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# Software Evolution : TOC

## Program Comprehension

- ❑ Modification of software with inaccurate and incomplete understanding is likely to degrade its performance and reliability
- ❑The program comprehension process is one of the most important parts of software maintenance.
- ❑ A program comprehension process is a sequence of activities that use existing knowledge about the program to generate new knowledge about it.
- ❑Program comprehension is estimated that 50 % to 90 % of the time in software maintenance is consumed on program comprehension (Mateis et al. , 2000)

## Program Comprehension - Goal

- Program comprehension is a process of knowledge acquisition
- Scope of program comprehension: complete program or part of a program
- A code maintainer tries to understand a program with a specific goal in mind.
  - Example 1: Debugging a program to detect the cause of a known failure
  - Example 2: Adding a new function to the existing program
- Identifying the goal can help in defining the scope of program comprehension.

# Program Comprehension - Knowledge

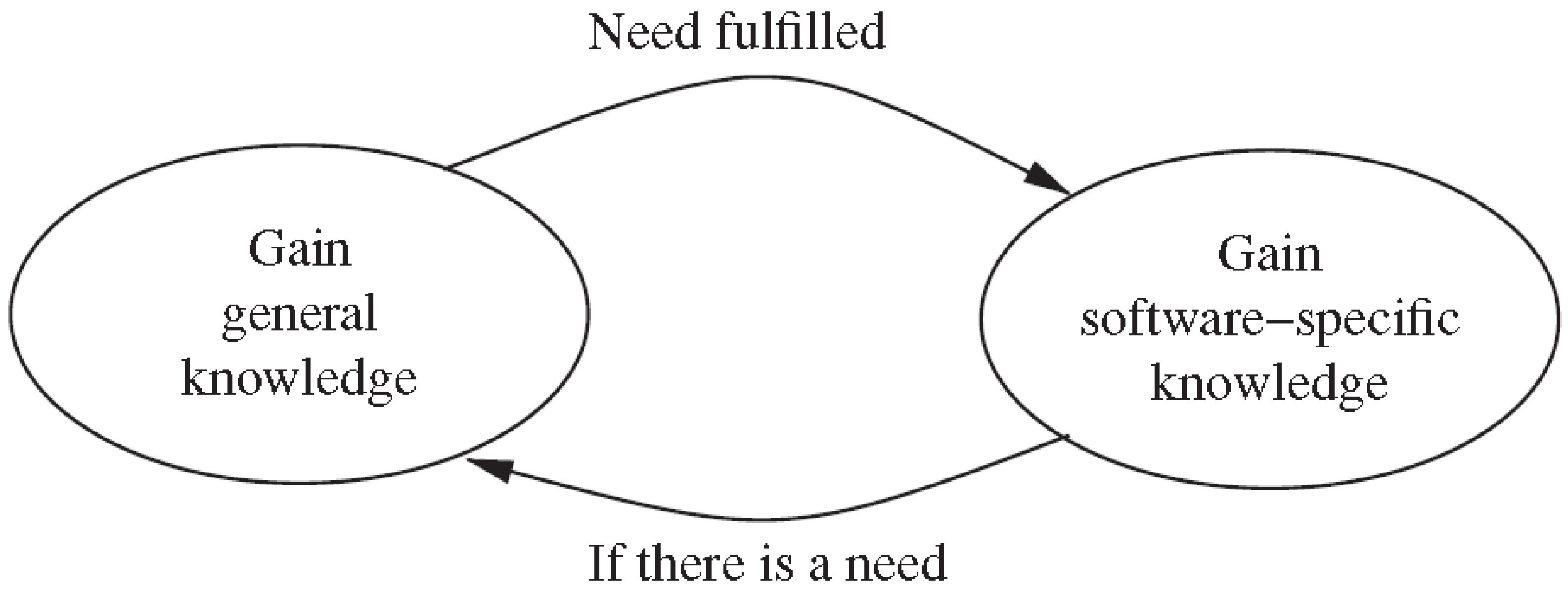
- ❑Two kinds of knowledge: General knowledge and Software-specific knowledge
- ❑General knowledge covers a broad range of topics in computer systems and software, such as :
  - Algorithms and data structures
  - Programming principles and Programming languages
  - Software architecture and design
  - Testing and debugging techniques

## Program Comprehension - Knowledge

- Software-specific knowledge represents a detailed understanding of the software to be modified.
- Some examples of software-specific knowledge are
  - The software system has implemented public-key cryptography for data encryption.
  - The software system has been structured as a three-tier client-server system.
  - Module x implements a location server.
  - A certain *for* loop in *method* y may execute for a random number of times.
  - Variable mcount keeps track of the number of times module z is invoked.

## Program Comprehension - Knowledge

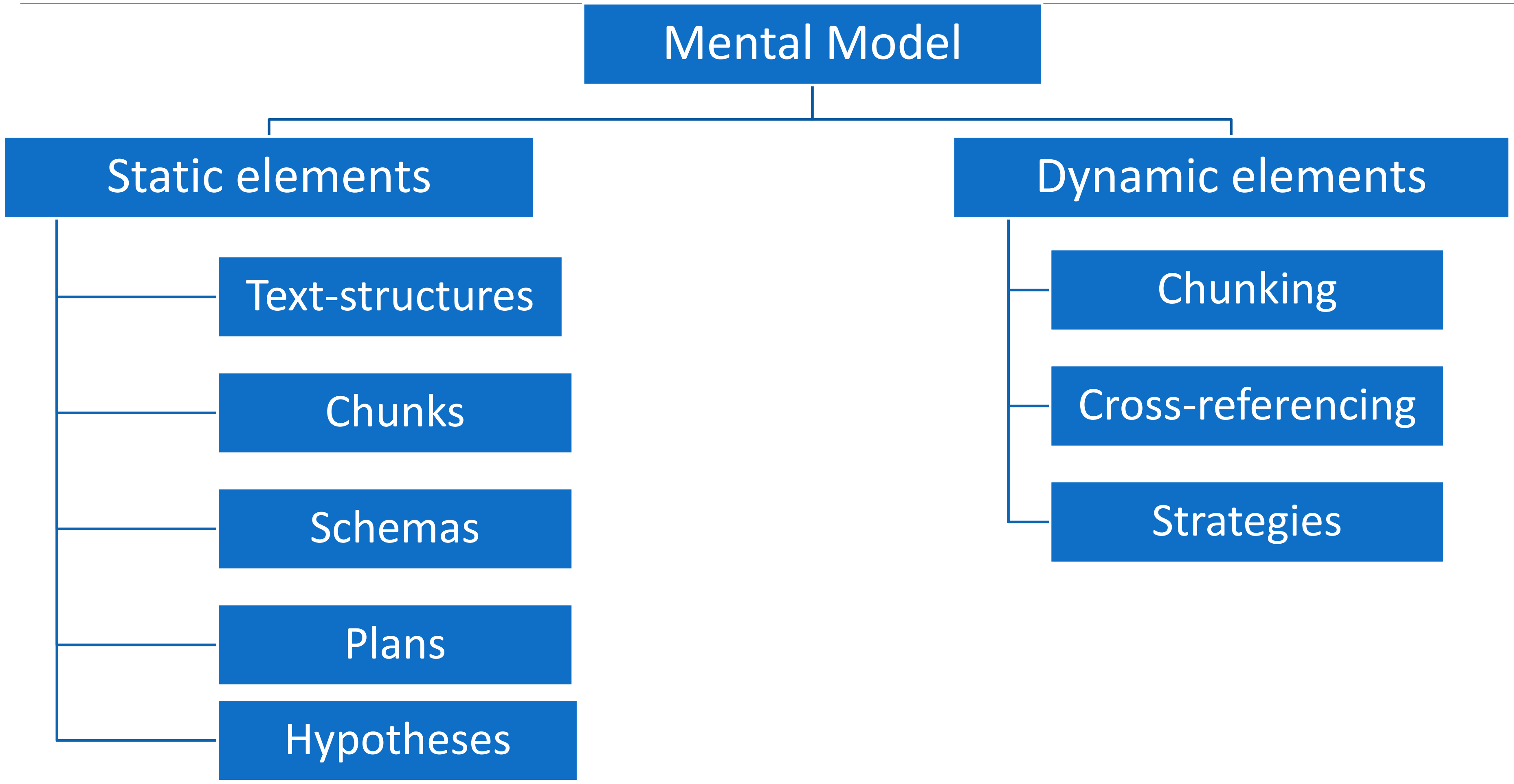
- A programmer/maintainer goes back and forth between acquiring general knowledge and software-specific knowledge
- A programmer/maintainer learns the details of the following aspects:
  - Functionality
  - Software architecture
  - Control flow and data flow
  - Exception handling
  - Stable storage
  - Implementation details



## Program Comprehension - Mental Model

- ❑A mental model describes a programmer's/ maintainer's mental representation of the program being comprehended.
- ❑A mental model of a program is not unique; different programmers view and interpret a programmer in different ways.
- ❑A programmer develops a mental model by identifying both static and dynamic elements of the program. Examples of program elements
  - for loop
  - A TCP (Transmission Control Protocol) connection
  - Cross-referencing

# Program Comprehension - Mental Model



## Mental Model – Text Structures

- Text-structures denote code and its structure, It is useful in gaining control flow knowledge in program understanding.
- The following text-structures can be identified :
  - Loop constructs: *for*, *while*, and *until*
  - Sequences
  - Conditional statements: *if-then-else*
  - Variable definitions and initializations
  - Calling hierarchies within and among modules
  - Definitions of module parameters.

Example: increment array items

```
    int i = 0;
    while (i <= a.length) {
            a[i] = a[i] + 1;
            i = i + 1;
    }
```

## Mental Model - Chunk

- ❑A program chunk is a block of related code segment.
- ❑Chunks enable programmers to create higher level abstractions from lower-level abstractions.

A code block initializing tells the nature of the parameters and their value ranges

```
c = head();
s = null;
while (c <> null && s == null) {
     if (c.value().matches("*fred*"))
          s = c;
     c = c.next();
}
```

Understanding the while loop enables to create an abstraction

## Mental Model - Schema

- Schemas are generic knowledge structures that guide the programmer’s interpretations, inferences, expectations, and attentions when chunks are comprehended.

# Mental Model - Plan

- ❑Plans are broad kinds of knowledge elements. A knowledge element is anything that is useful in understanding a program
- ❑A doubly-linked list is an example of a plan; a designer has planned to implement certain concepts with this data structure.
- ❑ A plan is a kind of schema with two parts  Slot type and Slot filler

  1. Slot types describe generic objects.
     - □ Example: A tree data structure is a generic slot type.
  2. Slot fillers are customized to hold elements of particular types.
     - □ Example: A code segment, such as a for loop’s code is a slot filler.
- ❑The programmer links the slot-type and slot-filler structures by means of the kind-of and is-a modelling  relationships.

# Mental Model - Plan

- There are two broad kinds of plans: Domain plans and Programming plans
- Domain plans
  - These include knowledge about the real world problem, including the program’s environment.
  - Example: in a numerical analysis application, plans will include schemas for different aspects of linear algebra, such as matrix multiplication and matrix inversion.

## Mental Model - Plan

- Programming plans
  - Programming plans are program fragments representing action sequences that repeatedly applied while coding.
  - Example: A programmer may design a for loop to search an item in a data set and repeatedly use the loop in many places in the program.
  - Such a for loop is an example of a programming plan to implement the system.
- Programming plans differ in their granularities to support low level or high level tasks.

# Mental Model - Hypotheses

- Programmers can test the results of their understanding as hypotheses or conjectures
  - Why: Why conjectures hypothesize the purpose of a program element.
    - Verification of a why conjecture enables a programmer to have a good understanding of the program element.
  - How: How conjectures hypothesize the method for realizing a program goal.
    - Given a program goal, the programmer needs to know how that goal has been implemented.
  - What: What conjectures enable programmers to classify program elements.
- Use hypotheses to refine view of system incrementally

## Mental Model - Chunking

- The process of creating higher level chunks is called chunking. The lowest level of chunks are code segments.
- To understand a program in terms of its higher level functionalities, a programmer creates higher level abstraction structures by combining lower level chunks.
  - When a block of code is comprehended, it is replaced by the programmer with a label representing the functionality of the code block.
  - A block of lower level labels can be replaced with one higher level label representing a higher level functionality.
  - The process of chunking is iterative to create increasingly higher levels of abstractions.

## Mental Model - Cross Referencing

- Cross-referencing means being able to link elements of different abstraction levels. This helps in building the mental model of the program under study.
- cross referencing is particularly helpful when tracking down problems in a large program
- Examples are:
  - Jump To Function, Variable Or Type Definition
  - List Uses Of Function, Variable Or Type
  - Determination Of Dependencies Between Separate Source Files

## Mental Model - Strategies

- ❑A strategy is a planned sequence of actions to reach a specific goal.
- ❑Example: if the goal is to understand the code representing a function, one can define a strategy as follows:
  1. Understand the overall functionality of the function by reading its specification (if it exists).
  2. Understand all the input parameters to the function.
  3. Read all code line by line.
  4. Identify chunks of related code.
  5. Create a higher level model of the function in terms of the chunks.
- ❑Strategies guide the two dynamic elements, namely, chunking and cross-referencing, to produce higher-level abstraction structures

# Acquiring knowledge From Code

❑Several concepts can be applied while reading code in order to gain a high-level understanding of programs.

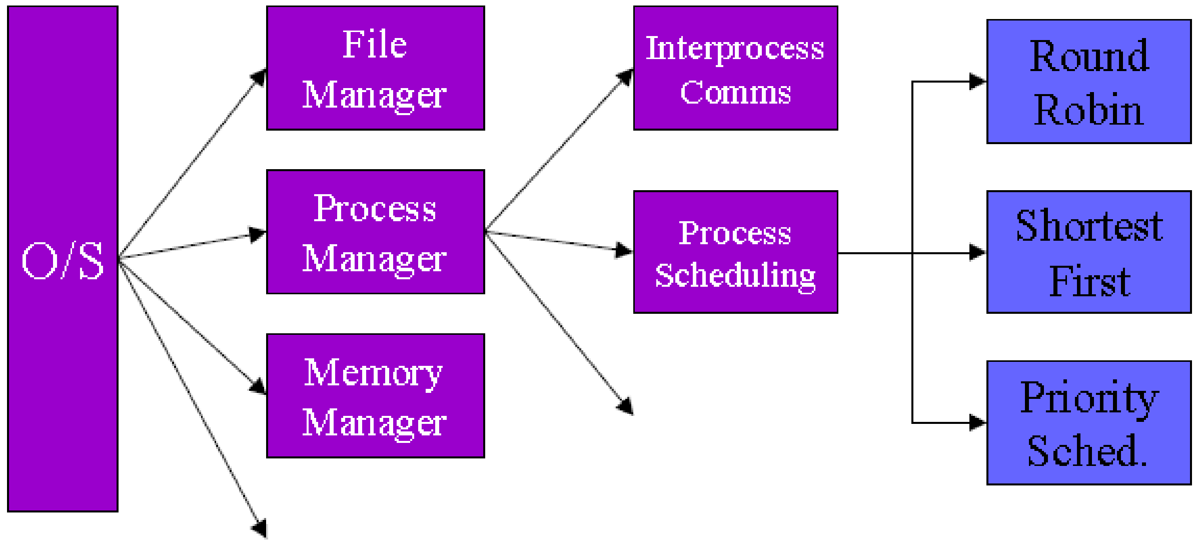
1. Beacons
   - A beacon is code text that gives a cue to the computation being performed in a code block.
   - Example swap(), sort(), select(), startTimer().
   - Code with good quality beacons are easier to understand.
2. Rules of programming discourse
   - Rules of programming discourse specify the conventions, also called "rules," that programmers follow while writing code , some examples of rules are:
     - ◻ Function name: The function name agrees with what the function does eg. openTCPconnection()
     - ◻ Variable name: Choose meaningful names for variables and constants e.g. MAX_USERS
     - ◻ The rules set up expectations in the minds of a reader about what should be in the program.

## Approaches to Code Comprehension

- ❑ Top- Down
- ❑ Bottom Up
- ❑ Opportunistic

# Approaches to Code Comprehension - Top Down Approach

- Suitable when programmer is familiar with the type of program to be comprehended
  - E.g. may have worked on several similar systems
  - Knows what components must be present
  - Knows what these components consist of
  - Use hypotheses to refine view of system incrementally
- Beacons are very important for this process



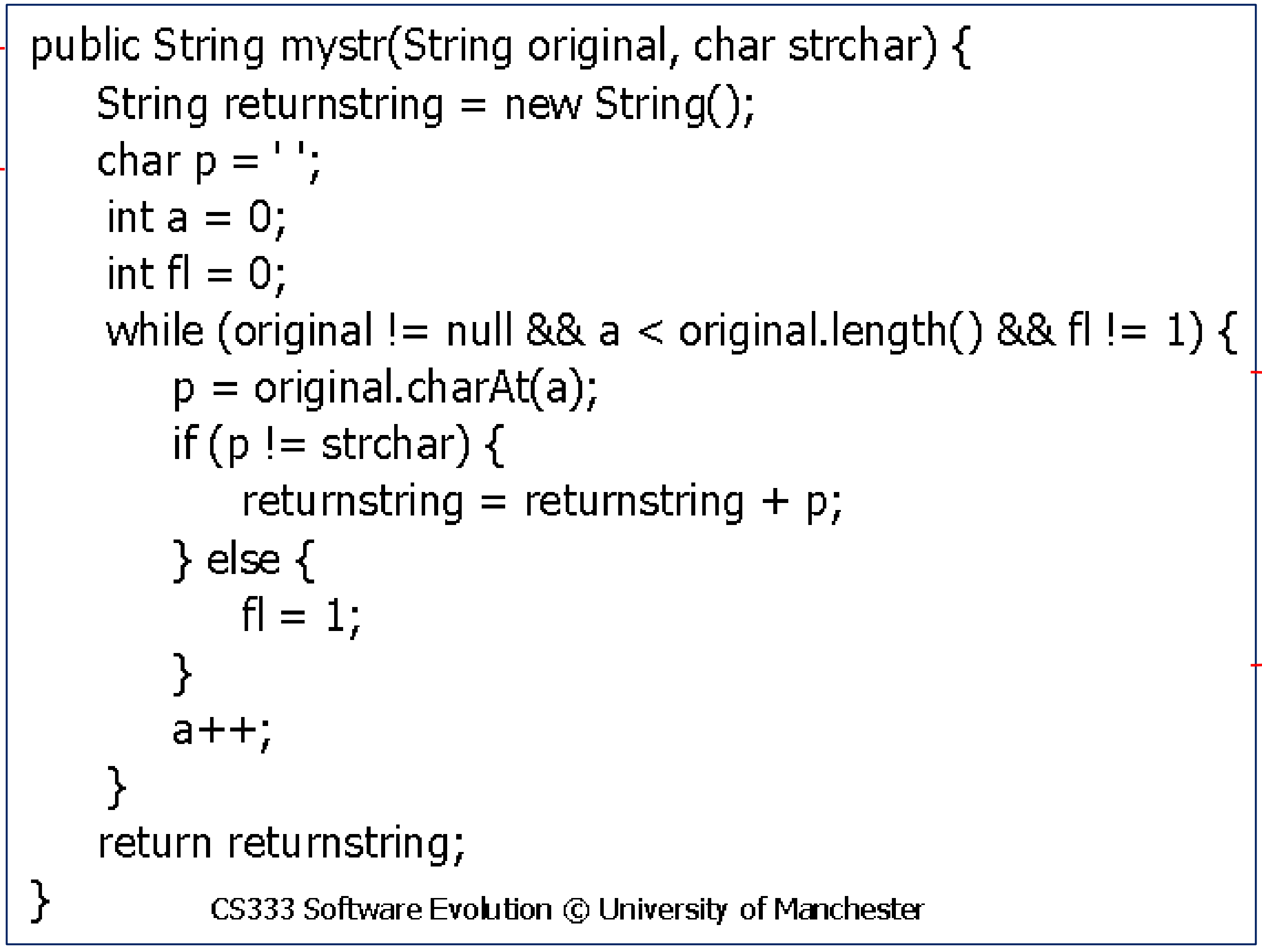
## Approaches to Code Comprehension - Bottom-Up Approach

- Typically used when unfamiliar with the code/application

1. Look for recognisable idioms within the code
   - E.g. the “swap” idiom
     - t = x;
     - x = y;
     - y = t;
2. Combine recognised units to understand even larger sections of the code

# Approaches to Code Comprehension - Bottom-Up Approach

A code block initializing tells the nature of the parameters and their value ranges



```
public String mystr(String original, char strchar) {
    String returnstring = new String();
    char p = ' ';
    int a = 0;
    int fl = 0;
    while (original != null && a < original.length() && fl != 1) {
        p = original.charAt(a);
        if (p != strchar) {
            returnstring = returnstring + p;
        } else {
            fl = 1;
        }
        a++;
    }
    return returnstring;
}
```

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Understanding *If* statement then the *while* loop enables to create an abstraction

# Approaches to Code Comprehension - Opportunistic Approach

❑ Opportunistic Approach is a hybrid of the two

1. Begin with top-down, gain an overview of the functions of the program
2. Then selectively apply bottom-up strategies when nearing “code level”
   - to verify hypotheses resulting from top-down reading
3. Presence of beacons can indicate opportunity for change of strategy
   - E.g. by suggesting a hypothesis that is best verified by non-current strategy

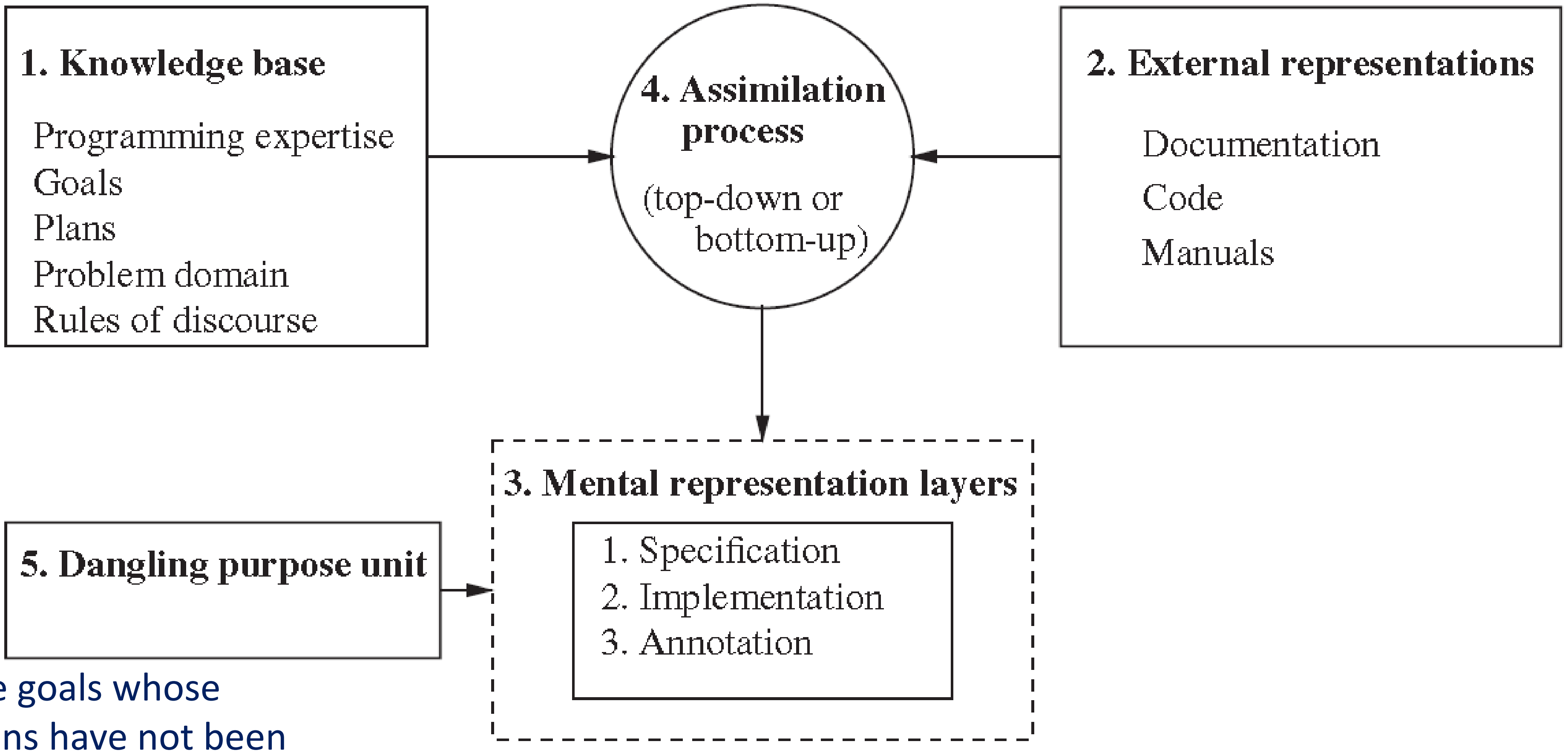
## Cognition Models For Program Comprehension

Several cognition models have been proposed the commonly referenced models are:

1. Letovsky model
2. Shneiderman and Mayer model
3. Brooks model
4. Soloway, Adelson, and Ehrlich model (top-down model)
5. Pennington model (bottom-up model)
6. Integrated metamodel

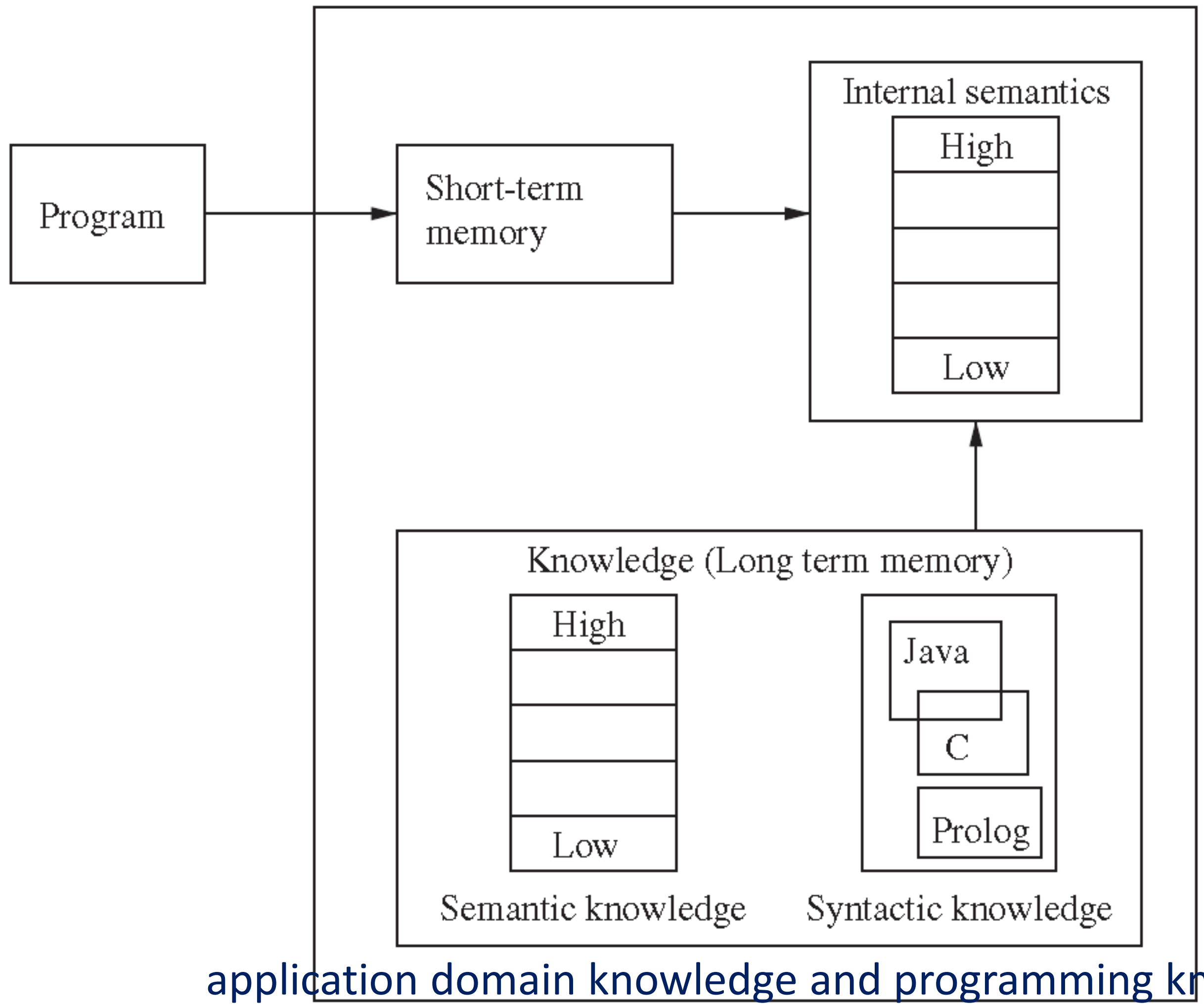
# Letovsky Code Comprehension Model

Why
How
What
Whether
Discrepancy



Captures those goals whose implementations have not been clearly understood.

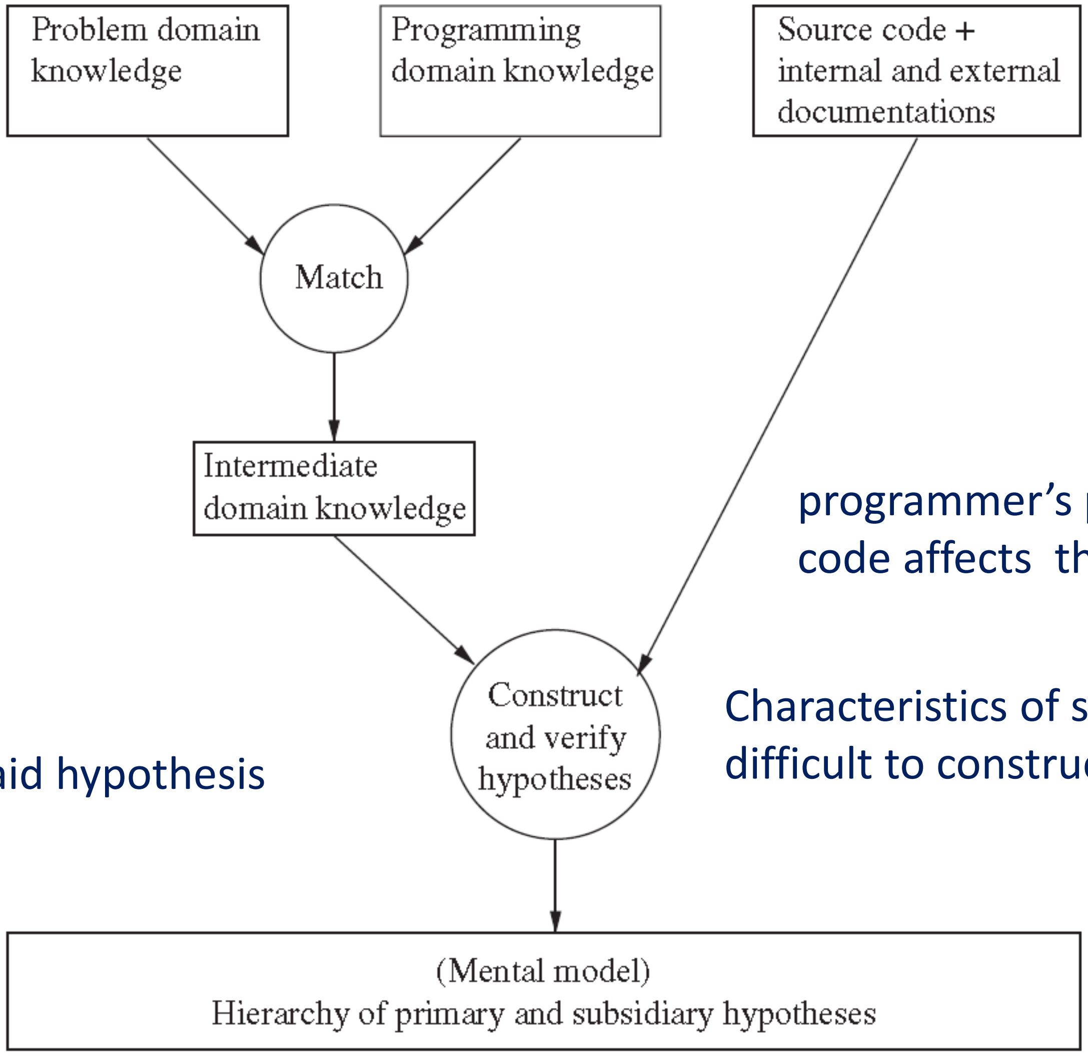
# Shneiderman and Mayer Comprehension Model



**Call graphs**—what modules are called by a given module and what modules use the services of the given module.

application domain knowledge and programming knowledge

## Brooks Comprehension Model


Problem domain knowledge
Programming domain knowledge
Source code + internal and external documentations
Match
Intermediate domain knowledge
Construct and verify hypotheses
(Mental model)
Hierarchy of primary and subsidiary hypotheses

programmer's perspective of the source code affects their comprehension process.

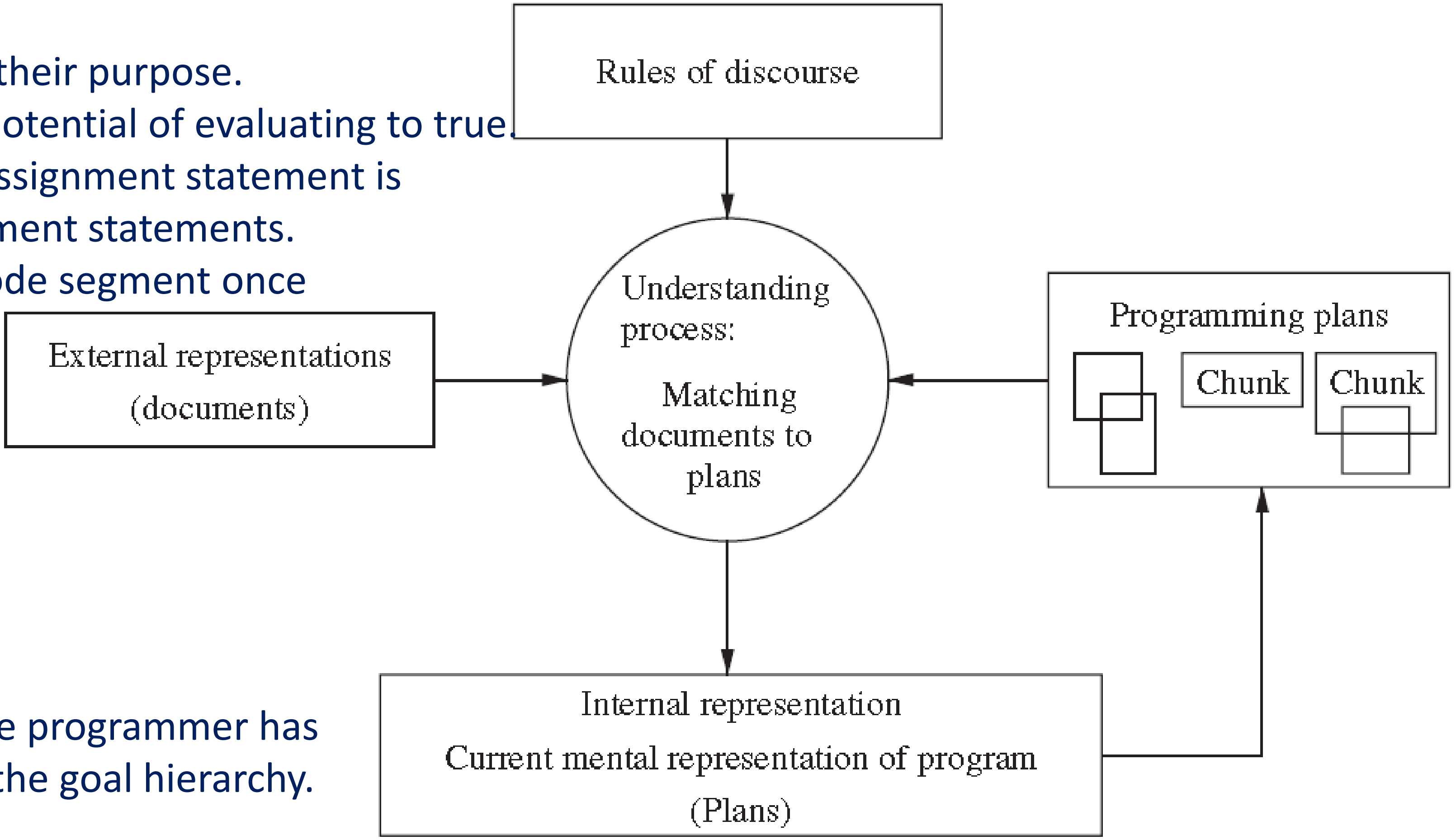
Characteristics of source code may make it difficult to construct a hypothesis

read code to find beacons to aid hypothesis construction

# Soloway, Adelson, and Ehrlich Comprehension Model

Example of rules of discourse

- The names of the variables reflect their purpose.
- A tested condition must have the potential of evaluating to true.
- A variable that is initialized by an assignment statement is subsequently updated with assignment statements.
- Use an if statement to execute a code segment once

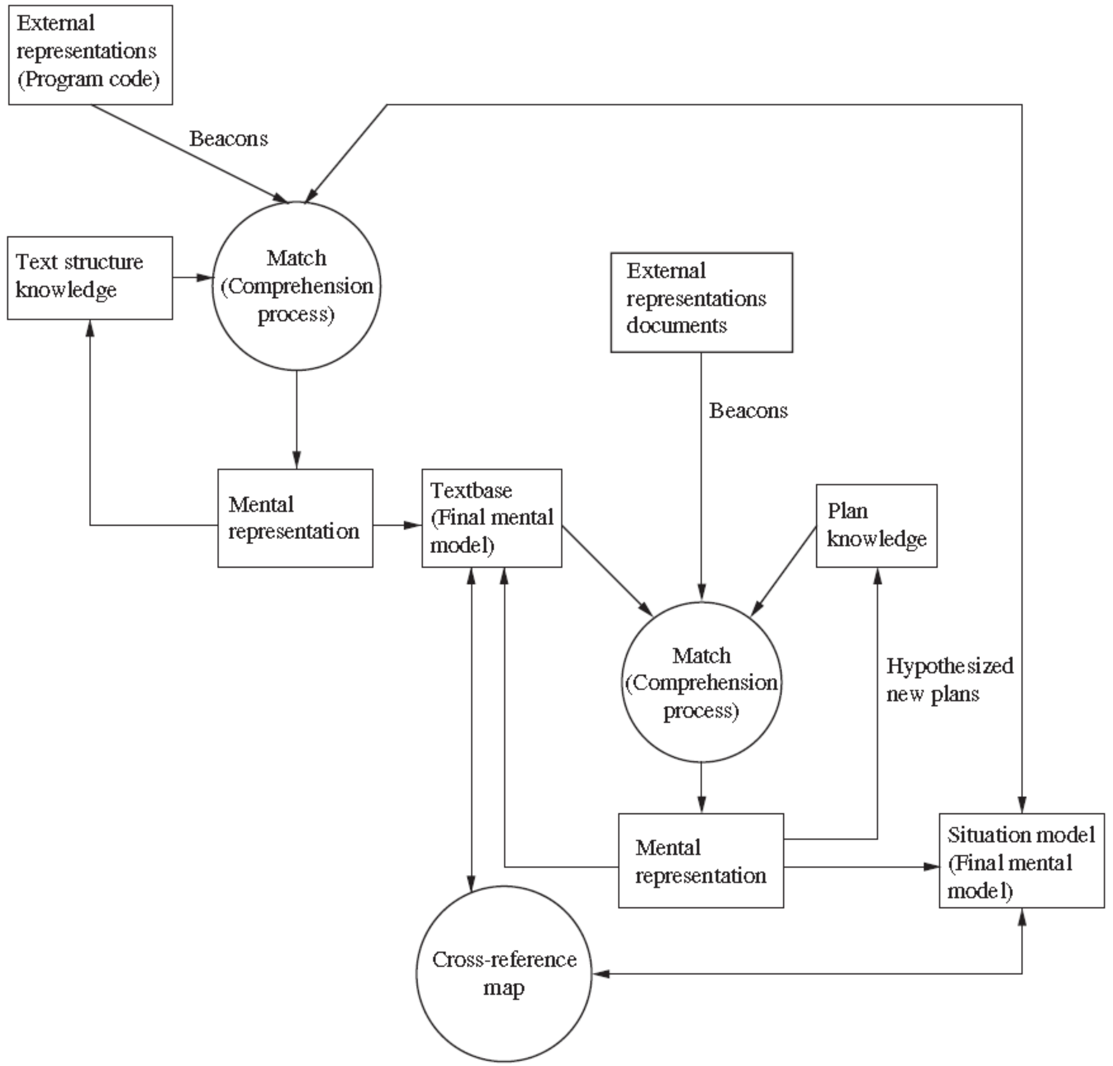


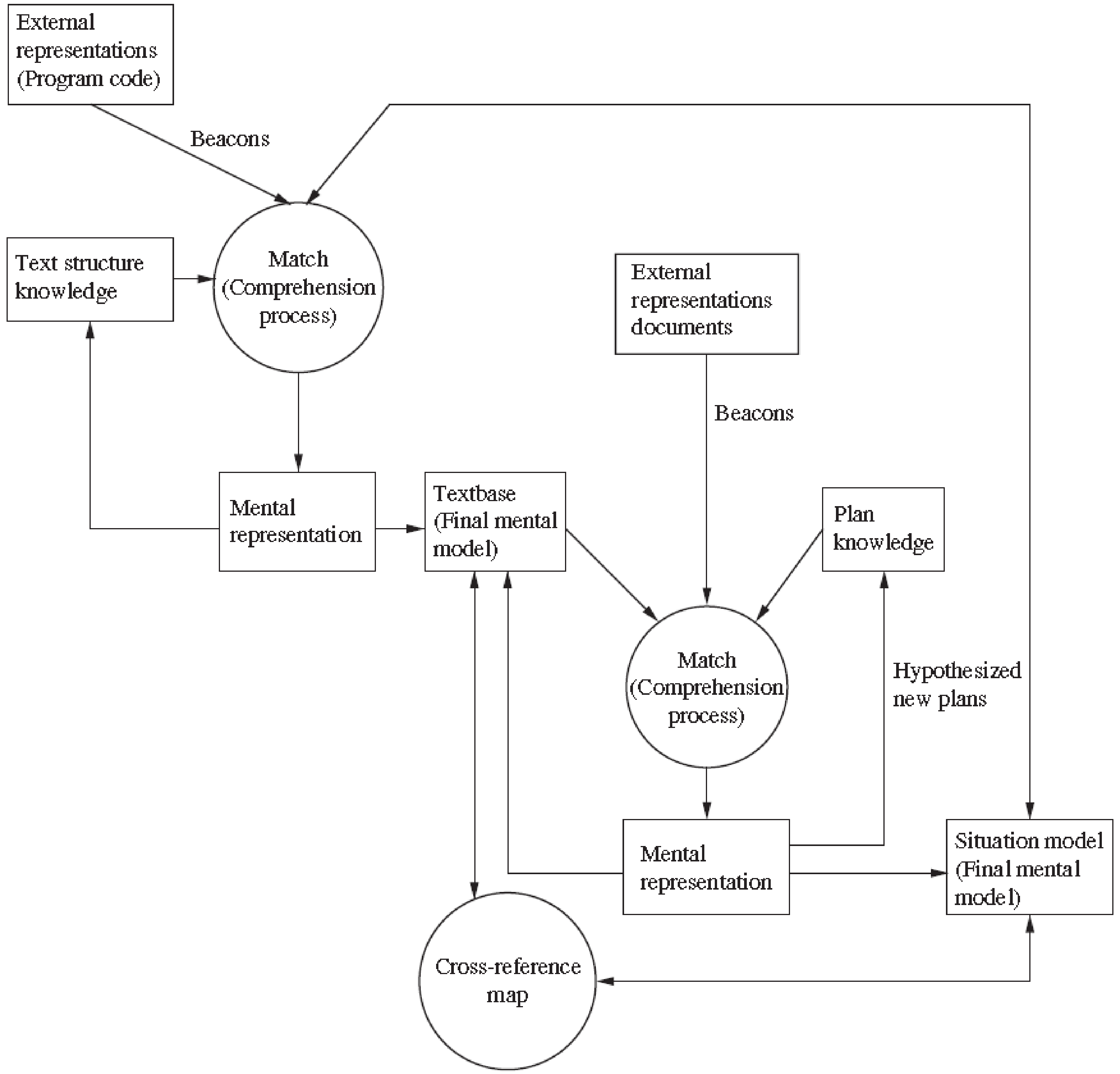
Rules of discourse
Understanding process:
Matching documents to plans
External representations (documents)
Programming plans
Chunk
Chunk
Internal representation
Current mental representation of program
(Plans)

The process is said to be complete when the programmer has associated all the programming plans with the goal hierarchy.

# Pennington Comprehension Model

- The programmer assimilates their understanding of the code, knowledge of the text structure, and the situation model to create a mental model in the form of a textbase.
- The programmer assimilates the documentations, plan knowledge, and the textbase to create the situation model.
- The textbase and the situation model are cross-referenced to refine and update the two models.


External representations (Program code)
Beacons
Text structure knowledge
Match (Comprehension process)
External representations documents
Beacons
Mental representation
Textbase (Final mental model)
Plan knowledge
Match (Comprehension process)
Hypothesized new plans
Mental representation
Situation model (Final mental model)
Cross-reference map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External representations documents
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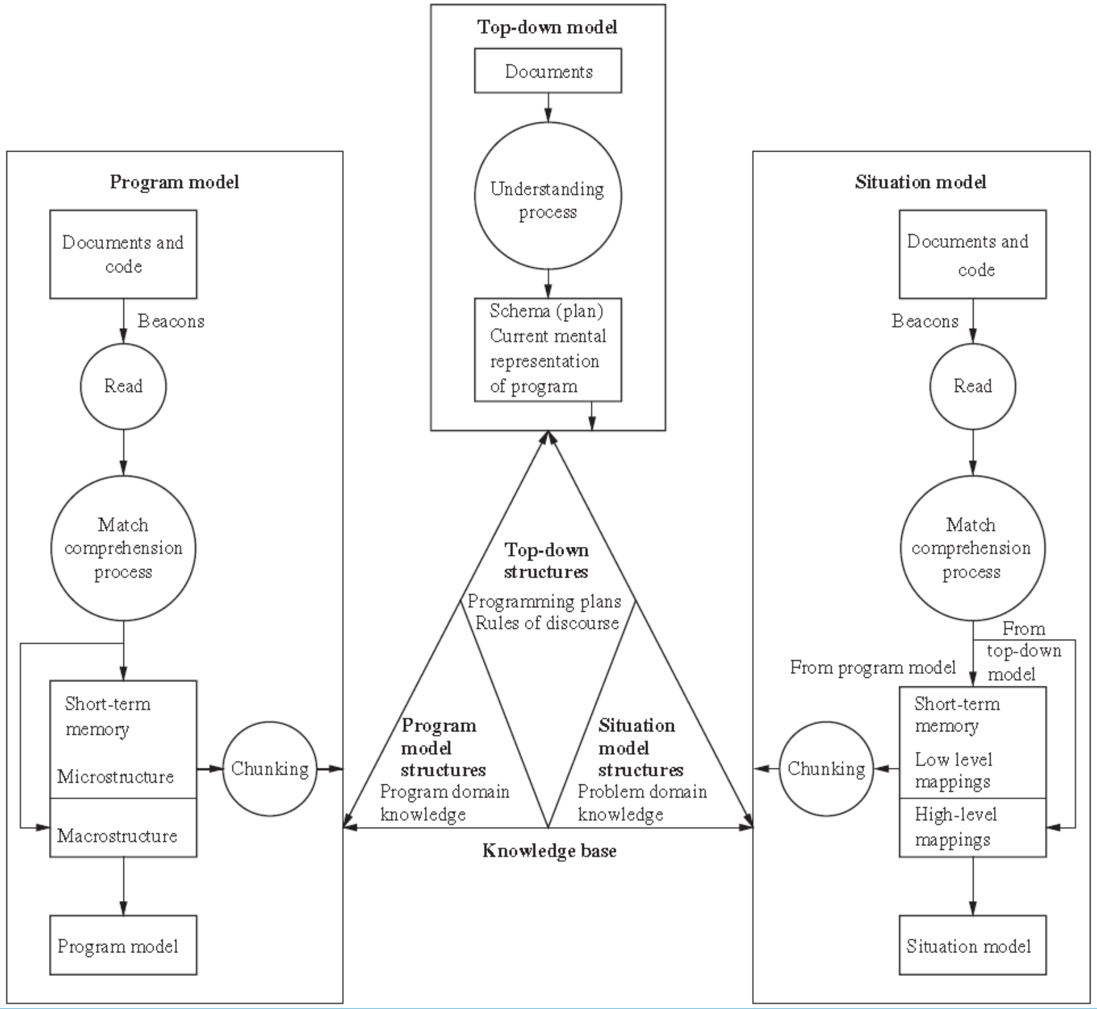
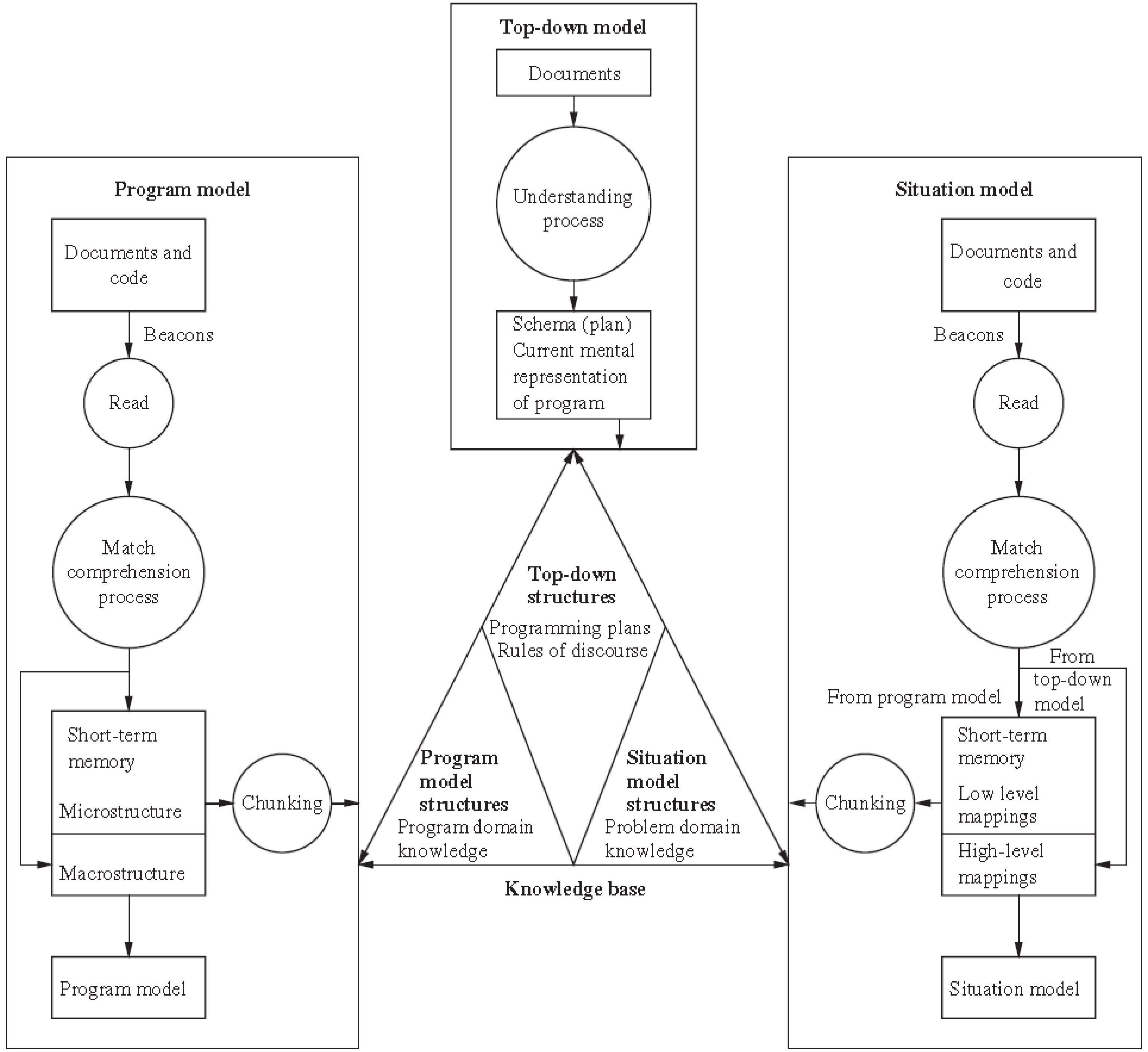
Cross-reference map

# Integrated Program Comprehension Model




Top-down model
Documents
Understanding process
Schema (plan) Current mental representation of program
Program model
Documents and code
Beacons
Read
Match comprehension process
Short-term memory
Microstructure
Macrostructure
Chunking
Program model
Top-down structures
Programming plans
Rules of discourse
Program model structures
Program domain knowledge
Situation model structures
Problem domain knowledge
Knowledge base
Situation model
Documents and code
Beacons
Read
Match comprehension process
From top-down model
From program model
Short-term memory
Low level mappings
High-level mappings
Chunking
Situation model

## Questions

?

## Readings

- ❑Chapter 8: 8.1, 8.2 , 8.3