

## Design of an action interface with networking ability for rehabilitation

Murray Lawn\*, Takashi Takeda\*\*

\*Dept of Computer Science, \*\*Dept of Mechanical Engineering, Nagasaki Institute of Applied Science  
536 Aba-Machi, Nagasaki 851-0193, Japan  
E-mail: lawnmj@cc.nias.ac.jp

*Abstract-* In the field of providing rehabilitation training programs and/ or equipment one of the major aspects of consideration is how to provide the motivation necessary for the patient or user to persevere with a given program for the time required to see the necessary results. One effective way is to introduce sporting or competitive aspects to the program. This paper presents an "action interface" operated in an augmented environment. The game chosen is that of table tennis. The game is operated over a network thus facilitating connection to any other person with the appropriate setup. It is proposed that this system be used for physiological examinations such as testing patient's coordination as well as for rehabilitation purposes.

*Key Words-* action interface, augmented reality, network game software, rehabilitation

### I. INTRODUCTION

This paper builds on a previous paper [1], which presented an "action interface". The action interface provided a means of taking video data in real time of part or all of a person and the background and superimposing on it computer generated graphics (CG) appropriate to the activity being undertaken. The term "action interface" has been used in keeping with the definition of [2] "an interface which upon capturing video data, responds in accordance to the user's actions (movement)". In an increasingly multimedia orientated age the value of action interfaces as a means of man-machine interface is being increasingly realized. Applications involving the fusion of actual images and CG images creating a virtual world referred to as augmented reality are continuing to find application, there development expanding upon the initial concepts of virtual reality. On account of new technology computers which support multimedia, the realization of this is relatively simple and inexpensive. The purpose of this research is to create an activity (game) which can be enjoyable while at the same time provide a means of analyzing brain functionality and furthermore to provide a means of assistance in the recovery of brain functionality that may be lacking. The use of VR in providing a means of cerebral analysis and assistance in cerebral rehabilitation has been presented in previous papers [3], [4]. Personal computers equipped with action interfaces may be increasingly used for rehabilitation due to there low cost, portability and ease of operation. This paper focuses on the addition of 3-D graphics and the networking of multiple computers. Thus for example persons in hospitals or other

care institutions may be able to partake in activities (games) together by means of appropriate communication linking.

### II. METHODS

#### A. System overview

The system schematic is shown in figure 1. The system hardware consists of a CCD camera and a PC equipped with a video card. The OS used is Windows 95, and the software was written in Visual C++.

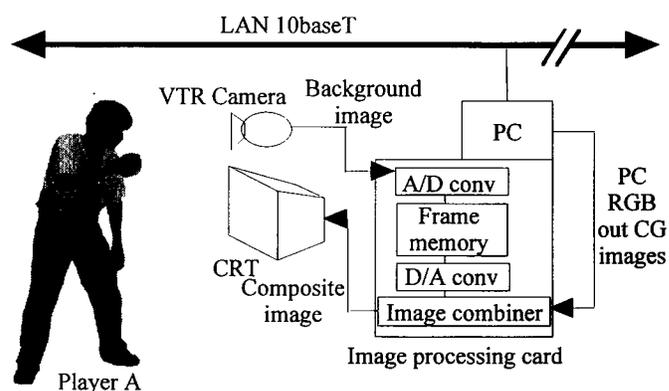


Fig 1. System schematic

#### B. The image processing card

The card used for image processing was the Chroma-key mixer card produced by Micro-technica (Japan). This card takes a monitor input from a PC and an input from such as a video camera, combines them and outputs the resultant image to a monitor. The image processing card's key functions are as follows:

- Separate RGB inputs, AD converters, frame memory and DA converters.
- High speed 8 bit AD and DA converters.
- Frame memory (1024x512x8 bits (full color - 16 million colors)).
- Picture data can be accessed from any part of the frame memory.

In terms of frame memory speed, it can operate up to 60 frames per second. Thus with continued updating smooth animation is possible.

C. Composition of the camera and CG images

Composition of the camera and PC's CG images for input to the image processing card are as follows:

- (1) Firstly for the purpose of using the same monitor the signal outputs from the camera and the PC must be synchronized. This is achieved by synchronizing the output frames from the PC with the output frames from the camera. Thus displaying of the two sets of picture data on the same screen is possible.
- (2) Next the color component of the camera and PC picture data are sampled and the result is used to decide the image priority.
- (3) Black is used as the masking color (RGB=0,0,0), CG objects are output using a back background.

The CG image appears at the front (1st priority) and the camera to the rear. Each image is 640x480 pixels, each coordinate is matched one for one. When the black mask color is detected in the CG image the camera data is given priority. Thus the result of this approach is that CG objects are given priority and the camera image makes up the background.



Fig 2. The composite 3-D CG and background image

D. Table tennis game - hit decisions in 3-D

The previous paper [1] outlined the means of superimposing 2-D CG images onto a photographic image. As the photographic image was 2-D, decisions regarding the point of contact with the ball were inherent as was the makeup of the 2-D CG image. But games that involve movement with depth and direction such as occurs in table tennis require a means of creating CG images appropriately in 3-D. If 3-D image data could be captured, the point of contact could be calculated

accurately with regard to depth and direction. However as capturing 3-D data is very complex it will for the time being remain as a future subject for further research. The aspect that has been investigated is the creation of the game of table tennis itself in 3-D. The software used to create the game was Direct3-D produced by Microsoft.

E. Table tennis game outline

The table tennis table and ball are modeled in 3-D. The table tennis ball can move about freely in the 3-D space. Figure 2 shows the resultant composition of the player with table tennis bat as taken by the camera and the 3-D CG depicting the table tennis table and ball. In a real game of table tennis the ball comes bouncing towards the player, the player then hits it with their bat to return it. But in this case as ones own image is captured and being displayed in composite form on the CRT, the ball is in effect heading in the opposite direction towards ones captured image.

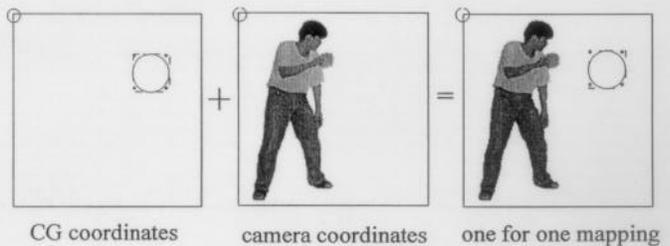


Fig 3. Image mapping

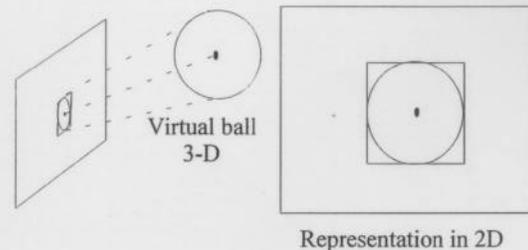


Fig 4. Projection of 3-D objects in 2-D

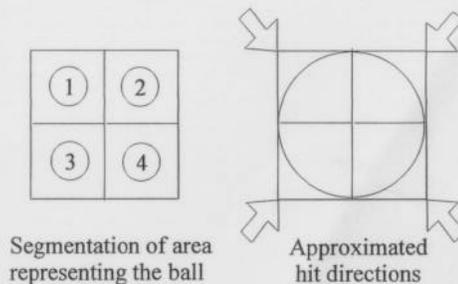


Fig 5. Segmentation of the virtual ball and respective hit directions

Initially the table tennis ball is bouncing on the table. From this point the player can alter the angle of the table to suit

their own preference. Preparations being set by clicking the mouse, the ball comes into play and the game is started. When the ball hits the table an appropriate sound is emitted (ball hitting table sound). Likewise when the ball is registered as hitting the racket an appropriate sound is made (ball hitting racket sound). The returned ball comes forward and after disappearing off the screen it bounces back into the scene. If the ball is not hit at all and falls to the floor a further sound (comment in Japanese) is emitted.

#### F. Hit decision

In 2-D CG the contact judgment is as follows:

- (1) Firstly as detailed in C, the camera and CG images are 640x480 pixels, the aspect of matching them pixel for pixel is very important this is depicted in figure 3.
- (2) In order to be able to register the player's red (for example) bat, the video's RGB's R (red) is monitored and at a preset level which responds optimally to the bat, the bat's location is decided. In order to reduce the chance of false detection on account of the surroundings a blue curtain in the background is used as is common practice.
- (3) Regarding the table tennis ball's movement in 3-D space. In order to align the ball and the player's bat the 3-D object as shown in figure 4, the ball's trajectory is converted to 2-D.
- (4) In order to facilitate game speed, as is shown in figure 5 a simple square is used to represent the ball's cross section. When this meets the bat's preset level of red a hit is judged to have occurred.
- (5) When this occurs, not all of the square's values are examined, rather once a few have been registered as meeting with the bat the ball rebounds. Then as per figure 5 the square is divided into four, the first aspect examined is which of the four sections intersected with the bat.
- (6) By this means an approximate estimate of the bat's direction of movement can be made and thus an approximation of the direction in which the ball will rebound.
- (7) To avoid false (early) detection of the ball being hit which could occur the instant the ball comes into view, should the bat be aligned with the ball in 2-D at that time, the hit detection mechanism is turned off until the ball has reached the edge of the table.

#### G. Competitive table tennis via a network

The form of table tennis detailed to this point is similar in principle to playing against a wall, in that the ball once hit would always be returned in a predictable way. As a result the player is likely to quickly tire of the game on account of excessive predictability. In a real game of table tennis one typically plays to take advantage of the opponents weak points. Making use of a network this kind of game becomes possible.

#### H. The network

The networking software used was DirectPlay produced by Microsoft. DirectPlay supports connection via LAN IPX, modem, serial cable or TCP (internet protocol). DirectPlay is implemented over a communication link using DirectDraw and DirectSound simultaneously. The following explains the main steps involved in setting up a game using DirectPlay over a network connection:

- (1) Gaining network access.
- (2) From this point the procedure divides depending on whether one is requesting to connect to another who is logged in verses request of connection when no players are logged on.
  - (3-1) In the first case the "Enum Session" request is used to search for persons currently on line. By selecting a session one obtains a session ID number.
  - (3-2) If no session number is open one can open one for the purpose of setting up a new game using the "open" request.
- (4) In order to differentiate between players, "Create Player" is used to create a player ID number. By making use of the player ID messages can be communicated between players appropriately for the purpose of game management.
- (5) By using the Send and Receive functions messages are transmitted and received respectively.
- (6) Ending the game.

#### I. Game progress on the network

Using DirectPlay two users initiate a game and can both see the table tennis table and ball displayed on their respective screens. The movement of the two table tennis balls are controlled by the user's PCs respectively. When the ball is returned, the player's hit direction is sent as an event message to the remote player's ID over the network. The remote player's ball position is updated upon reception of the message. The remote player upon receiving the message executes the same operation with the exception of individual program control preferences.

#### J. Synchronization

In the case of using multiple computers to play table tennis over a network as outlined above it is likely that the individual user's computers will vary in their respective processing speeds. As a result a time lag in the ball's position will be introduced. For example, as depicted in figure 6 if player B's PC's processing speed is faster than player A's, the ball's position on player A's screen will lag according to the difference in processing speed. This effect as shown results in player A's ball appearing in the middle of the table, whereas player B's ball is about to go over the edge of the table. Player B thus returns the ball, and the appropriate "ball returned" message is sent, however player A assuming the ball was mid table (still visible on their side of the table) is

suddenly confronted with a returning ball. To prevent this from occurring some form of synchronization is required. To minimize this problem for the purpose of initial tests identical computers were used.

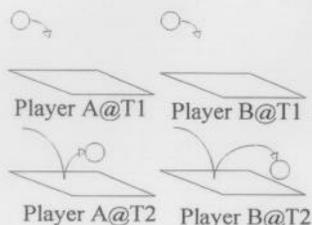


Fig 6 Player asynchronism

The table tennis game with two players thus operates as follows:

Firstly the table tennis applications are launched, then once the network protocol, host computer, and appropriate clients are selected the table tennis tables and balls appear in 3-D and the game begins. The ball once hit heads towards the other player and comes into view on their screen (along with the captured image of themselves), to which they respond by hitting the ball back. When one player hits the ball the appropriate sound is output from the player's computer. A message is also sent to the opponent's computer indicating that the ball has been hit and in what direction it has been hit. The trial game setup is shown in figure 7 (resembling as closely as possible the natural table tennis environment).

Another means of synchronizing is to synchronize with respect to time. That is to include an absolute time reference in the message, as well as the ball's coordinates and speed. Thus an estimate of the ball's current position can be made by reverse calculation. By this means upon reception of the message it should be possible to correct the ball's coordinates. This is also a subject for further investigation.

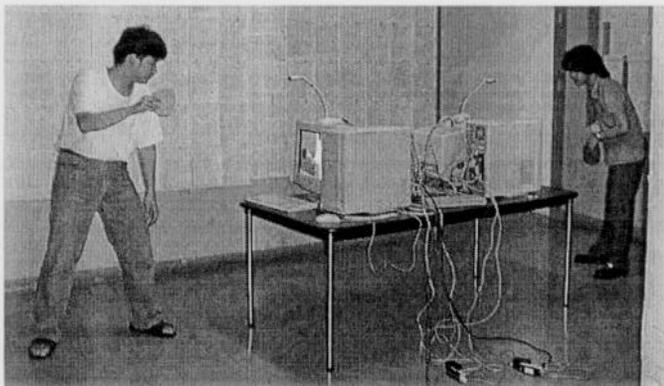


Fig 7. Augmented table tennis

### III DISCUSSION

Regarding the aspect of ball speed, it is currently a preference setting. Also the image update rate being used is approximately 24 frames per second (fps), although the video mixing card can process up to 60 frames per second the calculations necessary for CG rendering results in this capability not being fully utilised, however the resultant movement is quite acceptable. With regard to the use of networking the aspect of the effects of network transmission delays must also be considered in future research.

### IV CONCLUSION

An action interface has been equipped with network connectivity. Multiple computers have been networked and the game of table tennis requiring significant control speed has been created in 3-D and successfully trialed. The purpose being to create an interesting activity (game) that can be used to assist in patient/ user coordination diagnosis and rehabilitation. While the game is played in 3-D the data on which decisions are made such as when the ball has been hit are made based on 2-D data thus significant approximations are made resulting in inaccuracy. Means of overcoming this and other problems are currently under examination and will be detailed in further papers.

### ACKNOWLEDGMENT

Atsushi Kubodera for his support in the nuts and bolts of the action interface and assistance in the creation of the graphics.

### REFERENCES

- [1] A.Kubodera, T.Takeda, "Creation of Game Software using Action Interface" (in Japanese) (アクションインタフェースによるゲーム制作), in *Human Interface*, N&R Vol.12, No.2, pp.217-222. 1997.
- [2] Toshifumi, Taniguchi, Tamura, Shibuya, "On the usability of Action Interface related to Menu Allocation" (in Japanese) (アクションインタフェースのメニュー配置とユーザビリティ), in *Human Interface*, N&R Vol.12, No.1, pp.13-18. 1997.
- [3] T.Takeda, "A trial to make use of Virtual Reality Technology for Medical Treatment and Welfare" (in Japanese) (人工現実感技術を医療・福祉に役立てるために---リハビリテーションから機能検査まで---), in *proceedings of the 36th Symposium of The Japanese Society of Human Engineering*, Jun. 1995.
- [4] T.Takeda, Y.Tsutsui: "Construction of Virtual Environment with Force Display for Ball Dribbling" (in Japanese) (力覚提示機能を持つ玉ドリブル仮想環境の構築), in *The Journal of the Institute of Television Engineers of Japan*, Vol.4, No.10, pp.1339-1346. 1995.