# Mixed Reality based Character Animation System for Indoor Sports Climbing Education

**Myeong-Hyeon Heo[1], Dongho Kim[2]**

## Abstract

*Sports climbing is reported to have physically and mentally positive effects as a physical activity consisting of a series of movements of climbing an artificial wall or a natural wall using upper and lower part of the body. However, indoor sports climbing require repeated movements within a limited space or on a simple rock wall, which may cause climbers to lose their consistent interest in it. Furthermore, it is important that a coach should show accurate climbing movements to make sure that learners can understand them on their own. However, in the actual lessons, it is difficult for learners to make the movements in the same way their coaches do on the same artificial rock wall.*

*Mixed reality technology can be utilized to solve these problems. In physical education there had been studies about the effects of mobility learning and feedback utilizing mixed reality technology. Projection mapping is in a domain of mixed reality, and it is a technique that shows a different from of the image of an object than its original physical one by analyzing the 3D characteristics of its surface to project and align the images of light. Unlike other mixed reality based devices, projection mapping enables the many users to experience the spatial expression of a virtual object at the same time. Therefore, a realization of the mixed reality through the projection mapping of the character animation to an artificial rock wall for indoor sports climbing lessons may improve the efficiency of learning by having learners watch the changes in the real-time postures and movements. Considering this problem, this study aims to develop a mixed reality based character animation system and to verify its learning effects to improve the indoor sports lessons for beginners.*

*Keywords: Sports climbing, Projection mapping, mixed reality, Character animation*

## 1. Introduction

In physical education, learning a new skill requires a repeated process of spending much time and exerting many efforts. In this regard, a technology is desperately needed to motivate athletes to repeat learning monotonous skills and to reduce the time of going through a painful training by making them actively do exercise. To meet this need, efforts are being made to establish a new learning environment, which will combine and present virtual objects in the real world to allow athletes to have an experience-based learning [1][2][3].

Mixed reality is a next generation information processing technology that maximizes the usefulness and utility of information by combining the real-time information (e.g., computer graphics, sounds, haptic, smell, etc.) that is virtually generated on the objects in the real environment to enable users to interact with such information [4][5][6]. In addition, it is a technology that provides an improved sense of immersion or reality to users by seamlessly combining the real world and the virtual world in real time. Sports climbing is reported to have physically and mentally positive effects as a physical activity consisting of a series of movements of climbing an artificial wall or a natural wall using upper and lower part of the body [9]. In particular, indoor sports climbing is safer compared to outdoor sports climbing and can be enjoyed regardless of weather conditions. Furthermore, due to its higher spatial utility than those of other sports, the number of people who enjoy it is on a sharp increase. However, indoor sports climbing requires repeated movements within a limited space or on a simple rock wall, which may cause climbers to lose their consistent interest in it. Furthermore, it is important that a coach should show accurate climbing movements to make sure that learners can understand them on their own. However, in the actual lessons, it is difficult for learners to make the movements in the same way their coaches do on the same artificial rock wall. In conclusion, the traditional sports climbing lessons fail to provide smooth education because they are conducted in the way that a coach gives instructions on almost every movement of learners' hands and feet. An introduction of the projection mapping technique may help solve this problem. It is because the image training provided

[1] Soongsil University, Korea
[2] Soongsil University, Korea

by this may have a positive effect on the improvement of learners' motor skills and attitudes toward lessons.

Projection mapping is in a domain of mixed reality, and it is a technique that shows a different from of the image of an object than its original physical one by analyzing the 3D characteristics of its surface to project and align the images of light. Unlike other mixed reality based devices, projection mapping enables the many users to experience the spatial expression of a virtual object at the same time. Therefore, a realization of the mixed reality through the projection mapping of the character animation to an artificial rock wall for indoor sports climbing lessons may improve the efficiency of learning by having learners watch the changes in the real-time postures and movements.

Kajastila and Hämäläinen (2014) reported that the route information and game contents that can be used in sports climbing are effective in inducing users' interest and active participation [10]. However, the existing contents of the mixed reality based sports climbing are limited to the provision of the information on route and games through the interactive artificial holds and projection techniques, which makes it difficult for beginners to learn basic climbing postures and movement that are needed for effective sports climbing [10][11]. Considering this problem, this study aims to develop a mixed reality based character animation system and to verify its learning effects to improve the indoor sports lessons for beginners.

## 2. Mixed Reality based Character Animation System

In sports climbing lessons for beginners, they are usually instructed to climb the multiple holds attached to an artificial rock wall along the predetermined climbing route. Therefore, such lessons are aimed at learners' making the movements very similar to those of an actual sports climbing expert when a virtual character climbs along the predetermined climbing route assuming. In addition, the lessons had an expert group participate in the process of developing the program in order to apply the distinct characteristics of the spots climbing to the actual scenes. The expert group consisted of a total of 4 coaches: one incumbent coach of national athletes, two former national athletes, one Ph. D researcher in kinematics. A total of six times of consultations over the intermediate development were made and their results were reflected in the realistic implementations of the postures and movements of the sports climbing character animation.

### 2.1 Character Animation

As a method for processing the rotation of the joints at the place of the end-effector, inverse kinematics is a technique that is used for a natural control of postures. It can automatically construct the movements of the character's joints according to the location of objects through a program.

Therefore, the basic movements were generated using an inverse kinematics algorithm. However, these postures generated by such algorithm may cause a confusion in the values of the character's joints, which in turn create their distortion. To compensate this, the postures were generated using actual data to make sure that the value of each joint remained in the allowable limits of error.

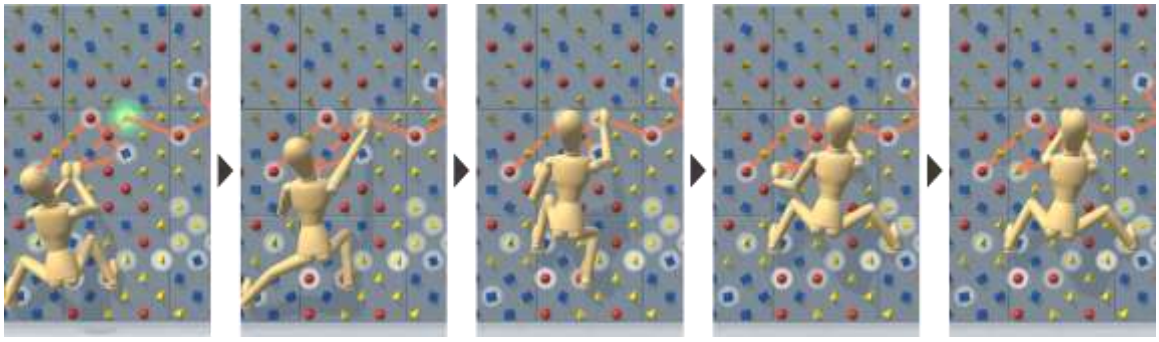

Fig.1. Example of the movements of character animation

The procedure of the movements of the virtual character was set in accordance with the basic procedure of those in actual sports climbing and its movements were generated. In addition, in order to express the shift of the character's center of gravity changing according to the movement as in Fig. 1, movements were generated by calculating the center of gravity from the locations of the hands and the feet, and the slope of the torso was modified by calculating the angle between the holds. In this

case, the reality of the movements was enhanced by processing the gaze considering the sequence and direction of the movements.

### 2.2 Projection Mapping Environment

The experimental artificial rock wall was 4m x 3m wide and had a total of 300 holds at a 0.2m interval in length and breadth on it, and InFocus IN5555L (InFocus, U.S.A. Inc.) was used for the beam projector(Fig.2). The PC used in the experiment was equipped with the following items: Windows 7 Pro 64bit (Microsoft, USA Inc.) operating system and Unity 4 USA (Unity, USA Inc.) engine, 3.7GHz Intel Core i7 CPU and NVIDIA geForce GTX 680 (NVIDIA, USA Inc.), 16GB RAM, and its resolution was 1920X1080.


Fig.2. Projection mapping environment (left) and the lesson using climbing character animation (right)

## 3. Measurement of Learning Effects

The participants of this study were 20 elementary school students aged more than 7 to less than 9, who had no sports climbing experience. The number of attendees per one class was limited to five, they were divided into 4 classes, and the same coach gave each class the lesson for 20 minutes. The animation character was projected onto the artificial rock wall, where it automatically assumed its postures according to the hold routes the coach wanted. The evaluation of the postures in sports climbing was set by the discussion among 4 former sports climbing national athletes in reference to Hörst (2012)'s indoor sports climbing training methods [12].

Table 1. Results of the comparative analysis of posture evaluation before and after the application of character animation system

| | Mean | SD | t | p |
|---|---|---|---|---|
| Pre | 14.55 | 2.80 | -13.26 | <.001** |
| Post | 22.65 | 2.20 | | |

*Note : **p<.001

For the purpose of the study, the evaluation criteria were based on the degree of use of toe, stable center of gravity, the degree of utilization of upper and lower body, and the naturalness of the serial movements, which beginners in sports climbing should master through their lessons. The score range for each item was from 1 to 5 points, and the climbing postures were evaluated by the average scores for all the four items.

The data collected by this study were statistically processed using the IBM SPSS Statics 23 statistical package program. A corresponding sample t-test was performed to investigate the posture difference before and after the application of the climbing character system.

As a result, the mean value before and after the application was found to be statistically significant with the value of t at -13.26, which means that the character animation system helps the users' learning of indoor sports climbing.

## 4. Conclusion

Considering the environment of the existing indoor sports climbing, this study, through the consultations with the expert group based on field coaches and literature reviews, researched the basic postures in sports climbing using inverse kinematics algorithm and movement algorithm to develop mixed reality based educational contents which are practically applicable. Based on this, it is thought that a gradual introduction of the contents suitable not only for the level and physical conditions of beginners but also for those of general people and elite athletes, will provide more effective tools for indoor sports climbing lessons. In particular, the character animation system developed by this study, when applied to the lessons, was shown to have a positive effect on sports climbing posture learning. It is thought to be due to the fact that indoor climbing learners could reduce the errors by recognizing the difference between their own movements and the character's correct movements and then modifying theirs to perform correct movements.

## References

[1] MAGILL, R. A.; ANDERSON, D. I. The roles and uses of augmented feedback in motor skill acquisition. Skill Acquisition in Sport: Research, Theory and Practice. N. Hodges and AM Williams, eds. 2012.

[2] WULF, Gabriele; SHEA, Charles; LEWTHWAITE, Rebecca. Motor skill learning and performance: a review of influential factors. *Medical education*, 2010, 44.1: 75-84.

[3] SIGRIST, Roland, et al. Augmented visual, auditory, haptic, and multimodal feedback in motor learning: a review. *Psychonomic bulletin & review*, 2013, 20.1: 21-53.

[4] AZUMA, Ronald T. A survey of augmented reality. *Presence: Teleoperators and virtual environments*, 1997, 6.4: 355-385.

[5] AZUMA, Ronald, et al. Recent advances in augmented reality. *IEEE computer graphics and applications*, 2001, 21.6: 34-47.

[6] BILLINGHURST, Mark, et al. A survey of augmented reality. *Foundations and Trends® Human–Computer Interaction*, 2015, 8.2-3: 73-272.

[7] SHEEL, A. W. Physiology of sport rock climbing. *British journal of sports medicine*, 2004, 38.3: 355-359.

[8] KAJASTILA, Raine; HÄMÄLÄINEN, Perttu. Augmented climbing: interacting with projected graphics on a climbing wall. In: *Proceedings of the extended abstracts of the 32nd annual ACM conference on Human factors in computing systems*. ACM, 2014. p. 1279-1284.

[9] LILJEDAHL, Mats; LINDBERG, Stefan; BERG, Jan. Digiwall: an interactive climbing wall. In: *Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology*. ACM, 2005. p. 225-228.

[10] HORST, Eric. *Learning to Climb Indoors*. Rowman & Littlefield, 2012.

## Acknowledgments

This research was supported by the Next-Generation Information Computing Development Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (No. 2012M3C4A7032182).