International Journal of Electrical and Computer Engineering (IJECE)
Vol. 12, No. 5, October 2022, pp. 5313~5320
ISSN: 2088-8708, DOI: 10.11591/ijece.v12i5.pp5313-5320

An alternative m-learning scoring approach to automatically evaluate *Iqro's* pronunciation based on pitch, volume, and rhythm features

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Article Info

Article history:

Received Nov 17, 2021
Revised May 10, 2022
Accepted Jun 9, 2022

Keywords:

Iqro'
M-learning
Pitch
Rhythm
Scoring
Volume

ABSTRACT

The *Iqro'* has been proven as an effective method to improve literacy for reading *Hijaiyah* letters which are the fundamental skill for reading the Qur'an. The *Iqro* method relies on a mentor to evaluate the accuracy of the student's pronunciation of the *Hijaiyah* letters. With the advancement of mobile technology, many mobile apps are available to assist the learning process. However, the existing solution that is available on the market only provides a one-way learning experience where users only focus on enhancing vocabulary, writing, and reading ability with a simple true-false assessment. Although enhancing the vocabulary and reading ability is important, training the correct *Makhraj* (Arabic pronunciation) is also essential in fundamental *Hijaiyah* learning. This paper presents the feasibility investigation of the usage of the pitch, volume, and rhythm as the more comprehensive audio assessment parameters in the voice recognition module to evaluate the student's ability to pronounce the *Hijaiyah* letter in an m-learning implementation. Instead of just presenting the true-false output, the proposed method will calculate the *Makhraj* correctness in the range 0 to 100. Experimental results with 10 respondents show that the sample correlation coefficient using Pearson between a manual assessment by *Ustaz* and the application result for *Iqro'* level 1 is 0.51 which means this approach is acceptable for future implementation.

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1. INTRODUCTION

Among children and the new learner, the *Iqro'* has been proven as an effective method to achieving a proper reading skill in *Hijaiyah* letters which are the fundamental skill for reading the Qur'an [1]–[3]. In general, learning with the *Iqro'* method requires a face-to-face native mentor (*Ustaz* or *Ustazah*) to evaluate the accuracy of the student's pronunciation of the *Hijaiah* letters. The limitation of time and mentor availability made face-to-face learning difficult to obtain. The assessment of a *Hijaiyah* performance is based on different criteria depending on the context and the age of the students. In the case of children and beginners, the evaluation criteria are mainly based on *Makhraj*, the proper pronunciation of the *Hijaiyah* letters. Most of the existing learning apps are either oriented to auxiliary learning tools, or they are designed as a one-way learning tool for a student enhancing their vocabulary, writing, and reading ability. Other important aspects such as *Makhraj* or Arabic pronunciation are not taken into account in the scoring process.

Although enhancing vocabulary, writing, and reading ability are necessary, *Makhraj* is one of the most important criteria in the performance assessment of a *Hijaiyah* reading ability. With the advancement of technology for mobile devices, many mobile apps are proposed as a tool to assist the *Hijaiyah* learning process. In the case of common *Iqro*' apps, the scoring of *Makhraj* is mainly based on the proper impost of voice which the output only true-false by using the voice recognizer application programming interface (API) such as Google Speech-to-Text rather than exact range value from 0 to 100 [4]–[6]. With that condition, the improvement level is difficult to trace.

Some studies have been working in the scientific field of performance analysis of the voice with acoustic features as parameters [7]–[10]. Previous research has proposed an automatic singing evaluating system based on acoustic features and rhythm [11]. An investigation to determine the effect of pitch and rhythm on vocal reading performance indicates that pitch and rhythm skills retained their relative in order to evaluate the input voice [12]. On the other hand, Gupta proposes two pitch-based similarity measures to build lexical modification techniques to determine how close a user's singing clip is to the reference singing clip with no background music [13]. In another study, Tsai and Lee [14] proposed an automatic evaluation system for karaoke singing in another study, emphasizing the use of pitch, volume, and rhythm features. They calculated the rhythm score by computing the deviation of the optimal path from a straight line fit in the cost matrix of the DTW between the pitch contours after aligning the test pitch contour with the reference pitch contour using dynamic time warping (DTW) [14]. The aforementioned studies proved that pitch, volume, and rhythm have a good potential to be the scoring parameters.

This paper presents the usage of the pitch, volume, and rhythm as the more comprehensive audio assessment parameters in the voice recognition module to evaluate the student's ability in pronouncing the *Hijaiyah* letter. Next, we investigate the feasibility of the pitch, volume, and rhythm for scoring parameters of the *Hijaiyah* m-learning implementation. The proposed application is expected to introduce *Hijaiyah* letters and guide the users to pronounce them with correct *Makhraj* pronunciation intuitively. Instead of just presenting the true-false output, the proposed will calculate the *Makhraj* correctness in the range 0 to 100. The proposed m-learning provide actual self-learning of *Hijaiyah* letter to students.

2. RESEARCH METHOD

In this section, we present the serial methods to support our goal to examine the user's perception and acceptance of the proposed minimum viable product. Considering contextual problems, voice recognition technologies also introduce a change in the conventional *Iqro*' reading and pronunciation assessment. The development of an m-learning prototype is not simply a matter of technical wizardry. This is due to the fact that calculating the acoustic parameter into a single score value only with a smartphone needs a fancy algorithm. We have focused on the implementation of the usage of pitch, volume, and rhythm as the *Iqro*' scoring parameters. The steps for retrospective diary study as part of requirement elicitation for the proposed app, concept of the proposed system, and system design strategies are discussed below.

2.1. Need findings

We conducted a field study by exploring individual responses about their experience with *Hijaiyah* m-learning. We collected our user's personas before we conduct the designing phase. A persona is a useful tool for describing the user profile of a specific target group, it conveys the relevant demographic, psychographic, behavioral, and needs-based attributes [15]. Then, based on insight from respondent data, we build a user journey to gather user requirements. A user journey map is a recently emerged method to gather requirements and design the user experience in the application product. This map adds a third-dimensional feature to a traditional user persona by focusing on a diachronic outline of a user and a product [16]. Recent works prove that this approach is an effective tool for rapidly gathering user stories in order to develop an intuitive application [17]–[20].

The number of participants involved in the field study and testing can be varied. Nielsen *et al.* [21] argue that five individuals will uncover as many usability issues as many test participants. In usability testing, five volunteers are sufficient to provide an adequate benefit-to-cost ratio [21]. According to the literature studies, we involve five participants in this research to elicit the basic requirement for *Iqro'* m-learning. They were at least familiar with Android mobile applications with minimum OS version 6. They have basic knowledge or experience with *Iqro'* level 1. From our studies, we have found some insights and barriers when reading *Hijaiyah* letter with an m-learning app, these are: i) respondents need features that can display reading scores in 0-100 ratings rather than just true-or-false and ii) respondents need an intuitive app so they can directly speak to the app to evaluate their pronunciation. Based on these insights, we proposed an intuitive *Iqro'* m-learning that emphasizes the utilization of pitch, volume, and rhythm as a scoring parameter that can be used independently by a user only with a smartphone.

2.2. The scoring algorithm

In general, volume, pitch, and rhythm are all directly connected to the accuracy of the pronunciation performance. The strength of sound in an audio composition is represented by volume. Pitch refers to the relative lowness or highness of a sound. Rhythm, which relates to the timing of the voice sound and silences. In 2011, Tsai and Lee [14] proposed a state-of-the-art method to evaluate the performance of karaoke singing based on pitch, volume, and rhythm features. This method compares the reference sound with solo vocal samples to determine the similarity and scoring of singing performance [14]. This study exploits various acoustic features to assess a singing performance, therefore, Tsai's method stands out from other approaches by providing an efficient calculation and giving natural experience when it is implemented in the way of interaction with smartphone. To calculate the overall score, the resulting scores from each acoustic feature are then combined using a weighted sum method:

$$WPit\ .SPit + WVol\ .SVol + WRhy.SRhy \tag{1}$$

Here, *SPit*, *SVol*, and *SRhy* denote the scores obtained from pitch-based rating, volume-based rating, and rhythm-based rating, respectively. *WPit*, *WVol*, and *WRhy* correspond to the adjustable weights that sum up to 1. In order to implement the scoring algorithm, the conversion audio source into Waveform and spectrogram are needed. To calculate the score of pitch-based rating, volume-based rating, and rhythm-based rating we use several processes as shown in Figures 1(a) to (c).

To get a pitch-based rating score, we need to convert the audio source which is the sound file recorded by the user into waveform audio format (WAV) format, sampling it, then convert the *Ustaz*'s voice file and the user's audio file into a spectrogram. To convert into a spectrogram in this study using the musicg library version 1.4.2.0 which already has the fast Fourier transform (FFT) algorithm. After getting the spectrogram, the next step is to use the class from PitchHandler on musicg which will later get the value in the form of an array. After getting this value, calculate it using the dynamic time warping (DTW) class obtained from the GART website to get the distance value. After getting the distance value, the result is calculated using the pitch scoring formula. The process of getting pitch-based scoring used the set of functions from musicg version 1.4.2 for the audio sampling process, runs the FFT algorithm, calculates the spectrogram of the audio file until it returns the value from max Frequency in the form of an array or list for the volume array, and gets the value of pitch arrays. The return value of this function is a Pair data type with pitch and volume array. This process was implemented 2 times because it is for the user's audio file with the audio file for the *Ustaz*. After getting the array values of pitch and volume for the two audio files, then instantiate an object from the DTW for calculating the distance between 2 variables, the distance is an array of user pitch with *Ustaz* and also an array of user volume with *Ustaz*. After that, call calculate the result to obtain the pitch-based score.

When an audio sound is composed, abbreviations or symbols known as dynamics are notated in volume scores to indicate the degree of loudness or softness of a piece of sound, as well as whether or not the volume changes. Instead of being absolute, dynamics are relative. The process for obtaining a volume-based score is the same as pitch-based scoring. After getting the spectrogram from 2 audio files, then getting the value in the form of the maximum frequency array using several functions from the musicg library. Then the array is calculated using the DTW to calculate the inbeat value, then calculate it using the volume scoring formula.

The basic idea of rhythm-based rating is to evaluate for the synchronicity (in-beat) between the *Ustaz* reference audio and the user voice sound. After we get a sample of 2 audio files, we conduct feature extraction from these 2 audio files to obtain the value of the delta energy in the form of an array. After getting the 2 corresponding arrays, it is then calculated using DTW to get the in-beat value.

2.3. Prototype description

The study is designed to investigate the feasibility of pitch, volume, and rhythm as the *Iqro*' scoring parameters. The Android-based m-learning prototype which was developed in our research aims at providing serials learning content of *Iqro*' and also the quiz and evaluation menu in one application. The proposed prototype is using a voice-based approach to take the user voice as input. Since we are developing a mobile app as a tool to validate our proposed method to overcome the aforementioned problems, we designed a lightweight architecture application design that has a noteworthy feature to display a pronunciation score to the user in a 0-100 rating value. This application needs to convert the raw user voice data from the smartphone microphone (mp3) into the waveform audio format (WAV). This application uses a default microphone to record user voice then automatically compare the result with the pre-loaded *Ustaz* audio file to calculate the overall score with pitch, volume, and rhythm parameters. Technically, we separate the module of the proposed app into two modules, the audio converter module, and the computation module. After a user voice input is converted, the system performs volume-based rating, pitch-based rating, and rhythm-based rating, using the pre-recorded *Ustaz* audio file of a specific *Hijaiyah* letter as a reference basis. Figure 2 depicts the proposed system architecture.

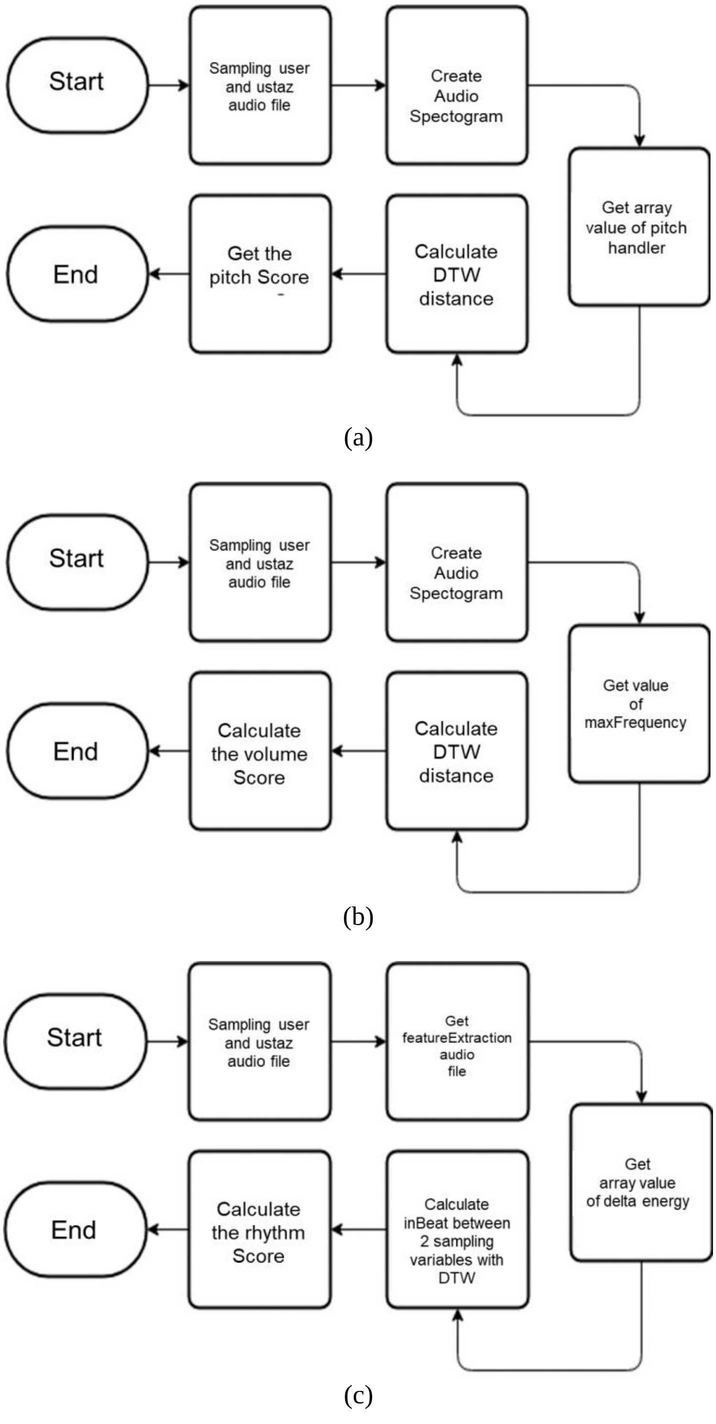

Figure 1. Process algorithm to obtain the rating score of (a) pitch, (b) volume, and (c) rhythm

In order to display the scoring result to the user, the proposed application needs to convert the raw user's voice to score value. This application uses the aforementioned algorithm with weight product to be 0.45, 0.16, and 0.39 for *Wpitch*, *Wvolume* and *Wrhythm* respectively [14]. Next, the application calculates the overall score and print the result into the application screen. Figure 3 shows the contextual block algorithm of the proposed scoring system.

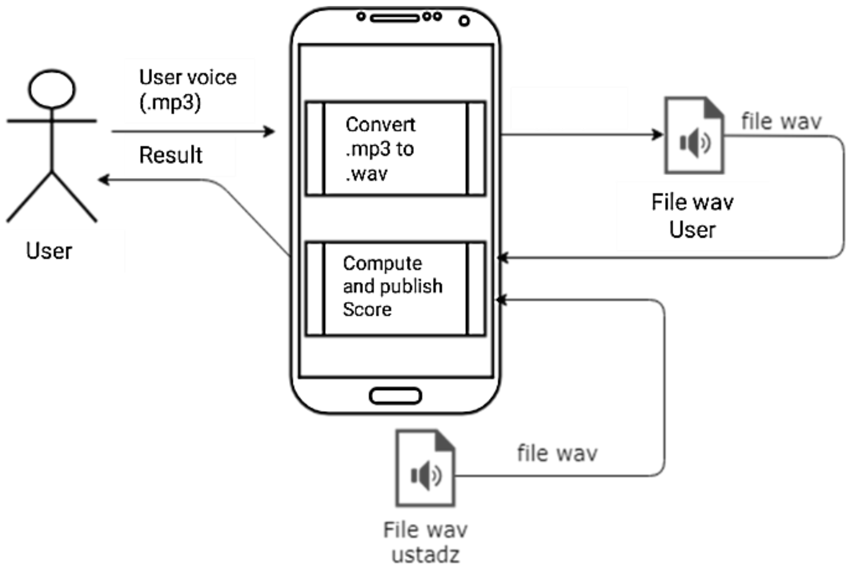

Figure 2. Proposed system architecture

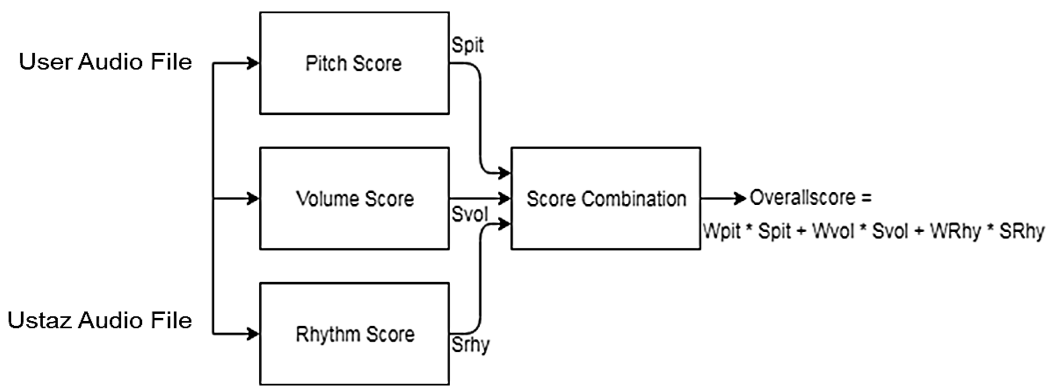

Figure 3. Proposed *Makhraj*-scoring system

2.4. Prototype evaluation

An experiment came out to assess the feasibility of the proposed scoring method using Pearson product moment coefficient correlation. The real *Makhraj* score from *Ustaz* will be compared with the application score result. Faulkner prescribes that 10 participants as a sample will discover as many usability issues as more individuals will do. The involvement of 10 contributors is capable enough to give the proportional value-to-cost ratio in usability testing [22]. According to the literature studies, we recruited a total of 10 student participants in this research. First, we record *Ustaz*'s voices when he read and pronounciate the set of *Hijaiyah* letters with the correct *Makhraj*, then the voices were inserted into apps as reference audio. The participant then explores the function of the apps and conducts the scoring test. We conduct the experiment in a quiet environment to minimalize the audio noise. In this study, we focus only investigated the student performance when they read the *Hijaiyah* letter in *Iqro's* level 1. The sample of implementation design and prototype of the proposed m-learning app which was used in this study can be seen in Figure 4.

This study will calculate the similarity result between the real *Makhraj* manually scored by *Ustaz* and the application score. Pearson correlation coefficient was used to proceed with this phase [23]. According to Ratner, we can get the similarity value with the Pearson correlation coefficient formula as shown in (2).

$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{[N\sum x^2 - (\sum x)^2] + [N\sum y^2 - (\sum y)^2]}} \quad (2)$$

where N is the amount of data, the value of x is the score of the application result, the value of y is the score from the *Ustaz*. The r-value can be – (negative value theoretically), the most important thing is that the similarity correlation is in the interval -1 and +1. If the value of r is 0, then it is certain that there is no correlation between the two variables, if the value of r=+1, then the two variables are correlated or the correlation is perfectly positive because if one variable increases its value, the other variable also increases its value linearly. If the value of r=-1 then the two variables are correlated or the correlation of similarity is perfectly negative because if one variable increases in value, the other variable decreases in value through a linear rule. A value of r= between 0 and 0.3 or on the negative side of 0 and – 0.3 indicates a weak positive or negative correlation through the linear rule. If the value of r= between 0.3 and 0.7 or on the negative side of -0.3 and -0.7 indicates a moderate or sufficient positive or negative correlation through the linear rule. If the value of r= between 0.7 and 1.0 or on the negative side -0.7 and -1.0 indicates a strong positive or negative correlation [24]–[26].

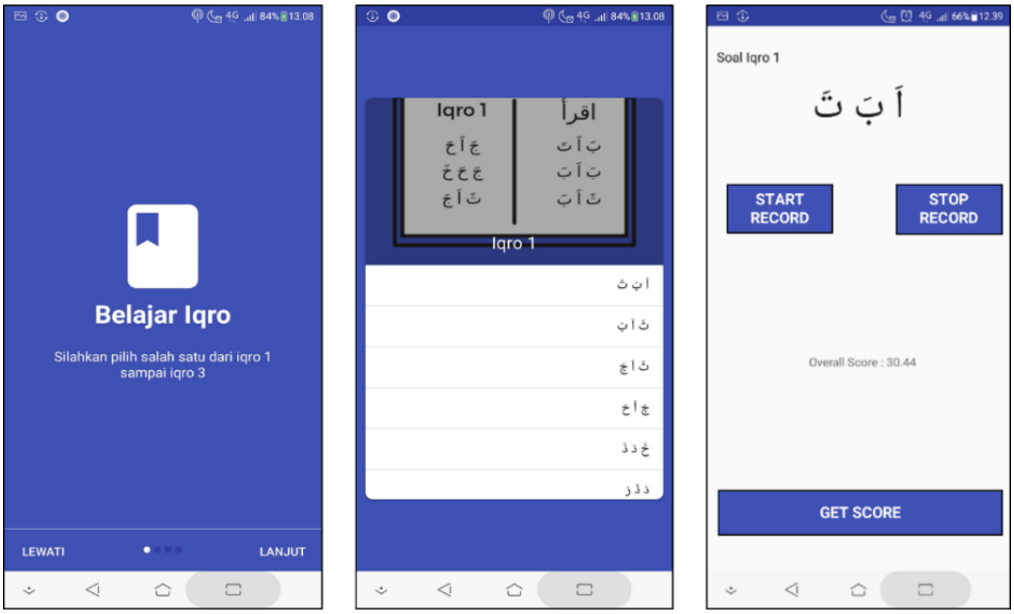

Figure 4. App screenshot that used in this study

3. RESULTS AND ANALYSIS

As part of the feasibility test of the proposed approach, a direct comparison was conducted to explicitly compare the two scoring results, one with the proposed application and another measured manually by the *Ustaz*. Each respondent read and record their pronunciation of the *Hijaiyah* letter ب أ ت then we compare the overall score result between *Ustaz* score and app score which is implemented the proposed approach in this study. The scoring process used the same acoustic parameters which are pitch, volume, and rhythm. The score range for each participant was recorded and the comparison result of the overall score is shown in Table 1.

Table 1. The comparison result of overall score

Respondent name	*Ustaz* *Overall score*	App *Overall score*
Responden 1	52.4	68.29
Responden 2	62.2	74.11
Responden 3	81.65	72.16
Responden 4	65.45	70.94
Responden 5	63.05	65.8
Responden 6	52.9	65.63
Responden 7	63.8	71.47
Responden 8	47.7	68.02
Responden 9	62.3	66.28
Responden 10	57.7	68.04
Pearson correlation result	**0.51**	

4. CONCLUSION

In this paper, we emphasize the utilization of acoustic features to proposed alternative *Makhraj* scoring method in *Hijaiyah* m-learning. To prove our concept, we developed m-learning prototype and direct comparison was conducted to evaluate the feasibility of pitch, volume and rhythm as a scoring parameter algorithm. Performance of 10 respondents when reading and pronounciate *Hijaiyah* letter were scored by *Ustaz* manually and application consecutively. By examining the data consistency between the results of the proposed m-learning which is using pitch, volume, and rhythm-based features and the subjective judgments of *Ustaz*, the correlation data showed that the proposed system is quite successful of providing an alternative scoring method with the Pearson product-moment correlation coefficient between them is 0.51. In the future, we will investigate the possibility of tuning the weight product of each feature that used in the computation to improve the proposed method performance. Due this study is still in preliminary phase; we also need more data set in evaluation process to validate our result for example by emphasize the implementation of the proposed method in more advanced level of *Iqro'*. In addition, we will explore the utilization of another acoustic features such as timbre-based analysis to further improve the system algorithm. With further analysis and accuracy improvement, the proposed m-learning application could provide a big help in evaluate the correct *Makhraj* of student who is in some conditions that cannot frequently meet with the *Ustaz* directly.

ACKNOWLEDGEMENTS

This work is part of the 2021 Research Road map of the Mobile, Game, Media, and Software Engineering Research Group, Department of Computer Science, Universitas Brawijaya. This work has been supported by Universitas Brawijaya research funding Grant No. 536.71.1/UN10.C10/PN/2021.

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