EXPERT PROBLEM SOLVING STRATEGIES FOR PROGRAM COMPREHENSION

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ABSTRACT

Program comprehension is a complex problem solving process. We report on an experiment that studies expert programmers' comprehension behavior in the context of modifying a complex PASCAL program. Our data suggests that program comprehension is best understood as a goal–oriented, hypotheses–driven problem–solving process. Programmers follow a pragmatic as-needed rather than a systematic strategy, they restrict their understanding to those parts of a program they find relevant for a given task, and they use bottom-up comprehension only for directly relevant code and in cases of missing, insufficient, or failing hypotheses. These findings have important consequences for the design of cognitively adequate computer–aided software engineering tools.

KEYWORDS

Software Psychology, Program Comprehension, Protocol Analysis

INTRODUCTION

> Yes, code please ... I'll probably go to the comments after that, when I realize that I don't understand the code. [Subject 08]

A central activity of the software maintenance process is *program comprehension*, the process of understanding program code unfamiliar to the programmer. The goal of our research is to provide strong empirical support for the paradigm that program comprehension is a hypotheses–driven problem–solving process. Consequently, cognitively adequate user interfaces for computer–aided software engineering tools have to support these empirically identified processes.

There is a growing body of research on the issue of program comprehension. Cognitive research since the early 1980's has focussed on comprehension strategies, the procedural aspect of expertise, as well as on the declarative aspect of how programming knowledge in general and the program under consideration in particular are conceptually represented [1, 5, 15, 19, 23, 25, 26].

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A study by Littman et.al.[17] (see also [16]) identified two equally dominant comprehension strategies: Programmers used either a *systematic* or an *as–needed* strategy. The former group used extensive symbolic execution of the data and control flow between subroutines to gain a detailed understanding of the program *prior* to modifying the code, whereas the latter group tried to minimize the understanding of the program by localizing those parts of the program that needed to be changed and studying those parts only. This view of program comprehension as a hypotheses–driven problem–solving process was first put forward by Brooks [3] in his model of "Beacons" that guide comprehension. Other studies [27, 28] demonstrated the role of code level beacons for understanding small, simple programs. Research at MCC on initial stages of software design ([8, 9, 10, 11, 14]) and comprehension [2, 4] also demonstrated the heuristic approach to software engineering tasks.

In contrast, there is a body of research that views program listings as a special class of display of information [7] and, consequently, sees program comprehension to be similar to (prose) text comprehension. Parsing models of the text comprehension literature [13] are adapted for the use with programming languages to predict reading times based on the "micro–structure" of program statements [6, 18]. Comprehension, understanding of the "macrostructure" of program code, is seen as a bottom–up chunking process [20, 21, 24]. Robertson et.al. [22] show that complete knowledge of the micro– and macro–structure of a program is not sufficient to predict the comprehension behavior of programmers. Here we show that subjects follow a pragmatic "as–needed" strategy rather than a systematic approach, that subjects restrict their understanding to parts of the code they consider to be relevant for the task and, thus, gain only a partial understanding of the program that might lead to misconceptions or errors. Tools will have to be developed that facilitate "as-needed" strategies and help programmers to avoid some of its inherent problems.

METHOD

Subjects

Twelve subjects participated in the study and were assigned randomly to the four different tasks. Subjects knew at least three programming languages, had programmed for 4 to 15 years (avg. 7.6), had PASCAL experience for at least 4 years, worked with large programs on a routine basis, and had a formal education in computer science or electrical engineering.

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