

Augmented reality using features accelerated segment test for learning tajweed

Adi Putra Andriyandi¹, Wahyudin Darmalaksana², Dian Sa'adillah Maylawati³,
Ferli Septi Irwansyah⁴, Teddy Mantoro⁵, Muhammad Ali Ramdhani⁶

^{1,3,6}Department of Informatics, UIN Sunan Gunung Djati Bandung, Indonesia

²Department of Ilmu Hadits, UIN Sunan Gunung Djati Bandung, Indonesia

⁴Faculty of Tarbiyah and Education, UIN Sunan Gunung Djati Bandung, Indonesia

⁵Department of Computer Science, Sampoerna University, Indonesia

³Faculty of Information and Communication Technology, Universiti Teknikal Malaysia Melaka, Malaysia

Article Info

Article history:

Received Aug 10, 2019

Revised Dec 2, 2019

Accepted Dec 23, 2019

Keywords:

Augmented reality

FAST corner detection

Multimedia

ABSTRACT

Currently, education forms students to think creatively and critically, this can be supported by the multimedia technology for education, including Islamic religious education. Islam requires all of its Muslim to read the Qur'an. Tajweed is an important because it is related to the articulation of reading the Qur'an properly and correctly. This article discusses the application of augmented reality (AR) as one of the multimedia technologies that can be used as an interactive educational medium to help study the tajweed of Qur'an. The method used in this research is Features from accelerated segment test (FAST) corner detection. The testing result with 31 tajweed objects show that FAST is able to recognize all Tajweed objects and display their AR. Besides, based on a survey with questionnaires to several students, the result shows that 88.2% of students responded very well and judged that it was sufficient to help study the tajweed.

This is an open access article under the [CC BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license.



Corresponding Author:

Dian Sa'adillah Maylawati,
Department of Informatics,
UIN Sunan Gunung Djati Bandung,
Bandung, Indonesia.
Email: diansm@uinsgd.ac.id

1. INTRODUCTION

The development of science and technology which is rapidly increasing has a considerable influence on the learning process and also influences the delivery of material in the teaching and learning process. Another meaning of learning is an effort that made by teachers with the aim that students can be helped in the learning process easily and quickly [1]. Interactive learning media in current digital era is needed, because learning media is a creative media used in providing subject matter to students so that the learning process is more effective, efficient, and enjoyable [2]. Therefore, the use of multimedia technology is very useful. This is also supported by the researches in the field of education that applies multimedia technology for learning are growing rapidly [3-9].

In current mobile technology, augmented reality (AR) is a modern and popular multimedia technology used as an interactive and interesting learning media [10-12]. For example in learning the bonding of chemical compounds [12], learning in chemistry [13-17], learning the solar system [18, 19], in biology to study the digestive organs [19], moreover to learn the culture such as learning traditional musical

instruments [20], learning temple as historical heritage [21], learning the museum objects [22, 23], to learn marine mammals [24], and so on. In Islamic religion education, AR can also be used as learning media, such as to learn *hijaiyah* letter (letter in Qur'an) [25], learning about *wudhu* (ablution) [26], and another Islamic religion education such as in learning *shalat* (prayer) [27].

Islam is one of the largest religions in the world, reaching 1.6 billion of the total world population of around 7.5 billion people. Indonesia became the country with the largest Muslim population in the world, reaching 222 million people. So, it is very necessary for Muslims to study Islamic education, one of which is recite the Qur'an. For Muslims all over the world, recite the Qur'an which is a way of life is mandatory. One of the important things in recite the Qur'an is paying attention to the rule of *tajwid* (tajweed). Where *tajweed* means articulating the verses of the Qur'an with the correct pronunciation in the prescribed rules. This research aims to implement AR technology as learning media for *tajweed* Al-Qur'an. This learning media is expected to be able to facilitate students in learning the punctuation as well as the good and right procedures for recite the Qur'an. Many methods or algorithms that can be used in AR, such as SURF (speeded up robust features) [28], Edge Detection methods [29], ORB (oriented FAST (features from accelerated segment test) and rotated BRIEF (binary robust independent elementary features)), and so on. This research uses feature from accelerated segment test (FAST) corner detection algorithm because FAST can streamline the calculated time in real-time with the impact of decreasing the accuracy of the angle detection stages [22]. The FAST algorithm identifies 3D objects by using the threshold of light from a 2D image object which is later used as a marker. The features displayed are very simple, while for the main display that is in the form of a camera capture to detect markers [30]. Therefore, in this study besides implementing the FAST corner detection algorithm, the accuracy and time process of FAST algorithm in detecting the *tajweed* will be investigated.

2. RESEARCH METHOD

Activity flow of this research that described in Figure 1 begin from collect and understand the rule of *tajweed* Qur'an, then collecting the images data of *Tajweed* Qur'an. Then, conducting markerless object tracking and FAST corner detection algorithm. Last, conducting the experiment and evaluating the usability of application with questionnaire.

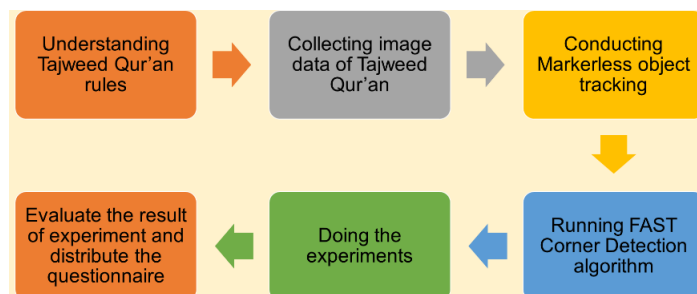


Figure 1. Research activities

2.1. Augmented reality

Augmented reality (AR) is a revolution in computer graphic technology that which presents visual images as if they were alive and very real [31]. AR is different with virtual reality (VR). VR is a combination between virtual reality is a combination of the real world and the virtual world so that like feeling in another real world, while AR is an integration of the digital world that created by computers with the real world in real time and following the environment in the real world. Actually, AR technology had been introduced in 1957 until now still be developed [32]. In this mobile era, almost AR technology for education use mobile application, especially android based [11, 33].

Generally, AR is divided into 2 methods, namely marker based tracking and markerless augmented reality [22]. Marker based tracking is used as a marker of an object in the form of a pattern in an image that can be read by a camera or other device, the marker basically uses a black and white illumination in the shape of a square and there is a black border with a white background. While, markerless augmented reality does not use marker boundaries on an object of detection and this method has the pattern recognition technique support, then the use of markers as object tracking is changed by marking object fields as object tracking (tracked objects). This research use markerless method in object tracking process.

2.2. Feature from accelerated segment test (FAST) corner detection

Corner detection symbolizes a computer system approach that is used as a detection tool for angles on an object. Corner detection also known as interest point detection. This method is often done in the process of object detection to determine the privilege of an object for example from the shape of an object and tracking an object [30]. FAST Corner Detection, performs the determination of the angle point by changing the image to black and white after it is changed then runs the algorithm. The algorithm will ensure the corner point by selecting the point that is p from the image that will be processed by detecting 16 pixels besides p will be checked. There are several different cases that have been set for each comparison such as in (1) for darker, (2) for similar, and (3) for brighter.

$$I_p \rightarrow x \leq I_p - t \quad (1)$$

$$I_p - t < I_p \rightarrow x < I_p + t \quad (2)$$

$$I_p + t \leq I_p \rightarrow x \quad (3)$$

where,

I_p = Intensity of center point

I_n = n^{th} neighbor intensity point

t = threshold value

$I_p \rightarrow x$ = pixel intensity of x .

Then, the next step after compare each intensity point is creating decision tree that can classify interest point in 16 location. Based on flowchart in Figure 2, FAST Corner Detection algorithm has a following process:

1. Determine the point p in the image that has a starting position (X_p, Y_p) .
2. Determine four points around the p point. The first point will be located at coordinates (X_p, Y_{p+3}) , the second point is located at coordinates (X_{p+3}, Y_p) , the third point is located at coordinates (X_p, Y_{p-3}) , the fourth point is located at coordinates (X_{p-3}, Y_p) .
3. Compare the intensity of the center point with the four surrounding points. If at least three points are obtained which are included in the following conditions, the center point is the vertex.
4. The checking process is to ascertain whether there are still pixels that need to be checked again. If there isn't, stop the process. If there is, then continue the next process is shifting the p point to the next position (+1) then the point will be compared again with the four surrounding points.
5. Repetition of the process will occur, until all points in the image have been compared in intensity.

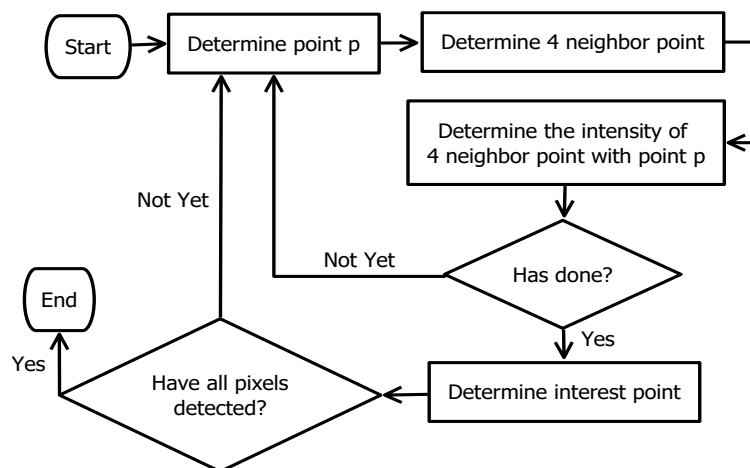


Figure 1. Flow chart of FAST corner detection algorithm

3. RESULTS AND DISCUSSION

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Begin from the types and rules of Tajweed Qur'an, implementing FAST corner detection algorithm, until evaluate the result of experiment and questionnaire distribution.

3.1. Understanding Tajweed Qur'an and collecting image data

Linguistically, the term "tajweed" in Arabic is defined as proficiency or proficient in showing expertise in doing something, while in relation to the reading of the Qur'an, tajweed means to articulate the verses of the Qur'an with the correct pronunciation in the prescribed rules [34, 35]. There are many rules of Tajweed that need to be understood by a reader. Generally, there are 7 section in Tajweed, among others [34]: (1) *nun sukun* and *tanwin*, such as *idzar*, *idgham bigunnah* or *idgham naqis ma'al gunnah*, *idgham bilagunnah* or *idgham kamil*, *iqlab* or *qalbun*, and *ikhfa*; (2) *mim sukun*, such as *ikhfa safawi*, *idgham mislain*, and *idzhar safawi*; (3) *nun* and *mim tasydid* such as *gunnah*; (4) *lafadz jalalah*, such as *tafkhim* and *tarqiq*; (5) *lam ta'rif*, such as *alif lam womariyah* (*idzhar qomari*) and *alif lam syamsiyah* (*idgham syamsi*); (6) *qalqalah* such as *qalqalah sugra* and *qalqalah qubro*; last is *mad* section, such as *mad tabi'i* or *mad asli*, *mad wajib muttasil*, *mad jaiz munfasil*, *mad arid lis sukun*, *mad badal*, *mad 'iwad*, *mad lazim musaqqol kalimi*, *mad lazim mukhaffaf kalimi*, *mad lazim harfi musyba*, *mad lazim mukhaffaf harfi*, *mad lin*, *mad silah qasirah*, *mad silah tawillah*, *mad tamkin*, and *mad farq*. However, in this research only 7 rules of tajweed that used as image data collection (provided in Table 1).

Table 1. Tajweed rules that used in this study

Tajweed	Letters	Causes	How to Read
<i>Ikhfa</i>	ت, ث, ج, د, ذ, ز, س, ش, ص, ض, ط, ظ, ف, ق, ك	نْ, مْ, يْ, ؤْ, وْ, يْ	The nasal voice with buzzed
<i>Ikhfa Safawi</i>	ب	م	Nasal voice in the nose
<i>Qalqalah</i>	ق, ج, د, ط, ق	<i>Qalqalah letters that die, or die because of forgiveness (stopped)</i>	Reflect or vibrate existing Qalqalah letters
<i>Iqlab</i>	ب	نْ, مْ, يْ, ؤْ, وْ, يْ	Replaces the sound with a <i>mim</i> (م)
<i>Idgham Bigunnah</i>	ن, م, و, ي	نْ, مْ, يْ, ؤْ, وْ, يْ	Melting dead of <i>nun</i> (نْ) or <i>tanwin</i> (ـ) accompanied by hum
<i>Idgham Mimi</i>	م	م	Make a duplicate or sing sound and must read the drone
<i>Gunnah</i>	ن, م	م, نْ	Sound coming out of the nose

3.2. Implementation of feature from accelerated segment test (FAST) corner detection

Before running FAST corner detection algorithm, image data of Tajweed Qur'an as an object will be tracked using markerless augmented reality object tracking method. Markerless is a tracking method that uses color images as markers. This method does not use frame markers as detected objects. In this AR application, the marker image is sourced from the Qur'an which is made into an image and then made as a marker. Markers that will be used in the AR Tajweed application are in the 3D (three dimension) form are from a picture of a piece of Al-Quran verses in accordance with the Tajweed available. The process of making Tajweed images into a marker is done by Vuforia. Qualqomm which is a library supporting the existence of AR on Android [30]. The image will be uploaded to the Vuforia website with the aim that the image is converted into a file with unity package format. The file will later be used as a marker. Based on the process in Vuforia is in Figure 3, the process of marker formation begin from preparing the image than will be made as marker with format file .JPG or .PNG with maximal size is 2.25 MB then save or upload the image into Vuforia. Then, resize process until the marker forming will be illustrated in Figure 4.

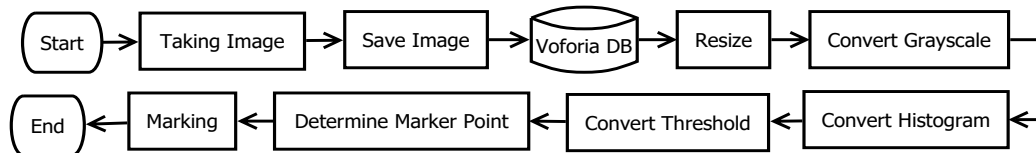


Figure 2. Stages of marker formation

Based on the FAST algorithm that explained in section 2.2, actually marker points that produced in Figure 4 are the result of FAST algorithm. For example, tajweed of "*qolqolah*" that provided in Figure 5, for each corner will be determined with several stages of light intensity comparison. The first step is determine point (*p*), starting from the upper left corner to the lower right corner, the process occurs until there are no more pixels that can be compared. Then, determine 4 neighbor point (*n*) with (1), (2), and (3). Last, light intensity of point (*p*) will be compared with with all four points around *n*₁, *n*₂, *n*₃ and *n*₄. If there are at least three points in accordance with the conditions, the center point (*p*) is an angle. There is a requirement to determine an angle that is the light intensity of the center point (*p*) must be brighter or darker than point *n*,

because if the intensity is the same then it cannot be called an angle. Figure 6 illustrates the example of corner detection using FAST algorithm for several tajweed form. Next, utilizing Vuforia for image tracking to show 3D object from the image that illustrated in Figure 7. Those 3D object are the result of AR application to learning tajweed.

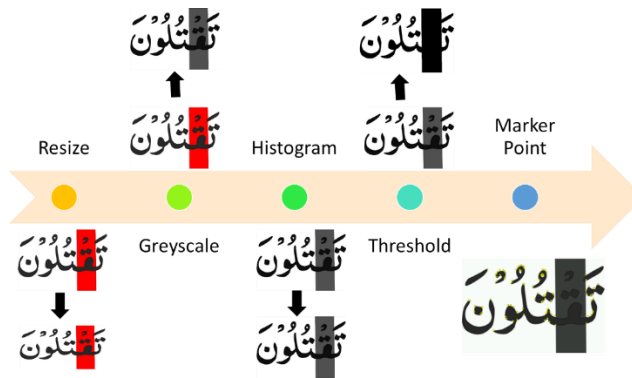


Figure 3. The example of marker forming for tajweed “qalqalah”

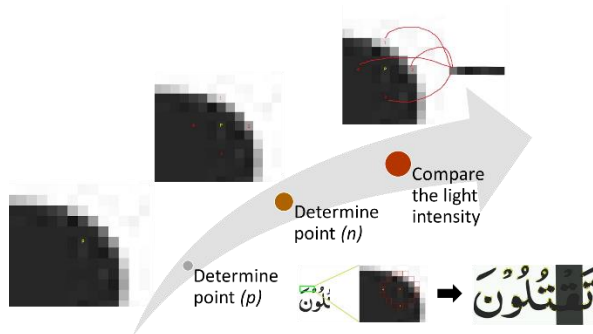


Figure 4. Illustration of corner detection using FAST algorithm

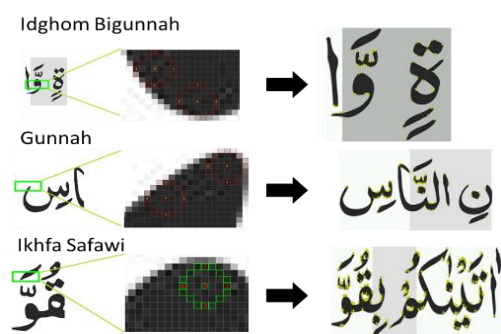


Figure 5. The example of corner detection using FAST algorithm
















Figure 6. The example of 3D object of tajweed Qur'an

3.3. Experiment and questionnaire distribution

The experiment is conducted using Android operating system 9th version (Pie) with 3 Giga Byte RAM and camera specification is 13 Mega Pixel (5 Mega Pixel + 8 mega Pixel). Software tools that used for experiment amog others Unity 3D 2017.3 64-bit, Vuforia SDK, Android SDK, and Adobe Photoshop. Besides blackbox testing to evaluate the functionality of the application, the experiment to evaluate FAST algorithm for detecting corner and tracking image target is conducted using 31 image data such as showed in Table 2.

Table 2. The example of experiment

Marker ID	Image	Tajweed	Time (s)	AR Result
m_01		<i>Qolqolah</i>	0.30	Detect Correctly
m_02		<i>Iqlab</i>	0.44	Detect Correctly
m_03		<i>Qolqolah and Ikhfa</i>	0.28	Detect Correctly
m_04		<i>Idghom Mimi and Ikhfa</i>	0.49	Detect Correctly
m_05		<i>Qolqolah</i>	0.47	Detect Correctly
m_06		<i>Idghom Mimi</i>	0.21	Detect Correctly
...
m_11		<i>Ikhfa Safawi</i>	0.37	Detect Correctly
...
m_20		<i>Gunnah</i>	0.35	Detect Correctly
m_21		<i>Gunnah</i>	0.23	Detect Correctly
m_22		<i>Ikhfa</i>	0.33	Detect Correctly
m_23		<i>Gunnah and Idghom Bigunnah</i>	0.51	Detect Correctly
m_24		<i>Iqlab</i>	0.38	Detect Correctly
m_25		<i>Iqlab</i>	0.37	Detect Correctly
...

Then, questionnaire distribution is conducted to evaluate the usability and benefits of the application. The questionnaire consist of 7 questions with 5 scales (1 for strongly disagree 2 for disagree, 3 for neutral, 4 for agree, and 5 for strongly agree) that related with usability and benefits of application, among others:

1. Is the tajweed Qur'an learning media on the augmented reality tajweed application good for children?
2. Is the tajwid augmented reality application indispensable in learning process of tajweed?
3. Does the tajwid augmented reality application more easily understand and learn the tajweed of the Quran?
4. Is the main display going well?
5. What is the suitability of the background/background display design in the tajwid augmented reality application?
6. Is the material presented easily understood?
7. Do the sound, exit and return buttons function correctly?

The result of questionnaire evaluation is provided in the Table 3 and Figure 8. While, the evaluation of experiment and questinnaire are explained in section 3.4.

3.4. Result evaluation of experiment and questionnaire

Based on the experiment and questionnaire distribution, this study gets the following result:

1. Every tajweed that used in this study, among others *ikhfa*, *ikhfa safawi*, *qalqalah*, *idgham bigunnah*, *idgham mimi*, and *gunnah* have succeeded in detecting and displaying 3D objects according to its Tajweed. The test results are successful if the image scanning is done on 1 or 2 tajweed. However, when scanning images are carried out throughout the entire Qur'an page, not all results of Tajweed will be displayed simultaneously. This happens because of the limitations of the Qur'an image data and the image resolution is not good enough so that the image detection is not perfect. Likewise for Qur'an words or sentences that containing adjacent Tajweed, the application is not able to detect it properly, or requires a longer detection process.

- Generally, FAST corner detection algorithm is fast enough in detecting the tajweed Qur'an, with an average value of processing time is around 0.335 seconds per object (provided in Figure 9). Although not always when the scanned tajweed object means it has a longer processing time. such as tajweed object m_03 which contains 2 Tajweed objects has a shorter processing time than other objects that only contain 1 Tajweed (for example m_02 and m_05). This can be influenced by image resolution so that the resulting marker points are less precise so it takes longer processing time.
- Based on the result of questionnaire with several respondents show that in accordance with benefits of multimedia technology for education [1-3], this study also proves that AR technology is interesting and helping student in learning, in this case Tajweed of Qur'an. It is supported by the questionnaire result that most of respondents agree (with percentage of questionnaire data analysis around 88.28%) that the AR for tajweed runs well and can help in learning tajweed Qur'an easily.

Table 3. Questionnaire result

Question No.	Total Frequency of Each Scale					Total Score $\sum \text{Weight} * \text{Frequency}$
	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)	
1	7	3	0	0	0	47
2	6	4	0	0	0	46
3	5	5	0	0	0	45
4	4	5	1	0	0	43
5	3	7	0	0	0	43
6	2	7	1	0	0	41
7	5	4	1	0	0	44
Average	88,28571429 %					

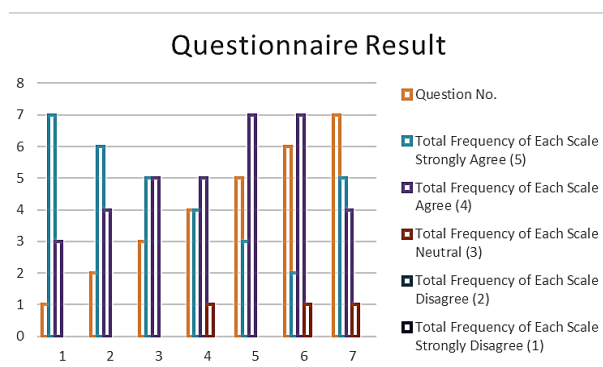


Figure 8. Questionnaire result

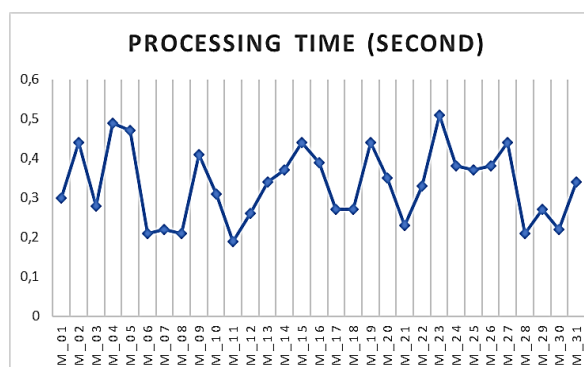


Figure 9. The example of 3D object of tajweed Qur'an

4. CONCLUSION

Learning tajweed Qur'an is important for Muslim because it is related with recitation Qur'an properly and correctly. This study success to utilize augmented reality (AR) technology as multimedia that support in learning tajweed Qur'an. Generally, AR in this study that use FAST corner detection algorithm has been run well with a relatively fast object detection process. However, it still lack in detecting tajweed objects simultaneously on one page of the Qur'an. Therefore, for the further study, the object and rules of Tajweed must be more complete. Then, the image data must be has high relotution so that the object can be detected better and faster.

ACKNOWLEDGEMENT

Authors wishing to acknowledge Research and Publication Centre of UIN Sunan Gunung Djati Bandung that supports and funds this research publication.

REFERENCES

- [1] A. A. Ibrahim, "Evolutionary Nature of the Definition of Educational Technology," *Int. J. Soc. Sci. Educ.*, vol. 5, no. 2, 2015.

- [2] RISTEKDIKTI, "Science and Technology Development and Higher Education in the Industrial Revolution Era 4.0 (in Bahasa: Pengembangan Iptek dan Pendidikan Tinggi di Era Revolusi Industri 4.0)," Press Conference, Number: 04 / SP / HM / BKPP / I / 2018, 2018.
- [3] M. Mustika, E. P. A. Sugara, and M. Pratiwi, "Development of Interactive Learning Media Using the Multimedia Development Life Cycle Method (in Bahasa: Pengembangan Media Pembelajaran Interaktif dengan Menggunakan Metode Multimedia Development Life Cycle)," *Jurnal Online Informatika*, vol. 2, no. 2, 2018.
- [4] S. Nurajizah, "Implementation of Multimedia Development Life Cycle in Children's Song Recognition Application (in Bahasa: Implementasi Multimedia Development Life Cycle Pada Aplikasi Pengenalan Lagu Anak-Anak)," *Prosisko: Jurnal Pengembangan Riset dan Observasi Sistem Komputer*, vol. 3, no. 2, pp. 14–19, 2016.
- [5] I. Binanto, "Comparison of Multimedia Software Development Methods Comparison of Multimedia Software Development Methods (in Bahasa: Perbandingan Metode Pengembangan Perangkat Lunak Multimedia Perbandingan Metode Pengembangan Perangkat Lunak Multimedia)," *Seminar Nasional RITEKTRA 2013*, 2014.
- [6] D. R. Firmanda, R. R. Isnanto, and I. P. Windasari, "Android-based Hajj and Umrah Pilgrimage Learning Application (in Bahasa: Aplikasi Pembelajaran Manasik Haji dan Umroh Berbasis Android)," *Jurnal Teknologi dan Sistem Komputer*, vol. 4, no. 4, pp. 510-517, 2016.
- [7] N. Fitriyani, D. Tresnawati, and N. Hadiyanto, "Development of Application for Recognizing Letters, Numbers and Colors for Early Childhood Based on Android (in Bahasa: Pengembangan Aplikasi Pengenalan Huruf, Angka dan Warna Untuk Anak Usia Dini Berbasis Android)," *Jurnal Algoritma*, vol. 11, no. 2, pp. 273-281, 2014.
- [8] D. Tresnawati and T. S. Nugraha, "Application Development for Introduction to Regional Art (in Bahasa: Pengembangan Aplikasi Pengenalan Kesenian Daerah)," *Jurnal Algoritma*, vol. 12, no. 1, pp. 156-165, 2015.
- [9] I. Mustaqim, "Utilization of Augmented Reality as Learning Media (in Bahasa: Pemanfaatan Augmented Reality Sebagai Media Pembelajaran)," *Jurnal Pendidikan Teknologi dan Kejuruan*, vol. 13, no. 2, pp. 174-183, 2016.
- [10] D. Nincarean, M. B. Alia, N. D. A. Halim, and M. H. A. Rahman, "Mobile Augmented Reality: The Potential for Education," *Procedia - Social and Behavioral Sciences*, vol. 103, pp. 657-664, 2013.
- [11] M. Dunleavy and C. Dede, "Augmented reality teaching and learning," *Handbook of Research on Educational Communications and Technology: Fourth Edition*, Springer, pp. 735-745, 2014.
- [12] S. Irsyad, "Augmented Reality Application as an Android-Based Chemical Bond Simulation Media Using the Fast Corner Detection Method (in Bahasa: Aplikasi Augmented Reality Sebagai Media Simulasi Ikatan Kimia Berbasis Android Menggunakan Metode Fast Corner Detection)," Undergraduate thesis, Universitas Islam Negeri Maulana Malik Ibrahim, 2016.
- [13] M. P. Chen and B. C. Liao, "Augmented reality laboratory for high school electrochemistry course," in *Proceedings-IEEE 15th International Conference on Advanced Learning Technologies: Advanced Technologies for Supporting Open Access to Formal and Informal Learning, ICALT 2015*, 2015.
- [14] F. S. Irwansyah, Y. M. Yusuf, I. Farida, and M. A. Ramdhani, "Augmented Reality (AR) Technology on the Android Operating System in Chemistry Learning," *IOP Conference Series: Materials Science and Engineering*, vol. 288, no. 1, 2018.
- [15] P. G. Crandall et al., "Development of an augmented reality game to teach abstract concepts in food chemistry," *Journal of Food Science Education*, vol. 14, no. 1, pp. 18-23, 2015.
- [16] S. Yang, B. Mei, and X. Yue, "Mobile Augmented Reality Assisted Chemical Education: Insights from Elements 4D," *Journal of Chemical Education*, vol. 95, no. 6, pp. 1060-1062, 2018.
- [17] Dedynggego, Mohammad, and M. Affan, "Design of 3D Interactive Learning Media Solar System Using Augmented Reality Technology For Grade 6 Students of Sangira Elementary School (in Bahasa: Perancangan Media Pembelajaran Interaktif 3D Tata Surya Menggunakan Teknologi Augmented Reality Untuk Siswa Kelas 6 Sekolah Dasar Sangira)," *Jurnal Elektronik Sistem Informasi dan Komputer*, vol. 1, no. 2, 2015.
- [18] T. A. Ananda, N. Safriadi, and A. S. Sukamto, "Application of Augmented Reality as a Learning Media to Know the Planets in the Solar System (in Bahasa: Penerapan Augmented Reality Sebagai Media Pembelajaran Mengenal Planet-Planet Di Tata Surya)," *Jurnal Sistem dan Teknologi Informasi*, vol. 4, no. 1, pp. 1-6, 2015.
- [19] R. E. Saputro and D. I. S. Saputra, "Development of Learning Media to Know Human Digestive Organs Using Augmented Reality Technology (in Bahasa: Pengembangan Media Pembelajaran Mengenal Organ Pencernaan Manusia Menggunakan Teknologi Augmented Reality)," *Jurnal Buana Informatika*, vol. 6, no. 2, pp. 153-162, 2017.

- [20] R. A. Setyawan and A. Dzikri, "Analysis of the Use of the Marker Tracking Method in Augmented Reality of a Traditional Musical Instrument in Central Java (in Bahasa: Analisis Penggunaan Metode Marker Tracking Pada Augmented Reality Alat Musik Tradisional Jawa Tengah)," *Jurnal Teknik Industri, Mesin, Elektro dan Ilmu Komputer (Simetris)*, vol. 7, no. 1, pp. 295-304, 2017.
- [21] M. Avief Barkah and R. Agustina, "Utilization of Augmented Reality (AR) as an Interactive Learning Media Introduction to Temples in Malang Raya Based on Android Mobile (in Bahasa: Pemanfaatan Augmented Reality (AR) Sebagai Media Pembelajaran Interaktif Pengenalan Candi-Candi di Malang Raya Berbasis Mobile Android)," *Bimasakti*, vol. 1, no. 5, pp. 1-6, 2017.
- [22] H. Vitono, H. Nasution, and H. Anra, "Implementation of Markerless Augmented Reality as an Android-Based Museum Information Media Collection (in Bahasa: Implementasi Markerless Augmented Reality Sebagai Media Informasi Koleksi Museum Berbasis Android)," *Jurnal Sistem dan Teknologi Infomarsi*, vol. 4, no. 2, pp. 1-7, 2016.
- [23] Y. A. Pramana, K. C. Brata, and A. H. Brata, "Development of Augmented Reality Applications for Object Recognition in Android Based Museums (Case Study: Blambangan Banyuwangi Museum) (in Bahasa: Pembangunan Aplikasi Augmented Reality untuk Pengenalan Benda di Museum Berbasis Android (Studi Kasus: Museum Blambangan Banyuwangi))," *Jurnal Pengembangan Teknologi Informasi dan Komputer*, vol. 2, no. 5, pp. 2034-2042, 2018.
- [24] I. Mulyana, M. I. Suriansyah, and J. Akbar, "Implementation of Natural Feature Tracking on the Introduction of Marine Mammals Based on Augmented Reality (in Bahasa: Implementasi Natural Feature Tracking Pada Pengenalan Mamalia Laut Berbasis Augmented Reality)," *Seminar Nasional Teknologi Informasi dan Multimedia 2018*, pp. 13-18, 2018.
- [25] D. Apriyani Meyti Eka, Huda Miftakhul, "Analysis of Use of Marker Tracking In Augmented Reality Hijaiyah (in Bahasa: Analisis Penggunaan Marker Tracking Pada Augmented Reality Huruf Hijaiyah)," *Jurnal Informatics, Telecommunication, and Electronics*, vol. 8, no. 1, 2016.
- [26] E. Setiawan, U. Syaripudin, and Y. A. Gerhana, "Implementation of Augmented Reality Technology in the Android Mobile Based Wudhu Handbook (in Bahasa: Implementasi Teknologi Augmented Reality pada Buku Panduan Wudhu Berbasis Mobile Android)," *Jurnal Online Informatika*, vol. 1, no. 1, pp. 28-33, 2018.
- [27] L. Hakim, "Development of Pie Based Learning Media Based on Augmented Reality (in Bahasa: Pengembangan Media Pembelajaran Pai Berbasis Augmented Reality)," *Lentera Pendidikan Jurnal Ilmu Tarbiyah dan Keguruan*, vol. 21, no.1, 2018.
- [28] H. Bay, A. Ess, T. Tuytelaars, and L. Van Gool, "Speeded-Up Robust Features (SURF)," *Computer Vision and Image Understanding*, vol. 110, no. 3, pp. 346-359, 2008.
- [29] R. Maini and H. Aggarwal, "Study and comparison of various image edge detection techniques," *International Journal of Image Processing (IJIP)*, vol. 3, no. 1, pp. 1-11, 2009.
- [30] R. R. Akbar, "Augmented Reality Technology Implementation in Android-Based Interactive Magazine Using the FAST Corner Detection Algorithm Method (in Bahasa: Implementasi Teknologi Augmented Reality pada Majalah Interaktif Berbasis Android Menggunakan Metode Algoritma FAST Corner Detection)," Thesis, Universitas Jember, 2016.
- [31] A. Hardiansyah, "Designing Android Based Augmented Reality Location-Based Service Application," *JOIN (Jurnal Online Informatika)*, vol. 2, no. 2, pp. 110-115, 2016.
- [32] M. A. Sánchez-Acevedo, B. A. Sabino-Moxo, and J. A. Márquez-Domínguez, "Mobile Augmented Reality," *Virtual and Augmented Reality*, 2018.
- [33] J. M. Mota, I. Ruiz-Rube, J. M. Doderio, and I. Arnedillo-Sánchez, "Augmented reality mobile app development for all," *Computers & Electrical Engineering*, vol. 65, pp. 250-260, 2018.
- [34] A. F. Al Baihaqi, Ed., "Al-Khumairah, The Qur'an Translate Tajwid color 17 in One (in Bahasa: Al-Khumairah, Al-Qur'an Terjemah Tajwid warna 17 in One)," CV. Alfatih Berkah Cipta.
- [35] S. A. M. Mu'abbad, "Taqiya-Complete Guide to Tajweed Science (in Bahasa: Taqiya-Buku Panduan Lengkap Ilmu Tajwid)," Taqiya Publishing, 2015.

© 2020. This work is published under
<https://creativecommons.org/licenses/by/3.0/>(the “License”). Notwithstanding
the ProQuest Terms and Conditions, you may use this content in accordance
with the terms of the License.