Staying Alive: A Virtual Reality Visualization Tool for Cancer Patients

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Abstract

We present a computer vision and virtual reality application for cancer patients. Currently, visualization and imagery techniques are becoming a routine part of the treatment of the ill. Mounting evidence shows the effectiveness of using self-imagery to encourage the immune system to boost its effort to defend the body from disease. Furthermore, while stress has been shown to retard the immune system, relaxation has the opposite effect. To that end, we are developing a virtual reality visualization tool for cancer patients called *Staying Alive*. The system provides a means for users to relax while directly visualizing their immune systems fighting off their diseases. White, red, and malignant blood cells are modeled as simple autonomous agents in the environment. The user controls a white blood cell, navigates through the blood stream, and "digests" malignant cells found along the way. To control the virtual environment, the user, free of wires and other such encumberments, engages the system simply by standing in a room, practicing *T'ai Chi* gestures. Computer vision techniques are employed to recognize the gestures in real time.

Introduction

The benefits of visualization techniques have been noticed by such disparate groups as athletes and cancer patients. Athletes are told that they must picture themselves hitting the ball, making the catch, scoring the goal to be able to do so. Similarly, cancer patients around the nation can visit almost any cancer center and enroll in programs to learn how to visualize their own immune system fighting off their disease. Though the full extent of the mind-body connection is unclear, there is a growing belief that visualizing something in the mind encourages the body to make it reality (Siegal 1986). In fact, Little claims that he sees a fifty-six percent increase in long-term survival rates for cancer patients who participate in his program of visualization, relaxation and positive thinking (Little 1994).

Similarly, relaxation appears to have a beneficial effect on the immune system. Numerous studies have shown that inducing the "relaxation response" enhances the effectiveness of the immune system while stress retards it (Sims 1987). Furthermore, imagery and relaxation have been shown to greatly reduce the stress and anxiety that cancer treatments can cause (Decker, Cline-Elsen, & Gallagher 1992; C. S. Feldman 1990).

Because visualization and relaxation promise so much benefit to both those with and without cancer, we are developing a virtual reality visualization tool called *Staying Alive*. If simply picturing something in the mind's eye is effective, experiencing the same thing in a virtual reality environment might be even more beneficial. Not only do virtual reality systems allow users to directly visualize the virtual world, but they also allow users to take an active role in influencing that world.

To help make *Staying Alive* a relaxing application, we have chosen to make a user's interaction with the system be through the practice of *T'ai Chi* (*taijiquan*). *T'ai Chi* is among the more popular forms of martial arts in China and the world. Though like all martial arts, this exercise includes movements for attack and defense, there are several forms of *T'ai Chi* which are slow and gentle, such as the Yang, Wu or Sun styles (Yen-Ling 1990). The gestures for this application were chosen from the Yang style, which is meant more for relaxation and wholeness than for fighting.

The application: Staying Alive

The test-bed in which this project is being developed is the *Interactive Virtual Environment (IVE)* space. The *IVE* space was developed based on the idea that a user should be able to interact with a virtual world in a natural way, free from goggles, wires, data gloves, or body suits. In an *IVE* space, a user is in front of some large display (such as a large projection screen). One or more cameras are mounted in the room, and the video from the cameras is blended with output from an SGI workstation and displayed on the screen. Users see themselves "in" the virtual world on the screen. In addition, the input from the cameras is digitized and processed on one or more separate workstations.

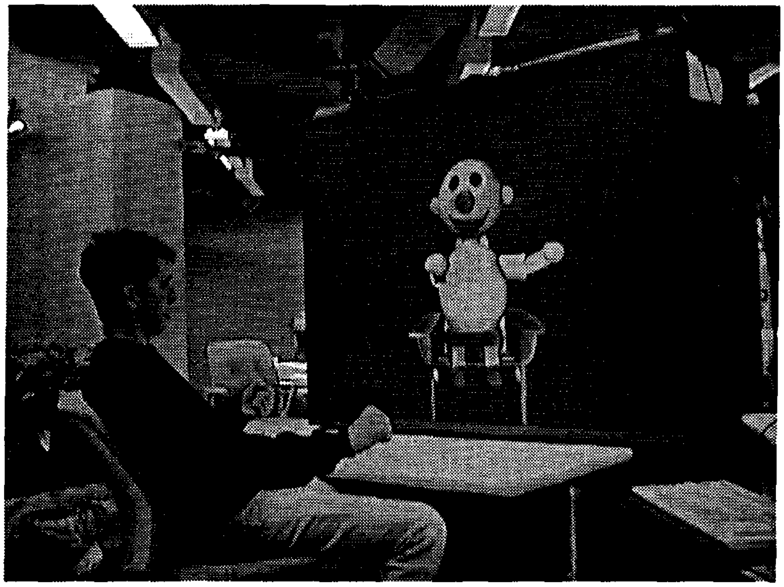

Figure 1: User Interacting with Virtual Teacher

The paradigm for *Staying Alive* is that a user enters into an *IVE* space and faces the screen. First, the user points to the area of the body in which the disease is centered. On the screen, the viewpoint zooms in and the user "becomes" a white blood cell in the blood stream in the designated area. Red blood cells zip by as the user moves along until a malignant cell is found. The task of the user is now to navigate the white blood cell to the malignant cell and gently destroy it by engulfing it or calling other cells in to contain it.

To control the white blood cell, the user performs *T'ai Chi* gestures. The gestures are recognized, and different gestures are mapped to specific actions of the white blood cell (movement, various means for removing malignant cells). The user sits in the *IVE* space and practices *T'ai Chi*, thereby having the virtual immune system fight off the disease. The whole experience is a relaxing one for the user. It is not a difficult task to control the disease cells, so that the user is not stressed by missing any malignant cells.

Since not everyone is familiar with *taijiquan*, another aspect of the project is a *T'ai Chi* "teacher." If a user performs a gesture incorrectly, a virtual teacher appears on the the screen and acts out the gesture in the correct form. In addition, if a particular gesture is suggested by the circumstances in the virtual world (for example, a malignant cell might be to the right of the user and hence an appropriate gesture would be that which causes the user's white blood cell to move to the right), the teacher appears and suggests that gesture by acting it out. Figure 1 shows a user interacting with the teacher.

Implementation

The tools for implementing this project, autonomous agents and gesture understanding, are well developed.

Autonomous Agents

Blumberg's method of action-selection (Blumberg 1994) is more than adequate to control the behavior of the red blood cells, which do nothing more complicated than flow through the artery. Malignant cells remain stationary in the bloodstream and wait to be destroyed by the user's white blood cell. The virtual teacher is a "puppet" whose movements are governed by the model of the particular gesture to be taught.

Gesture Understanding

In order for each *T'ai Chi* gesture to convey a different meaning in the virtual world, the system must be able to recognize when the user is performing a particular movement. This interpretation of human action is a goal shared by a large number of applications in the *IVE* space. Among them is the wireless virtual reality system, *ALIVE* (Darrell & Pentland 1995). In order for the "dog" in this system, Silas T. Dog, to understand the intentions of the human user, a real-time system called pfinder (person-finder) was developed (Wren *et al.* 1995) that tracks the user's head, hands and body. While the user's distance from the camera and x-y coordinates are determined by pfinder, there is no true, three-dimensional representation of the hands (the third dimension of the body is known, but the hands, of course, do not necessarily reside in the same depth plane as the body). To understand what the user is trying to convey, a simple gesture

GESTURE NAME	DESCRIPTION	VIRTUAL ACTION
Wave Hands Like Clouds	Hands move from one side to the other in large arcs	move to left
Grasp the Bird's Tail	Start with hands outstretched circle in front of chest and back up	move to right
Single Whip	Hands start in front of face and one hand traces an arc to the side in a horizontal plane	move upwards
Roll Arms	Like Single Whip, but hand dips down while tracing arc	move downwards
Opening Form	Move hands from in front of belly up to a rest in front of chest	engulf malignant cell
Brush the Knee	One hand drops in front of belly, other extends past knee	dissolve malignant cell
Apparent Close Up	Hands start by face, drop to belly and extend forward	digest malignant cell
High Pat on Horse	One hand extends up and out while other curls by side	chop up malignant cell

Table 1: Eight of the eighteen *T'ai Chi* gestures with their virtual meanings

understanding module takes, among other things, the locations of the hands and head as given by pfinder.

A richer representation of the hands, one that includes a true, third dimension, allows for the recognition of more sophisticated gestures, such as *T'ai Chi* gestures. Azarbayejani and Pentland have developed *STIVE*, a system similar to *ALIVE* but with two cameras, allowing for less noisy depth determination (Azarbayejani & Pentland 1996). A modified version of pfinder is run on the input from each camera, and the head and hand locations from the two cameras are triangulated to obtain depth.

In *Staying Alive*, the *STIVE* system is used to generate the three-dimensional locations of the head and hands. A Hidden Markov Model framework is used to interpret the gestures. Though HMM's have predominately been used by the speech and handwriting recognition communities, they are currently finding acceptance in computer vision research. Especially for work in which the recovery of the complete three-dimensional structure of a scene is not deemed necessary, HMM's are increasingly being used. Significant successes have been obtained in gesture recognition with a more simple view-based approach for which HMM's are appropriate (Starner & Pentland 1995; Wilson & Bobick 1995; Yamato, Ohya, & Ishii 1992). Starner achieved a recognition rate of ninety-seven percent (on a forty word lexicon) using a two-dimensional representation of the hands.

In *Staying Alive*, eighteen different *T'ai Chi* movements have meaning in the virtual world. Table 1 contains a list of some of the gestures with a brief description of the movements involved and their corresponding meanings for the user's white blood cell. A pictorial description of the gestures can be found in (Yen-Ling 1990). Figure 2 shows an example of the first gesture, "Wave Hands Like Clouds."

Five state HMM's (with skip states) are used to model the gestures. In addition, a two state HMM is employed to model "silence," which is used to reset the system if desired. A single user performed each gesture eighteen times to provide the training. For testing, six examples of each gesture were recorded in the same location as the training, in a translated location, and in a translated and rotated location.

It is not in the scope of this paper to fully discuss the selection of feature vectors (see (Campbell *et al.* 1996) for such analysis). However, using the (dx,dy,dz) (delta between frames) locations of the hands and head provides a ninety-five percent recognition level when the user practices *T'ai Chi* in the same location as where the training took place. A body-centered polar coordinate system is used to allow for invariance to translations and rotations. The user can generally be assumed to be facing the screen, making rotations unlikely. Currently, a recognition rate of ninety percent is achieved on translated *T'ai Chi*.

Future Work

Eventually, an interesting experiment will be to determine the actual benefit of the system on cancer patients. Patients using the system could be compared to those doing more standard visualization techniques to see if either the quality of life improved, presumably from reduced stress and anxiety, or if the length of remission increased.

Figure 2: Wave Hands Like Clouds, courtesy of Yen-Ling, 1990

In addition, another interesting extension of this work would be the integration of affective computing, "computing that relates to, arises from, or deliberately influences emotion" (Picard 1995). Specifically, Picard discusses the development of emotion recognition by computers, most simply through the use of sensors monitoring physiological responses such as heart rate or blood pressure. There are many issues which complicate the task. For example, similar physiological responses can arise through influences other than emotion (such as exercise) (Picard 1995). However, given a system which is capable of recognizing stress, a fascinating addition to the application would be the ability of the system to make the environment more soothing if the user were not becoming more relaxed.

Conclusion

There has been a recent explosion of evidence supporting the idea that visualization, imagery and relaxation bolster the immune system. A virtual reality application providing the tools for practicing these activities could be a real benefit to cancer patients. Not only does it allow for direct visualization, but it also allows a user to easily control the environment at a time when patients are facing a loss of control in their lives.

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References

Azarbayejani, A., and Pentland, A. 1996. Real-time self-calibrating stereo person tracking using 3-D shape estimation from blob features. In *Proceedings of 13th ICPR.*

Blumberg, B. 1994. Action-selection in hamsterdam: Lessons from ethology. In *Proc. of the 3rd Intl. Conference on the Simulation of Adaptive Behavior.*

C. S. Feldman, H. C. S. 1990. The role of imagery in the hypnotic treatment of adverse reactions to cancer therapy. *J. S. C. Medical Association.*

Campbell, L. W.; Becker, D. A.; Azarbayejani, A.; Bobick, A.; and Pentland, A. 1996. Features for gesture recognition using realtime 3d blob tracking. MIT Media Lab Perceptual Computing Group Technical Report No. 379, Massachusetts Institute of Technology. Submitted to 2nd International Face and Gesture Workshop, Killington VT.

Darrell, T., and Pentland, A. 1995. Attention-driven expression and gesture analysis in an interactive environment. In *Proc. Intl. Workshop on Automatic Face and Gesture Recognition (IWAFGR '95).*

Decker, T. W.; Cline-Elsen, J.; and Gallagher, M. 1992. Relaxation therapy as an adjunct in radiation oncology. *Journal of Clinical Psychology.*

Little, B. 1994. *Eight Ways to Take an Active Role in Your Health.* Harold Shaw Publishing.

Picard, R. W. 1995. Affective computing. MIT Media Lab Perceptual Computing Group Technical Report No. 321, Massachusetts Institute of Technology.

Siegal, B. 1986. *Love, Medicine, and Miracles: lessons learned about self-healing from a surgeon's experience with exceptional patients.* Harper and Row.

Sims, S. E. 1987. Relaxation training as a technique for helping patients cope with the experience of cancer: a selectivereview of the literature. *Journal of Advanced Nursing.*

Starner, T. E., and Pentland, A. 1995. Visual recognition of american sign language using hidden markov models. In *Proc. of the Intl. Workshop on Automatic Face- and Gesture-Recognition.*

Wilson, A. D., and Bobick, A. F. 1995. Learning visual behavior for gesture analysis. In *Proc. IEEE Int'l. Symp. on Comp. Vis.*

Wren, C.; Azarbayejani, A.; Darrell, T.; and Pentland, A. 1995. Pfinder: Real-time tracking of the human body. *SPIE Conference on Integration Issues in Large Commercial Media Delivery Systems.*

Yamato, J.; Ohya, J.; and Ishii, K. 1992. Recognizing human action in time-sequential images using hidden markov model. *Proc. Comp. Vis. and Pattern Rec.* 379–385.

Yen-Ling, S. 1990. *T'ai Chi Ch'uan: The Basic Exercises.* Sugawara Martial Arts.