QuranVision

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Abstract

Tajweed is a set of rules, which is required for every Muslim to learn in order to recite the holy Quran. These rules are needed to guide Quran's reciters from making any errors, such as mispronouncing words which are strictly prohibited when reciting Quran. The conventional learning process on Tajweed rules, which comes in the form of face-to-face learning between instructor and the students, although considered the most effective way to learn Quran, may be tedious and time consuming due to the need for prolonged session of direct contact for learning. On that note, a mobile application which can detect and recognize the feature of Tajweed rules via image processing in al-Quran using a deep learning technology is proposed. Convolutional Neural Network or CNN is the commonly used technology when it comes to object detection and image classification. Model based on CNN architectures will be utilized in developing a real-time detection and recognition mobile application, focusing on Meem Sakinah-based Tajweed rules which include Idgham, Ikhfa' and Izhar Shafawee. The key benefits of this application is in its ability to detect Tajweed rules in a real-time scenario and works in both black and white and color-coded Quran. This application provides an alternative way for new Quran's learners from varying backgrounds and age to learn about Tajweed rules on their own time through visual and audio learning as well as detailed descriptions of the Tajweed rules which can aid in understanding the material more effectively.

1. Introduction

The purpose of this study is to address the challenges associated with learning and applying Tajweed rules in Quranic recitation, particularly for non-native Arabic speakers and individuals with limited access to traditional learning methods. Tajweed rules are critical for ensuring the correct pronunciation and delivery of the Quranic text, as errors in recitation can alter the meaning and sanctity of the verses. According to Alagrami and Eljazzar (2020), mistakes such as mispronouncing words during Quranic recitation can significantly change the meaning of the text, emphasizing the importance of adhering to Tajweed rules. Traditional methods of teaching Tajweed, such as *Talaqqi Musyafahah*, which involve face-to-face interaction and lip-reading between teachers and students, are effective but time-consuming and dependent on the availability of qualified instructors (Dahlia Omran et al., 2023). Furthermore, Kamarudin and Salam (2020) highlighted that non-native

speakers often face difficulties in distinguishing similar-sounding words and adhering to Tajweed rules, making the learning process more challenging.

This study is motivated by the growing need for an accessible, efficient, and automated solution to facilitate the understanding and application of Tajweed rules. With advancements in technology and the increasing use of mobile applications in education, integrating these tools into Quranic learning offers a promising alternative. According to Taufik Ridwan and Nuur Wachid Abdul Majid (2018), the ubiquity of gadgets in daily life suggests that mobile applications could serve as effective tools for Quranic education, especially for individuals with limited time. Additionally, Fiza Joiya (2022) noted that Convolutional Neural Networks (CNNs) are highly effective for object detection and image classification tasks, making them a suitable choice for developing a Tajweed detection application. The study aims to leverage CNNs to create a mobile application that detects and classifies Tajweed rules, providing learners with instant feedback and guidance.

The research adopts a structured methodology that begins with data collection, focusing on Quranic text images that feature Tajweed rules such as Meem Sakinah and its variations. Using these images, the study designs a CNN-based model to classify and detect Tajweed features. The developed model is then integrated into a mobile application prototype, which is the proposed QuranVision, enabling users to engage with an interactive and accessible platform for learning Tajweed rules. To ensure the reliability and effectiveness of the application, rigorous prototype testing is conducted, evaluating its accuracy, usability, and performance in real-world scenarios.

1.1 Literature Review

Tajweed is mandatory to ensuring accurate Quranic recitation, with errors potentially altering the text's meaning. Various studies emphasize the complexity of learning Tajweed rules, particularly for non-native Arabic speakers and those without access to traditional face-to-face teaching methods. Dahlia Omran et al. (2023) said that the traditional *Talaqqi Musyafahah* method as effective but time-intensive, while Alagrami and Eljazzar (2020) underline the critical implications of mispronunciations. These challenges motivate the integration of technological solutions to enhance accessibility and learning efficiency.

In addressing this need, researchers have explored diverse methodologies for Quranic recitation and Tajweed rule detection. Optical Character Recognition (OCR) combined with thresholding algorithms, as employed by Meidi et al. (2021), achieved moderate success in identifying Quranic characters but faced limitations in accuracy. Similarly, Zuraiyah et al. (2020) leveraged pattern recognition and SURF algorithms for Tajweed segmentation, achieving high detection accuracy but requiring specialized computational resources. Rahman et al. (2018) explored automated Tajweed checking using audio features like Mel-Frequency Cepstral Coefficients (MFCC) and Hidden Markov Models (HMM), demonstrating effectiveness for pronunciation correction among children.

Convolutional Neural Networks (CNNs) have emerged as a transformative tool in image detection and classification. Fiza Joiya (2022) highlights their advantages in automating feature extraction, making them ideal for complex tasks such as Tajweed rule identification. Among CNN-based object detection algorithms, the Single Shot Multibox Detector (SSD) has proven particularly promising for balancing accuracy and speed (Liu et al., 2016). Comparative studies, such as those by Chen et al. (2018) and Xia et al. (2019), underscore SSD's efficiency in real-time applications, while retaining robust detection capabilities across diverse datasets.

Despite these advancements, several gaps persist. Existing models often struggle with generalizability across Quranic text styles and fail to address the unique challenges of detecting specific Tajweed rules, such as Meem Sakinah. Furthermore, prior studies have focused on isolated methods, leaving opportunities for integrating CNNs into mobile applications that offer user-friendly interfaces and real-time feedback. This study seeks to address these gaps by developing a CNN-based Tajweed detection prototype, leveraging SSD architecture to classify and detect Tajweed rules efficiently.

By critically synthesizing prior research, this review underscores the need for innovative, scalable solutions to support Quranic education. The proposed approach combines insights from multiple methodologies, integrating them into a comprehensive framework that addresses both the limitations and potential of existing systems. This ensures the study's contribution is both contextually relevant and practically impactful.

2. Research Methods

In order to complete the QuranVision application, it has to go through few phases involving preliminary studies, knowledge acquisition which involves doing literature study in order to determine the domain, scope and suitable techniques for this application. Secondly, data acquisition and data preprocessing phase. Followed by design, development, prototype testing and documentation phase. The workflow of research phases is illustrated in Figure 1 below.

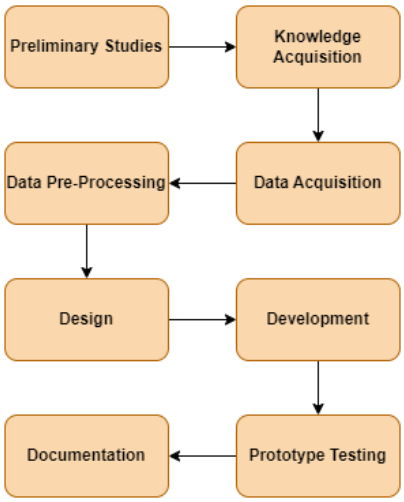

Fig. 1 Research phases of QuranVision development

In order to initiate the preliminary studies, this study has outlined three research questions and three research objectives. This help the study to focus on what the domain of study should be and define the outcomes which the study is heading forward to. This helps researcher to keep track of the progress and guide the research processes. Below is the research questions and objectives:

Research Questions:

- How to identify the features of Tajweed rules?
- What is the suitable CNN architecture to detect and classify Tajweed rules?
- How to develop the prototype application for detecting Tajweed rules?

Research Objectives:

- To identify the features of Tajweed rules.
- To construct a model for Tajweed rules detection using CNN architecture.
- To develop a prototype application for Tajweed rules detection using CNN.

As for the data acquisition phases of this study, the data collection focused on Quranic text images containing Tajweed rules, particularly Meem Sakinah and its associated rules (*Ikhfa' Shafawee*, *Idgham Shafawee*, and *Izhar Shafawee*). Images were captured manually from physical and online Quranic texts using a Realme GT2 smartphone camera and snipping tools. A dataset of over 2,000 annotated images was compiled, ensuring accuracy and consistency through cross-referencing with Tajweed books and Quranic texts. Sample of images is shown in Figure 2 which sources from digital Quran (left) and physical al-Quran (right).

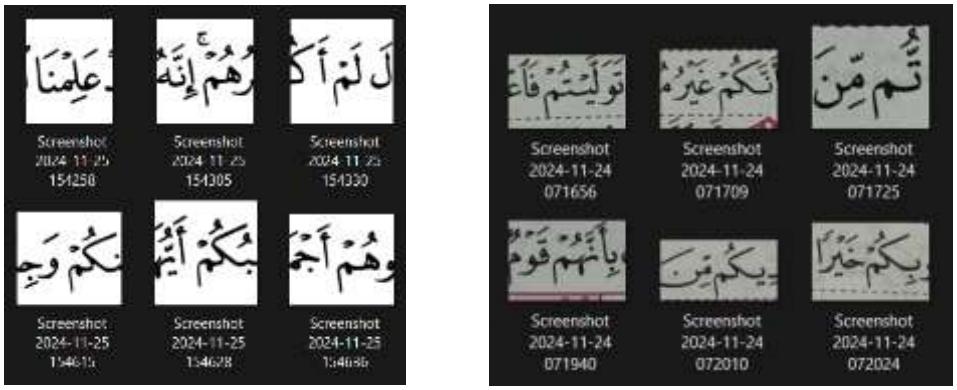

Fig. 2 Example of images that has been collected from online and physical Quran

After data has been collected, the images is uploaded to Roboflow for data pre-processing phase. Annotation was performed using Roboflow, a tool designed to facilitate object detection tasks. Bounding boxes were manually created around specific Tajweed features, such as *Meem Sakinah* and its related rules (*Ikhfa' Shafawee*, *Idgham Shafawee*, and *Izhar Shafawee*). These annotations provided precise location information for the targeted features, enabling the CNN model to learn their spatial characteristics effectively during training.

After annotations had been made to the images, data normalization was carried out to standardize the dataset and minimize variability caused by differing image properties. All images were resized to a uniform dimension of 640x640 pixels. This resizing ensured consistency across the dataset while reducing the computational load during model training. Additionally, the images were converted to grayscale to simplify their representation, as color information was not essential for detecting Tajweed rules. This step significantly reduced the dimensionality of the data, making the model training process more efficient without compromising detection accuracy.

Data augmentation also has been made to the original annotated data, in order to increase the variability in the dataset images so that the later-trained model can detect the rules even in different conditions and scenarios. Augmentation that has been made are as said before, gray scaling the images, adjusting the hue of the images, between -10% and 10% and lastly, adjusting the brightness from -12% to 12%. Figure 3 below shows the annotation phase in Roboflow and the normalization and augmentation made to the dataset.

Lastly, in data pre-processing phase, the dataset is balanced into 8:1:1 ratio which stands for 80% for training, 10% for testing and 10% for validation.

Fig. 3 Annotation and augmentation made in Roboflow tools.

The next phase of this study is the design phase. This will include two main processes which are mobile application design and model design. As for mobile application design, Figma is used to make a simple interface design and prototyping for the mobile application. As for the model design for QuranVision, it is based on the CNN that has good capabilities on image data and high degree of accuracy for detecting images. This research use CSP2SA (Convolutional block with Parallel Spatial Attention) for the feature extraction along with C3k2 (Cross Stage Partial with kernel size 2) block for improved efficiency and utilizes SPPF (Spatial Pyramid Pooling – Fast) in YOLOv11 architecture. Figure 4 shows the flowchart of QuranVision model design which highlight the fusion of CNN technique in its architecture (left) and mobile application design in Figma (right).

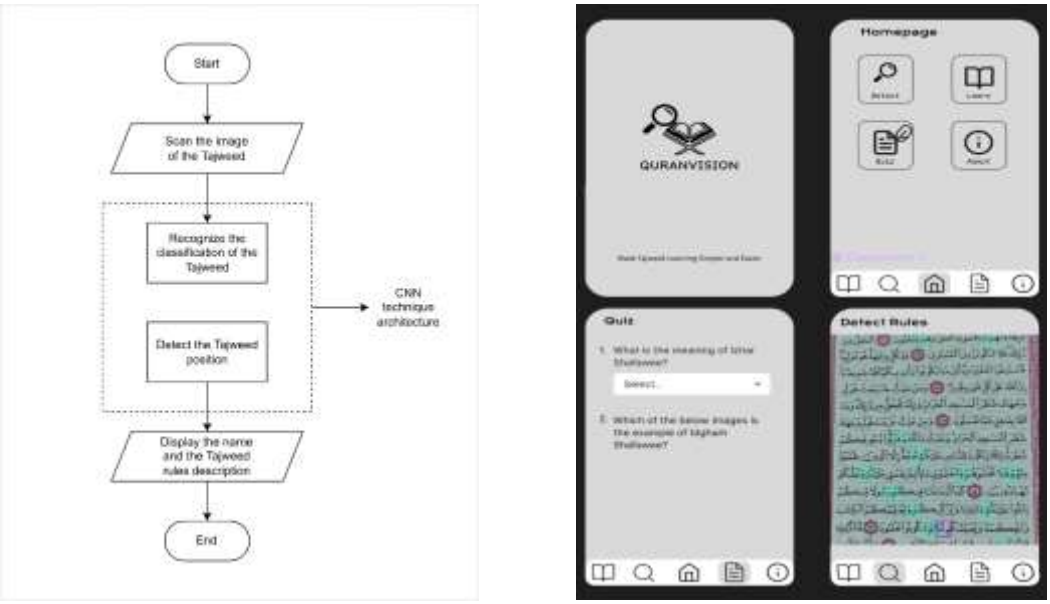

Fig. 4 Model design and mobile application design.

The next phase of this research is the development phase which is done through 2 types of platforms namely Visual Studio Code for the model development and Android Studio for the mobile application development. For the model development, first thing that needs to be done is creating a clean python environment for installing dependencies needed to run the model. Next step is installing pytorch, torchvision, and ultralytics. After environment is ready, dataset is downloaded from Roboflow. Before start training the data, the data.yaml file needs to be edited first in order to update the train, test and validation folder location according to their locations on the local machine. After that, the training process starts by writing the command in python terminal in VS Code. After finished training the data, the result will be saved in the file system of the computer

that contain weights folder for best model, graph curves, train and validation images, training epoch results in csv format, etc. Figure 5 below shows the training code and results folder.

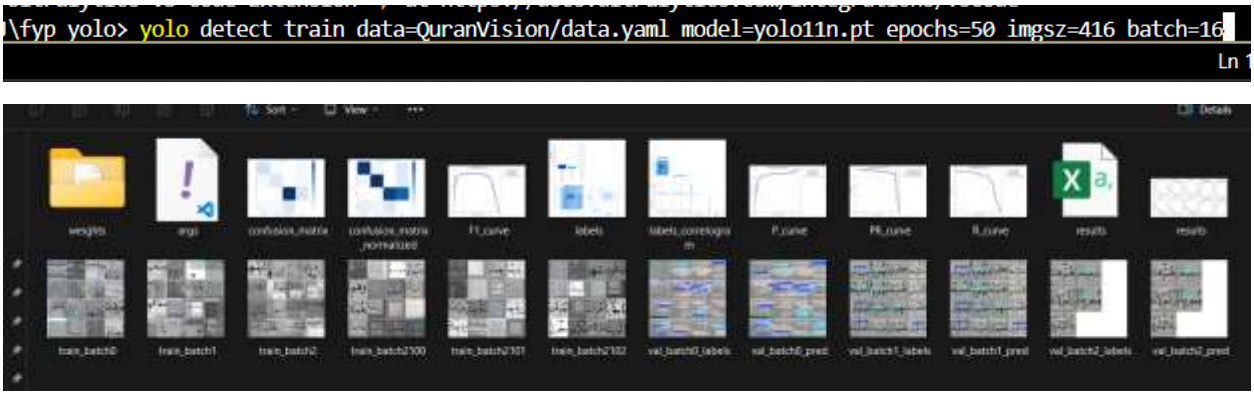

Fig. 5 Training code and results folder.

The mobile application development is conducted in Android Studio using Flutter:Dart language. This enables the QuranVision mobile application to run on both Android and IOS devices. In this process, the integration between the produced image detection model and the mobile application will be done. Figure 6 below shows the environment for which the QuranVision mobile application is developed on.

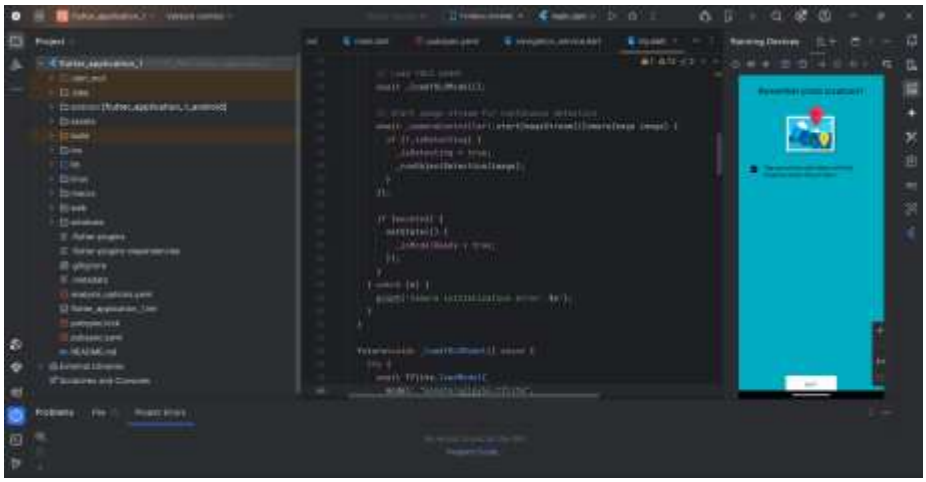

Fig. 6 Android Studio environment for developing mobile application.

Following the development process, the prototype testing phase begins. Several experiments are carried out to evaluate the prototype application's reliability and accuracy. This phase includes detecting and checking for errors so that they can be fixed. This phase also includes trying the trained models to choose the most feasible models for integration into the mobile application.

3. Result and Discussion

Discussion of the findings in this research was based on hyperparameters settings, which are decided upon executing the built-up configurations. Those hyperparameters is fine-tuned as tabulated in Table 1, in order to achieve the highest level of performance and accuracy fueled by 2500 data involved to complete the whole experiments.

Table 1. Parameters for Experiment 1 and 2

Parameters	Experiment 1			Experiment 2			
Dataset size	2.5k+			2.5k+			
Learning rate	0.01			0.01			
Train: Valid: Test Ratio	8:1:1			8:1:1			
Input size	32	128	416	128			
Epoch	50			50		100	
Batch	16			16	32	64	128

The integration of the model into the application allows for real-world testing and enables the assessment of its functionality and effectiveness in detecting and recognizing the objects as Idgham, Ikhfa' and Izhar Shafawee tajweed. The results demonstrate that the model is capable to deliver a reliable result in a real-world setting, and can assess its overall performance in detecting the tajweed rules. The workings of QuranVision application is visualize in Figure 7 as part of the interface through mobile launching usage which highlight the detection and recognition part as well as the details description of the rules.

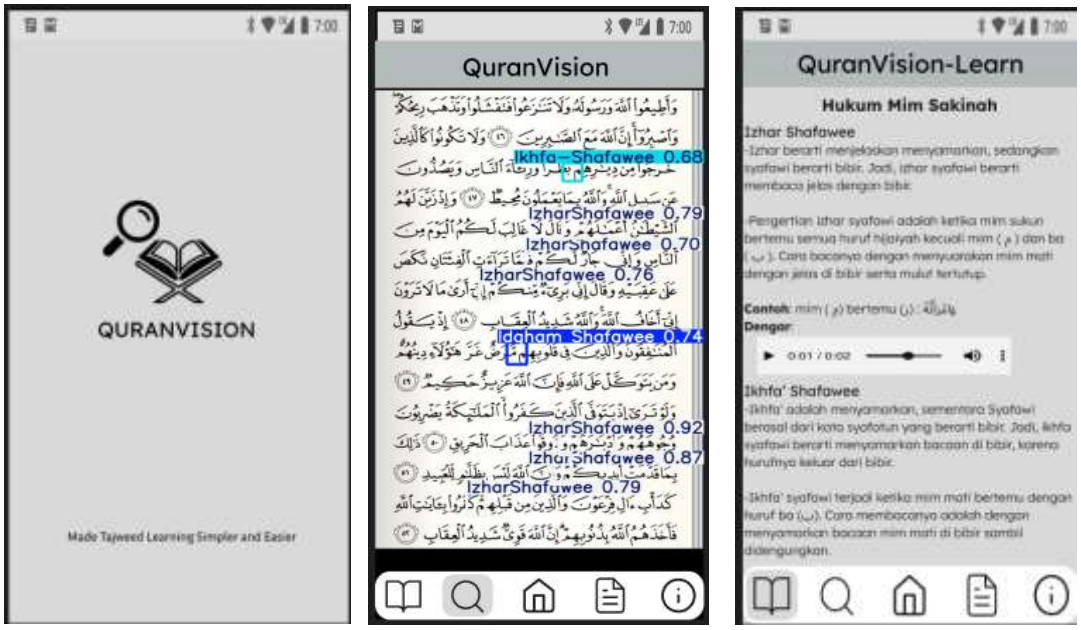

Fig. 7 Overview of QuranVision mobile application

4. Conclusions

There are a few points which highlight the strengths of QuranVision application which are real time detection and recognition, ability to accurately pinpoint the location of tajweed rules from the image input, can be operated through both black and white and color-coded Quran image input and lastly, the learning features which not only in the form of visual learning, but also through lengthy descriptions of tajweed rules and audio learning which can be seen at Figure 6, QuranVision-Learn page which provides audio cue for the example of the tajweed rules. QuranVision also provides a simple quiz regarding the tajweed rules which users have learnt

from the learn page. These features will enhance the learning process for better understanding and assimilation. Due to the advancement and sustainable technology that possessed by QuranVision, it can provide as an alternative and convenient way in al-Quran recitation at the same time catering to hinder the time consumption process in teaching and learning journey especially for new students and children learners.

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