

CogSysIII Lecture 7: Knowledge Representation and Users' Mental Models

Human Computer Interaction

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Knowledge

- Knowledge base vs. data base
- Traditional definition in **philosophy and linguistic**:
If “ P knows that X ” is true than it holds
 - X is true (\hookrightarrow knowledge is always true!)
 - P believes that X holds
 - P can justify why X holds
- in **cognitive psychology**: content of longterm memory;
justified, subjective belief
- in **AI**: content of the knowledge base of a system
(might be revisable, remember default logic)

There are a lot of specialized concepts of knowledge ...

Semantic vs. Episodic K.

- **General/Semantic/Conceptual knowledge:** knowledge about the meaning of concepts, their attributes and relations, knowledge which is viewed as “valid without restrictions” in form of propositions or rules

Apples are red, A dog is a mammal, Birds lay eggs

VS.

Episodic/Case-based knowledge: refers to concrete examples, includes context information (place and time)

My dog Lassie likes to sleep on the sofa

Declarative vs. Procedural K.

- **Declarative/explicit knowledge:** Knowledge about facts, verbalizable, accessible, represented in form of propositions, frames, explicit rules

vs.

Procedural/implicit knowledge: knowledge which immediately can be transformed into actions, not verbalizable, not accessible, represented in form of production rules, algorithms, functions

Further Kinds of K.

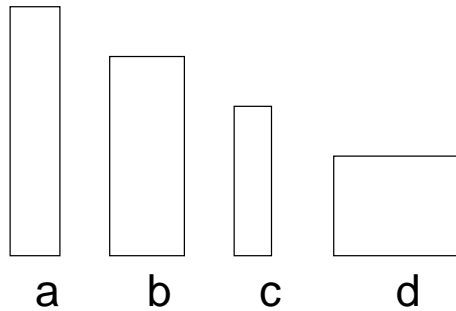
- World knowledge vs. language specific knowledge
- Heuristic knowledge: (cf. in problem solving)
- Strategic knowledge, Meta knowledge
- Background knowledge
- Domain-specific knowledge, common-sense knowledge
- ...

Knowledge Representation

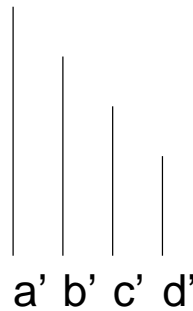
- Knowledge itself is a representation of “real facts” (“*Das logische Bild der Tatsachen ist der Gedanke*”, Wittgenstein, *Tractatus*)
- Knowledge is a *model* (in the logical sense), that is, a truth preserving mapping from “the real world” to a model which can be expressed in some (formal) language.
- Representation means the construction of a model for some part of reality.

Knowledge Representation cont.

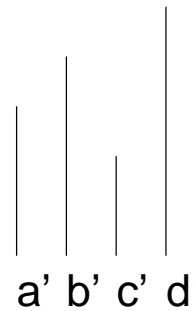
Represented World



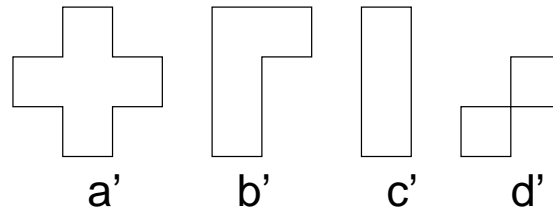
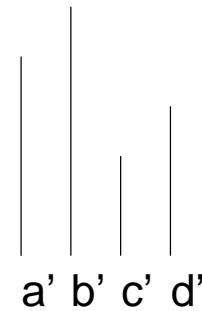
Taller than
→ longer than



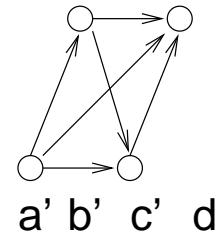
Wider than
→ longer than



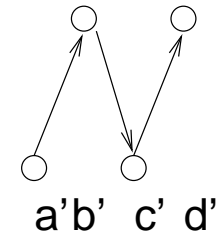
Larger than
→ longer than



Taller than → larger than



→ points to



→ chains to

(Palmer, 1978)

What do I represent and how do I represent it?

Representation and Computation

- The Roman and Arabic numerical systems are equivalent representations for positive integers (can be transformed into each other), *but*: arithmetic operations can be performed more efficiently in the arabic system!
- **Equivalence of (symbolic) representations** (Larkin & Simon, 1987): informational equivalence (can be transformed into each other) + computational equivalence
any inference which can be drawn easily and quickly in one can be also drawn easily and quickly in the other
- Representation and computation are interdependent!
(cf. computer programs: explicit storage in data structures + operations working on the data)

Example: Representation of Concepts

- Concept or category: group of objects or events
- Functions of categories:
 - orientation in the world and taking profit from previous experiences
- Different theoretical views/similarity-based approaches
 - Rule-based: definitory and characteristic attributes (cp. ontologies with “is-a” and “has-prop” relations)
 - Prototypes: probability that an object belongs to a category
 - Exemplars

Mental Models

- representations in the mind of real or imaginary situations
- sometimes “mental model” is used as synonym for “mental representation”
- narrower referent in the case of the theory of thinking and reasoning:
 - Kenneth Craik (1943): mind constructs “small-scale models” of reality to anticipate events
 - constructed from perception, imagination, or the comprehension of discourse
 - can be underlying an visual image or be abstract
 - are akin to architects’ models or to physicists’ diagrams in that **their structure is analogous to the structure of the situation** that they represent
 - unlike the structure of logical forms used in formal rule theories

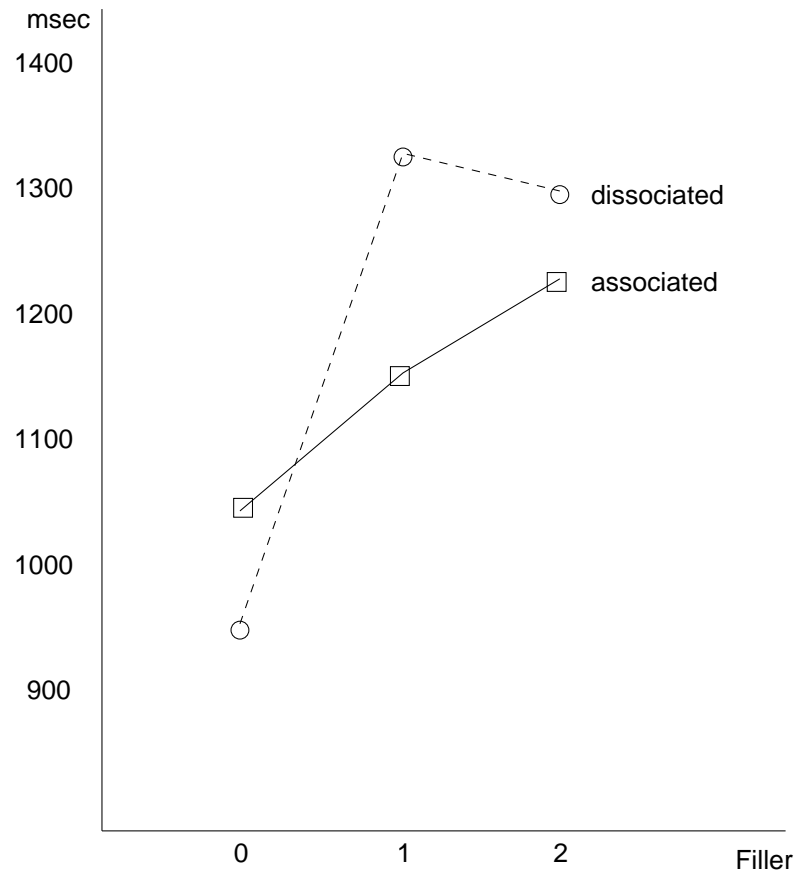
Three Turtles

- Bransford, Barclay and Franks, 1972
- Presentation “Three turtles rested on a floating log and a fish swam beneath them.”
- Recognition “Three turtles rested on a floating log and a fish swam beneath it.”
- vs. Presentation with “beside a floating log” instead of “on”

John's Sweatshirt

- Glenberg, Meyer and Lindem, 1987
- Setting: John was preparing for a marathon in August.
- Critical: After doing a few warm-up exercises, he took on/put off his sweatshirt and went jogging.
- Filler: He jogged half-way around the lake without too much difficulty.
- Filler: Further along the route, however, John's muscles began to ache.
- Question: Was the marathon to be held in summer?
- Verification task: Does probe word (e.g. "sweatshirt") appear in the text?

Distance Effect



- if sbjs construct a mental model of the text, the associated texts should produce faster verification, esp. as the delay grows and the character moves further in distance from the initial location

Mental Models in Thinking

- Philip Johnson-Laird
- A reader creates a mental model of the text being read, which simulates the 'world' being described, as the reader understands/interprets it.
- ambiguous passages of text can lead to more than one competing mental model,
- However, passages of text that unambiguously produce a single mental model are easier to comprehend.

Reasoning with Mental Models

Syllogistic reasoning:

- Construction of an integrated internal representation of the premisses
- “Read out” the conclusion

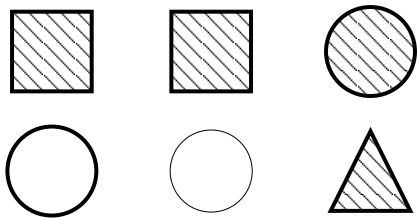
Influence factors on performance (error rates, performance time)

- Number of possible models
- Sequence of presentation of premises

Reasoning Example

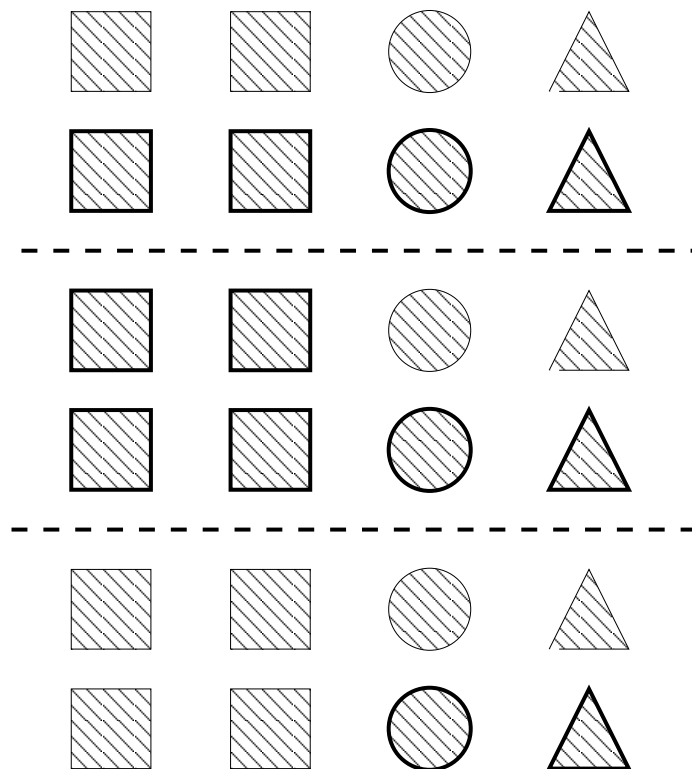
All squares are striped.
All striped objects have a bold margin.

All squares have a bold margin?



All squares are striped.
Some striped objects have a bold margin.

Some squares have a bold margin?



Related Concepts of Mental Models

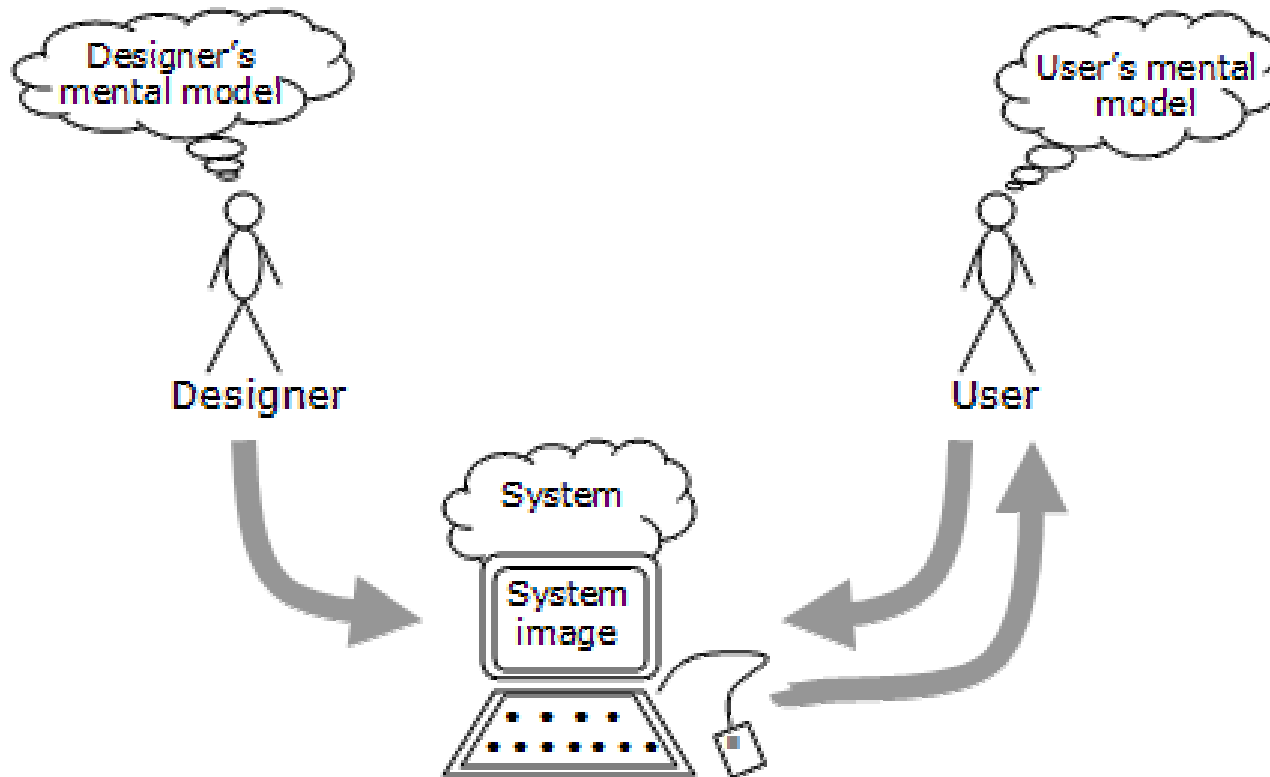
- In discourse: situation model (van Dijk and Kintsch, 1983)
- In naive physics (Forbus and Gentner,)
see also qualitative reasoning in AI
- In HCI (D.Norman)

Mental Models in HCI

- Slower processing of ambiguous sentences: relevant to interaction design
- Interaction designers are interested in measures of learnability and ease of use (explanatory power of the MM theory)
- 'System causality conveyance' (Donald Norman, "The Design of Everyday Things", 1988)
- Description how a system is designed and implemented on the basis of the designer's mental model
- Similar to a reader of a passage of text, the user develops a mental model of how he/she thinks the system works through interaction of the system
- This model is used to reason about the system, to anticipate system behaviour and to explain why the system reacts as it does

Users' Mental Models

- The designer reifies (materialises) his mental model of a given design, e.g. a computer system, which becomes the only means of conveying his mental model to the user



Mental and Conceptual Models

- “Some Observations on Mental Models” (Norman, 1983)
- “Conceptual models are devised as tools for the understanding or teaching of physical systems.
- Mental models are what people really have in their heads and what guides their use of things.”
- The designer designs a conceptual model into the system in order for it to appear graspable and coherent to the user. If he/she manages to get the conceptual model right, the correct mental model (in the mind of the user) will follow.(At least in theory.)
- Over-simplification, but captures some central dilemmas of interaction design by using mental models as a vehicle for explanation and illustration.

Do people necessarily create MMs?

- users do not only interpret the visible parts of the system (the “system image”) but also make guesses as to what goes on behind the scenes (“the system”)
- This makes the stringent separation of the user interface from the underlying technical processes a poor strategy for achieving ease of use (e.g. Gentner and Nielsen, 1996)
- This compulsion toward making a mental model of the ‘internal logic’ of the system may be part of the reason why many efforts in the HCI community in the early 80s were wasted since it appeared that “The aim of interface design was to invent metaphors that users could understand, but which had not much to do with the internal workings of the system” (Andersen, p.4).
- **see** http://www.interaction-design.org/encyclopedia/mental_models.html

Runnable Mental Models

(Newman & Lamming)

- Static vs. dynamic model
 - “I’ve stored *mm1*, *mm2*, and *mm3* in *Memos*”
 - “If I delete *Memos* then I’ll delete *mm1*, *mm2*, and *mm3*”



Runnable Mental Models

- Runnable mental model is dynamic and is a model of **causality!**
- How actions on one object cause actions on others
- Acquisition
 - by use
 - by observation of other users
 - from documentation
- Based on their mental models, users make predictions, e.g. the outcome of two different actions, in order to decide which action to adopt

Determinants for MMs

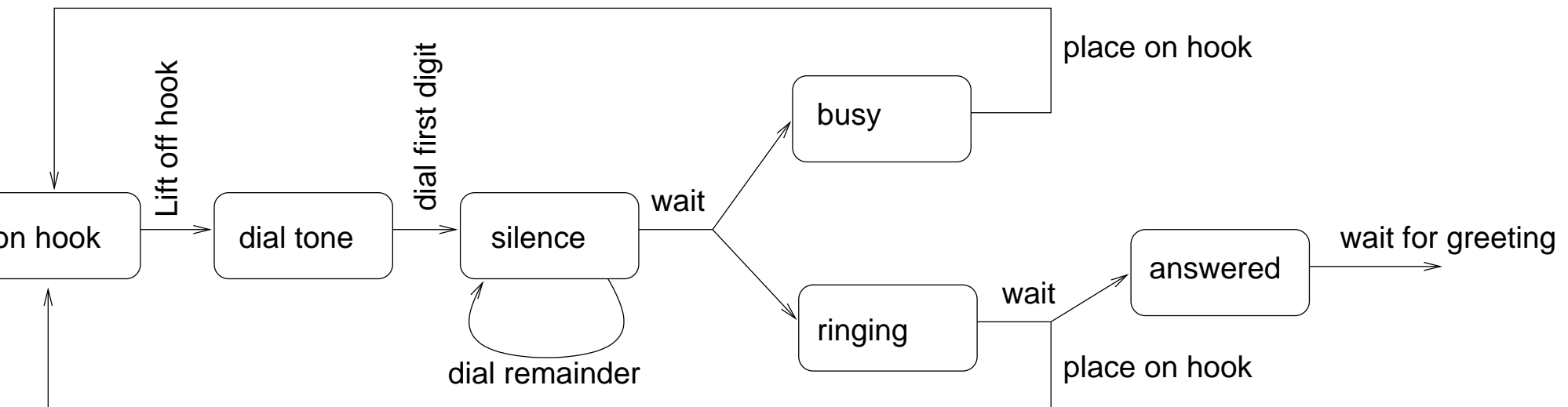
- Visible/audible system image (its presentation via interface) helps the user to understand the state of the system
- Existence of single dominant mental models facilitate conceptual design, but often different users have different models of the same system due to personal experience

Forms of Mental Models

- State transition models
- Object-action models
- Mapping models
- Analogies

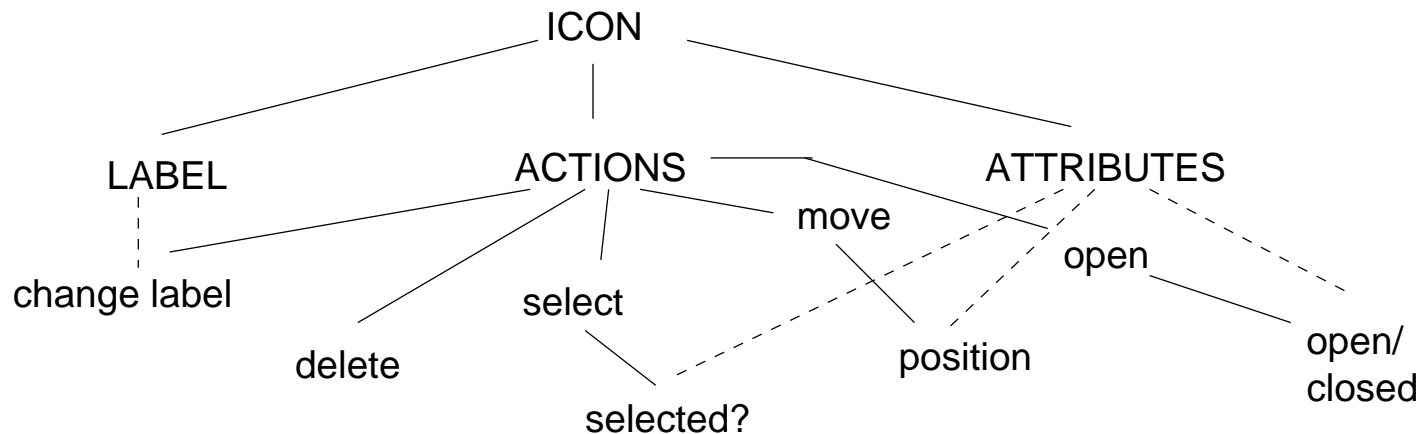
State Transition Models

- Models around observed changes in the system's overall state
- likely to be built if the system is seen to switch between different modes of behavior



Object Action Models

- Awareness of different objects, their states, attributes, causal interrelations, and actions that can be performed on them
- Basis for organizing knowledge about the systems functionality
- E.g., mental model of an icon



Mapping Models

- Mapping intentions into sequences of actions
- E.g., Intention of adding 2517 to 781 and subtracting 688 can be mapped to pressing the following keys:
2 5 1 7 + 7 8 1 - 6 8 8 =
- Likely to arise in systems with repetitive sequences of actions

Analogies

- Arise when users encounter a system which closely resembles a system he/she is familiar with
- Metaphors as non-explicit analogies
- Problem: misleading analogies