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An optimal secure and verifiable education content searching scheme for cloud-assisted edge computing

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Abstract: Cloud-assisted edge computing transforms service delivery by providing cloud-like services near the radio access network, ensuring low-latency services for mobile devices and alleviating significant pressure on the backbone network. The encryption and storage of multimedia data on untrusted cloud servers have prompted the adoption of searchable encryption for controlled keyword searches on ciphertext. Elevating online learning experiences requires sophisticated data analysis techniques, with Big Data playing a substantial role in efficiently processing extensive learning data and enhancing the value of E-learning platforms. Over time, E-learning management systems evolve into rich repositories of learning materials, enabling subject matter experts to reuse content for creating new online materials. To tackle challenges, we propose an optimal, secure, and verifiable education content searching scheme tailored for cloud-assisted edge computing. We introduce a lightweight encryption scheme for secure data storage and design a multi-scale quantum harmonic oscillator model to enhance content searching effectiveness and ensure accurate retrieval of educational information. Performance evaluation, utilizing benchmark datasets like Kaggle web contented, the CISI test set, and data from MAHE University, consistently validates the efficiency and feasibility of the proposed scheme for E-learning applications.
Keywords: E-learning, education content, online learning, lightweight encryption, secure data storage.

1. INTRODUCTION

As the demand for portable services continues to rise, there is shift towards running applications with high computational requirements, such as deep learning and self-driving technology, on mobile devices [1]. Despite the increasing intelligence of mobile devices, their computing power, storage capacity, and battery life remain limited compared to desktop computers. Executing complex applications on these devices can lead to poor performance and shorter operation times. To provide users with experience, divesting computation-intensive assignments [2] from moveable strategies to cloud data centers has become a standard solution. However, the exponential growth in mobile communications has resulted in massive mobile traffic, putting immense pressure on the backbone network where data centers are situated. This surge in traffic leads to high latency, significantly degrading user experience and posing potential issues for safety-critical applications. In response to these challenges, multi-access edge computing (MEC) has emerged as a computing paradigm [3]. MEC involves the flexible deployment of edge servers at the network edge, offering computing, storage, and software services for nearby mobile devices. This approach alleviates pressure on the backbone network, providing users with an enhanced experience. Nevertheless, the computing resources available on edge servers are limited due to space constraints, making it challenging for them to fully meet the diverse demands of mobile devices across different locations and scenarios [4]. In addressing this limitation, some scholars have proposed the concept of cloud-assisted MEC (CA-MEC), which introduces cloud support to edge servers [5].

In recent times, edge computing has shifted the functionality of cloud computing near network boundaries, emerging as a significant trend. Though, the inherent limitations of edge hosts, including constraints in computation, storage, and energy capacity, present numerous challenges, particularly in addressing workload fluctuations. When the workload surpasses the size of the edge host, it necessitates extending its capabilities by rental cloud examples to ensure user knowledge and Quality of Service (QoS) [6]. Conversely, when the dispensation capacity of the edge host, combined with tenanted instances, surpasses the assignments, releasing these instances becomes essential to save on tenanted costs. However, a potential risk of data damage arises if the tenanted instances are released straight. Therefore, it is imperative to address data migration issues before releasing tenanted instances [7]. Additionally, our ongoing focus remains on reducing response times. To achieve this, replicas can be strategically placed in advance within the edge host and tenanted instances, thereby minimizing response times and enhancing the overall user experience.

An effective strategy for enhancing privacy involves encrypting shared gratified before subcontracting it to cloud attendants. However, this encryption renders outdated plaintext retrieval methods inappropriate for encrypted gratified. Searchable encryption technology [8], allowing secure searches over cipher texts through keywords and selective retrieval of files of interest, is particularly crucial in the context of smart cities. In repetition, the server in the cloud is often seen as a semi-truthful but fascinating thing, capable of conducting a portion of search processes and returning false search results to users. Therefore, implementing a values confirmation instrument is essential to assurance the accuracy of exploration outcomes [9]. Additionally, access switch serves as additional safety method to ease gratified distribution in a manageable way, enabling owners to use switch over content access consents. Currently, ciphertext-policy attribute-based encryption [10], which supports one-to-many encryption, has proven to be a viable solution for fine-grained access control. For instance, an enterprise manager may have access to the entire records, while employees with lower access privileges can only access specific records. Assigning dissimilar access privileges to users based on their attributes is crucial for managing encrypted content effectively.

Our contributions: An optimal, secure, and verifiable education content searching scheme is proposed for cloud-assisted edge computing and the following key contributions to enhance the efficiency and reliability of the system.

1. A lightweight encryption scheme is implemented to ensure secure data storage. This scheme focuses on minimizing computational overhead while providing robust protection for educational data stored in local repositories. By employing advanced cryptographic techniques, the scheme aims to improve the reliability of data loading processes.
2. The proposed scheme incorporates a multi-scale quantum harmonic oscillator (MQHO) model specifically designed to enhance content searching effectiveness. This model introduces a sophisticated approach to information retrieval, leveraging quantum harmonic oscillators at multiple scales to optimize search accuracy. The multi-scale nature of the model allows for a nuanced and precise retrieval of educational information, contributing to the overall effectiveness of the content searching process.
3. The proposed scheme undergoes rigorous performance evaluation using benchmark datasets, Kaggle web content, CISI, and MAHE University. This evaluation assesses various aspects of the scheme, such as its efficiency, accuracy, and feasibility for real-world applications. The performance analysis aims to validate the proposed solution's effectiveness in comparison to existing frameworks and benchmarks, providing insights into its practical utility and potential advantages.

The following sections of the paper follow this structure: Section 2 delivers an impression of recently introduced technique for secure education content searching, discussing their merits and limitations as documented in the literature. Section 3 delves into the problem definition, system model, and the advantages of the projected work. Section 4 presents the fallouts and conducts a comparative analysis. Lastly, Section 5 completes this work.

2. RELATED WORKS

2.1 State-of-art works

Lin et al. [11] recommended a cutoff. Proxy creates a secure distributed storage system by combining a re-encryption algorithm with a decentralized erasure code. A distributed storage system not only provides for safe and resilient data storage and retrieval, but it also allows users to transfer data to storage servers without retrieving data for other users. The proxy re-encryption system provides encrypted message encryption as well as encrypted and decrypted message forwarding. They examine the amount of copies of messages delivered to storage servers as well as the number of storage servers requested by the primary server and provide recommendations based on their findings.

Liao et al. [12] suggested A scalable image mining system capable of supporting content analogy and search semantics in a distributed setting. Its core concept is to use local sensitive hashing characteristics to integrate picture feature vectors into a distributed hash table. As a result, without knowing the global information, photos with comparable content are aggregated into a node. To bridge the gap between low-level and high-level characteristics, we use the idea of matching in our system to recognize semantically closed pictures. They demonstrate that their strategy has a fast recall speed, effective load balancing, and needs less traffic.

Liao et al., [13] introduced LFFIR, a flexible image mining framework tailored for content-like search in distributed environments. The fundamental concept revolves around the effective integration of image retrieval based on multiple features into a peer model. LFIR, within this framework, amalgamates various features to encapsulate the overall characteristics of an image. The utilization of locale-sensitive hashing properties facilitates the creation of distributed indexes for streamlined merge operations. To assess system performance, the researchers developed a prototype system and conducted evaluations using two distinct image datasets. The results of the performance evaluations demonstrate notable improvements in both efficiency and accuracy when compared to advanced distributed image mining architectures.

Wang et al. [14] suggested an RMFSSRQ (Ranked Multi-keyword Fuzzy Search Scheme with Range Query) with Encryption Order Preserving and Locale-Sensitive Hashing. By designing an algorithm that facilitates the recovery of returned encrypted data, the technique accomplishes ranked fuzzy keyword matching. It can execute fuzzy search without the limits of a predetermined keyword dictionary and reduces the higher calculation and search costs associated with multi-keyword fuzzy search as compared to typical fuzzy keyword search techniques. Using two-layer BFs for each document, this approach can perform ranked multi-keyword fuzzy search and range query on cloud-encrypted data. Security research and test findings on real-world data sets demonstrate that this technique can meet the design goals of looking for keys in encrypted data while remaining secure.

Peddi et al. [15] suggested a based on the cloud mobile electronic wellness calorie system that can accurately recognize food items on a plate and calculate the overall calorie value of each item. We not only transfer the system's heavy computational activities to the cloud, but we also employ an intelligent cloud broker system to use cloud instances strategically and efficiently to give accurate and better reaction time results. The brokerage system employs a dynamic cloud allocation mechanism that makes real-time choices about the allocation and distribution of cloud instances, ensuring that the average response time remains within predefined bounds. When processing 60 photos in parallel, a dynamic cloud allocation approach is applied to lower average time consumption by 77.21%.

Li et al. [16] have focused The cloud provides an approach that frees data storage issues and cloud operators from accessing sensitive customer data. First, data collection faces a major challenge due to limited computing resources. When using big data, efficient synchronization with fewer users is desirable. The program proved useful when users found reliable communication configurations for an instant social network supported by reputation ratings. However, computing resources are under dramatic pressure when the number of big data users is high.

Muthurajkumar et al. [17] have proposed a temporally secure cloud graph reduction algorithm combines temporal constraints with graph reduction algorithms and chain mountain ciphers. The server stores graph reduction plans on all participating nodes. A cloud database system is made up of a collection of storage servers that offer ongoing storage and retrieval of information over the Internet. The graph reduction approach is utilized in this article to minimize energy usage in cloud data storage. A graph reduction task's execution duration is determined by the quantity of input information as well as the level of concurrency employed in transaction processing.

According to Rahim et al. [18], a trained CNN (Convolutional Neural Network) is utilized to extract features, which are then transformed into compact binary code using a deep auto encoder. The hash codes are returned to the mobile device, and they are kept in an encrypted table alongside the image's location. The ANN (Approximate closest neighbor) search method is used to quickly find needed photos without having to search the full image set. The main reason the public rejects automatic facial recognition services is that malicious hackers can track them from anywhere and search them illegally, especially if the computer is doing the search itself. However, this feature can make the system more intelligent in image search results, such as finding a list of pictures taken with a specific friend.

Handa et al. [19] suggested The notion of bucketization is an effective way to safe data retrieval. The typical amount of comparison per query is reduced as a result. Bucketization, in which keywords are allocated to buckets using consistent hash algorithms, was developed to improve search performance. The end user adds information relating to the query words to the query while constructing it. Because CS examines this bucket just to discover the document of interest, these bucket IDs assist decrease the time it takes to identify relevant documents. Using bucketization, this approach delivers 100% recall and 98.45% accuracy while lowering search time by 98.85% on the Reuters21578 dataset.

Elhoseny et al. [20] established a strategy for Improving VM Selection in Cloud-IoT Health Care Applications in Integrated Industry 4.0 to Effectively Handle Large Volumes of Data. The model intends to enhance healthcare system efficiency by shortening the time it takes to respond to stakeholder demands, improving the storage of patient large data, and offering a real-time data retrieval method for these applications. The four basic components of a hybrid cloud-IoT architecture are stakeholder devices, stakeholder needs, a cloud broker, and a network administrator. To create content search, evolutionary algorithms, PSO (Particle Swarm Optimizer), and PPSO (Parallel Particle Swarm Optimization) are employed to optimize the selection of VMs.

2.2 Research gaps

The effectiveness of the lightweight encryption scheme for secure data storage needs to be thoroughly evaluated to ensure its reliability. Challenges may arise regarding the encryption's robustness against potential security threats. The design and implementation of the multi-scale quantum harmonic oscillator model for content searching require careful consideration. Its complexity may pose challenges in terms of efficient integration and real-time performance. Challenges may emerge in achieving consistent and efficient results across diverse datasets. As the volume of educational content grows over time, the scalability of the searching scheme must be examined. Challenges may arise in ensuring that the scheme remains efficient and responsive as the size of the educational content repository expands. The results verification mechanism, crucial for ensuring the accuracy of search results, may face challenges related to false positives or negatives. Thorough testing and refinement are necessary to enhance the accuracy of the verification process. Incorporating cloud assistance in a manner that strikes a balance between rich resource utilization and high response times is a challenge. Ensuring seamless integration and optimal collaboration between edge servers and cloud resources requires optimal solution. Ensuring the adaptability to these changes is a challenge. Releasing tenanted instances to save costs poses the risk of data loss. Addressing these challenges will be crucial for the successful implementation and deployment of the verifiable education content searching scheme in cloud-assisted edge computing.

3. PROPOSED METHODOLOGY
3.1 Background study
As shown in Fig. 1, the proposed optimal, secure, and verifiable education content searching scheme for cloud-assisted edge computing comprises a systematic process designed to improve the efficacy, reliability, and security of educational data retrieval. Initiated by a lightweight encryption scheme, the method ensures the secure storage of educational content in local repositories, emphasizing confidentiality and data integrity. The introduction of a multi-scale quantum harmonic oscillator model adds sophistication to content searching, leveraging quantum harmonic oscillators at various scales for nuanced and precise retrieval of educational information. This process contributes to the overall reliability of data loading. Performance validation involves assessing the scheme against benchmark datasets, including web content of Kaggle, the CISI test set, and data from University of MAHE, enabling a comprehensive evaluation of efficiency against existing methods. The inclusion of a verifiability mechanism addresses concerns related to the semi-honest-but-curious nature of the cloud servers, ensuring the accuracy of search fallouts by detecting and rectifying false results introduced during search operations. This sophisticated access control system tackles challenges associated with providing different access privileges to users, ensuring that varying user roles receive appropriate access permissions while maintaining the security of encrypted content.

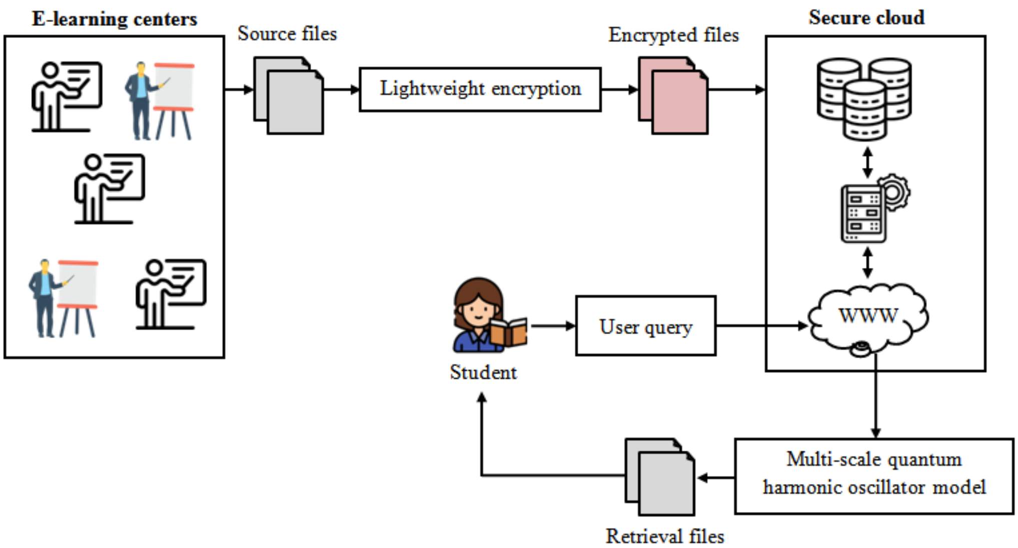

Fig. 1 Overall system design of proposed scheme

3.2 Lightweight encryption scheme
The lightweight encryption scheme introduced in the proposed optimal, secure, and verifiable education content searching scheme leverages the satin bowerbird optimizer to enhance the security of data storage. Satin bowerbird optimizer is nature-inspired metaheuristic optimization algorithm inspired by the mating behavior and nest-building activities of satin bowerbirds in the wild. This algorithm is known for its efficiency in finding optimal solutions in complex optimization problems. In the context of the encryption scheme, the Satin Bowerbird Optimizer (SBO) is employed to generate cryptographic keys or configurations that contribute to the encryption process. The lightweight nature of this scheme ensures that the encryption and decryption processes are computationally efficient, minimizing the computational overhead associated with securing educational content. The use of nature-inspired optimization algorithms, such as the SBO, adds a layer of sophistication to the encryption scheme, enhancing its robustness against

potential security threats. The specific details of the encryption algorithm, key generation, and how the SBO is integrated into the scheme may be outlined in the technical specifications of the proposed system. It focuses on striking a balance between robust security measures and computational efficiency, making it suitable for the storage of educational content in local repositories within the cloud-assisted edge computing environment. Along these lines, a male mimics grove working by choosing a thicket in view of its likelihood. This probability was established by. Fit_U is the fitness of the sixth solution, and NB is the number of bowers required to attain the Fit_U value.

$$XrOn_U = \frac{Fit_U}{\sum_{a=1}^{Av} Fit_a} \quad (1)$$

$$Fit_U = \begin{cases} \frac{1}{1+c(w_U)} c(w_U) \geq 0 \\ 1+|c(w_U)| c(w_U) \leq 0 \end{cases} \quad (2)$$

In this equation, the worth of the cost meaning at the eighth position, or bower, is referred to as $c(w_U)$. The cost function is one that should be optimized. New changes at any bower are calculated in accordance with during each cycle of the algorithm.

$$W_{Ul}^{New} = W_{Ul}^{Old} + \gamma_l \left(\left(\frac{w_{il} + w_{Elite,l}}{2} \right) - w_{Ul}^{Old} \right) \quad (3)$$

The Lth member of this vector W_{Ul}^{New} is the U-th bower or solution vector in this equation. w_{il} is selected as the target solution out of all the solutions in the current iteration.

$$\gamma_l = \frac{\alpha}{1+O_i} \quad (4)$$

The probability calculated using the goal bower and the largest step size are both included. With a specific likelihood, this step applies irregular changes to W_{Ul}^{New} .A normal distribution (A) with an average of W_{Ul}^{Old} and a variance of 2 is used for the mutation process here, as can be seen in.

$$w_{Ul}^{New} \approx A\left(w_{Ul}^{Old}, \sigma^2\right) \quad (5)$$

$$A\left(w_{Ul}^{Old}, \sigma^2\right) = w_{Ul}^{Old} + \left(\varpi^* A(0,1)\right) \quad (6)$$

The value of is a percentage of the space's width is compute as follows:

$$\varpi = P^* \left(\text{var}_{Max} - \text{var}_{Min}\right) \quad (7)$$

In varmax and varmin, variables have upper and lower bounds, respectively. The proportion of the difference between the upper and lower limits is the variable P parameter.

3.3 Content searching suing multi-scale quantum harmonic oscillator model

The multi-scale quantum harmonic oscillator (MQHO) model draws inspiration from quantum mechanics, particularly the harmonic oscillator system, which is a fundamental concept in quantum physics. In the context of content searching, this model is adapted to create a multi-scale framework that allows for a nuanced and versatile approach to information retrieval. The term "multi-scale" implies that the model can operate effectively across different levels or scales of educational content, accommodating varying degrees of granularity and complexity. The harmonic oscillator model, in its quantum form, involves energy quantization levels, and this concept is metaphorically applied to the educational content space. The multi-scale nature of the model enables it to adapt to the diverse nature of educational materials, offering a more refined and accurate search mechanism. By utilizing principles from quantum mechanics, the model introduces a level of sophistication that goes beyond traditional content searching algorithms, providing a unique and innovative solution tailored to the specific demands of educational information retrieval. The goal capability is subbed into the Schrodinger condition as a potential energy term is compute as follows.

$$\left(-\frac{j^2}{2a}\frac{F^2}{cp^2}+c(w)\right)\upsilon(w)=Z\upsilon(w) \tag{8}$$

The Schrodinger condition changes the improvement issue¨ from a deterministic issue into a probabilistic issue. As indicated by this quantum change and multi-scale process, the worldwide ideal arrangement of the goal capability can be approximated with high accuracy. The improvement issue F(p) can be extended by the Taylor grouping close to the worldwide least. To maintains the Taylor series' second-order term. After that, the Schrodinger equation becomes:

$$\left(-\frac{j^2}{2b}\frac{F^2}{Fw^2}+\frac{1}{2}lw^2\right)\upsilon(w)=Z\upsilon(w) \tag{9}$$

where the quantum harmonic oscillator's potential energy representation is 1 2 kx2. The wave function is as follows when the Schrödinger equation is solved:

$$V_0(o)=\frac{\sqrt{\sigma}}{\pi^{\frac{1}{4}}}z^{-\sigma^2o^2} \tag{10}$$

The probability density is compute as follows:

$$M(o)=|\upsilon_0(o)|^2=\frac{\sigma}{\sqrt{\pi}}z^{-\sigma^2o^2} \tag{11}$$

The probability distribution function is compute as follows:

$$C(o)=\int_{-\infty}^{o}\frac{\sigma}{\sqrt{\pi}}z^{-a^2o^2}Fo \tag{12}$$

The particle's position is determined by using stochastic Monte Carlo simulation:

$$o=\pm\frac{1}{\sigma}\lambda \tag{13}$$

Set Q = P x, the potential well's center, as the sampling center:

$$W=n\pm\frac{1}{\sigma}\lambda \tag{14}$$

where σ addresses the trademark length that relates to the complementary of the standard deviation in the Gaussian dispersion. This parameter is used as the scale parameter in the multi-scale process of the quantum harmonic oscillator algorithm, which is crucial to the algorithm's convergence.

4. RESULTS AND DISCUSSION

In this segment, we conduct a comprehensive presentation validation of the planned SBO-MQHO system using various standard datasets, including University of MAHE, Kaggle web gratified, and the CISI test set. The implementation of our SBO-MQHO scheme is carried out in the Google Colab reproduction situation, utilizing the Python programming dialectal. The presentation validation aims to assess the effectiveness and efficiency of the planned SBO-MQHO system across diverse datasets, each serving a distinct purpose.

1. MAHE University: Maintained by Manipal Academy of Higher Education (MAHE), this dataset comprises a substantial text document database consisting of 4,402,000 articles. The case studies conducted on this dataset focus on understanding how various MAHE institutions utilize paper and text documents. SBO-MQHO scheme is used to efficiently search and retrieve information from the documented text documents of the company.
2. Web content from Google: This dataset involves the retrieval and summarization of computer science content from well-known web search engines such as Google, AltaVista, and Yahoo. The content covers various computer science subjects, including networks, software engineering, database management, data structures, programming and

computer architecture. The experiment includes five different document sizes for each subject, resulting in a total of 20 topics.

3. Test Suite CISI: The Information Science exam dataset comprises 112 questions and 1,460 papers. The test set includes the entire text of the report, the subsequent source text, and a list of record influences. For each retrieved related document, details such as the takings list and credentials in the communication are provided.

Through these benchmark datasets, we aim to measure and show the robustness and versatility of the SBO-MQHO scheme in handling varied information retrieval scenarios.

Table 2 Comparative analysis of proposed and existing schemes for MAHE University

Schemes	Metrics (%)				
	Accuracy	Precision	Recall	Specificity	F-measure
LR	67.684	67.084	66.573	66.345	66.828
RF	71.253	70.653	70.142	69.914	70.397
K-NN	74.822	74.222	73.711	73.483	73.965
SVM	78.391	77.791	77.280	77.052	77.534
CNN	81.959	81.359	80.848	80.620	81.103
ANN	85.528	84.928	84.417	84.189	84.672
RNN	89.097	88.497	87.986	87.758	88.241
RCNN	92.666	92.066	91.555	91.327	91.810
SBO-MQHO	96.235	95.635	95.124	94.896	95.379

The comparative analysis of the proposed SBO-MQHO scheme and existing schemes for MAHE University, as presented in Table 2, reveals insightful metrics related to accuracy, precision, recall, specificity, and F-measure. Starting with Logistic Regression (LR), it demonstrates an accuracy of 67.684%, with a precision of 67.084%, recall of 66.573%, specificity of 66.345%, and an F-measure of 66.828%. Moving to Random Forest (RF), there is a noticeable improvement across all metrics, with an accuracy of 71.253%, precision of 70.653%, recall of 70.142%, specificity of 69.914%, and an F-measure of 70.397%. The K-Nearest Neighbors (K-NN) scheme exhibits further development, achieving an accuracy of 74.822%, precision of 74.222%, recall of 73.711%, specificity of 73.483%, and an F-measure of 73.965%. Support Vector Machine (SVM) continues this upward trend, demonstrating an accuracy of 78.391%, precision of 77.791%, recall of 77.280%, specificity of 77.052%, and an F-measure of 77.534%. Deep learning models, such as CNN (Convolutional Neural Network), ANN (Artificial Neural Network), RNN (Recurrent Neural Network), and RCNN (Region-Based Convolutional Neural Network), exhibit significant performance boosts. The accuracy increases from 81.959% to 92.666% across these models, with substantial improvements in precision, recall, specificity, and F-measure. Our SBO-MQHO scheme outperforms all other schemes, achieving an accuracy of 96.235%, precision of 95.635%, recall of 95.124%, specificity of 94.896%, and an F-measure of 95.379%. Fig. 2 signifies a notable enhancement in all evaluated metrics compared to the present schemes.

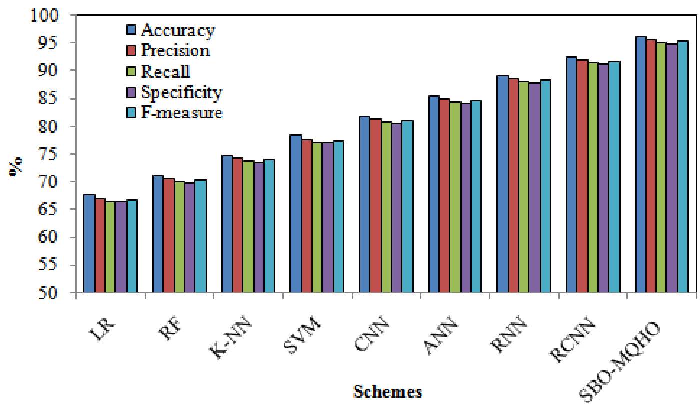

Figure. 2 Outcomes assessment of existing and proposed schemes for MAHE University

The comparative analysis of the proposed SBO-MQHO scheme and existing schemes for Web content from Google, outlined in Table 3. Commencing with the baseline model, LR exhibits an accuracy of 52.179%, precision of 51.839%, recall of 51.467%, specificity of 50.399%, and an F-measure of 51.653%. Subsequent models such as RF, K-NN, and SVM shows incremental improvements across all metrics, showcasing the progression from 57.811% to 69.075% accuracy. Deep learning models, namely CNN, ANN, RNN, and RCNN, exhibit substantial performance enhancements. Accuracy rises significantly from 74.707% to 91.603%, reflecting improvements in precision, recall, specificity, and F-measure. Remarkably, the proposed SBO-MQHO scheme outshines all other schemes with an outstanding accuracy of 97.235%, precision of 96.895%, recall of 96.523%, specificity of 95.455%, and an F-measure of 96.709%. This represents a substantial increase across all evaluated metrics, showcasing the efficacy of the proposed scheme in content searching for web data from Google. As shown in Fig. 3, our proposed SBO-MQHO scheme achieves remarkable improvement in accuracy, precision, recall, specificity, and F-measure when compared to the existing schemes, show its effectiveness in the context of web content retrieval from Google.

Table 3 Comparative analysis of proposed and existing schemes for Web content from Google

Schemes	Metrics (%)				
	Accuracy	Precision	Recall	Specificity	F-measure
LR	52.179	51.839	51.467	50.399	51.653
RF	57.811	57.471	57.099	56.031	57.285
K-NN	63.443	63.103	62.731	61.663	62.917
SVM	69.075	68.735	68.363	67.295	68.549
CNN	74.707	74.367	73.995	72.927	74.181
ANN	80.339	79.999	79.627	78.559	79.813
RNN	85.971	85.631	85.259	84.191	85.445
RCNN	91.603	91.263	90.891	89.823	91.077
SBO-MQHO	97.235	96.895	96.523	95.455	96.709

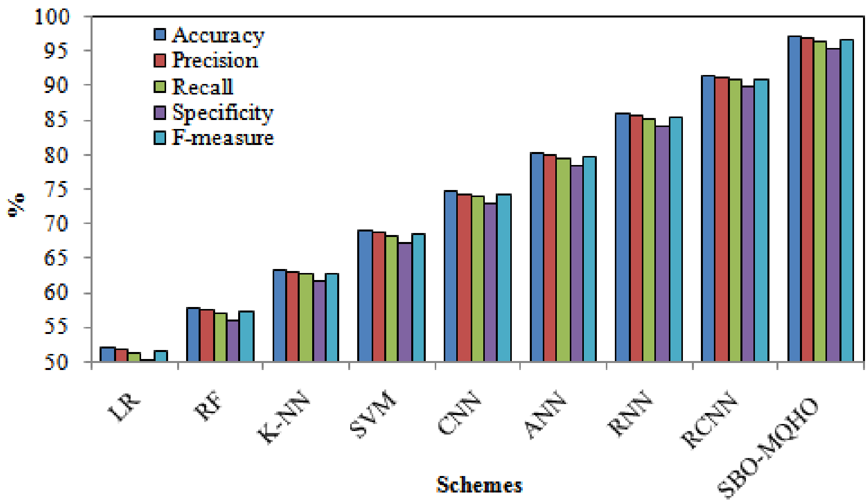

Fig. 3 Outcomes assessment of existing and proposed systems for Web content from Google

The comparative analysis presented in Table 4 evaluates the presentation of the planned SBO-MQHO arrangement against prevailing arrangements for the CISI Test Suite. Starting with the baseline model, LR, the accuracy stands at 59.931%, with precision, recall, specificity, and F-measure following suit. Subsequent models, RF, K-NN, and SVM, show an incremental improvement in accuracy from 64.532% to 73.733%. Deep learning models, such as CNN, ANN, RNN, and RCNN, exhibit further enhancements in accuracy, culminating in a remarkable 92.135% for RCNN. These models demonstrate a positive progression in precision, recall, specificity, and F-measure. The proposed SBO-MQHO scheme outperforms all counterparts, showcasing an exceptional accuracy of 96.735%, precision of 96.265%, recall of 95.824%, specificity of 95.176%, and an F-measure of 96.044%. This represents a substantial improvement across all assessed metrics, highlighting the superior efficacy of the proposed scheme in the context of the CISI Test Suite. Fig. 4 shows the SBO-MQHO scheme exhibits significant improvement in accuracy, precision, recall, specificity, and F-measure when compared to existing schemes, underscoring its effectiveness in content searching for the CISI Test Suite.

Table 4 Comparative analysis of proposed and existing schemes for CISI Test Suite

Schemes	Metrics (%)				
	Accuracy	Precision	Recall	Specificity	F-measure
LR	59.931	59.461	59.020	58.372	59.240
RF	64.532	64.062	63.620	62.972	63.841

K-NN	69.132	68.662	68.221	67.573	68.441
SVM	73.733	73.263	72.821	72.173	73.041
CNN	78.333	77.863	77.422	76.774	77.642
ANN	82.934	82.464	82.022	81.374	82.242
RNN	87.534	87.064	86.623	85.975	86.843
RCNN	92.135	91.665	91.223	90.575	91.443
SBO-MQHO	96.735	96.265	95.824	95.176	96.044

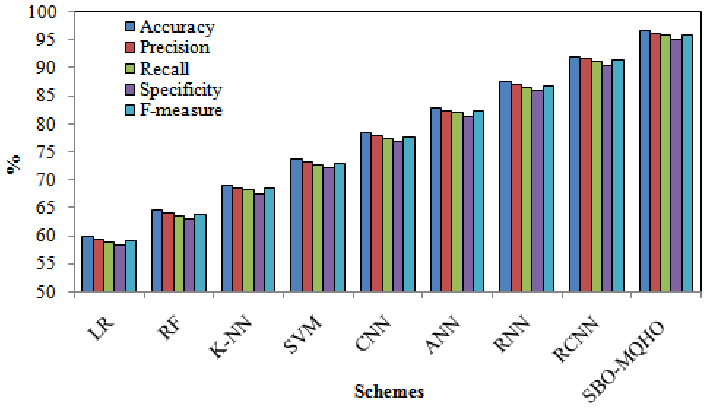

Fig. 4 Outcomes assessment of existing and proposed systems for CISI Test Suite

5. CONCLUSION

Our proposed optimal, secure, and verifiable education content searching scheme, specifically designed for cloud-assisted edge computing, has demonstrated remarkable efficacy. The scheme encompasses a lightweight encryption scheme for secure data storage and a multi-scale quantum harmonic oscillator (SBO-MQHO) model to amplify content searching effectiveness, ensuring the precise retrieval of educational information. The gotten fallouts show the effectiveness of the planned SBO-MQHO arrangement across diverse benchmark datasets. Notably, the accuracy percentages stand at 96.235%, 97.235%, and 96.735% for the University of MAHE, web content of Kaggle, and CISI test set, respectively. Additionally, the precision values exhibit consistent high performance, with percentages of 95.635%, 96.895%, and 96.265% for the three datasets. The recall percentages further underscore the robustness of the proposed scheme, achieving values of 95.124%, 96.523%, and 95.824% for the University of MAHE, web content of Kaggle, and CISI test set, individually. These compelling results affirm the proposed scheme's ability to achieve high accuracy, precision, and recall across diverse educational content datasets. Thus, the SBO-MQHO scheme presents a reliable and efficient solution for education content searching in cloud-assisted edge computing environments.

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