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TABLE OF CONTENTS

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Editorial

It is my distinct honor, pleasure, and privilege to serve as the Editor-in-Chief of the International Journal of Computers and Their Applications (IJCA) since 2022. I have a special passion for the International Society for Computers and their Applications. I have been a member of our society since 2014 and have served in various capacities. These have ranged from being on program committees of our conferences to being Program Chair of CATA since 2021 and currently serving as one of the Ex-Officio Board Members. I am very grateful to the ISCA Board of Directors for giving me this opportunity to serve society and the journal in this role.

I would also like to thank all the editorial board, editorial staff, and authors for their valuable contributions to the journal. Without everyone's help, the success of the journal would be impossible. I look forward to working with everyone in the coming years to maintain and further improve the journal's quality. I want to invite you to submit your quality work to the journal for consideration for publication. I also welcome proposals for special issues of the journal. If you have any suggestions to improve the journal, please feel free to contact me.

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In 2024, we are having four issues planned (March, June, September, and December). The next latest issue is taking shape with a collection of submitted papers.

I would also like to announce that I will begin searching for a few reviewers to add to our team. We want to strengthen our board in a few areas. If you would like to be considered, don't hesitate to get in touch with me via email with a cover letter and a copy of your CV.

Ajay Bandi, Editor-in-Chief
Email: AJAY@nwmissouri.edu

This issue of the International Journal of Computers and their Applications (IJCA) has gone through the normal review process. The papers in this issue cover a broad range of research interests in the community of computers and their applications.

IJCA Contributed Papers: This issue comprises papers that were contributed to the International Journal of Computers and their Applications (IJCA). The topics and main contributions of the papers are briefly summarized below:

Md Jakir Hossain Molla, Sandip Kumar Basak, Sk Md Obaidullah, Narayan C. Debnath, Soumya Sen and Aliah University , Kolkata, India, FAU Erlangen Nuremberg , Germany, Eastern International University, Vietnam, present their work "**A Lattice Based Service Oriented Framework for an Effective Human Resource Management**". This paper examines the In modern organizations, success often depends on the efficiency of human resources, yet measuring the performance and fit of employees is challenging due to the diverse skill sets required for different job roles. The recruitment process, especially for new candidates, varies based on the specific skills needed, and managing this process in-house can be costly. To streamline recruitment, many companies outsource the initial phases to third-party providers. The Lattice-graph model has been proposed to manage recruitment when skill sets remain static, offering a structured framework. However, it cannot adapt to evolving skill requirements, which led to the development of the Hybrid-graph Skill Set Model (HGSSM). HGSSM is dynamic, accommodating new skills as job demands change, making it more suitable for industries where skill requirements are fluid.

Indranil Roy, Swathi Kaluvakuri, Nick Rahimi, Bidyut Gupta and Narayan C. Debnath from Southeast Missouri State University, Cape Girardeau, USA, Southern Illinois University; Carbondale, IL, USA, Eastern International University, Vietnam, present their work "**Design of a Hybrid Interest-Based Peer-to-Peer Network Using Residue Class-based Topology and Star Topology**". This article introduces the work presents a hybrid peer-to-peer (P2P) network that combines the Residue-class (RC) based P2P network and the Star interconnection network to leverage the strengths of both architectures. The RC-based network is chosen for its two primary advantages: it groups peers with the same interest or resource type into a cluster with a diameter of one, and it forms a resilient ring of group heads that remains connected despite churn (nodes leaving or joining). The Star topology is utilized for its low diameter, ensuring efficient communication. By integrating the advantages of both systems, the hybrid topology achieves a diameter comparable to that of the Star topology, specifically the Star's diameter plus 2. The resulting structure is an n-star, where "n" refers to the number of group heads. This hybrid approach offers a significant improvement in data lookup latency and ensures message complexity of \(O(n)\), where "n" is much smaller than the total number of peers in the network, leading to more efficient data handling and reduced communication overhead.

Anjila Neupane, Indranil Roy, Reshmi Mitra, Bidyut Gupta and Narayan C. Debnath from Southeast Missouri State University, Cape Girardeau, USA, Southern Illinois University; Carbondale, IL, USA, Eastern International University, Vietnam, present their work "**Enhancing Trust in Peer-to-Peer Data Transfer: Implementing Zero-Knowledge Succinct Proofs and a Trusted Factor for Robust RC-based P2P Systems**". This article introduces the trust model for Residue Class (RC)-based P2P networks, which are decentralized and lack central authority. This openness makes them vulnerable to security issues, particularly in trust verification as nodes frequently join and leave the network. The proposed model uses a **Trust Factor (TF)** combined with **Zero-Knowledge Proof (ZKP)** to build trust and reputation among nodes. This approach helps detect malicious nodes and enhances secure communication and file-sharing within the network, reducing the risk of attacks in the decentralized system.

Sapna Sinha, Shilpi Sharma and Narayan Debnath from the University of Amity University, Noida, Uttar Pradesh India, Eastern International University, Binh Duong Province, Vietnam presented their work "**QUANTUM COMPUTING AND ITS APPLICATIONS**". The paper discusses the Quantum computing represents a revolutionary shift in computational technology, using quantum mechanics to process data in fundamentally new ways. This paper explores the principles of quantum computing, reviews current literature on its applications, and proposes its use in optimizing supply chain management. It highlights the potential impact of quantum computing in fields like cryptography, drug discovery, and artificial intelligence, while also addressing challenges such as hardware limitations and error correction, and outlining future research directions to overcome these issues.

Hend Fathy, Khalilfrom, Hesham F. A. Hamed, Eman Mohammed Mahmoud from Faculty of Engineering, Banha University, Banha, Egypt, Minia University, Minia, Egypt, Modern Academy for Engineering and Technology, Cairo, Egypt presented their work "**Skull Stripping for Improved Brain Tumor Detection In Orthogonal MRI Scans**". This study explores the use of detecting brain tumors early is a critical challenge for radiologists due to the rapid growth of these tumors and the associated decrease in survival rates when left untreated. This research presents an automated system designed for early detection of brain tumors through analysis of Magnetic Resonance Imaging (MRI) scans across different planes: Axial, Coronal, and Sagittal. The methodology involves preprocessing to enhance image quality, followed by K-means segmentation to isolate cancerous cells. Informative features are extracted using Discrete Wavelet Transform (DWT), Gray Level Co-occurrence Matrix (GLCM), and Principal Component Analysis (PCA). A Support Vector Machine (SVM) classifier—utilizing Linear, Gaussian, and Polynomial kernels—classifies these features for predictions. The approach includes two phases: a Skull Stripping phase, which improves tumor detection accuracy by approximately 7% when the skull is excluded, and a non-skull stripping phase. This automated technique effectively identifies and localizes tumors across various MRI imaging planes, offering an efficient method for early diagnosis.

Jahanvi Joshi, Siddhant Vats, Shilpi Sharma, Geet Sahu and Narayan C. Debnath, Amity University , Uttar Pradesh, , India. Siksha 'O' Anusandhan, Odisha, India.. Eastern International University, Vietnam. Presented their work "**Tropical Plant Disease Assessment Using Convolutional Neural Network** Plants serve as a great source of energy, yet their potential ability is affected due to biotic and abiotic disease, in turn affecting crop yield. Though significant research has been made in this field, early disease detection and prevention across multiple plant species still serve as a major challenge in the agricultural industry. This paper proposes a framework involving the detection of diseases in leaves with the Convolutional Neural Network (CNN) approach and utilizing computer vision and deep learning models. The proposed new model presents a comprehensive in-depth solution for advanced agricultural practices. The research also offers a shift towards efficient, accurate, and sustainable management of challenges associated with agriculture, specifically species recognition, disease assessment, and remediation strategies. Comparison of the proposed model with some other available models in the literature is included.

As guest editors, we would like to express our deepest appreciation to the authors and the reviewers. We hope you will enjoy this issue of the IJCA. More information about ISCA society can be found at http://www.isca-hq.org.

Guest Editors:

Ajay Bandi, Northwest Missouri State University, USA

September 2024.

A Lattice Based Service Oriented Framework for an Effective Human Resource Management

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Abstract

In modern day the success of majority of organizations depend on the efficiency of human resources. Measuring human resources and their performance are often challenging as there is no standard metric to measure how well a resource will fit in the organization. Moreover based on the job role the requirements of the skill-set of the candidates vary. For the newly joined candidates the requirements of most of the companies are same but different subset of skill are required as per the job role. As the number of subset of the skill set is high a standardized model is required to define a framework that will guide the recruitment process. The cost of recruitment goes high if a company organizes the recruitment from beginning to end phase. Generally the initial phases are same for a particular type of industry and this can be outsourced to a third party. A lattice based model named as Lattice-graph is proposed to manage the recruitment of newly joined candidates when the skill-set is static. However, when new skill(s) are added Lattice-graph can't incorporate these dynamic skills. Henceforth a new dynamic model is defined named as Hybrid-graph Skill Set Model (HGSSM) to incorporate the challenges of including new skill as per the requirement of the recruiter. Classification algorithms are also deployed to measure the accuracy of the newly joined candidate's recruitment based on the known skillset.

Key Words: Classification, Lattice, Hyper-lattice, Service-oriented model, Recruitment, Skill-set.

1 Introduction

Business organizations rely on their human resources for their growth and increasing profitability. Henceforth having the right person in the organization is now a key to success. Employees are hired in the organization through HR (Human Resource) department. Generally an organization recruits huge number of resources directly from the educational institutes. In this type of hiring, which is often termed as Fresher recruitment, candidates are evaluated with no previous working experience. Generally these candidates are recruited directly from a particular institute which is known as On- campus recruitment process. Another approach of recruiting fresher candidates is to call candidates from multiple institutes in one particular institute which is known as Pool-campus recruitment process. The benefit is that instead of visiting to multiple campuses recruitment is conducted in single campus and that is going to reduce the cost and timing drastically. An alternative to this is to invite the shortlisted candidates from different institutes based on the given criteria to a common place (May be the company owned premises), which is known as Off-Campus recruitment process. After getting the applications from the possible candidates a shortlisting process is followed. This is easy for the fresher candidates as they do not generally have special skills and they are evaluated based on their marks in the school / college / university level examinations and other parameters

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like backlog history, year of gaps etc. After the shortlisting they are called for the evaluation process of the company. This evaluation process comprises of testing different parameters such as aptitude, soft skill etc. It is to be noted at the fresher level the criteria are more or less same for the Human resource based organizations. For example IT companies are looking for some common skills that reflect their requirements. Again Core companies look into some common criteria as per their requirements. This is to emphasize at fresher level many of the criteria are generally same such as soft skill, aptitude etc. and some are domain specific such as computer proficiency, domain knowledge etc. As mentioned earlier though Pool-campus, Off-campus recruitment reduces cost still it involves the time and huge manpower to complete the entire recruitment process. This cannot be managed by the HR department and therefore people from development teams, testing teams are requested to help the process. Now these people are generally billable resources (company earns money from the clients against the service of these resources) and they are being overburden for the additional responsibility of recruitment process. Henceforth minimizing the involvement of these resources is a priority for any organization to reduce the cost. This can be done by outsourcing some of the steps of recruitment process that are common for all the candidates across the industry. Once these preliminary steps are done then the people from the own organization would be involved to evaluate the company specific requirements to finalize the selection. This demands a business model [1] or framework to justify the hiring process by reducing the cost, time and eliminating the involvement of the resources of own organization. A third-party agency could play a crucial role here that will conduct the basic steps of examination based on the several parameters that are required to evaluate a candidate. Companies can choose the candidates based on their various skill-set requirements from the trusted third party agencies who have already conducted the baseline tests. This would be a service model [2] as the third party agencies already conducted tests on several skill set parameters and the recruiting company would choose any of the subset of the tested skill-set as per the business requirement [3] of the different job roles. This model is to be justified based on the historical data and suitable analytical models [4] are required to prove the robustness of the proposed model or framework [5]. As the requirement of the industry is changing rapidly sometimes it is not possible to give training even to these newly recruited candidates and henceforth they are being evaluated based on the customized skill-set of the specific project. In this case it is expected that these candidates had earn the required knowledge on the given skill-set. This requirement adds another challenge to the proposed service model. In this research work a lattice [6] based service oriented framework [7] is proposed to optimize the recruitment process of newly joined candidates with common skill-set and it is further extended using the concept of Hyper-lattice [8] to meet the requirement of the customized skill set of the newly joined candidates.

The rest of the paper is organized as follows. Section 2 presents a related work on the campus recruitment process and service modeling framework. Section 3 depicts the Objective and Contribution of this work. Section 4 presents the Dataset & System Configuration. In the next section (Section 5) the Lattice-graph Model and Hybrid-graph Skill Set Model (HGSSM) are proposed with Lemmas and Case Study. Finally, in section 6 the research work concluded.

2 Related Work

Campus placement of the student is a critical aspect of higher education, as it provides students with opportunities to join industry/corporate. In this way the students become professionals and they start to earn money, which is one of the dream aspects of every human being. Moreover placement of an Institute is one of the key parameter to judge the quality of the Institute. There are different types of jobs are available in the markets and the students have different proficiency levels on different skill parameters. Henceforth recommending the students for suitable type of jobs is a challenge for an Institute and also for the corresponding business organization to identify the suitable candidate for their specific job role. This is an analytical challenge and this is addressed in different researches. The employability prediction and recommender system for students were built using fuzzy logic to resolve the students employability [9]. In this research work fuzzy model performs a high predictive accuracy based on the calculated mean absolute error (MAE) and root-mean-square error (RMSE) scores. Soft skill is considered as one of the key attribute for getting job and this is addressed in [10] on Moroccan labor market by analyzing engineering job ads. A mixed content analysis method has been designed based on the sequential exploratory. In order to visually analyze the placement of students in a higher educational institution the Exploratory Data Analysis (EDA) [11] is used to generate inferences mathematical models. EDA is a detailed examination that helps in discovering the structure of the data. A framework for engineering employability skill was proposed [12] for Malaysia considering local and global expectations. The interactions among the various skills, measurement tools for employability skills are considered in this framework. In another research work data is collected from 41 Engineering professionals based in UAE using an anonymously survey and it helps to give the recommendations to educational institutions related to the essential workplace skills which are critical for Engineering graduates' employability [13]. A combined methodology [14] was proposed with exploratory data analysis and advanced predictive modeling particularly emphasizing the roles of gender, academic performance analysis, and Degree and MBA specialization in placement outcomes to forecast placement success of the students. An Adaptive Fuzzy Campus Placement Optimization Algorithm (AFCPOA) [15] was developed for solving unconfined optimization problems related to candidates seeking campus placement. The framework were considered to describe the written test and interview process by employer visiting campus for hiring students the suitable candidates. Another research work [16] has attempted to develop an automatic system to predict the placement of candidates in the early phase of their education and positively impact the institute's skill training program and hiring activities and the machine learning techniques such as Logistic Regression, Support Vector Machine, K-Nearest Neighbor, Decision Tree, Random Forest, and AdaBoost classifier were considered to compute the accuracy of the forecasting. [17] highlights the motives behind the developing need for Machine Learning centered campus placement assessment. The framework confirms the efficient talent matching, reducing costs, and saving time for the entire process. The study also highlights the benefits of remote and flexible assessments, revealing how technology can replace the old methods of campus placement process. The research work of [18] carried out to explore how it can reform university graduate student's employability skill. The proposed predictive models analyses attributes like student performance, interests, and career objective to identify the best-fit job opportunities for individual student. A campus placement predictor system [19] was proposed to predict the campus placement chance with estimated salary package range one can get from the University/College campus placements process based on his/her academic scores and pre-placement training assessment scores at the early stage. It has been observed from the above survey work that different type of requirements exist for different organizations. As these requirements are different for different job roles service based modeling may help to reduce the cost. Service identification [20] is a crucial phase to design any service-oriented application. Granularity of the services is important to achieve flexibility and reusability. Separation of decision modeling from the processes modeling gained significant importance in literature [21], as it incorporates both concerns into a single model incorporating scalability, maintainability, flexibility, and understandability. The introduction of the Decision Model and Notation (DMN) [22] standard provides a suitable solution for externalizing decisions from processes and automating decision enactments for processes. Web services [23] are the standard way to deploy service to any data /information sensitive system. Micro service architecture is getting popularity to deploy the web services. Deployment of the service model on the recruitment process will be cost effective and time saving if the requirements and skills are matched properly and this is going to be beneficiary for both the recruiter and the applicants.

3 Objective and Contribution

The success and the growth of any organization is dependent on the human resources of that organization as they define the business plans, monitor the execution and make crucial decision making and strategies. The roles of human resources are more crucial for the organizations like IT, ITES, Consultancies etc. These types of knowledge-driven organizations are fully dependent on the employability skill of their employees at every level. Henceforth the recruitment process should be robust to recruit the deserving candidates as per their job roles and corresponding skill-set. Measuring the competency level of the human resources is always challenging and therefore a model or framework is highly desirable to quantify the ability of the human resources. It should be fully customized and dynamic in nature to manage the recruitment of the resources across the industry as per the different job roles. Moreover these different subsets of skill levels should be tested to measure the accuracy. The contribution of this research work is listed below:

Contributions:

1. Differentiating basic skill set and specific skill set of recruitment to fit in a model for evaluation.

2. Developing a customized model that will provide all possible subset of skill set required for an organization.

3. A service layer that allow to access desired skill set of the candidate for an organization as and when required.

4. Extending the model to add one or more skill set dynamically as per the requirement.

5. Measuring the accuracy of predictions of different subset of skills based on historical data applying standard classification methodologies.

4 Dataset & System Configuration

In this research work a real life dataset [24] is used that comprises of 12864 student's placement assessment data. The dataset used in this analysis is prepared with the information of the students who already completed their respective courses. This dataset is prepared by taking information from the placement departments of several technical/engineering colleges who have passed technical degrees. This is an anonymous dataset as the name and other identity information of the students are not given. A snapshot of the database is given below in Fig. 1:

Branch	Degree	Score/700	Aptitude	English	Quantitative	Analytical	Domain	Computer Fundamental	Coding	Placement Status
Applied Electronics and Instrumentation	B. Tech.	584	69 %	87 %	53 %	67 %	30 %	20 %	60 %	Placed
Mechanical Engineering	B. Tech.	584	76 %	80 %	73 %	73 %	55 %	40 %	00 %	
Electronics and Communications Engineering	B. Tech.	578	71 %	73 %	73 %	67 %	55 %	47 %	20 %	
Applied Electronics and Instrumentation	B. Tech.	578	71 %	93 %	40 %	80 %	50 %	33 %	20 %	
Electronics and Communications Engineering	B. Tech.	575	64 %	73 %	47 %	73 %	55 %	53 %	20 %	
Information Technology	B. Tech.	572	76 %	73 %	80 %	73 %	30 %	60 %	20 %	
Electronics and Communications Engineering	B. Tech.	566	64 %	60 %	53 %	80 %	60 %	20 %	58 %	
Computer Science Engineering	B. Tech.	560	60 %	73 %	47 %	60 %	45 %	40 %	36 %	
Information Technology	B. Tech.	560	69 %	80 %	47 %	80 %	25 %	27 %	20 %	
Mechanical Engineering	B. Tech.	557	67 %	80 %	53 %	67 %	50 %	20 %	00 %	Placed
Mechanical Engineering	B. Tech.	554	64 %	67 %	60 %	67 %	60 %	27 %	20 %	Placed
Mechanical Engineering	B. Tech.	554	64 %	73 %	47 %	73 %	55 %	20 %	00 %	Placed
Electrical Engineering	B. Tech.	554	64 %	60 %	73 %	60 %	55 %	40 %	20 %	Placed
Computer Science Engineering	B. Tech.	551	60 %	73 %	47 %	60 %	50 %	53 %	20 %	Placed
Applied Electronics and Instrumentation	B. Tech.	551	62 %	67 %	53 %	67 %	35 %	33 %	20 %	Placed
Mechanical Engineering	B. Tech.	551	64 %	87 %	27 %	80 %	40 %	13 %	00 %	Placed
Mechanical Engineering	B. Tech.	551	60 %	67 %	53 %	60 %	65 %	33 %	00 %	Placed
Computer Science Engineering	B. Tech.	548	56 %	60 %	40 %	67 %	45 %	47 %	56 %	Placed
Applied Electronics and Instrumentation	B. Tech.	548	58 %	73 %	40 %	60 %	40 %	53 %	20 %	Placed
Mechanical Engineering	B. Tech.	548	62 %	53 %	87 %	47 %	60 %	47 %	00 %	
Electronics and Communications Engineering	B. Tech.	545	60 %	60 %	60 %	60 %	35 %	40 %	20 %	Placed
Mechanical Engineering	B. Tech.	545	64 %	73 %	40 %	80 %	40 %	40 %	00 %	Placed
Mechanical Engineering	B. Tech.	545	64 %	87 %	40 %	67 %	30 %	27 %	00 %	Placed
Computer Science Engineering	B. Tech.	542	56 %	53 %	47 %	67 %	65 %	53 %	20 %	
Computer Science Engineering	B. Tech.	542	64 %	73 %	47 %	73 %	60 %	40 %	00 %	
Mechanical Engineering	B. Tech.	542	67 %	87 %	53 %	60 %	60 %	40 %	00 %	Placed
Electronics and Communications Engineering	B. Tech.	542	60 %	67 %	60 %	53 %	70 %	33 %	20 %	Placed

Figure 1: Snapshot of the Dataset

4.1 Data Description

The dataset contains a set of attributes which are described below.

a) Branch: Mentions the specific department where the student is enrolled.

b) Course: The particular course a student is currently pursuing.

c) Score: Evaluation of students out of 700 in the 7 different subjects namely Aptitude (given in column no. 4), English (given in column no. 5), Quantitative (given in column no. 6), Analytical (given in column no. 7), Domain (given in column no. 8), Computer Fundamental (given in column no. 9), and Coding (given in column no. 10). It is to be noted that the marks from column 4 to 10 are given in the percentage format and the examination was conducted out of 700 based on the 7 subjects as given in column 4 to 10.

d) Placement Status: Whether the student has been placed or not.

4.2 System configuration

The following hardware and software environment has been used to carry out the experiment. The experimental set up is described below: Hardware: All the experiments are carried on using Intel Core i5 processor with a 12 GB of RAM and 1TB of hard disk drive.

Software: Jupyter Notebook is used to conduct the experiment. In Jupyter Notebook Python 3.8.1 is used to carry out the experiment. Moreover several libraries have been used during the experiment for different purpose. Those are, pandas to manipulate the data, numpy for accessing the multidimensional arrays, matplotlib to visualize data, and sklearn to access efficient tools for machine learning and statistical modeling.

5 Proposed Methodology

In this section we will apply an algebraic model to formalize the recruitment process in terms of the given skill-set. The seven different types of skill (Aptitude, English, Quantitative, Analytical, Domain, Computer Fundamental, and Coding) that has been described in the Section-4 are the basic requirements of the majority of the organization. If we look at these skill-set more carefully we will find that four skill 'Aptitude', 'English', 'Quantitative', and 'Analytical' are almost always required by any organization. These four skills are represented by a set P=Aptitude, English, Quantitative, Analytical. Remaining skills are also required by the majority of the organization but all are not necessary for every job role. Henceforth all possible combination of the skill-set can play significant role in the selection process. It is found as per the job role, organizations can choose a resource based on any one of the given skill set or any combination of the given skill set. The requirement of all possible combination of the members of the set can be represented using lattice which is effectively used in data warehouse cuboids or in association rule mining [25].

A lattice is a partially ordered set (poset) in which every pair of elements has a unique Least Upper Bound (LUB) and Greatest Lower Bound (GLB). This algebraic model can represent all possible combinations of the skill set and they are closely connected to each other and can be traversed easily between different combinations of the skill-set.

5.1 Lattice-graph

The lattice model is going to be formed with 4 skill set parameters. Hereon we will refer to each skill-set parameter as dimension.

i) $P = \{\text{Aptitude, English, Quantitative, Analytical}\}$
ii) $D = \{\text{Domain}\}$
iii) $CF = \{\text{Computer Fundamental}\}$
iv) $C = \{\text{Coding}\}$

Here the proposed model is referred to as Lattice-graph. Initially this algebraic graph model will start with NULL value and that will be at level 0 and represented in the form of a node. Over the time new dimension(s) will be added at level 1 and every dimension is represented as node. In next level (level-2) two of the dimension will be added and that will form all the dimension pairs and each of these will be represented in the form of a node. This process will be continued to level n, where n is the number of skill set or dimensions.

The process of merging the dimensions is referred to as Integration. The reverse operation where we want to get back the unmerged dimensions are referred to as Discretization. In the Fig. 2 a Lattice- graph is formed with the four skill parameters P, D, CF and C as described above.

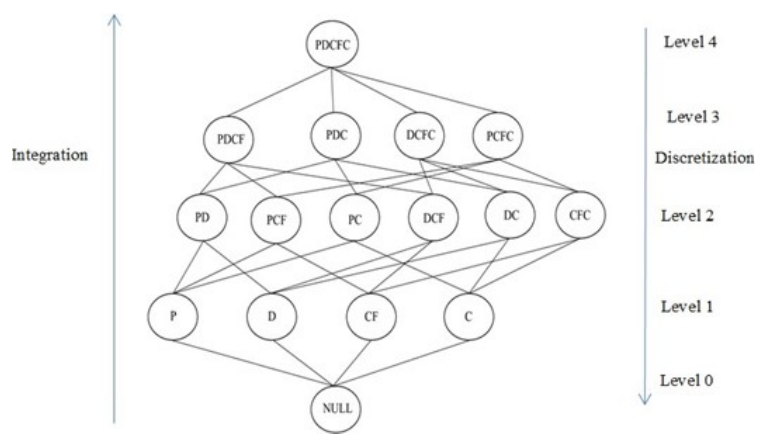

Figure 2: Lattice-Graph with Four Dimensions of Skill-set Parameters

The company that is conducting the assessment test is going to be referred to as Assessment Test Organizing Company (ATOC). ATOC maintains the database of different skill set of all the students and their marks. Now they can form the score sheet for each of the node of the Lattice-graph and can rank them. Any organization that wants to recruit candidates will go to the ATOC and tell about the required skill set for their different job roles and can also specify how many candidates (say M number of candidates) they want to allow for the further round of selections. As per this specification ATOC will provide the top M candidates from the given node of Lattice-graph. In every node they will store the information of every candidate by sorting the marks in descending order.

For example a company wants 200 candidates having the knowledge of set P and domain (D) and 100 candidates of set P, computer fundamental (CF) and coding (C) for the further round of selection. Now based on this specification ATOC will access node PD for top 200 candidates and node PCFC for top 100 candidates.

5.2 Lemmas on Proposed Lattice-graph Model:

Lemma 1: Number of nodes in each level $n >= 1$ is ${}^{n}C_{r}$where n is the number of dimensions and r ($r >= 1$) is the level number in Lattice-graph.

Proof : In level-1 for every dimension is represented in its own form, hence it is represented in terms of that dimension only. In level-1 the value of r=1. Hence for level-1 for every dimension it is represented in 1 form only. Thus ${}^{n}C_{1}$ is the number of representation in level -1. In the next level, r=2 and every node is represented by 2 dimensions by combining the nodes of level-1. Hence it is represented as ${}^{n}C_{2}$. In the next level, r=2 and every node is represented by 2 dimensions by combining the nodes of level-1. Hence it is represented as ${}^{n}C_{2}$. This process is continued till level = (n-1) where r=(n-1).In this level number of node is ${}^{n}C_{n}-1$ and this is same as ${}^{n}C_{r}$ as r=(n-1) in this level. Finally for level n number of nodes are ${}^{n}C_{n}$ where r=n. Hence we can say number of nodes is nCr for level r. Hence it is proved for all the levels $n \geq 1$.

Lemma 2: The number of dimensions d for a node of Lattice-graph in level r is r for $r \geq 1$.

Proof : In level-1 (r=1) number of dimension is 1 (d=1). In every upward level (r+1) number of dimension are increased by 1. Hence in level-2 (r=2) number of dimension are 2 (d=2). This is continued till level-n (r=n) and number of dimensions at that level are n (d=n).

Lemma 3: Number of nodes to be generated in Lattice-graph at level (r+1) from each node of level r using Integration operation is (n-r) for $r \geq 1$ and $r \leq n-1$.

Proof : In level-1(r=1) every node is combined with remaining of the node of level-1. As per lemma-2 number of dimensions of a node in level-1 (r=1) is 1. So a node in level-1 is combined with n-1 nodes (where r=1). In next immediate level each nodes has 2 dimensions and that can be combined with remaining of the (n-2) dimensions. In lemma-2 it is proved that numbers of dimensions of a node in level-2 (r=2) is 2. Since (n-2) holds for n=2. We continue this upto level r=n- 2. Finally for r=n-1 we get (n-(n-1)) = 1 which is the number of node to be generated at level n from the level (n-1).

Lemma 4: Number of nodes generated in Lattice-graph at level (r-1) from each node at level r using Discretization operation is ${}^{r}C_{r-1}$ where $r \geq 2$. Proof: In lemma-2 it is proved that number of dimensions in each node at level r is r. In every lower level nodes are generated with 1 less dimension of the previous level. As r is the number of dimension is current level and (r-1) is the number of dimension in the immediate lower level total number of nodes is represented by rCr-1. As the nodes are generated up to level-1 r is considered as $r \geq 2$.

5.3 Accuracy of Each Node based on Classification Algorithms

When a company wants to recruit candidates and they are taking the help of ATOC they might be interested to know how authentic this data set is. This authenticity problem can be framed by considering the historical data of their performance along with the placement record (whether placed or not). In order to ensure the authenticity different classification algorithms are applied on the given dataset. The five algorithms that are applied listed below.

a) SVM (Support Vector Machined)
b) Random Forest Classifier
c) KNN (K-nearest-neighbour)
d) Kernel-SVM
e) Decision Tree Classifier

For every node of the Lattice-graph classification algorithms are applied and for each of these 75% of data used for training and 25% for testing. We show the top two algorithms based on their accuracy in table 1

Combinations	Best accuracy with algo name	2nd best accuracy with algo name
1) PDCFC	97.57% (Random Forest)	97.41% (Decision Tree)
2) PDCF	97.35% (Decision Tree)	96.61% (Random Forest)
3) PDC	96.67% (Random Forest)	96.48% (Decision Tree)
4) DCFC	95.11% (Decision Tree)	95.08% (Random Forest)
5) PCFC	97.51% (Random Forest)	97.20% (Decision Tree)
6) PD	95.80% (Decision Tree)	95.42% (Random Forest)
7) PCF	96.26% (Decision Tree)	96.11% (Random Forest)
8) PC	96.23% (Random Forest)	95.95% (Decision Tree)
9) DCF	94.49% (SVM)	94.15% (Decision Tree)
10) DC	94.74% (Random Forest)	94.71% (Kernel SVM)
11)CFC	94.86% (Kernel SVM)	94.83% (Random Forest)
12) P	94.93% (Decision Tree)	94.74% (Random Forest)
13) D	94.49% (SVM)	94.49% (Kernel SVM)
14) CF	94.49% (SVM)	94.49% (Kernel SVM)
15)C	94.71% (Kernel SVM)	94.65% (Random Forest)

Table 1: Accuracy of Classification Algorithms for each node of Lattice-graph

The above table will give the idea on the quality of the student's data that a recruiting company will get from ATOC.

5.4 Hybrid-graph: Inclusion of New Skill for Assessment

The Lattice-graph model is conceptualized based on the defined skill-set. However in real life different business organizations may require human resources for some job roles based on some specific skill(s). This dynamic requirement of skill(s) can't be included in the lattice-graph as it is static in nature. Henceforth a new model is required that can overcome this limitation of Lattice- graph. Data warehouse and OLAP tools are based on lattice of cuboids [20] which is relevant to the concept of Lattice-graph. The limitations of lattice of cuboids were mitigated using Hyper-lattice, which supports the inclusion of new dimension.

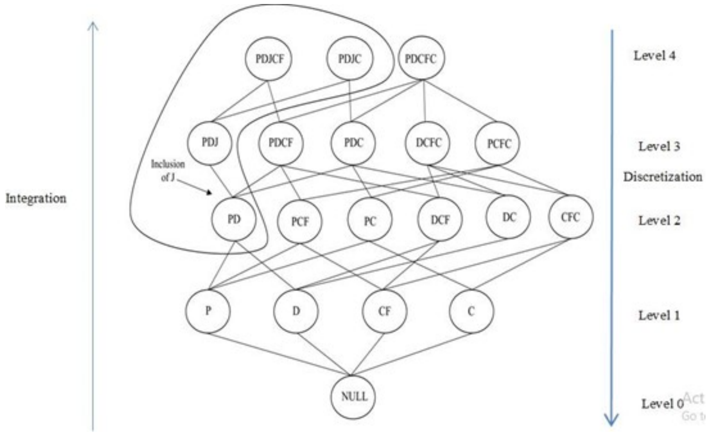

Figure 3: Inclusion of new skill (Japanese Language (J)) at level 2

In this research work we used the concept of Hyper-lattice to extend the proposed Lattice-graph to apply in the area of fresher recruitment based on pre- defined and new skill set. We consider that an organization wants to recruit employees based on the requirement of skill set P Aptitude, English, Quantitative, Analytical, skill D (Domain) and also with a new skill Japanese language (J). This is depicted in Fig. 3.

As we look into this structure we can find this is the merging of more than one lattice structure. However this structure degenerate the lattice structure as there are multiple Least Upper Bound (LUB) and Greatest Lower Bound (GLB). This structure is referred to as Hybrid-graph Skill Set Model (HGSSM). It may be possible more than one skill may be added in the different level of the graph.

This proposed HGSSM structure can be conceptualized as a composition of multiple Lattice- Graphs. This view is depicted in Fig. 4 where three Lattice-graphs are forming a HGSSM.

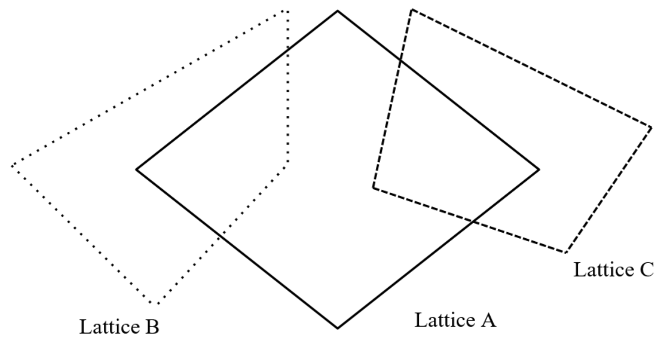

Figure 4: :
Hybrid-graph Skill Set Model (HGSSM) by merging three Lattice-graphs

HGSSM is a new structure and henceforth the properties of this new structure are to be defined. These are defined below.

5.5 Properties of Hybrid-graph Skill Set Model (HGSSM)

1. HGSSM consists of more than one Lattice-graph: HGSSM is a complex structure with more than one Lattice-graph.

2. Any number of dimensions could be added in the HGSSM: There is no restriction on how many dimension(s) could be added in the HGSSM.

3. New dimension may be added between level-1 to level (n-1): It is permissible to add new dimensions between level 1 to level (n-1). If added in level-0 then it will expand the Lattice-graph only. New dimension can't be added beyond level-(n-1) because over that it will exceed the existing level of HGSSM.

4. A new dimension may be added more than once in the HGSSM: This mode is flexible enough to add new dimension multiple times to reflect the business need.

5. The structure may have multiple upper bounds but unique lower bound that is NULL: As NULL is the starting point of the structure there is only one lower bound.

5.6 Case Study

In this case study we are considering the same company as defined in Section 5.1 is looking for resources having the skill set P Aptitude, English, Quantitative, Analytical, skill C (Coding) and also with a new skill Japanese language (J). The HGSSM of Figure 2 will be changed to a new HGSSM as given in Fig. 5.

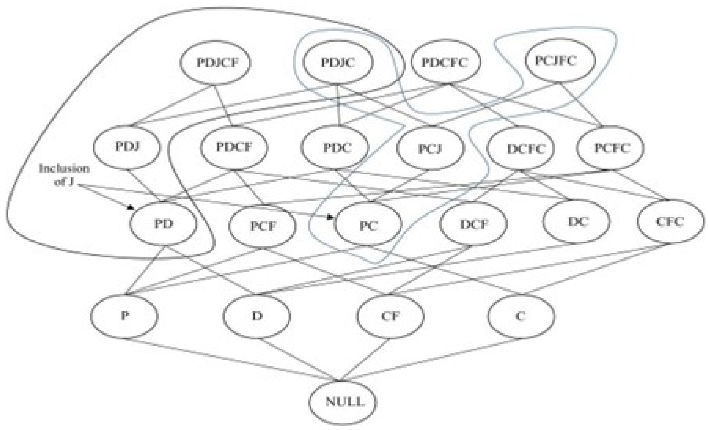

Figure 5: Modified HGSSM over a Figure 2, after inclusion of dimension J in PC node

6 Conclusion

This research work aims to develop a service based model to reduce the cost and time associated with the fresher recruitment. The model is based on the required skill set of the fresher candidates. The model is curated in a way so that any subset of the skill set could be selected based on the requirement of the any organization. An organization want to conduct the recruitment of fresher candidate do not need to start the process from scratch, rather they can take this service from Assessment Test Organizing Company (ATOC). This is going to significantly reduce the time and cost of the recruitment process. The proposed model termed as Lattice-graph gives the option to the recruiter to choose the required skill set as a service from the ATOC. Moreover this Lattice-graph model is extended to Hybrid-graph Skill Set Model (HGSSM) to adapt the requirement of customized skill-set of the candidates. The novelty of the framework is that once it is upgraded from Lattice- graph to HGSSM it has the capability to integrate customized requirement(s) of the skill-set of any organization as and when required. The limitation of the Lattice-graph is that it assumes few known skill-set to begin the construction of the structure. In order to use Lattice-graph in other applications the basic dimensions should be known at the beginning. However it will able to add new skill-set over the time dynamically to form Hybrid-graph Skill Set Model (HGSSM).

This framework could be improvised further to cater the requirement of the recruitment of the experienced resources. Specially, HGSSM will be suitable as it able to integrate new dimensions (skill parameters) as per the business / project specific requirement(s). The roles of experienced resources are often very much customized and HGSSM is fully scalable to any level of customization.

References

1. M. Verhagen, M. de Reuver and H. Bouwman, ”Implementing Business Models Into Operations: Impact of Business Model Implementation on Performance,” in IEEE Transactions on Engineering Management, vol. 70, no. 1, pp. 173-183, Jan. 2023, doi: 10.1109/TEM.2020.3046365.
2. M. Li, Q. Lu and M. Zhang, ”A Two-Tier Service Filtering Model for Web Service QoS Prediction,” in IEEE Access, vol. 8, pp. 221278-221287, 2020, doi: 10.1109/ACCESS.2020.3043773.
3. A. Amjad, F. Azam, M. W. Anwar, W. H. Butt and M. Rashid, ”Event-Driven Process Chain for Modeling and Verification of Business Requirements–A Systematic Literature Review,” in IEEE Access, vol. 6, pp. 9027-9048, 2018, doi: 10.1109/ACCESS.2018.2791666.
4. Christopher Westland, J. (2024). Analytical Review: Technical Analysis. In: Audit Analytics. Use R!. Springer, Cham. https://doi.org/10.1007/978-3-031-47464-4-5.
5. T. P. Tsiri, I. A. Daniyan and K. Mpofu, ”Development of a Business Process Modelling Framework for Continuous Improvements in Organisations,” 2022 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Kuala Lumpur, Malaysia, 2022, pp. 0675-0680, doi: 10.1109/IEEM55944.2022.9989810.
6. Mann, S., &Phogat, A. K. (2020). Dynamic construction of lattice of cuboids in data warehouse. Journal of Statistics and Management Systems, 23(6), 971–982. https://doi.org/10.1080/09720510.2020.1799498.
7. MonsalvePulido, J., Aguilar, J. & Montoya, E. Framework for the adaptation of an autonomous academic recommendation system as a service-oriented architecture. EducInfTechnol 28, 321–341 (2023). https://doi.org/10.1007/s10639-022-11172-8
8. Sen, S., Cortesi, A., Chaki, N. (2016). Hyper-lattice. In: Hyper-lattice Algebraic Model for Data Warehousing. SpringerBriefs in Applied Sciences and Technology.Springer, Cham. https://doi.org/10.1007/978-3-319-28044-8-1.
9. C. D. Casuat, A. SadhiqinMohdIsira, E. D. Festijo, A. SarragaAlon, J. N. Mindoro and J. A. B. Susa, ”A Development of Fuzzy Logic Expert-Based Recommender System for Improving Students’Employability,” 2020 11th IEEE Control and System Graduate Research Colloquium (ICSGRC), 2020, pp. 59-62, doi: 10.1109/ICSGRC49013.2020.9232543. .
10. H.CHAIBATE, A. HADEK, S. AJANA, S. BAKKALI and K. FARAJ, ”Analyzing the engineering soft skills required by Moroccan job market,” 2019 5th International Conference on Optimization and Applications (ICOA), 2019, pp. 1-6, doi: 10.1109/ICOA.2019.8727712.
11. J. Nagaria and S. V. S, ”Utilizing Exploratory Data Analysis for the Prediction of Campus Placement for Educational Institutions,” 2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT), 2020, pp. 1-7, doi: 10.1109/ICCCNT49239.2020.9225441.

12. A. Zaharim, Y. M. Yusoff, A. Mohamed, M. Z. Omar, N. Muhamad and R. Mustapha, ”Practical framework of employability skills for engineering graduate in Malaysia,” IEEE EDUCON 2010 Conference, 2010, pp. 921-927, doi: 10.1109/EDUCON.2010.5492478
13. S. Rajan and A. Pandita, ”Employability and Hiring Trends of Engineering Job Aspirants in UAE,” 2019 Advances in Science and Engineering Technology International Conferences (ASET), Dubai, United Arab Emirates, 2019, pp. 1-6, doi: 10.1109/ICASET.2019.8714256.
14. M. S. AmzadBasha, R. P. Kumar Raju, P. M. Oveis and M. Sarim, ”Unraveling Campus Placement Success Integrating Exploratory Insights with Predictive Machine Learning Models,” 2023 7th International Conference on Computation System and Information Technology for Sustainable Solutions (CSITSS), Bangalore, India, 2023, pp. 1-6, doi: 10.1109/CSITSS60515.2023.10334118.
15. A. Sunil, V. S. ATS and V. Chintham, ”Adaptive Fuzzy Campus Placement Based Optimization Algorithm,” 2023 5th International Conference on Energy, Power and Environment: Towards Flexible Green Energy Technologies (ICEPE), Shillong, India, 2023, pp. 1-6, doi: 10.1109/ICEPE57949.2023.10201630.
16. S. Bhoite, C. H. Patil, S. Thatte, V. J. Magar and P. Nikam, ”A Data-Driven Probabilistic Machine Learning Study for Placement Prediction,” 2023 International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT), Bengaluru, India, 2023, pp. 402-408, doi: 10.1109/IDCIoT56793.2023.10053523.
17. V. S. Tadla, P. M. Singh, K. M. Thakkar and R. Adatkar, ”Campus Placement using Machine Learning: An Extensive Review and Comparative Study of Machine Learning Methods,” 2023 6th International Conference on Advances in Science and Technology (ICAST), Mumbai, India, 2023, pp. 427-430, doi: 10.1109/ICAST59062.2023.10455050.
18. K. D. Thilak, K. Lalitha Devi, K. Kalaiselvi and J. Teja, ”Revolutionizing University Graduate Employability: Leveraging Advanced Machine Learning Models to Optimize Campus Recruitment and Placement Strategies,” 2023 International Conference on Research Methodologies in Knowledge Management, Artificial Intelligence and Telecommunication Engineering (RMKMATE), Chennai, India, 2023, pp. 1-6, doi: 10.1109/RMKMATE59243.2023.10369300.
19. S. Jadhav, G. Gujar, G. Shinde, S. Shivane and D. S. Jadhav, ”Placement Readiness Check: Predicting Placement Status Using Supervised ML Methods,” 2022 2nd International Conference on Intelligent Technologies (CONIT), Hubli, India, 2022, pp. 1-7, doi: 10.1109/CONIT55038.2022.9847863.
20. D. Bianchini, C. Cappiello, V. De Antonellis and B. Pernici, ”Service Identification in Interorganizational Process Design,” in IEEE Transactions on Services Computing, vol. 7, no. 2, pp. 265-278, April-June 2014, doi: 10.1109/TSC.2013.26.
21. F. Hasić, J. De Smedt, S. v. Broucke and E. Serral, ”Decision as a Service (DaaS): A Service-Oriented Architecture Approach for Decisions in Processes,” in IEEE Transactions on Services Computing, vol. 15, no. 2, pp. 904-917, 1 March-April 2022, doi: 10.1109/TSC.2020.2965516.
22. T. Górski and A. P. WOźniak, ”Optimization of Business Process Execution in Services Architecture: A Systematic Literature Review,” in IEEE Access, vol. 9, pp. 111833-111852, 2021, doi: 10.1109/ACCESS.2021.3102668.
23. AnjanDutta, RunaGanguli, PunyashaChatterjee, Narayan C. Debnath, SoumyaSen ”Improvement of Apriori Algorithm for Missing Itemset Identification and Faster Execution” ISCA International Journal of Computers and Their Applications Vol. 28 No. 2 (June 2021) Page 76-83 ISSN: 1076-5204.
24. https://github.com/jakir20788/Placement-Data-.git
25. Santanu Roy, SoumyaSen , Narayan C Debnath ”Optimal Query Path Selection in Lattice of Cuboids using Novel Heuristic Search Algorithm” Proc. of the 33rd International Conference on Computers and Their Applications (CATA 2018) Mar 19-21,2018, Las Vegas, USA. pp. 134-139 ISBN: 978-1-5108-5867-1.

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Design of a Hybrid Interest-Based Peer-to-Peer Network Using Residue Class-based Topology and Star Topology

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Abstract

In this work, a hybrid interest-based peer-to-peer network is presented. It consists of the existing Residue-class (RC) based peer-to peer (P2P) network and the Star interconnection network. The former one has been considered because of its two main advantages viz.(1) all peers with the same interest (or possessing same resource type) structurally form a group of diameter one, and (2) the group heads are connected in the form of a ring and the ring always remains connected even in presence of any churn. The Star topology has been considered because of its low diameter. We have incorporated these above advantages of the two architectures in the presented hybrid topology in a way that the diameter of the hybrid topology becomes comparable to the diameter of the star topology. In fact, it is equal to the diameter of the star topology plus 2. The proposed hybrid topology takes the shape of an n-star, and a remarkable improvement of data lookup latency with message complexity of $O(n)$is achieved, where n is the number of group heads, and n is usually very small compared to the total number of peers in the network.

Key Words: Residue Class, Interest-based, P2P Network, Star Interconnection Network, Diameter, Unicast Query, Lookup Latency.

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1 Introduction

Peer-to-peer (P2P) overlay networks are widely used in distributed systems due to their ability to provide computational and data resource sharing capability in a scalable, self-organizing, distributed manner. There are two classes of P2P networks: unstructured and structured ones. In unstructured systems [1] peers are organized into arbitrary topology. It takes help of flooding for data look up. Problem arising due to frequent peer joining and leaving the system, also known as churn, is handled effectively in unstructured systems. However, it compromises with the efficiency of data query and the much-needed flexibility. Besides, in unstructured networks, lookups are not guaranteed. On the other hand, structured overlay networks provide deterministic bounds on data sential discovery. They provide scalable network overlays based on a distributed data structure which actually supports the deterministic behavior for data lookup. Recent trend in designing structured overlay architectures is the use of distributed hash tables (DHTs) [2]-[4]. Such overlay architectures can offer efficient, flexible, and robust service [2]-[6]. However, maintaining DHTs is a complex task and needs substantial amount of effort to handle the problem of churn. So, the major challenge facing such architectures is how to reduce this amount of effort while still providing an efficient data query service. In this direction, there exist several important works, which have considered designing DHT-based hybrid systems [17]-[21]; these works attempt to include the advantages of both structured and unstructured architectures. However, these works have their own pros and cons. Another design approach has attracted much attention; it is non-DHT based structured approach [27]. It offers advantages of DHT-based systems, while it attempts to reduce the complexity involved in churn handling.

There exists yet another important approach; it is interest-based P2P networks. It is a structured approach without using DHT. Therefore, it does not have the problems that DHT based architecture faces, while at the same time it supports the deterministic behavior for data lookup. There exist several works in the literature in this direction [7]-[10], [14]-[16], [22]-[26].

It is an interest-based system. Two of the most prominent advantages relevant to the present work are: (1) all peers with the same interest (or possessing same resource type) structurally form a group of diameter one, and (2) the group heads are connected in the form of a ring and the ring always remains connected even in presence of any churn. These two advantages help in designing a very efficient data look-up algorithm [10]. However, we observe that there is scope to improve further the latency of the data look-up algorithm; all that is required for this purpose is to reduce the diameter of the ring, because this latency is dependent on the diameter (k/2) of the ring (with k group heads). As k increases, latency of the existing look up algorithm increases as well. We observe that a star topology with same number of nodes (group heads) has much smaller diameter compared to the RC based architecture. Therefore, to reduce the diameter further the work reported in [13] has suggested the possibility of designing a hybrid architecture that combines the structural advantages of both RC-based and star-based topologies [11]. Objective is to reduce data lookup latency which reduces as diameter reduces. Therefore, in this paper, we have considered designing a hybrid architecture consisting of RC-based ones and Star topology; we name this architecture as hybrid star architecture. We have identified several important architectural properties of Star topology and have used them to design an efficient low latency unicast query propagation algorithm suitable for the hybrid architecture. We have made sure that the diameter of the redesigned RC based hybrid architecture which takes the shape of a star network (say n-star) is comparable with that of a non-hybrid n-star network with the same number of nodes (group heads), thereby ensuring remarkable improvement of the data look-up latency. In the worst-case, the total number of message transmissions is only (2n-3) for an n-star hybrid network. In this work, we shall use the words, architecture and topology, interchangeably.

2 RC Based Topology and Star Topology

We first state briefly the architecture of RC based network followed STAR topology.

2.1 RC Based architecture [10]

Definition 1: We define a resource as a tuple $\langle R_i, V \rangle$, where R_i denotes the type of a resource and V is the value of the resource. A resource can have many values. For example, let R_i denote the resource type 'movies' and V' denote a particular actor. Thus $\langle R_i, V' \rangle$ represents movies (some or all) acted by a particular actor V'.

Definition 2: Let S be the set of all peers in a peer-to-peer system. Then $S = \{PR_i\}$, where $0 \leq i \leq n-1$, and PR_i denotes the subset consisting of all peers with the same resource type R_i. The number of distinct resource types present in the system is n. Also, for each subset PR_i, we assume that P_i is the first peer among the peers in PR_i to join the system. We call P_i the group-head of group G_i, which is formed by the peers in the subset PR_i.

A. Two level P2P architecture

It is a two-level overlay architecture and at each level structured networks of peers exist. It is explained below.

1. At level-1, we have a ring network consisting of the peers P_i where $0 \leq i \leq n-1$. The number of peers (i.e., group heads) on the ring is n, which is also the number of distinct resource types. This ring network is used for efficient data lookup and is named the transit ring network.

2. At level-2, there are n completely connected networks (groups) of peers. Each such group, say G_i, is formed by the peers of the subset PR_i, where $0 \leq i \leq n-1$, such that all peers $\in PR_i$ are directly connected (logically) to each other, resulting in a network diameter of 1. Each G_i is connected to the transit ring network via its group-head P_i.

3. Any communication between a peer p'_i ε G_i and p'_j ε G_j takes place only via the respective group-heads P_i and P_j.

The architecture is shown in Figure 1.

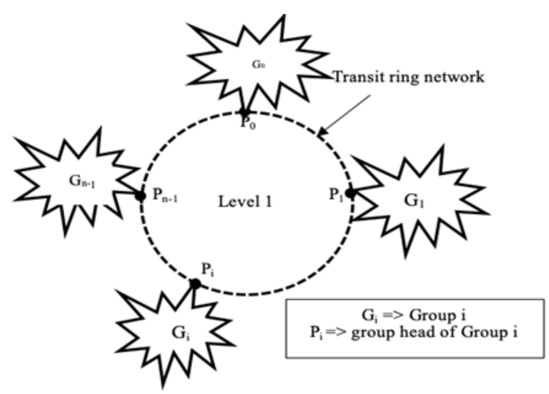

Figure 1: An RC-based P2P network

B. Assignments of overlay addresses

Consider the set S_n of nonnegative integers less than n, given as $S_n = \{0, 1, 2, \ldots, n-1\}$. This is referred to as the set of residues, or residue classes (mod n). That is, each integer in S_n represents a residue class (RC). These residue classes can be labeled as $[0], [1], [2], \ldots, [n-1]$, where

$$[r] = \{a : a \text{ is an integer}, a \equiv r (\text{mod } n)\}.$$

For example, for n = 3, the classes are:
[0] = ..., 6, 3, 0, 3, 6, . . .
[1] = ..., 5, 2, 1, 4, 7, . . .
[2] = ..., 4, 1, 2, 5, 8, . . .
A relevant property of residue class is stated below.

Lemma 1. Any two numbers of any class r of Sn are mutually congruent. Assume that in an interest-based P2P system there are n distinct resource types. Consider the set of all peers in the system given as $S = \{PR_i\}$, where $0 \leq i \leq n-1$. Also, as mentioned earlier, for each subset PR_i (i.e., group G_i), peer P_i is the first peer with resource type R_i to join the system.

In this overlay architecture, the positive numbers belonging to different classes are used to define the following parameters:

1. Logical addresses of peers in a subnet PR_i (i.e., group G_i). The use of these addresses has been shown to justify that all peers in G_i are directly connected to each other (logically), forming an overlay network of diameter 1. In graph theoretic terms, each G_i is a complete graph.
2. Identifying peers that are neighbors to each other on the transit ring network.
3. Identifying each distinct resource type with unique code.

The assignment of logical addresses to the peers at the two levels and the resources happen as follows:

At level-1, each group-head P_r of group G_r is assigned the minimum nonnegative number r of residue class $r \pmod{n}$ of the residue system S_n.

At level-2, all peers having the same resource type R_r will form the group G_r (i.e., the subset P_{R_r}) with the group-head P_r connected to the transit ring network. Each new peer joining group G_r is given the group membership address $r + j \cdot n$, for $j = 1, 2, \ldots$.

3. Resource type Rr possessed by peers in Gr is assigned the code r which is also the logical address of the group-head Pr of group Gr.

4. Each time a new group-head joins, a corresponding tuple <Resource Type, Resource Code, Group Head Logical Address >is entered in the global resource table (GRT).

Definition 3. Two peers Pi and Pj on the ring network are logically linked together if (i + 1) mod n = j. Remark 2. The last group-head $P_n - 1$ and the first group-head P0 are neighbors based on Definition 3. It justifies that the transit network is a ring.

Definition 4. Two peers of a group Gr are logically linked together if their assigned logical addresses are mutually congruent.

Lemma 2. Diameter of the transit ring network is n/2.

Lemma 3. Each group Gr forms a complete graph.

2.2 STAR Architecture [11]

The address of a node in an n-star Sn is identified by a unique permutation of the digits {1, 2, 3, ..., n}. Let fi, $(2 \leq i \leq n-1)$ be a function that maps permutation Pk of the digits 1, 2, 3, ..., n to another permutation P_k', i.e. $f_i(P_k) = P_k'$ where the first and the i^{th} digits in Pk are interchanged to generate P_k'.

The mapping function f_1 on P_k is such that the first and the nth digits in Pk are interchanged to generate P_m. That is, $f_1(Pk) = P_m$. In other words, the last digit of Pm is identical to the first digit of P_k and vice-versa; meaning thereby that Pk and Pm belong to two different Sn-1 stars which are the components of Sn and the nodes represented by these addresses, i.e., P_k and P_m are directly connected to each other. For example, in a 4-star, any two of the component 3-stars have two links connecting them. Thus, we see that number of nodes in a complete n-star is n!

An example of a complete 4-star, S4 is shown in Figure 2. Note that it has 24 (4!) nodes and each component 3-star, S3 is also a complete one and has 6 (3!) nodes. That is, the S4 has four component complete 3-stars. However, in general, a star may be an incomplete one as well. Later when we use the topological properties of a star to design the modified RC based network, a node in a star means a group head as in the RC based one.

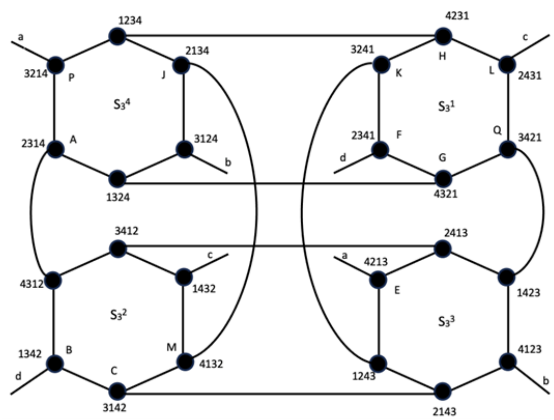

Figure 2: A complete 4-star architecture

2.3 Comparison of the diameters of the two architectures We shall consider number of overlay hops between nodes as the parameter to determine diameters. For this purpose, in RC based one, we consider only the group heads located on the ring. The peers inside a group form a network of diameter 1 and so, we may not need to count it while determining the diameter of the (transit) ring because a group head may not have any other member present at a given time. For Star architecture [11] we consider only the nodes that form the architecture. Later in this paper, we shall propose a hybrid star topology using both RC-based ones and star networks in which a node represents a group head of peers with identical interest. The comparison of diameters of RC-based networks and star interconnection networks is stated below.

From the information stated above, we observe that as the number of group heads/nodes increases, diameter of RC based architecture increases much faster compared to the diameter of a star architecture. Therefore, latency of any data look-up protocol will be much smaller in a Star network compared to that in an RC based network.

RC-based ring network		Star interconnection network		
Number of Group heads	**Diameter**	**Complete Star**	**Number of nodes**	**Diameter**
6	3	3-Star	6	3
24	12	4-Star	24	5
120	60	5-Star	120	7
720	360	6-Star	720	9

Table 1: Comparison of RC-based ring network and Star interconnection network

3 A Six-node Basic RC Component and A Complete 3-Star

We highlight below the similarities and dissimilarities between a six-node basic RC-based component and a complete 3-Star.

Let us consider the two architectures as shown in Figure 3 and Figure 4. We name the first one as a basic RC-based component. The second one shows a complete 3-star. One main reason to consider such an RC based component is that it is very unlikely that there will exist less than six distinct types of resources at any time. Even if it is, as will be clear later that (see Section 4, Figure 5 and Figure 6) the architecture will simply be an RC-based ring with less than six nodes. The structural similarities and dissimilarities of the two architectures are stated below. As is seen in the figures, the overlay addresses in the two architectures are based on RC based idea and star-based idea respectively. The two architectures have the same diameter (3 in terms of hop). So, data look-up latency in both can be at most 3. This is the similarity. Now, consider that node f has left. In Figure 3, the topology remains connected, i.e., it remains a ring [10]. So, performance of any data look-up protocol does not degrade. However, in Figure 4, the same is not true because the topology is a disconnected one resulting in an incomplete 3-star. This is the dissimilarity. This simple and yet important observation will be used in constructing the proposed architecture.

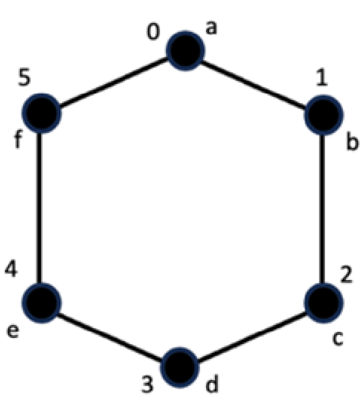

Figure 3: RC-based component

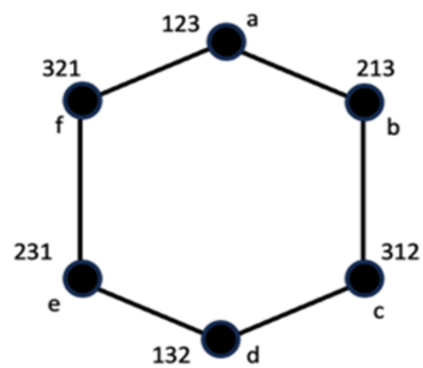

Figure 4: A complete 3-star

4 The Proposed Hybrid Architecture and Some Relevant Properties

In the proposed architecture we assume that it will consist of a number of basic RC-based components and the components will be connected to form a complete n-star. Data look-up inside an RC-based component will follow the existing data look-up protocol reported in [10] using the RC-based overlay addresses of the nodes and inter-component routing (i.e., to send any query from component to component) will use the star-based overlay addresses. Note that in the architecture, every node in the star will be a group-head of peers with the same resource type. We shall use group-head and node interchangeably. The reason for consideration of such intra-component and inter-component query protocols is two-fold: 1) under no circumstances an RC-based component can be disconnected, so there will be no degradation of performance of the look-up process, and the latency of intra-component query look-up will be limited by 3 hops, 2) overlay distance between any two nodes in the hybrid architecture will at most be equal to the diameter of the n-star plus 2; this 2 is due to the fact that diameter of each source group and destination group is 1. Therefore, it results in a much less latency required for the query propagation compared to that in an RC based ring topology with the same number of nodes n!.

In the above architectural design, a node needs to have a tuple of overlay addresses (a1, a2), in which a1 represents the node's RC-based overlay address and a2 represents its star-based overlay address. For example, in Figure 3, the address tuple of node 'a' will now become (0, 123). The first one is used for intra-component query propagation and the second one is used for the inter-component query propagation.

We now illustrate briefly how the proposed architecture is constructed. Let us start with a single node ‘a’. The address tuple of the node ‘a’ is (0, 123). Now consider that a second node ‘b’ joins (Figure 5). The address of this second node is (1, 213). Note that it is now a ring of two nodes (see the dotted link between the two nodes). Now consider that a third node ‘c’ joins. Its address tuple is (2, 312). The basic component structure is still a ring (see the dotted link in Figure 6). However, if we consider a 3-star with these three nodes, it is just incomplete and definitely the performance of any query in it will degrade. This will go on unless the component contains all six nodes. This is the reason which we mentioned earlier, why each component will be constructed using RC based idea. However, when a new node, say ‘g’, (seventh one) joins, it will form the second basic component (of a 4-star) with one node only and the overlay address tuple of ‘g’ will be 4231 while at the same time the second component address of each of the nodes in the first basic component will be updated as xxx4 (see Section 2.2). In addition, based on star topology, node ‘a’ and node ‘g’ will have a direct overlay link for inter-component query propagation. The structure is shown in Figure 7. In this way, using RC based components, star topologies of higher dimensions can be constructed. In this context, it may be mentioned that while the number of the distinct resource types is limited [12], the number of members in a group can be enormously large (theoretically infinite). This is one of the main characteristics (advantages) of the residue class-based design and it has been incorporated in the Star architecture (of the proposed design) consisting of basic RC Based components.

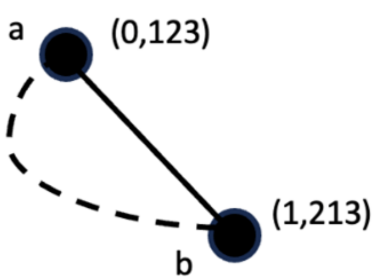

Figure 5: A two-node component

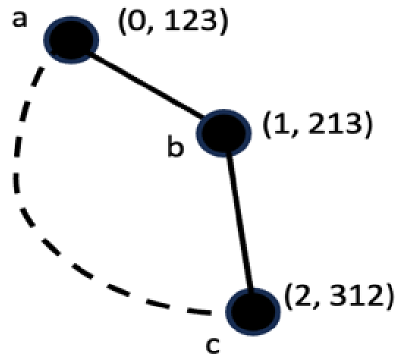

Figure 6: A three-node component

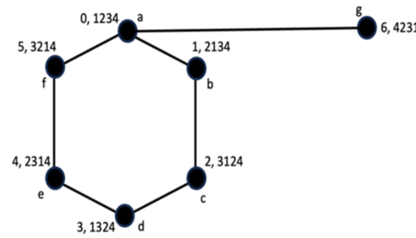

Figure 7: An incomplete 4-star

Note that in general, for an n-star, the star-based overlay address of any node will be a specific permutation of the n literals, viz., 1,2,3,. . . ,n.

We now define ‘neighbors’ of a node x in a basic RC-based component using its star-based overlay address. Let this address be ABC. Then, nodes with addresses BAC and CBA are the neighbors of node x. It means that node x has direct logical connections with these two nodes in the basic component which is also a complete 3-star. These connections can be used by node x for intra-basic component or simply intra-component routing. Now assume that the overlay topology appears as a complete 4-star. So, we now add another literal, say D in the overlay address of node x and the address becomes ABCD. Then, according to star topology node x will be logically connected to node DBCA that belongs to a different 3-star. Therefore, degree on node x increases from 2 in a basic component to 3 in 4-star topology. Thus, node x has three neighbors in 4-star topology. This connection to the 3rd neighbor implies that node x can use this for inter-component routing in the 4-star. Now consider that this 4-star is a part of a complete 5-star. Then, the address of x will consist of 5 literals and so it becomes ABCDE. Then, according to 5-star topology node x will be logically connected to node EBCDA. Therefore, node x now has 4 neighbors. To conclude, in an n-star overlay hybrid architecture, degree of any node is (n-1). Thus, any node can use these addresses (of neighbors) to multicast its information to different basic components of the topology. This idea may be used to incorporate parallelism in broadcasting by any node in the network. In this context, it is understood that the overlay address (be it basic RC-based component or not) of a node will be paired with its IP address.

Example:
In Fig 4, node with address 123 has its neighbors as 213 and 321.

In Fig. 2, the 4-star address of the above node will have 4 literals and it is 1234. Neighbors of the node with 4-star based overlay address 1234 are 2134, 3214, and 4231. The first two are in the same RC-based component as is the node 1234, and the 3rd one is in another RC-based component in the parent 4-star. We name this 3rd one as an inter-component neighbor of the node 1234. For inter component propagation of query/data from node 1234 to node 4231, and vice-versa, this 3rd neighbor is necessary. Note that the 3rd one is obtained by interchanging the first and the 4th literals of 1234.

If it is a 5-star, address of the above node will have 5 literals and it is 12345; its 4 neighbors are 21345, 32145, 42315, and 52341. The first two are in the same RC-based component as is the node 12345. In this case, the 3rd and 4th nodes are the inter-component neighbors of node 12345. The 3rd one is used for propagation of information from node 12345 to a different RC-based component belonging to the same parent 4-star. The 4th neighbor belongs to a different 4-star component of the 5-star topology and its address is obtained by interchanging the first and the 5th literals of 12345; it is used for information propagation between two 4-stars.

In general, a node in an n-star will have (n-1) different neighbors; two of them belong to its parent RC-based component and the rest are one for each higher order star respectively. It may be noted that the n-star is a nested architecture in a sense that it consists of (n-1) stars; each (n-1) star consists of (n-2) stars and so on till it comes down to component 3-stars.

For low latency propagation (limited by the diameter of a given star topology) we consider that the following information to be present with each node in an n-star. Each node maintains the following tables:

1) Resource table for basic component (RT-Basic)

2) Resource tables for next higher order stars (RT-4-Star, RT-5-Star, etc.)

3) Each node maintains a list of its (n-1) neighbors.

Example:
Consider the RC-based component and the 3-star of Figures 3 and 4. The RT-Basic for the nodes in a basic component appears as

Table 2: RT-basic

nodes	resource-code (ar)	3-star-based address (as)
a	0	123
b	1	213
c	2	312
d	3	132
e	4	231
f	5	321

In the above table, RT-based overlay address of a node and the resource code it possesses are the same ones.

Table for the 4-star of Fig. 2 is shown below:

Table 3: RT-4-Star

resource-code-range	4-star-based-address-range
0, 5	xxx4
6, 11	xxx2
12, 17	xxx1
18, 23	xxx3

In this table, each row corresponds uniquely to one 3-star component of a 4-star. In a row, the first entry denotes the lower and the upper code values of the six resources present uniquely with the six nodes belonging to a component 3-star; the second entry denotes that the star-based overlay addresses of the six nodes in it end with the same literal. Note that overlay addresses of the six nodes can be obtained by permutations of the first three literals (denoted as xxx) while the 4th literal is fixed in all these six addresses.

Table 4: RT-5-Star

resource-code-range	5-star-based-address-range
0, 23	xxxx5
24, 47	xxxx2
48, 71	xxxx3
72, 95	xxxx4
96, 119	xxxx1

In this table for a 5-star, each row corresponds uniquely to one 4-star component of a complete 5-star. The corresponding 5-star topology is not shown here; however, the above table actually gives the information of the topology. In a row, the first entry denotes the ranges of resources (resource codes) present in the component, and the second entry denotes that the overlay addresses of the 24 nodes in it end with the same literal. Therefore, we observe that for an i-star topology, it will have i numbers of component (i-1) stars. We denote a component as the m^th component in which the i^th literals in the overlay addresses of all nodes in the component are m. For example, in the above RT-5-star table, there are five 4-star components, and the respective 5^th literals in the overlay addresses of the five component 4-stars are 1, 2, 3, 4, and 5. That is, all nodes in component one will have 1 as the last literal in their overlay addresses; all nodes in component two will have 2 as the last literals in their overlay addresses; and so on.

In a similar way as above, tables can be built for higher order stars. However, it has been shown that in reality the number of distinct resource types is limited [12].

Therefore, we suggest that the design consideration should be restricted to a maximum of 6-star that contains 720 distinct resource types (Section 2.3). If necessary, a federation of 6-stars or even of 5-stars can be built (not covered in this paper). However, the proposed unicast algorithm in Section 5 is a general one that considers any hybrid n-star topology. In this context, we repeat that each node is the group-head of a group of peers possessing similar kind of resources, and the construction of each group is such that it can contain very large number of such peers (theoretically infinite). Note that for an n-star hybrid topology, the total number of rows of the tables together is (6+4+5+6+…+n), i.e., n(n+1)/2. Thus, for a 6-star topology, it will be 21x2 only, which is reasonably quite small for any group-head (node) to store.

5 Data Look-up Algorithm.

Let us present an algorithm for unicast communication. We assume that in an n-star hybrid topology a query for an instance of a resource with code ar' is originated at a node with a tuple of overlay addresses (ar, as). Each node maintains tables such as its parent RT-basic, RT- 4-star, RT-5-star, and so on. Each node maintains a list of its neighbors.

5.1 Algorithm Unicast

We start with a description of searching inside a RC-based component as this will be used in the main body of the unicast algorithm as a subroutine.

Algorithm 1 Intra-RC-Based-Component

if $ar' \in RT$-basic $[ar - ar'] > 3$
Diameter of a RT-based component is 3 *ar* forwards the query to its immediate predecessor
else
ar forwards the query to its immediate successor
for each intermediate receiving node N
N forwards the query until its code is equal to ar'
if$N$ has the answer to the query N unicasts the answer to node *ar* using the IP address of *ar*
else
One-hop communication since the diameter of each group-head is one N broadcasts the query in its group-heads
if $\exists p'$ with ar'
Peer p' unicasts ar' to *ar*
else
Search latency in the group-heads is minimal, i.e., only two hops Search latency in the group-heads is minimal, i.e., only two hops

else
Execute Algorithm Unicast

Algorithm Unicast:

1. The originator node, identified by the tuple of overlay addresses (ar, as), starts searching through the resource tables of higher-order stars.The search continues until a resource with the code ar' is found in some m^{th} component of an $(i-1)$-star of an i-star, where $4 \leq i \leq n$. Since the originator node belongs to a 3-star component, the search begins with its parent 4-star. The search then continues through progressively higher-order stars until the desired resource is located.
2. Node *ar* finds the *i*th literal, i.e., *m*, in the *n*-star-based overlay address of the *m*th component of the $(i-1)$-star.
3. If node ar''s overlay address starts with the literal *m*, node *ar* interchanges the first literal with the *i*th literal of its address. Node *ar* then forwards the query to the node with this modified address in the *m*th component of the $(i-1)$-star, and control flows to step 7.
4. Node *ar* finds its neighbor whose overlay address starts with the literal *m*. Each node in a 3-star component has exactly one neighbor in each higher-order star.
5. Node a_r forwards the query to the neighbor.

6. neighbor node interchanges the first literal with the ith literal of its address and forwards the query to the node with this address in the mth component (i-1)-star.

/ receiving node is an inter-component neighbor of the sending node

7. receiving node in the mth (i-1)-star now becomes the new originator node and the following steps 7.1, 7.2 are executed. /vspace10pt

7.1. new originator node searches its resource table to identify the (i-2)-star that has the resource; steps 2 to 6 are executed with this new originator and the (i-2)-star; this process continues until a 3-star is identified to have the resource

/ Resource tables of lower order stars from (i-2)-star to 4-star are searched

7.2 control flows to Algorithm Intra-RC-Based-Component

Theorem 1. Message complexity of Algorithm Unicast is O(n).

Proof. Proof is constructive. Worst-case appears when in Step 1 of Algorithm Unicast implies that if the resource is initially found in some component (n-1)-star of the n-star hybrid topology, steps 2 to 7.1 will be executed repeatedly until a 3-star is identified to have the resource. During each repetition, the query is sent to an appropriate node in a star of immediate lower dimension. Thus, so far (n-3) message-transmissions take place. Once in a 3-star it takes at most 3 overlay hops (diameter of a 3-star can be at most 3) to reach the final probable destination. So, all together there are [(n-3) + 3) = n] message-transmissions. However, if Steps 4 and 5 are to be executed in each repetition, (n-3) more message transmissions take place. Therefore, total number of message transmissions in the worst-case is n+(n-3), i.e.(2n-3). Hence, the message complexity is O(n).

Example of unicast query propagation

Let us consider the 4-star network of Fig. 2. Let a peer in group j with group-head address tuple (1, 2134) has requested its group-head for a particular instance of a resource with resource code 11. Note that the group-head may itself be the requesting peer. Let us denote this group-head as gj. Group-head gj maintains its tables RT-basic and RT-4-star. It first searches the table RT-basic and does not find the resource 11 in it. It then searches the table RT-4-star, and the 3rd entry (12, 17 xxx1) indicates that resources with codes from 12 to 17 exist with the peers of the RC-based component 3-star in which the 4-star based addresses of all six nodes end with the literal 1. Now g_j finds its neighbor that has its overlay address starting with the literal 1 and it is 1234. Node g_j sends the query to the neighbor 1234.

Node 1234 interchanges the first literal with the 4th literal of its address to obtain 4231 and sends the query to this new node 4231. If node 4231 possesses resource with code 11 and if has the answer to the query, it directly sends the reply to the requesting group-head gj; else it broadcasts the query in its group to learn if a peer in its group has the answer. If so, the peer sends the answer to gj directly; otherwise search fails. On the other hand, if node 4231 has different resource code, it then initiates the searching in its parent RT-based component 3-star. This searching to identify the group-head that owns the resource code 11 takes at most 3 overlay hops as the diameter of any RC-based component can be at most 3. Searching for the correct group-head can also be done without any propagation of the query in the basic component. It can be done by node 4231 via a simple search of the appropriate RT-basic table for the correct owner of the resource with code 11. Node 4231 then has to contact the owner directly informing about the query. However, because of very low diameter of a basic component, query propagation may be a reasonably good idea and therefore, in this work, we have considered the query propagation approach. Finally, as stated above if a peer (be it a peer in a group or a group-head itself) is found to have the answer, it will directly send the answer to the requesting group-head.

5.2 Fault Tolerance

Observe that links in a star topology are physical [11] while in our proposed hybrid architecture using both RC-based and star topology, links are virtual. Hence, there is no need to consider any link failure.

In addition, each node here is actually the group-head of a group of peers with similar kind of resources (interests) and the construction of each group is such that it can contain very large number of such peers (theoretically infinite); therefore, it is very unlikely that a complete group of peers will disappear because of churn [10]. It may be noted that inclusion or exclusion (leaving) of any peer, related to an existing group does not change the diameter of the group (which is one); since peers in a group form a complete graph.

6 Conclusion

In this work we have used some topological properties of Star inter-connection networks to redesign an already existing Residue class-based peer-to-peer architecture. The existing RC-based architecture has been the choice in this work because of its manifold advantages. Specifically, the following two structural properties are behind the choice: these are (1) all peers with the same interest (or possessing same resource type) structurally form a group of diameter one, and (2) the group heads are connected in the form of a ring and the ring always remains connected even in presence of any churn. However, data look-up latency is k/2 for an RC-based network with k group heads. It may appear substantial if k is large. In order to reduce this latency, some pertinent topological properties of Star network have been used to modify the existing RC based design. The proposed hybrid design has much less diameter than in its original design (RC based design). It reduces the data look-up latency remarkably. In an n-star hybrid topology, the overlay distance between any two nodes in the hybrid architecture will at most be equal to the diameter of the n-star network plus 2; this 2 is due to the fact that diameter of each source group and destination group is 1. Therefore, it results in a much less latency required for the query propagation compared to that in an RC based ring topology consisting of the same number of nodes n! as in the n-star hybrid network.

Future works aim at designing secured multicast and broadcast data look-up algorithms in the proposed design.

References

1. Y. Chawathe, S. Ratnasamy, L. Breslau, N. Lanham, and S. Shenker, "Making gnutella-like p2p systems scalable," Proc. ACM SIGCOMM, Karlsruhe, Germany, (August 25-29 2003).
2. B. Y. Zhao, L. Huang, S. C. Rhea, J. Stribling, A. Zoseph, and J. D. Kubiatowicz, "Tapestry: A Global-Scale Overlay for Rapid Service Deployment," IEEE J-SAC, vol. 22, no. 1, pp. 41-53, (Jan. 2004).
3. A. Rowstron and P. Druschel, "Pastry: Scalable, Distributed Object Location and Routing for Large Scale Peer-to-Peer Systems," Proc. FIP/ACM Intl. Conf. Distributed Systems Platforms (Middleware), pp. 329-350, (2001).
4. R. I. Stocia, R. Morris, D. Liben-Nowell, D. R. Karger, M. Kaashoek, F. Dabek, and H. Balakrishnan, "Chord: A Scalable Peer-to-Peer Lookup Protocol for Internet Applications," IEEE/ACM Tran. Networking, vol. 11, no. 1, pp. 17-32, (Feb. 2003).
5. M. Xu, S. Zhou, and J. Guan, "A New and Effective Hierarchical Overlay Structure for Peer-to-Peer Networks," Computer Communications, vol. 34, pp. 862-874, (2011).
6. D. Korzun and A. Gurtov, "Hierarchical Architectures in Structured Peer-to-Peer Overlay Networks," Peer-to-Peer Networking and Applications, Springer, pp. 1-37, (March 2013).

7. Bidyut Gupta, Nick Rahimi, Henry Hexmoor, Shahram Rahimi, Koushik Maddali, and Gongzhu Hu, "Design of Very Efficient Lookup Algorithms for a Low Diameter Hierarchical Structured Peer-to-Peer Network," Proc. IEEE 16th Int. Conf. Industrial Informatics (IEEE INDIN), July 2018, Porto, Portugal.
8. S.K. Khan and L.N. Tokarchuk, "Interest-based Self Organization in Cluster-Structured P2P Networks," Proc. 6th IEEE Consumer Communications and Networking Conf, Las Vegas, pp. 1-5, 2009.
9. L. Badis, M. Amad, D. Aissani, K. Bedjguelal, and A. Benkerrou, "ROUTIL: P2P Routing Protocol Based on Interest Links," Proc. 2016 Int. Conf. Advanced Aspects of Software Eng., Constantine, pp. 1-5, 2016.
10. Swathi Kaluvakuri, Koushik Maddali, Nick Rahimi, Bidyut Gupta, and Narayan Debnath, "Generalization of RC-based Low Diameter Hierarchical Structured P2P Network Architecture," IJCA, vol. 27, no. 2, June 2020, pp. 74-83.
11. S. B. Akers and B. Krisnamurthy, "A Group Theoretic Model for Symmetric Interconnection Networks," IEEE Trans. Computers, vol. 38, no. 4, pp. 555-566, 1989.
12. Cheng, J., & Donahue, R. (2013), "The pirate bay torrent analysis and visualization," International Journal of Science, Engineering and Computer Technology, 3(2), 38.
13. Indranil Roy, Reshmi Mitra, Swathi Kaluvakuri, Nick Rahimi, and Bidyut Gupta, "On Further Improvement of Data Look-Up Latency in Residue Class (RC) Based Peer-to-Peer Networks," EPiC Series in Computing, volume 98, pp. 69-76, (Proc. 39th CATA 2024, March).
14. H. Shen, G. Liu and L. Ward, "A Proximity-Aware Interest-Clustered P2P File Sharing System," IEEE Transactions on Parallel and Distributed Systems, 26(6):1509-1523, doi: 10.1109/TPDS.2014.2327033, 1 June 2015.
15. I. Roy, S. Kaluvakuri, K. Maddali, Z. Liu, and B. Gupta, "Efficient Communication Protocols for Non-DHT-Based Pyramid Tree P2P Architecture," WSEAS Transactions on Computers, (Invited paper), 20:108-125, July 2021.
16. I. Roy, B. Gupta, B. Rekabdar, and H. Hexmoor, "A Novel Approach Toward Designing a Non-DHT Based Structured P2P Network Architecture," EPiC Series in Computing, Proceedings of 32nd Int. Conf. Computer Applications in Industry and Engineering, 63:121-129, 2019.
17. P. Ganesan, Q. Sun, and H. Garcia-Molina, "Yappers: A Peer-to-Peer Lookup Service over Arbitrary Topology," Proc. IEEE Infocom 2003, San Francisco, USA, pp. 1250-1260, Vol. 2, March 30 - April 1 2003.
18. M. Yang and Y. Yang, "An Efficient Hybrid Peer-to-Peer System for Distributed Data Sharing," IEEE Trans. Computers, vol. 59, no. 9, pp. 1158-1171, Sep. 2010.
19. Z. Peng, Z. Duan, J. Jun Qi, Y. Cao, and E. Lv, "HP2P: A Hybrid Hierarchical P2P Network," Proc. Intl. Conf. Digital Society, pp. 86-90, 2007.
20. K. Shuang, P Zhang, and S. Su, "Comb: Resilient and Efficient Two-Hop Lookup Service for Distributed Communication System," Security and Communication Networks, vol. 8(10), pp. 1890-1903, 2015.
21. M. Kleis, E. K. Lua, and X. Zhou, "Hierarchical Peer-to-Peer Networks Using Lightweight SuperPeer Topologies," Proc. IEEE Symp. Computers and Communications, pp. 1-6, 2005.
22. Bidyut Gupta, Nick Rahimi, Shahram Rahimi, and Ashraf Alyanbaawi, "Efficient Data Lookup in Non-DHT Based Low Diameter Structured P2P Network," Proc. IEEE 15th Int. Conf. Industrial Informatics (IEEE INDIN), pp. 944-950, July 2017, Emden, Germany.
23. N. Rahimi, K. Sinha, B. Gupta, and S. Rahimi, "LDEPTH, A Low Diameter Hierarchical P2P Network Architecture," Proc. IEEE 14th Int. Conf. on Industrial Informatics (IEEE INDIN), Poitiers, France, pp. 832-837, July 2016.
24. Indranil Roy, Koushik Maddali, Swathi Kaluvakuri, Banafsheh Rekabdar, Ziping Liu, Bidyut Gupta, Narayan Debnath, "Efficient Any Source Overlay Multicast In CRT-Based P2P Networks A Capacity-Constrained Approach," Proc. IEEE 17th Int. Conf. Industrial Informatics (IEEE INDIN), July 2019, Helsinki, pp. 1351-1357, Finland.
25. Indranil Roy, Bidyut Gupta, Banafsheh Rekabdar, and Henry Hexmoor, "A Novel Approach Toward Designing A Non-DHT Based Structured P2P Network Architecture," EPiC Series in Computing, Volume 63, 2019, pages 121-129, (Proceedings of 32nd Int. Conf. Computer Applications in Industry and Engineering).
26. Indranil Roy, Nick Rahimi, Koushik Maddali, Swathi Kaluvakuri, Bidyut Gupta, and Narayan Debnath, "Design of Efficient Broadcast Protocol for Pyramid Tree-Based P2P Network Architecture," EPiC Series in Computing, Volume 63, 2020, pages 182-188, (Proceedings of 33rd Int. Conf. Computer Applications in Industry and Engineering, San Diego).
27. Shiping Chen, Baile Shi, Shigang Chen, and Ye Xia, "ACOM: Any-Source Capacity-Constrained Overlay Multicast in Non-DHT P2P Networks," IEEE Tran. Parallel and Distributed Systems, vol. 18, no. 9, pp. 1188-1201, Sep. 2007.

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Enhancing Trust in Peer-to-Peer Data Transfer: Implementing Zero-Knowledge Succinct Proofs and a Trusted Factor for Robust RC-based P2P Systems

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Abstract

Peer-to-peer (P2P) networks are a class of network systems distinguished by their capacity for large-scale distributed information sharing. In this context, a number of novel P2P topologies are put forth, including the interest-based Residue Class (RC) P2P networks, which are non-DHT. The RC-based P2P networks are open, dispersed, and anonymous, making them susceptible to a number of security issues. Because RC-based P2P networks lack a centralized authority to control the nodes that constantly join and exit the network, trust verification is a challenging problem. In this research, we offer a trust model designed for RC-based P2P networks. To build trust, we employ a Trust Factor (TF) in conjunction with the Zero-Knowledge Proof (ZKP) idea. The foundation of the model is the trust mechanism that allows nodes to improve and establish their reputation within the network. By effectively recognizing malicious nodes inside the RC-based P2P network and mitigating the likelihood of an attack on the decentralized system, the trust model ensures secure file-sharing and communication.

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1 Introduction

Peer-to-peer (P2P) overlay networks are commonly employed in distributed systems because of their ability to provide computational and data resource sharing in a scalable, self-organizing, distributed manner. Unstructured and structured P2P networks are the two subtypes of P2P networks. In unstructured systems, peers can be grouped in any topology at random [6]. It takes flooding to look up data. "Churn" — the challenges caused by peers joining and leaving the system frequently—is well managed in unstructured systems. Nevertheless, this reduces the vital flexibility and efficacy of data querying. There is no guarantee on lookups in unstructured networks. Structured overlay networks, on the other hand, provide deterministic boundaries for data discovery. Based on a distributed data structure that genuinely permits deterministic data search behavior, they develop scalable network overlays.

A recent development in the architecture of structured overlay systems is the use of distributed hash tables (DHTs) [16, 25, 44]. According to [16, 25, 26, 44, 48], overlay designs of this kind can offer effective, adaptable, and robust services. On the other hand, keeping DHTs while handling the churn issue gets costly. Designing an efficient data query service necessitates a major shift. Creating hybrid systems has been the subject of several noteworthy articles in this field [14, 35, 39, 49]. The aforementioned studies endeavor to integrate the advantages of both structured and unstructured frameworks. However, these efforts come with a unique mix of benefits and drawbacks [2].

There has also been much interest in a non-DHT-based structural design method that is interest/resource driven [18, 22]. In addition to aiming to reduce churn management complexity, it provides the advantages of DHT-based systems. Our paper presents a non-DHT fog computing architecture that is built on interest/resource and publish/subscribe mechanisms. This architecture facilitates efficient resource sharing for sensor data processing. In designing the architecture, we considered the non-DHT-based interest/resource-based architecture suggested in [18, 22].

Due to the lack of centralized authority to control the frequent joining and departing of nodes, peer-to-peer (P2P) distributed trust verification is a complicated problem [3]. The trade-offs between security, performance, and cost are substantial. The network may experience a considerable load as more nodes are added, marking each one as authentic. Second, devastating attacks like replay, sybil, and eclipse attacks—in which the adversary produces a large number of malicious peers—can occur on P2P networks. Furthermore, the processing and bandwidth capacity of these networks is constrained, which makes it challenging to deploy a resource-intensive protocol for defense and mitigation. It becomes very difficult to integrate traditional Public-key Infrastructure (PKI) because of these problems. In general, the dispersed network necessitates that users authenticate one another in a scalable, secure, and effective way. P2P networks are open and anonymous, which makes it simple for malevolent users to enter the network and cause havoc by introducing fake content [7]. Peers find it uncomfortable to initiate contact with unfamiliar users in such a setting until they are seen as trustworthy. Credibility can be offered through the use of a reputation system. Many experiments on reputation systems to simulate peers' prior behavior have been conducted in recent years [1], [24], [47], [41], [52], [53], [28], [40], [12], [32], [5], [46], [8], [9], and [45]. However, there is still work to be done in integrating them into the actual system. The most effective example of Google's reputation system, PageRank [34], determines a page's reputation based on how popular it is on the internet. The quantity of links pointing to the page and the popularity of the pages from which the connections originate are the two metrics used to gauge popularity. Reputation systems have been developed for peer ranking based on a similar principle, where the most reputable peer is deemed to be the most trustworthy [24], [52], [53], and [40]. In any such system, the network as a whole usually builds the consensus. There are four main, fundamental issues with these reputation systems.

Finding a balance between anonymity vs. trust [43] is a significant problem in P2P networks. Anonymity is a highly wanted feature for privacy reasons, allowing users to communicate without disclosing their identities or sensitive information. Users are shielded from targeted attacks, censorship, and spying as a result. However, this level of anonymity allows malicious actors to disrupt the system in a covert manner without triggering any detection mechanism. However, trust necessitates identification confirmation or tracking past behavior, both of which put users' anonymity at risk. Building trust in a highly anonymous network is extremely challenging, which makes it harder to hold malicious nodes responsible and boosts network-level attacks such as spamming and the spread of false information. However, a reliance on trust sometimes means relying on reputation or identity verification systems, which can compromise user privacy. Thus, it can be difficult to strike the right balance between these two opposing objectives in P2P networks.

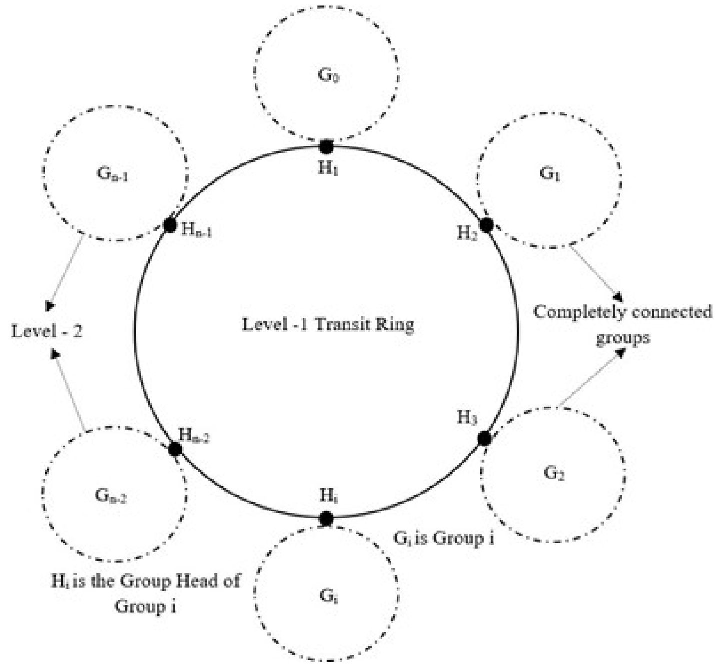

Figure 1: Sequence diagram for an encrypted message sent from sender to receiver after successfully verifying the receiver [11].

Lightweight cryptography using Zero Knowledge Proofs (ZKP) offers a compelling solution to address the above challenges. ZKP allows a prover to demonstrate to a verifier that a certain statement such as the legitimacy of a node is true, without revealing any information beyond the truth of the statement itself. This provides a mechanism for establishing trust while preserving user anonymity which is a challenging balancing act in P2P network. Moreover, ZKPs are beneficial in minimizing computational overhead and communication costs, essential for the effective operation of resource-constrained P2P networks. Furthermore, the unique aspect of ZKPs is to provide non-interactive proofs that are succinct and efficient, requiring minimum interaction between prover and verifier, reducing network latency, and speeding up the data transfer process.

The authors of [11] have presented a ZKP-based protocol that is lightweight, safe, and efficient for building and preserving trust between anonymous peers and group chiefs in a P2P network during the data transfer phase. The communication is started by the sender group head asking the recipient node to complete a one-step challenge (such SHA-ing a random number). The sender uses the unique solution they have received as a nonce to encrypt the message and send it to the recipient. Since the recipient node is the only one with the decryption key, only it can decrypt the message. It basically carries out a safe key transfer procedure together with a symmetric encryption algorithm. Without jeopardizing any private data, the sender node can easily create an alternative compact problem statement by altering the mathematical operation or random number. Additionally, without the intervention of a third party, the protocol can be performed numerous times until the verifier is satisfied with the prover's reliability.

When a recipient node fails to react within the predefined timeout period or responds incorrectly to the sender's challenge, it is classified as 'corrupt'. As a punishment and deterrent for breaking the protocol, nodes that have been flagged as corrupt are essentially barred from participating in any further phases of data transfer. The network's integrity is maintained by this continuous detection mechanism, which shields it from nodes that can jeopardize the security operation of the system.

By balancing user anonymity and the reliability of group head nodes, this protocol tackles the challenging problem of distributed trust verification in peer-to-peer networks. It is perfect for P2P networks with limited resources since it requires less interaction, which lowers communication and computing overhead. Furthermore, continuous trust verification is suggested by this method. This removes presumptions regarding intrinsic reliability and hence lowers the risk of assaults. It strengthens network security and protects user privacy by making our approach a reliable and scalable trust verification technique.

According to the authors in [11], in the worst case, the number of hops needed rises as 2k+3 (where k is the maximum number of puzzles the network administrator has set),and the ZKP puzzle transfer is only generated during the data transfer phase. This results in a lag in the data transfer process. Another problem with the security approach described by Deverasetti et al. [11] is that it has very strict policies that are not tolerant in the slightest. For example, a recipient node is labeled as "corrupt" if it fails to respond to a challenge from the sender within the predetermined timeout period or if it responds incorrectly. In this paper, we propose a regular maintenance approach to address these issues and make the policies more tolerant. We incorporate a Trust Factor (TF) that is updated each time the nodes exchange ZKP challenges, along with the same ZKP-based security approach as in [11]. Basically, this TF will allow the nodes/peers to self-correct in case drastic ; we'll go into more depth about this in section 3. Moreover, this approach suggests continuous trust verification, which reduces the likelihood of attacks by eliminating assumptions about intrinsic reliability.

This makes our methodology a scalable and trustworthy trust verification method, enhancing network security and safeguarding user privacy. This paper has four main sections. In Section 2, we give the overview of the previously proposed RC-based P2P network and the background on Zero Knowledge Proof (ZKP). Followed by in section 3 we propose our ZKP Maintenance Protocol and the secured data-lookup . Model evaluation and discussion is part of Section 4. We are concluding with the highlights of our work in Section 5.

2 Preliminaries

2.1 RC-Based P2P Network [19]

Here, we have taken into consideration some of the first results of an RC-based low diameter two level hierarchical structured P2P network [19, 21, 30]. We provide a structured design for an interest-based peer-to-peer system in this section. We will use the following notations and their meanings to define the architecture.

Definition 1: We define a resource as a tuple $<\text{Resi}, V>$, where Resi denotes the type of a resource and V is the value of the resource. Note that a resource can have many values.

Definition 2: Let S be the set of all peers in a peer-to-peer system. Then

$$S = \{P_{R_i}\} \quad (0 \leq i \leq n-1)$$

where P_{R_i} denotes the subset consisting of all peers with the same resource type *Resipeer* among the peers in P_{R_i} to join the system. We call H_i as the group-head of group G_i formed by the peers in the subset P_{R_i}. We now describe our proposed architecture suitable for an interest-based peer-to-peer system. Generalization of the architecture is considered in [21]. We use the following notations along with their interpretations while we define the architecture.

2.1.1 Two Level Hierarchy

It is a two-level overlay architecture and at each level structured networks of peers exist. It is explained in detail below.

1. At level-1, we have a ring network consisting of the peers H_i $(0 \leq i \leq n-1)$. The number of peers on the ring is n, which is also the number of distinct resource types. This ring network is used for efficient data lookup, and so we name it the transit ring network.

2.At level-2, there are n completely connected networks (groups) of peers. Each such group, say G_i, is formed by the peers of the subset PR_i $(0 \leq i \leq n-1)$, such that all peers (PR_i) are directly connected (logically)

3. Every group is also going to have a secondary group head G_{sh} to maintain a fault-tolerant architecture. The secondary group head is going to be the next highest logical address afterAfter the group head, an address will be assigned. For example, in a network of 10 different resource types, for group 0, G_0^h will be the group head and G_0^{sh2} will be the secondary group head.

4. Each peer in the network maintains a Information Resource Table (IRT) that consists of n number of tuples.

* The group heads will have a tuple of the form <Resource Type, Resource Code, Group Head public Key>for other group heads and <Peer Logical Address, Peer public Key>for the other peers present in their respective group. The Group Head Logical Address are assigned according to the proposed logical address assignment algorithm proposed in [23] and the public key of the group heads or the peers are exchanged when they are joining the network and the IRT is updated and broadcasted

in the network. Also, Resource Code is the same as the group head logical address. article amsmath

The peers P_i, who are not group heads but belong to a group G_i (where $P_i \in G_i$), will have the following tuples:

- $\langle$Resource Type, Resource Code, Group Head Public Key$\rangle$ for the group head of G_i.
- $\langle$Peer Logical Address, Peer Public Key$\rangle$ for the other peers present in G_i.

5.Any communication between a peer $G_{x,i} \in G_x$ and $G_{y,j} \in G_y$ takes place only through the corresponding group heads H_x and H_y.

Figure 2: Example of a simple ZKP Protocol.

The proposed architecture is shown in Figure 1. The assignment of the logical addresses is described in [19].

2.1.2 Salient Features of Overlay Architecture

We summarize the salient features of this architecture.

1. It is a hierarchical overlay network architecture consisting of two levels; at each level the network is a structured one.

2. Use of modular arithmetic allows a group-head address to be identical to the resource type owned by the group. We will show in the following section the benefit of this idea from the viewpoint of achieving reasonably very low search latency.

3. Number of peers on the ring is equal to the number of distinct resource types, unlike in existing distributed hash table-based works some of which use a ring network at the heart of their proposed architecture [26].

4. The transit ring network has the diameter of n/2. Note that in general in any P2P network, the total number of peers $N >> n$.

5. Each overlay network at level 2 is completely connected. That is, in graph theoretic term it is a complete graph consisting of the peers in the group. So, its diameter is just

1. Because of this smallest possible diameter (in terms of number of overlay hops) the architecture offers minimum search latency inside a group.

2.2 Assurance of Trust in Peer-to-Peer Networks

Managing trust is a crucial element in peer-to-peer (P2P) networks, particularly when it comes to secure data sharing. Trust-based systems are key in maintaining the integrity, privacy, and accessibility of data within P2P networks. Balfe et el. suggested a framework for trusted computing to improve security in P2P networks. Their strategy involves using trusted computing technologies to create a secure base for P2P interactions. By combining trusted platform components and secure boot processes, they show how it's possible to ensure secure communication and data transfer in P2P networks [3].

Selcuk et el. introduced a system for managing trust in P2P networks based on reputation. This system uses the reputation of nodes to gauge their reliability. They highlight the significance of reputation management in P2P networks and offer a detailed framework that includes trust calculation and decision-making processes for effective trust assessment [38].

Zhao et el. tackled the challenge of verifying results and scheduling in P2P grids, focusing on grid computing settings where nodes are spread across different locations. They developed a scheduling algorithm that takes into account both the reputation of nodes and the accuracy of their reported data. Their work on this topic is titled "Result Verification and Trust-Based Scheduling in P2P Grids" [51].

Frahat et el. introduced a secure and scalable approach to managing trust in IoT P2P networks. They recognized the distinct features and security issues of IoT environments and proposed a framework that guarantees secure communication and collaboration among IoT devices. Their approach includes trust evaluation, reputation management, and access control to build a secure and reliable IoT P2P network [13].

Hao et el. aimed to improve the reliability of P2P networks by incorporating blockchain technology. They suggested a blockchain-enhanced P2P topology that allows for quick and dependable information dissemination. The addition of trust mechanisms further enhances the reliability and trustworthiness of the P2P network [37].

2.3 Zero-Knowledge Proof (ZKP)

Zero-knowledge proofs (ZKP) are fundamental and powerful tools in cryptography. Zero-Knowledge Proof (ZKP) protocols are designed to assist provers in persuading verifiers that they possess certain knowledge, often confidential, while maintaining the integrity of the knowledge during the verification process (zero-knowledge) as shown in figure 2. Since its first introduction by Goldwasser et el. in [15], the notion of ZKP has been used in several authentication and identity systems.

A ZKP system is an interactive protocol in which the prover and the verifier communicate with each other for a predetermined number of rounds. If the assertion is true at the conclusion of these discussions, the verifier has to be persuaded of it. On the other hand, there is a good chance the verifier will find the lie if the assertion is not true. Three movements, or three communications named commitment, challenge, and answer, comprise each round. The statement to be proven is initially generated by the prover and sent to the verifier as a first message, or commitment. Next, a challenge is selected at random by the verifier and forwarded to the prover. Ultimately, the prover delivers the response to the verifier after computing it in light of the challenge.

A zero-knowledge proof is a demonstration that reveals nothing beyond the truth of a statement. Here, "proof" refers not to the traditional mathematical concept but to an interactive protocol where one party (the prover) convinces another party (the verifier) of the truth of an argument. In a zero-knowledge proof, the prover shows they know a secret without disclosing it. Research in zero-knowledge proofs has been driven by authentication systems where one party wants to prove its identity to another using secret information (such as a password) without revealing the secret itself. This is known as a ”zero-knowledge proof of knowledge.” While passwords are often too small or not sufficiently random for zero-knowledge proofs of knowledge in many systems, the underlying principle is still highly significant.

ZKPs have been crucial in maintaining privacy and security within peer-to-peer (P2P) networks. Numerous studies have been conducted to implement ZKPs in P2P networks for secure communication. Danezis and Diaz introduced SybilInfer, a system that leverages social network analysis to detect malicious entities. ZKPs are utilized to improve the reliability of detection and bolster the security of P2P networks [10].

Lu et al. have examined the use of ZKPs for authentication in anonymous P2P networks. The study focuses on the development and implementation of a pseudo-trust system through zero-knowledge authentication [29].

Pop et al. have looked into the application of ZKPs to enhance privacy in energy transactions on the blockchain. The research suggests a scheme that guarantees privacy while ensuring the integrity of energy-related transactions [36].

X Sun et al. offer a comprehensive overview and analysis of ZKPs in blockchain applications. The review covers various topics, including the different types of ZKPs and their potential uses and challenges within the blockchain environment [42].

Yang and Li introduce a digital identity management system using ZKPs within a blockchain framework. The work proposes a secure and efficient method for managing digital identities while safeguarding privacy [50].

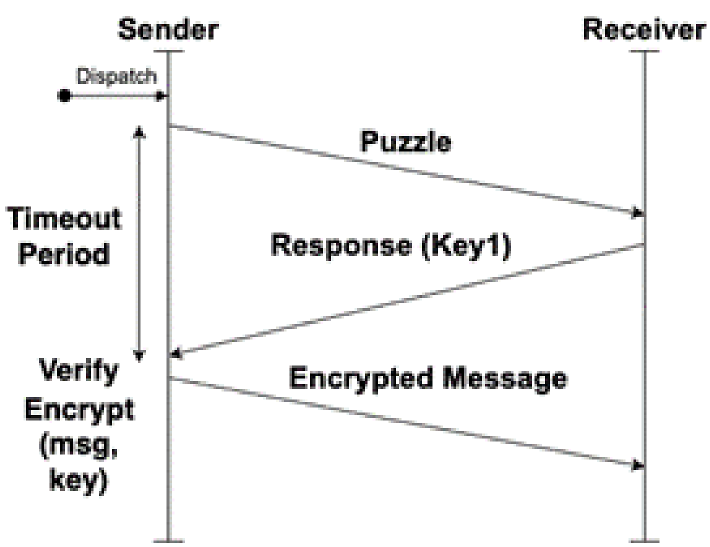

Figure 3: Sequence diagram for an encrypted message sent from sender to receiver after successfully verifying the receiver [11].

Harikrishnan and Lakshmy explore the application of ZKPs for secure payments in distributed networks. The authors suggest a scheme that ensures the confidentiality and integrity of digital service payments while maintaining anonymity [17].

Major et el. present an authentication protocol based on chaos theory and ZKPs. The paper introduces a new method to enhance security and privacy in authentication protocols [31]. Kosba et el. discuss the development of scalable ZKPs without a trusted setup. The work introduces a construction known as zk-STARKs, which provides an efficient and scalable solution for ZKPs [27].

Ben-Sasson et el. concentrate on the creation of scalable ZKPs with no trusted setup. The paper introduces a construction called zk-STARKs, which offers a highly efficient and scalable approach to ZKPs [4].

One of the most compelling uses of zero-knowledge proofs within cryptographic protocols is to ensure honest behavior while maintaining secrecy. The idea is to require a user to prove that their actions are correct according to the protocol. Because of the soundness property, we know the user must act honestly to provide a valid proof. Due to the zero-knowledge property, the user does not compromise the privacy of their secrets during the proof process.

For example, in [11] the authors have incorporated the concept of ZKP. Irrespective of the intricacy of the proposition being proved or the amount of data involved, the authors have employed succinct proof that is very verifiable.

A result, in comparison to traditional NP verification, they need less processing complexity. They are specifically chosen to minimize communication and processing overhead. Furthermore, in order to minimize communication between the prover and verifier, the protocol is intended to assure minimal interactions. chosen to minimize communication and processing overhead. Furthermore, in order to minimize communication between the prover and verifier, the protocol is intended to assure minimal interactions. Because of this, the issue formulation is appropriate for the P2P trust verification context, which has limited resources. The sender group head node suggests a one- step challenge for creating proof and building confidence, such as SHA-256 hashing a random integer.

It is simple to alter this random number in order to provide a fresh challenge for every hop and produce a fresh verification key. In response to this difficulty, the receiver node—which is also the group head—develops a special method that can serve as a nonce, a number that is only used once to make sure that previous messages are not repeated in replay attacks. They transfer the message to the following hop in the network until it reaches its intended destination, after utilizing ZKPs to confirm the group head node’s reliability. It eliminates any presumptions that a peer is inherently trustworthy by ongoing trust verification. Rather, every node must demonstrate and earn its authenticity and integrity, which lessens assaults from corrupted nodes via replay and sybil, among other methods.

Resource Type	Resource Code	Group Head Public Key	Trust Factor
A	0	MIGeMA0GCSqGSIb3DQEBAQUAA4GMADCBiAKBgH7KigBAm4tfautjDoas3lgjQd0a Vvz9oadWNFi7h3OuT8SxMIiaiKAvM/uWXUuSVR008cMI1XaAuhN5S710/vANT9zl DLZK6ACSiUVjm6+cP6QcEaGYAAYM+JC4LHlfx+nK6mT9PrtbB3DYqBvLeG7diUKI 6ORoaYmpNVIt9IA7AgMBAAE=	0
B	1	MIGeMA0GCSqGSIb3DQEBAQUAA4GMADCBiAKBgFUYeCH0kCJBk1JoyynPP4XzqG5U CSAMtwto74o0/46LM5Vj8UpHO7EJ7JfnX7VdRbbikMdHNRWTP2jPvYs2EgqWx/K5 eX98O0C3/o8uoYILVHOMfyrqwRTeAA6VjZVSbV7BNWvlYPEQLnDT4TmAcWvfcXNp FvaPsmF+qsddl+YbAgMBAAE=	0
C	2	MIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQCPVI3uLY7zlkZGEU51+2FWLL9w ZFAtfqhalqKo2/TLNq31hfL38CQwCSQjv3giCiv0FyPDEK33sE1CwVJRWwnDlsqB enzuu2Dh0rt3hurQOT+om7qAoa+llTK5t0AYreXfZ8e1c1u+DCleekuKl1cf47al Nm1uQFVjUgMcs4iD5QIDAQAB	0

Figure 4: IRT example with 3 resource types

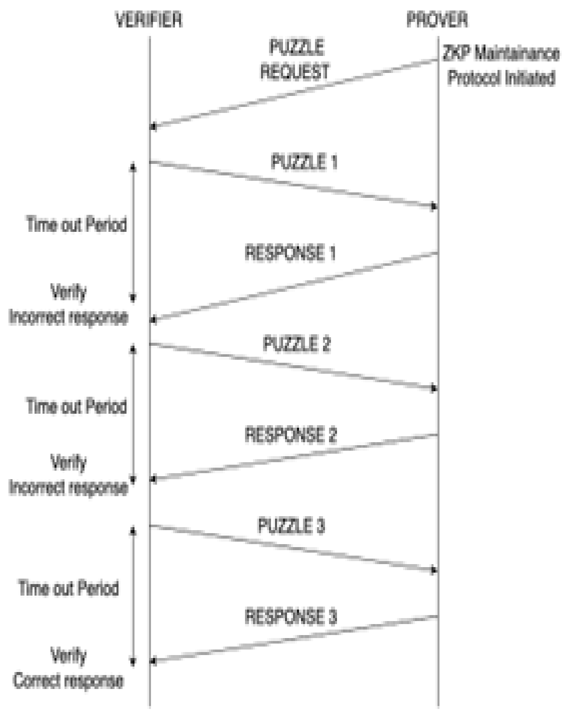

Figure 5: Sequence diagram for successful trust verification between Prover and Verifier

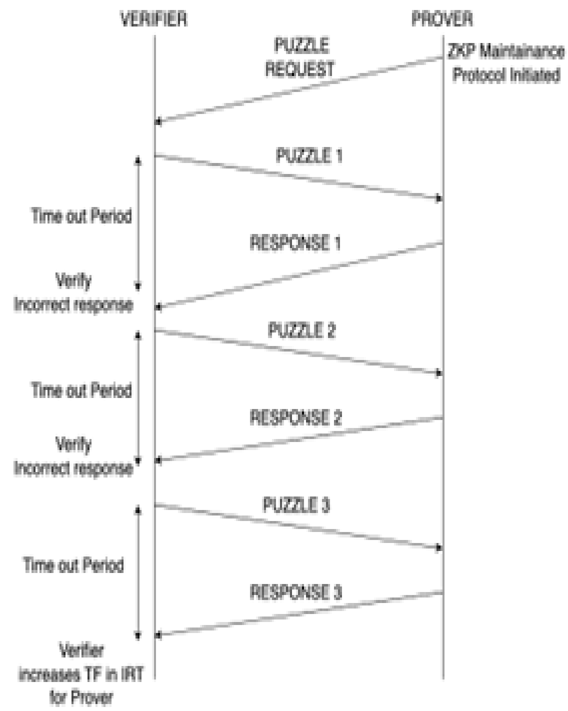

Figure 6: Sequence diagram for response lost during trust verification between Prover and Verifier

The ZKP puzzle transmission is only created during the data transfer phase, and in the worst scenario, the number of hops required increases as 2k+3 (where k is the maximum number of puzzles the network administrator has chosen), according to the authors in [11]. The data transfer procedure lags as a result. The highly rigorous and non-tolerant principles of the security method outlined by Deverasetti et el. [11] provide another issue. For instance, a receiving node is flagged as "corrupt" if it answers erroneously or does not answer to a challenge from the sender within the allotted delay period.

As a result, we suggest a routine maintenance strategy in the section that follows to deal with these problems and improve the policies' tolerance. We implement the same ZKP-based security method as in [11], coupled with an updated Trust Factor (TF) every time the nodes exchange ZKP challenges. In essence, if something goes wrong, this TM will let the nodes/peers self-correct. Additionally, this method proposes ongoing trust validation, which lessens the probability of assaults by dispelling the notion of inherent dependability. As a result, our technique improves network security and protects user privacy while being scalable and reliable for trust verification.

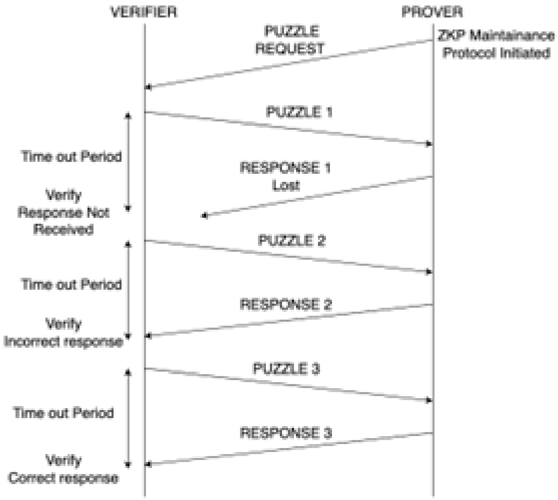

Figure 7: Sequence diagram for trust verification between Prover and Verifier where Prover is found to be potentially malicious

Algorithm 1 ZKP Maintenance Protocol

1: Counter = 0
2: Gh the Prover initiates the ZKP maintenance protocol
3: Gh unicasts challenge request Puzreq to Verifier **(Verifier → Gh, Gh and Gsh)**
4: Verifier, after receiving Puzreq, generates PuzV and unicasts it to Gh_{i+1}
5: Verifier waits for Tout **(Tout is the timeout set by the network administrator)**
6: Gh solves PuzV and responds with RePuzV to Verifier
7: **if** (RePuzV is true) **and** (verified by Verifier) **and** (within TPout) **then**
8: **if** TF of Prover = 0 **then**
9: No change in TF is made by the Verifier in IRT
10: **else**
11: TF is decreased by 1 by the Verifier in IRT
12: Broadcast it to other group heads using IRT
13: **end if**
14: **else**
15: **if** Counter ¡ 3 **then**
(Counter = Max TF value set by the network administrator) The respective Group Head re-initiates Step 6 Counter = Counter + 1
16:18: **else**
19: Verifier increases the TF for Gh in IRT by 1
20: Broadcast it to other group heads using IRT
21: Other group heads update their IRT
22: **if** TF for Gh == 3 **then**
23: Gh_i is marked as malicious and removed from the network and broadcasted updated IRT to all other group heads
24: The Gsh of Gi is made the new Gh and the next highest logical address after Gh_i is made the new Gsh
25: **end if**
26: **end if**
27: **end if**

3 Zero-Knowledge Succinct Proofs and a Trusted Factor for RC-based P2P

In this section we present the regular maintenance strategy that every group head in the RC-based P2P network is going to use to maintain the trust in the network. In this scenario, we propose of including a new column in the Information Resource Table (IRT) mentioned in section 2.1.1, this column will be the Trust Factor (TF) as shown in figure 4 as an example, for say group head of group 0 i.e. Gh with 3 different resource types. The TF will be range from 0-3 or some other maximum value as determined by the network designer. The score ranges from '0' being the most trusted, '3' being extremely malicious and mildly suspicious for intermediary values. Initially all the group heads will be assigned with the TF 0. Every group head has to initiate the regular ZKP maintenance protocol within a certain time period as determined by the network designer. In the regular ZKP maintenance protocol, the group head initiating it, will be acting as the prover and the group heads adjacent to it as well as the secondary group head of that particular group will be serving as the verifier.

Algorithm 2 Secured Data Look-up and Transfer Protocol for RC-based P2P Network

1: Gx initiates a look-up request for (Vreq , PubGx) and sends it to Gh
i
2: Gh broadcasts the request; every group head G_j receiving the broadcast message follows these steps:
3: **if** Gh finds Vreq its Resource type **then**
4: **if** Gh has Vreq **then**
5: Gh encrypts $E(Vdata, PubGx)$ and sends it back to Gx using the same path it received Vreq
6: Gx, after receiving, decrypts $D(E(Vdata, PubGx), PvtGx)$
7: **else**
8: Gh broadcasts in its group G_j
9: **if** Group G_y has Vreq **then**
10: Gy encrypts $E(Vdata, PubGx)$ and sends it back to Gx using the same path it received Vreq
11: Gx, after receiving, decrypts $D(E(Vdata, PubGx), PvtGx)$
12: **end if**
13: **end if**
14: **end if**

To generate proof and build confidence in ZKP maintenance protocol, the starting group head or the prover suggests a one-step challenge Puzreq, such as computing the SHA-256 hash of a random number. This random number can be altered to introduce a new challenge at each step and create a new reandom number. Upon receiving the Puzreq, the verifiers will devise a puzzle and forward it to the prover, setting a timeout period of T Pout. In case the prover respond within T Pout, the verifiers will check the response from the prover. If the response is incorrect, they will send the puzzle back to the prover, allowing them another opportunity to demonstrate their trust. The number of attempts can be set by the network administrator. The number of attempts can be set by the network administrator. If the response does not arrive within T Pout, the verifier will send the puzzle back to the prover, offering them another opportunity to prove their trust. Similarly, the number of attempts can be set by the network administrator. This process is essential because there's a possibility that the prover is trustworthy, but due to network delays, the response does not arrive within the specified T Pout. The scenarios are represented in figures 3, 6, and 7.

Whenever the ZKP maintenance protocol is started by the group head, for instance, Gh, the verifiers will record the time of its initiation. If it take longer than a predetermined time frame (established by the network administrator) after the initial recording, the verifiers will flag this as suspicious activity and increment the trust factor for that particular group head in the IRT. They will then notify all group heads of the updated IRT, prompting them to update their own IRT. This procedure guarantees continuous maintenance in the RC-based network and maintains trust among the group heads.

and maintains trust among the group heads. Let us consider a RC-based network with 10 resource types, therefore, the group numbers range from (G h 0 ..... G h 9), the group head of group 0, G h 0 wants to initiate the ZKP maintenance protocol, then G h 0 is the Prover and G h 1 , G h 9 and G sh 2 0 will be the Verifier. The ZKP maintenance protocol initiated by every group head is given in algorithm 1.

3.1 Secured Data Look-up and transfer Protocol for RCbased P2P netwo

Through the use of ZKP maintenance protocol proposed in algorithm 1, we can assure that there is trust being developed between the group-heads, as the group heads being the center of target for the network. The Trust Factor (TF) is specifically designed to make the protocol tolerant and give opportunity to the group-heads to prove their trust. Given this scenario, we propose the following data transfer protocol which happens after a successful data-lookup being done using the protocols proposed by the authors in [33]. Let us consider that peer G x i Gi is querying for a resource ¡ Vreq ¿. The broadcast protocol is used as described in [20]. The secured data-transfer protocol is presented in algorithm 2.

4 Evaluation

Our protocols, ZKP maintenance protocol and the secured data look-up and transfer protocol proposed in section 3 was thoroughly assessed, taking into account various conditions. The proposed data-lookup protocol unlike in [11], requires less number of hops to transfer the secured content from the destination to the source. The reason being in [11], every time a data look-p is initiated, the ZKP protocol was initiated, whichadded to the number of hops required to maintain trust, look-upand transfer of data. That is the reason why we proposed onmaking our ZKP as a maintenance protocol as it will not affectthe data look-up and transfer scenarios. Every time the ZKPmaintenance protocol is initiated, it develops thetrust between the group heads present in the RC-based P2P network.

On the other hand the protocols proposed in [11] were rigid in nature, thereby not letting the peers to rectify their mistakes or in other words good behaviour was not rewarded. We have that option in our protocols, as good/trusted behaviours are rewarded. The Trust Factor (TF) is proposed to increase if a malicious behaviour is noticed, and decreased if the peer is having trustworthy behaviour.

5 Conclusions

By utilizing Zero-Knowledge Proof (ZKP) maintenance protocol, our innovative approach effectively addresses the crucial problem of building and preserving trust in peer-to-peer(P2P) networks, guaranteeing optimal security, privacy, tolerant and speed in data transfers. By managing trust verification and maintaining a balance between user anonymity and node validity, the protocol improves network security and scalability while lowering the likelihood of malicious assaults. This enhances user experiences, increases network resiliency, and facilitates smooth data flows. Trust verification is a difficult issue in RC-based P2P networks since there is no central authority to manage the nodes that join and leave the network on a regular basis. In this study, we provided a trust model intended for P2P networks based on RC. We use a confidence Factor (TF) in combination with the Zero-Knowledge Proof (ZKP) concept to establish confidence.

Our future work for this paper will be concentrated on developing the algorithms in such a way that the overheads are reduced for mobile and IoT environments due to resource constraints. We also want to further expand the concepts proposed in this paper to include dynamic trust adaptation mechanisms that will adjust the Trust Factor (TF) based on realtime network configurations, which will enhance the model's resiliency towards the ever-changing P2P environments. We plan to integrate blockchain and machine learning technologies which further strengthen the model's robustness.

Acknowledgments

1. Karl Aberer and Zoran Despotovic. Managing trust in a peer-2-peer information system. In Proceedings of the Tenth International Conference on Information and Knowledge Management, CIKM '01, page 310–317, New York, NY, USA, 2001. Association for Computing Machinery.
2. Lyes Badis, Mourad Amad, Djamil A¨ıssani, Kahina Bedjguelal, and Aldja Benkerrou. "ROUTIL: P2P Routing Protocol Based on Interest Links". In 2016 International Conference on Advanced Aspects of Software Engineering (ICAASE), IEEE, pp. 1 - 5, 2016.
3. Shane Balfe, Amit D Lakhani, and Kenneth G Paterson. Trusted computing: Providing security for peer-to-peer

networks. In Fifth IEEE International Conference on Peer-to-Peer Computing (P2P'05), pages 117–124. IEEE, 2005.

4. Eli Ben-Sasson, Iddo Bentov, Yinon Horesh, and Michael Riabzev. Scalable zero knowledge with no trusted setup. In Advances in Cryptology–CRYPTO 2019: 39th Annual International Cryptology Conference, Santa Barbara, CA, USA, August 18–22, 2019, Proceedings, Part III 39, pages 701–732. Springer, 2019.
5. Ahmet Burak Can and Bharat Bhargava. Sort: A self- organizing trust model for peer-to-peer systems. IEEE Transactions on Dependable and Secure Computing, 10(1):14–27, 2013.
6. Yatin Chawathe, Sylvia Ratnasamy, Lee Breslau, Nick Lanham, and Scott Shenker. "Making Gnutella-like P2P Systems Scalable". In Proceedings of the 2003 Conference on Applications, Technologies, Architectures, and Protocols for Computer Communications, SIGCOMM '03, New York, NY, USA. Association for Computing Machinery, pp. 407-418, 2003.
7. Rube´n Cuevas, Michal Kryczka, Angel Cuevas, Sebastian Kaune, Carmen Guerrero, and Reza Rejaie. Unveiling the incentives for content publishing in popular bittorrent portals. IEEE/ACM Transactions on Networking, 21(5):1421–1435, 2013.
8. E. Damiani, S. De Capitani Di Vimercati, S. Paraboschi, and P. Samarati. Managing and sharing servants' reputations in p2p systems. IEEE Transactions on Knowledge and Data Engineering, 15(4):840–854, 2003.
9. Ernesto Damiani, De Capitani di Vimercati, Stefano Paraboschi, Pierangela Samarati, and Fabio Violante. A reputation-based approach for choosing reliable resources in peer-to-peer networks. In Proceedings of the 9th ACM conference on Computer and communications security, pages 207–216, 2002.
10. George Danezis and Prateek Mittal. Sybilinfer: Detecting sybil nodes using social networks. In Ndss, pages 1–15. San Diego, CA, 2009.
11. Sai Kiran Deverasetti, Anjila Neupane, Indranil Roy, Reshmi Mitra, and Bidyut Gupta. Establishing trust using zero knowledge succinct proof in peer-to-peer data transfer. In Proceedings of 36th International Conference on, volume 97, pages 91–100, 2024.
12. Xinxin Fan, Ling Liu, Mingchu Li, and Zhiyuan Su. Grouptrust: Dependable trust management. IEEE Transactions on Parallel and Distributed Systems, 28(4):1076–1090, 2017.
13. Rzan Tarig Frahat, Muhammed Mostafa Monowar, and Seyed M Buhari. Secure and scalable trust management model for iot p2p network. In 2019 2nd International Conference on Computer Applications Information Security (ICCAIS), pages 1–6. IEEE, 2019.
14. Prasanna Ganesan, Qixiang Sun, and Hector Garcia-Molina. "Yappers: A Peer-to-Peer Lookup Service Over Arbitrary Topology". In IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies (IEEE Cat. No. 03CH37428), 2: 1250–1260, 2003
15. S. Goldwasser, S. Micali, and C. Rackoff. The knowledge complexity of interactive proof systems. SIAM J. Comput., 18(1):186–208, feb 1989.
16. Mo Hai and Yan Tu. "A P2P E-Commerce Model Based on Interest Community". In 2010 International Conference on Management of e-Commerce and e- Government, IEEE, pp. 362-365, 2010.
17. M Harikrishnan and KV Lakshmy. Secure digital service payments using zero knowledge proof in distributed network. In 2019 5th International Conference on Advanced Computing Communication Systems (ICACCS), pages 307–312. IEEE, 2019.
18. Swathi Kaluvakuri, Bidyut Gupta, Banafsheh Rekabdar, Koushik Maddali, and Narayan Debnath. Design of rc-based low diameter two-level hierarchical structured p2p network architecture. In Mohammed Serrhini, Carla Silva, and Sultan Aljahdali, editors, Innovation in Information Systems and Technologies to Support Learning Research, pages 312–320, Cham, 2020. Springer International Publishing.
19. Swathi Kaluvakuri, Bidyut Gupta, Banafsheh Rekabdar, Koushik Maddali, and Narayan Debnath. Design of rc-based low diameter two-level hierarchical structured p2p network architecture. In Mohammed Serrhini, Carla Silva, and Sultan Aljahdali, editors, Innovation in Information Systems and Technologies to Support Learning Research, pages 312–320, Cham, 2020. Springer International Publishing.
20. Swathi Kaluvakuri, Bidyut Gupta, Banafsheh Rekabdar, Koushik Maddali, and Narayan Debnath. Design of rc-based low diameter two-level hierarchical structured p2p network architecture. In Innovation in Information Systems and Technologies to Support Learning Research, pages 312–320, Cham, 2020. Springer International Publishing.
21. Swathi Kaluvakuri, Koushik Maddali, Nick Rahimi, Bidyut Gupta, and Narayan Debnath. Generalization of rc-based low diameter hierarchical structured p2p network architecture. International Journal of Computer and Their Applications, page 74, 2020.
22. Swathi Kaluvakuri, Nick Maddali, Koushik sand Rahimi, Bidyut Gupta, and Narayan Debnath. Generalization of rc-based low diameter hierarchical structured p2p network architecture. International Journal of Computers and Their Applications, 27(2):74–83, 2020.
23. Swathi Kaluvakuri, Indranil Roy, Koushik Maddali, Bidyut Gupta, and Narayan Debnath. "Efficient Secured Data Lookup and Multicast Protocols with Anonymity in RC-Based Two-level Hierarchical Structured P2P Network.". International Journal for Computers Their Applications, 28(3):140-149, 2021.

24. Sepandar D. Kamvar, Mario T. Schlosser, and Hector Garcia-Molina. The eigentrust algorithm for reputation management in p2p networks. In Proceedings of the 12th International Conference on World Wide Web, WWW '03, page 640–651, New York, NY, USA, 2003. Association for Computing Machinery.
25. Mujtaba Khambatti, Kyung Dong Ryu, and Partha Dasgupta. "Structuring Peer-to-Peer Networks Using Interest-based Communities". In International Workshop On Databases, Information Systems, and Peer-to-Peer Computing, Springer, pp. 48–63, 2003.
26. Dmitry Korzun and Andrei Gurtov. "Hierarchical Architectures in Structured Peer-to-Peer Overlay Networks". Peer-to-Peer Networking and Applications, Springer, 7(4):359-395, 2014.
27. Ahmed Kosba, Andrew Miller, Elaine Shi, Zikai Wen, and Charalampos Papamanthou. Hawk: The blockchain model of cryptography and privacy-preserving smart contracts. In 2016 IEEE symposium on security and privacy (SP), pages 839–858. IEEE, 2016.
28. Xiaoyong Li, Feng Zhou, and Xudong Yang. Scalable feedback aggregating (sfa) overlay for large-scale p2p trust management. IEEE Transactions on Parallel and Distributed Systems, 23(10):1944–1957, 2012.
29. Li Lu, Jinsong Han, Yunhao Liu, Lei Hu, Jin-Peng Huai, Lionel Ni, and Jian Ma. Pseudo trust: Zero-knowledge authentication in anonymous p2ps. IEEE Transactions on Parallel and Distributed Systems, 19(10):1325–1337, 2008.
30. Koushik Maddali, Banafsheh Rekabdar, Swathi Kaluvakuri, and Bidyut Gupta. Efficient capacity-constrained multicast in rc-based p2p networks. In Proceedings of 32nd International Conference on, volume 63, pages 121–129, 2019.
31. Will Major, William J Buchanan, and Jawad Ahmad. An authentication protocol based on chaos and zero knowledge proof. Nonlinear Dynamics, 99:3065–3087, 2020.
32. Xianfu Meng and Dongxu Liu. Getrust: A guarantee-based trust model in chord-based p2p networks. IEEE Transactions on Dependable and Secure Computing, 15(1):54–68, 2018.
33. Anjila Neupane, Reshmi Mitra, Indranil Roy, Bidyut Gupta, and Narayan Debnath. Efficient and secured data lookup protocol using public-key and digital signature authentication in rc-based hierarchical structured p2p network. International Journal for Computers Their Applications, 30(2), 2023.
34. Lawrence Page, Sergey Brin, Rajeev Motwani, and Terry Winograd. The pagerank citation ranking: Bringing order to the web. Technical report, Stanford infolab, 1999.
35. Zhuo Peng, Zhenhua Duan, Jian-Jun Qi, Yang Cao, and Ertao Lv. "HP2P: A Hybrid Hierarchical P2P Network". In First International Conference on the Digital Society (ICDS'07), IEEE, pp. 18, 2007.
36. Claudia Daniela Pop, Marcel Antal, Tudor Cioara, Ionut Anghel, and Ioan Salomie. Blockchain and demand response: Zero-knowledge proofs for energy transactions privacy. Sensors, 20(19):5678, 2020.
37. Yingying Ren, Zhiwen Zeng, Tian Wang, Shaobo Zhang, and Guoming Zhi. A trust-based minimum cost and quality aware data collection scheme in p2p network. Peer- to-Peer Networking and Applications, 13:2300–2323, 2020.
38. Ali Aydin Selcuk, Ersin Uzun, and Mark Resat Pariente. A reputation-based trust management system for p2p networks. In IEEE International Symposium on Cluster Computing and the Grid, 2004. CCGrid 2004., pages 251–258. IEEE, 2004.
39. Kai Shuang, Peng Zhang, and Sen Su. "Comb: A Resilient and Efficient Two-hop Lookup Service for Distributed Communication System". Security and Communication Networks, 89:62-71, 2022.
40. ANTONINO SIMONE, BORIS SˇKORIC´ , and NICOLA ZANNONE. Flow-based reputation: More than just ranking. International Journal of Information Technology Decision Making, 11(03):551–578, 2012.
41. S. Song, K. Hwang, R. Zhou, and Y.-K. Kwok. Trusted p2p transactions with fuzzy reputation aggregation. IEEE Internet Computing, 9(6):24–34, 2005.
42. Xiaoqiang Sun, F Richard Yu, Peng Zhang, Zhiwei Sun, Weixin Xie, and Xiang Peng. A survey on zero-knowledge proof in blockchain. IEEE network, 35(4):198–205, 2021.
43. Patrick P Tsang and Sean W Smith. PPAA: Peer-to-peer anonymous authentication. In Applied Cryptography and Network Security: 6th International Conference, ACNS 2008, New York, NY, USA, June 3-6, 2008. Proceedings 6, pages 55–74. Springer, 2008.
44. Zhiyong Tu, Wei Jiang, and Jinyuan Jia. "Hierarchical Hybrid DVE-P2P Networking Based on Interests Clustering". In 2017 International Conference on Virtual Reality and Visualization (ICVRV), IEEE, pp. 378–381, 2017.
45. Shangguang Wang, Zibin Zheng, Zhengping Wu, Michael R. Lyu, and Fangchun Yang. Reputation measurement and malicious feedback rating prevention in web service recommendation systems. IEEE Transactions on Services Computing, 8(5):755–767, 2015.
46. Yao Wang and Julita Vassileva. Bayesian network-based trust model in peer-to-peer networks. In Proceedings of the Workshop on Deception, Fraud and Trust in Agent Societies, pages 57–68. Citeseer, 2003.
47. Li Xiong and Ling Liu. Peertrust: supporting reputation-based trust for peer-to-peer electronic communities. IEEE Transactions on Knowledge and Data Engineering, 16(7):843–857, 2004.
48. Ming Xu, Shuigeng Zhou, and Jihong Guan. "A New and Effective Hierarchical Overlay Structure for Peer-to-Peer Networks". Computer Communications, Elsevier,

34(7):862-874, 2011.

49. Min Yang and Yuanyuan Yang. "An Efficient Hybrid Peer-to-Peer System for Distributed Data Sharing". IEEE Transactions on computers, IEEE, 59(9):1158-1171, 2009.
50. Xiaohui Yang and Wenjie Li. A zero-knowledge-proof-based digital identity management scheme in blockchain. Computers Security, 99:102050, 2020.
51. Shanyu Zhao, Virginia Lo, and C Gauthier Dickey. Result verification and trust-based scheduling in peer-to-peer grids. In Fifth IEEE International Conference on Peer- to-Peer Computing (P2P'05), pages 31–38. IEEE, 2005.
52. Runfang Zhou and Kai Hwang. Powertrust: A robust and scalable reputation system for trusted peer- to-peer computing. IEEE Transactions on Parallel and Distributed Systems, 18(4):460–473, 2007.
53. Runfang Zhou, Kai Hwang, and Min Cai. Gossiptrust for fast reputation aggregation in peer-to-peer networks. IEEE Transactions on Knowledge and Data Engineering, 20(9):1282–1295, 2008.

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QUANTUM COMPUTING AND ITS APPLICATIONS

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Abstract

Quantum computing represents a revolutionary paradigm shift in computational technology, leveraging standards of quantum mechanics to process statistics in essentially new ways. This paper explores the underlying principles of quantum computing, critiques modern literature on its programs, and proposes a unique utility in optimizing supply chain control. The study underscores the transformative potential of quantum computing in various sectors, consisting of cryptography, drug discovery, and synthetic intelligence, while identifying key demanding situations and destiny research guidelines.

Key Words:Quantum Computing, Quantum Mechanics, Qubits, Quantum Supremacy, Cryptography, Drug Discovery, Artificial Intelligence, Supply Chain Management.

1 Introduction

Quantum Computing is an emerging subject of computer technological know-how and quantum mechanics, that outperforms classical computer systems. Where, quantum mechanics is the essential theories in physics that describes nature as smallest stage of atoms and sub atoms. Quantum computing gives overall performance with the aid of using principles of superposition, entanglement, and quantum interference. Researchers internationally are yet to unleash energy and packages of quantum computing, for which they may be operating very hard and identifying new avenues in which it is able to be used. Despite the theoretical blessings of quantum computing, realistic implementation faces several challenges. Quantum coherence, errors quotes, and qubit scalability are full-size limitations that want to be triumph over. Moreover, the development of efficient quantum algorithms and their integration with existing classical systems stay regions requiring enormous studies. This chapter aims to explore these aspects, evaluate modern applications, and propose a unique application for optimizing the usage of quantum computing.

2 Objectives

The objectives of this research paper are threefold:

1. To provide a comprehensive overview of the principles of quantum computing.
2. To review current and emerging applications of quantum computing in various fields.
3. To evaluate a novel application of quantum computing. .

Before moving ahead, let us understand quantum computing basics.

Quantum computing has seen big improvements in current years, with numerous corporations and institutions throughout the globe growing quantum computer systems. Here are the few splendid quantum computers owned by using diverse organizations are well worth citing, IBM is a pioneer in quantum computing, with its IBM Quantum Experience and IBM Q structures. The company has developed quantum processors consisting of the 27-qubit Falcon and the sixty five-qubit Hummingbird, and it targets to scale up to 1,000 qubits with its destiny Condor processor. IBM's quantum computer systems are accessible through the IBM Cloud, making them available for both instructional and industrial use (Bell T., 2017). Google has made good sized strides with its Sycamore processor and claimed quantum supremacy by outperforming classical supercomputers on precise tasks. Google's Quantum AI lab collaborates with NASA and other establishments to advance quantum studies. The Sycamore processor operates with fifty four qubits, and Google is operating in the direction of building even greater powerful quantum systems (Bell T., 2017).

Microsoft is growing quantum computers the usage of a topological qubit approach, which promises extra balance and errors charges. The organization's quantum computing efforts are integrated into its Azure cloud platform, presenting a complete-stack quantum solution that consists of the Quantum Development Kit and the Q programming language (Dargon J., 2023) (Bell T., 2017). Intel is growing quantum processors and

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has created a forty nine-qubit chip referred to as Tangle Lake. Intel's method focuses on improving qubit overall performance and scalability. The enterprise collaborates with QuTech in the Netherlands to enhance its quantum computing technology. Amazon Web Services (AWS) gives Amazon Braket, a totally managed quantum computing carrier that provides get right of entry to to quantum processors from D-Wave, IonQ, and Rigetti. AWS aims to facilitate research and development in quantum computing by using imparting scalable cloud-based quantum computing assets. Alibaba organization operates the Alibaba Quantum Laboratory in collaboration with the Chinese Academy of Sciences. The laboratory makes a speciality of quantum set of rules development and quantum processor advancements. Alibaba's cloud platform also offers quantum computing offerings for studies and industrial programs.

D-Wave is known for its quantum annealing processors, which can be designed for optimization problems. The today's D-Wave structures, which include the Advantage quantum laptop, feature over 5,000 qubits and are utilized by various research establishments and businesses globally. Rigetti computing has evolved superconducting qubit-based quantum processors and integrates them into its cloud platform. The business enterprise's quantum computers are reachable via the Rigetti Quantum Cloud Services (QCS), and that they recognition on hybrid quantum-classical computing answer. IQM Quantum Computers, Based in Finland, IQM makes a speciality of constructing scalable quantum computer systems and has carried out full-size benchmarks, which includes a 20-qubit machine with excessive constancy. IQM collaborates with research institutions and enterprise partners to improve quantum computing generation.

These businesses and institutions are leading the fee in quantum computing, each contributing to the improvement of this transformative era in precise methods. As quantum computing keeps to conform, those corporations are possibly to play pivotal roles in its commercialization and sensible software across diverse industries.

Fundamental principles of quantum computing

Qubit

Quantum computing makes use of microscopic item like: ion, electron and photon as a medium to switch and store digital data. In quantum computing, one bit (0 or 1) statistics are encoded the usage of orthogonal states of microscopic item, referred to as quantum bits (or qubit). Quantum computer units qubits in preliminary states and manipulates the states to get anticipated end result. Quantum circuits are designed the usage of quantum mechanics to explain the states. The states of qubits can be written as a vector $|\psi\rangle$ (represents superposition of states 0 and 1)

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

Where α and β (probability attribute to decide occurrence of 0 or 1) are the complex numbers such that

$$|\alpha|^2 + |\beta|^2 = 1$$

In this equation,$|\psi\rangle$ represents a qubit in a superposition of the states $0\rangle$ and $1\rangle$, with and as probability amplitudes. The condition $|\alpha|^2 + |\beta|^2 = 1$ ensures that the qubit's state is normalized, meaning the total probability of measuring the qubit in either state is 1.

Besides notation discussed above there are specific symbols and notations are used to describe the states of quantum systems.

Following are some of the key symbols and notations commonly employed:

1. Ket Notation: ($\rangle$)

Ket Notation is used to denote a quantum state.

For Example:

$|\psi\rangle$ represents a general quantum state, $0\rangle$ and $1\rangle$ are basis states.

2. Bra Notation ($\langle$)

The dual vector (or Hermitian conjugate) of a Ket vector.

For example:

$$\langle\psi| \text{ is the dual vector of } |\psi\rangle$$

3. Dirac Notation (Bra-Ket Notation):

Combines bra and ket to form inner products (overlap) and outer products (projectors).

For example:

$\langle\psi|\phi\rangle$ is the inner product (a complex number), and $|\psi\rangle\langle\phi|$ is an outer pro

4. Basis States:

Standard basis vectors, typically $|0\rangle$ and $|1\rangle$ for qubits.

For example:

$$|0\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \quad |1\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

5. Superposition State:

A linear combination of basis states.

For example:

$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$, where α and β are complex coefficients such that $|\alpha|^2$

6. Operators:

Represent physical observables or operations on quantum states. Common operators include the Pauli matrices σ_x, σ_y, and σ_z.

For example:

$\hat{H}|\psi\rangle$ where $\hat{H}$ is the Hamiltonian operator acting on state $|\psi\rangle$.

7. Eigenstates and Eigenvalues:

States that remain unchanged apart from a scaling factor when an operator is applied.

For example:

$\hat{H}|\phi\rangle = E|\phi\rangle$, where E is the eigenvalue associated with the eigenstate $|\phi\rangle$

8. Tensor Products ():

Used to describe the state of a composite system.

For example:

$$|\psi\rangle \otimes |\phi\rangle \text{ represents the combined state of two systems.}$$

9. Measurement Notation:
Represents the outcome of measuring a quantum state.
For example:

$$P(|0\rangle) = |\alpha|^2 \text{ is the probability of measuring the state } |0\rangle$$
$$\text{in the superposition } |\psi\rangle = \alpha|0\rangle + \beta|1\rangle.$$

10. Probability Amplitudes:
Complex numbers whose magnitudes squared give the probabilities of measurement outcomes.
For example:

$$\text{In } |\psi\rangle = \alpha|0\rangle + \beta|1\rangle, \alpha \text{ and } \beta \text{ are probability amplitudes.}$$

Examples in Context

1. Quantum State Representation:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle, \text{ where } |\alpha|^2 + |\beta|^2 = 1$$

2. Measurement:

$$P(|0\rangle) = |\alpha|^2, \quad P(|1\rangle) = |\beta|^2$$

3. Inner Product:

$$\langle\phi|\psi\rangle$$

4. Operator on State:

$$\hat{H}|\psi\rangle = E|\psi\rangle$$

These notations and symbols form the core language of quantum mechanics, enabling precise and concise descriptions of quantum states and their dynamics.

Superposition

Superposition is one of the fundamental principles of quantum mechanics and plays a crucial role in quantum computing. It allows quantum bits (qubits) to exist in multiple states simultaneously, which is a key difference from classical bits. In classical computing, a bit can be in one of two states, either 0 or 1. In quantum computing, a qubit can be in a state $|0\rangle$ (representing 0), $|1\rangle$ (representing 1), or any linear combination of these states, known as a superposition. Mathematically, this is expressed as:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

Here:

- $|\psi\rangle$ is the state of the qubit.
- α and β are complex numbers representing the probability amplitudes.
- $|\alpha|^2$ and $|\beta|^2$ are the probabilities of the qubit being in states $|0\rangle$ and $|1\rangle$, respectively, such that $|\alpha|^2 + |\beta|^2 = 1$ (normalization condition).

Implications of Superposition

Parallelism:
Superposition enables quantum computers to carry out many calculations simultaneously. For a system with n qubits, it can represent 2^n possible states simultaneously, unlike a classical computer which can represent only one state at a time. This property provides quantum computers with massive parallelism and the ability to solve certain problems much faster than classical computers.

Quantum Speedup:
Algorithms such as Shor's algorithm for factoring large numbers and Grover's algorithm for searching unsorted databases leverage superposition to achieve significant speedup over their classical counterparts.

Interference:
Quantum algorithms often use interference, where the amplitudes of different quantum states combine constructively or destructively, to increase the probability of correct outcomes and decrease the probability of incorrect ones. Superposition is crucial for this interference.

Real-World Example:

Quantum Gates
Quantum gates manipulate qubits, changing their states. An example is the Hadamard gate, which creates a superposition:

$$H|0\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$$

This operation transforms a qubit in the state $|0\rangle$ into an equal superposition of $|0\rangle$ and $|1\rangle$.

Visualization
Visualizing superposition can be challenging because it operates in complex vector spaces. However, a common tool is the Bloch sphere, where any qubit state $|\psi\rangle$ can be represented as a point on the surface of a sphere. The angles on the sphere correspond to the complex coefficients α and β, providing an intuitive way to understand the superposition of quantum states. Superposition is a cornerstone of quantum mechanics that fundamentally differentiates quantum computing from classical computing, providing it with powerful computational capabilities.

Entanglement
Entanglement is a fundamental phenomenon in quantum mechanics where the quantum states of two or more particles become interconnected such that the state of one particle cannot be described independently of the state of the other particles, even when the particles are separated by large distances. This non-local correlation is a key resource in quantum computing, enabling powerful computational and communication capabilities that are not possible with classical systems.

Basics of Entanglement
When two qubits are entangled, the state of each qubit is directly related to the state of the other, regardless of the distance between them. Mathematically, an entangled state of two qubits

can be represented as:

$$|\psi\rangle = \alpha|00\rangle + \beta|11\rangle$$

Here:

- $|\psi\rangle$ is the entangled state of the two qubits.
- α and β are complex coefficients such that $|\alpha|^2 + |\beta|^2 = 1$.
- $|00\rangle$ and $|11\rangle$ are the basis states of the two-qubit system.

If we measure one qubit and find it in the state $|0\rangle$, the other qubit will instantly be in the state $|0\rangle$, and similarly for the state $|1\rangle$. This instantaneous correlation persists no matter how far apart the qubits are, which Einstein famously referred to as "spooky action at a distance."

Implications of Entanglement

Quantum Parallelism:
Entanglement allows quantum computers to process many possibilities concurrently. When multiple qubits are entangled, operations on these qubits can encode and process vast quantities of information in parallel.

Quantum Teleportation:
Entanglement permits the transmission of a quantum state from one location to another without physically moving the particle itself. This is achieved by using a pair of entangled qubits shared between parties.

Quantum Cryptography:
Entanglement is used in quantum key distribution (QKD) protocols, such as BB84, to ensure secure communication. Any attempt to eavesdrop on the communication disturbs the entangled state, alerting the communicating parties to the presence of an interceptor.

Error Correction:
Entangled states are necessary for quantum error correction codes, which protect quantum information against decoherence and other quantum noise.

Practical Examples

Bell States:
The four Bell states are specific maximally entangled quantum states of two qubits, commonly used in quantum information theory:

$$|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$$

$$|\Phi^-\rangle = \frac{1}{\sqrt{2}}(|00\rangle - |11\rangle)$$

$$|\Psi^+\rangle = \frac{1}{\sqrt{2}}(|01\rangle + |10\rangle)$$

$$|\Psi^-\rangle = \frac{1}{\sqrt{2}}(|01\rangle - |10\rangle)$$

Quantum Gates for Entanglement:
Gates such as the CNOT (Controlled-NOT) gate can create entanglement. For instance, applying a CNOT gate to a pair of qubits in the state

$$\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \otimes |0\rangle$$

results in the entangled state

$$\frac{1}{\sqrt{2}}(|00\rangle + |11\rangle).$$

Quantum Algorithms:
Entanglement is a critical resource in quantum algorithms like Grover's search algorithm and Shor's factoring algorithm, providing speedup over classical algorithms by exploiting quantum parallelism and interference.

Experimental Realizations

1. Photon Entanglement:
Entangled photons are commonly produced using processes like spontaneous parametric down-conversion. These entangled photons are then used in experiments to demonstrate quantum teleportation and quantum cryptography.

2. Ion Trap and Superconducting Qubits:
Systems based on ion traps and superconducting circuits have achieved entanglement between multiple qubits, demonstrating the feasibility of scalable quantum computing architectures.

Algorithms Used in Quantum Computing

Quantum computing algorithms leverage the unique properties of quantum mechanics, such as superposition, entanglement, and interference, to solve problems that are computationally infeasible for classical computers. Below, we describe several foundational and advanced quantum algorithms, their purposes, and their significance.

1. Shor's Algorithm (Shor, P. W. (1997))
Purpose: Factorizing large integers.
Significance: Shor's algorithm can factorize integers in polynomial time, posing a threat to classical encryption methods like RSA, which rely on the difficulty of factorization.
Key Concepts:

- **Quantum Fourier Transform (QFT):** Central to finding the periodicity of functions related to factorization.
- **Period Finding:** Determines the period of a function, which is used to derive the factors of an integer.

Steps:

1. Initialization: Prepare a superposition of states.
2. Function Evaluation: Compute a function whose period is related to the factors of the integer.
3. QFT: Apply QFT to find the period.
4. Classical Post-processing: Use the period to determine the factors.

2. Grover's Algorithm (Grover, L. K. (1996))
Purpose: Searching an unsorted database.
Significance: Grover's algorithm offers a quadratic speedup, searching N items in $O(\sqrt{N})$ time versus $O(N)$ for classical algorithms.
Key Concepts:

- **Amplitude Amplification:** Enhances the probability of measuring the correct result.

- **Oracle:** Marks the correct item by inverting its phase.

Steps:

1. Initialization: Prepare a superposition of all possible states.
2. Oracle Application: Apply an oracle to mark the desired state.
3. Diffusion Operator: Apply the Grover diffusion operator to amplify the amplitude of the marked state.
4. Iteration: Repeat the oracle and diffusion steps approximately $\sqrt{N}$ times.
5. Measurement: Measure the state to obtain the solution.

3. Quantum Fourier Transform (QFT) (Nielsen, M. A., & Chuang, I. L. (2010))
Purpose: Efficiently transforming quantum states, critical for algorithms like Shor's.
Significance: The QFT is exponentially faster than its classical counterpart, the Discrete Fourier Transform (DFT).
Key Concepts:

- **Hadamard Gates:** Used for creating superpositions.
- **Phase Shifts:** Controlled phase shifts are applied to introduce the correct phases.

Steps:

1. Apply a series of Hadamard gates and controlled phase shifts to transform the input state.
2. Reverse the order of the qubits (optional but common).

4. Quantum Phase Estimation (QPE) (Kitaev, A. Y. (1995), Nielsen, M. A., & Chuang, I. L. (2010))
Purpose: Estimating the eigenvalue of a unitary operator.
Significance: Fundamental to algorithms like Shor's and useful for various quantum simulations.
Key Concepts:

- **Controlled Unitary Operations:** Used to entangle the state with the eigenvalue.
- **Inverse QFT:** Applied to extract the phase information.

Steps:

1. Prepare a register of qubits in a superposition state.
2. Apply controlled unitary operations to the state.
3. Perform the inverse QFT to extract the phase.
4. Measure the register to estimate the phase.

5. Variational Quantum Eigensolver (VQE) (Peruzzo, A., et al. (2014), McClean, J. R., et al. (2016))
Purpose: Finding the ground state energy of a quantum system.
Significance: Combines quantum and classical computing to solve problems in quantum chemistry and materials science.
Key Concepts:

- **Ansatz Preparation:** Use a parameterized quantum circuit.
- **Energy Measurement:** Measure the Hamiltonian's expectation value.
- **Classical Optimization:** Minimize the measured energy using a classical optimizer.

Steps:

1. Prepare an initial parameterized quantum state.
2. Measure the expectation value of the Hamiltonian.
3. Use a classical optimizer to update parameters.
4. Iterate until convergence.

6. Quantum Approximate Optimization Algorithm (QAOA) (Farhi, E., Goldstone, J., & Gutmann, S. (2014), McClean, J. R., et al. (2016))
Purpose: Solving combinatorial optimization problems.
Significance: Provides approximate solutions to hard optimization problems faster than classical approaches.
Key Concepts:

- **Parameterization:** Use parameterized unitary operations.
- **Cost Function Measurement:** Measure and optimize the cost function.

Steps:

1. Initialize the quantum state.
2. Apply parameterized unitary operations.
3. Measure the cost function.
4. Use a classical optimizer to update parameters.
5. Repeat until convergence.

7. HHL Algorithm (Harrow, Hassidim, & Lloyd (2009), Childs, A. M., et al. (2017))
Purpose: Solving linear systems of equations.
Significance: Offers exponential speedup for certain linear systems over classical methods.
Key Concepts:

- **State Preparation:** Prepare the quantum state representing the input.
- **Eigenvalue Estimation:** Use phase estimation to find eigenvalues.
- **State Inversion:** Prepare the state proportional to the inverse eigenvalues.

Steps:

1. Encode the input vector and matrix.
2. Apply phase estimation.
3. Use controlled rotations to invert eigenvalues.
4. Measure the output state to obtain the solution.

8. Quantum Walk Algorithms (Ambainis, A. (2003), Childs, A. M. (2004))
Purpose: Generalizing classical random walks for graph traversal and search problems.
Significance: Quantum walks provide speedups for various algorithms, including element distinctness and spatial search.
Key Concepts:

- **Unitary Evolution:** Simulate the walk's evolution using unitary operations.
- **Measurement:** Obtain information about the search space or graph structure.

Steps:

1. Initialize the quantum walk.
2. Apply unitary operations to simulate evolution.
3. Measure to infer properties or locate elements.

The diversity of quantum algorithms highlights the particular computational benefits of quantum mechanics. These algorithms are foundational to solving problems throughout cryptography, optimization, chemistry, and more, marking enormous improvements as quantum computing technology continues to adapt.

Programming Languages in Quantum Computing

Python:
Python is a popular programming language for quantum systems due to the availability of packages like QuTiP.

Qiskit (Open-Source Programming Tool):
Qiskit is the development toolkit provided by IBM in 2017. It is an open-source software development kit for quantum computing.

Ocean™ (Quantum Computing Programming Suite):
Ocean™ software is a suite of open-source Python tools accessible via the Ocean Software Development Kit on both the D-Wave GitHub repository and within the Leap quantum cloud service.

Q (Quantum Computing Programming Language):
Q (Q Sharp) is a quantum computing programming language developed by Microsoft in 2017. It is used with the Quantum Development Kit and is a domain-specific language designed for developing quantum algorithms.

Cirq (Google AI Programming Language):
Cirq is an open-source framework developed by the Google Quantum AI team, announced (public alpha) at the International Workshop on Quantum Software and Quantum Machine Learning in the summer of 2018. It includes built-in simulators (Qsim) for wave functions and density matrices.

Challenges and Future Directions

1. Decoherence and Noise:
Maintaining entanglement in the presence of environmental noise is challenging. Advanced error correction techniques and improved qubit isolation are crucial for preserving entanglement over longer periods.

2. Scalability:
As the number of entangled qubits increases, the complexity of managing and manipulating these qubits grows. Research is focused on developing scalable systems that can handle large-scale entanglement.

3. Entanglement Distribution:
Efficiently distributing entanglement over large distances, essential for quantum networks and the quantum internet, requires advances in quantum repeaters and communication protocols.

Future Applications of Quantum Computing

Quantum computing holds the promise of transforming numerous fields by solving problems that are currently intractable for classical computers. Here are several key areas where quantum computing is expected to have a significant impact in the future:

1. Cryptography:
Quantum computers have the potential to both break existing cryptographic systems and create new, more secure ones.

- **Breaking Encryption:** Shor's algorithm can factorize large numbers exponentially faster than the best-known classical algorithms, threatening widely used public-key cryptosystems such as RSA and ECC (Elliptic Curve Cryptography).
- **Quantum Cryptography:** Quantum key distribution (QKD) protocols, like BB84, ensure secure communication by leveraging the principles of quantum mechanics. Any eavesdropping attempt on a quantum communication channel can be detected, providing theoretically unbreakable encryption.

2. Drug Discovery and Material Science:
Quantum computing can simulate molecular structures and interactions at a level of detail that is currently impossible for classical computers.

- **Molecular Simulation:** Quantum computers can model complex molecular and chemical reactions to accelerate drug discovery processes, potentially reducing the time and cost involved in bringing new drugs to market.
- **Material Design:** Quantum simulations can help design new materials with specific properties, leading to advances in fields such as superconductors, catalysts, and photovoltaics.

3. Optimization Problems:
Quantum computing excels at solving complex optimization problems, which are common in many industries.

- **Supply Chain Management:** Quantum algorithms can optimize logistics and supply chain operations by evaluating vast numbers of possible routes and schedules more efficiently than classical methods.
- **Financial Services:** Portfolio optimization, risk management, and option pricing are areas where quantum computing can provide significant advantages by finding optimal solutions faster than classical algorithms.

4. Artificial Intelligence and Machine Learning:
Quantum computing can enhance machine learning algorithms, providing faster processing and more accurate models.

- **Quantum Machine Learning:** Quantum algorithms like the Quantum Support Vector Machine (QSVM) and Quantum Principal Component Analysis (QPCA) can process and analyze data more efficiently, leading to improved performance in tasks such as image and speech recognition.

- **Neural Networks:** Quantum computers can potentially optimize neural network architectures and training processes, leading to faster and more efficient machine learning models (Dargon J., 2023).

5. Climate Modelling and Earth Sciences:
Quantum computing can improve the accuracy and efficiency of climate models, aiding in the fight against climate change.

- **Climate Simulation:** Quantum computers can handle the vast amounts of data and complex calculations required for accurate climate modelling, helping scientists better understand and predict climate changes (Dargon J., 2023).
- **Resource Management:** Improved models for predicting weather patterns and natural resource distribution can lead to better management and conservation efforts (Boll Tom, 2017).

6. Quantum Internet and Communication:
The development of a quantum internet will revolutionize how we communicate and share information.

- **Secure Communication Networks:** A quantum internet will use entanglement and superposition to create ultra-secure communication networks that are immune to hacking.
- **Distributed Quantum Computing:** Linking quantum computers over a quantum internet can lead to distributed quantum computing, where complex computations are performed across multiple quantum systems.

7. Fundamental Science and High-Energy Physics:
Quantum computing can simulate and solve problems in fundamental science that are beyond the reach of classical computation.

- **Particle Physics:** Quantum simulations can model high-energy particle interactions and quantum field theories, contributing to our understanding of the universe at the smallest scales.
- **Cosmology:** Quantum computers can help simulate and analyze cosmic phenomena, such as black holes and the behavior of the early universe, leading to new insights in cosmology.

Current State and Challenges

Despite the theoretical potential, practical quantum computing is still in its infancy. Key challenges include:

- **Qubit Stability (Decoherence):** Qubits are highly sensitive to their environment and can lose their quantum state, making computations error-prone.
- **Error Correction:** Developing effective quantum error correction techniques to mitigate errors in quantum computations.
- **Scalability:** Building systems that can manage many qubits while maintaining coherence.

Future Directions

While the potential of quantum computing is immense, several challenges remain. Quantum computers are still in their infancy, with issues such as qubit coherence, error rates, and scalability hindering their practical application. Additionally, the development of quantum algorithms and the integration of quantum systems with classical infrastructure require further research. Future research should focus on overcoming the technical challenges mentioned above, as well as exploring new applications of quantum computing in diverse fields. Potential areas of research include:

- **Quantum Machine Learning:** Developing quantum-enhanced machine learning algorithms for applications in finance, healthcare, and cybersecurity.
- **Quantum Simulation:** Using quantum computers to simulate complex physical systems, such as materials science and climate modelling.
- **Quantum Cryptography:** Advancing quantum cryptographic protocols to enhance data security and privacy.
- **Quantum Network:** Building quantum communication networks for secure and high-speed data transfer.

Collaboration between academia, industry, and government will be crucial in driving the progress of quantum computing research and development.

3 Conclusion

Quantum computing, an interdisciplinary field drawing from physics, computer science, and mathematics, has garnered significant attention due to its potential to solve problems beyond the capabilities of classical computers. The foundation of quantum computing lies in quantum mechanics, particularly in phenomena such as superposition and entanglement. Superposition allows a qubit to be in a combination of 0 and 1 states simultaneously, unlike a classical bit that is either 0 or 1. Entanglement creates a scenario where the state of one qubit is directly related to the state of another, no matter the distance between them. These unique properties enable quantum computers to process complex computations at unprecedented speeds.

Quantum computing offers transformative potential across various domains, from cryptography and drug discovery to artificial intelligence and supply chain management. By leveraging the unique properties of quantum mechanics, quantum computers can solve problems that are currently intractable for classical systems. Continued research and development will unlock new applications and drive the next era of technological innovation.

References

1. Ambainis, A. (2003). Quantum Walk Algorithm for Element Distinctness. SIAM Journal on Computing, 37(1),

210-239.

2. Arute, F., Arya, K., Babbush, R., Bacon, D., Bardin, J. C., Barends, R., ... Martinis, J. M. (2019). Quantum supremacy using a programmable superconducting processor. Nature, 574(7779), 505-510..
3. Aspuru-Guzik, A., Dutoi, A. D., Love, P. J., Head-Gordon, M. (2005). Simulated Quantum Computation of Molecular Energies. Science, 309(5741), 1704-1707.
4. Ball T., (2017) ”Who owns the future of quantum computing?”, available at :https://techmonitor.ai/hardware/quantum-computing-pioneers, Extracted on June, 9, 2024.
5. Bennett, C. H., Brassard, G. (1984). Quantum cryptography: Public key distribution and coin tossing. Proceedings of IEEE International Conference on Computers, Systems and Signal Processing, 175-179.
6. Biamonte, J., Wittek, P., Pancotti, N., Rebentrost, P., Wiebe, N., Lloyd, S. (2017). Quantum Machine Learning. Nature, 549(7671), 195-202.
7. Childs, A. M., et al. (2017). Quantum Algorithm for Systems of Linear Equations with Exponentially Improved Dependence on Precision. SIAM Journal on Computing, 46(6), 1920-1950.
8. Dargan J., (2022), “Top 5 Quantum Programming Languages in year 2024” , available at: https://thequantuminsider.com/2022/07/28/state-of-quantum-computing-programming-languages-in-2022/ , extracted on June10th 2024.
9. Dargan J., (2023), ”An Overview of the Quantum Computing Landscape”, available at: https://thequantuminsider.com/2023/12/29/quantum-computing-companies/, extracted on June, 9th 2024.
10. Dirac, P. A. M. (1958). The Principles of Quantum Mechanics. Oxford University Press.
11. Farhi, E., Goldstone, J., Gutmann, S. (2014). A Quantum Approximate Optimization Algorithm. arXiv preprint arXiv:1411.4028.
12. Grover, L. K. (1996). A fast quantum mechanical algorithm for database search. Proceedings of the twenty-eighth annual ACM symposium on Theory of computing, (pp. 212-219).
13. Harrow, A. W., Hassidim, A., Lloyd, S. (2009). Quantum Algorithm for Linear Systems of Equations. Physical Review Letters, 103(15), 150502.
14. Kitaev, A. Y. (1995). Quantum Measurements and the Abelian Stabilizer Problem. arXiv preprint quant-ph/9511026.
15. McClean, J. R., et al. (2016). The Theory of Variational Hybrid Quantum-Classical Algorithms. New Journal of Physics, 18(2), 023023.
16. McMahon, D. (2008). Quantum Computing Explained. Wiley-Interscience.
17. Montanaro, A. (2016). Quantum algorithms: An overview. npj Quantum Information, 2(1), 15023.
18. Nielsen, M. A., Chuang, I. L. (2010). Quantum Computation and Quantum Information: 10th Anniversary Edition. Cambridge University Press.
19. Preskill, J. (2018). Quantum Computing in the NISQ era and beyond. Quantum, 2, 79.
20. Sakurai, J. J., Napolitano, J. (2017). Modern Quantum Mechanics. Cambridge University Press.
21. Shor, P. W. (1997). Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer. SIAM Journal on Computing, 26(5), 1484-1509.

Skull Stripping for Improved Brain Tumor Detection In Orthogonal MRI Scans

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Abstract

Detecting brain tumors at an early stage is an incredibly demanding responsibility for radiologists. The rapid rate at which these tumors grow is deeply concerning. When left untreated, patients commonly experience a significantly lower survival rate, intensifying the situation to a critical and potentially life-threatening condition. Consequently, the urgent need arises for an automated system capable of early detection of brain tumors. In this research, we present an approach that offers a streamlined method to effectively distinguish between cancerous and non-cancerous brain Magnetic Resonance Imaging (MRI) scans across multiple planes, including the Axial, Coronal, and Sagittal planes. The methodology encompasses several distinct stages for lesion analysis, beginning with preprocessing techniques to eliminate noise and improve image quality. Next, K-means segmentation is employed to accurately segment cancerous cells from the surrounding tissue. Feature extraction is performed using various methods such as Discrete Wavelet Transform (DWT), Gray Level Co-occurrence Matrix (GLCM), and Principal Component Analysis (PCA) to extract informative features from the segmented regions. In the final step, a Support Vector Machine (SVM) classifier is employed to classify the extracted features and make predictions using the given dataset. The research study utilizes three SVM classifier tools, namely Linear, Gaussian, Polynomial SVM, for the proposed analysis. The proposed methodology consists of two distinct phases: the Skull Stripping phase and the non-skull stripping phase. Additionally, we proposed a method for accurately detecting the skull in MRI scans. It has been observed that by excluding the skull from the analysis, the accuracy of tumor detection improves by approximately 7% compared to when the skull is not removed from the scan. By leveraging automatic detection techniques; we facilitate the detection of tumors in any plane of MRI imaging. This approach offers a convenient and efficient method for identifying and localizing tumors across various imaging planes.

Key Words: Brain tumors, K-mean, SVM, MRI imaging.

1 Introduction

A brain tumor refers to an abnormal growth of cells in the brain or the central nervous system. There are two primary categories of brain tumors: primary and secondary. Primary brain tumors originate from the cells that constitute the brain and its surrounding tissues. In contrast, secondary brain tumors are tumors that have spread or metastasized from other parts of the body to the brain.

There are two types of brain tumors: benign and malignant. Malignant tumors can grow quickly and may spread to other parts of the body or brain, but benign tumors are usually non-cancerous and grow more slowly[1]. Different types of tumors are classified based on the specific cells involved.

Glioma brain tumors are a type of tumor that develops from glial cells in the brain. They can be either benign or malignant, with malignant gliomas being particularly dangerous. These tumors pose significant risks due to their location within the brain and their potential to invade surrounding healthy tissue[2]. The dangers associated with glioma brain tumors stem from their ability to disrupt vital brain functions and exert pressure on adjacent structures. As they grow, they can cause a range of neurological symptoms, including headaches, seizures, cognitive impairments, and changes in personality or behavior. The invasive nature of malignant gliomas makes complete surgical removal challenging, and they can also spread to other parts of the brain or spinal cord[3]. Treatment options can be limited, as gliomas may be resistant to certain therapies. Early detection of glioma is vital for initiating timely treatment, improving treatment outcomes, implementing appropriate surveillance, and empowering patients in their healthcare decisions[4].

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Medical professionals utilize various imaging techniques to detect and diagnose brain tumors. Among these techniques, MRIs, or magnetic resonance imaging, are the most often used modality. MRI creates precise images of the brain using strong magnets and radio waves, making it possible to identify the features, size, and location of tumors[5]. Contrarily, computed tomography (CT) scans employ X-rays to produce cross-sectional brain pictures, which help evaluate tumor characteristics as well as any concomitant brain hemorrhage or edema[6].

MRI offers superior soft tissue contrast compared to CT scans, making it particularly effective in differentiating between different types of tissues[7]. It provides highly detailed and multi-planar images, enabling better visualization of brain tumors and the surrounding structures. To facilitate the interpretation and analysis of brain images, different imaging planes or orientations are commonly used.

The three orthogonal primary MRI brain planes employed in clinical practice and research are the axial plane, sagittal plane, and coronal plane. The axial plane, parallel to the ground when a person is upright, provides a comprehensive top-down view of the brain, allowing for assessment of structures like the cerebral hemispheres, ventricles, basal ganglia, thalamus, and brainstem. The sagittal plane divides the brain into left and right halves and offers a side view, revealing information about the cerebral cortex, corpus callosum, cerebellum, and midline structures[8]. Lastly, the coronal plane divides the brain into anterior and posterior sections, providing a frontal view that aids in assessing the frontal lobes, lateral ventricles, hippocampus, and other critical structures.

The three planes of MRI brain imaging, axial, sagittal, and coronal, each offer distinct anatomical perspectives, allowing for the identification and characterization of different brain regions, lesions, and abnormalities. By examining the brain in these orthogonal planes, radiologists and clinicians can gain valuable insights into the precise location, extent, and nature of brain pathologies. This comprehensive evaluation enables accurate diagnosis and effective treatment planning for patients. Figure (1) shows MRI brain images in multiple planes.

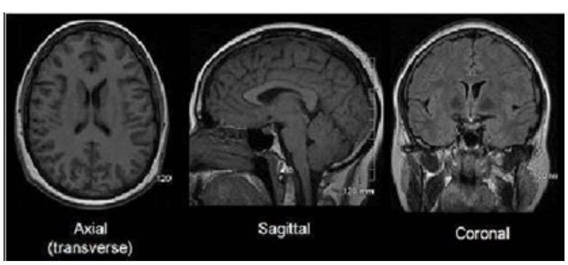


Figure 1: The descriptive process flow followed in the model

The proposed methodology comprises several sequential steps to facilitate the detection of tumors in any plane of MRI imaging, initiating with preprocessing methods to enhance image quality. Subsequently, K-means segmentation is applied to precisely delineate cancerous cells from the neighboring tissue. Then, extract meaningful features from the segmented regions. Finally, a Support Vector Machine (SVM) classifier is employed to classify the extracted features on the provided dataset. That experiment was implemented using MATLAB R2021a. The primary contributions of this research are as follows:

Automated Brain Tumor Detection and Classification: This study introduces an automated method aimed at detecting and classifying brain tumors using three orthogonal planes of MRI images. The proposed methodology encompasses multiple procedural stages, notably preprocessing, feature extraction, and classification.

Innovative Preprocessing Techniques: A novel skull stripping method is employed during the preprocessing phase, significantly impacting the accuracy of subsequent classification outcomes. This step plays a pivotal role in refining the input data for enhanced analysis.

Advanced Feature Extraction: In the feature extraction phase, a fusion of distinctive features is utilized, including:

- Tumor area feature
- Discrete Wavelet Transform (DWT) combined with Principal Component Analysis (PCA)
- Gray Level Co-occurrence Matrix (GLCM) features

These features encapsulate crucial tumor characteristics essential for classification.

Classification Strategy: The geometric family of Support Vector Machines (SVM) is employed, with various kernels such as Linear, Gaussian, and Polynomial, to determine the optimal configuration. This iterative process ensures the selection of the most effective classification approach.

Performance Evaluation on Kaggle Datasets: The proposed method undergoes rigorous evaluation using Kaggle datasets, with performance metrics primarily focusing on Accuracy (ACC).

2 Related Work

(Padlia, M., and Sharma, J. 2017) [9] Presents a technique for using T1-weighted and fluid- attenuated inversion recovery (FLAIR) brain images to identify and separate brain malignancies. A fractional Sobel filter is applied to the brain image to reduce noise and enhance its texture. The Sobel filter's fractional order () provides more versatility in optimizing the segmentation results. The detection of asymmetry between hemispheres is achieved through the application of Bhattacharya coefficients and mutual information. The hemisphere containing the tumor is determined using a histogram asymmetry method. Support vector machines (SVMs) are used to compute and classify statistical aspects of a specific window in order to segment the tumor region inside the recognized hemisphere. Images from the BRATS-2013 dataset are used for simulations, and performance measures like specificity, sensitivity, and accuracy are calculated for various values. The outcomes of the simulation show that the suggested strategy outperforms the majority of similar current techniques.

(Kumar, Rashmi, Ramadoss, Sandhya, and Sangeetha 2017)[10] Present a Support Vector Machine (SVM) classifier-based approach for brain tumor detection. It starts with the acquisition of magnetic resonance imaging (MRI) brain scans, which provide detailed anatomical information for tumor detection. The MRI scans are preprocessed to enhance the quality of the images. Feature extraction is then performed on the preprocessed images. Features such as intensity, texture, and shape characteristics are computed from the tumor region. An SVM classifier is trained using the retrieved features as input. The SVM is a machine learning algorithm that learns to classify different patterns based on labeled training data. In MRI scans, the SVM classifier performs admirably in differentiating between tumor and non-tumor regions.

(Vani, N., Sowmya, A., & Jayamma, N. 2017) [11]develop a model that will help identify and categorize brain tumors. Specifically, the objective is to classify whether a tumor is cancerous or non-cancerous by utilizing the SVM algorithm. While Artificial Neural Networks (ANN) based on Empirical Risk Minimization has been used in prior studies for detection, this paper introduces the application of the Support Vector Machine algorithm, which operates on structural risk minimization, for image classification. The SVM algorithm is implemented on medical images to extract tumors, and a Simulink model is created for the purpose of tumor classification. In order to classify the images and determine whether they are malignant or not, the research presents a prototype for SVM-based object detection. This study maintains a high detection accuracy of 82

(Rashid, M. H. O., Mamun, M. A., Hossain, M. A., and Uddin, M. P. 2018)[12] Proposed a method that involved three main steps: anisotropic filtering, support vector machine (SVM) classification, and morphological operations. Anisotropic filtering was applied to enhance the MR images and improve the quality of the tumor region. This filtering technique selectively smoothes the image in different directions, preserving edges and details. After the anisotropic filtering, The tumor and non-tumor areas were classified using the SVM classifier. The ideal hyper plane that divides the data points into distinct classes is found via SVM. In the final step, morphological operations were performed on the classified image to refine the tumor region and remove any noise or artifacts. Morphological operations involve the manipulation of image pixels based on their spatial arrangement. According on the experimental results, the SVM achieved 83% segmentation accuracy.

(Birare and Chakkarwar. 2018) [13]develop an automated system that uses the support vector machine (SVM) algorithm to identify brain tumor cells. Manual detection of tumor cells in microscopic images is a time-consuming and error-prone process, hence the need for an automated system. The authors propose a methodology that involves multiple steps. Firstly, they acquire microscopic images of brain tumor cells. Then, they preprocess the images to enhance the features and remove any noise. Next, they extract relevant features from the preprocessed images, which serve as input to the SVM classifier. SVM was used in the experiment to identify malignant and normal cells with 98.51% accuracy.

(Selvapandian and Manivannan 2018) [14]addresses the challenging task of detecting tumor regions in Glioma brain images, which are often characterized by low sensitivity in boundary pixels. The Non-Subsampled Contourlet Transform (NSCT) is used to improve the brain image, and texture characteristics are then extracted from the improved image. The Adaptive Neuro Fuzzy Inference System (ANFIS) technique is then used to train and classify these extracted features, allowing it to discriminate between brain scans with gliomas and normal ones. Then, using morphological functions, the tumor regions in the Glioma brain picture are segmented. The performance of the proposed Glioma brain tumor detection algorithm is assessed on the publicly available Brain Tumor Image Segmentation Challenge (BRATS) dataset. The suggested approach achieves 96.7% accuracy.

(Keerthana and Xavier 2018) [15]introduce an intelligent system that seeks to identify and categorize brain cancers in their early stages. The system incorporates various stages, starting with image acquisition using magnetic resonance imaging (MRI). After image acquisition, Preprocessing methods are used to improve the MRI image quality. These methods could include noise removal, intensity normalization, and spatial filtering. Next, To extract valuable information from the preprocessed images, feature extraction is done. Statistics pertaining to texture, shape, and intensity are calculated based on the tumor region. Tumor categorization uses the support vector machine (SVM). The results demonstrate that the proposed intelligent system achieves high accuracy in the early assessment and classification of brain tumors.

(Amin, J., Sharif, M., Raza, M., Saba, T., and Anjum, M. A. 2019) [16]develop a method for brain tumor detection using a combination of statistical and machine learning techniques. The researchers proposed a framework that utilized statistical features extracted from brain images and employed machine learning algorithms for tumor detection. Magnetic resonance imaging (MRI) scans were primarily used as the imaging modality for brain tumor detection. The framework comprised several steps. Firstly, pre-processing techniques were applied to remove noise or artifacts and improve the quality of the MRI images. Subsequently, pertinent information on the tumor site was retrieved from the pre-processed images using statistical features like mean, standard deviation, skewness, and kurtosis. Various classifiers, include k-nearest neighbors (KNN), support vector machines (SVM), and decision trees were experimented with to determine the most effective approach for tumor classification. At the fused feature-based level, the obtained results showed a specificity of 1.00, sensitivity of 0.92, accuracy of 0.93, 0.96 for both the dice similarity coefficient (DSC) and area under the curve (AUC).

(Hussain and Khunteta 2020)[17]utilizes a set of MRI images as input data and employs a series of preprocessing steps, including median filtering and skull stripping, to enhance the images. The thresholding process is performed using the watershed segmentation method to isolate the brain tumor tissues. After that, the gray-level co-occurrence matrix (GLCM) approach is used to extract features. A support vector machine (SVM) is then used to classify the images based on the features that were extracted. The system's accuracy on average is 93.05% surpassing the performance of other conventional models.

(Sharath Chander, Soundarya, and Priyadharsini 2020) [18]proposed method utilizes well-defined algorithms to handle challenging scenarios, such as poor image quality.To extract relevant tumor locations from the MRI data, an adaptive k-means clustering segmentation algorithm is used. The segmented images are then classified using a Support Vector Machine (SVM) classifier, which also helps identify the type of tumor. The linear kernel provides better accuracy results when the study compares the various SVM classifier kernel functions. By utilizing MRI imaging data, the proposed system seeks to offer a more precise method for brain tumor diagnosis and categorization.

(Chen et al. 2021) [19] provide a novel method for the automatic detection and classification of brain cancers utilizing support vector machines (SVMs) and extended Kalman filters (EKF). There were five parts to the EKF-SVM algorithm. The images were first subjected to image normalization, noise reduction using a non-local means filter, and contrast enhancement using enhanced dynamic histogram equalization. Second, image features were extracted using a gray- level co-occurrence matrix. Thirdly, an EKF was utilized to categorize brain cancers in the brain MRIs after the retrieved characteristics were supplied into an SVM to classify the MRI images initially. Fourth, cross-validation was done to confirm the classifier's accuracy. Lastly, brain tumors were identified using an artificial segmentation technique that included region growth and k-means clustering. The outcomes demonstrated that the EKF-SVM algorithm successfully classified brain tumors automatically with an astounding 96.05% accuracy rate.

(Shahajad, Gambhir, and Gandhi 2021) [20]proposes a method to determine the optimal number of quantifiable gray level co-occurrence matrix (GLCM) texture features for identifying brain cancers in medical MRI image collections as aberrant versus normal. After extracting all of the GLCM texture features from the MRI pictures, the best features are chosen via a method based on heat maps. The support vector machine (SVM) classifier then uses these chosen characteristics as input. Results show that the SVM classifier achieves high accuracy, with a peak testing accuracy of approximately 92% when using 6-7 features. However, further increasing the number of features does not lead to improved accuracy, as the accuracy plateaus.

3 Proposed Methodology:

Figure (2) Show the block diagram of proposed methodology.

3.1 MRI Scan of obtained Brain Tumor Images:

Magnetic Resonance Imaging (MRI) is a type of image that is represented using 8 bits, containing brightness information ranging from 0 to 255. A pixel value of '0' in this notation denotes black color, and a value of '255' denotes white color. We resized the MRI images to dimensions of 200x200 pixels. Grayscale images, which only consist of brightness information and lack color information, were used in this specific case.

3.2 Preprocessing:

3.2.1 Vertical Flipping for Sagittal plane images:

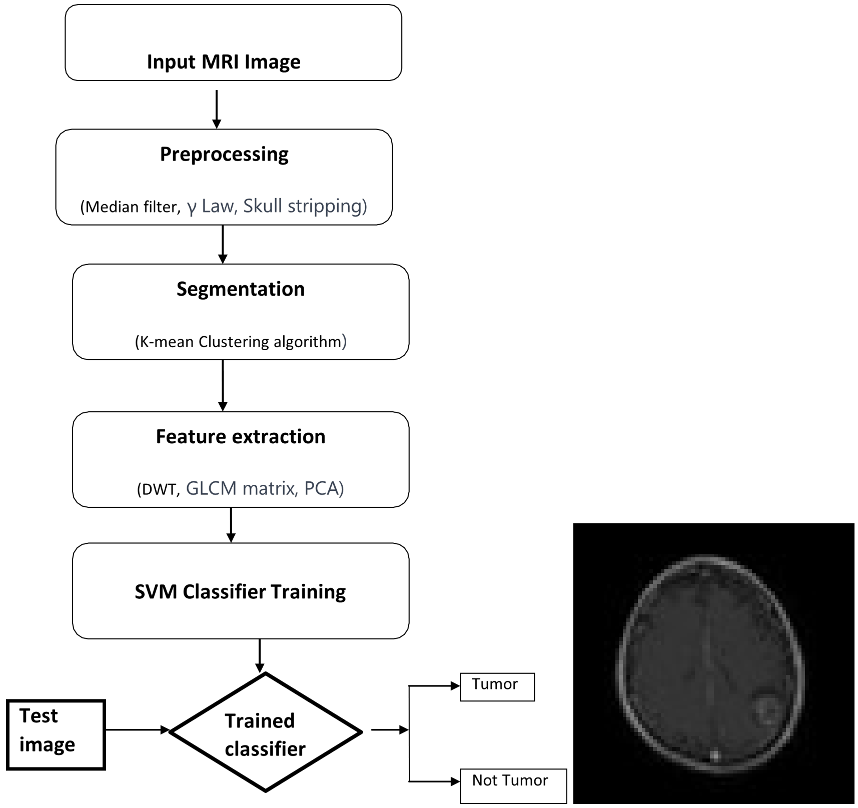
In the case of sagittal images, it is important to consider the different directions, namely right and left. When these images are utilized with varying directions, it can lead to a decrease in accuracy. To mitigate this issue, a possible solution is to flip all the images in the right direction. By consistently using a single direction, it has been observed that accuracy tends to increase.

3.2.2 3.2.2. Detected Area of tumor:

In this study, we proposed approach for the identification and quantification of tumor regions within medical images. Our method encompasses several stages, starting with the conversion of the original image into a binary representation. Subsequently, we proceed to calculate the solidity and area metrics for the detected regions. By comparing the density of these regions against a predefined threshold (0.5), we select the region with the highest density as the primary area of interest. To enhance the discriminatory power of our analysis, we employ advanced techniques for feature extraction. Specifically, we utilize the extracted area of the tumor region as a fundamental feature, which is then combined with features derived from Principal Component Analysis (PCA) and Gray-Level Co-occurrence Matrix (GLCM). This fusion of features allows for a comprehensive and multidimensional representation of the tumor, enabling a more refined and scientifically grounded analysis. Through the integration of these innovative methodologies, our research offers a robust and sophisticated framework for tumor area detection. By leveraging binary image conversion, density-based selection, and feature fusion techniques, we have achieved a significant advancement in the identification and characterization of tumor regions in medical imaging, paving the way for improved diagnostic accuracy and treatment planning.

3.2.3 3.2.2. Median Filter:

A nonlinear filter is the median filter. It operates extremely effectively to eliminate the "salt and pepper" noise, or impulse noise, from the image. The rationale behind the median filter



is to use the median of the gray levels in a neighborhood surrounding each pixel to replace the gray level of each individual pixel.

The following is a definition of the median filter operation:

$$I'(x,y) = \text{median}\left(I(x+i, y+j)\right) \quad \text{for} \quad (i,j) \in \text{filter window}$$

Where: I represents input image, I' represents the filtered image, (x, y) represents the pixel position in the image, and (x+i, y+j) represents the neighboring pixels within the filter window centered at (x, y). The filter window size is usually odd to ensure there is a unique median value. The median function sorts the pixel values within the window and selects the middle value as the new pixel value. The median is determined by averaging the two middle values if the number of pixels in the window is even.

3.2.4 Gamma Law:

For many image processing applications, such as color correction, image enhancement, and display calibration, gamma correction is a necessary first step. Gamma correction is a method that modifies an image's brightness or contrast by transforming the pixel values non-linearly. In the context of image preprocessing, gamma correction is often applied to compensate for the non-linear relationship between pixel values and perceived brightness. The gamma correction function is typically expressed as:

$$V\_\text{out} = V\_\text{in}^{\gamma} \tag{2}$$

Where:

- V_{out} is the corrected pixel value after gamma correction
- V_{in} is the original pixel value
- γ is the gamma parameter that controls the intensity transformation

The gamma parameter γ determines the degree of correction applied to the image. If $\gamma < 1$, the image becomes brighter because the transformation amplifies the lower pixel values. On the other hand, if $\gamma > 1$, the image becomes darker as the transformation compresses the lower pixel values[21].

3.2.5 Skull Stripping:

Skull stripping, also known as brain extraction or skull removal, is a process in medical image analysis that involves segmenting the brain tissue from other structures such as the skull and scalp in neuroimaging data, usually from scans using magnetic resonance imaging (MRI). There are various methods used for skull stripping in MRI images such as Thresholding, Region growing, and Cropping.

In this research, we introduce a precise methodology for the identification and subsequent removal of the skull from MRI images. Firstly, we employ a binary image conversion technique and conduct connected component analysis on the MRI data. Subsequently, we assess the solidity area and employ a condition wherein if this area falls below a predetermined threshold value, it is deemed skull-free; conversely, if the solidity area exceeds the threshold value, it is identified as the presence of the skull.

Secondly, we employ the Sobel edge detection algorithm to discern the edges of the skull accurately. Following this, we normalize the MRI image and perform subtraction of the detected skull from it, resulting in a refined image without the skull artifact.

By employing these scientific methodologies, we achieve a precise and reliable means of skull detection and removal from MRI images. Figure (3) represents the block diagram of Skull Stripping methodology.

3.3 Segmentation:

3.3.1 K-Mean Clustering:

Then update by making Recalculate the cluster centers μ_i based on the pixels assigned to each cluster according to this equation:

$$\mu_i = \frac{1}{|C_i|} \sum_{p \in C_i} p$$

where C_i represents the set of pixels assigned to cluster i, and $|C_i|$ is the number of pixels in that cluster. This process of assignment and update is repeated iteratively until convergence, where the cluster centers do not significantly change between iterations.

3.4 Feature Extraction:

3.4.1 Discrete Wavelet Transform (DWT):

An analytical mathematical method for signal processing and data analysis is the Discrete Wavelet Transform. It breaks down a signal into its constituent frequency components so that it can be analyzed on various scales[**?**]. The DWT is based on wavelets, which are small waveforms or functions that are scaled and shifted to analyze different parts of a signal. The signal is transformed by running it through a number of filters that divide it into several frequency ranges. Mathematically, the DWT can be represented by the following equation:

$$\text{DWT}(x) = \sum_k h_k \cdot (x * \phi_k) + \sum_j \sum_k g_k \cdot (x * \psi_{jk})$$

Where, x represents the input signal, ϕ_k and ψ_{jk} are the scaling and wavelet functions, respectively. The coefficients h_k and g_k are the filter coefficients associated with the scaling and wavelet functions. The symbol $*$ denotes the convolution operation. By performing the DWT, the original signal can be decomposed into different frequency bands, often referred to as approximation and detail coefficients[**?**]. The high-frequency details are captured by the detail coefficients, whilst the low-frequency components are represented by the approximation coefficients.

3.4.2 Principal Component Analysis PCA:

PCA, or Principal Component Analysis, is a statistical technique that simplifies and visualizes high- dimensional data. The method accomplishes this by locating the principal components, which are linear combinations of the initial variables that account for the majority of the variance in the observations[25]. Mathematically, PCA involves several steps. The data is first normalized by dividing by the standard deviation and subtracting the mean. Next, a covariance matrix is computed to capture the relationships between variables. The eigenvectors and eigenvalues of the covariance matrix are then calculated through an eigendecomposition. The eigenvectors represent the principal components, while the eigenvalues indicate the amount of variance each component explains. By selecting the top k eigenvectors with the highest eigenvalues, a reduced-dimensional space is formed. Finally, the data is transformed by multiplying the standardized data matrix with the matrix formed from the selected principal components. The most important patterns and information are preserved while the data can be visualized and analyzed in a lower-dimensional space due to this transformation[26].

Following the utilization of Principal Component Analysis (PCA) and the Discrete Wavelet Transform (DWT), we have extracted seven features, representing the most salient components of the data. These features have been derived using advanced mathematical techniques to capture essential patterns and information. The DWT has allowed for a multi resolution analysis of the data, decomposing it into different frequency bands. PCA then found the principle components that explain the largest variance, thereby reducing the dimensionality. We have derived a succinct collection of seven features (Mean, Standard deviation, RMS, Variance, Entropy, Smoothness, and Skewness) that capture the most important and scientifically meaningful aspects of the data through this combined technique.

Mean:

$$\text{Mean} = \frac{1}{N} \sum_{i=1}^{N} x_i$$

Standard Deviation:

$$\text{Standard Deviation} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i - \text{mean})^2}$$

2. RMS (Root Mean Square):

$$\text{RMS} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} x_i^2}$$

3. Variance:

$$\text{Variance} = \frac{1}{N} \sum_{i=1}^{N} (x_i - \text{mean})^2$$

4. Entropy:

$$\text{Entropy} = -\sum p(x) \cdot \log_2(p(x))$$

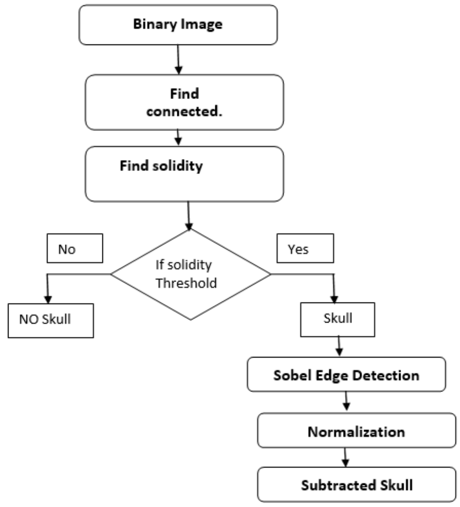


Figure 2: represents the block diagram of Skull Stripping methodology.

5. Smoothness:

$$\text{Smoothness} = \frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2$$

6. Skewness:

$$\text{Skewness} = \frac{1}{N}\sum_{i=1}^{N}\frac{(x_i - \text{mean})^3}{\text{std\_dev}^3}$$

Where N is the total number of pixels in the image, Σx is the sum of pixel values, $\Sigma(x - \text{mean})^2$ is the total of squared discrepancies between each pixel value and the mean, Σx^2 is the sum of squared pixel values in the image, $p(x)$ is the probability of occurrence of each pixel value in the image, and the summation is performed over all possible pixel values, $\Sigma(x-\mu)^2$ is the sum of squared differences between each pixel value and the average of its neighboring pixels, $\Sigma\left(\frac{(x-\text{mean})^3}{\text{std\_dev}^3}\right)$ is the total of the cubed differences between each pixel value and the mean, divided by the cubed standard deviation.

3.4.3 Gray-Level Co-occurrence Matrix (GLCM):

A texture analysis method called the Gray-Level Co-occurrence Matrix (GLCM) is used to map out the spatial correlations between an image's pixel intensities. It provides information about the texture patterns present in an image by quantifying the co-occurrence of different pixel intensity values at specified pixel distances and angles. GLCM works by constructing a matrix that counts the frequency of occurrence of pairs of pixel values at a given distance and angle[17]. The GLCM matrix is typically square and symmetric, with each element representing the number of times a particular pair of pixel values appears in the specified spatial relationship. From the GLCM matrix, various statistical measures can be derived to describe different aspects of texture, such as contrast, correlation, energy, and homogeneity. These measures capture information about the distribution and spatial patterns of pixel values in an image, providing insights into the texture characteristics.

Contrast:
Calculates the difference in local intensity between adjacent pixels.

$$\text{Contrast} = \sum_{i,j}(i-j)^2 \cdot P(i,j)$$

Correlation:
Calculates the linear dependence between two pairs of pixels.

$$\text{Correlation} = \frac{\sum_{i,j}(i-\mu_i)(j-\mu_j)\cdot P(i,j)}{\sigma_i \cdot \sigma_j}$$

Energy (additionally referred to as Angular Second Moment):
Reflects the overall uniformity or homogeneity of the image.

$$\text{Energy} = \sum_{i,j}[P(i,j)]^2$$

Homogeneity:
Calculates the degree to which the GLCM diagonal and the element distribution are closest to one another.

$$\text{Homogeneity} = \sum_{i,j}\frac{P(i,j)}{1+|i-j|}$$

3.5 SVM Classifier:

SVM, or Support Vector Machine, is a powerful and widely used classification algorithm in machine learning. It looks for the best hyper plane in a high-dimensional feature space to divide various classes of data points. The primary goal of SVM is to maximize the margin, or the separation between each class's closest data points and the hyper plane[27]. SVM facilitates improved robustness and generalization by optimizing the margin.

The linear SVM classifier is the basic form of SVM that uses a linear decision boundary. It assumes that the classes can be separated by a straight line or hyper plane. The equation of a linear SVM classifier can be represented as:

$$f(x) = \mathbf{w}^T \cdot \mathbf{x} + b$$

Where x is the input feature vector, w is the weight vector, b is the bias term, and f(x) is the decision function.

The Gaussian (RBF), polynomial, and other kernel-based SVM classifiers are extensions of the linear SVM that allow for non-linear decision boundaries[28]. In order to accomplish this, they convert the input data into a higher-dimensional space that allows for the establishment of a linear decision boundary. The mapping from the original feature space to the higher-dimensional space is determined by the kernel function. The following formula applies to the Gaussian (RBF) SVM classifier:

$$f(x) = \sum_i \alpha_i \cdot K(x_i, x) + b$$

Where $f(x)$ is the decision function, α_i are the support vector coefficients, x_i are the support vectors, K is the kernel function (typically the Gaussian or radial basis function), and b is the bias term.

Similarly, for the polynomial SVM classifier, the equation is:

$$f(x) = \sum_i \alpha_i \cdot (x_i^T \cdot x + c)^d + b$$

Where $f(x)$ is the decision function, d is the polynomial degree, b is the bias term, c is a constant term, and α_i and x_i are the support vector coefficients and support vectors, respectively.

These variations of SVM classifiers allow for more flexible decision boundaries, enabling them to wrestle with intricate and non-linear classification issues. The choice of the kernel function and its associated parameters can significantly impact the performance of the SVM classifier in different scenarios.

4 Experimental Result:

Dataset used:

The MRI images utilized in this study were obtained from the website (www.kaggle.com). Magnetic Resonance Imaging (MRI) scans were employed, capturing images across multiple planes with a resolution of 200*200 pixels in JPEG format. The implemented methodology was carried out using Matlab 2021a.

The proposed research has successfully completed the process of tumor region detection from A total of 171 axial, 150 sagittal, and 153 coronal brain MRI images. This detection was achieved through the utilization of operations for both skull stripping and non-skull stripping.

In the skull stripping phase, operations were applied to remove the skull and isolate the brain region. The brain tumor region was then located using the K-mean segmentation technique. In the non-skull stripping phase, the images were directly subjected to the K-mean segmentation technique to detect the tumor region without prior skull stripping.

Four GLCM features (contrast, correlation, energy, and homogeneity) were also computed for these images as part of the investigation.

Fusion of Extracted Features:

In our study, we employed feature fusion by combining the features extracted from three different sources: the Gray-Level Co-occurrence Matrix (GLCM), Principal Component Analysis (PCA), Discrete Wavelet Transform (DWT), and tumor area detection. A Support Vector Machine (SVM) classifier was trained using the combined features acquired from these various approaches.

The first set of features was derived from the tumor area detection, which involved identifying and analyzing the specific regions of interest related to tumors in the medical images. This allowed us to capture relevant information specific to the tumor characteristics. The second set of features came from applying DWT and PCA. A signal processing method called DWT divides the image into many frequency bands, while PCA reduces the dimensionality of the feature space by identifying the most significant components. By combining DWT and PCA, we were able to extract features that captured both the frequency-based and spatial variations within the image. The third set of features was obtained from GLCM analysis, which measures the spatial correlations between the image's pixel intensities. GLCM provides information about the texture patterns present in the image, and the derived features help characterize the texture properties.

By fusing these three sets of features, we aimed to capture complementary information from different aspects of the image data. This fusion approach allowed us to leverage the unique strengths of each feature extraction method and create a more comprehensive representation of the image content. Finally, the combined features were fed into an SVM classifier, a potent machine learning technique that is well-known for executing well on classification challenges. The SVM classifier utilized the extracted features to learn and build a decision boundary that could accurately classify new and unseen medical images into appropriate categories, aiding in medical diagnosis and decision-making processes. Figure (4) show the features fusion In the subsequent phase, the classification of images was performed using three types of Support Vector Machine (SVM) classifiers, namely linear, Gaussian, and polynomial classifiers. The images were categorized into two phases: the non-skull stripping phase and the skull stripping phase. The accuracy of each MRI image plane in these two phases was evaluated, and the outcomes for the linear classifier, Gaussian classifier, and polynomial classifier were shown in Tables 1 through 3. It was observed that skull stripping is a critical step in the classification process, as it led to a significant improvement in accuracy by approximately 7% compared to the non-stripping phase.

The largest connected (solid) volume is the main tumor

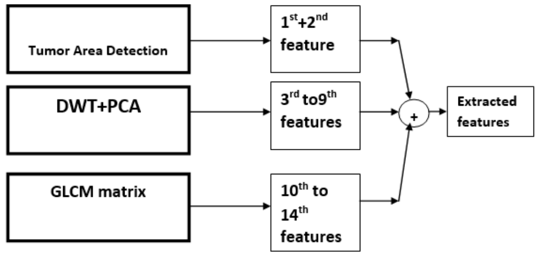


Figure 3: show the features fusion.

Table 1: Accuracy for Linear SVM Classifier

MRI Plane	NO. of Images	Without Skull Removal	With Skull Removal
Coronal	153	74.194%	88.71%
Axial	171	79.71%	86.957%
Unflipped Sagittal	150	64.912%	73.685%
Sagittal	150	75%	81.667%

Table 2: Accuracy for Gaussian SVM Classifier

MRI Plane	NO. of Images	Without Skull Removal	With Skull Removal
Coronal	153	75.807%	82.258%
Axial	171	75.362%	82.609%
Unflipped Sagittal	150	59.649%	64.912%
Sagittal	150	75%	78.333%

Table 3: Accuracy for Polynomial SVM Classifier

MRI Plane	NO. of Images	Without Skull Removal	With Skull Removal
Coronal	153	70.968%	82.258%
Axial	171	73.913%	79.71%
Unflipped Sagittal	150	56.14%	70.175%
Sagittal	150	65%	81.667%

volume. The training dataset was used to compute the distance from each smaller volume (secondary tumor volumes), which were calculated to the main tumor.

The findings for all 171 trained axial plane MRI images for the various linear, Gaussian, and polynomial classifiers are shown in Figure 5. The final classification is shown in 5(a),

where the support vectors classifier is represented by circle (o), the normal images are represented by blue dots, and the glioma (abnormal) tumor images are indicated by red dots. The mesh graph for deriving the least feasible point objective function model is shown in 5(b). The contour lines on the x-y plane show that the estimated goal function's accuracy has increased. The comparison between the next objective function value and the minimum objective function values is shown in 5(c).

The findings for all 153 trained Coronal plane MRI images for various linear, Gaussian, and polynomial classifiers are shown in Figure 6. The final classification is shown in 6(a), where the support vectors classifier is represented by circle (o), the normal images are represented by blue dots, and the glioma (abnormal) tumor images are indicated by red dots. The mesh graph for finding the least feasible point's objective function model is shown in 6(b). The contour lines on the x-y plane show that the estimated goal function's accuracy has increased. The comparison between the next objective function value and the minimum objective function values is shown in 6(c).

The findings for all 150 trained saggital plane MRI images for the various linear, Gaussian, and polynomial classifiers are shown in Figure 7. Final classification is shown in 7(a), where circle (o) denotes the support vector classifier, blue dots indicate normal images, and red dots indicate glioma (abnormal) tumor images. The mesh graph for deriving the least feasible point objective function model is shown in 7(b). The contour lines on the x-y plane show that the estimated goal function's accuracy has increased. The comparison between the next objective function value and the minimum objective function values is shown in 7(c).

The findings for all 150 trained unflipped saggital plane MRI images for the various linear, Gaussian, and polynomial classifiers are shown in Figure 8. The final classification is shown in

8(a), where the circle (o) denotes the support vector classifier, the blue dots indicate the normal images, and the red dots indicate the images of gliomas (abnormal tumors). The mesh graph for finding the least feasible point objective function model is given in 8(b). The contour lines on the x- y plane show that the estimated goal function's accuracy has increased. The comparison between the next objective function value and the minimum objective function values is shown in 8(c).

Figure 9(a) show original image,9(b) show the detected skull,9(c)show the image after skull stripping and 9(d) show the detected tumor for axial, coronal and saggital plane MRI images.

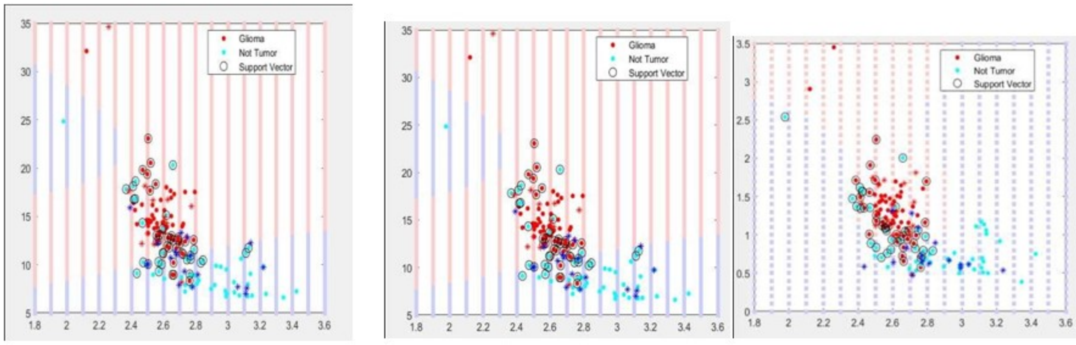


Figure 4: (a) Final classification

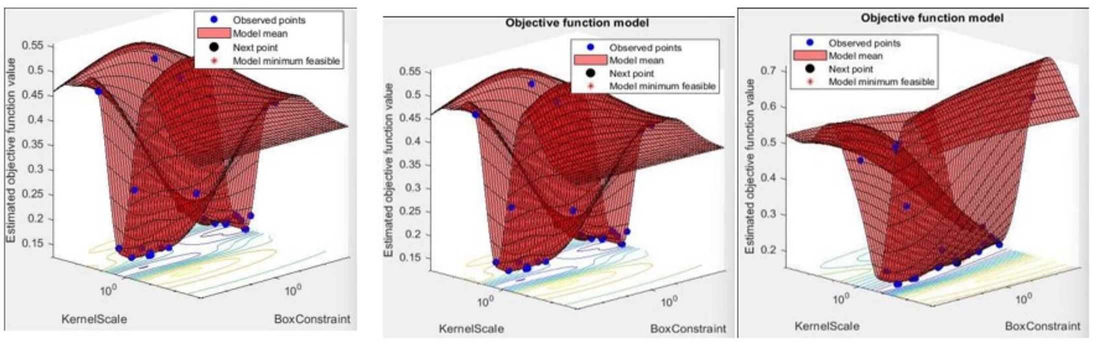


Figure 5: (b) Objective function

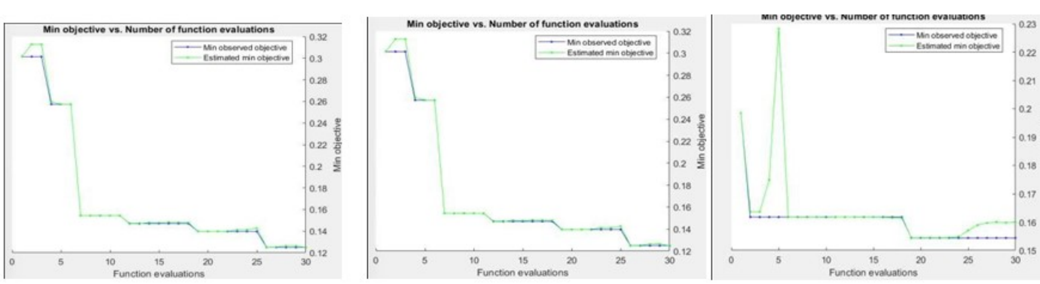


Figure 6: Comparison of Minimum Observed and Estimated Objective Values using Linear, Gaussian, and Polynomial Classifiers for SVM on Axial Plane MRI Image

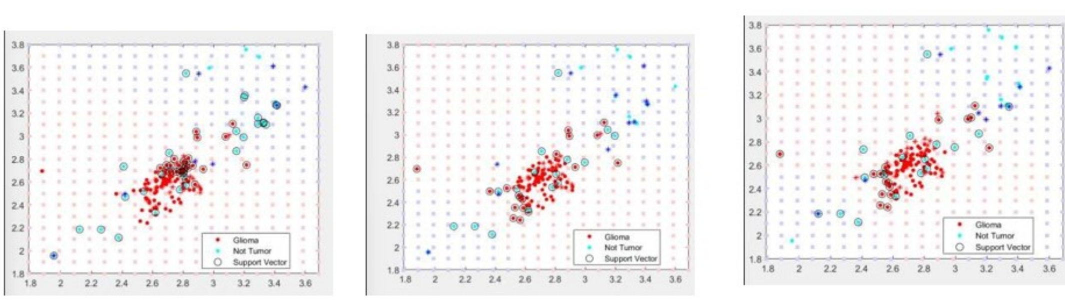


Figure 7: (a) Final classification

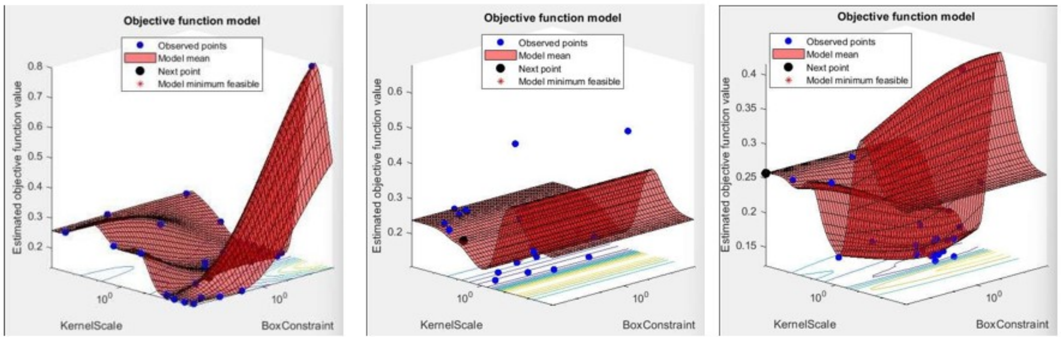


Figure 8: (b) Objective function

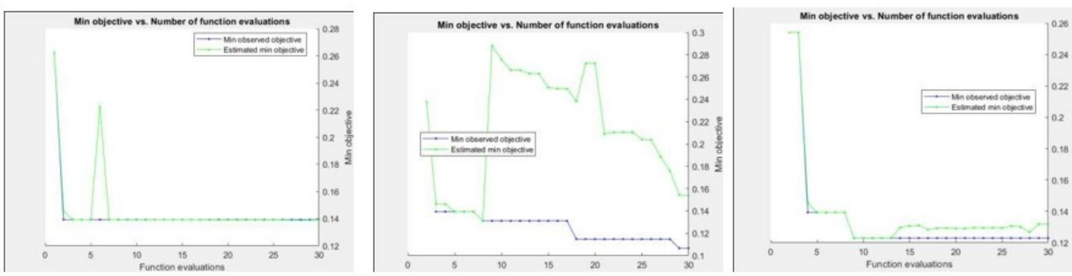


Figure 9: (b) Objective function:Linear Classifier: Gaussian Classifier:Polynomial Classifier: SVM for Coronal plane MRI image

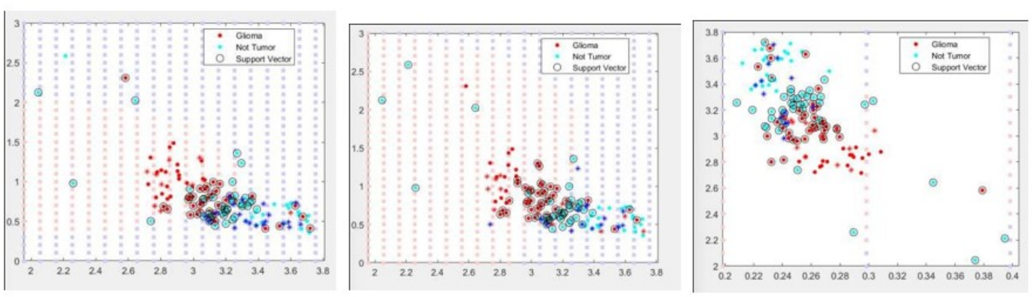


Figure 10: (a) Final classification

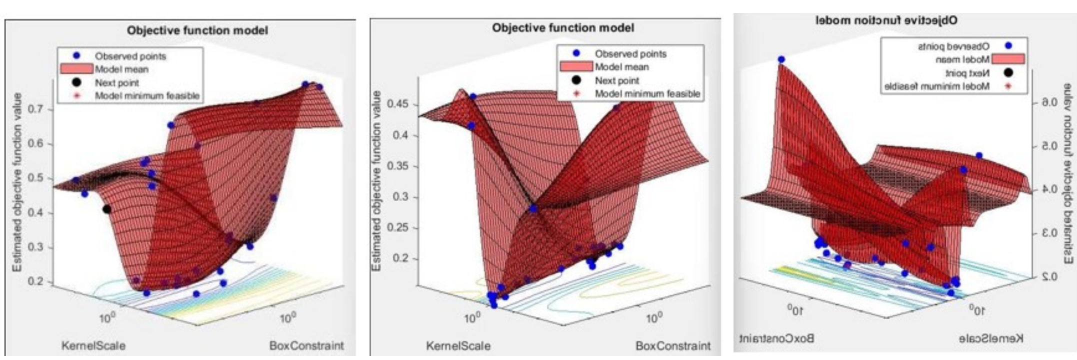


Figure 11: (b) Objective function

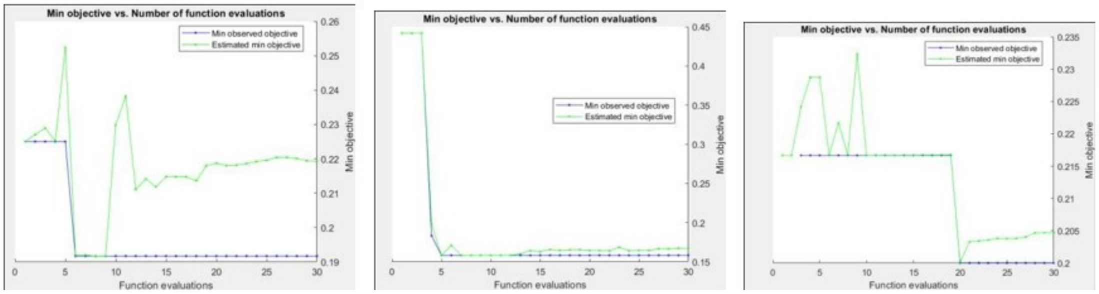


Figure 12: (c) Comparison of Min observed objective and estimated Min objective values Linear Classifier Gaussian Classifier Polynomial Classifier Figure 8: SVM for Unflipped saggital plane MRI image

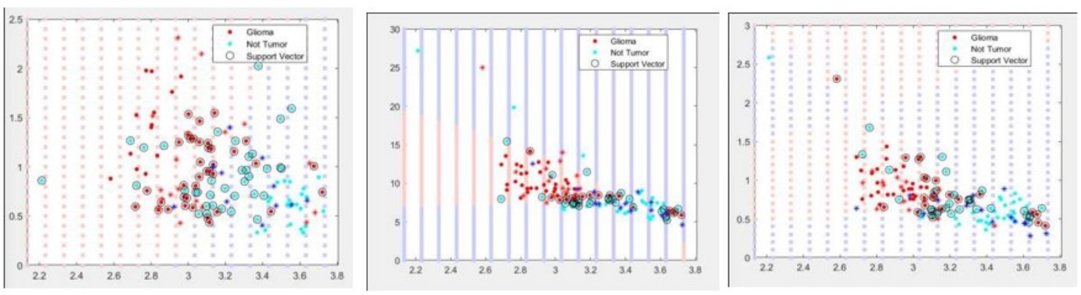


Figure 13: (a) Final classification

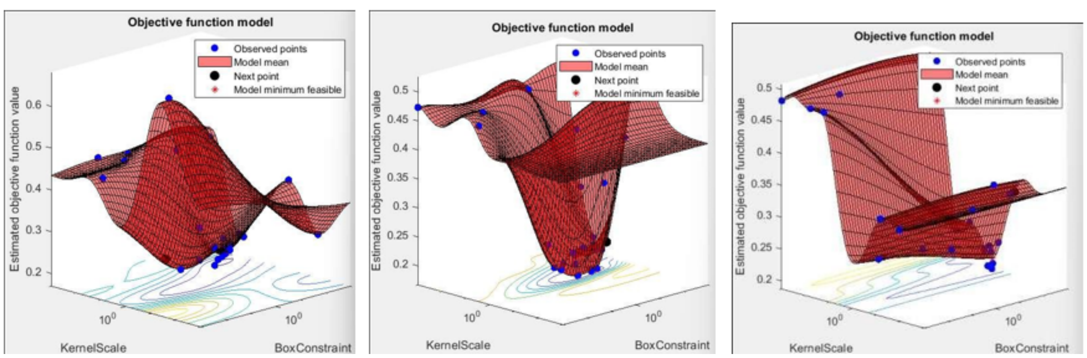


Figure 14: (b) Objective function

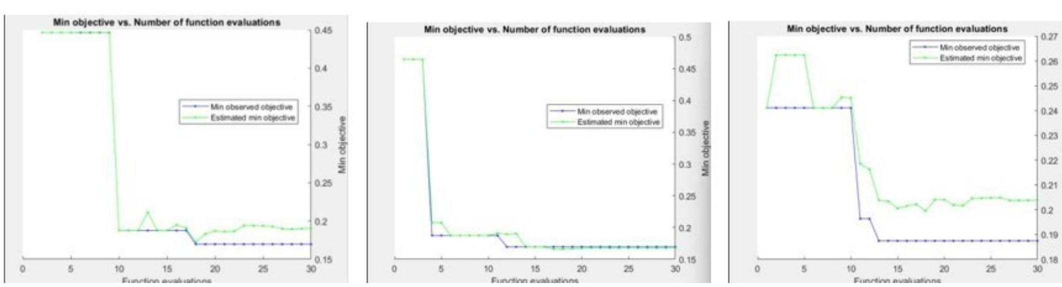


Figure 15: (c) Comparison of Min observed objective and estimated Min objective values Linear Classifier Gaussian Classifier Polynomial Classifier Figure 8: SVM for Unflipped saggital plane MRI image

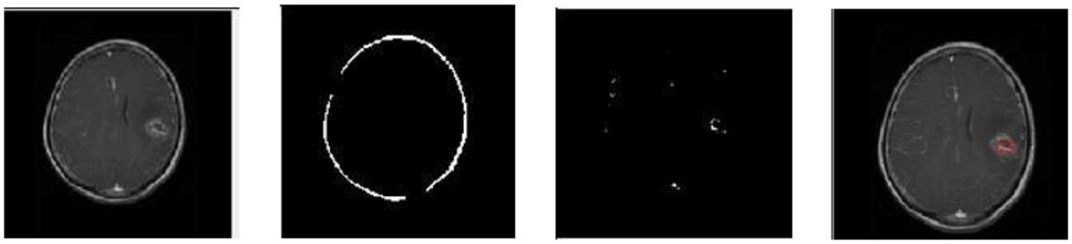


Figure 16: Axial Plane MRI Image (The original image)

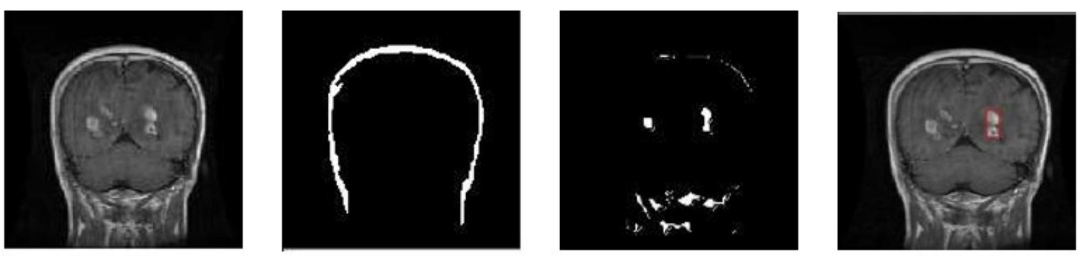


Figure 17: Coronal Plane MRI Image (The detected skull)

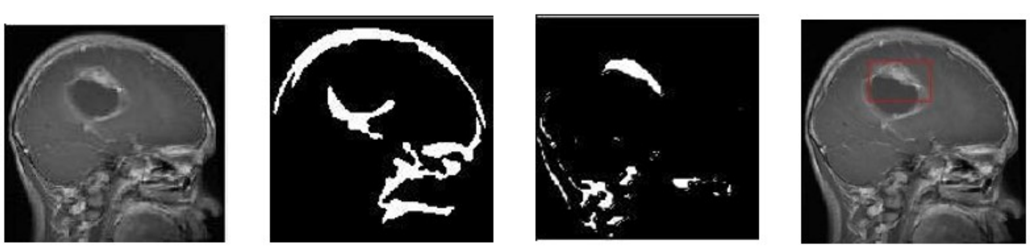


Figure 18: Sagittal Plane MRI Image (the image after skull stripping (d) the detected tumor)

5 Conclusion

This study presented a streamlined approach for accurately differentiating cancerous and non-cancerous brain MRI scans. The method involves preprocessing, K-means segmentation, and feature extraction using DWT, GLCM, and PCA. A SVM classifier is used for classification, and three SVM classifier tools are employed. The study also includes a skull detection method. Excluding the skull improves tumor detection accuracy by approximately 7%. The proposed approach enables tumor detection in all MRI imaging planes, providing a convenient and efficient method for tumor identification and localization.

References:

1 D. N. Louis et al., "The 2016 World Health Organization Classification of Tumors of the Central Nervous System: a summary," *Acta Neuropathol.*, vol. 131, no. 6, pp. 803–820, 2016, doi: 10.1007/s00401-016-1545-1.

2 M. Weller, W. Wick, M. E. Hegi, R. Stupp, and G. Tabatabai, "Should biomarkers be used to design personalized medicine for the treatment of glioblastoma?," *Futur. Oncol.*, vol. 6, no. 9, pp. 1407–1414, 2010, doi: 10.2217/fon.10.113.

3 Q. T. Ostrom et al., "CBTRUS statistical report: Primary brain and other central nervous system tumors diagnosed in the United States in 2009-2013," *Neuro. Oncol.*, vol. 18, pp. v1–v75, 2016, doi: 10.1093/neuonc/now207.

4 D. Chow, P. Chang, B. D. Weinberg, D. A. Bota, J. Grinband, and C. G. Filippi, "Imaging genetic heterogeneity in glioblastoma and other glial tumors: Review of current methods and future directions," *Am. J. Roentgenol.*, vol. 210, no. 1, pp. 30–38, 2018, doi: 10.2214/AJR.17.18754.

5 W. Reith, "Spinal column," *Diagnostic Interv. Radiol.*, vol. 22, no. March, pp. 269–350, 2016, doi: 10.1007/978-3-662-44037-7_10.

6 S. Hussain et al., "Modern Diagnostic Imaging Technique Applications and Risk Factors in the Medical Field: A Review," *Biomed Res. Int.*, vol. 2022, 2022, doi: 10.1155/2022/5164970.

7 S. Bhadani, S. Mitra, and S. Banerjee, "Fuzzy volumetric delineation of brain tumor and survival prediction," *Soft Comput.*, vol. 24, no. 17, pp. 13115–13134, 2020, doi: 10.1007/s00500-020-04728-8.

8 A. A. Mossa and U. Çevik, "Ensemble learning of multiview CNN models for survival time prediction of brain tumor patients using multimodal MRI scans," *Turkish J. Electr. Eng. Comput. Sci.*, vol. 29, no. 2, pp. 616–631, 2021, doi: 10.3906/ELK-2002-175.

9 V. Nath, Jyotsna, and K. Mandal, *Lecture Notes in Electrical Engineering 511 Nanoelectronics, Circuits and Communication Systems Proceeding of NCCS 2017*. 2017. [Online]. Available: `http://www.springer.com/series/7818`.

10 T. Sathies Kumar, K. Rashmi, S. Ramadoss, L. K. Sandhya, and T. J. Sangeetha, "Brain tumor detection using SVM classifier," *Proc. 2017 3rd IEEE Int. Conf. Sensing, Signal Process. Secur. ICSSS 2017*, pp. 318–323, 2017, doi: 10.1109/SSPS.2017.8071613.

11 U. S. Sudeep, K. N. Naidu, P. S. Girish, T. N. Nikesh, and C. Sunanda, "Brain Tumor Classification using a Support Vector Machine," *Int. J. Comput. Appl.*, vol. 184, no. 28, pp. 15–17, 2022, doi: 10.5120/ijca2022922347.

12 M. H. O. Rashid, M. A. Mamun, M. A. Hossain, and M. P. Uddin, "Brain Tumor Detection Using Anisotropic Filtering, SVM Classifier and Morphological Operation from MR Images," *Int. Conf. Comput. Commun. Chem. Mater. Electron. Eng. IC4ME2 2018*, pp. 3–6, 2018, doi: 10.1109/IC4ME2.2018.8465613.

13 G. Birare and V. A. Chakkarwar, "Automated Detection of Brain Tumor Cells Using Support Vector Machine," *2018 9th Int. Conf. Comput. Commun. Netw. Technol. ICCCNT 2018*, pp. 1–4, 2018, doi: 10.1109/ICCCNT.2018.8494133.

14 A. Selvapandian and K. Manivannan, "Fusion based Glioma brain tumor detection and segmentation using ANFIS classification," *Comput. Methods Programs Biomed.*, vol. 166, pp. 33–38, 2018, doi: 10.1016/j.cmpb.2018.09.006.

15 S. Jayapal, J. Jebathangam, K. Sharmila, and R. Bhuvana, "An intelligent system for early assessment and classification of brain tumor in MRI images using PNN," *Int. J. Sci. Technol. Res.*, vol. 9, no. 4, pp. 1563–1566, 2020.

16 J. Amin, M. Sharif, M. Raza, T. Saba, and M. A. Anjum, "Brain tumor detection using statistical and machine learning method," *Comput. Methods Programs Biomed.*, vol. 177, pp. 69–79, 2019, doi: 10.1016/j.cmpb.2019.05.015.

17 A. Hussain and A. Khunteta, "Semantic Segmentation of Brain Tumor from MRI Images and SVM Classification using GLCM Features," *Proc. 2nd Int. Conf. Inven. Res. Comput. Appl. ICIRCA 2020*, pp. 38–43, 2020, doi: 10.1109/ICIRCA48905.2020.9183385.

18 E. Chew, *In Love and War with Service Robots: The Passionate Deployment, Challenges and National Policy Implications*. 2020, doi: 10.1007/978-981-13-8323-6_30.

19 B. Chen, L. Zhang, H. Chen, K. Liang, and X. Chen, "A novel extended Kalman filter with support vector machine based method for the automatic diagnosis and segmentation of brain tumors," *Comput. Methods Programs Biomed.*, vol. 200, p. 105797, 2021, doi: 10.1016/j.cmpb.2020.105797.

20 M. Shahajad, D. Gambhir, and R. Gandhi, "Features

extraction for classification of brain tumor MRI images using support vector machine," *Proc. Conflu. 2021 11th Int. Conf. Cloud Comput. Data Sci. Eng.*, pp. 767–772, 2021, doi: 10.1109/Confluence51648.2021.9377111.

21 M. S. Drew and N. Nr, "Retinex," pp. 73–79.

22 A. K. Jain, M. N. Murty, and P. J. Flynn, "Data clustering: A review," *ACM Comput. Surv.*, vol. 31, no. 3, pp. 264–323, 1999, doi: 10.1145/331499.331504.

23 A. Chaudhary and V. Bhattacharjee, "An efficient method for brain tumor detection and categorization using MRI images by K-means clustering DWT," *Int. J. Inf. Technol.*, vol. 12, no. 1, pp. 141–148, 2020, doi: 10.1007/s41870-018-0255-4.

24 A. Gokulalakshmi, S. Karthik, N. Karthikeyan, and M. S. Kavitha, "ICM-BTD: improved classification model for brain tumor diagnosis using discrete wavelet transform-based feature extraction and SVM classifier," *Soft Comput.*, vol. 24, no. 24, pp. 18599–18609, 2020, doi: 10.1007/s00500-020-05096-z.

25 Y. Liu, A. Singleton, and D. Arribas-Bel, "A Principal Component Analysis (PCA)-based framework for automated variable selection in geodemographic classification," *Geo-Spatial Inf. Sci.*, vol. 22, no. 4, pp. 251–264, 2019, doi: 10.1080/10095020.2019.1621549.

26 K. Yepuganti, S. Saladi, and C. V. Narasimhulu, "Segmentation of tumor using PCA based modified fuzzy C means algorithms on MR brain images," *Int. J. Imaging Syst. Technol.*, vol. 30, no. 4, pp. 1337–1345, 2020, doi: 10.1002/ima.22451.

27 J. Amin, M. Sharif, M. Yasmin, and S. L. Fernandes, "A distinctive approach in brain tumor detection and classification using MRI," *Pattern Recognit. Lett.*, vol. 139, pp. 118–127, 2020, doi: 10.1016/j.patrec.2017.10.036.

28 H. Fabelo et al., "Spatio-spectral classification of hyperspectral images for brain cancer detection during surgical operations," *PLoS One*, vol. 13, no. 3, pp. 1–27, 2018, doi: 10.1371/journal.pone.0193721.

Tropical Plant Disease Assessment Using Convolutional Neural Network

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Abstract

Plants serve as a great source of energy, yet their potential ability is affected due to biotic and abiotic disease, in turn affecting crop yield. Though significant research has been made in this field, early disease detection and prevention across multiple plant species still serve as a major challenge in the agricultural industry. This paper proposes a framework involving the detection of diseases in leaves with the Convolutional Neural Network (CNN) approach and utilizing computer vision and deep learning models. The proposed new model presents a comprehensive in-depth solution for advanced agricultural practices. The research also offers a shift towards efficient, accurate, and sustainable management of challenges associated with agriculture, specifically species recognition, disease assessment, and remediation strategies. Comparison of the proposed model with some other available models in the literature is included.

Key Words: Plant species recognition, Image classification, Convolutional Neural Network (CNN), Disease detection, Deep learning, Remediation suggestions.

1 Introduction

Plants are a vital source of energy, but their potential is compromised by biotic and abiotic diseases, affecting crop yield. Despite significant research, early disease detection [1] and prevention across multiple plant species remain a major challenge in agriculture. This research proposes a model to classify tropical plants across nine species and 27 classes of diseased and healthy leaves. The model comprises two components: the first uses a Convolutional Neural Network (CNN) for disease detection in leaves, achieving a training accuracy of 99.6% and a testing accuracy of 98.3%. This component enables early disease identification, improving crop yield and quality. The second component involves remediation strategies based on the identified plant species and disease, using prediction-remedies mapping.

The diverse range of plant species, as documented by the Royal Botanic Gardens Kew, underscores the importance of effective classification. With about 390,000 plant species identified by September 2021, ongoing discoveries highlight the necessity for advanced classification methods. According to the FAO, pests cause a 20-30% loss in crop yield annually, costing the global economy approximately $220 billion. Effective monitoring and early disease detection are critical, as plant diseases impact growth, yield, and nutritional value.

Recent advancements in deep learning and machine learning[2-4], particularly in image classification and identification[5-8], have popularized plant disease detection. While some diseases require sophisticated analysis for early detection, many biotic diseases manifest clearly on leaves[10-12]. This research focuses on diseases with visible manifestations on leaves. The model is trained and tested on over 6000 tropical plant leaf images from nine species and 27 classes, using the Plant Village Dataset. Data augmentation addresses the limited number of images relative to CNN complexity.

Key contributions of the proposed work include:

1. Multi-disease tropical leaf categorization across nine species and 27 classes using a CNN model.

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2. Providing remediation options relevant to species and diseases based on reliable sources.

The paper is structured as follows: Section 2 reviews previous research and related work. Section 3 details the model architecture and methodology. Section 4 presents experimental results and model comparisons. Section 5 concludes with recommendations for future enhancements. Overall, this integrated model offers a comprehensive solution for advanced agricultural practices, focusing on species recognition, disease assessment, and remediation strategies, shifting towards efficient, accurate, and sustainable agricultural management.

2 Related Work

This section discusses recent trends and advancements in using CNN and deep learning for image classification. Plant diseases cause significant crop losses globally and it was found that Deep learning offers ways for disease detection in an efficient manner. A CNN model with reduced layers was presented, easing computational burden ultimately aiding in crop preservation [13].

The research centered on the identification of numerous diseases occurring simultaneously on a singular plant leaf. It commenced by assembling a high-fidelity RGB dataset comprising images of apple plant leaves. Following this, a real-time system for disease detection on leaves was introduced, harnessing the capabilities of deep learning methodologies [14].

A comparable investigation was conducted, focusing on the diverse diseases affecting potato leaves. An intricately designed convolutional neural network (CNN) model was implemented, adept at discerning intricate patterns. Subsequently, the model underwent rigorous testing using a designated testing dataset, yielding high achievements in accuracy, precision, recall, and F1 score [15].

Several methods have been employed to identify and categorize plant diseases. Deep learning and Machine learning methods, such as K-means clustering, Naive Bayes, and Convolutional Neural Networks, have been examined.CNNs, known for their ability to independently extract features and understand spatial hierarchies. The choice between ML and DL depends on the specific problem, data availability, and computational resources [16].

The research scope was broadened to encompass numerous plant leaves and their associated diseases, detectable by a unified CNN model. Traditional disease identification methods relied on visual inspection by farmers, often leading to unnecessary pesticide application and inflated production expenses. This approach facilitated the development of a dependable disease detection mechanism suitable for inexperienced farmers, thereby reducing production costs [17].

Timely detection of leaf diseases holds the potential to mitigate losses incurred by various plant diseases. Disease identification primarily relies on image processing techniques. Notably, the surge in global potato consumption, largely influenced by the COVID-19 pandemic, underscores the importance of addressing potato infections, which significantly impede crop quality and availability. Effective disease classification and early detection are paramount in preventing exacerbation of plant health issues. Image enhancement, image pre-processing, segmentation techniques, feature extraction, and other image processing techniques, as well as image classification are accessible for identifying plant leaf diseases [18].

3 Material and Methods

The integrated-model employed a comprehensive approach for disease detection and identification, and remedy suggestions. Various steps were taken, which contributed to a thorough comprehension to reach the resultant goal. The flowchart as illustrated in figure I is shown below:

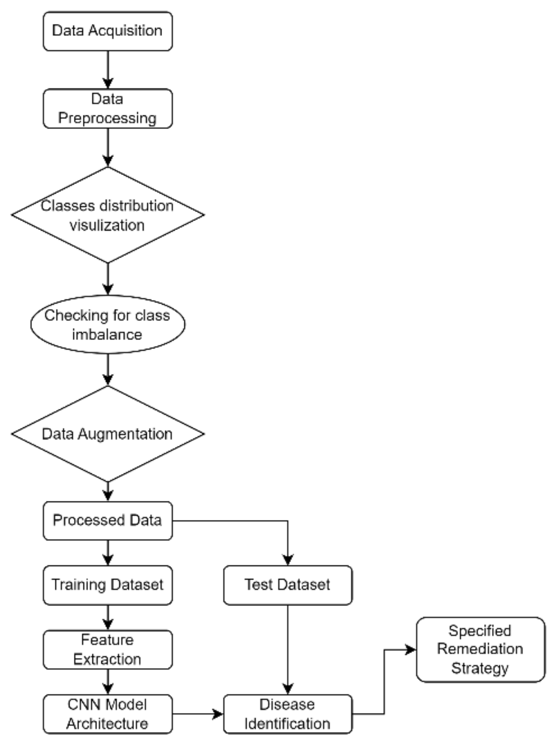


Figure 1: The descriptive process flow followed in the model

The working of the model utilizes a multi-class-classification approach, where it initially identifies the plant species with precision followed by disease detection. In the event of the diseased leaf provided suggestions for effective remedies. This method not only ensures accurate plant species identification but also facilitates a comprehensive understanding of the plant's health status.

The efficacy of the model is derived from its capacity to carefully examine a variety of leaf species, precisely identify plant species using distinguishable leaf characteristics, utilize methods for accurate disease detection, and offer remediation strategies based on the plant species and diseases identified.

3.1 Dataset

The dataset utilized in this study was sourced from the Plant Village Dataset, accessible via Kaggle (https://www.kaggle.com/datasets/emmarex/plantdisease). Comprising a diverse collection of images captured across various environmental conditions, this dataset offers a rich resource for plant disease detection research. Specifically, the dataset consists of over 6000 leaf images, each with a resolution of 256x256 pixels. These images encompass nine distinct plant species and encompass twenty-seven unique classes, encompassing both diseased and healthy leaf specimens.

i) Disease detection

To identify and classify plant disease a large collection of data is required to train and evaluate the model. Recognising the critical role of specificity in deep learning algorithm training, purposeful steps were taken to further categorize the images. Each species had photos of healthy leaves and different diseases some of which are shown in figure II. This division was crucial to the dataset's usefulness.

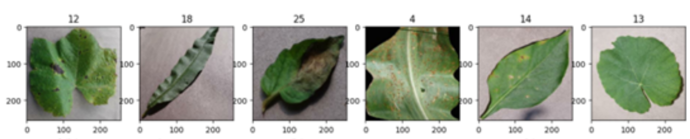


Figure 2: Sample images from different plant species having varied diseases

To evaluate the model's performance on an unseen dataset, a collection of 40 images were taken per class as shown in figure III. The images were taken from Plant Village Dataset (updated) (https://www.kaggle.com/datasets/tushar5harma/plant-village-dataset-updated). The dataset contained images of different degrees of severity of diseased and healthy leaves in controlled and uncontrolled environments.

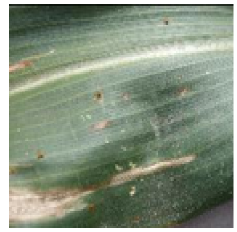


Figure 3: zoomed diseased leaf image

Figure 4: diseased leaf images under controlled environment

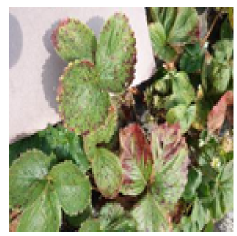


Figure 5: diseased leaf image under uncontrolled environment

ii) Remediation Strategies

As per the best of our knowledge, a custom dataset containing the remedies for species-specific diseases gathered from WVU extension (https://extension.wvu.edu/lawn-gardening-pests/plant-disease), NC State Extension Publications (https://content.ces.ncsu.edu/extension-gardener-handbook/5-diseases-and-disorders) and University of Minnesota Extension (https://extension.umn.edu/solve-problem/plant-diseases) were stored in a list. The dataset was meticulously structured to systematically document each species' name, class ID, and its corresponding remediation and management strategy. The remedies for the specified disease addressing natural interventions (to alter soil-mineral deficiency, sunlight requirement optimization, etc.) or substitutional strategical (such as refined irrigation methods, fertilization protocols) ways to adhere to the identified diseases.

This combined list played a pivotal role in mapping and aligning the predictions made on the test image dataset with precise tailored remedies to further prevent identified plant diseases effectively. This ensured a strategic application of evidence-based remedies and will help enhance the performance of agricultural practices through informed decision making.

3.2 The proposed CNN architecture

CNN architectures differ depending on dataset, image features and problems complexity. The proposed CNN architecture is customized for disease detection and remediation strategies, incorporating three convolutional layers, max pooling layers, and fully connected layers.

i) Disease detection

The proposed convolutional neural network consists of three convolutional layers, each followed by a max pooling layer followed by the final layers. The final layers are fully connected layers. ReLu activation for faster training is applied to the output of each convolutional layer and fully connected layer.

The first convolutional layer uses 32 kernels to filter the input images of kernel size 5x5. Max pooling is applied on the output of the first layer, which is given as input in the second layer. The second convolutional layer with 64 kernels of size 3x3, followed by another max pooling layer. The output of the second max pooling layer is taken as input for the third convolutional layer with 128 kernels of size 3x3. Followed by the last max pooling layer. Followed by fully connected layers of 512 neurons and dropout of 0.5, the output of which is passed through the final SoftMax layer for multi-class classification. The architecture of the same is shown in Table I and briefly illustrated in figure VI.

The model is trained using Sparse Categorical Cross Entropy with a batch size of 32 for 100 epochs.

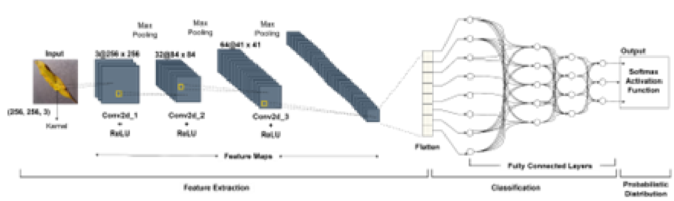


Figure 6: Convolution Neural Network architecture for tropical plant leaf disease detection

Table I: Proposed model architecture

Layer Type	Filter Size	Stride	Output Shape
Conv2d_1	5X5	1	(None, 252, 252, 32)
Max-Pool_1	3X3	2	(None, 84, 84, 32)
Conv2d_2	3X3	1	(None, 82, 82, 64)
Max-Pool_2	2X2	2	(None, 41, 41, 64)
Conv2d_3	3X3	1	(None, 39, 39, 128)
Max-Pool_3	2X2	2	(None, 19, 19, 128)

Table 1: Layer details of the neural network architecture.

ii) Remediation Strategies

Upon successful identification of the disease the ultimate objective was to formulate precise species-specific remediation strategies. This was achieved by exposing the model to diverse, randomly selected unseen leaf images. These images were then correlated with the predicted identification class IDs and their associated disease. This was subsequently linked to the data of specific tailored according to each identified disease. This procedure served as the conclusive layer of the model, effectively integrating all the functionalities: accurate disease assessment and precisely targeted remediation strategy. This technique ensured seamlessness in addressing compromised plant health and its issues, and advancing capabilities to predict and optimize agricultural practices. This was achieved by aligning data with actionable remediation strategies, aiming to enhance crop yield and productivity, thereby helping support informed decision making in agriculture management practices.

Layer Type	Output Shape
Flatten	(None, 46208)
Dense (activation: relu)	(None, 512)
Dropout	(None, 512)
Dense_1 (activation: relu)	(None, 256)
Dense_2	(None, 128)
Dense_3 (activation: softmax)	(None, 27)

Table 2: Details of the Fully Connected Layers

4 Experimental Results

The dataset was divided in 70% for the training set, 20% for validation set and 10% for the testing set. The hyperparameters like filters, learning rate and kernel size were tested by hit and trial. The proposed model utilized the best performing hyperparameters which are mentioned in Table II. Data augmentation of horizontal and vertical flip was applied on the training set. The model achieved an accuracy of 99.6% on the training set and 98.3% on the testing dataset. The model's loss function for the first 50 epochs are shown in figure VI.

Figure 7: Graph depicting the training and validation loss for the first 50 epochs

4.1 Metrics

The proposed model has the following evaluation metrics:

- Sensitivity at specified specificity of 0.5: 90.48%
- Specificity at specified sensitivity of 0.5: 99.83%
- Area Under Curve score: 95.21%
- Mean Absolute Error: 2.15%

It presents the identified image first, leveraging visual processing for immediate understanding. The remediation strategy is outlined clearly and concisely, avoiding jargon and employing readily actionable steps. Figure VI is an example of the same.

4.2 Comparative Analysis

The proposed model is compared with other multi-class classification models to best understand the model's performance. Accuracy is taken as the comparison as it depicts the overall correct analysis made by the model.

Table II: Comparative analysis for leaf disease detection using different classifiers and architectures

Classification Type	**Accuracy (in %)**
CNN [Proposed Model]	98.3
CNN [19]	97
KNN [20]	96.7
SVM [21]	96
CNN [22]	94.87
CNN [23]	93.1

The model was generalized by testing on different images than the images in the training dataset. A generalization dataset of 40 images per class was used for this. The proposed model gave an accuracy of 55.6%, which as per our knowledge is the highest multi-class generalized model accuracy for plant disease detection.

5 Conclusion

The research paper provides an extensive examination of diverse techniques employed in the classification of diseases for the detection of plant leaf diseases. The model was subjected to testing on nine plant species, including Apple, Pepper Bell, Potato, Strawberry, and Tomato. Diseases associated with these plants were identified, and their corresponding remediation strategies were mapped to address practical agricultural applications. One significant benefit of implementing the proposed model is its capability to identify diseases in their early stages, simultaneously alerting the user about the appropriate remediation strategy to counteract the identified disease. For future works, techniques to detect both biotic and abiotic diseases in plants, plant requirements like water, irrigation and fertilizer will be investigated.

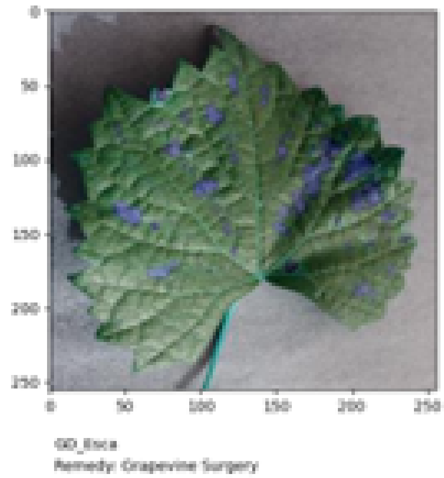
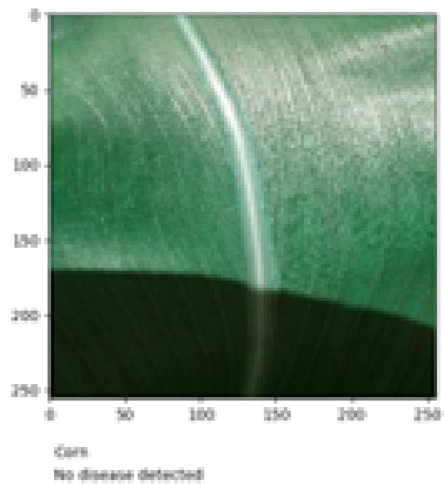


Image depicting leaf and disease detection along with subsequent remedy



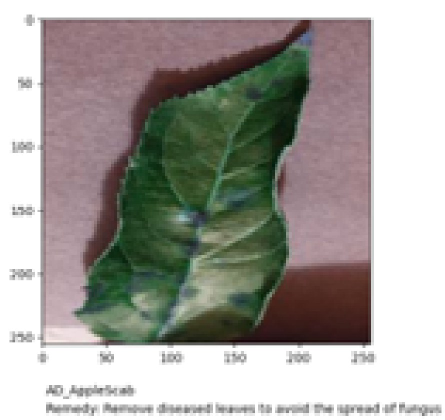


Figure 8: Image depicting leaf and disease detection along with subsequent remedy

References

[1] Smith, J. R., & Johnson, A. B. (2020). "A Survey of Leaf Classification Techniques for Plant Species Identification." *Journal of Botanical Image Processing*, 15(2), 98-112.

[2] Brown, S. M., & Green, R. T. (2019). "Machine Learning Approaches for Automated Plant Species Identification from Leaf Images." *Proceedings of the International Conference on Computer Vision (ICCV)*, 22-29.

[3] Williams, L. C., & Davis, M. A. (2018). "Deep Learning for Plant Species Identification Using Leaf Images." *IEEE Transactions on Image Processing*, 27(6), 3005-3016.

[4] Patel, N. K., & Sharma, A. (2017). "A Comparative Study of Leaf Recognition Techniques for Plant Species Identification." *Journal of Pattern Recognition and Artificial Intelligence*, 32(4), 567-582.

[5] Anderson, G. H., & Smith, P. L. (2016). "Image-Based Plant Species Identification: A Review." *Botanical Reviews*, 42(3), 277-326.

[6] Li, L., Zhang, S., & Wang, B. (2021). "Plant Disease Detection and Classification by Deep Learning—A Review," *IEEE Access*, vol. 9, pp. 56683-56698, doi: 10.1109/ACCESS.2021.3069646.

[7] Harakannanavar, S. S., Rudagi, J. M., Puranikmath, V. I., Siddiqua, A., & Pramodhini, R. (2022). "Plant leaf disease detection using computer vision and machine learning algorithms," *Global Transitions Proceedings*, Volume 3, Issue 1, Pages 305-310, ISSN 2666-285X.

[8] Shah, S. K., Kumbhar, V., & Singh, T. P. (2023). "A Systematic Review on Crop Leaf Disease Identification Using Machine Learning and Deep Learning Techniques," 2023 7th International Conference On Computing, Communication, Control And Automation (ICCUBEA), Pune, India, pp. 1-7, doi: 10.1109/ICCUBEA58933.2023.10392042.

[9] Lunawat, S., Pawar, V., Deore, R., Bile, A., Gawade, A., & Nikam, N. (2023). "An Efficient Approach for Crop Disease Detection using Deep Learning," 2023 2nd International Conference on Automation, Computing and Renewable Systems (ICACRS), Pudukkottai, India, pp. 1907-1914, doi: 10.1109/ICACRS58579.2023.10404661.

[10] Bedi, P., & Gole, P. (2021). "Plant disease detection using hybrid model based on convolutional autoencoder and convolutional neural network," *Artificial Intelligence in Agriculture*, Volume 5, Pages 90-101, ISSN 2589-7217.

[11] Agarwal, M., Singh, A., Arjaria, S., Sinha, A., & Gupta, S. (2020). "ToLeD: Tomato Leaf Disease Detection using Convolution Neural Network," *Procedia Computer Science*, Volume 167, Pages 293-301, ISSN 1877-0509.

[12] S. S. R., K. K., & C. J. Raman. (2024). "An Accurate Plant Disease Detection Technique Using Machine Learning," *EAI Endorsed Trans IoT*, vol. 10, Jan. 2024.

[13] Vishnoi, V. K., Kumar, K., Kumar, B., Mohan, S., & Khan, A. A. (2023). "Detection of Apple Plant Diseases Using Leaf Images Through Convolutional Neural Network," *IEEE Access*, vol. 11, pp. 6594-6609, doi: 10.1109/ACCESS.2022.3232917.

[14] Khan, A. I., Quadri, S. M. K., Banday, S., & Shah, J. L. (2022). "Deep diagnosis: A real-time apple leaf disease detection system based on deep learning," *Computers and Electronics in Agriculture*, Volume 198, 107093, ISSN 0168-1699.

[15] R. R., Bhargavi, M., Reshma, S. B., Manasa, C., & Chandana, J. H. (2023). "Potato Leaf Disease Detection Using Deep Learning," 2023 9th International Conference on Smart Structures and Systems (ICSSS), CHENNAI, India, pp. 1-6, doi: 10.1109/ICSSS58085.2023.10407085.

[16] Demilie, W. B. (2024). "Plant disease detection and classification techniques: a comparative study of the performances," *Journal of Big Data*, Jan. 2024.

[17] Gurumurthi, V., Vishnupriya, & Manohar, S. (2023). "Recognition of Plant Leaf Diseases Using CNN." In *IoT, Cloud and Data Science*. Trans Tech Publications Ltd, February 27, 2023.

[18] Jadaun, A. S., Sharma, D., & Singh, K. P. (2023). "Automatic detection and classification of plant leaf diseases using image processing: A survey." *American Institute of Physics Conference Series*, Vol. 2930, No. 1.

[19] Bisen, D. (2021). "Deep convolutional neural network based plant species recognition through features of leaf," *Multimedia Tools and Applications*, 6443-6456.

[20] Hossain, E., Hossain, M. F., & Rahaman, M. A. (2019). "A Color and Texture Based Approach for the Detection and Classification of Plant Leaf Disease Using KNN Classifier," 2019 International Conference on Electrical, Computer and Communication Engineering (ECCE), Cox'sBazar, Bangladesh, pp. 1-6, doi: 10.1109/ECACE.2019.8679247.

[21] Ponni, S., Sathya, A., Ramakrishnan, S., Shafreen, M. I., Harshini, R., & Malini, P. (2022). "Optimal Plant Leaf Disease Detection using SVM classifier with Fuzzy System."

[22] Kolli, J., Vamsi, D. M., & Manikandan, V. M. (2021). "Plant Disease Detection using Convolutional Neural Network," 2021 IEEE Bombay Section Signature Conference (IBSSC), Gwalior, India, pp. 1-6, doi: 10.1109/IBSSC53889.2021.9673493.

[23] Kulkarni, P., Karwande, A., Kolhe, T., Kamble, S., Joshi, A., & Wyawahare, M. (2023). "Plant Disease Detection Using Image Processing and Machine Learning."