Vision-Based 3D Tracking for Entertainment Systems via Visual Media

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1. Project Goal

In this project, we would like to develop entertainment systems using visual media, in which computer vision technology plays significant roles. Computer vision is a technology to make the computer understand included information in captured images with cameras, which has been extensively studied for recent 30 years. Although there are a lot of excellent works in computer vision have been published, we cannot find much practical application of computer vision in general. Part of the reason is the researchers are still focus on the novelty of the principle and/or algorithm of computer vision. However, I believe that we need to spend more effort to develop practical applications based on such computer vision technology, so that general people can be convinced that the computer vision can be really useful. As shown in the fact that a huge number of cameras, such as mobile phone cameras, web cameras, etc., have already been used in our life, practical application of computer vision should play important role to make use of such cameras in efficient manner.

In such background, we propose to apply computer vision technology to entertainment systems using visual media. The key technology in the entertainment systems is tracking of 3D information from camera images, such as pose, position, and shape. Such technology for 3D tracking has already been studied for a long time, but there is no generic way to achieve such tracking. Therefore, we need to come up with proper design to use of such computer-vision based tracking for every application system.

In this project, we would like to develop three entertainment systems using computer vision-based technology.

A) a system for supporting guitar playing by 3D tracking of the guitar for AR display of supporting information

B) a billiard strategy presentation system with mobile phone

C) an interactive observation system for sports event viewing

2. Technical breakthrough

<u>A) supporting guitar playing:</u>

Markerless tracking of guitar has been achieved as shown in the following figures. This tracking method uses the linear edge segments of the guitar fret pattern. For identifying the position on the fret, we take into account the trend of the displacement of each fret pattern, which is gradually smaller with the distance from the neck of guitar. Using this trend, we achieved scalability of tracking so that the method can adaptively be used for different kinds of guitars.

***Fig. 1** Markerless guitar tracking has been achieved even when the guitar is occluded by player's hand.*

We have also developed a system that measures and tracks the positions of the fingertips of a guitar player accurately in the guitar's coordinate system. A framework for colored finger markers tracking has been proposed based on a Bayesian classifier and particle filters in 3D space. ARTag has also been utilized to calculate the projection matrix. This implementation can be used to develop instructive software such as a chord tracker for a guitar learner.

Although we believe that we can successfully produce an accurate system output, the current system has the limitation about the colored finger markers because finger markers are required in our current system. This sometimes makes it unnatural for playing guitar in real life. As future work, we intend to make technical improvements to further refine the problem of the finger markers by removing these markers which may result in even greater user friendliness.

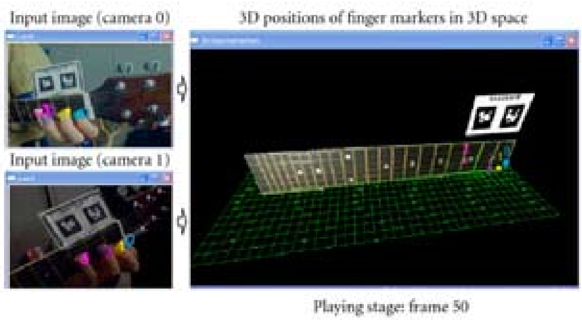

Fig. 2 Developed system that measures and tracks the positions of the fingertips of a guitar player accurately in the guitar's coordinate system.

B) billiard strategy presentation system with mobile phone:

We have also developed a system for supporting pool game based on analysis of ball positions for NineBall Game. Our system is implemented on a camera-mounted handheld display and does not use special equipment such as a magnetic sensor and artificial markers. A user can capture a pool table from an arbitrary viewpoint and see supporting information and ball behavior which are drawn on the captured images through the display. In our system, ball positions are estimated by computing a projection matrix of the captured image from an arbitrary viewpoint. As for supporting information, our system simulates ball behavior by giving several speeds to the cue ball and provides some desirable shooting ways based on the rule of the pool game. Moreover, supporting information and ball behavior are online drawn on the images while a user is capturing the pool table. In the experimental results, the accuracy of estimated ball positions is enough for analysis of ball arrangement. In addition, fifteen users evaluated supporting information of our system, and the effectiveness of our supporting information was presented.

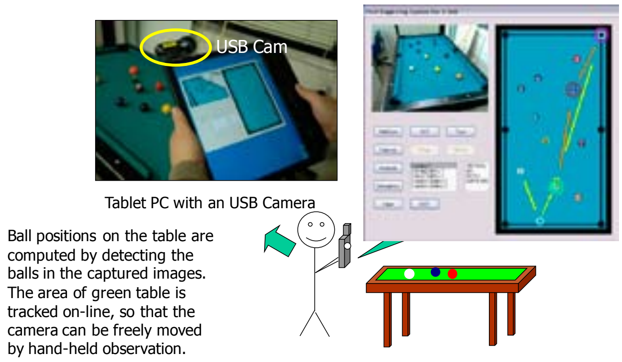

Fig. 3 Developed system for supporting pool game based on analysis of ball positions for NineBall Game.

C) interactive observation system

We have also developed two AR applications using vision-based tracking method: AR Baseball Presentation System and Interactive AR Bowling System. Both of the applications can be enjoyed on the tabletop in the real 3D world only with a web camera and a handheld monitor connected to a PC. It is a big advantage for home users that our applications do not require any special device such as positioning sensors or a high-performance PC.

3. Innovative Applications

Learning to play the guitar usually involves tedious lessons in fingering positions for the left hand. It is difficult for beginners to recognize by themselves whether they are accurately positioning their fingers on the string. For this reason, we developed the application of human-computer interaction (HCI) to guitar playing, named InteractiveGuitarGame, by applying the guitarist fingertip tracking method. This application aims to assist guitar learners by automatically identifying whether the fingertip positions are correct and in accord with the fingertip positions required for the piece of music that is being played.

The InteractiveGuitarGame application recognizes the guitar chord being played by a guitar learner based on the 3D position of finger markers in the virtual guitar coordinate spaces. Then, the system gives real-time feedback to guitar learners telling them if they are using the correct chords required by the musical piece. An example user interface of the application is shown in Figure 6. This application contains the lyrics, guitar chord charts, and vocal information. The lyrics are displayed on the screen in color which changes and is synchronized with the music. The guitar chord charts are shown in the top right of the user interface that can be used to guide student guitarists to play a song. Most importantly, this application recognizes if each successive chord contained in the music is being played correctly. It is considered that this would be of a great assistance to guitar learners because they are able to automatically identify if their own finger positions are correct and whether they are matching the correct chords required by the musical piece. This feedback is shown by small right/wrong symbols above the corresponding chords in real time. Finally, this application will show an overall evaluation score, as a percentage, indicating the user's accuracy when the performance has been completed which provides greater user friendliness. This application would be invaluable as a teaching aid for guitar learners.

Fig. 4 InteractiveGuitarGame: application of the guitarist fingertip tracking method.

Fig.5 shows an application of AR tracking for observing baseball game on your desktop. Fig. 6 shows AR bowling in which user can play bowling game with real touching of ball and virtual viewing from arbitrary viewpoints.

Users can interactively change their view points by moving around the tabletop because of multiple 2D markers. In usual AR applications using multiple 2D markers, users have to measure the distance between the markers. Of course, such extra task is unnecessary in our applications by applying the registration method with the 3D projective space. In contrast with usual CG viewers in which a mouse or a keyboard is used for changing view points, changing view points by moving the users is very intuitive and easy way. Such a facility is very important especially for children.

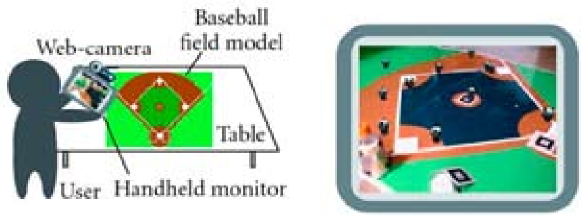

Fig.5 An application of AR tracking for observing baseball game on your desktop.

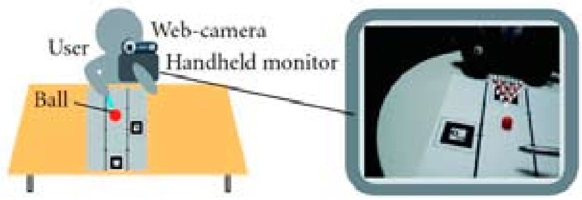

Fig. 6 AR bowling in which user can play bowling game with real touching of ball and virtual viewing from arbitrary viewpoints.

Using the baseball application, the users can watch a 3D virtual baseball game in front of themselves. It can be a future-oriented 3D game which is represented in movies or animations. The bowling application can interest children because their actions in the real world affect the virtual world.

4. Academic Achievement

10 papers with reviews are published in both international conferences and journals.

5. Project Development

The project was incorporated in a part of the project of JST CREST "Technology to display 3D contents in the air" (funding size is $3 million over 5 years), which produced the innovative results such as 3D interactive contents creation for 3D dot sequence display.

6. Publications

Paper publication

1) Yoichi Motokawa, Hideo Saito, Online Tracking of Guitar for Playing Supporting System by Augmented Reality, 5th IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR06), pp.243 - 244, Oct. 2006.
2) Yuko Uematsu, Hideo Saito, Interactive AR Bowling System by Vision-Based Tracking, Proceedings of the international conference on Advances in computer entertainment technology ACE '07, pp.236-237,June 13-15, 2007, Salzburg, Austria
3) Chutisant Kerdvibulvech, Hideo Saito, Markerless Guitarist Fingertip Detection Using a Bayesian Classifier and a Template Matching For Supporting Guitarists, Laval Virtual, Virtual Reality International Conference (VRIC'08), Apr. 9-13, Laval, France, 2008.
4) Hideaki Uchiyama, Hideo Saito, AR Display of Visual Aids for Supporting Pool Games by Online Markerless Tracking, Proc. 17th International Conference on Artificial Reality and Telexistence (ICAT 2007), pp. 172-179, 2007.
5) Yuko Uematsu, Hideo Saito, Improvement of Accuracy for 2D Marker-Based Tracking Using Particle Filter, Proc. 17th International Conference on Artificial Reality and Telexistence (ICAT 2007), pp. 183-189, 2007.
6) Chutisant Kerdvibulvech, Hideo Saito, Vision-Based Guitarist Fingering Tracking Using a Bayesian Classifier and Particle Filters, Proc. 2007 Pacific Rim Symposium on Image Video and Technology (PSIVT2007), LNCS.4872, pp.625-638, 2007.
7) Chutisant Kerdvibulvech, Hideo Saito, Real-Time Guitar Chord Recognition System Using Stereo Cameras for Supporting Guitarists, ECTI TRANSACTIONS ON ELECTRICAL ENG., ELECTRONICS, AND COMMUNICATIONS VOL.5, NO.2, pp.147-157, August 2007.
8) Yuko Uematsu and Hideo Saito, Visual Enhancement for Sports Entertainment by Vision-Based Augmented Reality, Advances in Human-Computer Interaction, Volume 2008 (2008), Article ID 145363, 14 pages.
9) Hideaki Uchiyama and Hideo Saito, AR Supporting System for Pool Games Using a Camera Mounted Handheld Display, Advances in Human-Computer Interaction, Volume 2008 (2008), Article ID 357270, 13 pages
10) Chutisant Kerdvibulvech and Hideo Saito, Guitarist Fingertip Tracking by Integrating a Bayesian Classifier into Particle Filters, Advances in Human-Computer Interaction, Volume 2008 (2008) , Article ID 384749, 10 pages.

Other Publication

1) Hideaki Uchiyama, Hideo Saito, Markerless AR Display System for Supporting Pool Games, The sixth International Conference on Mixed and Augmented Reality (ISMAR2007), demo session, Sept. 2007.
2) Yuko Uematsu, Hideo Saito, AR Baseball Presentation System Based on Registration with Multiple Markers, The 5th IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR06), Demos, Oct. 2006.