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REVIEW ARTICLE - COMPUTER ENGINEERING AND COMPUTER SCIENCE

Digital Quran Computing: Review, Classification, and Trend Analysis

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Abstract The proliferation of online digital multimedia content has enabled the rapid digitization of printed manuscripts, resulting in faster and more effective dissemination of digital publications. This scenario is also found in the context of digital Quran content, which has recently gained significant traction from the research and scientific communities with related discussions and studies covering a range of IT subject domains under the generic topic of Digital Quran Computing (DQC). In the past few years, a number of international conferences and symposia have been dedicated to the concept of DQC. This paper surveys and reports on the developmental trends and research hotspots in DQC, providing up-to-date theme categories and an analysis of published articles in the literature. First, the study provides a theme categorization based on the topical trends from recent conferences and symposia related to DQC. Second, a review is given for papers under each theme with a discussion of their key features, limitations, and research directions. Finally, a number of research hot spots that identify open challenges and primary areas in DQC for future work are outlined.

Keywords Holy Quran · Digital Quran Computing · Multimedia · Arabic digitization · Mobile applications · World Wide Web

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1 Introduction

The Holy Quran is the book of divine guidance and direction for humanity. It is the central religious text of Islam, which is the verbatim word of Allah (الله) [1]. Arabic countries have a history of vast recorded literature, which is not yet fully digitized. Converting such data into digital format is a challenging task for information systems and development based organizations. Considering that writing is the preferred method to express ideas and share information, traditional writing has now been integrated with digital documents using certain tools, such as digital pens, digital panels, personal digital assistant (PDAs), computer hardware, and mobile phones. Most of those tools employ touch sensitive screens, which assist the users in writing text on the screen as input to the device. However, today's online Quran and Islamic books are lagging behind in terms of employing structured digital content [2]. Moreover, security vulnerabilities within mobile applications for the Holy Quran are not clear and therefore lack in robustness to security threats [3]. Considering the importance of learning the Holy Quran and its sciences among all Muslims, and also due to the lack of available standard norms and learning environments, many

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research projects have been initiated in the general domain of IT for the service of the Holy Quran and its sciences. This paper discusses the latest learning methodologies and technologies used for digital Quran propagation, and reviews current practices and standards relevant to DQC.

Unlike other books in the world, the Holy Quran remains preserved and unchanged. Considering its significance, it is taught and memorized by millions of Muslims worldwide in the same form as it was revealed [4]. People memorizing the Holy Quran have to visit the institutions where it is taught to memorize it with the help of a dedicated Quran teacher. Muslims around the world find it difficult to find available Quran teachers to help recite the Quran correctly, particularly in non-Muslim countries. To overcome this difficulty, information technology is playing an important role to assist the Quran teachers by providing techniques for pointing out mistakes and provide options for distance learning. Arabic speech recognition techniques and learning management systems (LMSs) are some examples used to develop systems with the aforementioned capabilities. Among the many efforts done in the past by Muslims to safeguard the Holy book, one approach was to learn it by heart. Occasionally, the learners complain about forgetting despite spending significant time memorizing the Holy Quran. The research on the memorization of the Holy Quran in Malaysia has revolved mainly around the various techniques and methods used at different centers of *Tahfiz* and the effectiveness of these methods [5–7]. To overcome this difficulty, information technology has provided some new technologies to help learn the Holy Quran. For instance, a number of software and web portals have been developed to facilitate Quran recitation, translation, and learning. Such IT systems Quran software/applications cover many aspects of the Holy Quran, such as reading, memorizing, and recitations (both listening and practicing), and semantic search of the Quranic text is now being developed for mobile devices due to the internet accessibility of smart phones [8].

As readers of the Holy Quran are benefitting from information technology through the development of mobile Quran applications, the security threats and vulnerabilities associated with mobile Quran applications have also been constantly rising. These security threats are due to both the application developers and service providers. It is widely understood that applications such as banking, ecommerce, and medical applications are highly sensitive to security; a similar requirement can also be found in the case of Quranic content. Since many services are now transformed and presented using mobile platforms, the security aspect is also becoming very critical. Developers and platform providers are responsible for security flaws in such applications and are required to provide the robust tools needed to develop a secure mobile application that would guarantee security and protection of the published content/service as well as ensure the privacy of end user. Mobile Quran applications with features that enable users to read and interact with the Holy Quran must therefore provide the necessary level of protection. Any possible modifications that can compromise the originality of the Quranic content should be identified and resolved. It is a very challenging task to control the navigation and transfer of sensitive information and data through the Internet because of forgeries. Electronic tampering was previously detected in some versions of online digital Quran applications and was not detected by many regular users [9].

The Holy Quran plays an important role in the life of Muslims because many decisions in life are taken based on instructions from the Quran. The decisions made are totally dependent on the authenticity of the verses of the Holy Quran. Many Muslims cannot judge the authenticity of the verses quoted by the Holy Quran, and as such, they have to make an extensive search to confirm the as authenticity of the quotes. This task is very tedious and time consuming, especially when there are a number of missing words from the quotations. Typically, Quran verse quotations from online applications are compared with the verses of the original Quran to verify the authenticity of those quotes [10].

Many online applications quote Quranic verses, and therefore, it is very important that all those Quranic verses are authentic and free from any form of tampering and distortion. As such, the misplacement of a word is considered as an invalid quotation from the Quran. Therefore, an extensive mechanism should be developed to verify the authenticity of Quranic quotes and necessary measures should be taken to avoid and detect any tampering [11].

Currently, smart phones have already been used in many universities and schools as a classroom tool and as a medium of learning that enables students to engage in communication, collaboration, and participation [12]. This contemporary learning environment has made teaching and learning simpler, economical, and more interesting. Additionally, the use of multimedia elements in these applications would enhance the primary student's abilities that include listening, learning, and practicing for answering questions, and focusing on content. Furthermore, the mobile applications platform could in practice be seen as very advantageous in providing users with an on-the-go and mobile medium that suits today's education [13].

The main contributions of the paper can be summarized as follows:

- We present the most recent topics on DQC for learning and memorization of Quran in digital format with the help of information technology techniques for all groups of users.
- We highlight and discuss the major issues concerning the security and authentication of the digital Quran applications, with the state-of-the-art techniques for enhancing

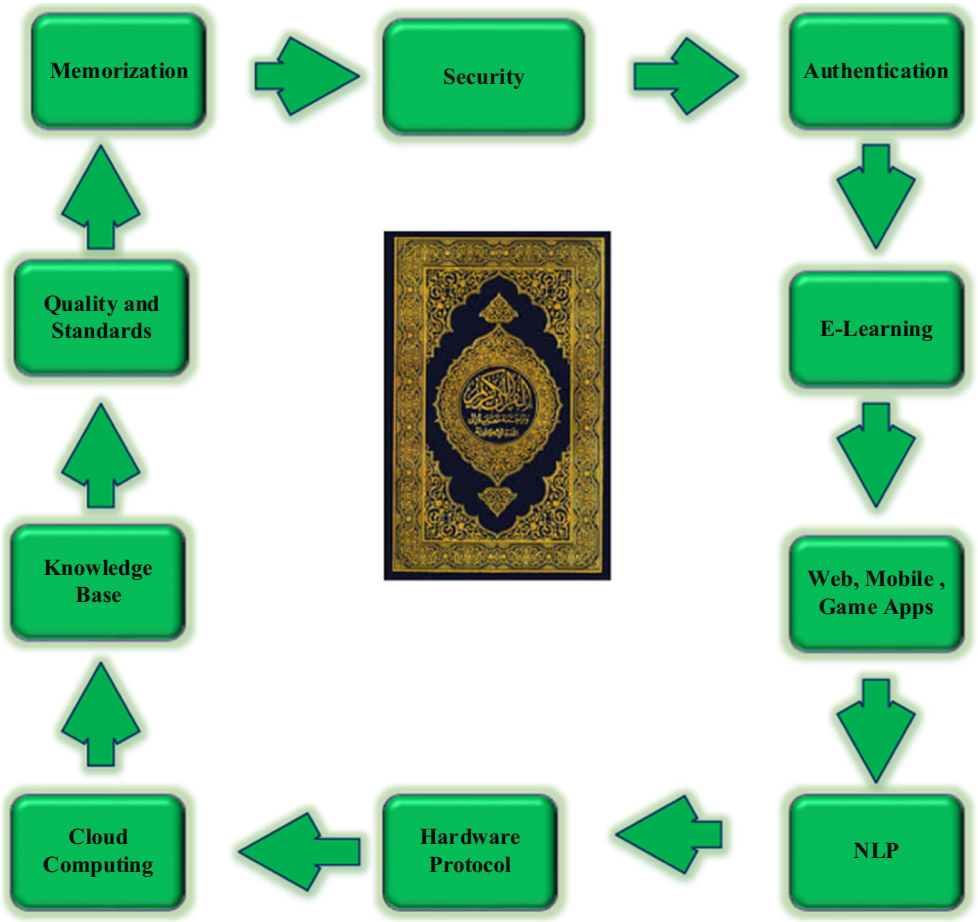

Fig. 1 Flow of the paper

the security of those applications against tampering and forgery attacks.
- We review the standards to maintain the quality of the digital Quran to preserve the authenticity of the digital version.
- We outline key recommendations and future research directions for researchers to help in further enhancing the area of DQC.
- We discuss, summarize, and compare all the techniques in a tabular format with key features, which include objectives, results, and limitations.

Relevant aspects to DQC that are reviewed in this paper are presented in Fig. 1. Additionally, Table 1 presents a detailed list of references categorized in together with taxonomy of the themes used. Table 1 categorizes papers in themes related to key areas including security, authentication, online learning, web and mobile applications, NLP, hardware tools, cloud computing, knowledge base sciences, quality, and standards. Table 2 categorizes those papers found in other themes that are related to voice recognition, role of IT for the service of Holy Quran, memorization tools, and standards in digital Quran applications.

The rest of the paper is organized as follows. Section 2 presents a literature review consisting of 13 subsections, which include almost all prior work related to Digital Quran Computing. Section 3 highlights open research issues and challenges, while Sect. 4 outlines future research directions in the area. Section 5 presents a list of recommendations with concluding remarks discussed in Sect. 6.

2 Literature Review

2.1 Security

The Holy Quran is now available on the Internet in the form of applications. Since many individuals are online all the time, this has facilitated the internet user to access the Holy Quran at any time. Software developers have exerted significant efforts to satisfy the online user, the gap between human and online Quran interactions has been reduced. Although online Quran has many advantages, there are also some draw-

Table 1 Taxonomy listing for the themes of related articles

Security	Authentication	Online learning	Web, mobile, and game applications for Quran	Natural language processing	Hardware and protocols for Quran	Cloud computing for Quran sciences resources	Knowledge base for Quran sciences	Quality and standards of the Holy Quran sciences resources
Norman et al. [14]	Sabbah et al. [15]	Zain et al. [16]	Ragab et al. [17]	Alfaries et al. [18]	Rasool et al. [19]	Hassen et al. [20]	Arbaoui et al. [21]	Boussenan et al. [22]
Shirali-Shahreza et al. [23]	AlAhmad et al. [24]	Abualkishik et al. [25]	Elsayess et al. [6,7]	Siddiqui et al. [26]	Wahsheh et al. [27]	Latiff et al. [28]	Haghighati et al. [29]	Elsayed et al. [30]
Al-Haidari et al. [31]	Tuncer et al. [32]	Saad et al. [33]	Jemaa et al. [34]	Nohuddin et al. [35]	Soliman et al. [36]		Saad et al. [37]	Ereksoussi et al. [38]
Tayan et al. [39]	Kurniawan et al. [40]	Al Abodi et al. [41]		Al-Kabi et al. [42]	Tayan et al. [43]			
Alginahi et al. [44]	Sabbah et al. [45]	Menacer et al. [46]		Najadat et al. [47]				
Kurniawan et al. [48]	Laouamer et al. [49]	Menacer et al. [50]		Yahya et al. [51]				
AlAhmad et al. [52]	Tayan et al. [53]	Nawaz et al. [54]						
	Kabir et al. [55]	Baig et al. [56]						
	Tayan et al. [57]	Mohamed et al. [58]						
	Alginahi et al. [59]	Adhoni et al. [60]						
	Tayan et al. [61]	Ragab et al. [17]						
	Tayan et al. [62]	Mssraty et al. [63]						
		Abdo et al. [64]						
		Yekache et al. [65]						
		Ibrahim et al. [66]						
		Tabbal et al. [67]						

Table 2 List of additional themes

Voice recognition	Role of IT for the service of the Holy Quran	Memorization	Holy Quran apps	Standardization of digital Quran
Elhadj et al. [68]	AlZoubi et al. [69]	Dzulkifli et al. [70]	Mobile [71]	Alam et al. [72]
Al-Hashmi et al. [73]	Algendy et al. [74]	Abro et al. [75]	Hadith [76]	Halimah et al. [77]
Harrag et al. [78]	Abdussalam et al. [79]	Hamiz et al. [80]	Quran Transliteration [81]	Baqai et al. [82]
Elhadj et al. [83]		Al-Mosallam et al. [84]	A.-M. Q. a. S [85]	Lazrek et al. [86]
Adhoni et al. [87]			L. Q. T [88]	Abudena et al. [89]
			P. Q. W [90]	Abdelhamid et al. [91]
			A.-Q. T [92]	
			Q. M. A. [93]	
			i. f. i. a. i. T [94]	
			Q. r. o. m. p. f. S. J [95]	
			Quran Recitation [96]	
			Q. M. S [97]	
			Z. T. Q. P [98]	

backs, such as that relating to the control and validity of such applications. Quran applications on the Internet are no longer 100% reliable since there is no standard procedure for the software developer or software firms to follow while developing a reliable Quran application. For this reason, the users are not fully satisfied on the content validity of the Holy Quran application. In Fig. 2, a pictorial representation is done, which classifies the Holy Quran security issues into two categories 1) Cryptographic algorithms and 2) Digital watermarking. Considering that the Holy Quran plays an important role in the daily life of Muslims, its authenticity is very important. The hard copies of the Holy Quran are printed in many Islamic countries such as Indonesia, Malaysia, and Saudi Arabia. Before being supplied to the local Muslims and in markets, the authenticity of the printed version is extensively checked to ensure its reliability. However, in the digital world, the use of Internet and mobile phones have proliferated the digital version of the Quran. Numerous versions of digital Quran applications are available on the Internet that can be freely downloaded. Since it is available for free on the Internet, the question of its reliability is raised, especially in Malaysia.

Many users are concerned of the authenticity of those software applications. Since the online contents are in software form, alteration is possible using available software tampering techniques to alter the contents of the online Quran. The availability of those techniques makes the users feel insecure about the contents published online. In Table 3, all the work done by researchers for the security of those applications are highlighted with the detailed objectives of each work, the core technique applied, the results obtained, and finally the limitations of each technique.

The authors in [14] applied a security management protocol to control the authenticity of an online Quran application. The security management standard explored is named as Systems Security Engineering Capability Maturity Model (SSECMM). The study investigated the common security criteria and the capabilities of SSECMM. These capabilities are then applied on the development procedure of secure online Holy Quran applications. In [23], the authors described the authentication issues and the methods to check the online content authentication online for Holy Quran applications. The protection schemes include verification of integrity, proof of authenticity, tamper detection, and copyright protection. Digital watermarking has played an important role in addressing security concerns in the present literature.

In the very recent publication about Quran authentication, text watermarking was applied in several studies. The earliest work found was in 2006 by Shirali-Shahreza, and Shirali-Shahreza [23]. In [23], the authors used Arabic language notation of dots(points) to store the embedded bits and hide them. The authors in [31] used *Kashidas* for Arabic text steganography, which has no influence on the Arabic text when hiding the secret data bits. This approach provides better security compared to other techniques as it used two words of Kashidas to store the secret bits [39].

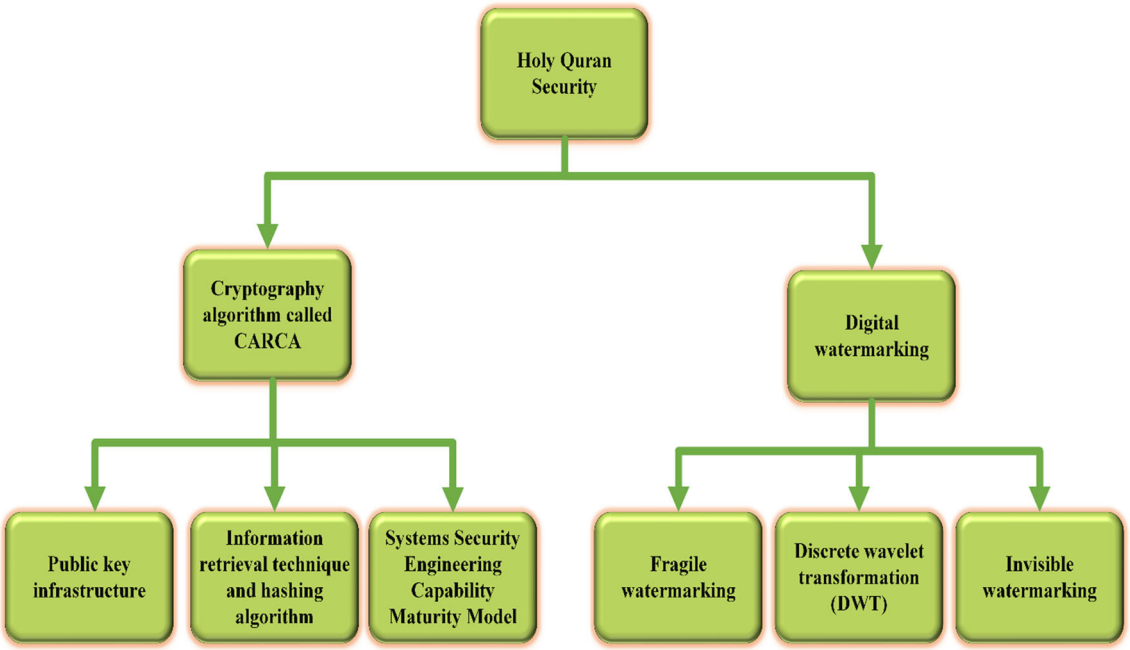

Fig. 2 DQC security approaches

The authors in [44] used Kashidas to embed the watermark but the techniques applied here involve invisible watermarking. Since text is the predominant mode of communication on the internet, the above technique is used as it secures and protects the text document. Kashida are placed to represent a "1" and omitted to represent a "0," depending of the predefinition of the watermarking key. When the algorithm goes through the document, a Kashida is inserted before a specific list of characters (ء،ا،أ،إ،آ،ئ،ذ،ر،ز،و،ؤ) until the end of the key is reached. If the end of the document is not reached, the algorithm is repeated with the remainder of the document by following the round robin approach until it reaches the end of the document.

The authors in [48] focused on verifying the integrity and protecting the contents of the digital Quran. In this work, a fragile watermarking method is implemented to embed the authentication bits in the wavelet domain and spatial domain. The proposed method involves parallel watermarking for the wavelet and spatial domains, which helps in improving the integration of watermarking technique. In addition, the encryption blocks applied in this work help in hiding the embedded watermark not known from intruders. The outcome of this work is very impressing, with both imperceptibility and detection of tampering activities.

The authors in [9] introduced a novel method to integrate the Quran images using watermarking. A fragile watermark approach is introduced with both frequency and spatial domains being considered for embedding the watermark. Initially, the input image is converted to the frequency domain with the help of discrete wavelet transformation (DWT). Thereafter, the watermark is embedded. The outcome of the method gives a robust image watermark for brute-force attacks. Furthermore, the blocks with the embedded watermarks are correlated, which helps in avoiding the attacks and increasing the robustness against collage attacks. This is achieved by applying the encrypted authentication code on the wavelet coefficients.

Alsmadi and Zarour [3] proposed an information retrieval technique and hashing algorithm to implement a Quranic authentication system. Many experiments have been conducted to evaluate the different characteristics that would influence the accuracy of the authentication process. The results suggested that hashing algorithm plays an important role in achieving more accuracy for automatic authentication with high confidence.

The authors in [52] proposed an cryptography algorithm called CARCA, which combines symmetric (AES) and asymmetric (RSA) cryptography. The protection of the Quran content is done by CARCA method, which encrypts the hash digest generated using Gear hash functions. The results show that the proposed hybrid method had improved the protection of Digital Quran content.

Mostafa and Ibrahim [99] presented an agent-based system on the internet for the security and verification of the digital Quran. To achieve this goal, the authors proposed a public key infrastructure (PKI) approach and a digital signature-based scheme. The proposed schemes require a well-known Islamic institute to play the role as authentication agency, which would verify the contents of the Quran for a subscribed Quran service provider as those of Al-Azhar or

Table 3 Security approaches for DQC

Ref. no.	Objective	Technique	Results	Features	Limitations
[14]	To achieve reliability state of online application of the Holy Quran	Systems Security Engineering Capability Maturity Model (SSECMM)	Determine the security management model suitable for the online application development of the Holy Quran	Explore the applicability of the common security management standards	N/A
[44]	To achieve the goal of text copyright protection and authentication	Invisible watermarking technique	Copyright protection, document authenticity verification, and document tamper proofing	Frequency recurrence statistics	N/A
[48]	Content protection and integrity verification of the digital Holy Quran	Fragile watermarking method	Watermarked image is imperceptible and fragile to the common attacks	Parallel watermark in wavelet and spatial domain	Vector quantization attack, low-pass filter attack, noise attack are not done
[9]	Authentication of Holy Quran images	Fragile watermarking method that works on block wise in the wavelet domain and pixel wise in the spatial domain	Detect any manipulation on the content of digital Holy Quran and thus preserves its content's integrity	Public key cryptography is utilized to encrypt the authentication bits, hash function is used	Blurring attack, noise attack, various image formats, watermarks on higher level of decomposition
[3]	Designing and evaluating a model to check the integrity of the tool the e-versions of the Quran	Hash algorithms	Automatic authentication process of Quranic verses based on information retrieval and hashing algorithms	Generating a meta data related to all words in the Quran	Same process and tasks can be applied to evaluate also Hadith
[52]	Protecting the digital Holy Quran	Symmetric cryptography "AES" and asymmetric cryptography "RSA"	Improve the protection of the digital Holy Quran Hash Digest	Introducing CARCA method, and two encryption algorithms	N/A
[99]	Secure and verify the content of Holy Quran script on the web	Agent-based system, public key infrastructure (PKI) and the digital signature	The proposed system assumes to have a well-known Islamic Institute, e.g., Al-Azhar or King Fahd Quran Complex (KFQC), to play the role of the authentication agency that signs		N/A

King Fahd Quran Complex (KFQC). The user can download the application from the authentication agency to verify the authenticity of the contents of the Holy Quran script.

In [100], an enhanced-Kashida encoding method was proposed. The encoding algorithms involved in the technique proved to yield enhanced robustness and improved imperceptibility as compared to the other Kashida-based methods in literature, while achieving our goal with a relatively low watermark capacity ratio. Advantageously, the use of frequency recurrence statistics of Arabic characters had enabled the dynamic variation of imperceptibility and robustness levels as required for a given target application as demonstrated in the results section. This shows the applicability of the presented methods for applications that include copyright protection, document authenticity verification, and document tamper proofing.

2.2 Authentication

In recent times, the usage of Internet and digital technology has increased exponentially. As a result, the distribution of digital media has become easy and more efficient. However, this also leads to the risk of spreading unauthorized and modified contents on the Internet. The digital media could be an image, a video file, an audio file or a PDF file with irreplaceable content such as the "Digital Holy Quran." To

Table 4 Authentication schemes

Ref. no.	Objective	Methodology	Results	Features	Limitations
[15]	Framework to detect and authenticate Quranic verses	Computing numerical Identifiers of words in the detected text, then comparing these identifiers with identifiers of original Quranic manuscript	The accuracy was 62% in average while the Precision and recall were 75 and 78%, respectively	Quranic verses extracted in a text from online source especially forums posts	Computational intelligence methods, which involve image processing
[24]	Watermarking PDF digital Holy Quran	Invisible fragile watermarking technique	Protecting the integrity of a PDF digital Holy Quran	DCT algorithm for feature extracting along with a Gear hash function to provide tampering detection	N/A
[10]	Develop a better framework to authenticate Quranic quotes	Quote authentication approach	Verify the Quranic e-contents over the internet	Algorithms that discuss the Quranic quotes	Developing the proposed algorithm on web services
[32]	Authenticate the raffle and to prevent the unauthorized distribution of printed or modified in establishing the digital samples	Watermarking techniques using steganography methods, XOR, LSB, and Border watermarking techniques are used	An authentication system is developed using watermarking	"XOR Watermarking Technique" and "LSB Watermarking Technique" have been found advantageous	Integrate the proposed system with the artificial intelligence system
[11]	Authentication of Quran verses	A zero watermarking	100% detection of any distortion made intentionally or unintentionally to Quran text	A key is generated for each verse of the Quran	N/A
[40]	Fragile watermarking method for digital Quran image authentication and tamper identification	Discrete wavelet transform (DWT)	The watermark is secure against local attacks	Watermark is encrypted using secret key	Other attacks can be considered, such as blurring attack and noise attack
[45]	Detecting the Quranic words in a text which are extracted from online sources	Support vector machine	Accuracy measurements achieved by the proposed approach are higher than the prior measurements	Different features categories such as the diacritics and statistical features are performed	Incorporating more machine learning and optimization techniques for achieving higher evaluation measurements

protect the copyright and the authentication of those media, Table 4 presents the techniques implemented in tabular format together with the objective of each technique, the core technique applied, and the ultimate results achieved followed by the limitations.

The authors in [15] presented a framework to detect the authenticity of the Quranic verses, which are extracted from online sources such as forums and posts. The entire framework is based on the assumption that the extracted text verses contain many diacritics (harakats). For texts containing fewer diacritics, other assumptions were also established to increase the accuracy of detecting the authenticity. The authentication methodology is based on comparison between the computed numerical identifiers of the original Quranic manuscripts and the identifiers of the detected text. Experimental results for both high and low diacritic text were highly encouraging. The accuracy was 62% in average while the precision and recall rates were 75 and 78%, respectively.

AlAhmad et al. [24] proposed a novel fragile watermarking technique for a Digital Quran content in PDF format. The generation of watermark was done by hashing the image features, which were extracted using the DCT algorithm to reduce the time consumption. Image features play an important role in this methodology to detect the tampering. The Selected Least Significant Bits (SLSB) algorithm is used to embed the watermark with less distortion in the color, which is more efficient at standing the statistical analysis than LSB.

The authors in [10] elaborated on the details of the algorithm used for detection and verification of Quranic quotes. The Quranic e-citations available on the Internet are verified by the user after knowing the details of the algorithm. The main purpose of the proposed algorithm is to confirm the authenticity of the Quranic quotes, which is based on the exclusive understanding of the Arabic language characteristics and the style of writing in the Holy Quran.

The authors in [32] presented an LSB and XOR watermarking scheme in the spatial domain for the color images. Both LSB and XOR were very advantageous in tamper detection. The XOR operation was found to be effective, such that it was not possible to extract the watermark without the original image. The security of the Quran could possibly be increased by integrating the proposed technique with artificial intelligence systems. The authors in [11] presented a zero watermarking approach to explore the characteristics of the Arabic characters without changing the text. The host verse characteristics play an important role in generating the watermark key. Each verses in the Quran would have a key generated by the proposed method, in which the name and number of the chapter is verified from the beginning. The verification authority has the entire key. During the verification process, the actual key was compared with the one stored with the verification authority. The results of the proposed method were 100% successful in detecting the random tampering for attacks and modifications, whether intentionally or unintentionally.

The authors in [40] developed a novel image authentication method to detect any alteration in Quran images and locate the place where tampering is done using a fragile watermarking method. The authentication code with both embedding and extraction of watermark is applied on the DWT and spatial domains. The experimental results show that, with minimum watermarking payload, the proposed technique could maintain high image quality and promising results for tampering and localization.

Sabbah and Selamat [45] proposed a machine learning approach, which detects the Quranic words from the text extracted from online sources. Support vector machines are used for the generation of learning models consisting of Quranic words, by training the learner with the training datasets of Quranic words. This learned classification model is then used to classify the real Quranic words taken from the online contents. A prototype was developed for different categories, including diacritics and statistical features, and experiments were carried out based on these features.

To protect the text image and to authenticate the source of the image, a novel watermarking approach was proposed in [49]. The experimental evaluation of this method was done on digital Quran text images for an ideal case study. The main contribution in this method was the found in the process of extracting the watermark from the attacked watermark image and the watermark image for perfect extraction of the watermark, which is used for invisible watermarking. The main outcome of this work was found in its ability for application with different sensitive data types such as digital text images with some graphical content.

The authors in [53] proposed an adaptive algorithm for text-based zero watermarking. The algorithm could then be used to protect all digital textual content from forgery and illegal content manipulation. Essentially, the algorithm works by embedding the watermark logo of the original publisher in an identical duplicate of the cover document to generate a characteristic key, which was then compared with the characteristic key of another sample document to prove authenticity and ownership.

The problem of text image protection and authentication was also addressed in [101] for digital Quran text images. The method was evaluated by measuring the similarity between the extracted watermark and the original watermark using two perspectives. In the first analysis, few mathematical operations are performed by making the extracted watermark as a function to the original watermark. In the second analysis, the researcher's digital watermarking community used pure empirical methods to detect the similarity.

The authors in [55] tried to explore the significance of the two parameters (word group set size and per-set accommodating the number of bits embedded) on the watermarking scheme used. These parameters were examined before the consequent impact on the capacity and imperceptibility properties of the watermarking scheme. The experimental results showed the effect of those two parameters, which had played an important role in optimizing the Arabic text application with desired capacity ratio level of imperceptibility. The paper shows how zero watermarking technique was applied for disseminating the sensitive textual content on the Internet with intact integrity for authentication of the data.

The work in [57] presents two watermarking methods, which are robust to attacks (Method A and Method B) and were also capable of detecting any modification to the data transferred. The authors in [57] carried out a comparative analysis of the results with the state-of-the-art techniques and concluded that two cost functions were specifically applicable to the target application with promising results.

The Quran quote verification algorithm given in [59] helped the user verify the Quranic e-citations over the Internet and provided confidence in the accuracy of the Quranic e-citations. The proposed system was executed in three stages, where each stage detects any intentional or unintentional tampering or distortion in Quranic quotations used in online text documents.

The authors in [61] proposed a novel algorithm for text-based zero watermarking. The algorithm was used to protect all digital textual content from forgery and illegal content manipulation. Essentially, the algorithm works by

embedding the watermark logo of the original publisher in an identical duplicate of the cover document to generate a characteristic key, which is then compared with the characteristic key of another sample document to prove authenticity and ownership. The zero watermarking approach presented in this study completely removed the vulnerability of watermarking attacks found in other/physical watermark-embedding approaches, since no data was inserted into the host cover document. The new design framework for text-based zero watermarking can help in the protection of text documents from attacks, which may be encountered during the transmission process.

The work presented in [62] proposes a novel hybrid approach involving concepts from digital signatures and logical text watermarking, independent on the underlying language, given that it can be encoded using standard Unicode. The proposed algorithm can be used to protect electronic documents and digital textual content from tampering, forgery, and illegal content manipulation, while removing many implementation redundancies and complexities found in previous schemes. Additionally, the proposed approach can achieve effective protection and authenticity verification, while its computational costs and quality of results obtained were completely practical.

2.3 Online Learning (E-Learning)

All the techniques applied for online Quran learning are listed in Table 5, with the highlight on the objectives for each work, the core technique applied, results achieved, and the limitation of each technique. Additionally, Table 5 is represented in pictorial format in Fig. 3, which lists all the categories of learning the Quran, including; blind people, children with Autism, and old people, using techniques like VLE and transliteration.

In [16], the authors described a proposed system for Braille Quran, that consists of many characters. The authors recommended dividing it into many volumes and bindings, as it becomes very thick to handle alone. The authors in [25] proposed a tactile system with many dots to help the blind to read the contents of the text by touching its dots instead of seeing it visually.

In [33], the authors developed a device for blind people to read the contents of a computer display, using a single line of the text in the form of a Braille characters called electronic Braille panel in order to recite the Quran. The architectural description of the system consists of several modules, one for storage of the database to store all the verses of the Holy Quran and one to display the *verse*. The reader selects the *verse* to read. The authors in their work proposed a system to recognize offline Arabic handwriting. The proposed system consists of three basic steps to recognize the handwritten Arabic contents. First, all Arabic characters were simplified into single pixels within images, which were then used to store the fundamental writing characteristics. Second, the stored single pixels were normalized into horizontal and vertical lines only. With this method, all the unique writing styles could be unified with the shapes of the characters being standardized.

Finally, the authors in [41] and [46] have designed the concept and architecture of learning the Quran and its sciences with a dedicated virtual learning environment to learn the Quran effectively and standardize all the available resources on the web and internet related to learning the Quran. All different technical aspects of the learning technologies were discussed in this work by providing a dedicated virtual system, which integrates various systems including a dedicated Quran learning management system.

The authors in [50] proposed a systematic approach to extract and collect the most relevant information in a structured manner from *Tafseer* books that were useful for academic purposes as well as for general use. The authors in [54] developed a system to recognize different words of the Holy Quran. Initially the system consisted of 23 attributes to recognize the words contained in the Holy Quran. However, as many as 70000 words were covered from the Holy Quran and relatively the number of attributes had also increased to 1.6 million. This study of information retrieval systems was examined using different fields, such as teaching and different research. The results of the proposed method led to the understanding of the Holy Quran along with its attributes.

In [102], the authors were concerned with educating children characterized by low functioning autism (LFA). Quran learning was achieved through the help of digital game-based learning processes and other related prototypes. Each prototype was designed after conducting a series of studies on various models selected to develop the prototype. In the process of learning the Holy Quran, the experiments had involved 15 children with age groups between 5 to 10 years to evaluate the effectiveness of the game for learning the Quran. The most effective prototype for LFA children was achieved with the game that had integrated five LACIP skills to learn the Quran interactively. The authors of [56] presented the development of a Quran recitation recognizer, which included a decoder with the capability of performing sub-word-level recognition at the phoneme level. During the training stage of the proposed method, the accuracy was increased by applying incremental refinements to the HMM models of the phoneme. Initially, during the HMM parameter estimation, the maximum likelihood (ML) criteria was applied, which allowed the average recognition accuracies to reach 83%. Thereafter, a discriminative technique was applied with minimum phone errors (MPE) to minimize the recognition error rate at the phoneme level. MPE was showcased to provide superior results, which are due to the minimization of phone errors.

Table 5 E-learning approaches for the Holy Quran

Ref. no.	Type of learning	Methodology	Results and outcomes	Features	Limitations
[33]	Braille	Electronic Braille panel	Blind people can read	Several modules and one storage database, inbuilt sound module	N/A
[41]	Offline Arabic Handwriting recognition system	Segmentation	Recognition of the characters with superior performance over the state-of-the-art approaches	Based on geometrical features of Arabic characters	N/A
[46]	Virtual learning environment	Integrates Quran Learning Management System (LMS), eMiqraa, and streaming of Media Quran	Quran learning management system		Additional development like Sharia law, finance, and Islamic education
[54]	Information retrieval system	Natural Language Processing (NLP)	Recognition of different words used in Holy Quran	Covered 70 000 of the words used in Holy Quran	Further enhanced to microlevel data structuring
[102]	The game in helping the process of learning Al-Quran	Digital game-based learning	Education of low functioning autism (LFA) children	Fifteen LFA children, age within five to ten years old will be conducted	N/A
[56]	Holy Quran recitation recognizer	Incremental refinements to the HMM models	The results show 3–4% improvement in recognition accuracies	Maximum likelihood (ML) criterion, minimum phone error (MPE)	Apply this speaker-independent recognition system for entire Holy Quran recitation
[58]	Blind people recitation by audio hearing	Google Speech API	Help to increase learners skills, attitude, motivation, grade, and knowledge while learning how to recite the Quran	Commands will be played back through the audio device for the blind people	Allow the students to learn the courses interactively
[60]	Transliteration of Quranic application in languages other than Arabic	Cloud-based programming interface	The transliteration of entire Quran in Urdu language has been successfully developed	Transliteration of the Quran in different languages	We look forward to report on portability issue

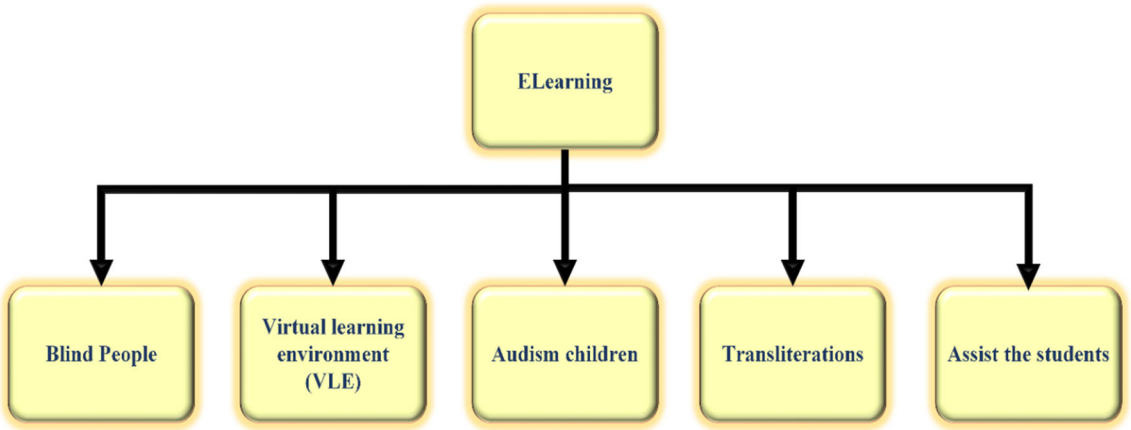

Fig. 3 e-Learning techniques for the Holy Quran

The authors in [58] focused on blind children, with the objective to assist the blind to use electronic online learning resources for the Holy Quran. The system was controlled by the blind child through the use of dictation which then enabled the system to fetch and playback the required audio content. The developed system was very interactive as it allowed the user to speak the command to be executed. Hence, this approach allowed the blind user to listen to the available prerecorded audio material repeatedly and as required in order to learn reading the Quran.

In [60], the authors proposed a unified framework that assists developers to build wide variety of Quranic applications for the purpose of retrieving knowledge. Quran search APIs are used to import many forms of transliterations into the Quran database. Recitation and transliterations are retrieved based on the search results. The proposed framework utilizes a cloud-based programming interface as a development environment to help develop Quran applications with the search feature of Quranic text in translation space, and in order to support developing Quranic applications in a languages other than Arabic.

In [17], the authors presented the design and implementation of a multimedia based e-learning Web site, which supports teaching the scientific encyclopedias and the miracles of the Holy Quran. The proposed interactive e-learning system assists students to improve their level of knowledge and literacy through the use of adaptive e-learning and multimedia technology. The system had consisted of an interactive navigation panel with effective presentation to assist student's interaction with the system. Other researchers used speech recognition techniques to assist the reader to read the Quran in its correct form. For instance the works in [63,64] describe a prerecorded Quran recitation system with multimedia and text to assist students to correctly recite the Quran. Additionally, the system provides a feature to correct mistakes using formal Arabic pronunciation. The works in [65–67] provided a positive contribution to the related research; however, the researchers focused on only one category of people while neglecting other categories, such as visually impaired and manually disabled people who cannot read.

The authors in [103] designed and developed a complete online cloud-based Quran portal. All the important themes and features of the Quran were included in the portal, and include "Al-Mushaf," "cross language information," "reciter and bookmarks," "translation and transliteration," "memorizer," "search," "social networking," "videos of scholars," "personalization or self-evaluation," "Quran for kids." An efficient framework was proposed in [104] for retrieving knowledge from the Quran related to scholarly text called 'DataQuest' and had modeled the information with the help of the semantic web. Different techniques were used for this purpose, including information extraction and natural language processing techniques. The study presented in [105] further explored natural language processing techniques and developed a Quranic search system (QSS), using the Z notation for expressing the formal specifications of three search techniques, which include text-based, stem-based, and synonyms-based systems used in QSS.

2.4 Web, Mobile, and Game Applications for the Holy Quran

Many digital Quran applications are available that allow offline users to read the Quran on mobile and handheld devices. This section describes several works from the research community that strive to provide various learning and platform techniques for reading and reciting the Quran.

The work in [17] presents the design and implementation of an adaptive e-learning Web site based on multimedia, which provides a scientific encyclopedia to teach the miracles of the Holy Quran. The work describes an interactive intelligent e-learning system that is dependent on adaptive e-learning systems and multimedia technologies to assist students in improving their level of learning. Additionally, the system has capability to assist students to find the most appropriate educational track for each student depending on the educational level. Support is also provided for selecting the suitable course and learning styles using adaptive navigation technology and adaptive presentation technology.

The "ReadVerse" company developed a prototype mobile application for teaching the recitation of the Quran. A major goal of the described system is to teach the proper pronunciation of the Arabic words. The described system uses the Arabic version of the Quran according to the rules of Tajweed as its basic teaching resource.

The work in [106] describes the development of a proposed application, the problems explored for creating the application, and the technical solutions used to overcome them. The paper in [34] presents a prototype for a comprehensive online encyclopedia for the Holy Quran and its sciences, based on a methodology presented during the conference titled "The Glorious Quran and Contemporary Technologies" and organized by The King Fahd Complex for the Printing of the Holy Quran in 2009.

2.5 Natural Language Processing for the Holy Quran and Its Sciences

Natural language processing (NLP) is the process of applying suitable extraction techniques to automatically extract information from the text content. Existing information extraction methods should be improved for further investigation by customizing the tools to support Arabic unstructured textual sources.

The work in [18] extracts Tajweed rules from the Quran text with the aim of providing the user with a tool to auto-

Table 6 Hardware and protocols for DQC

Ref. no.	Objective	Technique	Results	Features	Limitations
[19]	Optimization of Holy Quran	Dynamic broadcasting algorithm	Optimal battery consumption for portable devices	Switch between webRTC and WebSocket	N/A
[27]	Standardize common rules for identifying a secure, reliable, and effective way to transmit Holy Quran	HQTP (Holy Quran Transfer Protocol)	Reliability, integrity and availability of Quran Data	Header and payload to control the data and Quran translation respectively	Include more powerful cryptographic algorithms
[36]	Accelerating Quran applications	Architecture QrnPro	QrnPro executes multiscalar and vector instructions on the same parallel execution datapath	Uses VLIW Architecture and vector processing, data parallelism	Reduce the complexity of the decode stage and to increase the operating frequency
[43]	Authentic Quran propagation	Quran-on-Chip (QoC) subsystem within future multimedia product	Embedding the digital Quran content onto an ARM microcontroller	Compatible for embedding in other microcontroller architectures	Developing the prototypes into commercially viable solution

matically find the annotated letter. The purpose of the study was to explore this field by applying the IE technique for the Quran text. To achieve optimal results, rule-based IE techniques were implemented. GATE was used in this work to explore NLP techniques for Quranic text. GATE is an open source and flexible NLP environment; its basic purpose in this research was to build an application that processes an un-annotated Quranic text corpus.

In [26], a computational method was used to automatically discover the thematic structure of the Quran with the use of a topic model. Each chapter in the Quran was considered as an individual document and was used with latent Dirichlet allocation, a probabilistic topic modeling algorithm, to discover the topics/themes.

In [35], a combination of text mining and network analysis was used to extract keywords and identify relationships between keywords and chapters in the Tafseer of the Quran. The KCRA framework was proposed, which consists of (i) a keyword extraction module, (ii) a keyword–chapter relationship discovery module, and (iii) a keyword–chapter network analysis module.

The study in [42] tried to classify the Quranic verses according to the topics. The authors used the following four well-known classification algorithms: decision trees, K-nearest neighbors (K-NN), support vector machines (SVM) and Naïve Bayes (NB).

The study given in [47], applies special search options to extract the verses from the Quran with a single-word as the base for the query, depending on the meaning of the Quran's verse with additional features used as meanings to the search query. In other words, the exact meaning of the search query was added as the default search options for extracting the verses with the exact meaning of the search query. After the search was successfully completed, the search query was added as a search option which gives the user an ability to add new synonyms to further enhance the extraction process.

In the paper [51] describes a system design that collects all the necessary information related to Quranic grammar. The model was developed based on the XML language due to its compatibility and flexibility with various systems and environments.

2.6 Hardware and Protocols for the Holy Quran

All the hardware and protocols developed for the Quran are listed in Table 6. It highlights the objective of each study, the core technique applied, results obtained, and the limitations of this technique.

The authors in [19] developed an algorithm that automatically switches between WebRTC and WebSocket for portable devices in order to increase the efficiency of the battery. Moreover, it reduces the load at server by shifting broadcast to the browser in the presence of permanent power source or adequate availability of a battery source.

In [27], a novel networking protocol called the Holy Quran Transfer Protocol (HQTP) was proposed. HQTP presents an application layer protocol that aims to standardize common rules for identifying a secure, reliable, and effective way to transmit the Holy Quran (for both text and audio) over the Internet. Similar with other protocols, HQTP consisted of a header field and a payload field. The header contains control data that guarantees reliability, integrity, and availability. The payload contains the Holy Quran data as text or audio and other related information, such as Quran translation and explanation.

In [36], Quran applications were accelerated by a processor called QrnPro. The processor executes the data in parallel path with multiscalar and vector instructions, and provides a collection of modifications for a five-stage pipeline for (1) fetching 128-bit VLIW instruction (four individual instructions), (2) decoding/reading operands of the four instructions packed in VLIW, (3) executing four scalar/vector operations on parallel execution units, (4) loading/storing 128-bit (4×32-bit scalar/vector) data from/to data memory, and (5) writing back 4×32-bit scalar/vector results into the register file. Moreover, the study presented an FPGA implementation of QrnPro.

In [43], the authors proposed a system for end user devices with the functionality of playing and reading capability for the Holy Quran. The system concept was embedded in a single chip within an ARM microcontroller.

2.7 Cloud Computing for Quran Sciences Resources

Most of the Islamic manuscripts worldwide are not digitized yet. Such documents are very rich in knowledge and also constitute the heritage of Muslims. However, the weaknesses of current approaches and algorithms do not allow the possibility of digitizing those manuscripts. To achieve this goal, several researchers around the world proposed several algorithms, techniques, and approaches to develop an exclusive system for the purpose of digitizing the documents.

In [20], a key idea was presented in which cloud computing as an infrastructure was combined with K-NN/SVM for deriving an Arabic Islamic Manuscripts Recognition System (AIMRS). Additionally, cloud Storage as a Service (SaaS) was utilized to store and retrieve large amounts of Arabic Islamic manuscripts.

The authors in [28] proposed a grid-based architecture that offers a Quran Tafseer platform to facilitate the search and retrieval of information from different sources. Grid technology is deployed to increase the performance and the efficiency of the information retrieval process.

2.8 Knowledge Base for Quranic Sciences

There is a wealth of research and studies related to Quran and its Sciences that are largely not available online. The extraction of Quranic knowledge is a challenging task since the Quran is different from human literature.

In [21], a customized knowledge base system and its design concept was presented. The proposed Quran Research Knowledge base (QKB) was developed to manage the knowledge from research and studies concerning the Holy Quran and its sciences. The system is considered beneficial to researchers and organizations working in related areas.

The authors in [29] reviewed techniques used in the literature to reflect facets of interpreting the multilayered meanings of the noble Quran. Furthermore, descriptive statistical tools, such as stem-and-leaf plot, histogram, box plot, and cause-and-effect diagram, were proposed to enhance the knowledge extraction and pattern recognition within Quran verses. Finally, a scheme to relate the extracted Quranic patterns to IT applications for upgrading current IT systems was proposed.

The authors in [37] reported the extraction of knowledge from English Quranic translations using NLP techniques. The performance of the system was evaluated by using true-positive, false-positive, and false-negative metrics. The final outcomes of the experiments were very encouraging.

2.9 Quality and Standards of Resources for the Holy Quran and Its Sciences

Information technology has given the way for Holy Quran through the development of applications that have the capabilities of quick access, analysis, and indexing options. The capabilities of such systems include transfer of the information via the Internet. For instance, any companies/organizations have competed to develop online Quran systems. Since the information is very sensitive, it needs to be verified using some authentication and integration services. Establishing an authentic body requires standard rules for agreement between relevant stakeholders. In Table 7, the relevant standards are listed for quality applications related to the Quran and its sciences, together with the objectives for each study, the core technique applied, the results obtained, and the limitations.

The proposed standards should consist of key performance indicators, high-quality standards, and international benchmarking for accreditation. All the above features embody accreditation certificates for the accredited institutes.

The authors in [22] discussed the electronic management of Quran with three basic aspects being taken into consideration. The first aspect is related to the system with the problems related to searching and required objectives. The study was conducted on six sites of the Quran and was analyzed with an analysis tool. The next aspect was the theoretical aspect, which focuses on electronic management, knowledge, electronic Web sites, e-content development, and electronic publishing. The final aspect was the evaluation of those Web sites, which consist of technical and administrative standards, such as intellectual authority, use of multimedia, hypertext, digital files, interactivity, speed, rich features, hyperlink, and continuous updating.

In [30], the authors discussed a collection of regulations and standards to estimate the quality of the software. With the help of those standards, the IT Research Center for Holy Quran and its Sciences (NOOR) are able to estimate and accredit software that serve the Holy Quran according to the quality and standards specified. The proposed accreditation

Table 7 Quality and standards for resources of the Holy Quran and its sciences

Ref. no.	Objective	Technique	Results	Features	Limitations
[22]	Technical standards to control the quality and reliability of Information System to be used for the Holy Quran	Three important aspects related to electronic management of Quran Web sites are discussed	Products to receive the Quality Mark and Accreditation Certification from an accredited institution	Multiple management steps, systematic, theoretical, electronic management	N/A
[30]	Regulations and standards to measure the quality of Software systems serving the domain of the Holy Quran	Techniques to authenticate certification	Software is certified by the NOOR center	Accreditation validity, the rules of maintaining the accreditation and the conditions under which re-accreditation can be granted according to certain conditions	N/A
[38]	Correcting the present translations of the Holy Quran	Corpus studies of Quran translations	Correct translation and spreading the right message	This implementation needs shorter time and efforts	Does not contain all the translations of the Holy Quran

system follows certain rules and standards and does not allow accreditation of any software that does not adhere to the proposed standards.

In [38], the authors found that new approaches are urgently needed to aid corpus studies of Quranic translations. In particular, databases that contain the full corpora of the Quran and its translations are needed. The authors have considered two well-known programs intended for parallel concordance, namely; Word Smith and aConCord 0.4.3. However, neither of those programs could be used for our purpose since the Quran and translation are needed for appropriate punctuation before they can be processed. In short, if advances in IT could provide solutions for such limitations, it would contribute substantially in correcting the present translations of the Holy Quran, and hence, in spreading the right message.

2.10 Voice Recognition

Speech recognition has been envisioned as the future dominant method for human–computer interaction. Since the Holy Quran is written and transcribed in Arabic, it is considered as one of the main sources for the language. As a result, any improvement in processing the Arabic language from speech to text directly would be reflected in applications related to serving the Holy Quran.

In [68], a speaker-dependent recognizer based on phoneme was developed. The ML approach was used to model the training on the 30th part of the Quran. A phoneme inventory of about 60 phonemes was utilized in the experiments. The results obtained suggest that better performance could be achieved if geminate consonant sounds were removed. On the other hand, [73] suggested that all those techniques lack the discriminating ability of acoustic training like "Tajweed" to exactly describe the place and manner of articulating each sound along with its features.

The authors in [78] described the "Tajweed" rules taken from different Arabic language sources. The authors of [83] have made an attempt to list all the advanced techniques for the development of an environment that would make self-learning of the Quran easier. The study published in [87] used a cloud-based programming interface to design and develop a system that would translate the Holy Quran into different languages to assist users to recite and memorize the Holy Quran irrespective of their language. The main functions of the proposed system includes searching and translation into in different languages.

2.11 Role of IT for the Service of the Holy Quran

The roles of IT for the service of the Holy Quran are listed in tabular form in Table 8.

The authors in [69] discovered the best model that facilitates the perfect transfer and recitation of the Quran through using an online electronic Miqrah (recitation system) in which both Quran instructors and students communicate through voice and images directly. The proposed method has the following benefits: it supports Quran learning for those who cannot attend schools and supports distance education for students from different countries.

The study in [74] provided a draft of the recommendations/solutions required to address the obstacles in technical programming quality and its applications through a technology vision, and specialized legitimacy in application to the translation of Quranic stories. Considering that the process of

Table 8 Role of IT for the service of the Holy Quran

Ref. no.	Objectives	Technique	Results	Features	Limitations
[69]	Teach Quran recitations	Quran recitations online using electronic Miqrah	Remote Quran learning	Quran recitations for those who cannot attend school	N/A
[74]	Draft a recommendations/solutions to address the obstacles in technical programming quality	Technology vision, and specialized legitimacy	Translation of Quranic stories	N/A	Presentation and translation, there are still some obstacles for quality and technical presentation
[79]	Show how computers are used in serving the language of the Quran	N/A	Learning the Arabic text of Maqsurah ibn Duraid book	N/A	N/A

Table 9 Memorization techniques for the Holy Quran

Ref. no.	Type of memorization	Technique applied	Results accomplished	Features	Limitations
[75]	Language tutor using ASR technology with respect to Quran memorization	ASR technique	A system was developed for the task of automating the process of memorization of Quran	Identifies the major differences between simple (ASR) system and a language tutor	ASR technique which has proven to be incomplete method and thus need modification
[80]	Repetitive memorization Technique	Rule-based expert system	To help elderly memorize their Quranic Verses and improve their memory function	Optimize the memorization process	N/A
[84]	Visualization in Quran learning that will help in the memorization process	Mind maps technique in Quran memorization	Aims to help Quran learners memorize Quran easily	N/A	Implement this application and make it capable for including the mind maps

translating Quranic stories and its technical applications are subject to the rhetoric of the Arabic language, voice, complex structure, glossary, style and context must be preserved. It was concluded that such technological advancements remain primitive in this domain.

The work described in [79] used a model to show how computers are used in serving the language of the Quran (Arabic). The primary purpose of this research was to highlight the gap between the theoretical and practical aspects in learning the Arabic text named "Maqsurah ibn Duraid."

2.12 Memorization Techniques

Throughout many generations, Muslims worldwide have made many efforts to understand and preserve the Quran by memorizing it. However, this process requires that the learner memorizes and recites at a high standard. Hence, innovative technologies are needed to help students memorize the Quran with quality, while understanding its meanings and being able to connect its topics correctly. There are many applications developed to help memorizers with many features, including reading and listening, among others which are listed in Table 9 and represented in pictorial format in Fig. 4. Those approaches can be classified into: automatic Quran recognizers, mobile applications, and mind maps.

The study in [70], investigates the memory control process among a group of people who commit to memorizing the Holy Quran with accuracy and identifies the factors that help in effective and accurate memorization. The authors conducted an interview with those memorizing the Quran in order to determine the major factors effecting the memorization of the Holy Quran. Some of those factors include rehearsal, motivation, interest, and self-discipline.

The study in [75] addresses the need to help the students memorize the Quran by utilizing an automatic Quran recognizer as opposed to a human instructor. The authors differentiate between traditional automatic speech recognition (ASR) systems and human instructors and apply ASR technology directly for Quran memorization. The traditional ASR technique was not effective when applied alone for Quran memorization. Thereafter, the authors [75] investigated means to extend the technique. An artificial intelligence

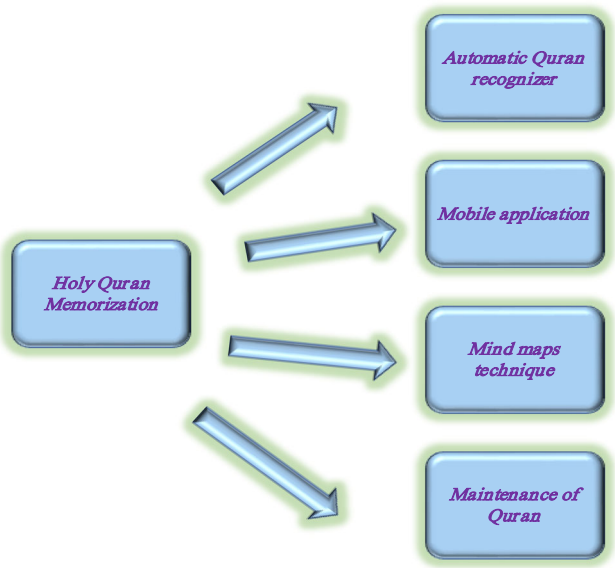

Fig. 4 Memorization techniques for the Holy Quran

(AI) technique was then applied with ASR in order to achieve higher accuracy for speaker-dependent Arabic (similar) sentence recognition.

The authors in [80] focused on elderly people interested in memorizing the Quran by assisting them with through the use of a mobile application. The system was developed following the design process developed according to a survey based on expert systems, which had identified the users' requirements for memorization based on past usage experience and optimization processes to support more effective memorization. The developed system included interactive features, portability and flexibility, which enhanced the functionality of the application. The outcome of this research had increased the spirituality and supported the memorization function among elderly people.

In [84], the authors followed the visual approach, which applies mind maps to help users in memorizing the Quran. The main idea of the proposed work depends on utilizing the visualization of Quran learning, which assists in the memorization process. This system uses mind maps to help learners understand the meaning of the chapter in an attractive manner. The system also helps the learner by splitting the assigned page to be memorized into smaller sections based on the topics, which makes the learner self-dependent. Finally, the integration between the mind maps and memorization process was found to assist the learner.

In [67], the authors proposed a speaker-dependent Quran recognition system. The SPHINXIV framework was used, with the system being developed with the help of the ML approach for acoustic training models.

2.13 Holy Quran Applications

Software developers have come up with many Quran related application for online and offline users of computer and mobile devices. The increase in the use of the internet allowed the users to browse and read the Quran, Hadith, and Islamic literature with ease. Furthermore, the increase in mobile phones and portable devices has had an impact on learning the Quran through those devices with Internet connectivity.

The Quran Mobile software [71] is a mobile application that helps users to read the Quran anywhere and anytime with translation and without the need for any Arabic support for the application to work properly. Alim.org [76] has developed a Quran and Hadith portal in the form of a social networking site with the main focus on various Islamic contents that include Tafseer, Hadith, and Islamic history. It also provides tools for memorizing the Quran. The Quran Transliteration site [81] was developed to help non-Arabic speakers to read and understand the Holy Quran. The user is able to translate the whole Quran in different languages and is provided with options for using colored characters.

Al-Mudarris Quran Software [85] claims to be an 'All-in-one Quran software solution'. The software supports functions for reciting the Quran, provides assistive memorization, and translates the verses of the Quran in different languages. Additionally, the software supports verse search and bookmarking with notes in addition to copying the verses and pasting them. Live Quran Tutoring [88] helps the user to learn the Quran online with many attractive categories for learning that includes Quran recitation and its lessons, reading the Quran with Tarweed, translating the Quran and memorization, and conducting recitation based quizzes/competitions. The Pocket Quran Website [90] is developed for all devices with J2ME, such as Pocket Quran for Android, Blackberry, Palm, Microsoft PC, Microsoft smart phones, Nokia series 9500/9300 phones, UIQ2, Nokia Series 90, and On-Hand/computers.

Al-Quran Terjemahan [92] is a new application for reading the translation of the Quran in the Malay language. A complete Quran software called Palm Quran was developed [93] in Arabic. This software does not require any Arabic support or any extension and runs on palm OS 3.5+. This software comes with an Arabic–Latin soft keyboard with additional Arabic character handwriting recognition ability. It has many features, including a high-quality display with two fonts (Naskh and Koufi). The display is flexible for both horizontal and vertical displays and has very advanced searching capability to include searches for all word root derivatives and highlighted words.

The all new iQuran III [94] software was developed for iPhones and iPod touch devices, which has the complete Quran written using Uthmani fonts and separate color codes for Tajweed and translation of verse The Quran Recitation

[95] software is currently compatible with many modern day mobile phones, including Nokia, Sony Erricson, Samsung, LG, Motorola, Symbian, Windows Mobile, HTC, Imate, Blackberry, and many more phone models.

QuranExplorer.com [96] is another Web portal developed in Oct 2005. It has many features, which includes translating with drop-down menu and audio translation. The Quran Majeed [97] software has many services to provide, such as searching verses online, reading the Quran in Arabic with other languages such as Urdu and English using various navigation themes.

The Zikr Quran [98] software is developed to run on windows like any other windows application. This software is completely filled with the most advanced features that include advanced searching, navigation, and recitation with commenting ability. The Al-Anvar [107] is an open-source software developed for conducting research in Quranic studies. It has many features that include advanced searching, commenting tools, grouping and indexing and special addons for different, translations and commentaries for many languages, with online and offline recitation.

A new free open-source [108] Quran application called Quran Android has been developed for Android devices. It has many features including updating the index, playback of audio with gaps, bookmarking verses, sharing verses, and audio recitations, with the support for streaming and downloading audio. Verse by Verse Quran [109] is an application particularly developed for memorizing the Quran and is also very effective for learning it. This Web site is developed to provide the users with free access to the Quran in MP3 format for individual verse playback.

GlobalQuran API [110] is used to develop a complete Quran Site Code in JavaScript, which is also available online for developers to use anywhere for customization and uploading of new customized layouts.

In [111], a cloud-based Quran portal is developed with the help of Drupal technology. This portal was made available for many purposes and is hosted using a cloud service to allow access from around the globe through the use of Internet services. This portal also includes many features such as providing learning resources for users. It is designed in such a way that any user can further enhance its features by developing a new tool and integrating it into the portal with the help of API's.

2.14 Standardization of Digital Quran

Significant efforts were found in the literature on the standardization of digital Quran content. The result of those works has led to the availability of the Quran in different formats, such as XML and SQL databases among others. Table 10 lists all the formats found relating to efforts for standardizing Quranic content, along with the objectives of each approach, the core techniques applied, the results obtained, and the limitations of each technique. Alongside the original Arabic text, various translations are also available to supplement the original text [72]. English translations of the Holy Quran were found to suffer from problems, such as misrepresentation and misinterpretation due to the recent increase in the number of different translation copies distributed that can lead to poor propagation of Islamic concepts and principles.

In [77], the authors worked on five different English translations of the Quran by applying the concepts, and principles as parameters for analysis. The results had suggested that there is an urgent need for a mechanism that would help in the formation of a standardized version of the translated copy that would be used as an authorized version worldwide.

In [82], semantic web technology is applied to standardize and model the knowledge extracted from the Holy Quran and religious texts. In [86], the authors proposed an idea to standardize the saved format of the digital Quran that would help in the verification process and enhance the outcomes of Arabic search engines by using the XML language as the core for developing the proposed model.

In relation to standardization of the digital Quran, the authors in [89] proposed a standard method for printing the Quran by using digital technology to facilitate the computerized writing of Quran text. Consequently, the large times and error rates associated with traditional Quran writing techniques, such as manual calligraphy, would be avoided. To solve the confusion created by the existence of many Arabic keyboard layouts, the Arab Standardization and Metrology Organization (ASMO) developed a standard for the Arabic keyboard layout as shown in Fig. 3.

The authors in [91] discovered the importance and capability of using ontology to link the verses of the Quran with the multimedia resources found on the Web. Based on the common ontology terms, the system was capable of dynamically searching the web for resources with the related verses of the Quran. Due to its expert Islamic knowledge, the MAT ontology of topics was chosen as the gold standard. It has the capability of arranging the verses of the Quran according to the context of the verses, which displays the exact picture of the meanings of the verses. The system initially starts with the data collection process that includes content from the Quran, AHadith, and related text. The stored information is then transformed into standardized format using the metadata generation process, which parses the collected text to extract the metadata.

3 Open Challenges

A number of open challenges are identified and discussed in this section to pave the way for further research in the field of DQC and in order to assist potential researchers to expose

Table 10 Standardization studies for the Holy Quran

Ref. no.	Objective	Technique	Results	Features	Limitations
[72]	Standardizing the representation of the holy scripture in the digital space	XML and SQL	Framework for defining and classifying the tags to Quranic verses	Tagging, hierarchal navigation, visualization	N/A
[77]	The translation of the Quran	Evaluate five different English versions of the translation of the Quran	A standardized version of an explanatory translation of the meanings of the Quran	Urgent need for a mechanism that will help using the formation of a standardized version	N/A
[82]	To model Quran domain knowledge	Semantic Web technologies	Enhance Quran knowledge by enabling queries in natural language	N/A	N/A
[86]	To standardize the saved format of the digital version of the Holy Quran	XML language	Facilitate the verification and to enhance the results of the Arabic search engines	N/A	N/A
[89]	Develop a standard for the Arabic keyboard layout	Digital technology to facilitate and computerize writing of Quranic scripts	Arab Standardization and Metrology Organization (ASMO)	Quranic keyboard "AL-DANI"	Writing the Holy Quran only by hand
[91]	Linking the verses of the Holy Quran with the multimedia resources found on the web	The MAT ontology	Arranges the verses of the Quran according to the context of the verses	Dynamically searching the web for resources related to the verses of the Holy Quran	Providing alternative solutions to the confronted problems, the proofing and filtering subsystem

themselves to such challenges and to provide solutions. The main challenges identified are as summarized in Table 11.

In [44], a detailed analysis is suggested for various potential attack scenarios, such as vector quantization attacks, low-pass filter attacks, and noise attacks in order to increase the detection accuracy for tampering. The authors from [9] suggest implementing their proposed system to evaluate with Hadith before ranking the websites that cite Quran verses based on authenticity. The reader is provided with the top list of Web sites with authenticated Quranic verses. The second phase of the work in [10] implemented the proposed algorithm using a web service as a prototype to provide integration and accessibility coupled with the use of a cloud computing infrastructure to enhance the framework.

In [40], analysis of other attacks were considered, including; blurring attacks, noise attacks, and others known attacks. The authors in [101] anticipated that the work of multimedia host–data/contents fall sunder the two major application domains of copyright protection and authenticity verification/tamper detection. The method to examine this work was described in [20], which involved deploying the proposed OCR application on a multicloud infrastructure. The process

Table 11 Summary of open challenges in DQC

Ref. no.	Challenges
[9]	Devise a ranking for Quran web sites with evaluation and AHadith
[10]	Enhance the proposed technique by further applying web services
[44]	Attacks like vector quantization attack, low-pass filter, and noise attacks should be tested for the proposed technique
[101]	Authenticity verification/tamper detection can be checked for copyright
[20]	Deploy proposed OCR application on a multicloud infrastructure
[21]	Expand and diversify the repository and try to collaborate with third parties
[29]	Develop a specialized powerful statistical toolbox
[78]	The dataset can be segmented and labeled
[70]	Development of standard Quranic dataset
[75]	Make the ASR technique to work as an automatic Quran tutor
[84]	Expand and obtain more detailed mind maps for the whole Quran

of creating a cloud computing service specialized in Arabic Islamic Manuscripts Digitization (AIMD as a Service) was not elucidated.

The challenge in [21] was to expand and diversify the repository and the collaboration process with third parties, with the objective to sustain the development and growth of the Quran Knowledge base system (QKB). Authors in [29] discussed the need for a specialized powerful statistical toolbox for Quranic research that covers aspects including phonology to morphology, syntax, and speech.

The proposed dataset in [78] requires a great deal of work to be done with segmentation and labeling in order to make it compatible with other types of linguistic studies. The challenge posted in [75] was to adapt the ASR technique for automatic Quran tutoring. In [84], a further challenge was to develop detailed mind maps implemented for the whole Quran. The major challenges for developing a system as in [70], were hindered due to the lack of available Quran databases for training the system under error and non-error conditions. The second challenge was that of checking the similarity of content in all verses of the Quran.

The mind maps described in [84] requires more detail and expansion of the work. Potential scope for future work involves implementing the application with the inclusion of mind maps for relating similar verses of the whole Quran.

4 Future Directions

This section lists several potential areas for future research and encourages researchers to address the open issues to advance the state-of-the-art in DQC. The areas identified for future work are represented in tabular format, together with the citations in Table 12.

The authors in [14] called on the need for conducting investigative research to explore and design a standard procedure for the development of a Quran environment for local use. The work in [23] can be further extended for electronic texts, which can be used for hard copy documentation. Additionally, the technique in [31] can be extended to work efficiently for other similar languages, such as Urdu and Persian.

Notably, the work presented in [39] opened a new track of research on multimedia security for DQC by investigating new trends and requirements for emerging Quran applications on smart phones. The authors in [48] suggested opportunities for further investigation by introducing different attacks, such as vector quantization, low-pass filter, and noise.

Furthermore, the work in [15] could be extended by calculating the identifier with distinct Quranic words and applying computational intelligence to further improve the detection and authentication rate. In [32], it is expected that the integration of the described techniques with artificial intelligence systems would result with improved security of the Quran content.

In [45], further work involves applying more machine learning and optimization techniques to achieve higher evaluation measurements, and incorporate such methods for improving the detection and authentication of Quranic verses from images.

The authors in [49] provided a number of future research directions that includes the need for multimedia watermarking techniques with some specific requirements of the host data to be investigated. Further work in [46] could also be considered, which would cover more general and specialized Islamic studies, such as Shariah law, finance, and Islamic education. The system proposed in [50] could be further extended to develop a microlevel data structure that can then be directed toward Quranic education and its research.

Table 12 Summary of future directions in DQC

Ref. no.	Future work
[14]	Conduct background investigation to develop local Quran environment
[23]	Extend approach to electronic text for hard copying
[31]	Extend technique to Urdu and Persian languages
[39]	Investigate the requirements of new Quran applications for smart phones
[48]	Investigate further using some known attacks such as vector quantization and low-pass-filtering
[15]	The detection and authentication technique can be further improved by applying computational intelligence
[32]	Artificial Intelligence can be used with the proposed method to enhance the security
[45]	The detection capability could be increased by applying machine learning and optimization techniques
[49]	Multimedia watermarking techniques could be implemented
[46]	More general and specialized Islamic studies, such as Sharia law, finance, and Islamic education could be undertaken
[50]	Develop a microlevel data structuring approach for Quran education
[54]	The system can be made more interactive by applying the attributes to each and every word of the Holy Quran
[102]	More advanced techniques could be incorporated such as margin-based classifiers
[56]	Makes the system more interactive
[58]	Makes the system portable
[18]	Applying rule-based IE techniques to Quran text to assist in developing applications
[26]	Apply this techniques to all the chapters of the Quran
[19]	Other API's can be applied to improve the accuracy
[27]	Better security could be achieved by adding a search request option

The work in [54] provides a future direction in terms of applying the attributes to each and every word of the Holy Quran and to make this system user interactive for Quran learners. In [102], further advanced techniques like margin-based classifiers could be incorporated to avoid the mismatch between training and test conditions for practical situations. Based on the study in [56], further research could be conducted to help the system become more interactive for the learners and help them by generalizing the idea and make them study their courses with ease.

In [58], the authors have developed a system that could be modified in the future and can be made as a portable system so that the users can access it from anywhere and obtain assistance from the system dynamically. The work presented in [18] could be further extended by applying rule-based IE techniques to Quran text to assist in developing applications for both Muslim scholars and students. These techniques [26] could be applied to all the chapters in the Quran, as it was not done in the current experiments.

The algorithm in [19] can be further improved for accuracy by applying other API's such as the system information API and the Network Information API, which would greatly improve the currently built communication backbone. In [27], more options such as add search requests and response services, and evaluation of the protocol could be included, which would result with improved transmission security.

5 Recommendations

This section provides recommendations on key aspects related to hotspot topics in the domain of DQC and of benefit to end users of digital Quran applications, researchers, developers and publishers. These recommendations are also listed in tabular format in Table 13 with the reference number of the relevant papers.

Security and Authentication

- Emphasis is laid on the need for monitoring other holy scriptures/content, such as AHadith (Prophetic narrations), that are available in a wide variety of digital formats and accessible on Internet-enabled smart mobile phones and portable devices.
- There is an urgent need to have an authorized International Quran publishing body solely dedicated and responsible for monitoring, scrutinizing, endorsing and publishing the digital copies of the Holy Quran and related content.
- A number of technical details need to be considered as trade-offs when investigating how new or existing approaches/algorithms may be applied for the specific attributes of digital Quran multimedia content [49,62,101]. For instance, investigation is required to determine the degree of complexity in the implementation as well as computational processing times, as in the case where real-time processing is required for the target application.
- In the case of watermarking-based authentication, a number of critical design factors need to be considered with care as per Quran application requirements, that includes robustness versus fragile watermarking, transform versus spatial watermarking, watermark visibility, (visible, semi-visible, or invisible), watermark extraction strategy (blind, semi-blind, or non-blind), content validation-only capability versus tamper detection and recovery capability, and robustness to attacks [49,62,101].

Table 13 Summary of recommendations

Security	e-Learning	Quality	Standardization	Knowledge	Translation
Monitoring other holy materials like Hadiths	Develop a draft standards to be followed for online learning platforms	Moving people away from tempting cybercrimes	Incorporate Hadith Ontology	Diversify the Islamic literature repository	Should be officially institutionalized
International Islamic Body solely dedicated and responsible for monitoring	Should be user friendly and interactive	Coordinating and collaborating with other Quranic and Islamic organizations	Extensive algorithms should be written		Translator should first strive not only to understand its multifaceted meaning
	Help the children in learning the Holy Quran speaker-independent recognition system for entire Holy Quran recitation				

- In general, the techniques and approaches employed should be extendable for processing different Quran writing styles, whether for image processing or OCR-based techniques.
- Finally, approaches are required for developing the research into productive tools for verifying content authenticity, capable of tracing resources back to the original publisher at any time. Such tools would be useful for a certification body or an authorized digital Quran publisher [49].

E-Learning Approaches and Quran Knowledge base

- It is recommended for application developers and researchers to collaborate in order to develop a complete standard to be followed for use with online learning platforms (systems), which would help in teaching the Holy Quran in an effective and up to data manner.
- The systems developed for online use should be user friendly and interactive to help the learner.
- Additional game-based learning approaches could be explored to develop a system that reflects its features more effectively and helps children in reciting and learning the Holy Quran.
- Apply discriminative training approaches for speaker-independent recognition systems suitable for Quran recitation.
- It is recommended to expand and diversify the existing Islamic literature repository with the collaboration of third parties, aiming to sustain the development and growth of a Quran knowledge base system (QKB).

Unified Translations

- The translation of the Holy Quran should be officially institutionalized and governmentally authorized. An official and authorized institution should be established to take responsibility of this crucial undertaking and be continuously following up readers' reactions, attitudes, and feedback on using the only official and authoritative translated version of the Quran for each language.

Standardization and Quality of Service

- The standardized version of the translated Quran should be suitable in all aspects and not subject to misunderstanding, misconception or distortion of any of the principal concepts of the original text, and thus maintain the language, spirit, and dynamicity of the original version as close as possible.
- Quranic organizations need to raise their performance levels. This can be achieved by providing quality products and services, as well as through coordination/collaboration with other Quranic and Islamic organizations working in the same domain.
- More extensive algorithms should be written that could cope with more complex and ambiguous user queries in Quran ontology.

Due to the importance for developing a unified and international standard in the domain of digital Quran content propagation and storage, this section identifies our preliminary investigations of key requirements and components, which are considered as essential for a standard applicable to DQC. The following lists such components and their requirements:

1. Domain of the Proposed Standard: Information Technology standard that is specific to digital Quran content propagation and storage.
2. Application Domain: Quran Web sites, mobile applications and other general applications software.
3. Support Types: The standard should provide coverage and compatibility for general software development tools and a large range of hardware devices existing in the marketplace.
4. Requirements specific to Quran and Islamic Rulings: The standard should include complete coverage of all the requirements from an Islamic perspective regarding the intended Quran application/product and its appropriateness.
5. Compatibility with Other Existing Standards: The standard should include those relevant aspects from current and related standards such as those from the World Wide Web Consortium (W3C) Web standards.
6. Quality Assurance Procedures: Compliance and adherence should be made with reference to other relevant and known IT and information security-based quality assurance procedures and requirements.
7. Use of Testing Tools: Testing and validation of technical aspects can be achieved using known and stable online validation tools.
8. Performance Measures: There should be clearly identifiable key performance indicators that rely on clearly measurable and quantitative parameters/metrics.

6 Conclusion

This paper has presented a holistic survey and analysis for Digital Quran Computing (DQC). This work has provided a comprehensive coverage to the current state of the art in the majority of areas related to digital Quran applications, their trends and challenges. A comprehensive and detailed survey was provided that encompasses most of the previous work and emerging issues related to DQC includ-

ing Quran authentication, e-Learning, mobile and game techniques, memorization techniques, natural language processing (NLP), standardization, and voice recognition. This paper has also outlined open challenges and future research directions, particularly related to the security and authentication of digital Quran content. The findings of this paper calls on the research community to provide technical solutions to solve outstanding problems such as tamper detection and prevention techniques to protect the originality of the Quran, and also sends a call for the establishment of an authorized body/monitoring agency for disseminating and monitoring the authenticity of online Quran publications. Such efforts need to be orchestrated and organized by Muslim nations and organizations to devise bodies, standards, and polices for monitoring and protecting the dissemination and propagation of online Quran content. Finally, a concise set of recommendations were highlighted based on key DQC hotspot topics and based on the reported findings discussed in this paper. Some of the main findings had recommended a number of opportunities for general improvements and expanding the work as well as specific technical design trade-offs that must be considered during implementation. Finally, this paper has proposed a number of essential components and their requirements as part of future standards applicable to DQC.

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