User Modelling

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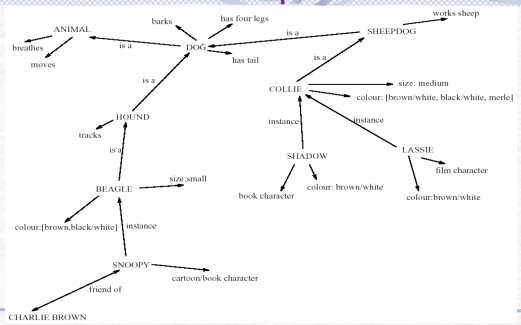
Overview

- Mental Models
  - Definition
  - Characteristics
  - Types
  - Elicitation
  - Purposes
- Adaptive systems
- User Modelling in HCI

Knowledge Organisation

- Semantic networks
  - nodes (objects) and links (relations between objects)
- Schemata
  - network of general knowledge based on previous experience which facilitate our understanding of commonplace events

Example



Example

Schemata – **restaurant script** (specific schemata which describes a characteristic scenario of behaviour in a particular setting).

Script	Component	Specific action
Eating at a restaurant	Entering	Walk into restaurant Look for table Decide where to sit Go to table Sit down
	Ordering	
	Eating	
	Leaving	

Limitations

- Schemata theory can not explain flexible behaviour, such as:
  - inferring in complex situations
  - predicting future states
  - comprehending situations never experienced before
- Mental models
  - accounts for the dynamic aspects of cognitive activity

Mental Models

- constructs explaining human understanding of objects and phenomena (Johnson-Laird, 1981).
- deeply rooted assumptions, continuously processed for each situation (Henderson, 2002).
- representations of some domain or situation that support understanding, reasoning, and prediction (Gentner, 2002).
- representations that users adopt to guide their interactions and aid their understanding of the system (Hanisch, 1991).
- representations that are more than mere copies of the external reality: such representations consist of a higher organisation of knowledge with an integrated structure (Winn, 2003).

Example

- Classic example: how does a thermostat work?
- The room is cold and you just want to warm it quickly (about 20° C).
- Do you: set the thermostat higher than 20° C or set it to 20° C?
- Answer: set the thermostat to 20° C.
- Mental model of central heating drawn from experience with other types of heating, i.e. were the more gas means the more heating.
- Valve/tap model ≠ threshold/switch model

Conceptual delimitations

- Mental model
  - developed by the users for solving tasks during their interaction with the system
  - it resides in user's head
- User model
  - a model that a system has of its users
  - it resides inside a computational environment

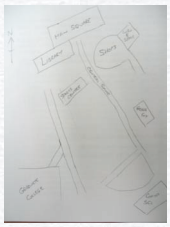
Example

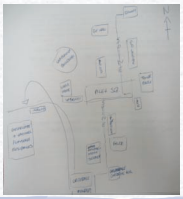
- Cognitive maps
  - reflection of space in the minds of man (Shemyakin, 1962)
  - symbolic and internalised mental reflection of spatial action (Piaget, 1967)
  - internalised cognitive representation of space (Hart, 1973)
  - internal representation of perceived environmental features or objects and the spatial relations among them (Golledge, 1999)

Characteristics

- Cognitive maps are complex, highly selective, abstract and generalised representations which bear merely a functional analogy with the environment which inspired them
- Maplike mental constructs that can be mentally inspected
- The basic components of cognitive maps are organised in an emergent hierarchical structure which ensures flexibility, anticipation and decision making in the space of future potential events.
  - Define boundaries of places of interest
  - Integrate separately learned routes into a configuration as a whole
  - Allow an overview, the so-called bird's eye view

Example





Characteristics

Mental models

- represent qualitative relations rather than quantitative relations;
- permit mental simulations;
- can be contradictory, in the sense that people can hold two inconsistent models within the same domain;
- when held by novices usually are context-specific and lack generalisation (Gentner, 2002).

Embedded Knowledge

Mental models consist of two fundamental types of knowledge:

- Declarative ≈ Explicit
- Procedural ≈ Implicit

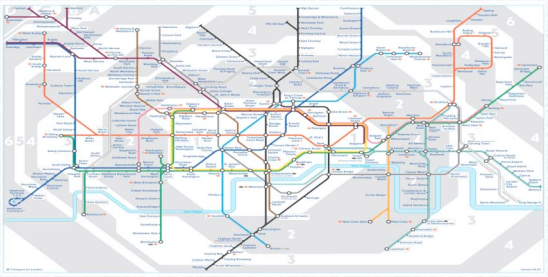
knowledge that people can report and of which they are consciously aware.
Ex. facts, what things are

knowledge that lack awareness
Ex. "knowing-how"

Types of Models

- **Structural model** assumes that the user has internalised the structure of how the system works in memory (how it works)
- **Functional model** assumes that the user has internalised procedural knowledge about how to use the device or system (how to use it)
  - London underground map – a representation of the station locations and the lines that connect them.
  - This schematic form provides a structure which regular commuters learn to internalise.

London Tube Map



London Tube Map

- Harry Beck's craft
- Well constructed graph
- Geographically inaccurate
- Only horizontal, vertical and 45 degree lines
- Coherent image of a complex structure

Structural Models

- Describe the internal mechanics of a device, in terms of its component parts.
- Enable predictions about the behaviour of the device
- Advantage
  - by explaining how a device works, they allow a user to predict the effects of any possible sequence of actions and to work out how to achieve most tasks possible with the device;
  - useful when a device breaks down
- Disadvantage
  - require efforts, both in learning the models and in using them to work out what to do.
  - do not account for how the users are going to perform their actions (as functional model does)
  - limited applicability.

Functional Models

- Functional or task-action mapping models distinguishes between task domain and action domain. Designers try to identify the simpler connection between these two domains.
- They are develop from past knowledge about similar domain and NOT from models of how the device works.
- Structured around a set of tasks
- Context –dependent
- Easier to use

Types of models

- Competence models
  - Predict possible behaviour sequences without reference to whether they can be executed by users
  - Expected behaviour but not in terms of its demands on the user
  - Acquisition of a plan of activity
- Performance models
  - Describe the necessary behaviour sequences in terms of what users need to know and how this is related to the actual task execution
  - Focus on routine behaviour in limited applications
  - Execution of a plan of activity

Studying Mental Models

- Elicitation
- Externalisation
- Validation
  - Symbolic modelling
  - Subsymbolic modelling

Elicitation

Direct methods

- introspection
  - protocol analysis
- questionnaires
- interviews
- focus groups

Limitations of direct methods

- introspection – "any attempt to use introspection in order to become conscious of something that is normally unconscious is unlikely to succeed" (Jonhson-Laird, 1981).
- questionnaires – not clarifying the shared meaning
- interviews – interviewer bias and post-rationalisation
- focus groups

- Novices' models: globally inconsistent or contradictory!

Elicitation

Indirect methods - inferring the mental model based on its externalisation

- response time
- eye movement
- movement paths
- patterns of correct and incorrect responses
- patterns of retention for new materials in the domain

Externalisation

- Verbal techniques
- Graphical techniques (i.e. sketching, drawing maps)
- Limitation: assuming a particular level of verbal skills, in particular introspection, and drawing skills respectively. Limited user capabilities lead to inadequate external representations, despite the fact that the internal representation held by the user could be quite accurate.

Representation forms

Symbolic

- Propositional representations - language-like statements
- Analogical representations - picture-like images

Subsymbolic

- Distributed representations - network of nodes where knowledge is implicit in the connections between nodes
- images and propositions can co-exist at a higher level of representation, and they should be viewed as emergent properties of a neural network of nodes

Symbolic Modelling

- Hierarchical representations of users' task and goal structure
  - GOMS
- Physical and device-level models
  - KLM
- Cognitive architectures
  - SOAR
  - ACT-R

GOMS

- Goal, Operators, Methods, Selection (Card, Moran, Newell, 1983)
- Goals – what the user wants to achieve, "memory points"
- Operators – basic actions performed by users to achieve their goals;
  - impact on the system or on user's mental state
  - granularity
- Methods – different goal decompositions (ways in which a goal can be split into subgoals)
- Selection – a rule predicting the choice of methods, based on the user, state of the system and the goals.

Example GOMS

Move word

- identify word
  - locate word
  - select word
- cut word
  - copy word
  - delete word
- paste word
  - identify new location
  - place it there

Operations:

- move mouse, drag, press key, read dialog box etc.

Method: select word

- Move mouse pointer to the first letter of word
- Depress button
- Drag to the last letter
- Release

Or:

- move mouse pointer on any letter of the word
- double click

GOMS

- A single high level goal
  - Decomposed into a sequence of subgoals, further decomposed down to the level of basic operators.
  - Understanding of user's problem solving strategies and of the application domain.
- A basis for cognitive modelling in HCI
- Good for describing how experts perform routine tasks
- Never intended to provide information about the user's knowledge for comparison across tasks to predict training or transfer time.

KLM

Keystroke-Level Model (Card, Moran, Newell, 1980)

- Exploits the understanding of human motor system
- Detailed prediction of user performance
- Tasks (< 20 sec.) i.e changing a font size, replacing a character etc.
- Expert users in the latter stage of activity, when there is no need for high level mental activity

KLM

Decomposes the task execution into:

- Physical motor operators:
  - **K** Keystroking
  - **P** Pressing a mouse button
  - **P** Pointing, moving the mouse at a target
  - **H** Homing, switching the hand between mouse and keyboard
  - **D** Drawing lines using the mouse
- Mental operator
  - **M** Mentally preparing for a physical action
- System response operator
  - **R** System response which may be ignored if the user does not have to wait for it.

Example KLM

Select Word

Reach for mouse	H	0.40
Point to first letter	P	1.10
Click button down	K	0.60
Drag to last letter	P	1.20
Release	K	0.60
Total		3.90

Cognitive architectures

- SOAR
- ACT-R

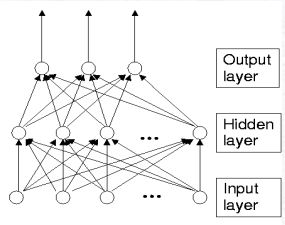
SOAR

- An architecture for intelligent behaviour
- Based on a theory of cognitive processing:
  - knowledge, planning, reaction, search and learning
- Works on a full range of tasks
- Applying knowledge to situations to yield behaviour
- Behaviour (S, O), with S = states, O = operators
- Problem solving: selection and application of operators to a state to achieve some goal.

ACT-R

- Goal: provide models for behaviours
- Distinction:
  - Declarative knowledge – configuration of small number of elements
  - Procedural knowledge – production rules for retrieving declarative knowledge for problem solving

Subsymbolic Modelling



Strengths

- Distributed representations
- Parallel processing
- Robustness to noise or degradation
- Biological plausability

Artificial Neural Networks

- Finding patterns in large amount of complicated and imprecise data.
- Applications in HCI:
  - Task analysis and task evaluation
  - Natural interaction (gesture, speech, handwriting)
  - Adaptive interfaces

Rationale

- Studying mental models
  - understanding and predicting human behaviour
  - people's beliefs about a domain influence their decisions
- User model may seek to describe:
  - the cognitive processes that underlie the user's actions;
  - the differences between the user's skills and expert skills;
  - the user's behavioural patterns or preferences;
  - the user characteristics.

Purpose of mental models

- Means of communication
- Understanding
- Predicting & control
- Training (Wahlstrom88)
- user mental models "should help to explain aspects of the user's performance, learning and reasoning about a system, as well as providing guidelines for good design". (Young, 83)

Purpose of mental models

Important feature for model classification

- the purpose of a mental model is to allow the person who owns it to understand and to anticipate the behaviour of a system, whereas conceptual models are devised as tools for the understanding or teaching of systems. (Norman, 94).
- "What is the purpose of the User Model? Is it to assist designers? to assist the user? to provide an adaptive capability for the system? to assess the knowledge of the user? to develop and refine other models? to assist research into human cognition?" (Benyon, 1993)

User Modelling

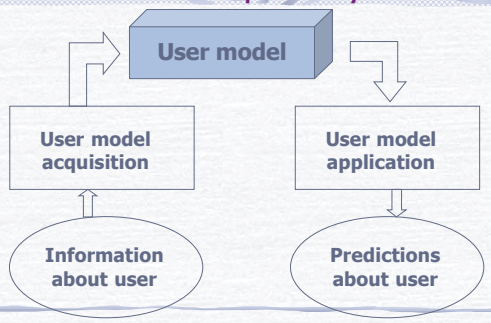
User modelling is a growing discipline in the field of HCI,

- Heterogeneous users
- Usability - in order to adapt themselves to the end-user, systems must be able to make assumptions about their users, relevant for tailoring their behaviour to the users (Kobsa, 1994; Fischer, 2001).
- Adaptive systems
- Related areas inputting in User Modelling:
  - machine learning
  - knowledge representation
  - and HCI

Adaptive Systems

- Aim: learning something about each user for the purpose of adapting its behaviour to him/her
  - Inferring behaviour
  - Decision-making ability for adjusting
- Machine learning techniques

Schema of adaptive system



Individual differences

- Demographics
- Technological skills
- Stable individual characteristics
- Transitory state of the individual

User Modelling and Design

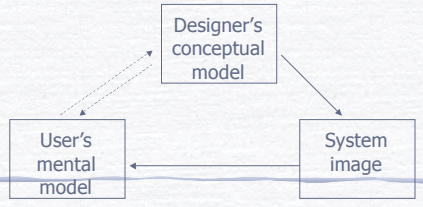
- Conceptual models - umbrella term for capturing the various ways in which **people** understand a system.
  - Users
  - Designers
- Designing – capitalise on user's knowledge and find a suitable metaphor.
- Designer's goal: helping users to develop accurate mental models of the system.
  - It is the designer's job to enable the user to assimilate their view by getting the device to project an appropriate image of itself

User Modelling and Design

- Designers' models and users' mental models.
- Ideally, the user's mental model should map into the designer's model.
  - Allowing the user to make full use of system's capability, as intended by the designer.
  - Unfortunately, users develop partial mental model of the designer's model.

User Modelling and Design

- Users understand the system through the system image: its interface, behaviour or documentation.
- If the system image is not able to convey the design model clearly and intuitively, then users may develop incorrect mental models (difficulties understanding the system).



Metaphor

- Understanding how people develop mental models can help developing more appropriate mental models of system functionality
- Ex. A design principle is to try to make systems transparent so people can understand them better and know what to do

Metaphors

- Transparency
- Not to be understood as literal
- Useful feedback
- Intuitive in use
- Clear and easy to follow instructions
- Appropriate online help
- Context sensitive guidance of how to proceed when stuck