Immersive 3D Environment for Remote Collaboration and Training of Physical Activities

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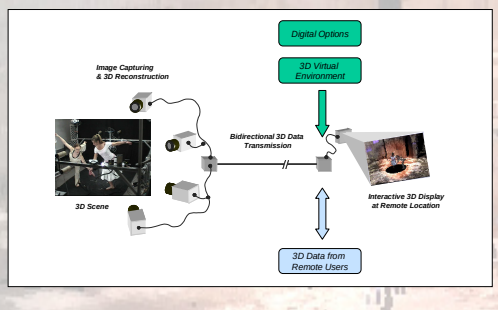
Abstract

We present a framework for immersive virtual environment intended for remote collaboration and training of physical activities. Our multi-camera system performs full-body 3D reconstruction of human uses in real time and renders their image in the same virtual space allowing local and remote users to interact. We have successfully demonstrated practical use of the system in combination with the tele-immersive virtual environment for learning of Tai Chi, remote collaboration and in extensive remote dancing experiments.

Introduction

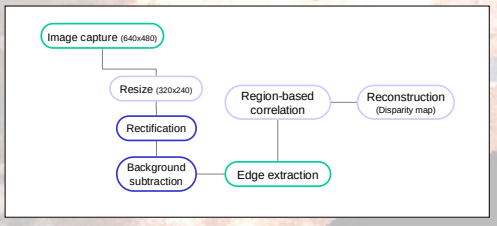
Many applications of immersive virtual reality feature avatars to represent the human user inside the computer generated environment.

In contrast to avatars, only full body 3D reconstruction can realistically represent the user's appearance and full dynamics of movement, including subtle movements such as facial expressions, chest movement during breathing and movement of hair or clothing.

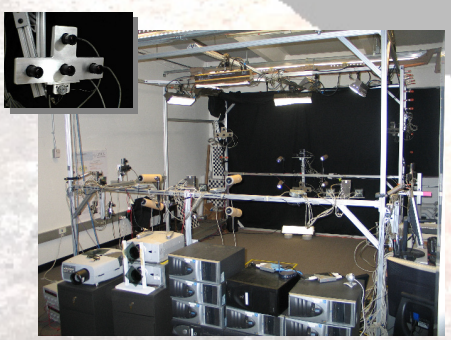


Overview of Technology

Our tele-immersion apparatus for real-time 3D reconstruction consists of 48 externally triggered cameras connected to 12 PCs. Each cluster consists of three B&W cameras for stereo reconstruction and a color camera for texture acquisition.



The reconstruction algorithm runs with about 5-7 FPS. The full stream of 3D video sent through the network requires 2~3 Mbps. Data streams from all the clusters are combined into a 3D model inside the point-based renderer which can also receive data streams from a remote site.



3D Remote Interaction

In this experiment we have streamed 3D live video from UC Berkeley into Cave VE at UC Davis. Two dislocated users were able to manipulate a floating 'jello'-like object which dynamically deformed when pushed or pulled. The position of the two remote users' hands was tracked using electro-magnetic tracking system.

The experiment demonstrated feasibility of remote interaction with 3D objects inside our tele-immersive environment.

Tai Chi Learning

In this study we have examined learning of Tai Chi using immersive VE as compared to 2D video. 3D Recording of a Tai Chi teacher was projected into the virtual space simultaneously with the real-time data from a student.

In the study we have demonstrated that immersive virtual reality provides better learning of physical movements than a two-dimensional video.

Tele-immersive Dancing

Over the past two years we have conducted several local and remote experiments with dancers. The dancers had to accommodate to technical limitations of the system, such as frame rate (5~7 FPS) and transmission delays (~500 ms).

The dancers introduced new techniques to take advantage of the technology, such as digital transformations, disappearing, dissolving into 'particles', and 'virtual touch'.

Future Work

Currently, we are upgrading our system with an improved, faster (15~20 FPS) and more robust stereo reconstruction algorithm using finite elements and triangular wavelets and better calibration of the multiple cameras. We are investigating requirements for a portable version of the tele-immersion system. Also we are interested in designing other application and experiments where tele-immersion can be used.

Conclusions

The presented framework offers new possibilities for learning and training individuals to perform physical movements (e.g., physical therapy and exercise). 3D data captured by our system can be used to analyze subject's movement and present it as feedback on his/her performance.

Our successful dance experiments suggest many possible applications in art and dance where different digital effects can be applied in real-time to create what would be 'impossible' on live stage.

The users can be immersed inside existing or non-existing virtual environments, such as ancient buildings, ruins or future architectural designs, to allow interactive exploration.

Tele-immersion in 3D can further enhance video conferencing for business and personal meetings. The users can share different synthetic objects inside the same virtual space (e.g. CAD designs, laser-scan data).

Finally, there are many applications of social networking and entertainment (e.g. games, interactive music video, 3D karaoke) where the users could interact in real-time over the network.