PENPETS: A Physical Environment for Virtual Animals

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INTRODUCTION

PenPets is an application running on a Video-Augmented Environment (VAE) called *SketchTop*. Most of this paper and demonstration present the application, in which virtual animals interact in real time with physical objects and users. But first we explain the design rationale for *SketchTop*, which supports rich interaction through sketching, augmented physical objects and mobile virtual objects.

THE SKETCHTOP VIDEO-AUGMENTED ENVIRONMENT

In a VAE, graphical information is projected onto physical objects that users manipulate. The VAE senses manipulation events and interprets them as user input, changing the augmentations in response. Although VAEs may respond to *transient* manipulation events (for example a hand gesture over augmented objects) and to *permanent* manipulation events (for example, ripping up a piece of augmented paper), they derive most of their power through *literal* interaction with *temporary* (undoable) manipulation events. Literal interaction means that manipulation has a physical or metaphorical interpretation [1]. In the context of a VAE, augmentations that are anchored to physical objects, and change in response to physical manipulations, provide the impression of literal coupling between real and virtual worlds. Literalism offers two fundamental benefits. First, physical affordances cue users about what augmented objects can do, as demonstrated, for example, in the *Tangible Media* work of Ishii *et al* [2]. Second, physical possibilities and constraints determine the organization of functionality. For example, *LivePaper* [3] was designed to respect the physicality of paper by allowing augmented pages and cards to be moved freely, overlapped, occluded and stacked. The result is a natural and transparent multi-object VAE. However, this adherence to literalism means that *LivePaper*, in contrast to other desktop VAEs (notably [4]), treats writing on paper as a permanent manipulation event (because erasure is cumbersome). Writing events are tracked but not used for interaction. The interactive potential of writing is undermined by the physical constraints of ink and paper.

On a whiteboard, writing is easy to erase. It is a source of flexible, temporary manipulation events. Existing whiteboard VAEs [5,6] have not, however, provided as rich interactivity as their desktop counterparts, for two reasons.

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First, a vertically-mounted whiteboard cannot support other augmented objects. Second, a whiteboard and its markings (once written) are static, so the literalness of interaction that comes through registering augmentations to moving objects is lost. *SketchTop* was designed to solve both these problems and thereby provide a rich literal interaction interface via static-but-erasable writing.

SketchTop is a whiteboard mounted horizontally at desk height together with other physical objects that can be augmented. Its VAE hardware is conventional: a video camera and a data projector are mounted high above the worktop, images of the environment are captured and processed several times per second, the system's augmentations change in response to the events it sees. However, in additional to conventional augmentations, registered to objects or the environment as a whole, *SketchTop* projects virtual objects that move relative to the physical environment. Dynamic encounters between static physical objects (particularly writing) and moving virtual objects give an impression of connectedness between the two worlds, similar to the literalness of augmentations that track the motion of physical objects.

THE PENPETS APPLICATION

We are developing a number of *SketchTop* applications including a circuit simulator and a traffic simulator. But the focus of this demonstration is *PenPets*, an artificial life application in which virtual animals roam the augmented space, encountering objects and events in the physical world. Each animal has a behavioral model which determines how it interacts with the environment. Whenever an animal meets a gesturing hand, a drawn line or a physical object resting on the whiteboard surface, it reacts to the encounter in a literal way. That is, the physicality of the object/event involved (e.g. moving cupped hands, erasing a line, or placing an object shaped like a tunnel entrance in the path of a moving animal) determines what the agent will do, subject to its behavioral model.

Figure 1 shows two snapshots of *PenPets* in action. The demonstration will focus on virtual animals that have maze-solving ability as part of their behavioral model. These sense their local environments and interpret drawn lines as obstructions – effectively maze walls. They will carefully navigate and solve a static pen-drawn maze (avoiding getting stuck in tapered corridors and other hazards). Because their sensing is local, users can easily

hinder the maze-solving ability by opening up new exits and closing old ones during an animal's search. In practice, therefore, the maze-solving ability simply provides consistent rules for the animal to explore areas, rather than being a goal.

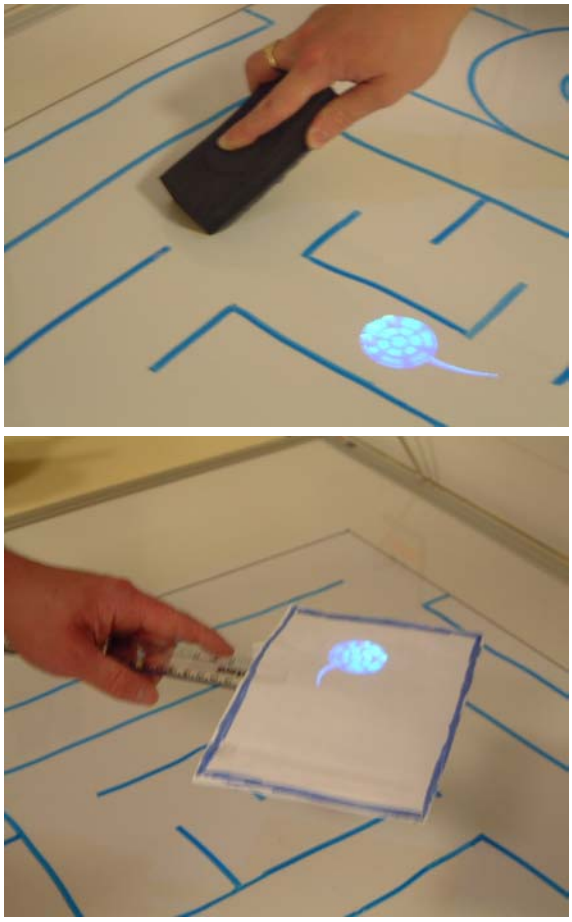

Figure 1. Two snapshots of *PenPets* in action: (a) user modification of the environment while a maze-solving agent tries to find its way out; (b) moving an agent with a fishing net above the whiteboard.

Users can instantiate multiple animals, all acting within the world of the augmented whiteboard, with different visual appearances and behavioral models. The agents can interact with each other as well as with the human users.

There are three types of physical objects that *PenPets* recognizes in addition to writing. The first is hands: users can pick up or block animals by gesture. The second type is objects with programmed literal interaction significance. These include a coffee jar lid that when placed inverted on the whiteboard looks like a tunnel entrance and provides a way for animals to slip "under" the board. There they continue to burrow, hidden until they find a tunnel exit (a lid the other way up which looks like a mound of earth) from which they re-emerge. Other physical objects with programmed meaning include a poison jar. The third type of recognized physical object is a paper model with markings. An example is the fishing net shown in figure 1, which can be used to carry an animal from one part of the environment to another.

Paper models as interaction objects were not part of the design of *PenPets* but arose from spontaneous user invention. They are an example of how users and demonstration audiences have found different ways of interacting with the environment. As well, individuals in groups develop ways of interacting with each other through the medium of *PenPets*. We have observed children inventing collaborative and competitive games involving goals for their own "pet" animals. The demonstration will show these and other modes of interaction that *PenPets* provides. We will also briefly report the possibilities for extension suggested to us by different classes of users.

CURRENT AND FUTURE DEVELOPMENT

As we develop richer behavioral models for *PenPets*, we are incorporating a wider range of interaction objects. Some of our animals have gained culinary interests, so apple, cheese and teapot recognition are being implemented. We are also developing more sophisticated responses to direct contact between animals and hands, though this presents significant gesture analysis problems (for example, distinguishing between a gentle stroke, a flick and a pinch). At the other end of the behavioral model scale, we have implemented sketchable pinball (using animals as balls). But it appears that reconfiguring a pinball game (or even a maze) on the fly is less interesting to users than using drawing and objects to interact directly with the animals.

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