A New 3D Augmented Reality Application for Educational Games to Help Children in Communication Interactively

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Abstract. In recent years, the use of technology to help children for augmented and alternative communication (AAC) is extremely a vital task. In this paper, a novel three-dimensional human-computer interaction application is presented based on augmented reality (AR) technology for assisting children with special problems in communication for social innovation. To begin with, three-dimensional human hand model is constructed to estimate and track the hand's position of users. An extended particle filter is applied for calculating the pose of background and the positions of children. The likelihoods based on the edge map of the image and pixel color values are utilized to estimate the joint likelihood in three-dimensional model. A flexible real-time hand tracking framework using the 'golden energy' scoring function is integrated for capturing region of interests. An inertial tracking technique is used for calculating the quaternion. Three-dimensional models from Google SketchUp are employed. We then use a built QR-code for scanning to access the system, and then utilize for selecting a character three-dimensional designed cartoon by applying the Vidinoti image application. After that, representative three-dimensional cartoons and augmented environments are overlaid, so that it is able to entertain children. A printed coloring photo, called Augmented Flexible Tracking is designed and provided in the system for visualization. The process of the system is done in real-time. Our experiments have revealed that the system is beneficial both quantitatively and qualitatively for assisting children with special needs in communication interactively.

Keywords: Augmented reality · Augmented and mixed reality · Educational games · Communication · Children with special problems · Human-computer interaction · Three-dimensional interaction

1 Introduction and Related Works

In the 21st century, computer with innovative technology has emergently evolved from conventional teletypewriters to smart technological tools in an interdisciplinary aspect for social innovation and connecting people to people, even people with special needs

O. Gervasi et al. (Eds.): ICCSA 2016, Part II, LNCS 9787, pp. 465–473, 2016.
DOI: 10.1007/978-3-319-42108-7_35

in communication to limitless opportunity. The emerging innovative technology has transformed the way we communicate markedly. Augmented reality (AR) is a vitally new field of computational science, computer science and computer engineering. In recent years, it has being explored to enhance, help and assist children with special problems in spoken and written communication with social interaction. Several interesting augmented reality applications have been recently presented to help children in communication.

For example, Tanner et al. [1] built an augmented reality classroom, presented in 2014, using educational tablet technology. Their goal is to attempt for helping and educating students with their comprehension of a certain procedural task, such as creating Lego robotic devices. They used the Aurasma application to interact with an animated Lego robotic device of the same static manual. Next, Bhatt et al. [2], proposed similarly in 2014, created an augmented reality game for assisting children by enhancing hand-eye coordination and social interaction. In their case, they specifically focused only on children with Asperger syndrome, a neurobiological autism spectrum disorder on the higher-functioning end. They used Adobe Flash CS6 and Actionscript 3.0 to create this emotion game to interact with only the faces of children. Therefore, although this augmented reality game has a limitation for an automatic facial recognition, it is able to allow children for dragging and dropping features interactively onto their faces to build freely an expression. Furthermore, Bai et al. from the University of Cambridge [3] built an augmented reality system, presented lately in 2015, for conceptualizing the representation of pretense visually for eliciting pretend play for small children with special needs. Their main aim is to help small children with autism spectrum condition only aged lower than 7 to be able to interact with the system. Moreover, Magnenat et al. [4], proposed recently in 2015, from Disney Research Zurich developed a printed coloring book method for children. It is done by texturing and displaying the color characters in three dimensions using a smartphone in a children's coloring book. In their work, a texturing algorithm was also presented in real-time for transforming the input texture from a two-dimensional colored drawing to a three-dimensional character. Furthermore in 2015, Persefoni and Tsinakos [5] described a good recent overview for the use of augmented reality in modern education in many different context aware technologies. In their case, they use augmented reality technology in tablets and smartphones for providing interactively and uniquely educational experiences. Several open course projects using augmented reality in the Eastern Macedonia and Thrace Institute of Technology are included and discussed for a modern educational way. Also, one of the pioneering research works in the study of augmented reality technology for rehabilitation of cognitive children with special problems is the work of [6] proposed preliminarily by Richard et al. They defined the term of Augmented Reality applied to Vegetal. The term is shortly called ARVe. They implemented the application for allowing people, focusing on disabled children and pupils with special problems, to handle plant entities in both two dimensions and three dimensions generated graphics. Different senses of olfactory, vision or auditory are used for helping disabled pupils in an elementary school in France for decision making. A similar work using augmented reality technology for exploring the feasibility of utilizing augmented reality technology in early educational school was also presented in the very recent work of [7] by Huang et al. in 2016. But this design-based work was used and tested in different location (i.e., in Hong Kong kindergarten) Besides in 2015, Zünd et al. from ETH Zurich used the term "augmented creativity" [8] to describe their augmented reality-based work for enhancing creative play for children. Their research aim is to musically allow people to make their own cartoon using augmented reality on smartphones. Cunha et al. [9] also presented recently on February 2016 an augmented reality-based application called GameBook for helping young people with autism spectrum disorders (ASD). It is aimed for recognizing and acquiring emotions of children with special needs by involving interactively their motivation and attention. In addition, augmented reality is not only technology to possibly help children in communication, but it also includes some related technologies such as virtual reality (VR) and multimedia. Multimedia is basically content combined from a number of different types of forms, including sounds, texts, images, animated video, and interactive contents. Due to the variety of forms of multimedia interactively and virtually, it is able to be applied to support people recently in different fields, including disabled people with special rehabilitation. Significantly, it is also able to help developing assistive technology (AT) for contributing to the improvement of the life of people with disabilities. There are some interesting multimedia-based assistive technology applications for supporting people with special needs and children with disabilities to perform tasks that they were previously unable to achieve, or had difficulty achieving extremely.

However, to the best of our knowledge, in every previous system, they have different goals for our presented work in this paper. Our main purpose of the research described here is to assist people, especially children, who have problems in communication at school for educational games, focusing in primary school aged between 8 and 12 for augmented and alternative communication (AAC). Some representative three-dimensional cartoons and augmented environments for visualization are shown during running the system. The rest of our presented paper is organized as follows. The next section (Sect. 2) will explain about our proposed system configuration and how does it work. We then show our representative experimental results in Sect. 3. Finally in the last section (Sect. 4), we conclude the paper and points out the directions of our future work.

2 System Configuration and Proposed System

This section describes the system configuration and the presented system. We, in this paper, propose a novel three-dimensional human-computer interaction application based on augmented reality technology for helping children with special problems in non-verbal communication in a unique way for social innovation. We first track a camera to estimate the pose of background and the positions of people by using a robust particle filter extended as described in [10] in real-time. In this system, we use and adapt three-dimensional models from Google SketchUp [11] to create several new three-dimensional cartoon models for educational games. A built QR-code is also utilized to scan to access the system. This QR-code is then used to choose and select a character three-dimensional designed cartoon by applying the Vidinoti image application [12]. After that, we apply the hand tracking using extended distance transform and our geometric hand model we created using a set of quadrics, roughly representing the position and anatomy of a real hand of human.

It is used for locating the pose of 27 DOF human hand model for overlaying as explained in [13]. We also extend a flexible real-time hand tracking method proposed and presented by Sharp et al. [14] from Microsoft Research in 2015 to capture region of interests. We estimate the quaternion for obtaining the better results.

As shown in Fig. 1, the hand model is built from 39 truncated quadrics with 27 DOF: 4 for the pose of four fingers, 5 for the position of the thumb, and 6 for the global hand pose using OpenGL. In this system, we use the likelihoods based on the edge map of the image and pixel color values in each input image. Therefore, the joint likelihood of is calculated using

Fig. 1. The hand model we constructed from the input hand images using OpenGL and the 'golden energy' scoring function

$$\begin{aligned} p(z \mid x) &= p(z^{edge}, z^{sil} \mid x) \\ p(z^{edge}, z^{sil} \mid x) &\approx p(z^{edge} \mid x)p(z^{col} \mid x), \end{aligned} \tag{1}$$

while the p(z|x) is denoted as observations z in both images to the unrecognized state x, z^{edge} is the edge map in each image, and $z^{sil}$is the pixel color values of silhouette in an image. By analyzing the edge likelihood, we use the chamfer distance function to estimate and extract feature in the image. This distance function is calculated and estimated for various model templates by employing and utilizing a distance transform of the edge image. The silhouette likelihood is then calculated by utilizing a Bayesian classifier as presented and described in [15]. The likelihood function is adaptively computed using

$$p(z^{edge} \mid x) = \frac{1}{Z} \exp(-\lambda d(A(x), B(z^{edge}))). \tag{2}$$

In this likelihood equation, A(x) is the set of template points in the shape template P, while B is denoted as the set of edge points received from the edge image. After that, a flexible real-time hand tracking algorithm [14] according to the 'golden energy' scoring function is integrated and utilized to capture region of interests where a model pixel we used is tracked and determined using

$$E^{au}(Z \mid R) = \sum_{ij} \rho(\overline{z} - r) + C, \tag{3}$$

where Z is a tight region of interest in an image and C in the equation is a constant value. We attempt to calculate the quaternion for simplifying the results. By applying the inertial tracking method as presented in [16] by Baldi et al., we then calculate and compute the quaternion, called r(t), using

$$r(t) = \alpha * g(t) + (1 - \alpha)q(t), \tag{4}$$

where the value of α we used in this process is between 0 and 1. Representative three-dimensional cartoons and augmented environments are then immediately overlaid onto the background we created to help and entertain children for educational games in a limited amount of time. In this presented system, we also design and provide a printed coloring photo, called Augmented Flexible Tracking, for providing and giving it to entertain children. User participation is also done in our system development process. Finally, experiment from this human-computer interaction system is done to evaluate and assess the performance of the presented work with real children with special needs in the real situation using a mobile phone. The experimental results have revealed that our application is beneficial for children with special needs and specific learning difficulties and assessment in non-verbal communication interactively and effectively. Figure 2 depicts the system configuration of the proposed human-computer interaction work using augmented reality for educational games. In this configuration, it is composed of a smartphone which can be alternatively any device from the internet of things. After tracking the position of camera, a QR-code is used for scanning to access and choose a character three-dimensional cartoon using a mobile phone. After children

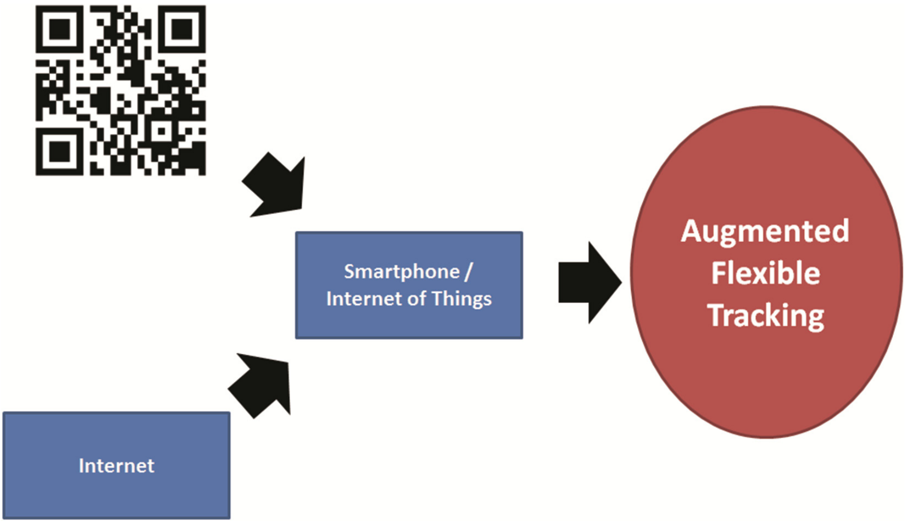

Fig. 2. System configuration of the proposed human-computer interaction work using augmented reality technology

enter in the scene, three-dimensional cartoons and augmented environments are then immediately overlaid onto the background for entertaining children in real-time for visualization. Augmented Flexible Tracking is ultimately used for printing a coloring photo for people focusing on children for educational games.

3 Representative Results

In this section, we show our representative experimental results. We conducted a user study to test and evaluate the robustness of the presented system both quantitatively and qualitatively. The processing speed (i.e., the computation time) for this presented educational application is about 14 frames per second, which is quite real-time. For qualitative results, we randomly selected ten children with special needs in primary school aged between 8 and 12. Each child was asked to test our presented system. It is important to note that, in the experiment, we did not know each child personally beforehand. This is to avoid some possibly unbiased answers, so that most children were chosen randomly to make sure that they are unbiased. Each child took about 10 min to run the study for educational games. Almost children were able to use the application after a brief explanation in 2-3 min., even though there was one child who took slightly long time to understand how to use the system (i.e., 5 min.). After the individual tests, every child was asked to give qualitative feedback. Table 1 shows and illustrates representative qualitative feedback from these ten participants. This included interest in the proposed application, user satisfaction, smoothness of the presented application, ease of use of the designed interface, and overall system impression. General comments on the test were also collected from every participant.

Table 1. Qualitative results from users who were randomly chosen to test the system

	Minimum score (10 points)	Maximum score (10 points)	Average score (10 points)
Interest in the application	7	10	8.24
User satisfaction	8	10	9.23
Smoothness of the system	8	10	9.01
Ease of use of the interface	6	10	7.72
Overall impression	8	10	8.41

According to the qualitative user study we conducted, we received mainly positive comments. Many participants agreed that they are satisfied with the smoothness of the proposed system. The range of the application scores for smoothness of the system is 8 through 10, with the average score at 9.01 from 10. Regarding about interest in this application from each participant, the range of the application scores is 7 through 10, with the average score at 8.24 from 10. They reasoned that this was since the application is able to perform in real time. Moreover, many participants indicated that they were impressed by the system, especially by the idea of developing this application. The range of the application scores for user satisfaction is 8 through 10, with the average score at 9.23 from 10. This average score for user satisfaction is the highest. Generally, the range of the application scores for overall impression is 8 through 10. The average score for overall impression is at 8.41 from 10. Nevertheless, the most common non-positive feedback was about ease of use of the application. They commented that the current system may not extremely be easy to use, if no one teaches them some giving instructions of how to use the system. There is one participant who suggested that the system should provide some short instruction manual of how to use the application for every new user. This was the reason why they gave lower scores to ease of use of the interface than other individual criterion scores. The range of the application scores for ease of use of the interface is 6 through 10 with the average score at 7.72 from 10. Although this score for ease of use of the interface was not too low, it could be improved in the future with some new technical methods. However, we believe that these numbers from qualitative results of participants are quite suitable enough to make the presented application practical for helping children with special needs in communication for educational games. Also, several representative experimental results are shown. Figure 3 illustrates some examples of our augmented reality application in several representative parts showing and overlaying some three-dimensional cartoons for educational games and augmented environments onto the background we built. After testing and conducting the experiment both qualitatively and quantitatively, it has revealed that children with specific learning difficulties are satisfied with this new augmented reality based-system interactively.

Fig. 3. Examples of our augmented reality application in some representative parts for helping children with special needs in communication interactively for educational games

4 Conclusions and Future Works

In computational science, augmented and mixed reality has been recently an extremely popular topic. In recent years, many emerging applications usually bring augmented and mixed reality to make them novel, interesting and robust in an advanced manner differently. In this paper, we have developed a novel vision-based application that assists children with special problems in communication based on augmented and mixed reality approaches. We construct three-dimensional human hand model for detecting and tracking the hand's position using a particle filter extended. The likelihoods based on the edge map of the image and pixel color values are applied for calculating and estimating the joint likelihood in three-dimensional model. A flexible real-time hand tracking technique based on the 'golden energy' scoring function is then used to determine some region of interests. We also use three-dimensional models from Google SketchUp for creating educational games. A QR-code for scanning to access the system is achieved to allow users to choose a character three-dimensional designed cartoon freely using Vidinoti image application for visualization. Therefore, several cartoons and augmented environments in three-dimensions can be overlaid for entertaining children. In the proposed system, a printed coloring photo is provided also for three-dimensional interaction. The process of the system is done quite quickly and performed in real-time.

After conducting a user study, we believe that we can achieve a robust current system output to assist children in a novel way. However, the system has still some limitations for improvements. Therefore, our future work is aimed to deal with the problem of the occlusion of tracking. We also plan to cope with the problem of ease of use of the interface while using the system automatically. In the future, we intend to make technical improvements to apply and potentially extend some continuously adaptive mean shift techniques such as [17] and several adaptive randomized ensemble tracking algorithms such as [18] to further refine these problems in a robust manner.

Acknowledgments. This research presented herein was partially supported by a research grant from the Research Center, NIDA (National Institute of Development Administration).

References

1. Tanner, P., Karas, C., Schofield, D.: Augmenting a child's reality: using educational tablet technology. J. Inf. Technol. Educ. Innovations Pract. (JITE) **13**, 45–54 (2014)
2. Bhatt, S.K., De Leon, N.I., Al-Jumaily, A.: Augmented reality game therapy for children with autism spectrum disorder. Int. J. Smart Sens. Intell. Syst. **7**, 519–536 (2014). Massey University
3. Bai, Z., Blackwell, A.F., Coulouris, G.: Using augmented reality to elicit pretend play for children with autism issue. IEEE Trans. Vis. Comput. Graph. **21**(05), 598–610 (2015)
4. Magnenat, S., Ngo, D.T., Zund, F., Ryffel, M., Noris, G., Röthlin, G., Marra, A., Nitti, M., Fua, P., Gross, M., Sumner, B.: Live texturing of augmented reality characters from colored drawings. In: IEEE International Symposium on Mixed and Augmented Reality (ISMAR 2015), Fukuoka, Japan, 10 p., 29 September 2015
5. Giannakos, M.N., Divitini, M., Iversen, O.S., Koulouris, P.: Making as a pathway to foster joyful engagement and creativity in learning. In: Chorianopoulos, K., Divitini, M., Hauge, J.B., Jaccheri, L., Malaka, R. (eds.) ICEC 2015. LNCS, vol. 9353, pp. 566–570. Springer, Heidelberg (2015). doi:10.1007/978-3-319-24589-8_58

6. Richard, E., Billaudeau, V., Richard, P., Gaudin, G.: Augmented reality for rehabilitation of cognitive disabled children: a preliminary study. IEEE Virtual Rehab. IEEE Eng. Med. Biol. Soc. pp. 102–108, Venice, Italy, 27–29 September 2007
7. Huanga, Y., Lia, H., Fonga, R.: Using augmented reality in early art education: a case study in Hong Kong kindergarten. Early Child Dev. Care **186**(6), 879–894 (2016). doi: 10.1080/03004430.2015.1067888
8. Zünd, F., Ryffel, M., Magnenat, S., Marra, A., Nitti, M., Kapadia, M., Noris, G., Mitchell, K., Gross, M., Sumner, R.W.: Augmented creativity: bridging the real and virtual worlds to enhance creative play. In: Proceeding of ACM SIGGRAPH Asia 2015, Mobile Graphics and Interactive Applications, Article No. 21, Kobe, Japan, 2–6 November 2015
9. Cunha, P., Brando, J., Vasconcelos, J., Soares, F., Carvalho, V.: Augmented reality for cognitive and social skills improvement in children with ASD. In: 13th International Conference on Remote Engineering and Virtual Instrumentation (REV), pp. 334–335. IEEE Publisher, Madrid, Spain, 24–26 February 2016
10. Kerdvibulvech, C.: Human hand motion recognition using an extended particle filter. In: Perales, F.J., Santos-Victor, J. (eds.) AMDO 2014. LNCS, vol. 8563, pp. 71–80. Springer, Heidelberg (2014)
11. Grover, C.: Google SketchUp: The Missing Manual, 1 edn., 602 p. O'Reilly Media, Sebastopol, 1 June 2009
12. Perdikakis, A., Araya, A., Kiritsis, D.: Introducing augmented reality in next generation industrial learning tools: a case study on electric and hybrid vehicles. In: Procedia Engineering, The Manufacturing Engineering Society International Conference (MESIC), vol. 132, pp. 251–258. Elsevier Publishing, ScienceDirect (2015)
13. Kerdvibulvech, C.: Hand tracking by extending distance transform and hand model in real-time. Pattern Recogn. Image Anal. **25**(3), 437–441 (2015). Springer Publisher
14. Sharp, T., Keskin, C., Robertson, D., Taylor, J., Shotton, J., Kim, D., Rhemann, C., Leichter, I., Vinnikov, A., Wei, Y., Freedman, D., Kohli, P., Krupka, E., Fitzgibbon, A., Izadi, S.: Accurate, robust, and flexible real-time hand tracking. In: ACM Conference on Human Factors in Computing Systems (CHI), Seoul, Republic of Korea, 18–23 April 2015
15. Papoutsakisa, K.E., Argyros, A.A.: Integrating tracking with fine object segmentation. Image Vis. Comput. **31**(10), 771–785 (2013)
16. Baldi, T.L., Mohammadi, M., Scheggi, S., Prattichizzo, D.: Using inertial and magnetic sensors for hand tracking and rendering in wearable haptics. In: 2015 IEEE World Haptics Conference (WHC), Evanston, IL, pp. 381–387, 22–26 June 2015
17. Im, J., Jung, J., Paik, J.: Single camera-based depth estimation and improved continuously adaptive mean shift algorithm for tracking occluded objects. In: Ho, Y.S., Sang, J., Ro, Y.M., Kim, J., Wu, F. (eds.) PCM 2015. LNCS, vol. 9315, pp. 246–252. Springer International Publishing, New York (2015)
18. Li, W., Lin, Y.: Adaptive randomized ensemble tracking using appearance variation and occlusion estimation. Math. Prob. Eng. **2016**, 1–11 (2016). Article ID 1879489