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Development of Game Environment System based on Spatial Augmented Reality using a Real Creature

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ABSTRACT

Recent development in game technologies has offered various game environments, but the existing games have not provided realistically felt game environments because the element of the game is virtually generated in most of the games. Therefore, we propose a mixed game environment based on spatial augmented reality by using a creature that really exists. In the proposed game environment, tracking based on camera images created in real-time enables the provision of information about the real creature that is both still and moving. The game environment is presented with virtual object by using the coordinate of a real creature. Then, spatial augmented reality technology is applied for mixing a real creature and virtual game elements. Thus, the game scene is displayed by the spatial augmented reality technique based on the real-time coordinate of real creatures. Moreover, by providing the realistic game environment based on the spatial augmented reality, our system can be applied to various game contents that are actually felt as real. Most importantly, our system arouses the players' interest in a new kind of game environment.

Key words: Spatial Augmented Reality, Real Creatures, Game Environment

1. INTRODUCTION

The existing game environment is merely made of virtual characters in virtual space. The realism about a game cannot be provided since game elements of the game are made in the virtual space. Interested in applying the newest technology of computer graphics, virtual reality and augmented reality into the game and other contents to generate new demonstration effects and game environments, game techniques have been developed by using the augmented reality along with the technology about the computer graphics and the virtual reality [1-7]. In other words, the game environment is more feelingly provided by adding the virtual object to the real world. However, there is a limit in using the separate display device like HMD in a game to look at the game scene in which the real world and the virtual object are mixed.

In this paper we propose a new game environ-

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ment system based on the spatial augmented reality technique using a real creature at the video game for the diversity of content. The real game environment and the additional information about fish are visualized simultaneously by applying the recently issued spatial augmented reality (SAR) technology [8,9]. The proposed game environment system provides more realistic images to users after mixing the real world and the virtual object without special equipment. The proposed real three-dimension game environment not only enables the players to watch the game scenes without wearing special devices but also enhances the sense of reality and total immersion.

This paper is organized as follows. In section 2, we survey the present research and review the related works. Section 3 outlines the proposed system and scenario of the game. Section 4 describes Game Environment based on Spatial Augmented Reality which is used in this system. Section 5 discusses our experimental results, and Section 6 concludes the paper.

2. RELATED WORK

When augmented reality is combined with computer or video games, virtual world is brought out of a computer screen. Augmented reality can provide immersive feeling to users by augmenting virtual objects in real space. With increasing interest in augmented reality, there have been many researches about merging augmented reality with computer entertainment. In all these systems [1-5], wired controllers, either held or worn, are used as interaction and special display devices. Therefore, the players feel uncomfortable when wearing them and it is practically impossible for many to watch them simultaneously.

In many situations, SAR displays are able to overcome technological and ergonomic limitations of conventional AR systems. Due to the fall in cost and availability of projection technology, personal computers and graphics hardware, there has been a considerable interest in exploiting SAR systems in universities, research laboratories, museums, industry and in the art community. Various methods for providing more realistic display environment to users have been studied. The spatial augmented reality-based display system [8,9] was introduced as an example in the Bauhaus-University Media Lab. In this approach, some additional virtual information is augmented into the real environment by using the technique of augmented reality. And then visitor directly can see and feel. However, we propose the spatial augmented display system at the video game for the diversity of content. In this paper, after we apply in a real creature by using the object tracking algorithm and add the interaction element simultaneously, we provide a realistic environment in a game.

Recently, it is applied the various contents through an interaction between a real creature and the human which is not background of the real world [10-12]. In other words, these technologies provide the different game environment to a user by using the real creatures as one elements of a game. However, since the game display is completely represented in virtual environment, it provides only interaction element with a real creature but it is difficult to regard as the game which directly can see a real creature. In other words, existing technologies are the game form which separates the real world and virtual world. To overcome this limitation, this paper proposes to mix a real creature and a virtual character in the game

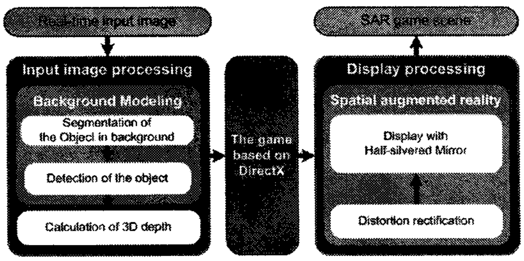


Fig. 1. System workflow.

environment of the real world.

3. GAME ENVIRONMENT

3.1 System Overview

The proposed real 3D system is organized as follows. First, the system detects the real object and calculates coordinates in real-time. Second, it executes the video game based on the DirectX. At this time, the calculated coordinates of real object are used for the interaction with the virtual object in the game. Third, the game scene is displayed through the monitor with a Half-silvered mirror for spatial augmented display. Finally, the spatial augmented reality based game is offered.

3.2 Game Scenario

In this system, the game is progressed after the aquarium is set to the background of the game which operates with real fish and virtual character. The overall game summary (Fig. 2) is as follows. First, if the game is launched, a screen is presented which is capable of selecting the depth of water corresponding to difficulty selection. A difficulty is adjusted by increasing the striking power of the fish according to the depth of the selected depth of water, because it is impossible to actually control the depth of water which is in real space. In a game, the fish spouts with water drop and attacks. It comes out in the location in which the water drop sprays out based on the fish center calculated from the image which is input through a camera. And then, a character contacts the water drop in a movement, or if it collides with the fish, it is progressed with the form in which the energy is reduced. The characters in the game are comprised of a total of two humans. One human rescues the other human drowning in the water, avoiding a collision with fish and the water drop attacks the fish. Finally, it succeeds in a rescue within the designated time.

4. SPATIAL AUGMENTED REALITY GAME ENVIRONMENT

4.1 Object Tracking & Segmentation

Tracking the moving object in real-time is important for the calculation about coordinate of the object.

As shown in Fig. 3, we use the normal CCD camera installed in the ceiling of our system. The camera (Fig. 3.a) installed in the ceiling of our system provides the image for calculating the location information of the moving object (gold fish) by taking a photograph the aspects of on a real time. At this time, it assigns with the space for the object (goldfish) in which it moves with the real fish tank space (Fig. 3.b) of the silver-mirror back side and the moving object for tracking is arranged. That is, this displays the fish tank and goldfish on the

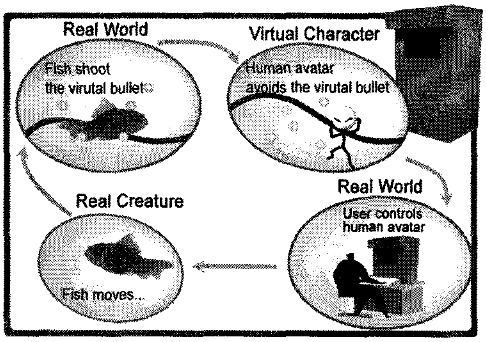


Fig. 2. Concept of the game in our system.

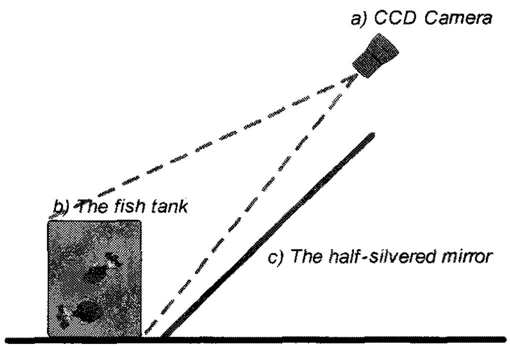


Fig. 3. Object tracking using CCD camera.

real space (Fig. 3.b) of the mirror back side. The upper side and front side of the fish tank is input to real-time video through the camera (Fig. 3.a) installed in a ceiling. And the image generated by the inner computation is outputted on the LCD display equipment. It is projected on the half-silver mirror (Fig. 3.c).

For classification of objects, the existing methods of detecting the specific color of the input image and different domains after comparing each frame of the input image impose restrictions on the environment. So we use the tracking technique based on background modeling [13].

We calculated R, G, B data by using the "Foreground Separation using Color Channel Characteristics" technique[14], and it solved almost all the problems of the conventional system. In this case, when the objects are separated from the background, the shadows of an object have the disadvantage of being included. So we calculate with standardized R, G, B color model which does not have brightness data of color. Thus, we are able to exclude the shadow of a moving object. The conventional method calculated with the threshold value of each color, but in this paper, the color differences between the object and the background scene in normalized RGB color model are based only on chromaticity. In RGB color model, we differentiate chromaticity as well as luminance of the object from the background. Thus, we can observe the shadows around the segmented object.

After separating the background from the input image, we train respectively about RGB color model of background and object in order to calculate the coordinate of the object. First, we calculate mean data and standard deviation data from background image. In this case, we need the characteristics of color channel, for that reason divide the image data to R, G, B channel data.

However, if we simply use mean data and standard deviation data, cannot calculate the coordinate of moving object by the shadow. As noted above, R, G, B color model is standardized and then mean data and standard deviation data are calculated using equation 1.

$$r=\frac{R}{T},\ g=\frac{G}{T},\ b=\frac{B}{T} \qquad (1)$$

Where R, G, B are each color channels, and r, g, b are standardized each color channels as well as $T=R+G+B$. In this case, standardized R, G, B color model was removed brightness, so do not divide different of each color. As the result, we can remove the shadow areas from the input images.

$$M_R=\frac{1}{N}\sum_{i=0}^{N-1}I_{R_i} \quad S_R=\sqrt{\frac{1}{N}\sum_{i=0}^{N-1}(I_{R_i}-M_R)^2}, \qquad (2)$$

$$M_G=\frac{1}{N}\sum_{i=0}^{N-1}I_{G_i} \quad S_G=\sqrt{\frac{1}{N}\sum_{i=0}^{N-1}(I_{G_i}-M_G)^2}, \qquad (3)$$

$$M_B=\frac{1}{N}\sum_{i=0}^{N-1}I_{B_i} \quad S_B=\sqrt{\frac{1}{N}\sum_{i=0}^{N-1}(I_{B_i}-M_B)^2}. \qquad (4)$$

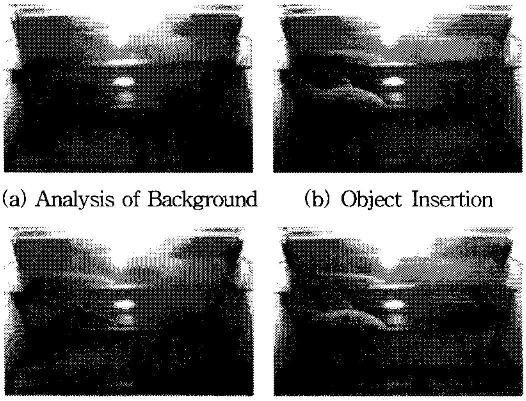
$$m_r=\frac{1}{N}\sum_{i=0}^{N-1}I_{r_i} \quad s_r=\sqrt{\frac{1}{N}\sum_{i=0}^{N-1}(I_{r_i}-m_r)^2}, \qquad (5)$$

$$m_g=\frac{1}{N}\sum_{i=0}^{N-1}I_{g_i} \quad s_g=\sqrt{\frac{1}{N}\sum_{i=0}^{N-1}(I_{g_i}-m_g)^2}, \qquad (6)$$

$$m_b=\frac{1}{N}\sum_{i=0}^{N-1}I_{b_i} \quad s_b=\sqrt{\frac{1}{N}\sum_{i=0}^{N-1}(I_{b_i}-m_b)^2}. \qquad (7)$$

Secondly, we calculate mean data and standard deviation data from standardized R, G, B color model as equation 2, 3, 4. At this formulation, I_R, I_G, I_B are background images will be learned, and N is the number of total frames will be learned. M_R, M_G, M_B are mean images for each channels, and S_R, S_G, S_B are standard deviation images for each channels. At the equation 5, 6, 7, m_r, m_g, m_b are mean images for each standardized channels, and s_r, s_g, s_b are standard deviation images for each standardized channel.

To calculate mean image and standard deviation image from background leaning as in Fig. 4(a), we compare the images with real-time input images as in Fig. 4(b). The object is segmented by calculating pixel differences between the two images. Errors on the background image in the process are



(a) Analysis of Background (b) Object Insertion

(c) Segmentation (d) Calculation of Center Point

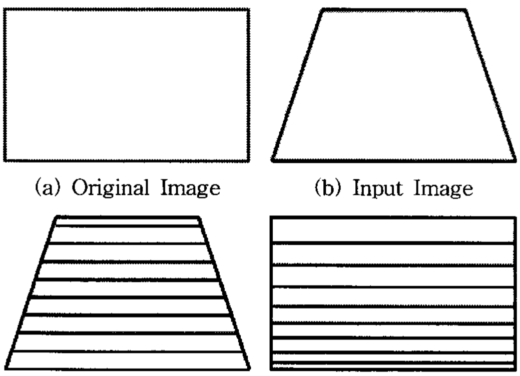
Fig. 4. Segmentation of background and object.

eliminated by the blob method. Finally, the coordinate of the object is calculated as in Fig. 4(c), and then we can also calculate the center point as in Fig. 4(d).

4.2 3D depth calculation

In this paper, we calculate the 3D depth data through the angle of input images applying the display technique for Spatial Augmented Reality. We appoint 4 summits at camera input images whose points are the same as the summit of water surface. Then we can assign the front and the back side and the front side the back side are divided.

Fig. 5(a) shows the image of water surface.



(a) Original Image (b) Input Image

(c) Divided Image (d) Error

Fig. 5. Because of distortion image, generation of error.

However, the camera distorts the input image as in Fig. 5(b) because of the camera's angle. In the case of unilaterally dividing the input image like Fig. 5(c), an error is generated from the actual distance as in Fig. 5(d). When it consistently divides in the view of a camera, a distance is short at its front and it becomes gradually longer as it is behind materially. To modify the image distorted by the camera angle, this paper utilizes the homography matrix method. The distorted image is rectified through the following method.

The points on one plane and their corresponding points on the other plane are defined as 3×3 matrix. H is 3×3 matrixes and represents the projective transformation between the two planes. This is called Homography[15]. If the 9×1 vector lexically arranges that homography matrices are multiplied the n×9 matrix compounding the point on the plane and the correspondence point on the other one plane, the result becomes 0. In this process, h (9 by 1 vectors) can be obtained through the Singular Value Decomposition (SVD). However, as A (n by 9 matrixes) is not a square matrix, it cannot be applied to the SVD. To resolve the problem, the pseudo-inverse (A^TA) is generally used.

$$
\begin{aligned}
&X_i = (x_i, y_i, z_i)^T,\\
&X_i = (x_i', y_i', z_i')^T,\\
&X_i' = HX_i,\\
&X_i' = \frac{1}{z_i'}\begin{pmatrix} x_i' \\ y_i' \\ z_i' \end{pmatrix},\\
&H = \begin{bmatrix} h1 & h2 & h3 \\ h4 & h5 & h6 \\ h7 & h8 & h9 \end{bmatrix},\\
&X_i = \begin{pmatrix} x_i \\ y_i \\ z_i \end{pmatrix}, (*\, z_i = 1)\\
&Ah = 0.
\end{aligned}
\tag{8}
$$

In other words, as the equation 8, in, $Ah=0$ is h vector lexically arranging that H matrices and A is $n\times 9\,(n \geq 4)$ matrix, a combination of X and X'. The homography matrix consists of eigenvector which is the minimum Eigenvalue of A^TA.

By using the above homography matrix, a rectified image can be obtained as in Fig. 6(b). The depth information (Fig. 6(d)) of the object can be calculated by simply dividing the image by equal distance as in Fig. 6(c). As to this, we can confirm on Fig. 6.

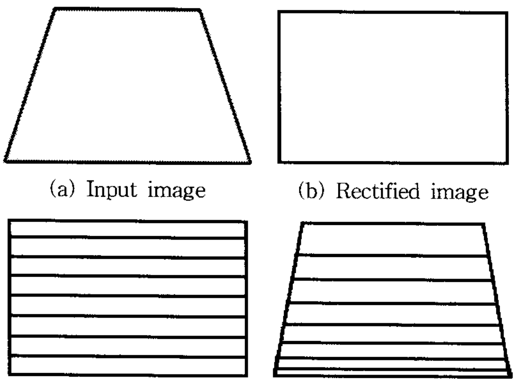
Fig. 7(b) is generated by applying the homography matrices to real input image as in Fig. 7(a). Then, the z coordinate is designated by the object's position.

4.3 Design for the SAR Display

We use the recently issued spatial augmented reality (SAR) technology in order to provide realistic game environment. This technology provides the more realistic image to a user after mixing the real world and virtual object without the special equipment. Through this, we provide the augmented game environment by operating with the game environment with the real creature. Moreover, we develop the real three-dimension game environment which is not game display environment of simple two dimensional planes by using the half-silver mirror. Therefore, we use the half-silvered mirror (Fig. 8) that is one of the display ways for the spatial augmented reality.

Spectators (Fig. 9.e) can watch not only the fish through the half-silvered mirror (Fig. 9.b) but also the reflected annotation (Fig. 9.c) around the fish. The annotation (Fig. 9.d) appears to be displayed inside the fish tank (Fig. 9.a), but it is a mirror-reflected image of a monitor, which is built as in Fig. 9.

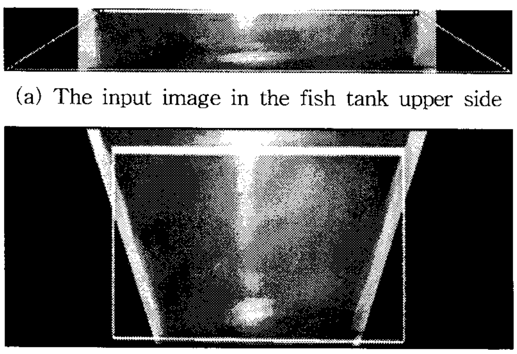
The half-silvered mirror is used for spatial augmented display to make sure that the reflected



(a) Input image (b) Rectified image

(c) Divided image (d) Result image

Fig. 6. The rectified image based depth information calculation.



(a) The input image in the fish tank upper side

(b) The fish tank image after rectification

Fig. 7. The camera input image which is applied distortion rectification.

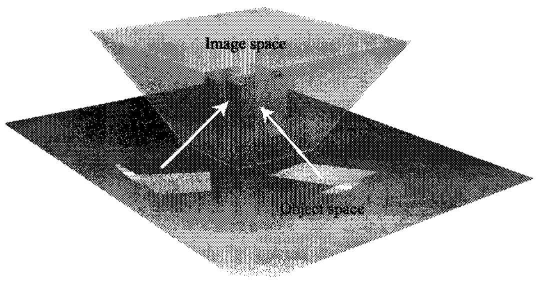


Fig. 8. Spatial augmented reality environment using by the half-silver mirror.

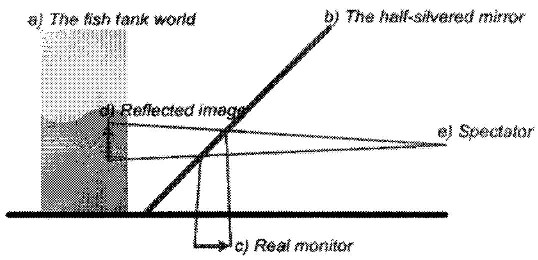


Fig. 9. Composition of spatial augmented reality system.

image is differently distorted by the leaning degree of the mirror. If we set the half-silvered mirror to 45degree, then the reflected image is not distorted. In this case, we can use only a small system. If we use a large system, the system will need a very large place, creating many problems. This undesirable situation can be fixed by using the Reflection Transformation Matrix (equation 10). As the relationship between the leaning degree of the mirror and the degree of distortion of the outcome can be calculated, it is possible to apply beforehand the converted image into Reflection Transformation Matrix. Then, the final image can be realized as expected.

Note that the reflection transformation of planar mirrors is a rigid-body transformation, and preserves all properties of the transformed geometry. With known plane parameters of the half-silver mirror within the world coordinate system, a point in 3D space can be reflected with:

$$p' = p - 2(np + d)n. \tag{9}$$

Where p' is the reflection of p over the mirror plane $[n,d] = [a,b,c,d]$.

This is equivalent to multiplying p with the 4×4 reflection matrix:

$$R = \begin{bmatrix} 1-2a^2 & -2ab & -2ac & -2ad \\ -2ab & 1-2b^2 & -2bc & -2bd \\ -2ac & -2bc & 1-2c^2 & -2cd \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{10}$$

Note that $R = R^{-1}$.

The reflected viewpoint e' of the observer (which, for instance, is head-tracked) can be computed with the equation above or by multiplying the original viewpoint e with the reflection matrix.

To transform the known image space geometry appropriately into the object space, we can apply different, slightly modified transformation pipelines for a planar mirror section. With known plane parameters ($[n,d] = [a,b,c,d]$) for a mirror, we have to integrate two modifications into the common Model-view Transformation. Then Reflection Transformation Matrix is grafted in Model-view Transformation using OpenGL as shown in Fig. 10. Object Coordinates are set for modeling work for easy OpenGL. World Coordinates can merge each modeling data, and Eye Coordinate expresses based on the time of looking at an object. However, when we use Reflection Transformation Matrix, World Coordinates and Eye Coordinates are changed by the Reflection Transformation Matrix. Reflected World Coordinates and Reflected Eye Coordinates are calculated by the matrix as noted above.

As a result, the half-silvered mirror is set as in Fig. 11(a), spectators watching at the position of Fig. 11(b). Then the calculated image comes out from Fig. 11(c) to Fig. 11(d). Thus, spectators can feel as if the object exists inside the showcase as in Fig. 11(e). Also we can control the lighting can also be controlled as in Fig. 11(g) to make the brightness of the real and virtual object the same.

5. EXPERIMENTAL RESULT

The configuration of our system (Fig. 12) used

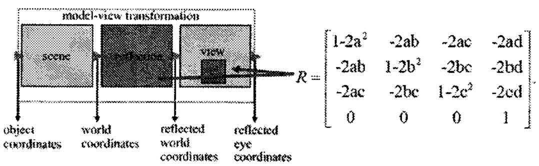


Fig. 10. Reflection transformation matrix in Model-view Transformation.

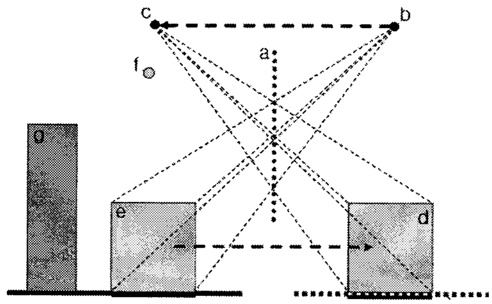


Fig. 11. The principles of spatial augmented reality using the half-silver mirror.

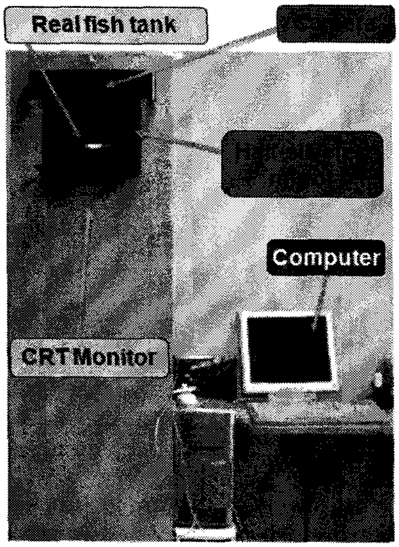


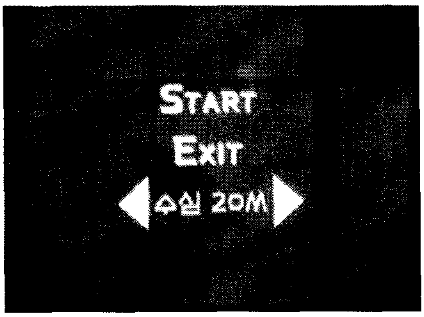
Fig. 12. The hardware configuration of our proposal system.

for this environment consists of a computer, a camera, a half-silvered mirror, a real fish tank, and CRT monitors. We have implemented the approach described in this paper and applied it to generate a game environment based on spatial augmented reality using a real creature.

Our system has been implemented on Pentium 4 1.8GHz, 1GB RAM using the Visual C++, and a camera with 1024 × 768 resolution by 30 frames. Fifty images were captured for the background modeling. And then the "Foreground Separation using Color Channel Characteristics" technique was used because the existing methods impose restrictions on the environment. In other words, we separate objects from the background because the shadows of an object have the disadvantage of being included. The half-silvered mirror was set to 45degree To overcome the distortion problem by the leaning degree of the mirror and to provide 3D game environments for spatial augmented display. Our system is designed to respond to the movements of the real creatures such as gold fish, tracking in real time for displaying coordinates information of gold fish. Therefore, the game scene is displayed by the spatial augmented reality technique based on the real-time coordinate of real creature.

At our system, we insert a fish for the active creature, then coordinates of the fish are calculated through the background modeling technique. After the separating the background and the object, then the video game programmed based on DirectX is executed (Fig. 13(a)). The game runs on the basis of calculated coordinates of the real active creature and interaction between virtual objects and the real object. In this game, all the actions take place in accordance with coordinates of the real object (Fig. 13(b)).

In comparison with other previous systems, current human-animal interaction between human and real creatures mostly involves simple games and contents. Infiltrate [10] is a system which displays a virtual scene from the point of view of a fish tank with fishes. A fish is selected and a screen projecting a virtual scene of what the selected fish is seeing is displayed. Although this



(a) The game starting screen

(b) The game playing scene

Fig. 13. The real game scene in our system.

system remains true of the general interaction one has with fishes, it offers no form of interaction between the audience and the fishes or the display screen other than a simply viewing of the tank through the fish's eyes. After all, in this system, interaction is nothing more than an owner viewing a swimming display. However, in our game contents system, we offer various game views through the SAR display. And Metazoa Ludens [11,12] is a new computer mediated gaming system which allows pets to play new mixed reality computer games with humans via custom built technologies and applications. During the game-play the real pet chases after physical movable bait in the real world within a predefined area; infra-red camera tracks the pets' movements and translates them into the virtual world of the system, corresponding them to the movement of a virtual pet avatar running after a virtual human avatar. The human player plays the game by controlling the human avatar's movements in the virtual world, this in turn relates to the movements of the physical movable bait in the real world which moves as the human avatar does. In other words, because of being the game shape which is the real life and virtual world separated in previous game, there are definite differences between proposal system mixing the virtual character with the game background of the real life and previous system.

Finally, the experimental result demonstrated that a player becomes totally absorbed into the realistic and immersive game with a new kind of game display and the interactive virtual object which provided the realistic game environment based on the spatial augmented reality.

6. CONCLUSIONS

In this paper, we proposed a new method of creating the game environment system by using spatial augmented reality based display. Unlike the existing augmented reality based games, the proposed system arouses interest by using real creatures as one element of the game and by gaining coordinate information of real creature through a real time tracking algorithm by using a camera. Then, the game is programmed on the basis of DirectX for the development of the game environment by using the coordinate information of the calculated real creature. Therefore, the real creature and virtual object were mixed when the game environment was provided through the spatial augmented reality display technique. Our system was developed with the half-silvered mirror for the display of the spatial augmented reality. Finally, the experimental result demonstrated that a player is immersed in a new kind of game environment enjoying the video game with his/her interest aroused in a totally new kind of video game display and the interactive virtual object.

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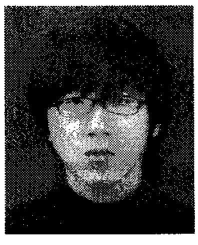

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