May-June 2020
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Efficient Hand Gesture Recognition Using Modified Extrusion Method based on Augmented Reality

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Abstract

Recognition of hand gesture with efficient methodology is an unsolved research problem in order to apply in education sector specially for improving learning process. In this context, mathematics is in great consideration by the researchers to make the process of learning easier using technology especially for the learners who are in the preliminary stage. Previously, research involved in improving learning process of mathematics using gesture recognition could not progress in large extent due to lack of comprehensive experimental validation and high computational complexity in lieu with less cost effective, deformation of hands, color of skin or unusual gesture. This research proposes modified extrusion method for hand gesture recognition which converts 2D shape to 3D shape in order to control these augmented geometrical shapes by gesture. In addition, proposed modified extrusion method is validated with standard performance metrics, i.e. accuracy, error rate and processing speed based on two perspectives, i.e. tracking and non-tracking of hand. Proposed method achieved accuracy rate of 95% in lieu with 10% error rate which reveals better performance comparing with previous research methods. Thus, experimental results reveal the efficiency of the proposed methodology.

Keywords: *Gesture recognition, augmented reality, computer vision*

1. Introduction

Mathematics is always core concern from the very beginning of educational institutions where process of learning is the most affluent areas for research investigation. Process of learning varies from preliminary stage about mathematics. Learners of mathematics often feel lack of knowledge of many particular areas of mathematics causes the fundamental areas of mathematics remains weak and next phases of their learning curve starts get harder to them. As a result, in future, learners find the whole mathematics as with complexity and fear. In this context, gesture recognition based augmented reality reflects potentiality in improving learning process of mathematics especially for the preliminary stage learners of mathematics which is the main concern addressed by this research by proposing modified extrusion method for hand gesture recognition based on augmented reality.

Augmented reality has been becoming more and more fertile research domain to the researchers, which actually makes them think that augmented reality can be a better medium of learning. Augmented Reality mix the real world with a virtually created object and give a better way to that object so that it seems the user is engaging with a real-time object. Nowadays, many games and application based on augmented reality are found and children are interacting with them properly. A tool like a device is needed to interact with the augmented object. So, the focus is to use the technology based on Hand Gesture as the hand works as the best interactive tool with real-time object and gesture is natural. But, there are many obstacles exist in this field, i.e. posture of the hand

TEST Engineering & Management
May-June 2020
ISSN: 0193-4120 Page No. 4020-4027

(Hu, Wong, Dai, Kankanhalli, Geng, & Li, 2019; Islam et al., 2017), different shape, color (Mahayuddin & Saif, 2018) etc. So, many researchers proposed many ideas to recognize hand gesture with maximum efficiency. Moreover, research in educational discipline is also trying to ensure that both student and teacher can interact so that the learning process can be more fruitful. In this context, distance is also another issue to be concerned to deal because student from different distance should participate in interacting with the augmented object. This research proposes modified extrusion method which includes processing of hand gesture through real time scene interpretation dynamically and 2D shape is converted to 3D shape.

Rest of this paper is demonstrated as follows: section 2 illustrates a comprehensive and critical background study about previous research progress, section 3 depicts proposed research methodology, section 4 demonstrates extensive experimental results and analysis for comparison and finally, section 5 illustrates concluding remarks of this research.

2. Previous Research Study

Gesture recognition based on augmented reality is now a potential research domain which has come a long way from scratch to this modern form. Many unsolved research issues are now in consideration to be solved by augmented reality, i.e. sign language recognition (Ren, Yuan, Meng, & Zhang, 2013), motion analysis (Mahayuddin & Saif, 2019), medical rehabilitation (Hu, Wong, Dai, Kankanhalli, Geng, & Li, 2019) , vehicle detection (Saif, Prabuwono, & Mahayuddin, 2013), human robot interaction (Nguyen, Brun, Lézoray, & Bougleux, 2019), corner feature extraction (Saif, Prabuwono, Mahayuddin, & Himawan, 2013), Aerospace (Cheng, Sun, Li, Jiang, & Liu, 2019), edge feature extraction (Saif, Prabuwono & Mahayuddin, 2013 etc. Initially, augmented reality started with only the motive of entertainment but now it is becoming a tool of learning which is considered as the primary motivation addressed by this research. Now a day, another goal of technology is to use the spatial ability which presents important aspect of human intelligence, i.e. movement analysis of human (Mahayuddin & Saif, 2019), facial image analysis (Saif, Prabuwono, Mahayuddin, & Mantoro, 2013) etc. There are five specifications which can fundamental blocks of spatial ability, i.e. perception, visualization, rotation, mental rotation and orientation (Saif & Mahayuddin, 2015). In this context, existing research verified that spatial ability can be improved by augmented reality based hand gesture recognition, i.e. geometry education. There are some other immersive works related to pure education using augmented reality, i.e. CyberMath, Geometer's Sketchpad, Cindarella, Euklid and Cabri Geometry (Kaufmann & Schmalstieg, 2002). Proposed research proposes a modified extrusion method for hand gesture recognition based on augmented reality where number of fingers is identified considering simple and complex background.

Previous researcher used various methods in the context of recognizing gestures, i.e. Extrusion method (Le & Kim, 2017), an auto encoder model (Tao & Ma, 2015), K-Means clustering (Maharani, Fakhrurroja, & Machbub, 2018), Support Vector Machine (Maharani, , Fakhrurroja, & Machbub, 2018), Masking Approach and Gradient approach (Vishwakarma, Majithia, & Mishra, 2017), HOG-LBP Featured model (Zhang, Liu, Zou, & Wang, 2018), bidirectional rank pooling method converting the depth sequences into images (Wang, Li, Liu, Gao, Tang, & Ogunbona, 2016; Hussain et al., 2016) etc. Extrusion method creates 3D shapes from 2D shapes but produces high complexity for some shapes (e.g. circle) (Le & Kim, 2017). To overcome this disadvantage, an auto-encoder model based on Semi-supervised Learning was introduced which is based on semi-supervised learning but only for static gestures (Tao & Ma, 2015). In this context, Cheng et al. (2019) also illustrated static gesture recognition, where they used Convolutional Neural Network in order to perform supervise feature extraction as a part of joint network for gesture recognition. However, for complex background scenario, their research does not perform well. Dynamic gestures are often a contiguous sequence for which auto-encoder model is inadequate for real-time use. In this context, Hu et al. (2019) processed dynamic gestures by proposing cross-modal association model constructed based on the adversarial learning. However, their research requires further investigation due to the need of robust validation. In addition, Masking and Gradient approach was introduced in the previous research which depended on every single pixel point of an image. That means regarding data storage, Masking and Gradient approach has an advantage but regarding high resolution images, Masking and Gradient approach will not work well (Vishwakarma, Majithia, & Mishra, 2017). A hand acknowledgment strategy dependent on HOG-LBP intertwined highlights and spiral base capacity bolster vector machine denoted as efficient research work in terms with ordering hand signals (Zhang, Liu, Zou, & Wang, 2018). This approach focuses on the static gesture recognition and has complexity in dynamic gesture. Adapted Convolutional Neural Network approach was also applied previously for ordering static hand motion information such as shifting in lighting, clamor, scale, rotation and interpretation (Alani, Cosma, Taherkhani, & McGinnity, 2018). Proposed calculation by Adapted Convolutional Neural Network approach utilizes an image-based analysis and put together different human signals where involvement can take place in regular daily existence. Nguyen et al. (2019) proposed neural network based hand gesture recognition. However, their research did not consider background issue during experimental validation which initiates the need further investigation of their research. Previously, researchers also focused on detecting and recognizing manual movements of hands in a natural environment (Vishwakarma, 2017). In this

May-June 2020
ISSN: 0193-4120 Page No. 4020-4027

context, Bidirectional rank pooling method converts depth sequences into images that improve the recognition accuracy largely (Wang, Li, Liu, Gao, Tang, & Ogunbona, 2016; Joarder et al., 2015). Proposed iterative plan by Bidirectional rank pooling method is computationally proficient in examination with the generally utilized channel-based quadrature techniques, in spite of the fact that Bidirectional rank pooling method is a long way from real time validation where individual's involvement in regular daily existence. Also, Bidirectional rank pooling method is sensitive to the initial selection of real image sequences (Yeasin, & Chaudhuri, 1999). A three – dimensional geometry building tool that build geometry dynamically named as Construct3D is mature enough to be used in educational practice (Kaufmann & Schmalstieg, 2006). The main benefits of using Construct3D in secondary school geometry education are that students actually visualize three dimensional objects (Kaufmann, Steinbügl, Dünser, & Glück, 2005). However, advancement of considerable instructive substance will require comprehensive assessment for the real value of an education tool (Kaufmann & Schmalstieg, 2002).

Based on the critical analysis of previous research methods, this research proposes modified extrusion method for hand gesture recognition based on augmented reality using color features where number of fingers is identified efficiently. To achieve this aim, several approaches are combined together, i.e. segmentation of skin, action mapping and AR marker processing for optimum recognition performance in terms with accuracy, error rate and processing speed. In this context, proposed research preferred segmentation instead of frame difference approach for real time scene interpretation during hand movement recognition.

3. Proposed Research Methodology

Proposed modified extrusion method recognizes hand gesture in the basis of detecting number of fingers in real time where visualization is demonstrated through real time scene interpretation. Then proposed methodology bounds the hand from other parts of the body as the skin types are quite similar for hands and other parts of the body. After that, AR marker is obtained from real time scene where in both cases of recognizing hand gesture and AR marker, AR Toolkit libraries overlays and displays exactly 3D virtual object on physical AR markers in the AR environment. Overall methodology for the proposed modified extrusion method is shown in Fig. 1.

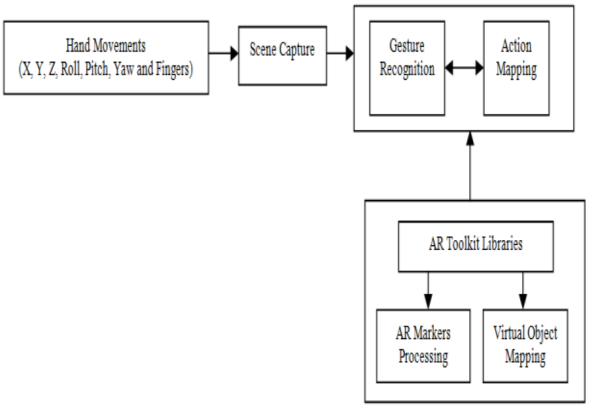

Figure 1: Proposed modified extrusion method

Recognition process starts with hand gesture recognition where segmentation part is composed of YCrCb skin detection, skin color detection and HSV color detection in order to recognize hand fully. As color features based segmentation faces unique kind of disturbance like same color constraint issues during foreground and background subtraction, proposed method used segmentation methodology instead of using frame difference or optical flow methodology. In this context, movement of ten fingers, i.e. pinch, zoom in, zoom out and rotation are considered to be detected as hand gestures after segmentation of hands which later described as tracking and non-tracking of hands to process the recognition for number of fingers. To achieve this purpose, some predefined gestures were stored for matching perspectives. Later, interactor's action is observed through scene which is mapped through action mapping functionalities in order to augment the desired shape. Next, recognition of a marker is performed using AR Toolkit libraries in order to use features and function, i.e. video orientation, camera calibration, scene interpretation, virtual object visualization etc. Every marker presents one sort of a geometrical shape. With AR Toolkit libraries, various markers can be perceived and pictured from real time scene in lieu with physical position and size.

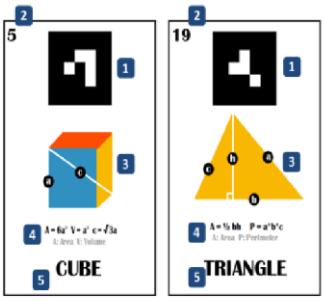

Figure 2: Physical markers for both 2D and 3D shape

Proposed modified extrusion method consists of various function to build up two dimensional and three-dimensional geometrical shape where construction of

May-June 2020
ISSN: 0193-4120 Page No. 4020-4027

three-dimensional geometrical shapes dependent on a 2D shape or a lot of two-dimensional shapes. Fundamentally, two dimensional shapes are provided through the framework, and after that framework will naturally produce comparing 3D shapes from them. Demonstration of a case of this capacity where a block, a circle and barrel are shown in Fig. 2 by changing 2D shapes, for example, a square, a circle and a chamber, separately (Munasinghe, 2018). Three noteworthy communication strategies for geometrical changes are determined: turn, scaling and panning, which can be performed by utilizing two hands and fingers. Utilization of two hands can be used for scaling and center fingers to turn the items and utilize the forefinger for panning or moves the sources around. It shows test associations utilizing hand motions which comprise of turn, moving, on a level plane and vertically scaling. The signals are indicated as straightforward as feasible to recollect and perform effectively and helpfully. Point of view during the execution of the proposed methodology is also a significant issue in this research to get a proper precession point to observe the geometrical shape with proper angle and perspective.

4. Experimental Results and Discussion

Proposed research methodology is composed into three phases, i.e. recognition of hand gesture, recognition of AR marker and generation of geometrical shape with the interaction process. For overall experimental methodology, proposed research used EmguCV, a cross platform image processing library which is closely related to OpenCV as EmguCV is a .NET wrapper to OpenCV (Mahayuddin, Saif & Prabuwono, 2015). In addition, proposed research also used Python as a programming language, OpenCV library (Saif, Prabuwono, & Mahayuddin, 2014) and Numpy array (Saif & Mahayuddin, 2018). In addition, proposed research used various performance metrics, i.e. accuracy, error rate and tracking rate (Saif, Prabuwono, & Mahayuddin, 2014) to validate proposed modified extrusion method. To validate the overall methodology, proposed research testified the recognition of number of fingers for which two types of experimentation were done, i.e. with tracking and without tracking of hands. Comprehensive details for each of these experimentations are mentioned in the next subsections.

a. Experimental results based on tracking approach

Recognition of number of fingers is performed based on tracking hand from any position by extracting from other parts of the body. This task depends on the similarity of skin types for hands and other parts of the body which follows by putting AR markers around the hand. Proposed modified extrusion method based on convex hull measurement is performed in various backgrounds shown in Fig. 3, Fig. 4 and Fig. 5. For simple background scenario like where color pallet of the background is different from skin color pallet, proposed modified extrusion method is able to track and recognize the gesture which resulted as correct recognition of number of fingers shown in Fig. 3. Besides, proposed research considers complex background scenario where color pallet of the background is same with the skin color pallet. In this kind of complex scenario, proposed modified extrusion method countered high difficulties in tracking the hand where most of the time proposed modified extrusion method tracked the background instead of hand. Sample correct recognition in complex background scenario is shown in Fig. 4 and incorrect recognition in complex background scenario is shown in Fig. 5.

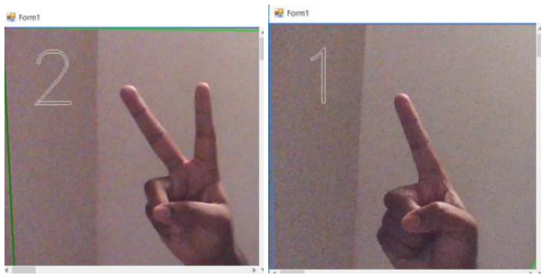

Figure 3: Recognition in simple background based on tracking

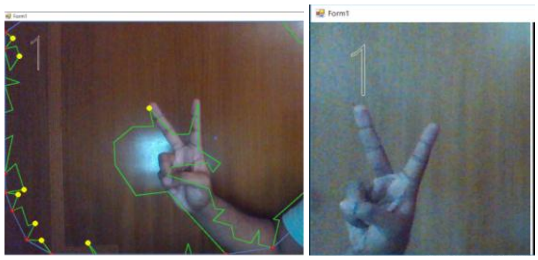

Figure 4: Recognition in complex background

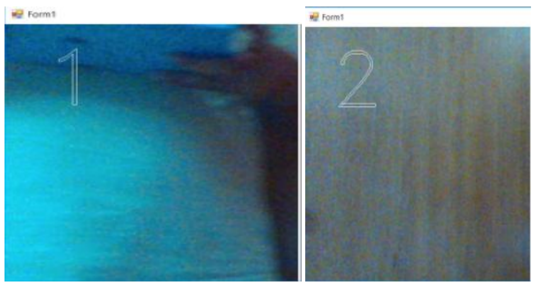

Figure 5: Incorrect recognition in complex background

Details performance for simple background and complex background for tracking based hand gesture recognition is shown in table 1. Proposed modified extrusion method achieved high accuracy rate of 90% with low error rate of 10% for simple background scenario where color pallet of the background is different from skin color pallet. In this scenario, proposed research achieved tracking rate of 65%. However, as described above for complex background scenario, proposed modified extrusion received very low accuracy rate of only 20% with high error rate of 80% in lieu with 10% tracking rate.

Table 1: Experimental results based on tracking approach

Background type	**Accuracy**	**Error**	**Tracking rate**	**System**
Simple (Non-Complex)	90%	10%	65%	Core i5 CPU with 2.70 GHz processor
Complex	20%	80%	10%	

b. Experimental approach based on without tracking approach

Proposed modified extrusion method is able to recognize number of fingers where only the hand will be shown from a specific position. As proposed modified extrusion method recognizes hand gesture from a specific area, hence proposed methodology does not need to track hand from the overall background scenario. Proposed modified extrusion method is also experimented based on without tracking approach in simple and complex background scenarios. Proposed research is able to recognize gesture when the hand positioned in a specific area for simple background scenario shown in Fig. 6. As the color pallet of the background is different from skin color pallet, proposed modified extrusion method received high accuracy in this scenario. However, in the case of without tracking for complex background scenario, proposed modified extrusion method faces difficulties in tracking hands shown in Fig. 7 which results in low accuracy.

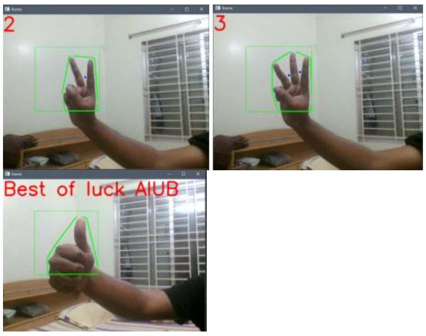

Figure 6: Recognition in simple background

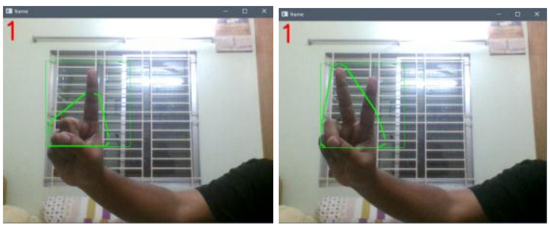

Figure 7: Incorrect recognition in complex background

Experimental results for simple background and complex background for without tracking based hand gesture recognition is shown in table 2. Proposed modified extrusion method achieved high accuracy rate of 95% with low error rate of 5% for simple background scenario. However, in case of complex background scenario, proposed modified extrusion method achieved accuracy rate of 70% with error rate of 30% which is very promising results in comparison with tracking-based hand gesture recognition mentioned in table 1.

Table 2: Experimental results based on without tracking approach

Background type	**Accuracy**	**Error**	**Tracking rate**	**System**
Simple (Non-Complex)	95%	5%	None	Core i5 CPU with 2.2 GHz processor
Complex	70%	30%		

c. Comparison of Experimental Results with Previous Research Results

Le and Kim (2017) receives accuracy rate of 80% where background scenario in terms with tracking or without tracking of hands was not addressed for validation. Hu et al. (2019) and Nguyen et al. (2019) received accuracy rate of 65.7% and 91.65% were background issue was not also addressed for reliable validation shown in Fig. 8. Ren et al. (2013) received accuracy rate of 93.2% where background issues were not addressed also for robust validation. For non-tracking scenario, proposed modified extrusion method received accuracy rate of 95% in case of simple background denoted as MEM-W.T.S in Fig. 8. In this context, accuracy rate reduced to 70% in case of complex background denoted as MEM-W.T.C in Fig. 8. However, for tracking of hand case, accuracy falls to 20% only when the background becomes complex by using proposed modified extrusion method denoted as MEM-T.C denoted in Fig. 8. On the contrary, accuracy rate is 90% if the background is simple denoted as MEM- T.S in Fig. 8. Besides, opposite scenario was seen in terms of error rate shown in Fig. 9. As the recognition rate is higher for the proposed modified extrusion method, error rate becomes lower. However, Le and Kim (2017) and Cheng et al. (2019) receives error rate of 20% and 8.3% respectively where background issues were not addressed adequately for reliable validation. For no-tracking scenario, proposed modified extrusion method receives 5% error rate for simple background and 30% error rate in complex background scenario. For tracking of hand, proposed modified extrusion method receives 10% error rate for simple background, but when the background become complex, error rate rise up to 80% which will be further investigated by this research in future. Proposed research required 58.3 second to process the overall methodology demonstrated by this research. However, for recognition part, proposed research required 9s to complete recognition task. In this context, extrusion method can be called as process dependent method as the processing speed depends on the processor.

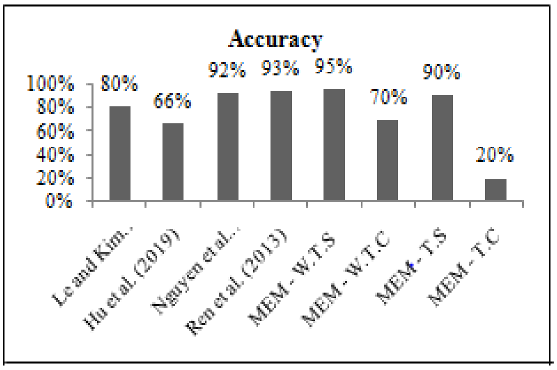

Figure 8: Accuracy comparison with previous research

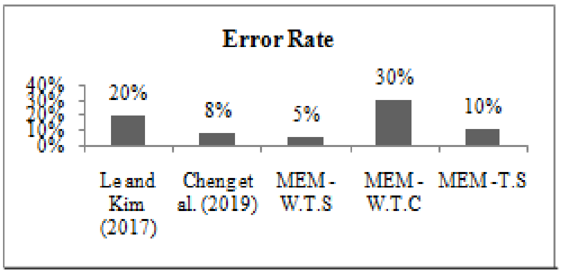

Figure 9: Error rate comparison with previous research

5. Conclusion

This research proposed modified extrusion method which essentially centered the integration of two principle concerns, i.e. hand gesture recognition and augmented reality towards hands-on learning approach for the preliminary stage learners. Previously, very few researchers addressed the issue of using hand gesture recognition and augmented reality to enhance the learning process of mathematics for preliminary stage learners due to the need of comprehensive validation in lieu with solving core research problems regarding integrating the field of computer vision and image processing, i.e. object detection, object recognition, motion detection, skin segmentation etc. Proposed modified extrusion method integrated these aspects to recognize hand gesture with maximum efficiency. In addition, comprehensive validation based on standard performance metrics, i.e. accuracy, error rate and processing speed is also demonstrated by this research. Experimentation of the proposed research was done based on two perspectives, i.e. tracking and non-tracking of hand where accuracy rate of 95% was achieved in case of non-tracking of hand scenario. In addition, experimental validation considered two types of environment, i.e. simple background and complex background to ensure the robustness of the experimentation for the proposed methodology. However, in case of increasing the size of data in the datasets, complexity is still a big concern which is considered as future concern by this research. Recognition of hand gestures outfits an instinctive and advantageous path to enhance the learning process. In addition, augmented reality helps the learners to absorb fundamental ideas of various shapes of by giving dynamic representation of 3D structures. In this context, proposed modified extrusion method is expected to contribute significantly in the field of gesture recognition and augmented reality in the broader aspects of computer vision, image process and pattern recognition research domains.

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