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

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

Techniques

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

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
```

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.

  Texecute = 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

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