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## Monterey, California



RAPID PROTOTYPING FOR SOFTWARE EVOLUTION

W.P. YIN, LUQI and M.M. TANIK

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Prepared For:

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Washington, DC 20550

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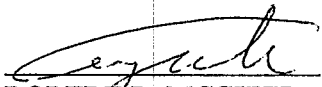


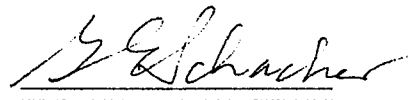
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## Rapid prototyping for Software Evolution

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*Abstract* — This paper describes the basic concepts of a mixed-level software process and rapid prototyping. Some practical methods, and software tools for using rapid prototyping to support software evolution are also presented. The research results show that prototyping can be used to stabilize the requirements for either an initial software development project or a proposed enhancement to an existing system.

As society becomes increasingly depending on computers, the public demands for computer software becomes more complex than perhaps any other human construct [FPB87]. The facts of missed schedules, blown budgets, and flawed products have shown that engineering of software needs technology innovations to increase software productivity and quality. More and more computer scientists [RTY87, FPB87] believe that concentration on the front-end technologies, specification and design, are the first priority. The positive results in these fields have potential for breakthroughs in the engineering of software.

To achieve any significant gain in software productivity it has been proposed that an alternative software development and evolution is necessary [RTY87]. Figure 1 depicts such a paradigm. Software is a spectrum concept that covers all the information obtained during software developments and evolutions. The productivity of software engineering much depends on the software process model. Among a number of software process models, the waterfall model (Figure 2) has become the basis for most software acquisition standards [BWB88]. The experience has proved that the waterfall model has some fundamental difficulties, such as the inherent discontinuity among the

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phases, the lack of good control in the front-end of the process, and costly product maintenance. In the alternative model, the concentration is shifted to the front-end, namely, requirement specification and design; and the mixed-level process conducts the prototyping, performance measurement, verification, code synthesis as well maintenance.

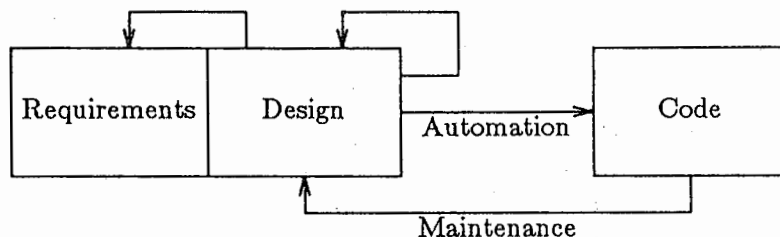


Figure 1. An Alternative Software Development Model

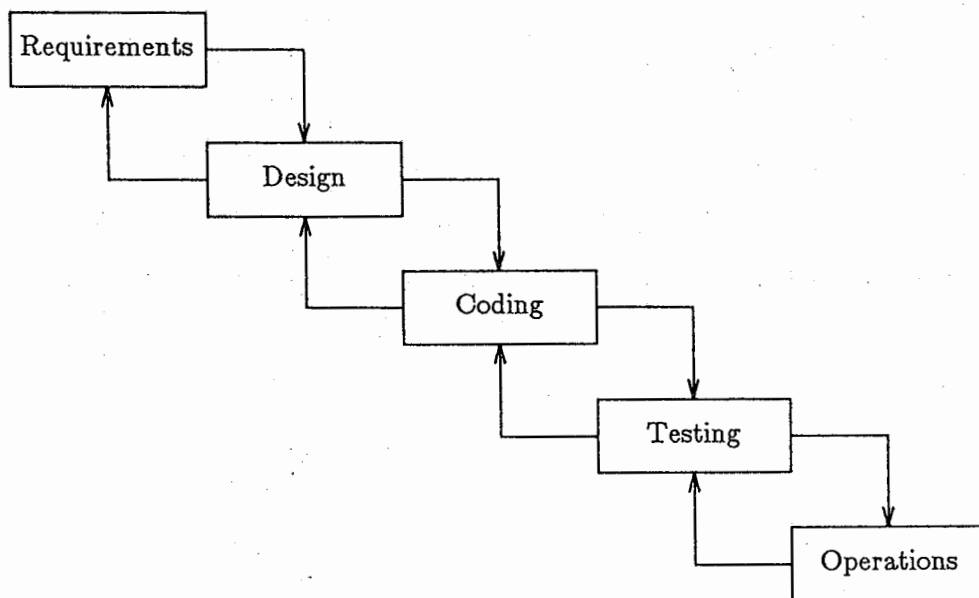


Figure 2. Standard Waterfall Life Cycle Model

In order to apply the alternative software process model, a number of technology innovations are required. In this paper, we represent a concrete mixed-level design process and a practical rapid prototyping system. The mixed-level design process (Figure 3) employs three design activities representing different levels of software development [T&Y89]. The activities are Construct Design, Exercise Design and Translate Design. These activities support the design evolution. Testing and

maintenance are performed directly on the design. Utilizing prototyping technique in the mixed-level design process obviously helps software evolution.

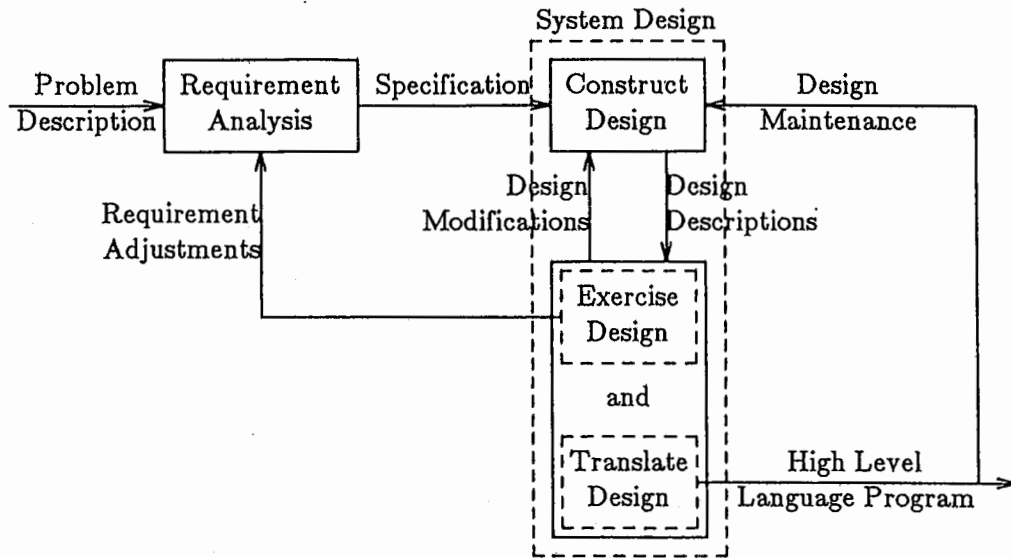


Figure 3. A Mixed-level Design Process

In our approach, a prototype is a concrete executable model of selected aspects of the proposed system, and rapid prototyping is the process of building and evaluating a series of prototypes rapidly. Figure 4 illustrates the iterative prototyping cycle. The user and the designer work together to define the requirements and specifications for the critical parts of the envisioned system. The designer then constructs a model or prototype of the system in a prototype description language at the specification level. The constructed prototype is a partial representation of the system, including only those attributes necessary for meeting the requirements, and is used as an aid in analysis and design rather than as production software. During demonstrations of the prototype, the user validates the prototype's actual behavior against its expected behavior. If the prototype fails to execute properly the user identifies problems and works with the designer to redefine the requirements. This process continues until the user determines that the prototype successfully captures the critical aspects of the envisioned system. Following this validation, the designer uses the validated requirements as a basis for the design of the production software.

A set of computer-aided software tools, the Computer-Aided prototyping System (CAPS) [L&K88], has been designed and integrated to support prototyping of complex software systems such

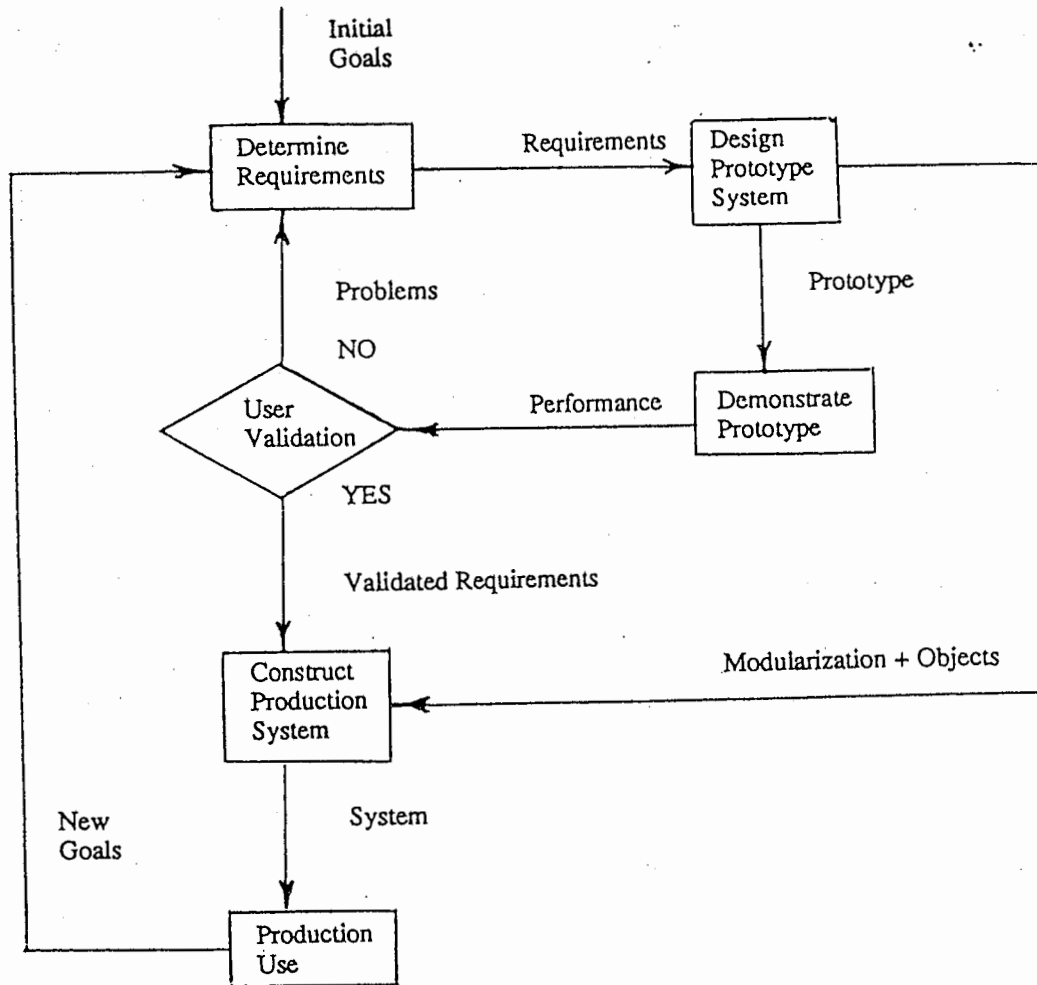


Figure 4. The prototyping Cycle

as control systems with hard real-time constraints. The requirements for such systems are especially difficult to determine and their feasibility is hard to establish without constructing an executable model of the envisioned system [LUQI89a].

The CAPS System contributes to software evolution by providing software tools for creating prototypes and adapting them to new requirements. If the prototyping process is carried out manually, the associated benefits are limited because it takes too much time and effort. CAPS can increase the leverage of the prototyping strategy by reducing the effort that must be spent by the designer in producing and adapting a prototype to perceived user needs.

The evolution of a prototype starts after one pass through the prototyping cycle shown in Figure 4: the analysts have determined the initial requirements by talking to the customers, constructed



an initial prototype, and demonstrated it to the customer, who finds some aspects of the prototype's behavior unacceptable and requests some modifications.

Initially, the facilities provided by CAPS are used to adapt the prototype to the new requirements. Modifications to the production software can be implemented by using CAPS to (1) add changes to prototype systems, (2) retrieve software components from the software base, (3) generate production code if needed, (4) assemble production systems via the prototyping cycle, and (5) manage the process via the prototyping database.

The main components of CAPS are a special prototyping language and a set of tools illustrated in Figure 5. The main subsystems of CAPS are the user interface, the software database system, and the execution support system. Those components are described in detail in [LUQI89b].

We have applied the rapid prototyping techniques to build a prototype in the philosophy of CAPS [WPY89]. The prototype is implemented by using knowledge-based techniques, representations and inference mechanism. It is build on the top of ART (The Automatic Reasoning Tools), and runs on TI Explorer under system software version 3.1. The structure of the prototype consists of the following components (Figure 6).

(1) The Uniform Design Representation:

The fundamental problem of a design process is finding the right representation of design information. A good design representation is the first step forward to a successful mixed-level design process. A uniform design representation is the only connection among the user interface, design construction, design exercise and design translation. With the uniform representation, each subsystem works independently without knowing the internal representation of all other subsystems and accessing data at all times in every internal status. Using a uniform representation is also reducing the number of transformation from one internal representation to another. In our prototype, the uniform design representation is a hybrid of object-oriented and constraint-based form.

(2) Static Analyser:

The analyser performs static dependency analyses of the software design, such as data dependency, control dependency, interface dependency, etc. These dependencies are useful at design validation and maintenance.

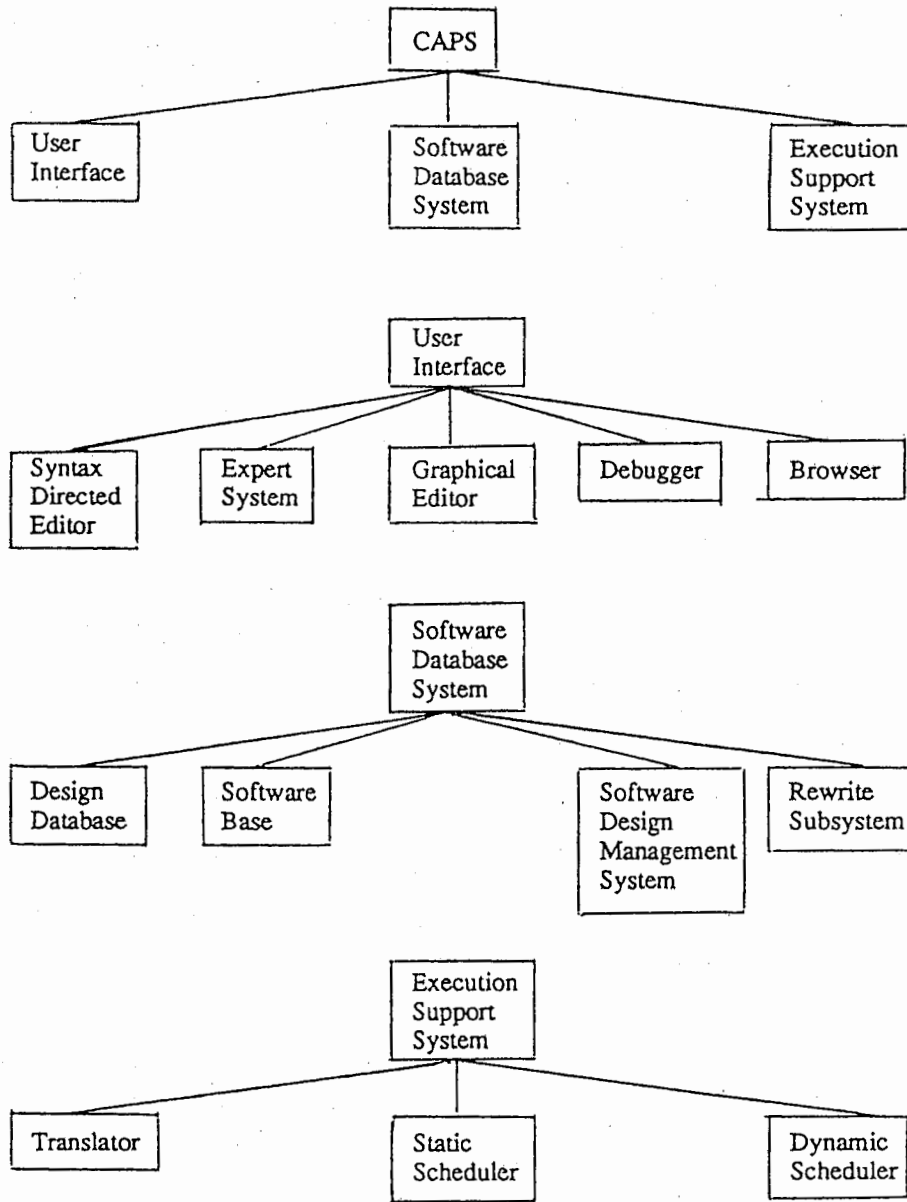


Figure 5. Main CAPS Tools

(3) Exerciser (Simulator/Interpreter):

The main function of the exerciser is to expose the behavior of the software system being designed and detect the design errors by dynamic analyses. Exposing the system behavior at design phase can give both customers and designers early feedback, reducing the cost of changes to the implementation.

(4) Automatic Program Generator:

After testing the design, the desired high level language program can be automatically generated from the design. The automation guarantees to reserve the designed functionalities. Direct modification on code is not necessary. The resulted program may also be executed by the exerciser to validate the intended design.

(5) Design Component Base:

The design component base stores and retrieves previous designed software components. Each design component in the base is described in the uniform design representation. The base management supports design maintenance and reusability directly.

(6) User Interface:

The main function of a user interface is to provide communications between the designer and design environment. The user interface offers the following facilities:

a. Design acquisition:

The design acquisition consists of graphics tools and editors. The editors cooperate with multiple external design representations and graphics tools, such as dataflow-oriented editor, state machine-oriented editor, language-oriented syntax-directed editor, etc. All those editors take different external design representations as inputs and convert them into the uniform design representation. The designer can choose an editor supporting the design methodology he is familiar with.

b. Testing Display:

The testing display shows the prototype execution or the interpretation of the design as well as the target program execution results. The display may be a time chart indicating the system state changes or the desired system behavior sequence like dialogue, input/output, reactions, etc.

c. Analysis Display:

The analysis display shows the results of the static analyses as the designer required.

d. Program Output:

The program generated based on the current status of the design can be retrieved by the designer and delivered to the customers.

According to the above discussion, the uniform design representation is the center of the design

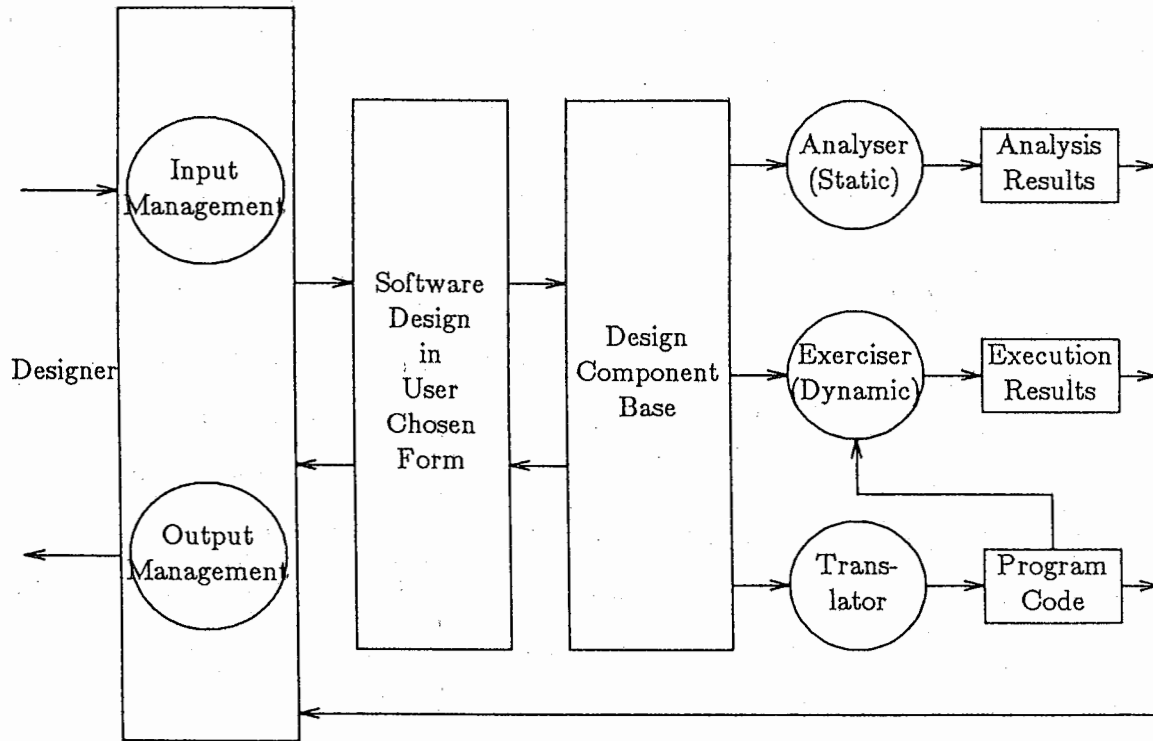


Figure 6. A General Structure of Design Environment

environment. All of the user preferred external information format will be converted to the uniform representation as the internal format, or vice versa, and all of subsystems operate on the internal representation, eliminating the redundant subsystems. Another advantage of using a uniform internal representation is to make an open architecture for the design environment in order to meet a variety of user interface requirements according to designer's preferences.

The results of our research work on a mixed-level software process represent an advancement in the state-of-art of software process model. The development of CAPS is a step toward many software technology innovations. The prototyping experience has demonstrated the great potential in software evolution. Although, much more need to be done, such as distributed information management, it is our belief that progresses would have to be made stepwise, at great effort, and persistence will eventually pay.

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