap, Deep Learning, Machine Learning, and CBIR*

1. INTRODUCTION

Recent developments in technology have resulted in the widespread use of digital computers, multimedia, and storage systems, resulting in the recent development of extensive repositories containing large volumes of images and multimedia content. This abundance of multimedia data finds applications in various fields such as medical treatment, satellite data analysis, electronic games, archaeology, video and still image repositories, moreover, digital forensics and surveillance systems. The continuous growth of shared and stored multimedia

data presents a challenge in retrieving relevant images from archives. Systems for retrieving images operating on a large scale are in constant demand. The main goal of any model for retrieval of images is to search and organize images in a visual semantic relationship with the user's query. Content-Based Image Retrieval (CBIR) automates this process by extracting low-level characteristics of the image, like color, texture, shape, or other features inherent to the image. The CBIR system's performance relies heavily on these feature selections. Techniques such as navigation, browsing, and query-by-example leverage similarity calculations between low-level image contents for the extraction of pertinent images. The main obstacle within CBIR frameworks is addressing the semantic gap, which represents the information loss when translating an image from high-level semantics to low-level features. This gap exists between the visual information captured by imaging devices and the information of visual perceived by the human vision system (HVS) [1][2]. Ways to close this disparity include embedding domain-specific knowledge or utilizing machine learning techniques to develop intelligent systems trained to emulate the HVS. The core of CBIR lies throughout the feature extraction process, encompassing shape, texture, and color features derived from images. Color, being a crucial low-level visual feature, allows the human eye to distinguish visuals based on differences the color, unaffected by image translation, scale, or rotation. Shape and texture are also vital low-level features aiding in the identification of real-world textures, shapes, and objects. Figure 1 depicts a CBIR system's whole operation.

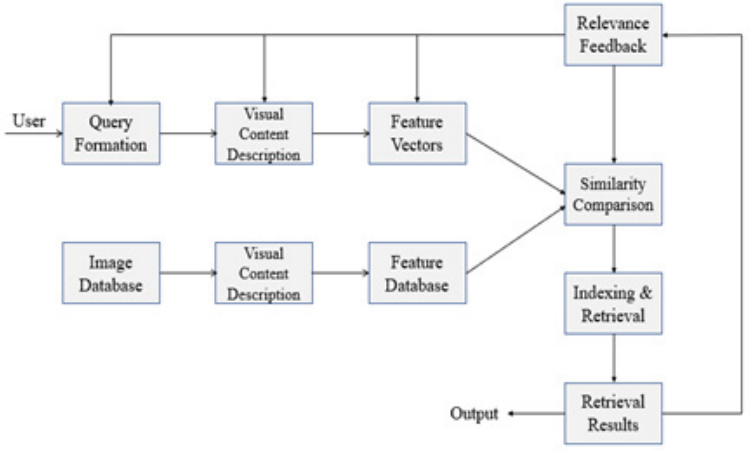


Figure-1: Overarching Flow Diagram of System for CBIR

Query Information: This refers to the input provided by the user to search for relevant images. It could be in the form of text, keywords, or an example image.

Image Database: This is the repository where all the images are stored. It could be a collection of images sourced from various places, such as the internet, databases, or user-uploaded content.

Visual Content Description: This component involves extracting descriptive features from the images in the database. These features could include color histograms, texture descriptors, shape information, or deep learning-based representations extracted from convolutional neural networks (CNNs). The goal is to represent the visual content of each image in a numerical form.

Feature Vectors and Database: After extracting visual features, each image in the database is represented as a feature vector. A feature vector is a numerical representation of the visual content of an image based on the extracted features. These feature vectors are stored in a database for efficient retrieval.

Similarity Comparison: This component computes the similarity between the query image's feature vector and the feature vectors of images in the database. Various distance metrics, such as Euclidean distance, cosine similarity, or Manhattan distance, can be used to measure the similarity between feature vectors.

Indexing & Retrieval: Indexing involves organizing the feature vectors in the database for faster retrieval. This could involve techniques like creating inverted indices, spatial indexing, or tree-based indexing structures. Retrieval refers to the process of searching the indexed database to find images that are most similar to the query image based on their feature vectors.

Relevance Feedback: Relevance feedback allows the user to provide feedback on the retrieved results, helping to refine the search and improve the relevance of subsequent searches. The user might indicate which retrieved images are relevant or irrelevant, and this feedback can be used to adjust the search algorithm to better meet the user's preferences.

This paper endeavors to present an all-encompassing summary of recent research trends challenging the field of CBIR and feature representation, in addition to the techniques employed to retrieve pictures.

2. RELATED WORK

The research contributions on CBIR were made by several authors and below is a summary of the several feature extraction strategies.

2.1. Deep Learning-Based CBIR

Sirisha Kopparthi et al. [4] conducted experiments on two datasets, namely the Land Use Dataset at UC Merced, utilizing a pre-trained model trained on millions of pictures and fine-tuned regarding the retrieval task. Employing pre-trained Convolutional Neural Network (CNN) models for generating image feature descriptors, their proposed architecture exhibited outstanding performance in the extraction of features and learning, even if you had no prior knowledge of the pictures. A variety of performance criteria were utilized to assess the effectiveness of the approach.

Ouhda Mohamed et al. [5] introduced a straightforward yet efficient CNN-based deep learning architecture for quick image retrieval and Support Vector Machine (SVM), comprising extraction of features and classification. Extensive empirical studies across various CBIR tasks using image databases yielded encouraging results, providing valuable insights for enhancing CBIR performance.

Heba Abdel-Nabi et al. [6] addressed challenges in CBIR by using Deep Learning, and leveraging the fast-growing technology. The study explored the impact of merging characteristics taken from the layers of the deep network to achieve superior retrieval outcomes. Based on the quantity of pertinent photos that were retrieved, the experimental findings demonstrated the effectiveness of the recommended technique and mean average precision, to preserve low computing complexity (AlexNet) deep convolutional model was used to train the model, thereby reducing the complexity associated with training a deep model from scratch.

Ying Liu et al. [10] suggested a retrieval technique for picture databases based on feature fusion and transfer learning. Their approach involved fine-tuning a pre-trained CNN for obtaining semantic information from pictures, followed by Principal Component Analysis (PCA) for dimension reduction and computational complexity reduction. The final step involved fusing the semantic features with traditional low-level visual characteristics to increase retrieval precision. The consequences of the findings showed how useful this technique is for retrieving images from databases.

2.2. Machine Learning-Based CBIR

M. Alrahhal et al. [7] introduced a novel CBIR system employing Local Neighbor Pattern (LNP) with supervised machine learning techniques. Performance evaluation, conducted on Corel 1k, Vistex, and TDF face databases, compared this system with Local Tetra Pattern (LTrP) across three types of databases (color, texture, and face). The analysis revealed that LNP outperforms LBP,

LDP, and LTrP average recall. To enhance system accuracy, Machine learning techniques were coupled with the LNP method., demonstrating improved average accuracy.

P. Kaur et al. [8] suggested a method for using Gabor filtering in feature extraction., further optimizing these features using lion optimization. Classification is then performed using SVM for cuckoo search optimization and optimization using decision trees. Testing across various parameters indicated improved results with Lion optimization compared to cuckoo search optimization.

Palepu Pavani et al. [11] suggested an enhanced relevance-feedback method supporting user queries through representative image selection and weighted ranking of retrieved images. Using an SVM facilitated learning to bridge the semantic gap between users and CBIR systems. Experiments indicated that this learning method empowered users to enhance their search results based on CBIR system performance. Additionally, solving the imbalance training set issue improved CBIR performance.

Rajeev Srivastava et al. [13] suggested a quick and efficient CBIR system employing supervised learning-based image management and retrieval techniques. Statistical moments and orthogonal-combination of local binary patterns (OC-LBP)-based lightweight texture features and features of color were extracted, and a multi-class SVM classifier was trained by using annotations of ground truth. This classifier acted as a manager, categorizing images into libraries. At query time, features were extracted and entered the SVM classifier, narrowing down the search to the corresponding library. The supervised model with weighted Euclidean Distance (ED) reduced irrelevant images and accelerated search times, showing significant improvements in retrieval accuracy and response time compared to conventional CBIR models. Praveen Yadav et al. [15] proposed formulas derived from shape, texture, and color-based feature extraction, employing Discrete Wavelet Transform for Euclidean distance calculation and clustering using modified K-Means clustering. Texture, shape, and color were extracted to calculate how similar query and database images are to one another. The integrated approach improved image retrieval accuracy, reducing the semantic gap between local and high-level features. The modified K-Means algorithm exhibited faster computation times, making it optimized for both small and large databases.

2.3. Handcrafted Feature-Based CBIR

Ibrahim Abood, Zainab et al. [3] propose a CBIR system employing four feature extraction techniques: colored histogram features, properties features,

gray level co-occurrence matrix (GLCM) statistical features, and a hybrid technique. To find the similarity measure, features are taken out of the test and database images. CBIR aspects is similarity-based matching, and three types of similarity measures—normalized Mahalanobis distance, Euclidean distance, and Manhattan distance—are used and compared. The results indicate that, for the database images considered in this study, the CBIR using the hybrid technique outperforms others, achieving a higher match performance (100%) for each similarity measure, making it the most effective for image retrieval.
Deepa Dubey et al. [9] predominantly focus on selecting features of images such as edge, texture, and color for the system of retrieving images based on content that utilizes an intelligent genetic algorithm. To extract color characteristics, mean and standard deviation are used, texture features through BDIP and BVLC, and edge features using a careful edge indicator. Additionally, enhanced weights of images are calculated by applying a genetic algorithm to the two-dimensional entropy. The term ‘interactive genetic algorithm' (IGA) aligns more closely with user needs, enhancing user satisfaction with image retrieval.

Poorani M et al. [14] demonstrate a retrieval method that makes use of integrated aspects, such as shape, color, and texture. Color histogram calculations for RGB and HSV pixel count and Color Moment values are used to extract color characteristics. Using Hu Moments and Edge detection features of shape are extracted. To extract texture features they used a technique called texture analysis, with parameters including contrast, correlation, homogeneity, entropy, and energy. In order to perform integrated features and provide extremely accurate recovered images, they measured similarity using Euclidean distance.

Nehal M. Varma et al. [16] propose a hybrid feature-based image retrieval mechanism incorporating color features obtained through utilizing a histogram color for color gradient determination. The Gabor wavelet method is employed for extracting outer and inner edges. The final feature vector is constructed by combining these methods to retrieve visually comparable pictures. The algorithm is tested on diverse datasets, with the matching score being used to performance evaluation and subjective analysis, showing competitive results compared to recently proposed methodologies.

2.4. Semantic Based CBIR

Neither individual visual features nor combinations of multiple features can adequately represent the higher-level concepts present in images. Furthermore, traditional image retrieval methods relying on low-level features have proven to be unsatisfactory in performance. Consequently, there is a growing

consensus in research to shift towards retrieval systems that focus on semantic meaning. This involves extracting cognitive concepts understood by humans to bridge the gap between low-level image features and high-level concepts. Additionally, representing image content using semantic terms enables users to search for images using text queries, which is more intuitive and preferred by end-users compared to using images directly. For instance, users may prefer searching for "an image of a sunset" rather than specifying colors such as "red and yellow." The general framework for Semantic-based Image Retrieval is illustrated in Figure 2.

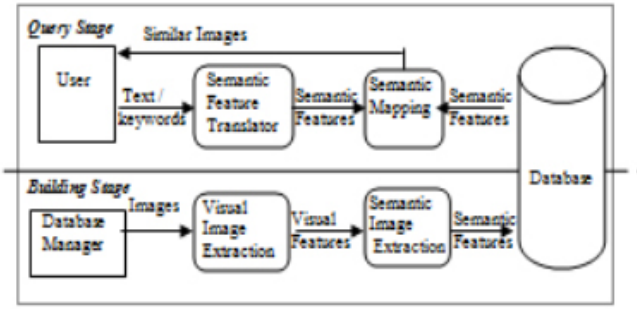


Figure-2: General Framework of Semantic-Based Image Retrieval

Every image undergoes a process of extracting visual features, which involves identifying significant regions or objects by analyzing their similar characteristics. Subsequently, these object or region features undergo semantic image extraction to obtain a semantic description of the images, which is then stored in a database. Image retrieval operates on higher-level concepts, allowing users to query based on textual input. These queries are translated into semantic features through a semantic features translator. The semantic mapping process matches the segmented regions or objects with the best-fitting concept based on visual features between the query image and those in the database. Typically, this mapping is achieved using supervised or unsupervised learning techniques to link low-level features with object concepts, which are then annotated with textual descriptions through an image annotation process.

3. SEMANTIC GAP

Addressing the semantic disparity in image retrieval remains an exceptionally complex challenge awaiting resolution [26,27]. Expressing images in semantic terms is a crucial and demanding endeavor that must be undertaken to meet human expectations and enhance the intelligence of image retrieval systems.
Humans possess the ability to interpret images on various levels, encompassing basic attributes such as color, shape, texture, and object recognition, as well as

higher-level semantics like abstract concepts or events. In contrast, machines can only analyse images based on their low-level features. Furthermore, users often express queries in terms of high-level concepts [28,29], whereas content-based image retrieval (CBIR) systems typically index images using low-level features. This leads to a discrepancy between the descriptors assigned to images and the high-level semantics users seek, known as the semantic gap [3,29]. This gap reflects the disparity between the semantic categories desired by users and the low-level features provided by CBIR systems. Bridging this semantic gap, which persists between the low-level visual characteristics and the semantic concepts identified by users, remains a significant challenge in content-based image retrieval [27].

The representation of semantic content has emerged as a critical aspect in closing the semantic gap in accessing visual information. It is recognized as an effective means of describing and representing an image, enabling the capture of its meaningful contents. Additionally, users tend to articulate their information requirements at the semantic level rather than focusing on initial image features. Furthermore, textual queries typically offer a more precise description of users' information needs.

3.1 Bridging the Semantic Gap: Mapping From low-level features to High-level Concept

A primary challenge in Image Retrieval involves establishing meaningful connections that reduce the semantic disparity between high-level semantic concepts and the low-level visual features present in images. However, these high-level concepts are not directly derived from visual content; rather, they denote the more significant meanings of objects and scenes perceived by humans in the images. These conceptual aspects are closely linked to users' preferences and subjectivity. While semantic concepts typically differ from visual image features such as color, texture, shape, and spatial relation, these attributes still convey information about semantic meaning. Thus, to bridge the gap between features and concepts, it's essential to effectively extract and select low-level features that correlate with high-level semantic descriptions for image interpretation, resulting in more intelligent and user-friendly retrieval systems. In addition to conventional low-level visual features, there's a need to learn new features that better represent semantic concepts [31]. An approach to addressing the disparity between high-level semantics and low-level features involves representing images at the object level [32].

Table I displays the typical methods employed to narrow the semantic divide in image retrieval, essentially translating from lower-level to higher-level concepts.

Table-1: Research Works on Bridging the Semantic Gap in Image Retrieval

Techniques		Researchers	Approaches
Annotation	Manual	Wikipedia image collection [31]	User annotated - whole image
		google image labeler [32]	User annotated - whole image
		Inotes [33]	User annotated - region/object
		Facebook [34]	User annotated - region/object
	Semi-Automatic	Bradshaw [35]	Bayer probability
		Ghoshal et al [36]	Cooccurrence model
		Ilaria Bartolini and Paolo Ciaccia [37]	Graph based link
	Automatic	Huang et al. [38]	Decision Trees
		Feng and Chua [39]	Bootstrapping
		Gao et al. [40]	Latent Semantic Analysis
		Mori et al. [41]	hidden Markov model
Relevance feedback		Yang et al. [42]	Semantic feedback mechanism
		Rege et al. [43]	multi-user relevance feedback
		Lin et al. [44]	semantic manifold
		Janghyun Yoon and Nikil Jayant [45]	multi-modal model feedback
Object Ontology		P.L. Standchev et al [46]	Color representation ontology
		V.Mezaris [47]	High level concept ontology
		Huan Wang [48]	multi-modality ontology
Semantic template		S.F. Chang [49]	Semantic visual template

3.2. Effective Machine Learning Approaches for Image Retrieval in CBIR

In the domain of Content-Based Image Retrieval (CBIR), several machine learning algorithms have been employed to facilitate effective image search. Some of the most commonly used machine learning algorithms that are compatible with CBIR are:

Convolutional Neural Networks (CNNs): CNNs have revolutionized image understanding tasks due to their ability to automatically learn hierarchical features directly from image data. They are widely used for feature extraction in CBIR systems, where features extracted from CNN layers serve as representations of image content.

Siamese Networks: Siamese networks are designed to learn embeddings that measure similarity between pairs of input images. They have been employed in CBIR for learning similarity metrics, enabling efficient retrieval of visually similar images.

Triplet Networks: Similar to Siamese networks, triplet networks learn embeddings for images, but they are trained using triplets of images (anchor, positive, negative). Triplet loss functions are used to encourage the embeddings of similar images to be closer together and dissimilar images to be further apart. Generative Adversarial Networks (GANs): GANs are used to generate realistic images by learning the underlying distribution of training data. In CBIR, GANs

can be utilized to generate synthetic images or to augment existing datasets, thereby improving the diversity and richness of the feature space.

Autoencoders: Autoencoders are neural networks trained to reconstruct their input data. In CBIR, they can be used for unsupervised feature learning or dimensionality reduction, where the encoder network learns to compress input images into a low-dimensional latent space representation.

Deep Metric Learning: Deep metric learning methods aim to learn embeddings that preserve similarity relationships between images. These embeddings can be used to measure similarity or distance between images directly, making them suitable for image retrieval tasks.

Attention Mechanisms: Attention mechanisms allow models to focus on relevant parts of an image while ignoring irrelevant regions. They have been used in CBIR to improve feature extraction by dynamically weighting different parts of the image based on their relevance to the retrieval task.

Graph Neural Networks (GNNs): GNNs are designed to operate on graph-structured data and have been adapted for image retrieval tasks where images are represented as nodes in a graph. GNNs can learn contextual information from image graphs to enhance similarity measurements.

These machine learning algorithms offer various capabilities and can be tailored to different aspects of CBIR systems, such as feature extraction, similarity measurement, or learning representations. The choice of algorithm depends on factors such as the specific requirements of the application, the available data, and computational resources.

4. CONCLUSION

CBIR is a method that utilizes visual content to look for images within extensive image databases. In our comprehensive literature review, various techniques for CBIR and image representation have been discussed. The primary emphasis of this investigation is to provide a summary of diverse techniques employed in various research models. Through this review, it becomes clear that the representation of image features involves the utilization of low-level aspects of the image such as texture, color, form, and spatial arrangement. Recognizing the diversity in image datasets and the nonhomogeneous properties of images, it is apparent that is not enough to have just one feature representation. To increase CBIR's effectiveness and image representation, one viable solution is the fusion of low-level features. The incorporation of different local features through fusion proves effective in addressing the semantic gap, as these features represent images in patch form, ultimately enhancing performance.

5. FUTURE WORK

Here are some key points to include the future work of CBIR:

Advanced Feature Representation: Investigate novel methods for feature representation that capture more semantic information from images. This could involve exploring deep learning architectures, such as convolutional neural networks (CNNs), to extract high-level features that better represent image content.

Semantic Understanding: Focus on enhancing CBIR systems' semantic understanding capabilities to enable more accurate and context-aware image retrieval. This may involve incorporating natural language processing techniques or leveraging knowledge graphs to better understand the relationships between images and their associated metadata.

Cross-Modal Retrieval: Explore techniques for cross-modal retrieval, where users can search for images using different modalities such as text, audio, or sketches. Developing robust cross-modal retrieval methods would enable more flexible and intuitive image search capabilities.

Scalability and Efficiency: Address scalability and efficiency challenges to enable CBIR systems to handle increasingly large-scale image datasets. This could involve optimizing algorithms for parallel processing, distributed computing, or leveraging cloud-based infrastructure.

Interdisciplinary Collaboration: Encourage interdisciplinary collaboration between computer vision, machine learning, psychology, and other relevant fields to foster innovative approaches and address complex challenges in CBIR.

Real-World Applications: Explore real-world applications of CBIR beyond traditional image search, such as medical image analysis, cultural heritage preservation, remote sensing, and environmental monitoring. Understanding the specific requirements and challenges of these domains can drive targeted research efforts.

By addressing these future research directions, the field of CBIR can continue to evolve and make significant contributions to various domains and applications.

REFERENCES

1. Latif, Afshan & Rasheed, Aqsa & Sajid, Umer & Jameel, Ahmed & Ali, Nouman & Ratyal, Naeem Iqbal & Zafar, Bushra & Dar, Saadat & Sajid, Muhammad & Khalil, Tehmina. 2019, "Content-Based Image Retrieval and Feature Extraction: A Comprehensive Review". *Mathematical Problems in Engineering.* 2019. 10.1155/2019/9658350.

2. Ibrahim Abood, Zainab & Muhsin, Israa & T., Nabeel, 2013, "Content-

based Image Retrieval (CBIR) using Hybrid Technique". *International Journal of Computer Applications*. 83. 17-24. 10.5120/14500-2307.

3. Kopparthi, Sirisha & Nynalasetti, Konadala Kameswara Rao, 2020, "Content based Image Retrieval using Deep Learning Technique with Distance Measures" *Science, Technology & Human Values.* 9. 251-261.

4. Ouhda, Mohamed & Elasnaoui, Khalid & Ouanan, Mohammed & Aksasse, B, 2019, "Content-Based Image Retrieval Using Convolutional Neural Networks". 10.1007/978-3-319-91337-7_41.

5. H. Abdel-Nabi, G. Al-Naymat and A. Awajan, 2019, "Content Based Image Retrieval Approach using Deep Learning,", 2*nd International Conference on new Trends in Computing Sciences (ICTCS), Amman, Jordan*, 2019, pp. 1-8, doi:10.1109/ICTCS.2019.8923042.

6. M. Alrahhal and K. P. Supreethi, 2019, "Content-Based Image Retrieval using Local Patterns and Supervised Machine Learning Techniques," *Amity International Conference on Artificial Intelligence (AICAI), Dubai, United Arab Emirates,* pp. 118-124, doi: 10.1109/AICAI.2019.8701255.

7. Palwinder Kaur, Dr. Rajesh Kumar Singh, "Content Based Image Retrieval Using Machine Learning And Soft Computing Techniques", *International Journal Of Scientific & Technology Research* Volume 9, Issue 01, January 2020, pp. 1327-1332.

8. Deepa Dubey, Vivek Suryawanshi, 2016, "Color, Texture and Shape Hybrid Features Based Image Retrieval System", I*nternational Journal of Computer Science and Information Technologies,* Vol. 7 (4), 1795-1800.

9. Liu, Ying & Peng, Yanan & Lim, Kengpang & Ling, Nam, 2019, A novel image retrieval algorithm based on transfer learning and fusion features. *World Wide Web*. 22. 10.1007/s11280-018-0585-y.

10. Palepu Pavani and T. Sashi Prabha, 2013, "Content-Based Image Retrieval Using Machine Learning Approach", F*ICTA, Advances in Intelligent Systems and Computing* 247, pp 173-179. DOI: 10.1007/978-3-319-02931-3_21

11. D.Shinde, Yogita & Thepade, Sudeep, 2015, Content-based Image Retrieval using Sectorisation of Self Mutated Hybrid Wavelet Transforms. *International Journal of Computer Applications,* 120. 16-19. 10.5120/21408-4419.

12. Singh, Vibhav & Srivastava, Rajeev & Pathak, Yadunath & Tiwari, Shailendra & Kaur, Kuldeep "Content-based image retrieval based on supervised learning and statistical-based moments" *Modern Physics Letters* B. 33. 1950213. 10.1142/S0217984919502130.

13. Poorani, M., 2013, Integrated Feature Extraction for Image Retrieval. 2. 28-35.

14. Praveen Yadav, Mrs. Mamta Yadav, 2016, “A Hybrid Technique For Content Based Image Retrieval Using Dwt And Modified KMeans”, *International Journal of Computer Science and Mobile Computing, IJCSMC*, Vol. 5, Issue. 7, pg.545 – 552.

15. N. M. Varma and A. Riyaz, 2018, "Content Retrieval using Hybrid Feature extraction from Query Image", *International Conference on Information, Communication, Engineering, and Technology (ICICET)*, Pune, India, 2018, pp. 1-4, doi: 10.1109/ICICET.2018.8533700.

16. Yang, Y., Jiao, S., He, J., Xia, B., Li, J. and Xiao, R., 2020. Image retrieval via learning content-based deep quality models towards big data. *Future Generation Computer Systems*, 112, pp.243-249.

17. Haq, N.F., Moradi, M. and Wang, Z.J., 2021. A deep community based approach for large scale content based X-ray image retrieval. *Medical Image Analysis*, 68, p.101847.

18. Loddo, A., Loddo, M. and Di Ruberto, C., 2021. A novel deep learning-based approach for seed image classification and retrieval. *Computers and Electronics in Agriculture*, 187, p.106269.

19. Trappey, A.J., Trappey, C.V. and Shih, S., 2021. An intelligent content-based image retrieval methodology using transfer learning for digital IP protection. *Advanced Engineering Informatics,* 48, p.101291.

20. Barhoumi, W. and Khelifa, A., 2021. Skin Lesion Image Retrieval using Transfer Learning-based Approach for Query-driven Distance Recommendation. *Computers in Biology and Medicine*, p.104825.

21. Gulzar, Y., Hamid, Y., Soomro, A.B., Alwan, A.A., Journaux, L., 2020. A convolution Neural network-based seed classification system. Symmetry 12, 1–18. https://doi.org/10.3390/sym12122018.

22. Wu, Z.Z., Zou, C., Wang, Y., Tan, M. and Weise, T., 2021. Rotation-aware representation learning for remote sensing image retrieval. *Information Sciences*, 572, pp.404-423.

23. Wang, H., Mao, K., Yuan, Z., Shi, J., Cao, M., Qin, Z., Duan, S. and Tang, B., 2021. A method for land surface temperature retrieval based on model-data-knowledge-driven and deep learning. *Remote Sensing of Environment,* 265, p.112665.

24. C.Y.Chang, H.Y.Wang, C.F.Li., 2009 “Semantic analysis of real-world images using support vector machine”. *Expert systems with application: An international journal ACM*

25. Najlae Idrissi, October 2009, “Bridging the Semantic Gap for Texture-based Image Retrieval and Navigation", *Journal of Multimedia*, Vol.4, No.5.

26. M. L. Kherfi, D. Ziou, and A. Benard. “Image retrieval from the World

Wide Web: Issues, techniques and systems". *ACM Computing Surveys,* 36(1):35{67, 2004}

27. A. W. M. Smeulders, M. Worring, S. Santini, A. Gupta, and R. Jain, December 2000, "Content-based image retrieval at the end of the early years". *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 22(12):1349-1380.

28. Ying Liu, Dengsheng Zhang, Guojun Lu, Wei-Ying M, 2007, "A survey of content-based image retrieval with high-level semantics", *Pattern Recognition.*

29. Wei Jiang, Kap luk chan, Mingjing Li., 2005, Mapping low-level features to high-level semantic concept in region-based image retrieval". *IEEE CVPR05.*

30. Chuan yu chang, hung jen wang, chi fang li. 2009, "Semantic analysis of real-world images using support vector machine". *Expert systems with application: An international journal ACM.*

31. http://wikipedia.org

32. http://images.google.com/imagelabeler/

33. http://www.iath.virginia.eduinote

34. http://www.facebook.com

35. Bradshaw B. Oct. 30-Nov.4, 2000, "Semantic-based image retrieval: a probabilistic approach" *Proceedings of the ACM International Conference on Multimedia,* Los Angeles, California; 167- 176.

36. Ghoshal A, Ircing P, Khudanpur S. Aug 2005 "Hidden Markov models for automatic annotation and content-based retrieval of images and video". P*roceedings of the 28th International ACM SIGIR Conference on Research and Development in Information Retrieval*, Salvador, Brazil, 544-551

37. Ilaria Bartolini and Paolo Ciaccia. "Towards an Effective Semi-Automatic Technique for Image Annotation"

38. Huang J., Kumar SR., Zabih R. 1998, "An automatic hierarchical image classification". *Proceedings of the ACM International Conference on Multimedia,* Bristol, UK.

39. z. Feng and T.-S. Chua. November 2003, "A bootstrapping approach to annotating large image collection." *Proceedings of the Fifth ACM SIGMM international workshop on Multimedia information retrieval (MIR '03)*, pages 55{62, Berkeley, California, USA.

40. S. Gao, D.-H. Wang, and C.-H. Lee. May 2006, "Automatic image annotation through multi-topic text categorization". *Proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP 2006)*, volume 2, pages II{377{II{380, Toulouse, France.

41. Y. Mori, H. Takahashi, and R. Oka. October 1999 , "Image-to-word

transformation based on dividing and vector quantizing images with words". *In Proceedings of the First International Workshop on Multimedia Intelligent Storage and Retrieval Management*, Orlando, Florida.

42. C. Yang, M. Dong, and F. Fotouhi. 2006, "S-iras: An interactive semantic image retrieval and annotation system". *International Journal on Semantic Web and Information Systems*.

43. M. Rege, M. Dong, and F. Fotouhi. March 2007, "Building a user-centered semantic hierarchy in image databases". *Multimedia Systems*.

44. Y. Y. Lin, T.L. Liu and H.T. Chen. 2005, "Semantic manifold learning for image retrieval." *In Proceedings of the ACM International Conference on Multimedia.*

45. Janghyun Yoon and Nikil Jayant. "Relevance Feedback for semantics-based Image retrieval"

46. P.L. Stanchev, D. Green Jr., B. Dimitrov, 2003, "High-level color similarity retrieval", *Int. J. Inf. Theories Appl.* 10 (3) 363–369.

47. V. Mezaris, I. Kompatsiaris, M.G. Strintzis, 2003, "An ontology approach to object-based image retrieval", *Proceedings of the ICIP,* vol. II, pp. 511–514.

48. Huan Wang, Song Liu, Liang tien chia, 2008, "Image retrieval with a multi-modality ontology". *Multimedia System*.

49. S.-F. Chang, W. Chen, H. Sundaram, October 1998, "Semantic visual templates: linking visual features to semantics", International Conference on Image Processing (ICIP), *Workshop on Content Based Video Search and Retrieval*, vol. 3, pp. 531–534.

Performance Evaluation of GLCM, HOG, and LBP using T1- Weighted MR Brain Image

Hanumanthappa S[1]✉ and Dr. C D Guruprakash[2]

[1]*Research Scholar, SSAHE, Agalakote, B.H.Road, Tumakuru – 5720107*

[2]*Professor, Dept. of CSE, SSIT, Tumakuru-572105, India*

Corresponding author: hanukit@gmail.com

Abstract

Medical image processing and pattern recognition research is being done in the area of brain tumor categorization. A brain tumor is an aberrant mass of tissue in which certain cells proliferate and expand out of control, seemingly unaffected by the same mechanisms that govern healthy cells. Tumor development occupies space inside the skull and disrupts regular brain function. Early tumor detection is critical to treatment outcome. Because tumor tissues vary greatly in appearance throughout patients and can resemble normal tissues, automating this process is a difficult undertaking. In this paper, we used a hybrid technique for classifying MR-brain images into normal and abnormal categories. First, this system uses three feature extraction methods: the Histogram of Oriented Gradient (HOG), the Local Binary Pattern (LBP), and the Gray-Level Co-Occurrence Matrix (GLCM). A support vector machine classifier processes the resulting feature vector from each method. We use a fusion operator to merge the dissimilarity measure values of the classifiers, thereby improving the classification accuracy. To validate the system's performance, we used a radiopaedia dataset. We assess the performance of the MR-Brain classification system by contrasting the simulation results with those from current approaches.

Keywords: GLCM, LBP, HOG, SVM

1. INTRODUCTION

An advanced medical imaging method called magnetic resonance imaging (MRI) is mostly utilized in radiology to produce high-resolution images of the body's components, architecture, and functions. It offers fine-grained pictures of the human body in any aircraft. With the use of magnetic resonance imaging (MRI), scientists can see both deep and surface structures in great anatomical detail and track the occurrence of subtle changes in these structures over time. Nuclear magnetic resonance imaging (NMRI) was the first term for the method.

However, since the public linked the term "nuclear" with exposure to ionizing radiation, it is now simply referred to as "MRI." Additionally, MR imaging can be used to monitor a brain tumor's growth about how well or poorly it reacts to treatment. A trustworthy technique for categorizing the tumor would be helpful. An accurate way to find brain tumors in humans is via an MRI scan. The human brain's magnetic resonance imaging (MRI) is displayed in **Figure 1**. Tumor classification on magnetic resonance imaging (MRI) is a crucial challenge. But even for specialists, doing it by hand takes a lot of time[1].

Finding a tumor's primary location can be done with the help of projection images. Because tumor tissue appears differently in each patient and because tumor and normal tissues often resemble one another, automating the process is a difficult undertaking. The photos are in a common format that may be used with digital imaging and communication for medical applications (DICOM). Magnetic resonance imaging (MRI), computed tomography (CT), and positron emission tomography (PET) are a few of the diagnostic imaging methods that can be used to detect brain malignancies early on. The most reliable method for finding brain cancers is magnetic resonance imaging (MRI). The main reasons for this are its non-evasiveness, strong contrast of soft tissues, great spatial resolution, and absence of harmful radiation. The Magnetic Resonance Image (MRI) from the BRATS database is classified as either an aberrant brain tumor or a normal one, as shown in Figure 2(a) and (b).

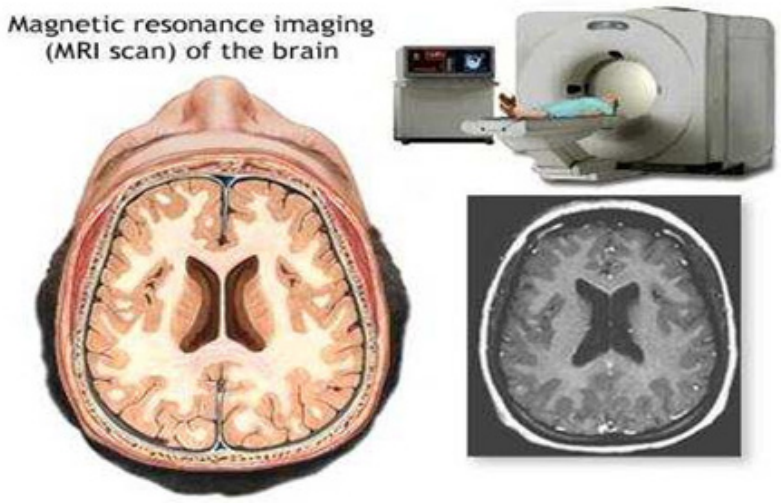
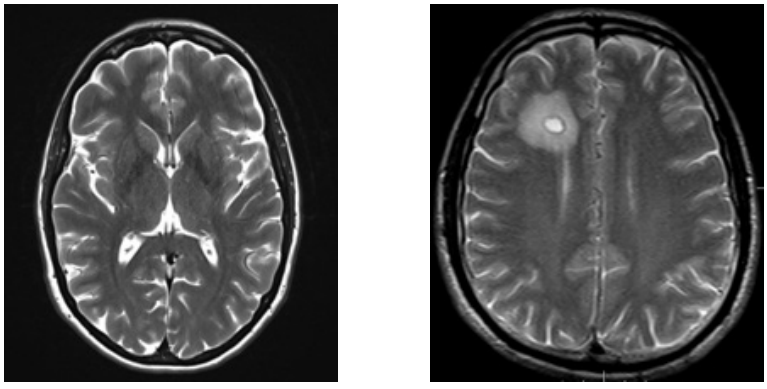


Figure-1: Brain MRI Image

Machine learning mechanisms are important in many areas, including preventive and diagnostic medicine. Few studies have investigated the feasibility of using magnetic resonance imaging (MRI) to screen for brain cancers. The majority of the studies concentrated on managing MRI images using conventional approaches. Some researchers investigated whether Brain tumor identification may benefit from the application of deep learning techniques. Numerous systems for classifying MR-Brain images have been proposed in the literature. These approaches all adhere to distinct processes, such as dimension reduction, feature extraction, and classification. Classifiers known as Generalized Eigenvalue Proximal SVM (GEPSVM)[15], AdaBoost algorithm, and random forests[6]. Wavelet transforms are used by experts a lot in the feature extraction step because they can be utilized for visualizing images at different levels of resolution[13][14][15][16][17]. The study focused only on cranial MR scans that showed the existence of masses to reduce the workload for medical professionals. An astounding accuracy rate of 97.18% was attained in the classification of cranial magnetic resonance images through empirical trials. The evaluation results indicated that the performance of the proposed technique surpassed that of prior contemporary research endeavors. The results of the trial provided more evidence that the suggested method is effective in streamlining computer-assisted brain tumor diagnosis[2].



(a) Normal **(b) Abnormal**

Figure-2: MRI of the brain's normal and abnormal images

To analyze sagittal, coronal, and axial MRI images from patients with meningioma, glioma, and pituitary tumors, the author proposed a neural model that could do so without the need for previous preprocessing to eliminate elements that are used in computer-assisted brain tumor diagnosis, such as structures of the skull or vertebral column. This method was compared to both deep learning and traditional machine learning approaches to be validated. A publicly accessible MRI imaging dataset including 3064 slices from 233 patients was used for the evaluation. Notably, this system achieved an exceptional tumor classification accuracy of 0.97325, outperforming other methods utilizing the same dataset[4]. A publicly accessible research dataset was used to evaluate the suggested model, and the results were impressive: an F1-score of 99.66%, precision of 99.61%, recall of 100%, and accuracy of 99.67% were obtained. This technique showed the highest accuracy when compared to several models such as ExceptionNet, ResNet101, ShufeNet, GoogLeNet, AlexNet, ResNet50, Darknet53, and MobileNetV2. In terms of magnetic resonance imaging brain tumor categorization, the proposed model was found to be the most effective one[5]. The automated models outperformed the manual models in the n-fold model that the authors built for image categorization. Moreover, a capsule network is employed in [6] to improve the precision of brain tumor MR image classification. An improvement in accuracy of 86.5% was reported by the researchers. The authors in reference [7] introduced a neural network model designed to classify brain images. A diverse range of models was developed, each consisting of 64 hidden neurons and a Max Pool layer, to achieve various classifications. The model achieved an accuracy of 98.5% during the training phase and 84% during the validation phase. The hybrid approach proposed by the authors in reference [8] involves the integration of evolutionary algorithms and neural networks to classify brain images. The suggested method classified photos from the pituitary, meningioma, and glioma groups with 90.9% accuracy. To supplement data, N. Nar et al. in [9] used scaling in conjunction with rotation and shifting operations. After the augmentation process, Several deep-learning models were utilized to classify tumors. The integration of transfer learning techniques was employed to extract features from MR images and VGG19 in these models. In [10], Bodapati et al. employed a median filter on the tumor data that had been segregated from MR images using k-means clustering as a first step. Enhanced Support Vector Machines (SVM) were employed to classify the BT by computing the Euclidean distance from each cluster center.

Wavelet transforms are the primary instrument of the feature extraction technique in almost all of the works that are currently under publication, with

an emphasis on the classification step. The objective of this study is to enhance current MR classification systems through a specific emphasis on feature extraction. The classifier employed is SVM, whereas three feature extraction approaches, namely GLCM[8], LBP[9], and HOG[10], are utilized. These techniques are commonly employed in many pattern recognition approaches, although They have received little focus in MR-Brain image classification. Our suggestion is an attempt to enhance the current state-of-the-art methods by comparing and contrasting these three feature extraction algorithms. We also hope to show how we might improve classification accuracy by combining the complementary data provided by each method. Finally, the given system will be compared to other MR-Brain techniques.

The structure of this document is as follows. The subsequent section presents the proposed approach for classifying MR-Brain images. It also includes a demonstration of the feature extraction methods that were employed and an instance of how the fusion operation was utilized at the classification level. The findings are presented in Section 3, accompanied by comparisons to several state-of-the-art categorization methodologies. The paper is finally concluded in section 4.

2. PROPOSED METHODOLOGY

A schematic representation of the proposed methodology is depicted in Figure 3. The trials in this approach utilize the Radiopaedia tumor dataset [22], which is a well-accepted benchmark in the field. The tumor images are subjected to a median filter for smoothing. Preprocessing of all tumor images is essential for the extraction and categorization of robust features. The Radiopaedia dataset-70 is partitioned into two classes, namely normal and abnormal, for feature extraction. The retrieved features are represented using Support Vector Machines (SVM) for classification.

1. Feature extraction: We utilize three feature extraction methods—GLCM, LBP, and HOG—to generate three feature vectors for every image.
2. Classification: The second step is classification, which involves applying the feature vectors to three support vector machine classifiers that each produce a different dissimilarity measure value.
3. Fusion operation: A fusion operator takes the three values of the dissimilarity measure and uses them to decide if the query image is normal or abnormal.

2.1 Feature Extraction

2.1.1 GLCM

A statistical method known as the Gray-Level Co-Occurrence Matrix (GLCM) considers the spatial relationship between pixels. Find out how often in an image pixel pairings separated by a specified distance, or doc, occur using a 2D histogram called GLCM.

The objective of texture analysis is to identify a unique method for describing the fundamental attributes of textures in a simplified and distinctive manner, enabling their utilization in reliable and precise recognition. The gray-level co-occurrence matrix is a geometric technique used to analyze texture by examining the spatial relationships between pixels. The methodology and efficacy of the Gray Level Co-occurrence Matrix (GLCM) technique are outlined in the reference [21].

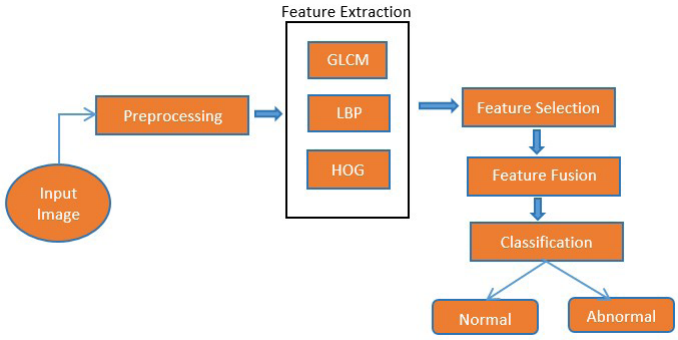


Figure-3: Proposed Methodology

2.1.2 HOG

The Histogram of Oriented Gradients (HOG) technique involves segmenting an image into discrete areas known as cells and calculating a gradient orientation histogram for each cell. Subsequently, several interconnected cells are merged into a block, and cell histograms within the block can be standardized. The image's HOG feature vector is made up of the sum of all the histograms. The following procedures are followed to extract an image's HOG feature vector:

1. To calculate an image's horizontal gradient (Ii(i, j)) and vertical gradient (Ij(i, j)), apply the [1; 0; 1] gradient filter.
2. Calculate the angle þ(i; j) and magnitude I(i; j) of the gradient.

$$|I(i,j)| = \sqrt{Ii(i,j)2 + Ij(i,j)2} \quad (1)$$

$$\theta(i,j) = arctan(\frac{I_j(i,j)}{I_i(i,j)} \quad (2)$$

Separate a picture into 8 × 8 pixel cells Step 3. The following step is to generate a bin histogram with nine possible orientations ranging from 0 to 180 degrees. The value of this bin will be the sum of all magnitudes |I(i, j)| whose relevant angles θ(i, j) are in the same bin. The Cell histograms in a set of four linked cells can be normalized using the Lowe-style clipped L2 norm, often known as the L2-Hys normalization process. When all of the image's histograms are added together, the result is the HOG feature vector.

2.1.3 LBP

The Local Binary Pattern (LBP) operator applies labels to the central pixel when a window is swept across an image. It does this by thresholding the area around the middle pixel, assigning its neighbors binary numbers, and using its center value. After that, the LBP adds up all the binary values and multiplies them by two powers. Examining the distribution of these 256 unique labels provides one perspective on the material.

It is uncertain how big the neighborhood is that is being evaluated. Here, we'll use the pixel neighborhood notation (P, R), which stands for P sampling points on a circle with radius R.

The value of a pixel's (ic, jc) LBP code is supplied by

$$LBP_{P\,R} = \sum_{P=0}^{P-1} S(g_{P-}g_c)\,2^P \quad (3)$$

Where

$$S(X) = \begin{cases} 1\ if\ X \geq 0 \\ 0\ otherwise \end{cases}$$

2.2 Classification

We use the support vector machine (SVM) classifier, one of the most well-known traditional non-parametric supervised classification methods, during the classification phase. To classify an input feature, we pick k=1 and One potential distance metric that can be employed as a measure of dissimilarity. The vector Vtest is used to train the nearest training vector Vtrain. In this study, the Euclidean distance is employed.

$$d(V^{test}, V^{train}) = \sqrt{\sum_i^{L_v}(V_i^{test} - V_i^{train})2} \quad (4)$$

In this context, Lv represents the length of the feature vector, while Vi test and Vi train represent the i-th element of the feature vectors Vtrain and Vtest, respectively.

2.3 Feature Fusion

The test image Itest is initially assigned the appropriate class after normalizing the output distance vector of each classifier within the range of 0 to 1. Subsequently, a fusion calculation is performed. The incorporation of fusion operators is motivated by the objective of harnessing the integrated knowledge offered by the three classifiers to efficiently categorize patterns. It is important to note that different methods for extracting features are used with the same settings of the SVM classifier. We employ the following fusion operators in this work:

Sum Rule

$$d_{sum}(V^{test}, V^{train}) = \sum_{f=1}^{F} d_f(V^{test}, V^{train}) \quad (5)$$

Product Rule

$$d_{Product}(V^{test}, V^{train}) = \prod_{f=1}^{F} d_f(V^{test}, V^{train}) \quad (6)$$

Minimum Rule

$$d_{min}(V^{test}, V^{train}) = \min_{f=1} F d_f(V^{test}, V^{train}) \quad (7)$$

Maximum Rule

$$d_{max}(V^{test}, V^{train}) = \max_{f=1} F d_f(V^{test}, V^{train}) \quad (8)$$

Median Rule

$$d_{median}(V^{test}, V^{train}) = \text{median}_{f=1} F d_f(V^{test}, V^{train}) \quad (9)$$

F is the total number of combined feature extraction methods for all of the fusion operators mentioned above. For this job, F = 3 has been selected.

3. EXPERIMENTS

This section outlines the experimental approach that was employed to verify the suggested methodology. We test the suggested system's sensitivity, specificity, and accuracy in terms of the true classified image rate, true negative rate, and true positive rate, respectively. The following defines the three parameters:

$$Sensitivity = \frac{TP}{TP+FN} \quad (10)$$

$$Specificity = \frac{TN}{TN+FP} \quad (11)$$

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (12)$$

3.1 Results and Discussions

The suggested plan has been put into practice using actual human brain MR imaging data. T1-weighted MR brain images with an axial plane in-plane resolution of 256 x 256 make up the collection. These images, which come from the Radiopaedia which is publicly available online, are grouped into two classes. In Fig. 1, we can see representative samples of the various MR image classes employed to study healthy and diseased brains. Remember that we are trying to solve a binary classification problem where we must distinguish between abnormal and normal brains. All disorders are considered aberrant brains. Because the classifier is trained on a particular dataset, it might only attain high classification accuracy for the training dataset and not yet for other independent datasets.

$$Total\ Number\ of\ Images = \frac{70}{200}$$
$$-Normal = \frac{20}{22}$$
$$-Abnormal = \frac{50}{178}$$
$$Training\ Images = \frac{65}{158}$$
$$-Normal = \frac{17}{18}$$
$$-AbNormal = \frac{48}{140}$$
$$Testing\ Images = \frac{13}{34}$$
$$-Normal = \frac{4}{5}$$
$$-Abnormal = \frac{9}{29}$$

We assessed the three feature extraction methods—GLCM, LBP, and HOG—based on performance criteria. Table 1 summarizes the categorization results from these different descriptors on datasets. One may observe that HOG exhibits superior sensitivity, specificity, and accuracy when compared to alternative descriptors. The classification accuracy of GLCM is 92.30%. With different levels of sensitivity and specificity, LBP achieves a rise in classification accuracy to 92.30% and HOG performs the best, achieving 100% classification accuracy. The comparison of sensitivity, specificity and accuracy are shown in Figure-4, 5 and 6 respectively.

Table-1: The performance of GLCM, HOG, and LBP

Feature Extraction Techniques	TP	FP	TN	FN	Sensitivity (%)	Specificity (%)	Accuracy (%)
GLCM	4	1	8	0	100	88.88	92.30
LBP	4	1	8	0	100	88.88	92.30
HOG	4	0	0	0	100	100	100

In Figure 4, the y-axis displays the sensitivity parameter values, while the x-axis displays the various brain tumor detection performance approaches, including GLCM, LBP and HOG. The y-axis in Figure 5 shows the specificity parameter values. Figure 6 shows the accuracy parameter values on the y-axis respectively.

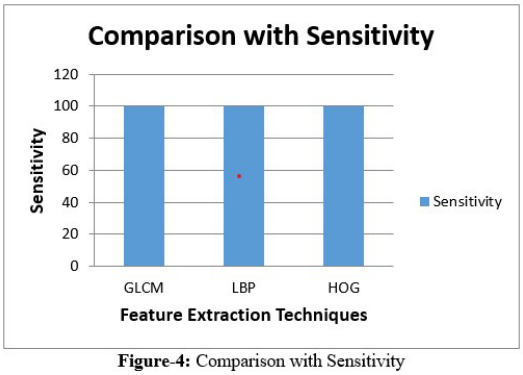


Figure-4: Comparison with Sensitivity

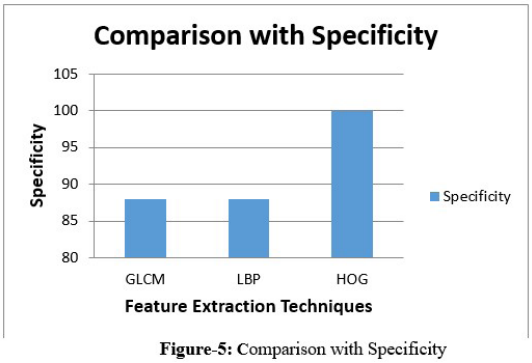


Figure-5: Comparison with Specificity

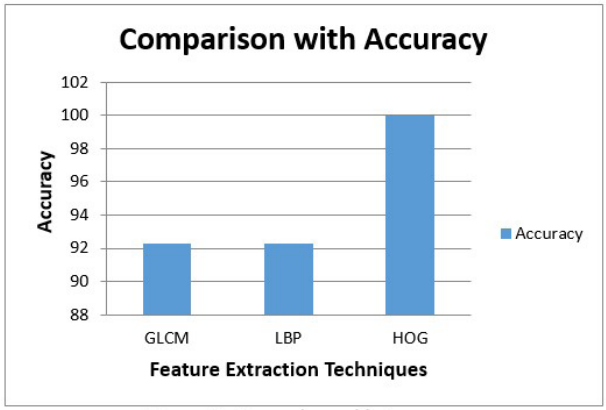


Figure-6: Comparison with Accuracy

The classifiers derived from three feature extraction techniques are integrated using a variety of fusion operators to enhance the accuracy of classification. Table 2 provides evidence of the superior performance of the sum operator, achieving a 100% accuracy rate. There exist scenarios in which the fusion operator exhibits sub-optimal performance. The weakest classification strategies are produced by the median operator. Classification accuracy produced by the min operator is comparable to LBP, whereas that produced by the max operator is comparable to HOG. Performance is far worse than that of extracting a single feature. The comparison of fusion operators performance as shown in figure-7. In Figure 7, the y-axis displays the performance of the fusion operators, while the x-axis displays the various fusion operators, including Sum, Product, Minimum, Maximum and Median.

Fusion operators	Sum (%)	Product (%)	Minimum (%)	Maximum (%)	Median (%)
Performance	100	97	94.50	99.50	93.23

Table-2: Comparison of several fusion operator s performance

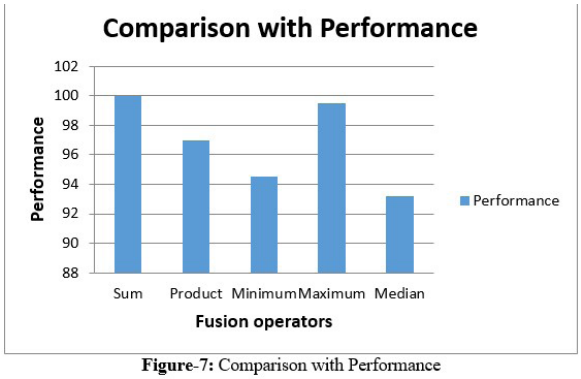


Figure-7: Comparison with Performance

The classifiers derived from three feature extraction techniques are integrated using a variety of fusion operators to enhance the accuracy of classification. Table 2 provides evidence of the superior performance of the sum operator, achieving a 100% accuracy rate. There exist scenarios in which the fusion operator exhibits sub-optimal performance. The weakest classification strategies are produced by the median operator. Classification accuracy produced by the min operator is comparable to LBP, whereas that produced by the max operator is comparable to HOG. Performance is far worse than that of extracting a single feature. The comparison of fusion operators performance as shown in figure-7. In Figure 7, the y-axis displays the performance of the fusion operators, while the x-axis displays the various fusion operators, including Sum, Product, Minimum, Maximum and Median.

Author	Accuracy
[3]	98.29
[5]	99.30
Proposed Work	**100**

Table-3: Comparison of proposed method performance with existing methods.

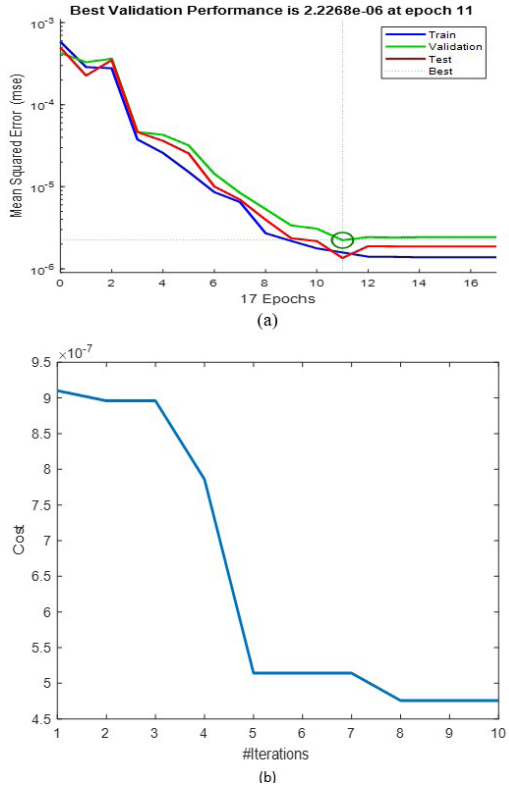


Figure-8: Sample runs of the proposed method (a) and (b) for 10 Iterations

4. CONCLUSION

We have presented a novel MR-Brain image categorization technique in this study. We initially compared three distinct feature extraction techniques: GLCM, LBP, and HOG. Our research has demonstrated that HOG is the optimal choice for classifying MR-Brain images. Subsequently, the performance was improved by employing fusion operators to leverage the advantages of each descriptor. The sum operator has yielded the most precise classification. Finally, a comparative analysis has been conducted between the obtained outcomes and those of several contemporary methodologies.

REFERENCES

1. G. Mohan and M. M. Subashini, "MRI-based medical image analysis: Survey on brain tumor grade classification", *Biomed. Signal Proc. and Control 39 (2018) 139-161.*.URL https://doi.org/10.1016/j.bspc.2017.07.007

2. E. A. El-Dahshan et al., "Computer-aided diagnosis of human brain tumor through MRI: A survey and a new algorithm", *Expert Syst. Appl. 41 (11) (2014) 5526-5545*. URL https://doi:10.1016/j. 225 eswa.2014.01.021

3. Y. Zhang, et al., "A hybrid method for MRI brain image classification", *Expert Syst. Appl.* 38 (8) (2011)10049-10053.URL https://doi:10.1016/j. eswa.2011.02.012.

4. E. A. El-Dahshan, T. Hosny and A. M. Salem, "Hybrid intelligent techniques for MRI brain images classification",*Digital Signal Processing* 20(2) (2010) 433-441. doi:10.1016/j.dsp.2009.07.002. URL https://doi.org/10.1016/j. dsp.2009.07.002

5. Y. Zhang et al.,"Preclinical diagnosis of magnetic resonance (MR) brain images via discrete wavelet packet transform with tallis entropy and generalized eigenvalue proximal support vector machine(gypsum)",*Entropy17(4)* (2015)1795-1813.doi:10.3390/e17041795.URL http://www.mdpi.com/1099-4300/17/4/1795

6. S. Wang et al., "Feed-forward neural network optimized by hybridization of PSO and ABC for abnormal brain detection", I*nt. J. Imaging Systems and Technology* 25 (2) (2015) 153-164. doi:10.1002/ima.22132. URL https://doi. org/10.1002/ima.22132

7. R. Haralick et al.,"Texture Features for Image Classification", *IEEE Transactions on Systems, Man, and Cybernetics.* 3 (6) (1973).

8. T. Ojala, M. Pietikainen and T. Maenpaa., "Multiresolution Gray-Scale and Rotation Invariant Texture Classification with Local Binary Patterns", *IEEE Trans. Pattern Anal. Mach. Intell.* 24 (7) (2002)971-987.URL https:// doi.org/10.1109/TPAMI.2002.1017623

9. N. Dalal and B. Triggs, “Histograms of oriented gradients for human detection”, in 2005 I*EEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR 2005),* 20-26 June 2005, San Diego, CA, USA, 2005, pp. 886-893. URL https://doi:10.1109/CVPR.2005.177

10. V.Vani and M. Kalaiselvi Geetha., “Automatic Tumor Classification of Brain MRI Images” *International Journal of Computer Sciences and Engineering* Vol.-4(10), Oct 2016, E-ISSN: 2347-2693.

11. Ari, A. & Hanbay D., “Deep learning-based brain tumor classification and detection system”. Turk. J. Electr. Eng. Comput. Sci. 26(5), 2275–2286 (2018).

12. Huang, Z. et al., “Convolutional neural network based on complex networks for brain tumor image classification with a modified activation function”. I*EEE Access* 8(1), 89281–89290 (2020).

13. Díaz-Pernas et al., “A deep learning approach for brain tumor classification and segmentation using a Multiscale convolutional neural network”. *Healthcare* 9(2), 1–14 (2021).

14. Raza, A. et al.,” A hybrid deep learning-based approach for brain tumor classification”. *Intell. Data Sens. Process. Min. Commun.* 11(7), 1–17 (2022).

15. P. Afshar, A. Mohammadi, and K. N. Plataniotis., “Brain tumor type classification via capsule networks," in Proc. 2*5th IEEE Int. Conf. Image Process. (ICIP),* Oct. 2018, pp. 3129-3133.

16. Saeedi et al., “MRI-based brain tumor detection using convolutional deep learning methods and chosen machine learning techniques”, *BMC Medical Informatics and Decision Making* 23, no. 1 (2023): 1-17.

17. A. Kabir Anaraki, M.Ayati, and F. Kazemi., “Magnetic resonance imaging-based brain tumor grades classification and grading via convolutional neural networks and genetic algorithms”, *Biocybern. Biomed. Eng.,* vol. 39, no. 1, pp. 63-74, Jan. 2019,

18. Çınar N, Kaya B, & Kaya M., “Comparison of deep learning models for brain tumor classification using MRI images”. *IEEE International Conference on Decision Aid Sciences and Applications (DASA)* (pp. 1382-1385), 2022.

19. Bodapati N et al., “Brain Tumor Detection on MR Images Using Improved Support Vector Machine”. *IEEE International Conference on Electronics and Renewable Systems (ICEARS)* (pp. 1022-1029), 2022.

20. F. Albregtsen.,”Statistical texture measures computed from GLCM”, I*mage processing Laboratory, Dept of Informatics, University of Oslo,* 2008.

21. E. A. El-Dahshan, T. Hosny and A. M. Salem, “Hybrid intelligent techniques for MRI brain images classification”,*Digital Signal Processing*

20(2) (2010) 433-441. doi:10.1016/j.dsp.2009.07.002. URL https://doi.org/10.1016/j.dsp.2009.07.002.

22. Prashantha S J, Prakash H N and Padmajadevi G, "A study on Computer-Aided Diagnosis of Human Brain Tumor Detection and Classification using Binary Genetic Algorithm and Deep Learning Techniques", *14th International conference on Advances in computing, Control and Telecommunication Technologies*, ACT 2023, 2023-june,pp. 1583-1591.

23. Hanumanthappa S & C. D. Guruprakash. (2023),"A Novel Technique for Brain Tumor Detection and Classification using T1-Weighted MR Image". I*nternational Journal of Online and Biomedical Engineering (iJOE),* 19(17), pp. 51–65. https://doi.org/10.3991/ijoe.v19i17.44309.

24. Hanumanthappa S & C. D. Guruprakash (2023),"Feature Extraction from Brain MR Images for Detecting Brain Tumor Using Deep Learning Techniques". *International Research Journal on Advanced Science Hub*, 5(07), 242-247. https://doi.org/10.47392/irjash.2023.049.

25. Prashantha S J and Prakash H N, "Feature Level Fusion Framework For Brain MR Image Classification Using Supervised Deep Learning And Hand Crafted Features". *Jordanian Journal of Computers and Information Technology (JJCIT),* Vol. 08, No. 04, December 2022.

26. Hanumanthappa S and Guruprakash C D, "Recent Development of Brain Tumor Detection and Classification Techniques: A Review", *14th International conference on Advances in computing, Control and Telecommunication Technologies*, ACT 2023, 2023-june,pp. 1562-1568.

Effectiveness of Covaxin and Covishield in Reducing Severe COVID-19 Among Hospitalized Patients in India

Neha Nagaraj[1]✉, . Gopinath S[2]

[1] *Postgraduate, Dept. of Community Medicine, Sri Siddhartha Medical College, SSMC Camous, Tumkur – 572107, India*

[2] *Senior Resident, Dept. of Community Medicine, Sri Lalithambigai Medical College, Chennai – 600095, India*

*Corresponding Author: nehanagaraj2208@gmail.com

Abstract

Introduction: COVID-19 is among the most devastating diseases. Worldwide, numerous vaccines were created to prevent and manage the virus. However, the frequent mutation of SARS-CoV-2 variants has led to concerns about the effectiveness of commonly used vaccines in preventing severe disease in the Indian population. This study aimed to assess the effectiveness of the BBV152 (Covaxin) and ChAdOx1-S (Covishield) vaccines in preventing severe forms of COVID-19. Materials and Methods: This retrospective study utilized hospital records and included 204 vaccinated COVID-19 patients selected through consecutive sampling. Information on vaccination status, comorbidities and CT severity scores from HRCT lung reports was extracted from patient case sheets. Fisher's exact test and binomial logistic regression analysis were used to determine the independent associations of various factors with the dependent variables. Results: Out of 204 records, 57.5% were males with a mean age of 61.8 ± 9.8 years. The study demonstrated that both vaccines provide effective protection against severe illness (90.2%), with BBV152 showing superior efficacy compared to ChAdOx1-S. Further more, male gender, partial vaccination, presence of comorbidities, and the specific type of vaccine administered were identified as independent factors predicting severe lung involvement. Conclusions:This study reveals that both vaccines were highly effective (90%) in preventing severe COVID-19 in fully vaccinated individuals. When comparing the two vaccines, BBV152 showed a slightly higher effectiveness than ChAdOx1-S in preventing severe illness of COVID-19.

Key-words: *COVID-19 vaccination, CT severity scores, and the aged population*

1. INTRODUCTION

COVID-19 has emerged as a highly impactful infectious disease. The World Health Organization declared it a pandemic on March 11, 2020 [1], leading to substantial global mortality, morbidity, and socio-economic disruptions [2]. Efforts worldwide have focused on developing safe and effective vaccines to combat COVID-19, with approximately 13 vaccines approved by the WHO under Emergency Use Authorization [3]. In India, 12 COVID-19 vaccines have been authorized, with the Whole Virion Inactivated BBV152 (COVAXIN®) and the recombinant ChAdOx1-S (COVISHIELD™) being prominently administered to adults [4]. COVAXIN is developed by Bharat Biotech in collaboration with the Indian Council of Medical Research, while COVISHIELD is produced by the Serum Institute of India, based on technology from the University of Oxford [5,6].

Initially, ChAdOx1-S was reported to have an efficacy of 85% against moderate to severe illness, while BBV152 showed 93.4% efficacy against severe COVID-19 [5,6]. However, concerns have arisen due to the continuous mutation of SARS-CoV-2 variants, potentially affecting vaccine effectiveness [7,8]. Against the Delta variant (B.1.617.2), BBV152 and ChAdOx1-S vaccines have demonstrated reduced effectiveness at 65.2% and 70.4%, respectively [9,10]. Against this backdrop, the current study aimed to evaluate the effectiveness of COVAXIN and COVISHIELD in preventing severe COVID-19 using HRCT lung reports among vaccinated patients admitted during the second wave to a designated COVID-19 hospital

2. MATERIALS AND METHODS:

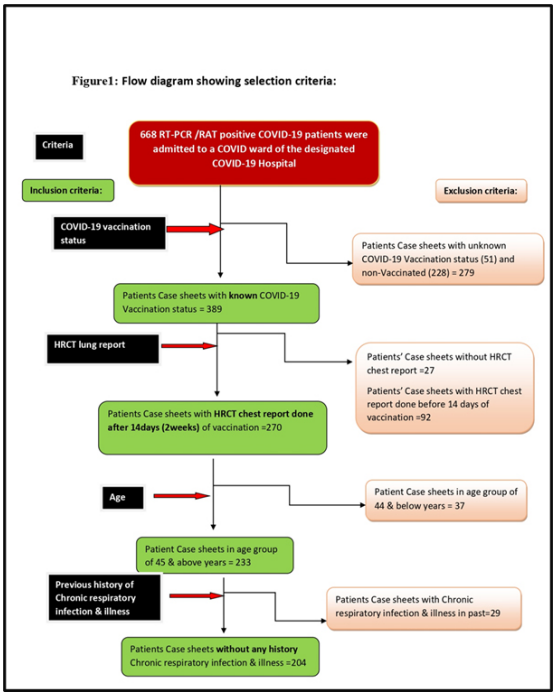
2.1 Study design and setting:

This retrospective study was conducted among COVID-19 patients admitted to a designated COVID-19 centre in southern India, between April 1, 2021, and July 31, 2021, utilizing hospital records.

2.2 Selection criteria:

The study reviewed records of COVID-19-positive patients admitted during the specified period. It included patients aged 45 years and above who had undergone High-Resolution Computed Tomography (HRCT) lung scans, tested positive for the virus via RT-PCR within 14 days of COVID-19 vaccination, and received treatment for symptoms in the hospital. Patients under 45 years old, those with chronic respiratory diseases or infections, individuals with unknown vaccination status or who were unvaccinated, and those whose HRCT chest reports were unavailable or taken more than 14 days after vaccination

were excluded from the study (Figure-1). Patients were categorized into two groups based on the type of COVID-19 vaccine received: Group 1 received COVAXIN (BBV152 vaccine), and Group 2 received COVISHIELD (ChAdOx1-S vaccine)



2.3 Data collection:

All necessary information was extracted from the selected case sheets using a semi-structured abstraction form comprising three sections:

- A: Demographic details, including MRD number, age, gender, and history of comorbid illnesses.
- B: Patient's vaccination history, detailing the type of COVID-19 vaccine administered and the number of doses received (one dose for partial vaccination, two doses for full vaccination).
- C: Patient's CORADS (COVID-19 Reporting and Data System) and CT Severity Scores (CTSS) obtained from their HRCT lung report.

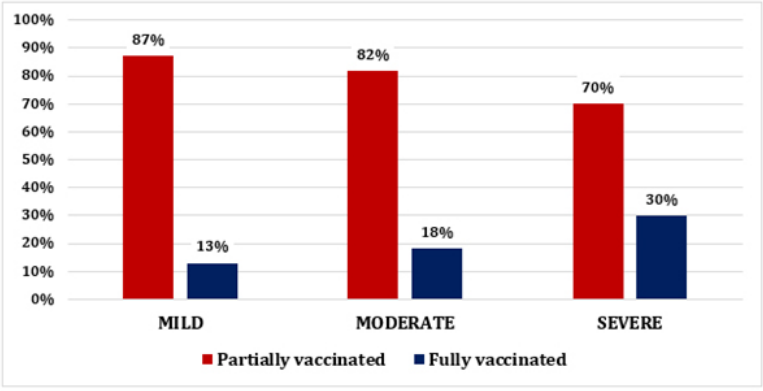
Given that CT imaging provides a direct and objective assessment of lung parenchymal involvement compared to non-specific inflammatory markers, the severity of lung involvement was categorized using the CT severity score based on the protocol for COVID-19 management - revised version 2.1, as issued by AIIMS on May 3, 2021 [11]. According to this classification, CTSS 8 indicated

mild lung involvement, CTSS 9–15 indicated moderate lung involvement, and CTSS >15 indicated severe lung involvement [12].

2.4 Data analysis:

The raw data collected was entered into Microsoft Excel 2019. Analysis was conducted using SPSS version 20 software, which included both descriptive and inferential statistics. Descriptive statistics such as frequencies and percentages were used for categorical variables, while means and standard deviations were calculated for continuous variables.

To determine associations between vaccinated COVID-19 patients and the severity of their illness based on explanatory variables, Fisher's exact test and binary logistic regression were employed. The significance level for all tests was set at 5%, with associations considered significant for P values less than 0.05.



3. RESULTS:

3.1 Characteristic of COVID-19 patients:

In this retrospective study, 204 vaccinated patients diagnosed with COVID-19 were admitted to a designated COVID-19 facility. The mean age of the participants was 61.8 ± 9.8 years, with more than half (52.7%) falling into the 61 years or older age group. The majority of participants (57.5%) were men. Among the vaccinated patients, 63.7% received the ChAdOx1-S vaccine (COVISHIELD) and 36.3% received the BBV152 vaccine (COVAXIN). A significant proportion (82.6%) were partially vaccinated (received one dose). Regarding CT severity, a higher percentage of partially vaccinated patients (6.9%) showed high severity compared to fully vaccinated patients (2.9%), regardless of the vaccine type (Figure-2). Among all vaccinated individuals, only 9.8% had severe disease with a CT severity score of 15 or above, based on their HRCT lung reports (Table-1).

Table -1: Distribution of demographic profile, vaccination status and severity of illness among COVID-19 patients (N=204).

VARIABLE		FREQUENCY N	PERCENTAGE %
AGE	45-60 YEARS	96	47.1
	61& ABOVE YEARS	108	52.9
GENDER	FEMALE	88	42.5
	MALE	118	57.5
CO-MORBIDITY	NO	132	64.7
	YES	72	35.3
TYPE OF VACCINE	COVIDSHIELD	130	63.7
	COVAXIN	74	36.3
DOSE OF VACCINE	PARTIALLY VACCINATED	168	82.4
	FULLY VACCINATED	36	17.6

3.2 Association:

Table 2 presents the findings of the Fisher exact test analysing the association between COVID-19 patient demographics, vaccination status, and HRCT lung results. The analysis revealed statistically significant differences in CT severity scores between male and female patients (p=0.001), with higher severity observed among male patients. Similarly, patients with a history of comorbidities exhibited significantly more severe lung involvement compared to those without comorbidities.

Furthermore, fully vaccinated patients, regardless of the vaccine type, showed less severe lung involvement than partially vaccinated patients, a difference that was statistically significant. Specifically, the study highlighted that patient who received the BBV152 vaccine had lower severity of lung involvement (1%) compared to those who received the ChAdOx1-S vaccine (8.8%).

Table- 2: Associated between CT severity score of HRCT lung report and demographic factors & vaccination status among COVID-19 patients.(N=204)

VARIABLE		CT SEVERITY SCORE CATEGORY			FISHER'S EXACT TEST VALUE	P-VALUE
		MILD (<8)	MODERATE (9-15)	SEVERE (>15)		
AGE	45-60 YEARS	32(15.7%)	58(28.4%)	6(2.9%)	3.237	0.189
	61& ABOVE YEARS	28(13.7%)	66(32.4%)	14(6.9%)		
GENDER	MALE	38(18.6%)	62(30.4%)	18(8.8%)	13.075	0.001***
	FEMALE	22(10.8%)	62(30.4%)	2(1%)		
COMORBIDITY	NO	46(22.5%)	86(42.2%)	0	43.217	0.001***
	YES	14(.9%)	38(18.6%)	20(9.8%)		
TYPE OF VACCINE	COVIDSHIELD	50(24.5%)	62(30.4%)	18(8.8%)	26.989	0.001***
	COVAXIN	10(4.9%)	62(30.4%)	2(1%)		
COVIDSHIELD	PARTIALLY VACCINATED	48(36.9%)	54(41.5%)	12(9.2%)	9.446	0.007**
	FULLY VACCINATED	2(1.5%)	8(6.2%)	6(4.6%)		
COVAXIN	PARTIALLY VACCINATED	4(5.4%)	48(64.9%)	2(2.7%)	5.890	0.037*
	FULLY VACCINATED	6(8.1%)	14(18.9%)	0		
SIGNIFICANT *P-VALUE<0.05, **P-VALUE<0.01, ***P-VALUE<0.001						

3.3 Regression:

Binary logistic regression was utilized to examine the relationship between the severity of lung involvement based on HRCT reports and the type of COVID-19 vaccination and doses administered (Table 3). The overall regression model demonstrated statistical significance with a Nagelkerke R^2 ranging between 7% to 9%.

Patients who received the BBV152 vaccine exhibited lower levels of lung involvement compared to those who received the ChAdOx1-S vaccine, and this difference was statistically significant. Moreover, individuals who were fully vaccinated (received two doses) with the ChAdOx1-S vaccine had a 1.6 times lower likelihood of experiencing severe illness compared to those who were partially vaccinated (received one dose), which was also statistically significant.

Table -3: Relationship between severity of lung involvement based on HRCT report and vaccination status among COVID-19 patients by using Binary Linear Regression.

VARIABLE		B	Exp B	SE	95% Confident interval for Exp B		P-value (<0.05)
					Lower	Upper	
TYPE OF VACCINE	COVAXIN	Ref					
	COVIDSHIELD	-1.755	0.173	0.761	0.039	0.767	0.021***
	CONSTANT	3.584	36.00	0.717			0.001***
COVAXIN	FULLY VACCINATED	Ref					
	PARTIALLY VACCINATED	17.94	62133.62	8987.42	0.001	0	0.998
	CONSTANT	-21.2	0.001	8987.42			0.998
COVIDSHIELD	FULLY VACCINATED	Ref					
	PARTIALLY VACCINATED	1.629	5.100	0.600	1.574	16.525	0.007***
	CONSTANT	0.511	1.667	0.516			0.323
Dependent reference group: Mild to moderate lung involvement (CTSS<15)							
*Reference group SIGNIFICANT *P-VALUE<0.05, **P-VALUE<0.01, ***P-VALUE<0.001							

4. DISCUSSION:

This study examined COVID-19 patients aged 45 years and older who received vaccination, aiming to assess how the severity of lung involvement, as determined by HRCT reports, correlates with the effectiveness of two commonly used vaccines. The age group was chosen based on Indian government guidelines prioritizing vaccination for those 45 and older due to higher COVID-19 severity in older adults [13]. The study participants had an average age of 61.8 ± 9.8 years, with more than half (52.5%) aged 61 years or older. However, there was no statistically significant link found between age and disease severity, consistent with findings from other diverse populations [14].

The study noted significantly higher disease severity among males (8.8%) compared to females (1%), which aligns with previous research by Kushwaha et al., Jin et al., and Betron et al. This difference may be attributed to behaviours such as smoking and biological factors affecting immune responses [17-19]. Comorbidities also played a critical role in disease severity, confirming previous research on their impact on COVID-19 progression [14,20,21].

Furthermore, the study highlighted that patient who received two doses

of either the BBV152 or ChAdOx1-S vaccine exhibited notably lower CT severity scores compared to those who received only one dose. This finding is consistent with studies conducted in other parts of India [22,23], underscoring the importance of completing the full vaccination schedule to reduce the risk of severe illness.

A noteworthy finding was the significantly higher effectiveness of the BBV152 vaccine compared to the ChAdOx1-S vaccine among fully vaccinated individuals, similar to findings reported by Fiolet et al. This difference may be attributed to the BBV152 vaccine's focus on the nucleocapsid protein, potentially offering better protection against prevalent mutated variants in the study region [24,25,26,27].

5. CONCLUSION:

This study demonstrates that both vaccines were highly effective (>90%) in preventing severe disease after two doses. When comparing the two vaccines, the BBV152 vaccine showed slightly greater effectiveness than the ChAdOx1-S vaccine in preventing severe forms of COVID-19.

5.1 Limitations & Recommendations:

This retrospective study, with its limited participant numbers, suggests the need for larger, longitudinal studies to comprehensively understand the natural progression of the disease and the vaccine's effectiveness against it. The current study classified participants into mild, moderate, and severe categories based on HRCT lung reports. Future research should consider incorporating clinical and serological parameters to provide a more detailed exploration of the disease process.

REFERENCES:

1. WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020 [Internet]. [cited 2023 May 6]. -19-11-march-2020

2. Chang, D., Chang, X., He, Y. et al. The determinants of COVID-19 morbidity and mortality across countries. *Sci Rep 12,* 5888 (2022). DOI: 10.1038/s41598-022-09783-9.

3. WHO-EUA-qualified-covid-vaccines.pdf [Internet]. [cited 2023 May 6].

4. India – COVID19 Vaccine Tracker [Internet]. [cited 2023 May 6].

5. Harder T, Külper-Schiek W, Reda S, et al. Effectiveness of COVID-19 vaccines against SARS-COV-2 infection with the delta (b.1.617.2) variant: Second interim results of a living systematic review and meta-analysis, 1 January to 25 August 2021. *Eurosurveillance*. 2021;26(41). Doi: 10.2807/1560-

7917.ES.2021.26.41.2100920

6. India's "Covaxin" vaccine shows high efficacy against COVID-19 infections in phase 3 trial [Internet]. [cited 2023 May 6].

7. Tartof SY, Slezak JM, Fischer H,et al. Effectiveness of mRNA BNT162b2 COVID-19 vaccine up to 6 months in a large integrated health system in the USA: a retrospective cohort study. *The Lancet.* 2021 Oct 16th.

8. Hadizadeh, N., Naderi, M., Khezri, J. et al. Appraisal of SARS-CoV-2 mutations and their impact on vaccination efficacy: *an overview. J Diabetes Metab Disord 21*, 1763–1783 (2022). Doi: 10.1007/s40200-022-01002-6

9. COVAXIN - India's First Indigenous Covid-19 Vaccine | Bharat Biotech [Internet]. [cited 2023 May 6].

10. Press statement by the Drugs Controller General of India (DCGI) on restricted emergency approval of COVID-19 virus vaccine. Press Information Bureau. Government of India; [cited 2023 May 6].

11. AIIMS - Version 2.1 - Protocol for COVID-Management - Dt 03.05.21. pdf [Internet]. [cited 2023 May 6].

12. Francone M, Iafrate F, Masci GM, et al. Chest CT score in COVID-19 patients: Correlation with disease severity and short-term prognosis. *European Radiology*. 2020;30(12):6808–17. DOI: 10.1007/s00330-020-07033-y

13. Guideline for COVID-19 vaccination of children between 12-14 years of age [Internet]. MoHFW Home. Government of India; 2022 [cited 2023 May 6].

14. Sharma R, Thakker V, Sharma RB, et al. Effect of vaccination on the HRCT profile of COVID-19 patients – a single-centre experience. *Journal of Family Medicine and Primary Care*. 2022;11(6):2938. Doi: 10.4103/jfmpc.jfmpc_2355_21

15. Boehmer TK, DeVies J, Caruso E et al. Changing age distribution of the COVID-19 pandemic – United States, May–August 2020 [Internet]. *Centres for Disease Control and Prevention*; 2020 [cited 2023 May 22].

16. Nicoli F, Solis-Soto MT, Paudel D, et al. Age-related decline of de Novo T cell responsiveness as a cause of covid-19 severity. *GeroScience*. 2020;42(4):1015–9. Doi: 10.1007/s11357-020-00217-w

17. Kushwaha S, Khanna P, Rajagopal V,et al. biological attributes of age and gender variations in Indian covid-19 cases: *A Retrospective Data Analysis. Clinical Epidemiology and Global Health*. 2021;11:100788. Doi: 10.1016/j.cegh.2021.100788

18. Jin J-M, Bai P, He W, et al. Gender differences in patients with covid-19: Focus on severity and mortality. *Frontiers in Public Health*. 2020;8. Doi: 10.3389/fpubh.2020.00152

19. Betron M, Gottert A, Pulerwitz J,et al. Men and COVID-19: Adding

a gender lens. *Glob Public Health*. 2020 Jul;15(7):1090-1092. Doi: 10.1080/17441692.2020.1769702

20. Gupta N, Kaur H, Yadav P, et al. *Clinical characterization and genomic analysis of covid-19 breakthrough infections during second wave in different states of India*. 2021 Sep 7;13(9):1782. Doi: 10.3390/v13091782

21. Vaidiyanathan B, Dhanger S, Raajesh J, et al. To determine the clinical efficacy of COVID vaccine in post-vaccinated individuals with severe pneumonia in preventing ICU mortality in a COVID designated Tertiary Care Centre: A retrospective study. *Archives of Anaesthesia and Critical Care*. 2022;8(3):208-212.

22. Gurumurthy B, Das S, Shetty S, et al. CT severity score: an imaging biomarker to estimate the severity of COVID-19 pneumonia in vaccinated and non-vaccinated population. *Egyptian Journal of Radiology and Nuclear Medicine*. 2022;53(1); 88. Doi: 10.1186/s43055-022-00768-2

23. Verma A, Kumar I, Singh PK, et al. Initial comparative analysis of pulmonary involvement on HRCT between vaccinated and non-vaccinated subjects of COVID-19. *Eur Radiol*. 2022;32(6):4275–83. Doi: 10.1007/s00330-021-08475-8

24. Fiolet T, Kherabi Y, MacDonald C-J,et al. Comparing covid-19 vaccines for their characteristics, efficacy and effectiveness against SARS-COV-2 and variants of concern: A narrative review. *Clinical Microbiology and Infection*. 2022;28(2):202–21. Doi: 10.1016/j.cmi.2021.10.005

25. Das S, Kar SS, Samanta S,et al. Immunogenic and reactogenic efficacy of Covaxin and Covishield: *A comparative review. Immunologic Research*. 2022;70(3):289–315. Doi: 10.1007/s12026-022-09265-0

26. Singh DD, Parveen A, Yadav DK. SARS-COV-2: Emergence of new variants and effectiveness of vaccines. *Frontiers in Cellular and Infection Microbiology.* 2021;11: 777212. Doi: 10.3389/fcimb.2021.777212

27. Mohammadi M, Shayestehpour M, Mirzaei H. The impact of Spike mutated variants of SARS-cov2 [alpha, beta, gamma, Delta, and lambda] on the efficacy of subunit recombinant vaccines. *The Brazilian Journal of Infectious Diseases*. 2021;25(4):101606. Doi: 10.1016/j.bjid.2021.101606

Grid Interconnected Solar Photovoltaic System Using SAPF

Mallikarjuna G D[1]✉, Dr. Sheshadri G.S[2],

[1] *Research Scholar, SSAHE, Agalakote, B.H Road, Tumakuru 572107, Karnataka, India,*
[2] *Professor, Department of EEE, SSIT, Tumakuru 572105, Karnataka, India,*

e-mail ID: mallugoudru@gmail.com

Abstract

This paper shows a Shunt Active Power Filter (SAPF) integrated with a grid-connected solar PV system, focusing on its role in enhancing power quality. The SAPF is designed to dynamically compensate for harmonics, reactive power, and load imbalances by injecting compensating currents to the power system. This compensatory action ensures that the supply current remains sinusoidal and in phase with the voltage, thereby improving overall power quality. Simulation is done in MATLAB version 2018b.

Key Words: *SAPF, Solar, Power quality, Harmonics*

1. INTRODUCTION

Power quality maintenance is made more difficult when renewable energy sources, including solar photovoltaic (PV) systems, are integrated into the power grid [1]. The electrical grid's stability and efficiency may be negatively impacted by voltage fluctuations, harmonics, and reactive power problems brought on by the erratic and intermittent nature of solar power [2]. The installation of a Shunt Active Power Filter (SAPF) linked to a solar PV system [3–4] provides a practical remedy for these power quality issues. So as to maintain excellent power quality in contemporary power systems, shunt active power filters are crucial components. Dynamically correcting for reactive power, harmonics, and imbalances in load, SAPFs contribute to the dependable and effective functioning of electrical systems.

The meaning of SAPF [5] in reducing power quality concerns is becoming more and more crucial as the call for clean, steady electricity grows. This helps to ensure that sophisticated technologies and renewable energy sources are seamlessly integrated into the grid [6-7]. Extensive simulations and practical investigations are worn to assess the SAPF-connected solar PV system's performance and show its efficacy in a range of operational scenarios. The results show that the SAPF may significantly increase the efficiency and reliability of solar PV integration into the grid by demonstrating improvements in voltage stability, harmonic reduction, and power factor correction [8-10].

2. PROPOSED SAPF CONFIGURATION

A standalone grid is integrated with the 91kW of solar PV array through a DC-DC boost converter and a three leg conventional voltage source converter. Solar PV arrays are framed with 104 numbers of series and 4 numbers parallel connected cells with open circuit voltage of 36.6V at short circuit current of 7.97A. In this system Perturbation and observation based control maximum power point tracking technique is proposed to track the maximum power from the solar PV panels. At maximum power voltage and currents are 29.3V, 7.47A respectively. A voltage source converter's harmonics can be filtered using a bank of capacitors. Due to an unbalanced and non-linear load connected to the grid, a three phase transformer rated at 400V is connected in shunt with the line to inject harmonic current. The system's DC link capacitor supports both SAPF integration and solar photovoltaics. To sustain the required smoothing power to the load, the DC link capacitor is connected to support both SAPF and the grid.

Capacitor voltage is given by

$$Vc(t) = Vdc(t)*m$$

Where Vc(t) capacitor voltage, Vdc(t) dc voltage and m is modulation index. The SAPF functions by continually monitoring the load current and separating its reactive and harmonic components. Next, a reference signal representing the intended compensatory current is created by the control system.

The VSI follows this reference signal to produce the necessary compensating currents, which are injected into the power system in real-time. This process effectively cancels out the harmonic and reactive components of the load current, ensuring that the supply current remains sinusoidal and in phase with the voltage. SAPFs can eliminate a wide range of harmonics. Figure 1 shows the block diagram of SAPF integrated SPV.

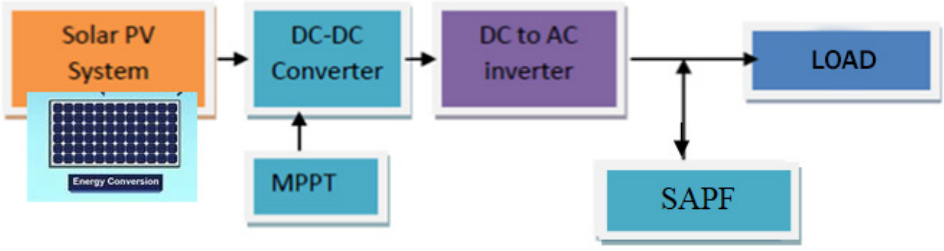


Figure-1: Block diagram of SAPF integrated SPV

3. SIMULATION RESULTS

The solar system parameters are shown in table 1.

Parameters			Values
PV Source	DC Voltage		117 V
	Power		91 kW
	Boost Converter	Inductor	58 µH
		Capacitor	2.2 mF
		Switching Frequency	10 kHz
Load	Voltage		415 V
	Frequency		50 Hz
Load Arrangements	Linear Loads	ABC	60 kW
	Non Linear Load	R	100Ω
	Unbalanced Loads	Phase - A	150Ω
		Phase - B	80Ω
		Phase - C	120Ω

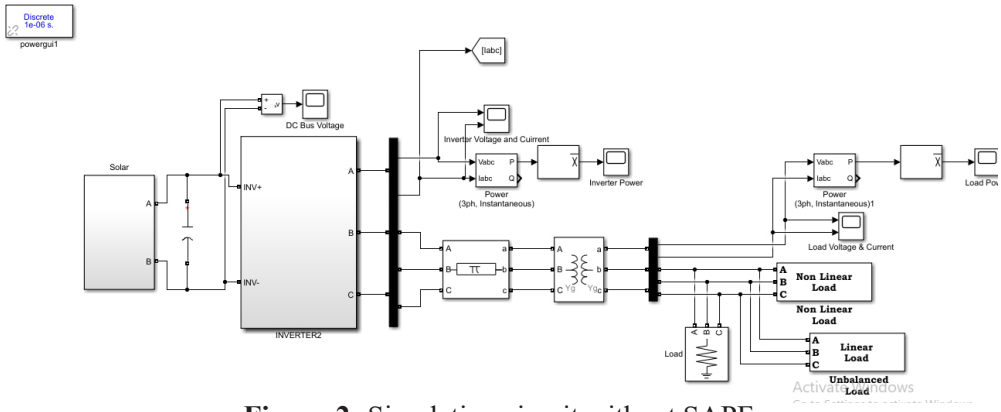


Figure-2: Simulation circuit without SAPF

The simulation circuit without SAPF is exposed in figure 2 and figure 3 shows the waveform of load voltage and current without SAPF.

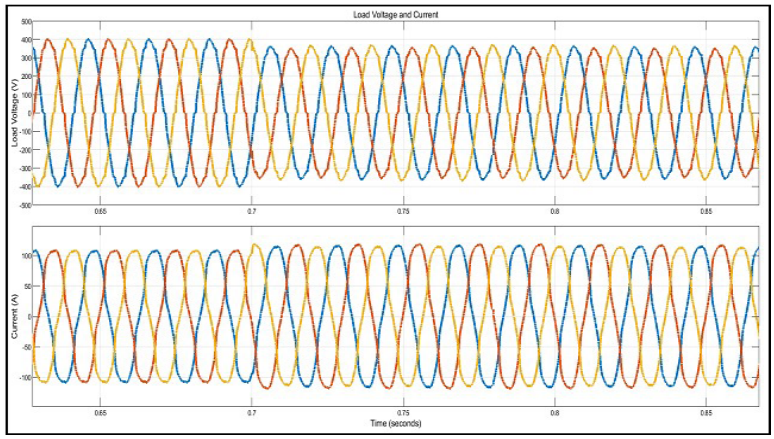


Figure-3: Load Voltage and the Current without SAPF

Due to the inclusion of unbalanced load at t=0.7s and reduction in PV power generation at t=0.8s, the load voltage is reduced. The same is reflected in the load power curve as shown figure 4.

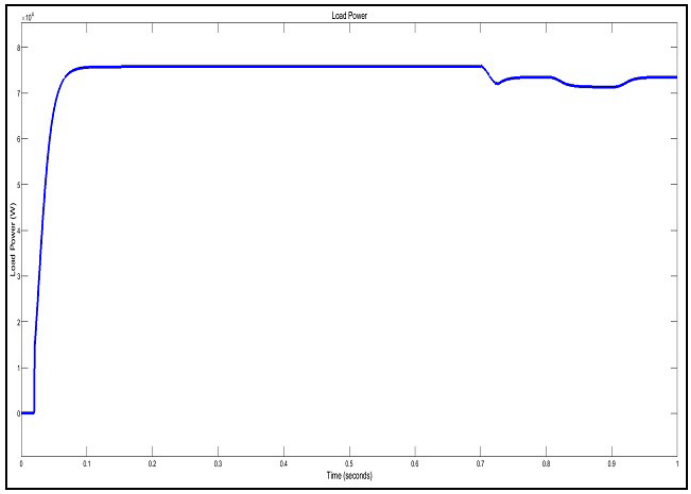


Figure-4: Load Power curve

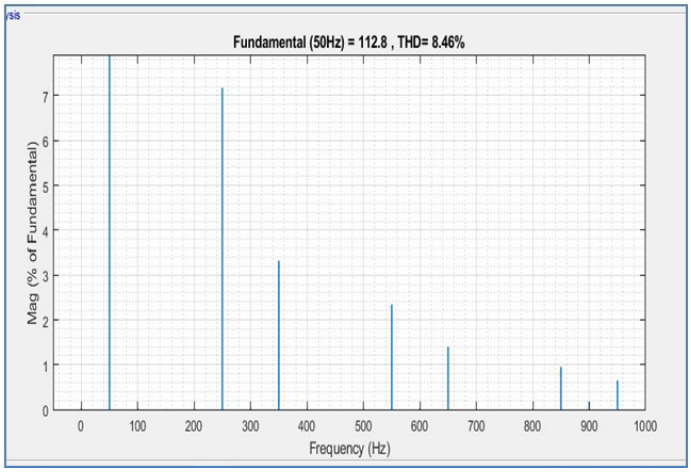


Figure-5: THD of the load current without SAPF

Figure 5 presents the THD of the load current without SAPF. The load current's THD is around 8.46%, above the IEEE recommended value. Figure 6 depicts the basic system's simulation circuit using SAPF.

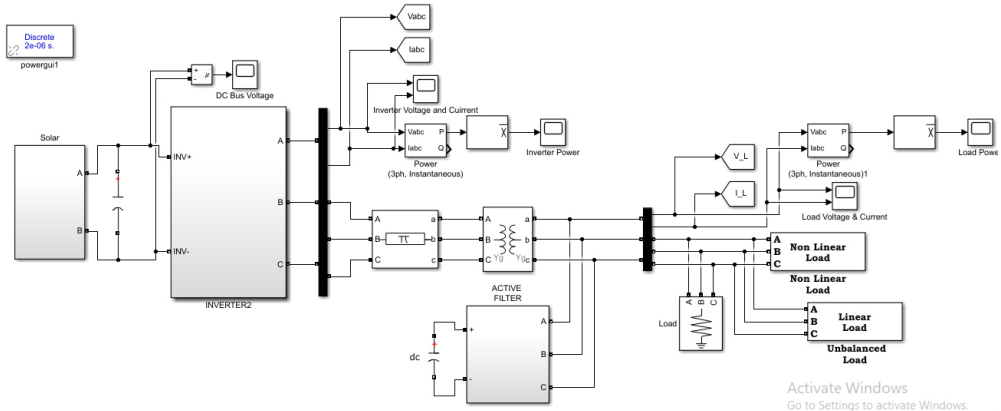


Figure-6: SAPF connected Solar system

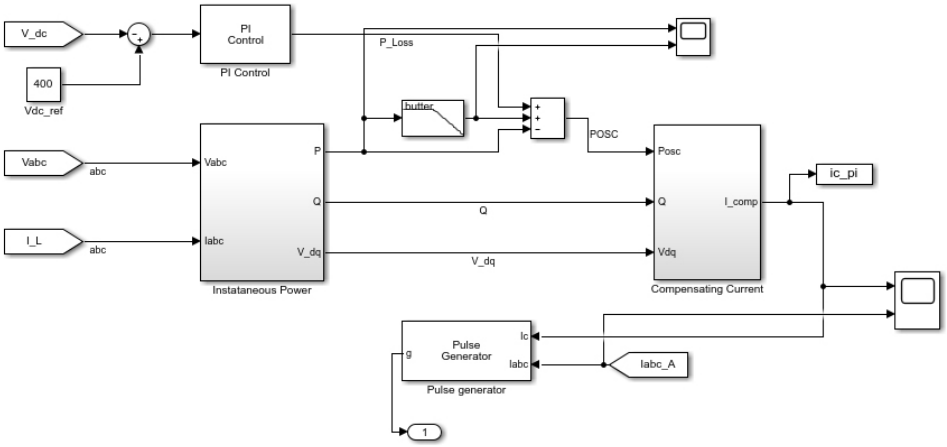


Figure-7: SAPF control circuit

Figure 6 depicts a solar system connected to SAPF. In Figure 7's control circuit for the SAPF, the measured and reference DC voltages with an amplitude of 400V are compared. After that, the PI control receives the mistake and causes the power outage. The power compensation signal is then generated by comparing this power loss with the observed DC oscillations once again. This signal is subsequently utilized to generate the reference compensation current and the output filter current. The error current is then sent to the hysteresis control, which produces the pulses for the voltage source inverter that is connected in parallel with the system. In Figure 8, the load current using SAPF is displayed. The oscillations redused after 0.7 seconds when the filter current regulates the load current.

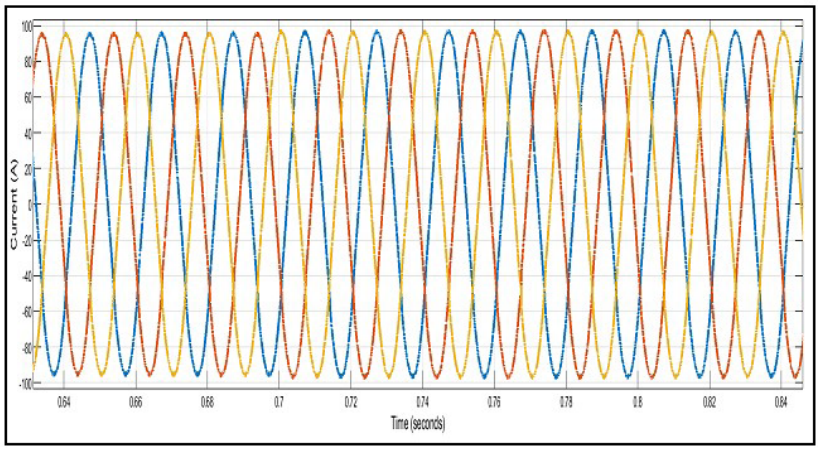


Figure-8: Load current with SAPF

Figure 9 displays the THD of the load current with SAPF. Approximately 2.24% is the THD of load current with SAPF, which is four times lower than that of the basic system without compensatory devices.

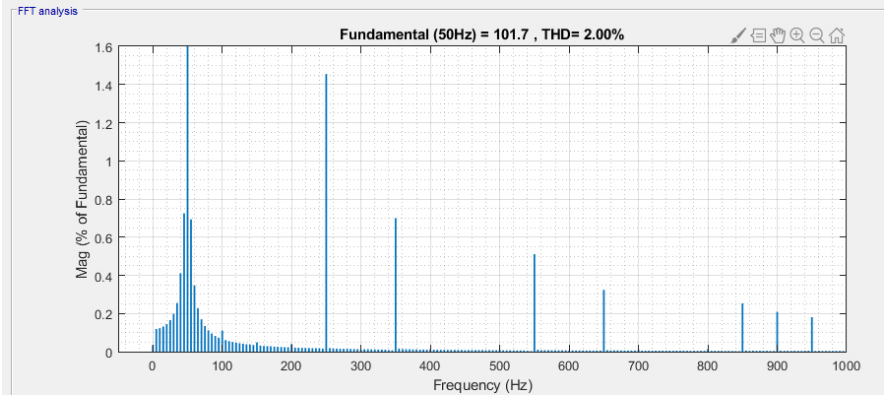


Figure-9: THD of load current with SAPF

The simulation result depicts that current obtained after filtering and voltage waveforms are in phase. Table 2 provides the performance of filter to run the system more stable form.

Table 2: Performance Analysis

SAPF	THD Without SAPF	THD With SAPF
Paper (8)	32.31%	2.87%
Proposed Filter	08.46%	2.00%

4. CONCLUSION

A comprehensive strategy to handle power quality issues is given by the integration of a SAPF with a solar PV system, which lowers harmonics from 8.46% to 2.0% and supports the wider adoption of solar energy while maintaining the stability and dependability of the electrical grid. The effectiveness of cutting-edge power electronic technologies in improving performance of renewable energy systems is highlighted by this research work.

5. ACKNOWLEDGEMENT

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REFERENCES

1. Acharya, Subhashree Choudhury, Power quality enhancement of a photovoltaic based micro grid system using optimized fuzzy controller with SAPF, In 2019 International Conference on Smart Systems and Inventive Technology (ICSSIT), 2019, pp. 67-72. IEEE.
2. Belaidi, Rachid, Mohamed Fathi, Performance of grid-connected PV system based on SAPF for power quality improvement, In 2016 International Renewable and Sustainable Energy Conference (IRSEC), 2016, pp. 542-545. IEEE.
3. Boopathi, Rajendran, Vairavasundaram Indragandhi, Solar photovoltaic-interfaced shunt active power filter implementation for power quality enhancement in grid-connected systems, *International Journal of Circuit Theory and Applications* 51, 2023, no. 11: 5305-5323.
4. Belaidi, Rachid, M. Mghezzi Larafi, A Three-Phase Grid-Connected PV System Based on SAPF for Power Quality Improvement, *TELKOMNIKA (Telecommunication Computing Electronics and Control)* 15, (2017), no. 3: 1003-1011.
5. Boukezata, Mabrouk Hachemi, Predictive current control in multifunctional grid connected inverter interfaced by PV system, *Solar Energy*, 2016, pp. 139: 130-141.
6. Gautam, Seema Agrawal, Performance analysis of three phase grid connected PV array with ANN controlled SAPF, In 2021 2nd Global Conference for Advancement in Technology (GCAT), 2021, pp. 1-6. IEEE.
7. Kumar, Ravinder, Hari Om Bansal, Real-time implementation of adaptive PV-integrated SAPF to enhance power quality, *International transactions on electrical energy systems*, no. 5, 2019: e12004.

8. Rachid Belaidi, A. Haddouche, Shunt active power filter connected to a photovoltaic array for compensating harmonics and reactive power simultaneously, *4th International Conference On Power Engineering, Energy And Electrical Drives,* 2013, 13-17 May.
9. Kumar, Ravinder, Dinesh Kumar, Improving power quality and load profile using PV-battery-SAPF system with metaheuristic tuning and its HIL validation, *International Transactions on Electrical Energy Systems,* 2020, no. 5: e12335.
10. Rathi, Kala, N. Rathina Prabha, Grid interconnected photo voltaic system using shunt active filter for power quality improvement, *International Journal of Power Electronics and Drive Systems*, 2018, no. 1: 365.

Utilizing an enhanced deep convolutional neural network for disease detection based on human cough sounds.

Channakrishnaraju[1]✉, M Tamilarasan[2]

Professor, Dept of CSE, Sri Siddhartha Institute of Technology, Tumkur, Karnataka, rajuck@ssit.edu.in

2nd year M.TECH, Dept of CSE, Sri Siddhartha Institute of Technology, Tumkur, Karnataka, tamilarasanm.m.tech@gmail.com

Abstract

The healthcare industry is only one of several that have been impacted by the recent explosion in the use of artificial intelligence (AI) methods, especially deep learning algorithms. In this study, we provide a new method for illness identification that makes use of deep convolutional neural networks (CNNs) that have been upgraded using human acoustic inputs. A non-invasive, efficient, and cost-effective way for early illness detection is the goal of the suggested system. The technology takes use of the unique properties of human voice transmissions, which provide important information about a person's physiological condition. Potential indications of different illnesses can be identified by studying these signals for small changes and trends. We do this by using a deep convolutional neural network (CNN) architecture that has been fine-tuned for the processing of audio input. For better pattern recognition in the input audio signals, our improved CNN model makes use of state-of-the-art methods including hierarchical learning, dimensionality reduction, and feature extraction. Furthermore, we use data augmentation methodologies to strengthen the model's capacity to generalize and handle varied patient groups and diseases more effectively. Denoising techniques using Wavelet transform denoising, segmentation via K-mean clustering, feature extraction employing Recursive Feature Elimination (RFE), and classification utilizing Enhanced Deep Convolutional Neural Networks (EDCNN) are integrated into our comprehensive approach, enhancing the system's accuracy and reliability in detecting diseases based on human sound signatures.

Keywords: *Artificial Intelligence, Cost-Effective, Disease Detection, Early Detection, Enhanced Deep Convolutional Neural Network, Recursive Feature Elimination.*

1. INTRODUCTION

Innovations in medical technology continue to revolutionize healthcare, with recent advancements focusing on non-invasive and efficient methods of disease detection. One such innovative approach is the Human Sound-Based Disease Detection System, which harnesses the power of sound analysis to identify potential health issues in individuals [1-3]. The system operates by utilizing specialized microphones or sensors capable of capturing various sounds produced by the human body [4-5]. These sounds include but are not limited to heartbeat patterns, respiratory sounds, gastrointestinal noises, and vocal characteristics. Each of these sounds carries valuable information about the physiological state of an individual [6-7]. The process begins with the collection of sound data from the individual using wearable devices or dedicated recording equipment [8]. The captured sound signals are then processed through sophisticated algorithms designed to analyze and interpret the acoustic patterns. These algorithms leverage machine learning and artificial intelligence techniques to recognize specific sound patterns associated with different diseases or health conditions [9].

Healthcare is one of several fields that has benefited greatly from the revolutionary age brought about by the fast adoption of artificial intelligence (AI), especially with the help of sophisticated deep learning algorithms [10]. Using improved deep convolutional neural networks (CNNs) in tandem with human speech inputs, this research presents a novel method for illness identification [11]. An efficient, non-invasive, and cost-effective way to diagnose diseases early on is the main goal of this suggested system, which uses the abundance of information contained in human sound waves [12]. One novel way to investigate non-traditional yet useful biomarkers is via human sound waves, which intrinsically provide important clues regarding an individual's physiological condition [13]. The possibility of revealing markers of different illnesses arises from the careful examination of minute differences and patterns within these signals. We use a tailored deep CNN architecture that has been fine-tuned for processing audio data in order to carry out this complex operation [14]. To guarantee accurate capture of subtle patterns in the input audio signals, our improved CNN model uses advanced approaches including hierarchical learning, dimensionality reduction, and feature extraction [15].

1.1 Motivation of the paper

This research uses an improved deep convolutional neural network (CNN) to sift through a large dataset of human speech patterns in search of new ways to diagnose diseases early on. Training and validation are both made possible

by the dataset's inclusion of a wide range of physiological and pathological situations. For hierarchical feature extraction, the custom-designed CNN architecture uses preprocessing steps like noise reduction and segmentation on raw acoustic data. The architecture also includes numerous convolutional and pooling layers. The complex patterns in the input audio signals are captured by combining advanced approaches like feature extraction, dimensionality reduction using methods like principal component analysis (PCA), and hierarchical learning.

2. BACKGROUND STUDY

De Souza, L. et al. (4) the new corona virus pandemic in 2020 brought a lot of attention to the relatively young area of study into disease detection using forced cough noises. In this paper, we provide a Deep Learning topology for COVID-19 health classification along with a training prototype that incorporates an Early Stopping (ES) strategy. Evaluating the suggestions was done using data from the Cascara and COUGHVID databases. The databases are comprised of a single dataset that includes both clinical information and recordings of forced coughs. It was suggested to use a data augmentation strategy to the training set in order to address the significant data imbalance, with 81.76% belonging to the negative class.

Hamidi, et al. (5) based on speaker independent ASR technology; we have reported the diagnosis of COVID-19 patients and healthy persons in this study. We have evaluated the cough train system's performance in three HMM states and several Gaussian mixture distributions via our trials. Findings demonstrated that a 5% to 10% increase in the identification rate of COVID-19 infected speakers compared to non-infected speakers was achieved after training the system with cough sounds of infected individuals. Furthermore, the percentage of COVID-19 infected individuals was 5% to 10% lower than the rate of non-infected speakers when we trained the system using cough sounds of healthy individuals. Classification sensitivity of 90% and specificity of 10% were attained, respectively, in the best case scenario.

Kaulamo, J.T. et al. (6) The majority of individuals without chronic cough had never sought medical attention for it, whereas a small percentage had gone to the doctor many times in the previous year for reasons linked to coughing. Those who used healthcare services often did not have the most severe coughs. People with chronic phlegm respiratory diseases and impaired quality of life were characterized by frequent visits to the doctor because of their cough.

Naqvi et al. (8) the dynamic physiological process of coughing helps clean the airways, but it can also indicate pulmonary illness. Infectious illnesses are

in a special position to take advantage of the mechanical power that coughing occurrences provide in order to spread from one person to another. There are still many unsolved concerns in the subject, despite the fact that experiments are being conducted to determine the exact nature of the interactions between infectious pathogens and the neurons in the brain that cause coughing.

Pahar, M., et al. (9) Our bed occupancy detection system is based on machine learning and utilizes the accelerometer signal recorded by a consumer smart phone that is fastened to the patient's bed. Because knowing when the patient is in bed is crucial for reliably calculating cough rate, bed occupancy recognition is necessary for the implementation of automated long-term cough monitoring utilizing the same accelerometer signal. Compared to wear able or video monitoring, a sensor put on the bed is more practical and less invasive, and the use of acceleration measures alone inherently protects privacy.

Vhaduri, S., et al. (11) shows that when comparing three modeling approaches—unguided, semi-guided, and guided—using ten random splits, the user can anticipate a 12%-28% increase in accuracy and F1 score when identifying cough and non-cough sounds using guided models. Moreover, we discover that semi-guided models perform better than their unguided counterparts. Although this study demonstrates the approach's practicality, more research is needed to validate the models in a clinical setting before the work can be commercialized.

2.1 Problem definition

The early diagnosis of illnesses is still a big difficulty, even with all the great healthcare developments. Even in settings with plenty of resources, traditional diagnostic approaches can be inconvenient because they need invasive procedures, expensive testing, or a lot of time. The need for an efficient, low-cost, and non-invasive means of early illness detection is discussed in this article. In light of the revolutionary possibilities of AI methods, especially deep learning algorithms, the suggested approach centers on tapping into the wealth of physiological data contained in human speech signals.

3. MATERIALS AND METHODS

A thorough and individualized approach is used to achieve the objective of efficient and non-invasive illness diagnosis via the use of human sound waves. With an emphasis on cutting-edge deep learning techniques, this section details the resources and procedures that went into creating and refining the suggested system. Methods including feature extraction, dimensionality reduction, hierarchical learning, and data augmentation are a part of the approach,

which also includes building a varied dataset and designing a unique deep convolutional neural network (CNN) architecture.

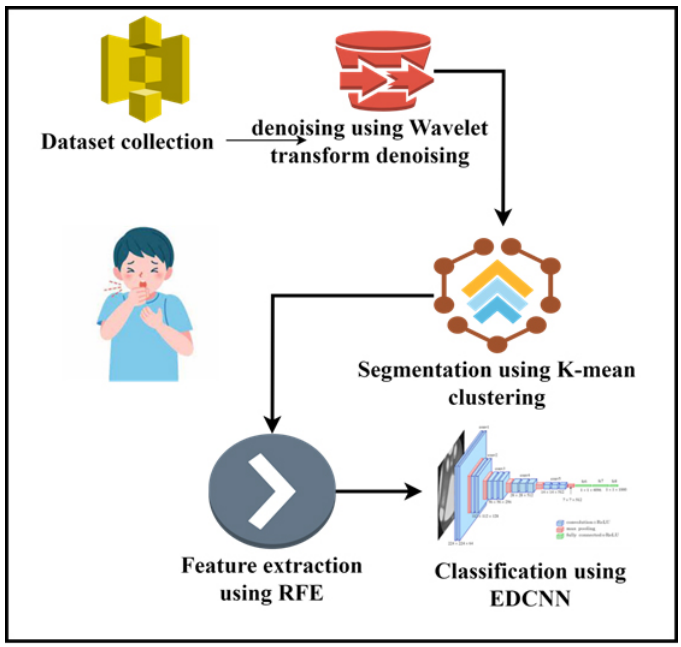

Figure-1 : Workflow architecture

3.1 Dataset collection

The dataset collected from the kaggle website https://www.kaggle.com/datasets/andrewmvd/covid19-cough-audio-classification Cough audio signal classification has been successfully used to diagnose a variety of respiratory conditions, and there has been significant interest in leveraging Machine Learning (ML) to provide widespread COVID-19 screening. This dataset, also known as CoughVid, provides over 25,000 crowdsourced cough recordings representing a wide range of participant ages, genders, geographic locations, and COVID-19 statuses.

3.2 Denoising using Wavelet transform denoising

Denoising using Wavelet transform involves a signal processing technique that aims to remove unwanted noise from a signal while preserving important features. The Wavelet transform decomposes the signal into different frequency components, allowing for the separation of noise from the signal of interest. In this method, the signal is transformed into the wavelet domain where noise typically appears sparse or spread out compared to the signal. By thresholding

or filtering coefficients in the wavelet domain, the noise can be effectively attenuated or removed while retaining the essential components of the signal. Wavelet transform denoising offers several advantages over traditional methods such as Fourier transform-based filtering. It can handle signals with non-stationary or time-varying characteristics more effectively, making it suitable for processing audio signals where noise can vary in both frequency and time domains.

Reconstructing *x(t)* after decomposing it into low-frequency approximation coefficients and high-frequency detail coefficients is as follows :

$$x(t) = \sum_{m=1}^{L}[\sum_{m=1}^{\alpha} D_m(k)_{m,k}(t) + \sum_{k=-a}^{\alpha} A_l(k)\emptyset_{L,k}(t)] \quad (1)$$

Where, the detailed signal is at scale 2m, and $\sum_{m=1}^{L}$. at scale 2l, the estimated signal is denoted as$A_l(k)$. In the case of D_m and (t), Through the use of scaling and wavelet filters, $A_l(k)$ is derived. "Tina et al. (2023)"τIn this context, t represents discrete scaling, $D_m(k)$ represents the discrete analysis wavelet, and l k.

$$h(n) = 2^{-1/2} < \emptyset(t), \emptyset(2t-n) > \quad (2)$$

$$g(n) = 2^{-1/2} < \mu(t), \emptyset(2t-n) > \quad (3)$$

$$= (-1)^n h(1-n) \quad (4)$$

A pyramid transfer procedure can be used to calculate the wavelet coefficient. The methods make use of a Fourier transform (FIR) filter bank that includes a low-pass filter (h), a high-pass filter (g), and two-fold down sampling at each step.

3.3 Segmentation using K-mean clustering

Segmentation using K-means clustering in the context of disease detection using human sound involves partitioning audio signals into distinct segments based on similarities in their features. This process aims to identify patterns or segments within the audio signals that cancorrespond to different physiological conditions or disease states. The K-means algorithm iteratively assigns data points, represented by extracted audio features, to clusters based on the Euclidean distance to cluster centroids. By grouping similar segments together, K-means clustering helps identify relevant portions of the audio signals that can be further analyzed or classified for disease detection purposes. This segmentation approach enhances the effectiveness of subsequent processing steps, such as feature extraction and classification, in human sound-based disease detection systems by focusing on relevant segments for analysis.

In a nutshell, the k-means algorithm seeks to reduce the sum of squares inside each cluster.

$$argmin \sum_{i=1}^{k} \sum_{x_j \in S_i} D^2 \left(X_j, \mu_i\right) \quad (5)$$

With k being the total number of clusters, i S being the set of elements in the ith cluster, and i being the cluster mean, the distance between any given point xj and the cluster mean i can be expressed as $2\ j\ i\ D\ (x,)$. These equations describe the third and fourth steps mathematically.

$$S_i^{(t)} = \{x_p : D\left(x_p : D\left(x_p, \mu_i^{(t)}\right) \leq D\left(x_p, \mu_j^{(t)}\right) \forall 1 \leq j \leq k\right\} \quad (6)$$

$$m_i^{(t+1)} = \frac{1}{\left|S_i^{(t)}\right|_{x_j \in S_i^{(t)}}} \sum x_j \quad (7)$$

Iteration t and the number of items in set ith(Si) are denoted by | S_i^((t))|. Si is the unique set to which each point xp is allocated.

Several other kmeans algorithms were developed, all of which were built upon the first k-means algorithm. Keep in mind that the k-means algorithm can only identify a local minimum value for equ.1 if the top k sites are known. The computational time complexity of k-means is affected linearly by the number of clusters, iterations, dimensions, and observations. The problem with this method is that it is too sensitive to outlying data. Consequently, it is recommended to use a variety of outlier analysis approaches to remove the outlier points before using the k-means algorithm.

3.4 Feature extraction using RFE

Feature extraction using Recursive Feature Elimination (RFE) is a technique commonly employed in machine learning to select the most relevant features from a given dataset referred by Habibi, A. et al. (2023). In the context of disease detection using human sound-based systems, RFE is utilized to identify the most informative acoustic features that contribute significantly to the classification of different physiological conditions or disease states. The RFE algorithm operates iteratively by first training a machine learning model on the entire set of features and evaluating their importance based on a predefined criterion. Then, it recursively eliminates the least important features from the dataset and retrains the model on the reduced feature set. This process continues until a specified number of features or a desired level of performance is achieved. By iteratively removing less relevant features, RFE effectively identifies a subset of features that best discriminates between different classes or conditions in the dataset. This subset of features typically contains the most discriminative information while reducing the dimensionality of the data, which can lead to improved classification performance and model generalization.

The result will be inaccurate classifications and a lack of generalizability. Recursive feature elimination, or RFE for short, is an effective and efficient way to reduce the model complexity by removing unnecessary predictors. There are a lot of machine learning algorithms that might utilise RFE as their

main feature selection technique since it is essentially a wrapper approach that leverages filter feature selection. Coefficient or feature significance is then used to rank the characteristics according to their relevance. The model is re-fitted one feature at a time, eliminating the weaker ones. Iterations of the technique continue until the desired number of features is reached.

$$\overline{Rank_i} = \{r_{i1} = 1, r_{i2} = 2, \dots, r_{ip} = p\} \quad (8)$$

We next determine the feature cut-off points by using eight distinct ML-RFE techniques. These are the qualities that most people think are most important. Accordingly, this technique selects |αP| features from each feature subset in order to construct each optimal feature subset.

$$FS_i^{opt} = \{f_{i1}, f_{i2}, \dots, f_i, |\alpha P|\} \quad (9)$$

Where the round-down operator is represented in mathematics by |αP|

By doing so, we can eliminate features that aren't accurate and robust. To be more precise, imagine that the parameter τ is greater than the AUC of the N best feature sets for predictive classification. Because of this, they are identified as

$$\overline{fi^{opt}} = \{FS_1^{opt}, \overline{FS_2^{opt}}, \dots, FS_N^{opt}\} \quad (10)$$

Similarly, we define the robust biomarker screening issue as an N-feature subset stable combination problem. All potential permutations of the sets in FS_2^{opt} are evaluated for stability.

3.5 Classification using EDCNN

An essential part of the suggested illness detection system is the EDCNN classification procedure. The procedure entails using the customized EDCNN architecture after preprocessing the raw audio signals and building a varied dataset. You can trust EDCNN to accurately identify illness signs in audio data since it is built for fast feature extraction, dimensionality reduction, and hierarchical learning. The training and assessment method optimizes the parameters of EDCNN to achieve accurate and generalizable illness classification across varied situations, while data augmentation strengthens the model's resilience.

Superior In-Depth The feature maps are created by twisting the CNN's input layer with the classifier's weight. The results are then passed on after using a non-linear activation function. It is possible to extract patterns from each location, but only if the feature map neurons are same but the conv layer weights are distinct.

The Equation (1)-specified segments from SFCM's output are sent into the Enhanced Deep CNN as input. When N convolutional layers are considered, the output for the units at (u,v) is written as,

$$\left(R_x^g\right)_{u,v} = \left(H_x^g\right)_{u,v} + \sum_{s=1}^{F_1^{s-1}} \sum_{r=-h_1^g}^{h_1^g} \sum_{z=-h_2^g}^{h_2^g} \left(K_{x,s}^g\right) \quad (11)$$

Where$\left(R_x^g\right)_{u,v}$, represents fixed feature map, and represents the convolutional operator needed to extract local patterns from the output generated from the preceding layers. 1

The output of the conv layer, represented byF_1^{s-1}, is passed on as input to the subsequent layer. The Enhanced Deep CNN weight, denoted by $K_{x,s}^g$, is optimized by training using the suggested CCO method. The G conv layer's weight is denoted by $K_{x,s}^g$. The filter $K_{x,s}^g$ links the feature map at layer (g 1) to the th x feature map at the th g conv layer, and its size is $\sum_{s=1}^{F_1^{s-1}} \sum_{r=-h_1^g}^{h_1^g} \sum_{z=-h_2^g}^{h_2^g} \left(K_{x,s}^g\right)$. The $G\ x\ H$ matrices denote the g conv layer's bias settings. The kernel's dimension is given as, which is written as $\sum_{s=1}^{F_1^{s-1}} \sum_{r=-h_1^g}^{h_1^g} \sum_{z=-h_2^g}^{h_2^g} \left(K_{x,s}^g\right)$.

Pooling (POOL), convolutional (conv), and Full Connected (FC) layers make up a Deep CNN. In Deep CNN, each of the three layers serves a distinct purpose. The feature maps are created in the conv layers by subsampling the segments of the preprocessed picture, and the subsampling process continues in the pool layers. The categorization is refined in the FC layer, the third stage. The input maps are subjected to convolution with the convolutional kernels in the convolutional layer, which then generates an output map. The output map has a size proportional to the kernel number, and the kernel matrix has a size of [3*3]. Totally interconnected strata: The FC layer does the high-level reasoning after the pool and conv levels expose the abstract characteristics. Also, the FC layer's output is described as

$$j_x^g = C\left(I_x^g\right) \quad (12)$$

By incorporating elements like bidirectional recurrence to capture both past and future context, attention mechanisms for adaptive focus on informative parts of the sequence, skip connections to mitigate vanishing gradient issues, and regularization techniques like dropout and batch normalization to prevent over fitting, the Enhanced Deep convolutional Neural Network (EDCNN) for classification improves on the classic EDCNN design. Fine-tuning the model's hyper parameters follows optimization through hierarchical structures, ensemble learning, and careful tweaking.

$$g(x_t) = LSTM^{le}\left(x_t^{'}\right) \quad (13)$$

$$m_{t+1} = LSTM^{ld}\left(g(x_t)\right) \quad (14)$$

The output of the encoder's le layers is denoted by $g(x_t)$, whereas the output of the convolutional layers is denoted by x 0 t. The output m_{t+1} of a network with an ld layer decoder is computed based on the current input and the network's state history. So, we have m_{t+1} as the l2-norm model.

Algorithm 1: EDCNN

Input:

- Raw audio signals representing physiological sounds (e.g., heartbeat patterns, respiratory sounds, vocal characteristics).

Steps:

• Preprocessing: Preprocess the raw audio signals to extract relevant features or segments, which are then fed into the EDCNN for further analysis.

$$\left(R_x^g\right)_{u,v} = \left(H_x^g\right)_{u,v} + \sum_{s=1}^{F_1^{s-1}} \sum_{r=-h_1^g}^{h_1^g} \sum_{z=-h_2^g}^{h_2^g} \left(K_{x,s}^g\right)$$

• Feature Extraction: Utilize the Spectral Flatness Centroid Method (SFCM) to extract specific segments from the preprocessed audio data.

•$j_x^g = C\left(I_x^g\right)$

• Bidirectional Recurrence: Incorporate bidirectional recurrence to capture both past and future context of the input sequences.

$$g(x_t) = LSTM^{le}(x_t')$$

• Attention Mechanisms: Utilize attention mechanisms to adaptively focus on informative parts of the input sequences.

$$m_{t+1} = LSTM^{ld}\left(g(x_t)\right)$$

• Skip Connections: Implement skip connections to mitigate vanishing gradient issues and facilitate information flow between layers.

Output:

- Classification Results: Output the predicted illness classifications based on the input audio signals, obtained through the EDCNN classification process.

4. RESULTS AND DISCUSSION

The results and discussion section presents the outcomes of implementing the Enhanced Deep Convolutional Neural Network (EDCNN) for illness detection using audio data. This section analyzes the effectiveness and performance of the proposed EDCNN classification procedure in accurately identifying illness signs from raw audio signals. Furthermore, it discusses the implications of the results and potential avenues for future improvements and applications.

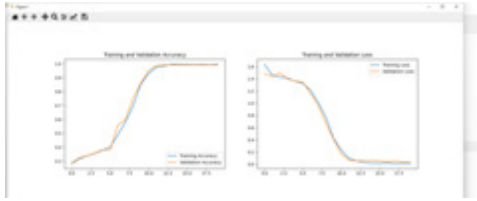

Figure-2: Training accuracy and training loss comparison chart

The figure 2 shows training accuracy and training loss comparison chart the x axis shows epochs and the y axis shows values.

Figure-3: Confusion matrix

4.1 Performance evaluation

1. Accuracy: The fraction of samples with the right classification out of all samples. Mathematically:

$$Accuracy = \frac{(TP + TN)}{(TP + FP + TN + FN)} \quad (15)$$

2. Precision: Ratio of samples with accurate identification to total samples with accurate identification. Mathematically:

$$Precision = \frac{TP}{TP + FP} \quad (16)$$

3. Recall (also known as sensitivity or true positive rate): The proportion of correctly classified samples out of the total number of actual pest samples. Mathematically:

$$Recall = \frac{TP}{TP + FN} \quad (17)$$

4. F1 score: A middle ground between accuracy and memory that strikes a harmonic mean. Mathematically:

$$F1\ score = 2 * Precision * Recall\ /\ (Precision + Recall) \quad (18)$$

Table-1: Classification performance metrics comparison

	Algorithm	Accuracy	Precision	Recall	F-measure
Existing methods	ANN	94.21	94.65	95.01	95.23
	CNN	96.35	95.87	96.10	96.07
	DCNN	97.11	96.32	97.75	98.14
Proposed methods	EDCNN	98.99	98.11	98.84	99.21

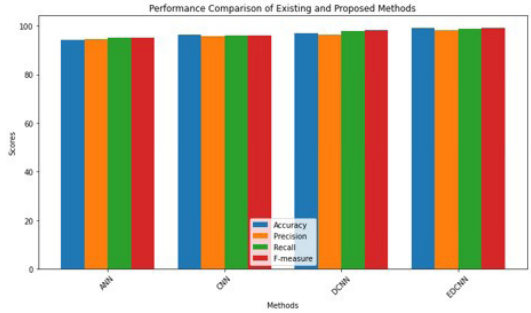

Figure-4: Performance metrics comparison chart

The table 1 and figure 4 shows classification performance metrics comparison table presents the accuracy, precision, recall, and F-measure scores for existing methods (ANN, CNN, and DCNN) and the proposed method (EDCNN). EDCNN outperforms all existing methods across all metrics, achieving the highest accuracy of 98.99%, precision of 98.11%, recall of 98.84%, and F-measure of 99.21%. This indicates that EDCNN demonstrates superior performance in accurately identifying illness signs from audio data compared to traditional neural network architectures. The results highlight the efficacy of the proposed method in achieving both high accuracy and balanced performance across precision, recall, and F-measure metrics, making it a promising approach for illness detection in healthcare applications.

5. CONCLUSION

This research presents a ground-breaking method for illness diagnosis using an Enhanced Deep Convolutional Neural Network (EDCNN) in conjunction with novel human speech inputs. The revolutionary potential of technology in early illness detection is shown by the integration of artificial intelligence, especially deep learning, into healthcare. The urgent need for an efficient, low-cost, and non-invasive diagnostic tool is satisfied by the suggested system. The system takes use of the physiological insights conveyed by human sound signals by using the extensive information included in these signals. A viable path for early detection can be found by analyzing small fluctuations and patterns within the sound data, which allows for the identification of potential markers for different illnesses. The enhanced EDCNN architecture for sound data processing is the backbone of our technique. EDCNN outperforms all existing methods across all metrics, achieving the highest accuracy of 98.99%, precision of 98.11%, recall of 98.84%, and F-measure of 99.21%. Feature extraction, dimensionality reduction, and hierarchical learning are some of the sophisticated approaches that have been used to improve the model's ability to detect complex patterns in audio data. Incorporating data augmentation tactics also improves the model's capacity to generalize and handle different patient groups and circumstances.

REFERENCES

1. Altshuler, Ellery, Bouchra Tannir, Gisèle Jolicoeur, Matthew Rudd, Cyrus Saleem, Kartikeya Cherabuddi, Dominique Hélène Doré et al. Digital cough monitoring–A potential predictive acoustic biomarker of clinical outcomes in hospitalized COVID-19 patients. *Journal of Biomedical Informatics* 138 (2023): 104283.

2. Cai J, Vhaduri S, Luo X. Discovering COVID-19 Coughing and Breathing Patterns from Unlabeled Data Using Contrastive Learning with Varying Pre-Training Domains. *arXiv preprint* arXiv:2306.01864. 2023 June 2.

3. Campana, M.G., Delmastro, F. and Pagani, E., Transfer learning for the efficient detection of COVID-19 from smartphone audio data. *Pervasive and Mobile Computing*, 89, pp101754 2023.

4. De Souza, L., Bernardino, H., de Souza, J., & Vieira, A. COVID-19 Detection Using Forced Cough Sounds and Medical Information. *Revista de InformáticaTeórica e Aplicada,* 30(1), 44-52. 2023.

5. Hamidi, Mohamed, OuissamZealouk, Hassan Satori, NaouarLaaidi, and Amine Salek. COVID-19 assessment using HMM cough recognition system. *International Journal of Information Technology,* 15, no. 1 (2023): 193-201.

6. Kaulamo, J.T., Latti, A.M. and Koskela, H.O., Healthcare-seeking behaviour due to cough in Finnish elderly: too much and too little. Lung, 201(1), pp.37-46. 2023.

7. Najaran, Mohammad Hassan Tayarani. An evolutionary ensemble learning for diagnosing COVID-19 via cough signals. *Intelligent Medicine* (2023).

8. Naqvi, Kubra F., Stuart B. Mazzone, and Michael U. Shiloh. Infectious and Inflammatory Pathways to Cough. *Annual review of physiology,* 85, pp.71-91, 2023.

9. Pahar, M., Miranda, I., Diacon, A. and Niesler, T., 2023. Accelerometer-based bed occupancy detection for automatic, non-invasive long-term cough monitoring. IEEE Access, 11, pp.30739-30752.

10. Valergaki, P., COVID-19 Diagnosis from cough samples using Deep Learning methods, 2023.

11. Vhaduri, S., Dibbo, S.V. and Kim, Y., 2023. Environment Knowledge-Driven Generic Models to Detect Coughs From Audio Recordings. *IEEE Open Journal of Engineering in Medicine and Biology.*

12. Vishniakou, U. A., and B. H. Shaya. Voice Detection Using Convolutional Neural Network. 21, no. 2 (2023): 114-120.

13. Wu, Yuan, Jian Zhang, Yanjiao Chen, Junkongshuai Wang, WuXuan Shi, and Qian Zhang. Ubi-Asthma: Towards Ubiquitous Asthma Detection using the Smartwatch. *IEEE Internet of Things Journal* (2023).

14. Zealouk, Ouissam, Hassan Satori, Mohamed Hamidi, NaouarLaaidi, Amine Salek, and Khalid Satori. Analysis of COVID-19 resulting cough using formants and automatic speech recognition system. *Journal of Voice* 37, no. 6 (2023): 971-e9.

15. Zhu, Yi, Mahil Hussain Shaik, and Tiago H. Falk. On the importance of different cough phases for COVID-19 detection. *IEEE International Conference on Acoustics, Speech and Signal Processing* (ICASSP-2023), pp. 1-5. IEEE, 2023.

16. Tian, Chunwei, Menghua Zheng, Wangmeng Zuo, Bob Zhang, Yanning Zhang, and David Zhang. Multi-stage image denoising with the wavelet transform. *Pattern Recognition* 134 (2023): 109050.

17. Habibi, A., Delavar, M. R., Sadeghian, M. S., Nazari, B., and Pirasteh, S. . A hybrid of ensemble machine learning models with RFE and Boruta wrapper-based algorithms for flash flood susceptibility assessment. *International Journal of Applied Earth Observation and Geoinformation*, 122, 103401. 2023.

Presence of Third Molars in Mandibular Angle Fractures: a Retrospective Study of 3 years.

Vishnuprya kolla[1], R.Mahesh kumar[2], K R Ashok kumar[3], B. jambukeshwar[4], Pal Supriyo[5], Aysha kaleem pasha[6]

mahu017@gmail.com

Abstract

Introduction: *Mandibular fractures are the second most common fractures after nasal bone fractures. The most common sites of mandible fractures are symphysis and par symphysis followed by condyle and angle fractures. Among these, complication rate of fractures related to angle are high and is very difficult to manage because of presence of third molars. This study evaluates the prognosis and healing of mandibular angle fractures in presence or absence of third molars in the line of fracture.*

Materials and methods: *A retrospective cohort study was performed in the patients reported to department of Oral and maxillofacial surgery from January 2021 to March 2024. The study variables are presence or absence of third molars in angle fractures. The study included patients with unilateral Mandibular angle fractures. Preoperative and postoperative orthopanthogram of patients were evaluated.*

Result: *Fifty patients were included in the study. In 72%cases third molar teeth were retained and in 28% third molar was extracted. 6 patients showed infection in tooth retained group and 3 patients showed infection in extracted group due to which plate was removed.*

Conclusion: *Postoperative complications were not statistically significant when tooth present in fracture line at the Mandibular angle. Selective removal of tooth in line of fracture may not decrease the complication rate.*

Key Words: *Mandibular angle fractures, Presence of third molars, tooth in fracture line*

1. INTRODUCTION

The mandibular angle is the common site of fracture which occurs near the junction of ramus and body usually near the third molar area. Given its prominence, the mandible is the most usual site to fracture. Since the mandibular third tooth is in the fracture's path, treating angle fractures is challenging and controversial [1].In comparison to when it is absent, angle fractures are more common in presence of third molar [2].

The probability of post-operative infection is higher in angle fractures. Several factors, including surgical techniques, teeth in line with fracture and inadequate accessibility to oral hygiene aids cause infection.

Over the years the treatment methods has evolved from Intermaxillay fixation(IMF), Plates and screws, compression and non compression plate. To retain or to remove the tooth is still a debate among surgeons despite the advancements in treatments. Still, no predetermined algorithm exists for the same.

This study assessed the impact of lower third molar presence and management on the frequency of postsurgical problems and the requirement for miniplate removal in mandibular angle fractures.The findings of this study may contribute to our understanding postoperative outcomes when stable internal fixation is employed.

2. MATERIALS AND METHODS:

A retrospective analysis of the inpatient records of cases with Mandibular angle fractures at Sri Siddhartha Dental and Sri Siddhartha Medical College, department of Oral and Maxillofacial Surgery was done. Surgical and radiographic case records of 50 patients with Mandibular angle fractures were diagnosed, treated and followed up between January 2021 to April 2024. Patients with angle fractures requiring open reduction and internal fixation, regardless of gender and age between 18 and 50 years, were the inclusion criteria. The exclusion criteria were patients with an infected fracture site, comminuted, compound or infected fractures, pre-existing medical conditions, closed reduction patients and patients with less than six months of post operative follow-up. Intermaxillary fixation was done in all the patients to reduce the fracture segment. Demographic data like age, gender, etiology of injury were recorded. Post operative complications like infection in tooth retained site and infection in extracted site and their management were recorded. After a regular physical examination, routine radiological examination and routine hematological, biochemical and general evaluation, all patients underwent general anesthesia for their operations.

The fracture was approached by an intraoral vestibular incision, internal fixation was done using 2mm titanium miniplates and four 2mm×10mm screws along the external oblique ridge on the superior border of mandible and anatomic reduction was achieved [3]. Single operating surgeon has performed and evaluated all the cases. Third molar extraction was performed due to pre-existing pericoronal/periodontal infection, dental caries, tooth mobility and exposure or involvement of the apical half or more of the root. Postoperative

infections, such as purulent discharge, necessitates surgical intervention, such as plate removal.

Before the start of procedure all patients were given antibiotics orally and 0.1% chlorhexidine gluconate mouth rinse. Before the start of procedure Intravenous antibiotics were administered to the patients and continued for at least 48 hours post surgery. Oral antibiotics and 0.1%chlorhexidine mouth rinse was continued for 7-10days post surgery.

Post operative follow up were performed up to 6months after surgery (2,4,6,12 weeks and 6 months). During this period patients were examined clinically and a radiograph was taken at the end of this follow-up period.

The statistical evaluation was done using Chi square test. Mean values and percentage values are calculated. Descriptive statistics for both the outcome and predictor measures are presented. The statistical significance of hypotheses was at 0.05.

3. RESULTS:

In the study total 50 patients with mandible fractures who has undergone open reduction and internal fixation and 66% were males and 34%were females involved in the study (Table 1). The average age group was 28.97 (18-50 years) . Of the 50 patients in angle fractures, Third molar was retained in 72 % (n=36), while in 28% third molar was extracted (n=28%). (Table 2)

The etiology of cases were majorly due to Road traffic accidents, assault. The signs and symptoms were inflammation, pain and swelling. By the end of 6 month follow up 6 cases showed infection in tooth retained group and 3 cases showed infection in tooth extracted group due to which plate was removed under local anesthesia following aseptic precautions.

TABLE 1 : Age distribution

PATIENT AGE	NO OF PATIENTS
18-25	22
26-30	18
31-50	10

TABLE 2 : Male and female ratio

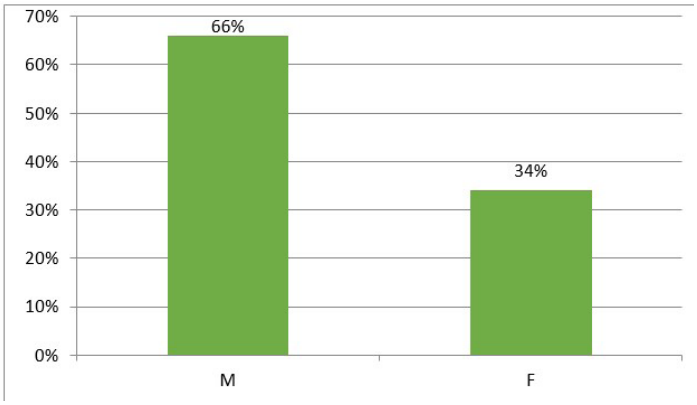

TABLE 3: Teeth retained and extracted in fracture line.

RETAINED
EXTRACTED

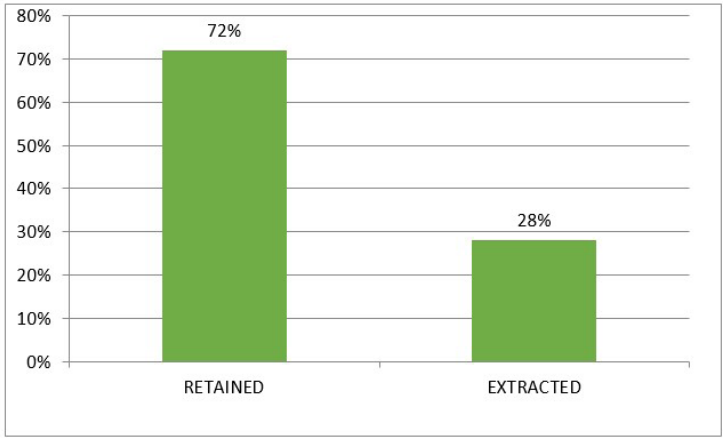

TABLE 4: Distribution of Infection

INFECTION IN TOOTH RETAINED	6	66%
INFECTION IN TOOTH EXTRACTED	3	34%

4. DISCUSSION:

The purpose of this retrospective study was to determine the course of the mandibular third molar over a six-month period along the fracture line in mandibular angle fracture. The impact of the third molar in mandibular angle fractures, many studies has put forward that the presence of this tooth weakens the region of the mandibular angle, leading to the occurrence of fracture in this region. The last teeth to erupt in the permanent teeth series are third molars, these teeth are the most likely to be impacted. The position and angulation of third molars is determined in relation to the anterior border of ramus and position of second molar. Research studies shown that fractures caused at significantly lower forces when the mandibular third molar teeth were deep within the bone. Recent clinical studies showed that the risk of angle fracture is greater for superficially placed third molars and decreased for deeper impactions. However some studies shown that the impact of angle fracture, however, does not seem to be influenced by the severity of impaction.

Since the introduction of open reduction and internal fixation for maxillofacial fractures, this has been a contentious issue, with opinions on the literature differing on the risk of keeping or extracting the tooth. In the current investigation angle fracture was found in the age category of 18 to 50 years old, with a mean age of 28.97 years. The patients were divided into two age groups according to their age: younger (18 to 30 years), middle-aged (31 to 50 years). 32 of the 50 patients who were part of the study were young, 18 were middle-aged.These results suggest that mandibular angle fractures mostly seen in the younger age group, with the most prevalent cause being traffic accidents [4]. This age group exhibits a high incidence of non-erupted third molars, which is the explanation. There were 34% of female patients and 66% of male patients in our study.

This observation aligned with research by Barde D et.al, which found a male predominance in angle fractures [5]. These studies suggest that men are more susceptible to facial trauma risk factors, such as engaging in violent acts, incautious driving, physical aggression, and contact sports. 93.9 percent of the cases are due to road traffic accidents. Impacted third molars had higher risk of angle fracture than those without third molar and those with impacted molar were less likely to have condylar fracture6. This outcome was in line with research by Ugboko et al. who found that mandibular angle fractures were primarily caused by traffic accidents. There are several reasons for this, but the primary ones include alcohol or other intoxicating substances used, speeding and not wearing a helmet, and a lack of awareness of traffic laws.

Intermaxillary fixation using Erich arch bars or interdental wire fixation

of non communited Mandibular angle fractures treated in champys line of osteosynthesis is not neccasary in all cases of angle fracture [7]. There was no discernible correlation between the side and angle fracture. Usually, the impact location is limited to the fall's side. A direct fracture will happen at the place of application if it is high velocity impact. An indirect fracture will result from the bow transferring to the contralateral side of the impact if it occurs at a low velocity then there will be a direct fracture at the application location. An indirect fracture will result from the bow transferring to the contralateral side of the impact if it occurs at a low velocity.

Because the bulk of the cases in our study belonged to the younger age group, 51% of the cases showed impacted lower mandibular third molar , while 49% of cases in our study had their third molar fully erupted. Mesioangular impaction was found to be the most prevalent form among the impacted instances, which is consistent with the research findings. Mesioangular impacted teeth have been linked to an increased risk of mandibular angle fracture because the root is positioned toward the mandibular angle, potentially acting as a wedge to split the angle. This causes the forces towards the mandibular angle, where a reduction in bone density heightens the risk.

The following positions of third molars were noted in decreasing order along with mandibular angle fractures: vertical, horizontal, and distoangular. The kind of impacted teeth has no bearing on whether the tooth should be extracted or saved during surgery [8]. During the post-operative period, it was observed that the partially impacted instances had greater symptoms of infection, which ultimately resulted in the extraction of the impacted teeth. The reason for this is that the tooth's position makes it a potential site for the accumulation of debris and bacteria, which can lead to periodontal illness, as the study by Balaji et al. found.

Few authors had done tooth extraction has observed that site developed infection during period of follow-up. However, infection is observed in the retained group also. There was no statistical significance to this. The study's conclusion was that there was no discernible difference in infection rates between keeping or extracting the third molar. In the pre-antibiotic era, extractions were performed as a preventive strategy to prevent infections; this was the standard procedure to remove the entire tooth in fractured areas. This was essentially carried out with the belief that a tooth of that kind would be a vulnerable point where bacteria may enter and lead to diseases. The development of antibiotics and antimicrobials, along with improved aseptic surgical techniques, allowed doctors to focus on saving the healthy tooth while the drugs treated the bacteria's unwanted side effects. Nonetheless, it is impossible to overstate the impact of

a tooth in the fracture line. Muller had suggested in an Ellis et al. essay that multi-rooted teeth at the fracture line should always be extracted. In addition to increasing the surgical trauma at the site, the fracture site may be unstable and the reduction process more challenging. On the other hand, keeping a tooth in the fracture line could increase stability. In our study, teeth from within the fracture line were taken from 22 patients whereas the remaining patients had their teeth left in situ. It was discovered that both groups infection rates were comparable. According to our research, the tooth in the fracture and tooth retained does not have much significant difference [9].

In our investigation, the interval between the injury and treatment had no effect. Over the course of the various treatment durations, there was little variation in the rate of problems. While some writers discovered that extra days has not negatively impact the outcome of these fractures, few others thought that likelihood of complications increased with the amount of time that passed. Given that there is a few days gap between trauma, the current findings seem to confirm the earlier theory. Social factors such as alcohol misuse and smoking played a significant role in the development of postoperative problems. This emphasizes how crucial it is to provide patients post-operative instructions and make sure they follow them to the letter. Retaining third teeth in the fracture line does not appear to enhance the risk of unfavorable postoperative outcomes. Whenever feasible, third molars should be kept in the line of fracture until clinically recommended to be extracted.

REFERENCES:

1. Ellis E 3rd. Treatment methods for fractures of the mandibular angle. *Int J Oral Maxillofac Surg*. 1999 Aug;28(4):243-52.

2. Ugboko VI, Oginni FO, Owotade FJ. An investigation into the relationship between mandibular third molars and angle fractures in Nigerians. *Br J Oral Maxillofac Surg*. 2000 Oct;38(5):427-9.

3. Edwards T, David D. A comparative study of miniplates used in the treatment

of mandibular fractures. *Plastic Reconstruct Surg 1996*;97:1150–6.

4. Menon S, Sham ME, Kumar V, Archana S, Nath P, Shivakotee S, Hoda M. Maxillofacial Fracture Patterns in Road Traffic Accidents. *Ann Maxillofac Surg*. 2019 Jul-Dec;9(2):345-348. doi: 10.4103/ams.ams_136_19.

5. Barde D, Mudhol A, Madan R. Prevalence and pattern of mandibular fracture in Central India. *Natl J Maxillofac Surg*. 2014 Jul-Dec;5(2):153-6

6. Erratum in: *J Oral Maxillofac Surg* 1994 Sep;52(9):1004.

7. Assael LA. Treatment of mandibular angle fractures: plate and screw

fixation. *J Oral Maxillofac Surg*. 1994 Jul;52(7):757-61.

8. Erol Cansiz, Sabri Cemil Isler, B. Alper Gultekin, "Removal of Deeply Impacted Mandibular Molars by Sagittal Split Osteotomy", *Case Reports in Dentistry*, vol. 2016, Article ID 1902089, 3 pages, 2016.

9. Santosh P. Impacted Mandibular Third Molars: Review of Literature and a Proposal of a Combined Clinical and Radiological Classification. *Ann Med Health Sci Res*. 2015 Jul-Aug;5(4):229-34.

10. Tatsumi H, Matsuda Y, Toda E, Okui T, Okuma S, Kanno T. Postoperative Complications following Open Reduction and Rigid Internal Fixation of Mandibular Condylar Fracture Using the High Perimandibular Approach. *Healthcare (Basel)*. 2023 Apr 30;11(9):1294.

Data Security for Stegosploits: A Review

RekhaReddy[1]✉, Raju A S[2]

[1]*Research Scholar, Sri Siddhartha Institute of Technology, SSAHE, Tumakuru*

[2] *Research Supervisor, Sri Siddhartha Institute of Technology, SSAHE, Tumakuru*

rakhareddy.tl@gmail.com

Abstract

Data security is crucial in today's digital environment. Organizations are constantly at risk of cyberattacks, which can result in data breaches and the exposure of critical information. Stegosploits are a growing problem due to the covert embedding of malicious code within seemingly harmless files, making them challenging to identify. Stegosploits present a substantial threat to data security because of their hidden characteristics. Stegosploits, unlike conventional malware, evade detection by antivirus software as they are concealed within innocuous items like photos or documents. This characteristic makes them especially hazardous, as they can remain undetected for long times, enabling attackers to covertly penetrate networks and pilfer important data. This paper reviews different techniques of data hiding and provides a detailed overview of different techniques to detect and avoid stegosploits.

Key Words: *Stegosploits, Steganography, data hiding, covert communication*

1. INTRODUCTION

Stegosploits pose a significant risk to data security due to their concealed and covert nature. Stegosploits can avoid detection by antivirus software by hiding within seemingly harmless files like photos or documents. This trait makes them extremely dangerous, allowing attackers to go unnoticed for long periods and steal sensitive information without being detected. Examining the common characteristics of stegosploits is crucial for gaining a deeper understanding of the associated risks. Exploring steganography techniques for embedding malicious code, finding ways to bypass traditional security measures, and considering the potential for remote command execution are some key aspects to consider. By delving into these risks, we can create successful strategies to reduce their impact.

Several methods, such as cryptography, are utilized to maintain confidentiality during data transmission. One method that has gained significant recognition and effectiveness is steganography. Steganography involves hiding or disguising written content to secretly incorporate various types of information within host media. Within the scope of this study, the cover media includes various multimedia files such as images, audio files, and videos [1]. Users can

potentially use different types of cover media to hide content, depending on the content and their intentions. Various tools, both free and paid, are readily accessible in today's market, allowing individuals without specific technical knowledge to hide content within other media. These tools follow particular algorithms to hide and recover information [2][3].

In the field of steganography, the most commonly used algorithm/technique is the Least Significant Bit (LSB). Embedding secret information within the least significant bits of a carrier medium, like an image or audio file, is a common technique. This method is commonly used because of its straightforwardness and efficiency in hiding information without raising any red flags. Operating by substituting the least significant bit of an image with the corresponding bit of a message that is intended to be concealed within said image is the algorithm known as the Least Significant Bit (LSB). When concealing information within an image, a popular method is to swap the least significant bit (LSB) of each pixel with a bit from the hidden information. By employing this technique, the image's visual appearance is preserved, making it undetectable to the naked eye. The phenomenon shows significant effectiveness when used on high-resolution color images. It's important to consider that the effectiveness of the mentioned method might decrease when dealing with black and white or greyscale images, especially if they have lower resolution. [4][5].

Steganography and digital watermarking are two different techniques. Digital watermarking uses visible watermarks for purposes other than hiding data. Similarly, it's crucial to understand that steganography should not be seen as a replacement for cryptography. Although cryptography makes the content unreadable, it doesn't change its visibility. When working in steganography, it is crucial to ensure that the hidden content cannot be detected by the end-user, making it impossible for them to identify any concealed information in the media. By combining cryptography with steganography, the concealment of information is improved through encryption of the hidden content. As a result, anyone trying to access the hidden data would have to decrypt both the steganography and cryptographic algorithms. The user has shared a set of numerical references The references are [8][9][10].

Stegosploit is a type of malicious software that is strategically hidden within specific additional data segments of an image. This particular malware is a type of malicious software that appears as JavaScript code, created to be loaded and then run by a web browser. This script can independently retrieve and obtain harmful payloads, send data to external sources, and run code with malicious intent. One interesting finding involves the embedding of malware in an image, while the image maintains its innocent look. Identifying and preventing these

attacks present significant challenges due to the factors mentioned above.

Image-borne malware has long been a significant concern in the cybersecurity field. It was at a cyber security conference in 2015 that the term "Stegosploit" was first introduced by Saumil Shah, a well-known figure in the field. In 2019, Shah introduced a new method to hide JavaScript inside an image file, allowing the code to run when the image is being loaded by a web browser.

1.1 Common Data Security Vulnerabilities in Stegosploits

Stegosploits take advantage of different vulnerabilities to access systems and compromise data. It is essential to comprehend these vulnerabilities to establish efficient data security measures. Stegosploits often focus on exploiting common vulnerabilities such as outdated software and operating systems, weak passwords, lack of user awareness, and insecure network configurations. Using old software and operating systems can make it easier for stegosploits to gain access. Exploiting known vulnerabilities in outdated versions allows attackers to breach systems, leading to severe outcomes. Just as weak passwords can make it simpler for attackers to obtain unauthorized entry to important information. Teaching users about the significance of strong passwords and incorporating multi-factor authentication can greatly decrease this risk.

Being well-informed is a crucial aspect of data security. Stegosploits are often spread through phishing emails or malicious websites, taking advantage of users' limited understanding to deceive them into opening infected files. Training users to identify these threats and teaching them safe browsing habits can help organizations reduce the chances of stegosploit infections.

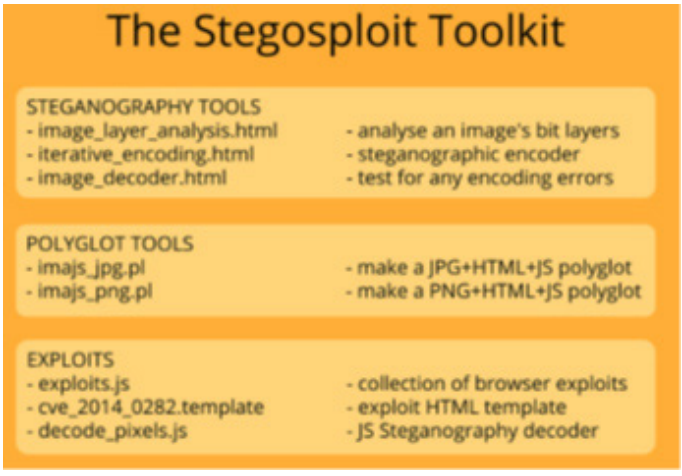

Figure-1: Understanding Stegosploit Toolkit

This illustration shows how the stegosploit toolkit is used to generate a polyglot image. During the experiment's early stages, a specially designed image/ pixel encoder was used to hide browser exploit code within an image through steganography techniques. Through this process, a unique encoded image was created. The new image has been added to the images library along with an autorun steganography decoder-script. Through this integration, an ultimate -polyglot image will be created, potentially serving as a tool for attackers to exploit. The attackers plan to share the image through email or public image sharing platforms to launch an attack on the victim's web browser.

Once we start our investigation, we may use the stegosploit technique with the default exploit code for CVE-2014-0282 to create a set of images with multiple exploits. We need not use the generated polyglots for browser exploitation; our main focus is on detecting and analyzing images. We may try to identify them with a personalized Python script.

Several steganography algorithms have been developed and studied, in addition to the least significant bit (LSB) algorithm. These tools consist of outguess, LSB2, F5, DCT, and several others. It's worth mentioning that the tool mentioned in this paper exclusively supports the LSB algorithm. Thus, this study focuses only on analyzing and assessing the LSB algorithm. This tool's functionality allows for manipulating bit layers in an image while excluding the least significant bit (LSB) layer. It is advisable to concentrate on layers 0, 1, and 2 for steganography, as these layers show minimal to no visual abnormalities in the image.

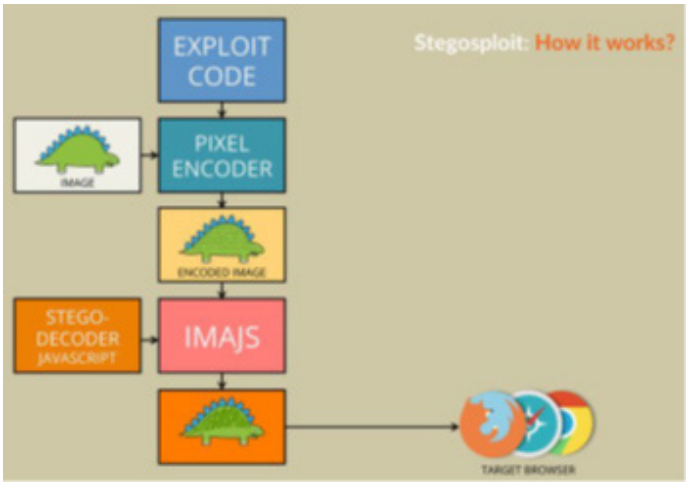

Figure-2: Process of making of polyglot image

2. LITERATURE REVIEW:

In this section, a comprehensive survey will be presented on diverse data hiding techniques that aim to enhance the security of data transmission over communication networks.

2.1 Reversible Data Hiding by Histogram Shifting:

Investigating reversible data hiding, with a specific focus on histogram shifting, is the main objective of this study. Exploring the feasibility and effectiveness of concealing data within digital images while ensuring full recovery of the original image without any loss. Utilizing histogram shifting, secret data can be concealed by leveraging the zero or minimum point of the histogram. In case the highest value in the histogram is lower than the minimum or zero point, it is advisable to increase the pixel values from a point above the peak until reaching a value below the minimum or zero point. When embedding data, a comprehensive search is carried out across the entire image. When you come across a peak-pixel value, the appropriate action depends on the bit that needs to be embedded. If the bit is found to be '1', the pixel in question will be increased by a value of 1. On the other hand, if the bit is found to be '0', the pixel will stay unchanged. Looking at things differently, it's noted that when the peak of the histogram is higher than the lowest point, the method suggests decreasing the pixel values by one. To embed a bit '1' in a histogram, you need to pinpoint a peak-pixel value that falls between the highest and lowest points in the histogram. In order to accomplish this, the peak-pixel value encountered is reduced by 1. Just as encoding is a straightforward process, decoding follows a similar path.

Deciphering is the opposite of encoding. Utilizing this method has a significant advantage due to its straightforward nature, adding to its overall attractiveness. Moreover, it maintains a steady peak signal-to-noise ratio (PSNR) of 48.0 decibels (dB), which adds to its appeal. In this context, the technique being discussed shows a very low level of distortion and a high embedding capacity. The histogram shifting technique has a notable limitation in its capacity, which depends on the frequency of the peak-pixel value in the histogram. This restriction suggests that the method may not be appropriate for situations that demand a large capacity. Moreover, the method requires several rounds of examining the image, leading to a considerable amount of time being spent. As a research student, one might find that the time-consuming nature of this technique could potentially impede its practicality in real-time applications or situations where efficiency is crucial.

2.2 Difference Expansion based embedding:

This work utilizes a high-quality reversible watermarking approach with

a significant capacity, based on the principle of difference growth. Data embedding is carried out by utilizing pixels. The differences seen may be due to the possibility of significant duplications in the neighboring pixel values found in natural photographs.

During embedding, the calculation of disparities between neighboring pixel values is carried out. Variable components are recognized in this context, and certain distinctions are selected to be expandable by one bit, leading to a higher number of changeable bits. The final bit-stream is created by combining the compressed original changing bits. The investigation includes embedding the hash of the original image and the position of increasing difference numbers within the changeable bits of those numbers. The embedding process is conducted in a randomized sequence to ensure the concealment of the indicated information within the data. Watermarked pixels are generated by using an inverse transform to calculate the resulting differences.

When extracting watermarks, the method involves measuring the discrepancies between neighboring pixel values. We will now identify the variable components in the estimated discrepancies. The variable bitstream is extracted following the pseudo-random order utilized throughout the embedding process. The extracted bitstream is divided into three components: the compressed original changeable bitstream, the compressed bitstream with the locations of enlarged difference values, and the hash of the original picture. Each individual bitstream is decompressed, leading to the reconstruction of the original image by substituting the alterable bits. This work aims to calculate the hash value of a rebuilt image and then compare it with the retrieved hash value.

The method has numerous benefits. Both audio and visual data maintain data integrity during compression and decompression processes. Using encryption methods to secure compressed position maps and dynamic bit-streams with changing numerical values has been found to improve overall security measures.

One downside of difference expansion is the risk of facing round-off errors. The method's effectiveness is significantly impacted by the image's level of smoothness. Applying this strategy to textured images is not possible because of their severely restricted or maybe nonexistent capacity. Substituting sections of gray scale pixels leads to a significant decline in visual quality.

2.3 LSB Substitution based Data Hiding:

This approach's methodology focuses on evaluating and analyzing the least significant bit (LSB). The process involves manipulating the least-significant-

bit (LSB) planes. The process involves directly replacing the Least Significant Bits (LSBs) of the cover picture with the message bits. LSB approaches have shown a notable ability to conceal information. Applying an appropriate pixel adjustment technique to the stego-image, generated using the basic least significant bit (LSB) substitution method, can greatly improve the image quality. The goal can be achieved with minimum increase in computational complexity.

Data concealment in graphics using the LSB substitution approach involves randomly substituting bits. This method improves the resilience and security of the watermarking technique, while significantly boosting the quality of the generated stego image to be on par with the original cover image.

An image that has undergone LSB substitution is highly vulnerable to Gaussian noise. This strategy shows a respectable level of sustainability in the presence of salt and pepper sounds. LSB replacement is limited in its capacity to encode hidden data within the cover image.

2.4 Data hiding Based On Search Order Coding for VQ Compressed Images:

Vector quantization (VQ) is a commonly used and highly respected technique for compressing digital images. Using Vector Quantization (VQ) in image processing results in significant reductions in image size. This method has the ability to efficiently reduce the expenses related to storage space and image distribution. This work utilizes Search-Order Coding (SOC) to alter the histogram of a VQ-compressed image, which is initially randomly distributed, to get the values closer to zero. Encoding techniques enable the concurrent implementation of encoding and data concealing procedures. Indicator is not required to identify index kinds during encoding. The lack of an indication really improves compression performance. The proposed technique can fully restore a VQ-compressed image after extracting secret data.

A new reversible approach based on Self-Organizing Map (SOC) idea is used to increase the embedding capacity for data concealment. By utilizing SOC (Spatially Ordered Coding) and other hiding tactics, the embedding capacity of a picture can be increased, and lossless reconstruction of the cover image can be accomplished.

This technique utilizes spatially ordered coding (SOC) to compress an image using vector quantization (VQ) in order to create a compressed image with SOC, allowing for increased data embedding capacity. During encoding, the SOC (Source of Cover) indices are altered to hide sensitive information. This alteration removes the necessity for an indication, leading to a reduced bit rate and a substantial embedding capacity. The program successfully retrieves both the secret data and the cover image throughout the extraction process, ensuring a high-quality extraction. The lengthy duration of this method is due to the complex algorithm it utilizes.

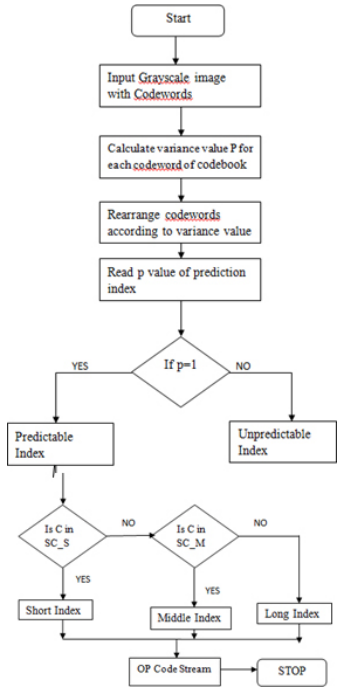

Figure-3: Flow Chart of Data Embedding Procedure

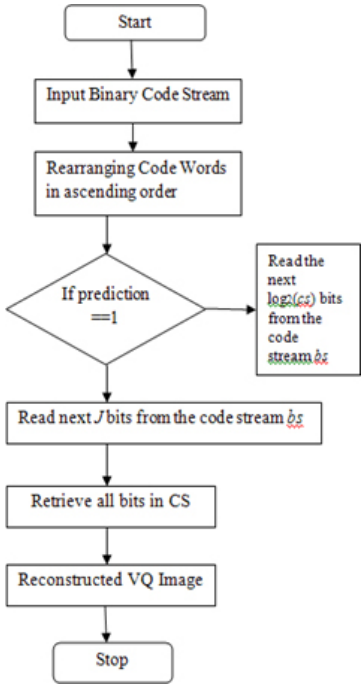

Figure-4 : Flow Chart of Data extraction Procedure

2.5 Information Hiding Based on Block Match Coding for VQ-Compressed Images:

This strategy has proven to be quite successful for data concealment. The process entails hiding sensitive data within a compressed image to ensure its secrecy. Compressed images can be recovered to their original condition without any loss of information when the secret data is extracted at the decoder. Vector Quantization (VQ) technology is used for compressing images. Vector quantization involves using index modification and side match vector quantization techniques to hide data. SMVQ, or Split Multi-Stage Vector Quantization, is known for its beneficial features like high embedding capacity and low bit rate. Nevertheless, it is crucial to acknowledge that these advantages are accompanied by heightened intricacy and a greater time investment. The use of data hiding through the index altering technique has a limited embedding capacity and results in a high bit rate.This strategy is known for its simplicity and efficiency, leading to a decrease in time spent. This approach combines the benefits of both techniques while eliminating their drawbacks. The scheme being evaluated demonstrates the following unique features:

Extracting hidden data from the original cover image enables a full restoration of the image. This method has a high embedding capacity, allowing a substantial quantity of data to be concealed within the image. The embedding rate is high, which ensures efficient and effective data concealing. Additionally, the time needed for this process is restricted, which increases its practicality and usability. A prediction index codebook is efficiently generated with the help of a computational technique.Encoding or concealing can be easily accomplished by using a codebook and conducting simple computations, rather than depending on a database search method.

Processing a 256 × 256 color image takes 1.09 milliseconds on average, whereas processing a 512 x 512 color image takes 0.89 milliseconds on average. The measured execution time to convert a 256 x 256 grayscale image is 0.89 milliseconds, and the execution time for a 512 x 512 grayscale image is 0.85 milliseconds. In this experiment, a peak signal-to-noise ratio (PSNR) of more over 30 decibels (dB) was obtained. There is a 1:1 size ratio evident in the dimensions of the original image and the embedded image in the result.

Parameters	Data Hiding Techniques				
	Simple LSB Substitution	Difference Expansion	Histogram Shifting	Search Order Coding for VQ	Block Match Coding for VQ
EC	Low	Low	Moderate	Moderate	High
BR	High	Moderate	Moderate	Low	Low
ER	Low	Moderate	Moderate	Moderate	Moderate
PSNR Value	≈ 32	≈ 36	≈ 42	≈ 45	≈ 46
Time Consuming	Less	Less	Less	More	More
Complexity	Low	Low	Moderate	High	High

Table-1 Performance Measurement of Various Data hiding Techniques

3. STEPS TO ENHANCE DATA SECURITY IN STEGOSPLOITS

Stegosploit protection necessitates a multi-layered strategy that takes into account both human and technological vulnerabilities. Organizations can lower the risk of stegosploit attacks and improve data security by implementing a number of measures.

• Perform Regular Software Updates: Keeping software and operating systems up to date is crucial for preventing stegosploits. Regular updates patch known vulnerabilities, making it harder for ttackers to exploit them.

• Implement Strong Access Controls: Restricting access to sensitive information is crucial for reducing the potential consequences of stegosploits. Through the implementation of role-based access controls and consistent review of user permissions, organizations can guarantee that only authorized individuals can access critical information.

• Educate Users: Training users is crucial in preventing stegosploit infections. By educating individuals on recognizing phishing emails, steering clear of questionable websites, and being careful with attachments, organizations can greatly decrease the likelihood of stegosploit attacks.

• Implement Intrusion Detection Systems: Identifying and blocking stegosploit attacks in real-time can be facilitated by intrusion detection systems. Examining network traffic to detect patterns and anomalies that may signal the existence of stegosploits.

• Regularly Backup Data: When facing a stegosploit attack, it's crucial to have current backups of important data for recovery. Ensuring data is consistently backed up and confirming the backups' integrity can assist organizations in system restoration and reducing the consequences of an attack.

4. AVAILABLE PRACTICES FOR SECURING SENSITIVE DATA IN STEGOSPLOITS

Securing sensitive data from stegosploits involves using a mix of encryption methods and access restrictions. By following industry standards, companies can safeguard their data against stegosploit attacks.

• Encrypt Data at Rest and in Transit: Securing confidential information adds an extra level of defense against cyber threats. With robust encryption algorithms, companies can guarantee that if a hacker gets hold of the data, it will stay unintelligible without the decryption key.

• Implement Data Loss Prevention (DLP) Solutions: DLP solutions help organizations detect and prevent the unauthorized transmission of sensitive data. These solutions can identify files containing hidden stegosploits and block their transmission, ensuring that sensitive information remains within the organization's network.

• Regularly Monitor and Audit Data Access: Monitoring and auditing data access is crucial for identifying suspicious activity and potential stegosploit infections. By regularly reviewing access logs and analyzing user behavior, organizations can detect and respond to stegosploit attacks in a timely manner.

5. DATA ENCRYPTION TECHNIQUES FOR STEGOSPLOITS

Encryption plays a significant role in protecting data from stegosploits. Several encryption techniques can be employed to safeguard sensitive information.

• Symmetric Encryption: Symmetric encryption uses a single key to both encrypt and decrypt data. While efficient, the key must be securely shared between the sender and recipient.

• Asymmetric Encryption: Asymmetric encryption uses a pair of keys – a public key for encryption and a private key for decryption. This technique eliminates the need for secure key exchange but comes with increased computational overhead.

• Homomorphic Encryption: Homomorphic encryption allows computations to be performed on encrypted data without decrypting it. This technique is

particularly useful in scenarios where data needs to be processed by third parties while maintaining confidentiality.

6. The Role of Access Controls in Data Security for Stegosploits

When it comes to stegosploits data security, access controls are essential. Organizations can guarantee that only authorized personnel have access to sensitive data by putting in place the proper access control procedures.

• Role-Based Access Control (RBAC): Permissions are assigned by RBAC according to established responsibilities in an organization. This method makes access control easier to maintain while guaranteeing that users have the minimal amount of privileges required to complete their jobs.

• Multi-Factor Authentication (MFA): By asking users to supply additional credentials, such a fingerprint scan or a one-time password, in addition to their username and password, MFA offers an extra layer of security.

• Regular Access Reviews: Finding any unlawful or excessive permissions is made easier by routinely examining user access privileges. Organizations can make sure that access controls are current and meet business goals by regularly conducting access reviews.

7. DATA BACKUP AND RECOVERY STRATEGIES FOR STEGOSPLOITS

Strategies for data backup and recovery are crucial for lessening the effects of stegosploit assaults. In the case of an attack, organizations can reduce downtime and data loss by putting strong backup protocols in place.

1. Regularly Backup Critical Data: Making regular backups of important data makes ensuring that, in the event of a stegosploit attack, it can be quickly restored. Establishing a backup plan that complements recovery goals and testing the restoration procedure on a regular basis are important for organizations.

2. Implement Off-Site and Cloud Backups: An extra security measure is to store backups in the cloud or off-site. Off-site backups guarantee that data is secure and usable even in the case of physical damage or theft.

3. Test Restoration Procedures: To make sure that backups are reliable and capable of being properly restored, restoration techniques must be tested. Organizations can address any problems or anomalies in the backup process before an actual attack happens by regularly conducting restoration testing.

8. COMPLIANCE AND REGULATORY CONSIDERATIONS FOR DATA SECURITY IN STEGOSPLOITS

For stegosploits, compliance and regulatory standards are crucial to data

security. Ensuring compliance with pertinent standards and regulations is crucial for organizations in safeguarding confidential data.

1. General Data Protection Regulation (GDPR): Guidelines for the protection of personal data within the European Union are outlined in the GDPR. Its regulations, which cover data encryption, breach reporting, and data protection impact assessments, must be complied with by organizations.
2. Payment Card Industry Data Security Standard (PCI DSS): Organizations that handle credit card information must comply with PCI DSS. Adopting strict access restrictions, conducting frequent vulnerability assessments, and encrypting cardholder data are all necessary to comply with this requirement.
3. Health Insurance Portability and Accountability Act (HIPAA): HIPAA governs how patient data is protected in the healthcare sector. For organizations to comply with HIPAA regulations, the right security measures—including data encryption—must be put in place.

9. CONCLUSION

Security of data is of the utmost importance in the linked world of today. The proliferation of stegosploits is a serious challenge for organizations, necessitating the implementation of stringent guidelines for the protection of sensitive data. In order for enterprises to safeguard their sensitive data from these covert attacks, it is necessary for them to have a thorough grasp of the dangers connected with stegosploits and to apply best practices. It is vital to take a complete approach to data security, which includes not only the practices of encryption and access controls, but also the implementation of frequent software updates and user awareness training. Through the use of the tactics described in this article, you will be able to maintain a competitive advantage and strengthen your defenses against stegosploits. Despite the fact that cyber dangers are constantly growing, it is imperative that you protect your data and guarantee the availability, integrity, and confidentiality of your information.

REFERENCES:

1. Yaw-Hwang Chiou, Jiann-Der Lee, Reversible Data Hiding Based on Search-order Coding for VQ-compressed, *Journal of Convergence Information Technology(JCIT)* Volume6, December 2011.
2. Zhicheng Ni, Yun-Qing Shi, Nirwan Ansari, and Wei Su, “Reversible Data Hiding” , *IEEE transactions on circuit and systems for video technology*, VOL. 16, NO. 3, March 2016
3. Chi-Kwong Chan, L.M. Cheng, Hiding data in images by simple LSB substitution, *City University of Hong Kong* accepted 11 August 2023.

4. Jiann-Der Lee, Senior Member, IEEE, Yaw-Hwang Chiou, and Jing- Ming Guo, Information Hiding Based on Block Match Coding Vector Quantization-Compressed Images, *IEEE systems journal*, VOL. 8, NO. 3, September 2019
5. Chin-Chen Chang, Fellow, IEEE, Yi-Pei Hsieh, and Chih-Yang Lin, Lossless Data Embedding With High Embedding Capacity Based on Declustering for VQ-Compressed Codes, *IEEE transactions on information forencics and security*, VOL. 2, NO. 3, September 2017.
6. Nilam R. Bagul, Secure Information Hiding Using Block Match Coding For VQ - Compress Images, *International Journal of Research and Engineering* Vol.01.
7. Jun Tian, Reversible Data Embedding Using a Difference Expansion, *IEEE transactions on circuits and systems for video technology*, VOL. 13, NO. 8, August 2022.
8. Chin-Chen Chang , Guei-Mei Chen, Min-Hui Lin, Information hiding based on search-order coding for VQ indices, 18 May 2017.
9. G. Boopathy S. Arockiasamy Implementation of Vector Quantization for Image Compression, *GJCST Computing Classification*.,22Vol.10,Issue3, April2020.
10. Thai-Son Nguyen , Chin-Chen Chang, and Meng-Chieh Lin , Hiding Scheme for SMVQ-Compressed Images using SOC Coding, *Smart Computing Review*, vol. 4, no. 3, June 2014.

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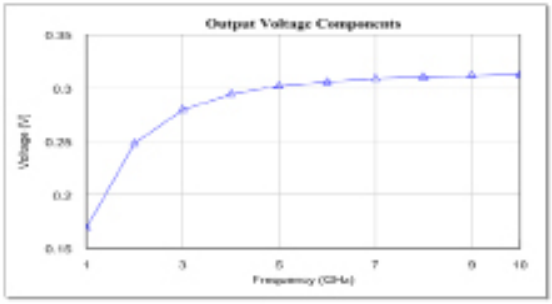

Figure-1 (Times New Roman, 11pt, bold) Photo-current and substrate temperature of the device (Times New Roman, 11pt) centered

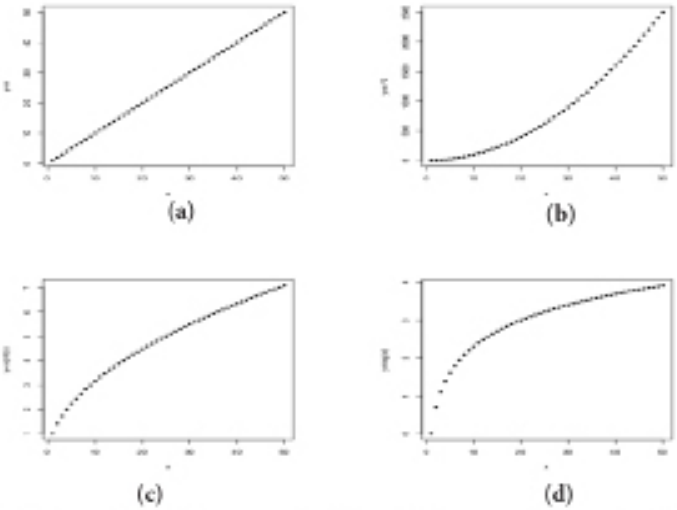

Figure-2 (Times New Roman, 11pt, bold) Basic mathematical functions (Times New Roman, 11pt) (a) linear y=x (b)Quadratic $y=x^2$ (c)Square root $y=\sqrt{x}$ (d)Logarithmic y=ln x

Table format is to be as follows:

Table-1 (Times New Roman, 10pt, table heads is to be bold) Kinematic parameter table of the developed robot(Times New Roman, 11pt) centered

Type	Θ_k	$\mathbf{d_k}$	$\mathbf{a_k}$	α_k	**SHP**
Base	Θ_1	d_1	0	90^0	0
Shoulder	Θ_2	0	a_2	0	90^0
Elbow	Θ_3	0	a_3	0	$\pi/2$
Tool pitch	Θ_4	0	a_4	90^0	-
Tool roll	Θ_5	d_5	0	0	90^0

5. CONCLUSIONS (Times New Roman, 12pt, bold)

The conclusion of a research paper need to summarize the research work carried out and mentions the applications and future scope of the research work. (Times New Roman, 12pt).

Legend (Times New Roman, 12pt, bold)

No symbol which is used in the paper should be left undefined, and should be listed here. Greek symbols should come first and small letters first and capital symbols last. All should be in Times New Roman,12 pt. Please don't use spaces but use tabs for alignment. Above should include all symbols used in equations, figures and tables.

Γ	=	Cumulative error in measurement
Ω	=	Potential
β	=	Angle made with respect to vertical
θ	=	Angle made with respect to horizontal
k	=	Hydraulic Conductivity
kx	=	Hydraulic Conductivity in horizontal direction
n	=	Manning's coefficient
H	=	Depth of water upstream of dam
H1	=	Height of dam

6. ACKNOWLEDGEMENT (Times New Roman, 12pt, bold)

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REFERENCES (Times New Roman, 11pt)

The reference for various types should strictly be made in the mentioned format. In the paper the reference should appear in ascending order.

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For Journal articles

1. Udayakumar N. L. and Siddappa M., Multi-level Security for Virtualization in Cloud Services, PARIPEX- *Indian Journal of Research,* 2017, 6(5), pp.78-80.

For Books

2. Kollgaard E B and W L Chadwick, *Development of Dam Engineering in the United States,* Pergamon Press, Elmsford, NY, 1988.

For Conference and proceeding papers

3. Peters J. Musculovenous pumps in the human lower limb. In: *ASME conference on automatic transmissions,* 29 May–2 June 2003, pp.4–10. New York: ASME.

For Journal articles which are accepted but yet to be published

4. Ludbrook J. Musculovenous pumps in the human lower limb. *Am Heart J.* Epub ahead of print 12 June 2011.

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