# Mental Models for Program Understanding

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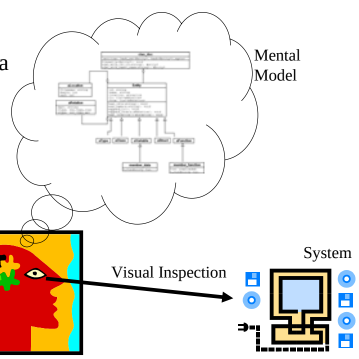
## What is a Mental Model?

Internal (mental) representation of a real system's behavior, organization, and internal structure.




## Mental Models

Must construct a mental model of a system in order to use/modify a software system

The goal is to understand how a system works and is constructed well enough to support a given task

We use:

- Visual inspection, reading
- Knowledge about the problem domain, the system, past experience, heuristics

## Example

Using a car versus fixing one.

- Only need to understand that the gas petal on a car is pressed down to make the car go faster – if all you want to do is drive the car this is fine.
- If the goal is to fix a sticky accelerator then you need to look under the hood and (maybe) in a technical manual.

"You don't have to know how to rebuild a motor to drive a car"

## Complexity of Model

The accuracy and complexity of the model depends on the task or usage scenario

Only relatively simple mental model of an automobile is required for driving one

A complex and accurate mental model of an automobile is necessary to repair or build one

## Mental Models of Software

For many years researchers have tried to understand how programmers comprehend programs (software) during:

- Software Development
- Software maintenance/evolution

Novice versus Expert

## What Purpose Does a Mental Model Serve?

Mental models allow researchers a way to analyze the cognitive processes behind software development and maintenance

## What Makes up a Mental Model?

- static elements
- dynamic elements

## Static Elements

- Text Structure
- Chunks
- Plans
- Hypotheses
- Beacons
- Rules of Discourse

## Text Structure

The program text and its structure

- if-then-else
- loops
- variable definitions
- parameter definitions

## Chunks

- Knowledge structures containing different levels of abstractions of text structures.
- Miller’s work from ’56 – 7 +-2
  - macro-structure
  - micro-structure

## Plans

- Knowledge elements for developing and validating expectations, interpretations, and inferences.
- They correspond to a vocabulary of intermediate level programming concepts such as a counter.
- Example: The average plan includes a counter plan.

## Hypothesis

- Conjectures that are results of comprehension activities that can take seconds or minutes to occur.
- They are drivers of cognition. They help to define the direction of further investigation.
  - why
  - how
  - what

## Beacons

- Signals that index into knowledge.
- An example of a beacon is a swap.
- It has been proven that experienced programmers recall beacon lines much faster than novice programmers.
- They are used most commonly in top-down comprehension.

## Rules of Discourse

- Rules that specify the conventions in programming.
- They set the expectations of the programmer.
- Examples:
  - Variables should reflect function
  - Don’t include text that won’t be used
  - If there is a test for a condition, the condition should have the potential to be true.

## Dynamic Elements

- Strategies
- Actions
- Episodes
- Processes

## Strategies

A sequence of actions that lead to a particular goal.

- – opportunistic strategy
- – systematic strategy

## Actions

Classify programmer activities implicitly and explicitly during a specific maintenance task.

## Episodes

Are made up of a sequence of actions.

## Processes

An aggregation of episodes.

## Maintenance Tasks

- adaptive
- perfective
- corrective
- reuse
- code leverage

## Adaptive

- Understand the system
- Define requirements
- Develop preliminary and detailed design
- Code changes
- Debug
- Regression tests

## Perfective

- Understand the system
- Diagnosis and requirement definition for improvements
- Develop and design preliminary design
- Code changes and/or additions
- Debug
- Regression tests

## Corrective

- Understand the system
- Generate and/or evaluate hypotheses concerning the problem
- Repair the code
- Regression tests

## Reuse

- Understand the problem, find solution based on close fit with predefined components
- Obtain predefined the components
- Integrate predefined components

## Code Leverage

- Understand the problem, find solution based on predefined components
- Reconfigure solution to increase likelihood of using predefined components
- Obtain and modify predefined components
- Integrate modified components

## Mental Model

The type of mental model a programmer uses is determined by the type of development/ maintenance task he has to perform.

## Proposed Mental Models

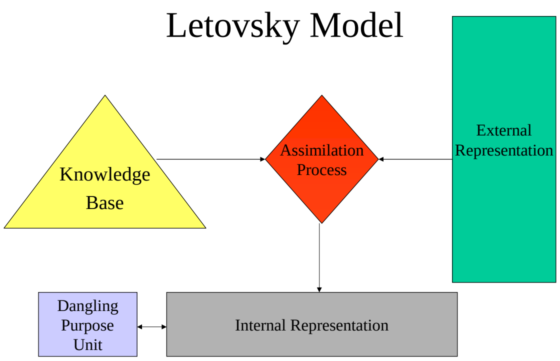
- Letovsky ‘86
- Shneiderman ’79, ‘80
- Brooks ’77, ‘83
- Soloway / Ehrlich ’83, ’84, ‘88
- Pennington ‘87
- Integrated (Von Mayrhauser ’94, ’95, ’97)

## Letovsky Model

Opportunistic approach. This model has three main parts:

- knowledge base
- mental model
- assimilation process (bottom-up/top-down)

## Letovsky Model

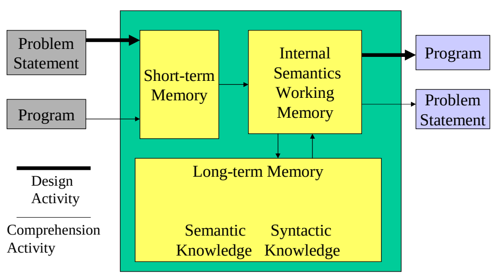


## Shneiderman Model

The main parts of this model are:

- short-term memory (uses chunking)
- internal semantics (working memory)
- long-term memory

## Shneiderman Model

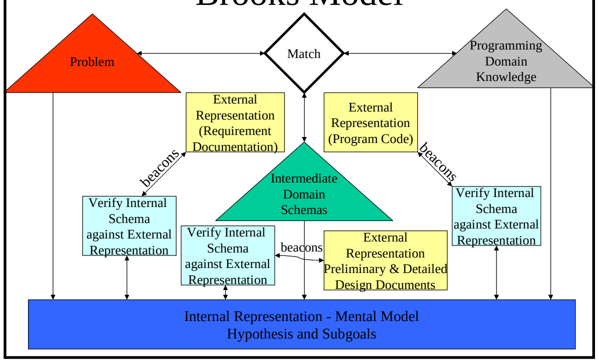



## Brooks Model

Top-down model.This model uses:

- hypotheses
- beacons

## Brooks Model

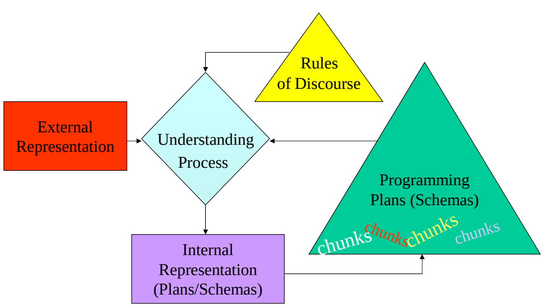



## Soloway / Ehrlich Model

Top down approach. Also known as *domain model.* This model uses:

- plans
- rules of discourse
- chunks

## Soloway / Ehrlich Model

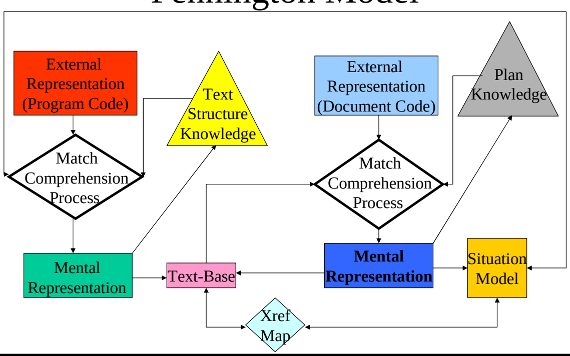


## Pennington Model

Bottom-up approach. This model uses:

- beacons
- text structures
- chunks
- plans

## Pennington Model

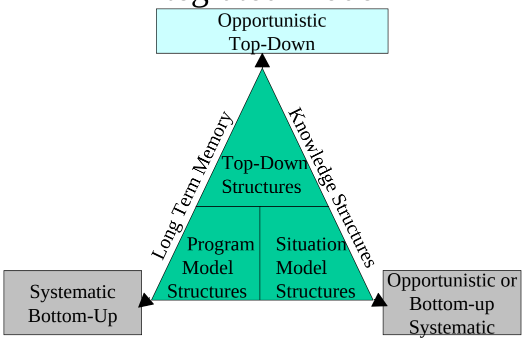



## Integrated Model

Top-down, bottom-up approach. This model contains the following:

- top-down model
- bottom-up model
- program model
- knowledge base

## Integrated Model




## Common Elements of Mental Model

- Knowledge
  - general knowledge
  - software specific knowledge

## Comparison of the Six Models

- Letovsky Model - general
- Shneiderman Model - hierarchical organization
- Brooks Model - hypothesis driven
- Soloway / Ehrlich Model - knowledge similar to Letovsky Model
- Pennington Model - detailed, lacks higher level knowledge
- Integrated Model - combination of the other 5 models.

## Conclusion

- It is important to learn how programmers understand code.
- This could lead to better tools, better maintenance guidelines and documentation.