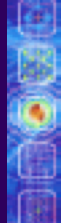
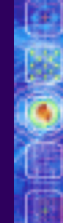




HUMAN-COMPUTER INTERACTION

THIRD
EDITION

DIX
FINLAY
ABOWD
BEALE



chapter 12

cognitive models

Cognitive models

- goal and task hierarchies
- linguistic
- physical and device
- architectural

Cognitive models

- They model aspects of user:
 - understanding
 - knowledge
 - intentions
 - processing
- Common categorisation:
 - Competence vs. Performance
 - Computational flavour
 - No clear divide

Goal and task hierarchies

- Mental processing as divide-and-conquer
- Example: sales report
 - produce report
 - gather data
 - . find book names
 - . . do keywords search of names database
 - *further sub-goals*
 - . . sift through names and abstracts by hand
 - *further sub-goals*
 - . search sales database - further sub-goals
 - layout tables and histograms - further sub-goals
 - write description - further sub-goals

goals vs. tasks

- goals – intentions
what you would like to be true
- tasks – actions
how to achieve it
- GOMS – goals are internal
- HTA – actions external
– tasks are abstractions
- Thin border between goals and tasks,
especially for elementary ones.
- In practice one may model higher level goals
and more detailed and elementary tasks and
subtasks.

Issues for goal hierarchies

- Granularity
 - Where do we start?
 - Where do we stop?
- Routine learned behaviour, not problem solving
 - The unit task
- Conflict
 - More than one way to achieve a goal
- Error and error recovery

Techniques

- Goals, Operators, Methods and Selection (GOMS)
- Cognitive Complexity Theory (CCT)
- Hierarchical Task Analysis (HTA) - Chapter 15

GOMS

GOMS has been originally proposed as a theory of the cognitive skills involved in human-computer activities. It is based upon an information processing framework that assumes a number of different stages or types of memory (e.g., sensory store, working memory, LTM) with separate perceptual, motor, and cognitive processing. All cognitive activities are interpreted in terms of searching a problem space.

GOMS

Goals

- what the user wants to achieve

Operators

- basic actions user performs

Methods

- decomposition of a goal into subgoals/operators

Selection

- means of choosing between competing methods

GOMS example

GOAL: CLOSE-WINDOW

```
.    [select GOAL: USE-MENU-METHOD
      .    MOVE-MOUSE-TO-FILE-MENU
      .    PULL-DOWN-FILE-MENU
      .    CLICK-OVER-CLOSE-OPTION
GOAL: USE-CTRL-W-METHOD
      .    PRESS-CONTROL-W-KEYS]
```

For a particular user:

Rule 1: Select USE-MENU-METHOD unless another rule applies

Rule 2: If the application is GAME,
select CTRL-W-METHOD

Exercise

- A more abstract GOAL: Improve the vision of the lessons
 - Subgoals?
 - Methods?
 - Operators (=tasks)
 - Selection?

Possible Solution

- Method: Buy-a-better-screen
 - find the screen you want based on your needs/constraints
 - buy the screen
 - get it home
 - install it
- Method: Improve-current-screen-performances
 - find a better position
 - tune parameters

Selection: RULE1 select Improve-current-screen-performances unless another rule applies
RULE2 Buy-a-better-screen if money

Cognitive Complexity Theory

- Two parallel descriptions:
 - User production rules
 - Device generalised transition networks
- Production rules are of the form:
 - if condition then action
- Transition networks covered under dialogue models

Example: editing with vi

- Production rules are in long-term memory
- Model working memory as attribute-value mapping:
 - (GOAL perform unit task)
 - (TEXT task is insert space)
 - (TEXT task is at 5 23)
 - (CURSOR 8 7)
- Rules are pattern-matched to working memory,
 - e.g., LOOK-TEXT task is at %LINE %COLUMN is true, with LINE = 5 COLUMN = 23.

Four rules to model inserting a space

Active rules:

```
SELECT-INSERT-SPACE  
INSERT-SPACE-MOVE-FIRST  
INSERT-SPACE-DOIT  
INSERT-SPACE-DONE
```

New working memory

```
(GOAL insert space)  
(NOTE executing insert space)  
(LINE 5) (COLUMN 23)
```



SELECT-INSERT-SPACE
matches current working memory

```
(SELECT-INSERT-SPACE  
IF (AND (TEST-GOAL perform unit task)  
        (TEST-TEXT task is insert space)  
        (NOT (TEST-GOAL insert space))  
        (NOT (TEST-NOTE executing insert space))))  
THEN ( (ADD-GOAL insert space)  
        (ADD-NOTE executing insert space)  
        (LOOK-TEXT task is at %LINE %COLUMN)))
```

Notes on CCT

- Parallel model
- Proceduralisation of actions
- Novice versus expert style rules
- Error behaviour can be represented
- Measures
 - depth of goal structure
 - number of rules
 - comparison with device description

Problems with goal hierarchies

- a post hoc technique
- expert versus novice
- How cognitive are they?

Linguistic notations

- Understanding the user's behaviour and cognitive difficulty based on analysis of language between user and system.
- Similar in emphasis to dialogue models
- Backus–Naur Form (BNF)
- Task–Action Grammar (TAG)

Backus-Naur Form (BNF)

- Very common notation from computer science
- A purely syntactic view of the dialogue
- Terminals
 - lowest level of user behaviour
 - e.g. CLICK-MOUSE, MOVE-MOUSE
- Nonterminals
 - ordering of terminals
 - higher level of abstraction
 - e.g. select-menu, position-mouse

Example of BNF

- Basic syntax:
 - nonterminal ::= expression
- An expression
 - contains terminals and nonterminals
 - combined in sequence (+) or as alternatives (|)

draw line ::= select line + choose points + last point
select line ::= pos mouse + CLICK MOUSE
choose points ::= choose one | choose one + choose points
choose one ::= pos mouse + CLICK MOUSE
last point ::= pos mouse + DBL CLICK MOUSE
pos mouse ::= NULL | MOVE MOUSE+ pos mouse

Measurements with BNF

- Number of rules (not so good)
- Number of + and | operators
- Complications
 - same syntax for different semantics
 - no reflection of user's perception
 - minimal consistency checking

Task Action Grammar (TAG)

- Making consistency more explicit
- Encoding user's world knowledge
- Parameterised grammar rules
- Nonterminals are modified to include additional semantic features

Consistency in TAG

- In BNF, three UNIX commands would be described as:

copy ::= cp + filename + filename | cp + filenames + directory

move ::= mv + filename + filename | mv + filenames + directory

link ::= ln + filename + filename | ln + filenames + directory

- No BNF measure could distinguish between this and a less consistent grammar in which

link ::= ln + filename + filename | ln + directory + filenames

Consistency in TAG (cont'd)

- consistency of argument order made explicit using a parameter, or semantic feature for file operations
- Feature Possible values
Op = copy; move; link
- Rules
file-op[Op] ::= command[Op] + filename + filename
 | command[Op] + filenames + directory
command[Op = copy] ::= cp
command[Op = move] ::= mv
command[Op = link] ::= ln

Other uses of TAG

- User's existing knowledge
- Congruence between features and commands
- These are modelled as derived rules

Physical and device models

- The Keystroke Level Model (KLM)
- Buxton's 3-state model
- Based on empirical knowledge of human motor system
- User's task: acquisition then execution.
 - these only address execution
- Complementary with goal hierarchies

Keystroke Level Model (KLM)

- lowest level of (original) GOMS
- six execution phase operators
 - Physical motor: K - keystroking
 P - pointing
 H - homing
 D - drawing
 - Mental M - mental preparation
 - System R - response
- times are empirically determined.
$$T_{execute} = TK + TP + TH + TD + TM + TR$$

KLM example

GOAL: ICONISE-WINDOW

[select

GOAL: USE-CLOSE-METHOD

. MOVE-MOUSE-TO- FILE-MENU

. PULL-DOWN-FILE-MENU

. CLICK-OVER-CLOSE-OPTION

GOAL: USE-CTRL-W-METHOD

PRESS-CONTROL-W-KEY]

- compare alternatives:
 - USE-CTRL-W-METHOD VS.
 - USE-CLOSE-METHOD
- assume hand starts on mouse

Is M always the
same?

USE-CTRL-W-METHOD		USE-CLOSE-METHOD	
H[to kbd]	0.40	P[to menu]	1.1
M	1.35	B[LEFT down]	0.1
K[ctrlW key]	0.28	M	1.35
		P[to option]	1.1
		B[LEFT up]	0.1
Total	2.03 s	Total	3.75 s

Architectural models

- All of these cognitive models make assumptions about the architecture of the human mind.
- Long-term/Short-term memory
- Problem spaces
- Interacting Cognitive Subsystems
- Connectionist
- ACT

Display-based interaction

- Most cognitive models do not deal with user observation and perception
- Some techniques have been extended to handle system output
(e.g., BNF with sensing terminals, Display-TAG)
but problems persist
- Exploratory interaction versus planning