Evaluating Program Representation in a Demonstrational Visual Shell

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ABSTRACT
For Programming by Demonstration (PBD) systems to reach their full potential, a program representation is needed so users can view, edit and share programs. We designed and implemented two equivalent representation languages for a PBD desktop similar to the MacIntosh Finder. One language graphically depicts the program's *effects*. The other language describes the program's *actions*. A user study showed that both languages enabled users with no prior programming experience to generate and comprehend programs, and that the first language doubled users' abilities to generate programs.

KEYWORDS: End-User Programming, Programming by Demonstration, Visual Language, Visual Shell, Pursuit.

INTRODUCTION AND MOTIVATION

A visual shell, e.g., the Macintosh Finder, is a direct manipulation interface to a file system. Although easy to use, these interfaces lack of a way for users to automate repetitive tasks. The Pursuit visual shell [3] is exploring ways to provide programming to non-programmers *in a way that is consistent with the direct manipulation paradigm.* Pursuit is a Programming by Demonstration (PBD) system [1] that infers a program as the user executes actions on real data. Many PBD systems have shown promise in enabling non-programmers to automate tasks (e.g., SmallStar, Metamouse,Eager, Mondrian), but they admit a well-known shortcoming: how to represent the resulting program to end users. Without a representation, users cannot verify inferences, review or modify a program.

To address this, we are investigating ways to represent the evolving program *while the user is demonstrating it* so that users know what the system has inferred (by observing the growing program representation) and can interactively learn the syntax and semantics of the language. By allowing a program to be edited and saved, users can have an artifact to later examine, edit and share.

	Avg. No. Errors (2)		Avg. Time (Minutes)	
	state-based	text-based	state-based	text-based
Simple	0.25	0.75	12.16	12.10
Complex	0.88	1.75	19.15	21.29

Table 1: Generation Results

THE TWO REPRESENTATION LANGUAGES

To construct a program in Pursuit, users demonstrate the program's actions on pieces of data. As the user executes each operation, Pursuit presents the evolving program in a special program window in one of two representation languages.

The *state-based* language (Fig. 1) uses a comic strip metaphor. Data are represented with icons. Operations are implicitly represented by changes to data icons. Control constructs are represented by graphical objects. A program is a series of operations and control constructs. Essentially, programs are static representations of the dynamic changes to data.

The *text-based* language (Fig. 2) has a verb/argument structure. Data are represented with familiar icons. Operations consist of a name followed by data icons. Control constructs are represented with keywords and indentation. A program is a list of commands and control constructs. Essentially, programs describe how data is manipulated.

Although conceptually different, the languages are functionally equivalent. There is a 1-to-1 mapping between their commands and constructs. Moreover, actions to construct programs are identical across the languages so that the concepts users need to learn do not vary between the languages.

EVALUATION STUDY

Sixteen non-programmers were randomly assigned to the state-based or text-based group. In the generation study, users were given 4 task descriptions – 2 *simple* tasks, containing no loops or conditionals, and 2 *complex* tasks, containing both a loop and a conditional – and asked to constructs programs. Table 1 summarizes the results. A two-way ANOVA showed that the state-based group was twice as accurate in generating programs, F(1,28)=13.00, p<.002. All subjects were more accurate (F(1,28)=9.31, p<.005) and faster (F(1,28)=12.90, p<.002) when constructing simple programs.

In the comprehension study, users were presented with 14 (task description, program) pairs and had to decide if the program was correct or contained a bug. Table 2 summarizes the results.

	Avg. No. Errors (7)		Avg. Time (Minutes)	
	state-based	text-based	state-based	text-based
Simple	1.88	2.00	1.48	1.14
Complex	2.00	4.13	1.62	1.30

Table 2: Comprehension Results

All subjects did well, with the state-based group performing better for complex programs (t(14)=1.84, p<.04), and the text-based group performing significantly faster (F(1,28)=6.44, p<.02).

	Avg. No. Errors (4)		Avg. Time (Minutes)	
	state-based	text-based	state-based	text-based
Simple	0.50	0.75	1.55	1.60
Complex	0.13	0.38	1.48	1.58

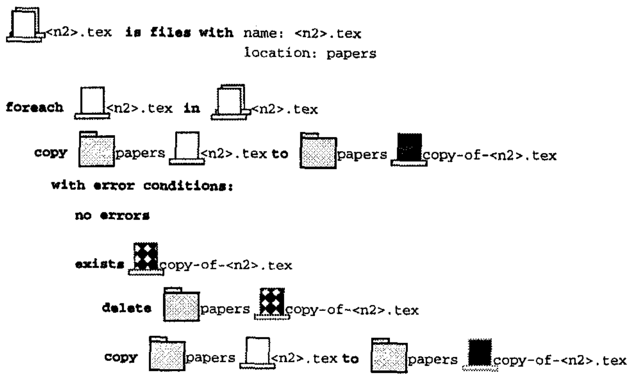
Table 3: Identification Results

In the identification study, for each of 8 task descriptions, users indicated which of 4 programs implemented the task. Table 3 summarizes the results. All subjects did well, and ANOVAs revealed no reliable main effects or interactions.

DISCUSSION AND CONCLUSION

Although preliminary, the results are promising. Both groups generated and comprehended programs, demonstrating that combining PBD with an editable program representation does help non-programmers access the power of programming.

We were surprised to see the great effect that language had on users' ability to generate programs, since the user actions in constructing programs are identical across languages. One reason could be the representation of control constructs in the state-based language. The fact that users in the text-based group rarely constructed *complex* programs correctly and did much worse for *complex* programs in the other studies suggests that possibly the state-based representation of loops and conditionals enhanced users' understanding of these concepts. Responses in a post-study questionnaire support this. The state-based group cited branches (4 users), loops (2) and operations (2) as the most intuitive features in the language, whereas the text-based group cited only files and folders.



```
<n2>.tex is files with name: <n2>.tex
                       location: papers

foreach <n2>.tex in <n2>.tex
  copy papers <n2>.tex to papers copy-of-<n2>.tex
   with error conditions:
    no errors

    exists copy-of-<n2>.tex
      delete papers copy-of-<n2>.tex
      copy papers <n2>.tex to papers copy-of-<n2>.tex
```

Figure 1: The program in Fig. 1 represented in the text-based language. The loop is represented by a combination of keywords (**foreach**) and indentation of operations indicating its scope. A similar combination represents the branch on the outcome of the copy operation (**with error condition:**).

We plan a future study that establishes users' understanding of programming concepts at various points, and that focuses on the micro-structure of the languages to see if the graphical representations of control constructs affect comprehension. This study should also help us determine what features of the two languages make them successful for particular user tasks.

REFERENCES

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2. F. Modugno. Pursuit: Programming in the User Interface. PhD Thesis, Carnegie Mellon. Expected Feb. 95.

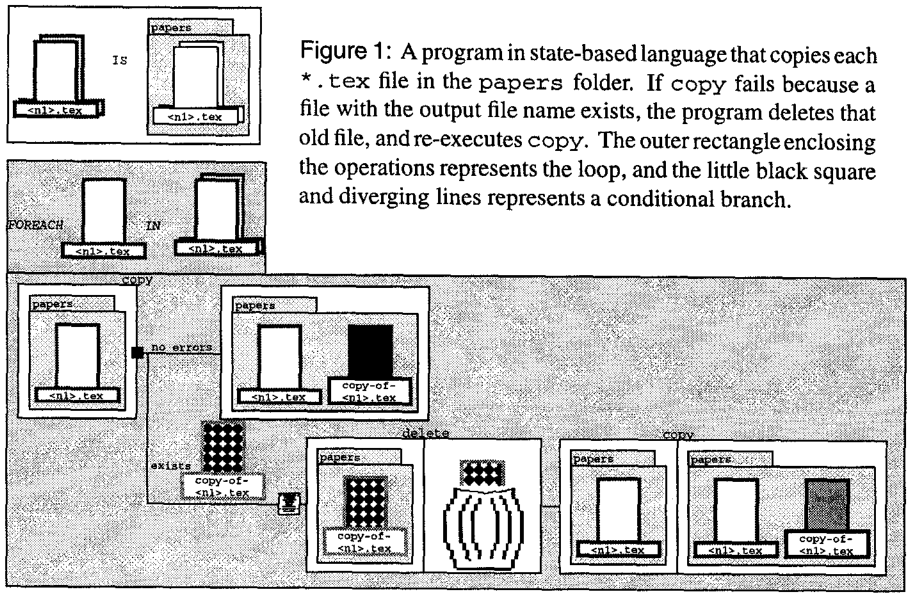

Figure 1: A program in state-based language that copies each *.tex file in the papers folder. If copy fails because a file with the output file name exists, the program deletes that old file, and re-executes copy. The outer rectangle enclosing the operations represents the loop, and the little black square and diverging lines represents a conditional branch.