Architectures of Cognition Lecture 1

Niels Taatgen
Artificial Intelligence
Webpage: http://www.ai.rug.nl/avi

Carnegie Mellon

RuG

Organizational

2

- Practical assignments start Next Week
  - Work in pairs
  - 3 assignments
  - Grade = (1/4)*assignments + (3/4)*exam
  - Two afternoons but you don't have to attend both
- Two readers (but not printed yet)
- Slides will be on the website

Carnegie Mellon

RuG

Goals of this course

3

- What is cognitive modeling about, and what are architectures of cognition
- Compare different proposals for architectures (ACT-R, EPIC, Soar, Neural Networks)
- Examine how a particular architecture, ACT-R, can offer theories for diverse areas of cognition

Carnegie Mellon

RuG

What cognitive phenomena will we examine?

4

- Individual differences in Working Memory Capacity
- Learning the Past Tense in English
- Learning the Balanced Scale task
- Learning Air Traffic Control

Carnegie Mellon

RuG

Practical Assignments

5

1. Multi-column addition
2. Subitizing
3. Alphabet Arithmetic

Carnegie Mellon

RuG

Contents

6

- History of cognitive modeling
- Some philosophy of science
- Example of a cognitive model: learning without consciousness
- Applications of cognitive modeling

Carnegie Mellon

RuG

History: The Turing thesis/test

7

Computers can do anything
Human Intelligence is something

Computers can do human intelligence

Carnegie Mellon

RuG

Turing test/thesis

8

- Turing's work was very comforting for the first wave of AI research
  - Newell & Simon: Logic Theorist and General Problem Solver
  - Minsky: Microworlds
- Early successes were followed by great future claims

Carnegie Mellon

RuG

AI Today

9

- AI is concerned with programs that do intelligent things without any claims of mimicking human intelligence.
- Example: Deep Blue

Carnegie Mellon

RuG

Cognitive Modeling

10

- No longer aspires (at least not openly) to build a conscious intelligent machine
- Attempts to better understand human intelligence by using computer simulation
- However: the legacy of Turing, computers can do anything, has become a hindrance

Carnegie Mellon

RuG

You can't play Twenty Questions with Nature and win

11

- Paper (1973) by Alan Newell. The title of the paper refers to a game
- Newell argues psychologists study phenomena and try to explain them by all kinds of binary oppositions

Carnegie Mellon

RuG

Some phenomena

12

- Subitizing (Klahr)
- Continuous rotation effect (Shepard)
- Serial position effect in free recall
- Chunks in STM (Miller)
- Linear search in sets in STM (Sternberg)

These are just 5 of the list of 59

Carnegie Mellon

RuG

Some binary oppositions

13

- Nature vs. Nurture
- Serial vs. Parallel processing
- Continuous vs. all-or-none learning
- Conscious vs. Unconscious
- Innate vs. learned grammars (Chomsky)
- etc.

Carnegie Mellon

RuG

An endless game...

14

- According to Newell, this type of research will never reach the goal of understanding cognition
- So he proposes a number of solutions

Carnegie Mellon

RuG

Newell's solutions

15

- Study large, real-life tasks, and find out all aspects of that task (example: chess)
- Complete processing models: formal, computational models of human thinking
- Newell: "The best theory of a phenomenon is a computer program that produces it"

Carnegie Mellon

RuG

Problems

16

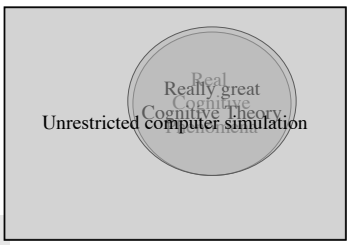
- Problem with computational models: they can do anything in principle
- Solution: Look for constraints

Carnegie Mellon

RuG

Look at it from the Kuipers perspective

17

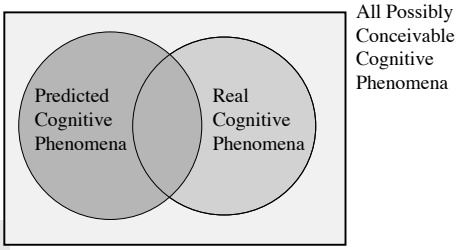


Carnegie Mellon

RuG

A more realistic theory

18



Carnegie Mellon

RuG

Conclusion

19

- A cognitive theory based on simulation needs constraints, boundaries on the power of universal computation.

Carnegie Mellon

RuG

Sources of constraint

20

- Neural architecture
- Constraints on what can be achieved in a certain time-step
- Constraints on the basic units of knowledge
- The constraint of learning

Carnegie Mellon

RuG

Modeling Paradigms

21

- Symbolic
- Connectionist
- Dynamical systems
- Artificial life
- Hybrid

Carnegie Mellon

RuG

What architectures are there?

22

- Early work by Newell and Simon: General Problem Solver
  - Purely symbolic
  - Focus on problem solving
  - Corresponds to present-day AI search techniques
- Contemporary successor: Soar

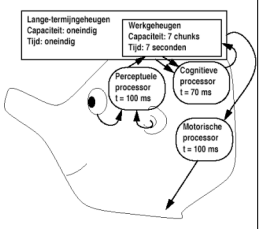
Carnegie Mellon

RuG

What architectures are there?

23

- Engineering models: Model Human Processor (Card, Moran & Newell, 1983)
  - No theory on knowledge representation or knowledge processing
  - Predictions about timing
- Contemporary successor: EPIC



Carnegie Mellon

RuG

What architectures are there?

24

- Neural networks
  - No "real" cognitive architecture or unified theory of cognition
  - Constraints derived from limitations imposed on cells in the network

Carnegie Mellon

RuG

What architectures are there?

25

- ACT-R
  - Hybrid architecture
  - Has symbolic aspects derived from AI (production system architecture)
  - Has adapted EPIC's perceptual/motor theory
  - Has adapted (some) learning and activation principles from neural networks

Carnegie Mellon

RuG

The idea of constraints is at odds with current memory research

26

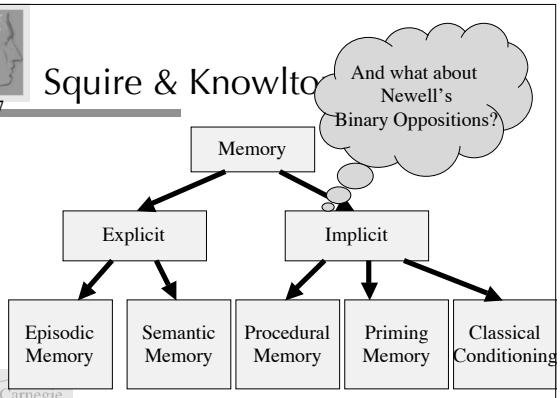
- Try to identify different memory systems by separating different memory functions
- Problem: each additional memory systems loosens the constraints on the systems, and opens up more explanations for a particular phenomenon instead of less

Carnegie Mellon

RuG

Squire & Knowlto

27



Carnegie Mellon

RuG

Sugar Factory Task

(Berry & Broadbent, model by Wallach)

28

- Participants have to achieve a certain goal output of a sugar factory by setting the number of workers for each day
- The output is calculated on the basis of the number of workers and the output on the previous day, but the formula is unknown to participants

Demo

Carnegie Mellon

RuG

Sugar Factory details

29

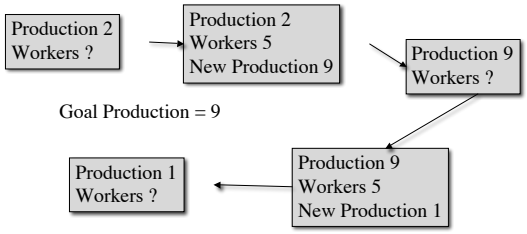
- Keep the production P of a simulated sugar factory at a target value T, by allocating an appropriate number of workers W to the job.
- System dynamics are controlled by:
  $P_t = 2\ W_t - P_{t-1} + \text{Random Factor (-1/0/1)}$
- Production depends on previous day
- Random Factor makes it hard to find underlying rule

Carnegie Mellon

RuG

Sugar Factory task

30

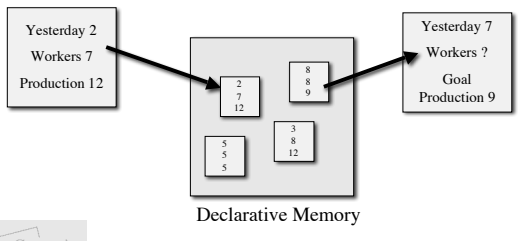


Carnegie Mellon

RuG

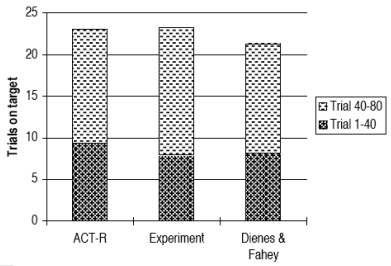
Wallach's model

31



Results

32



Discussion

33

- Reasoning is based on patterns
- There is no (real) strategy, there are no attempts of inference, and there is no deliberate storage of experiences
- Yet the model performs the task as well as participants
- Participants *do* attempt to find rules, but are unsuccessful, so it doesn't impact their performance

Implicit vs. Explicit memory?

34

- The Sugar Factory task can be explained by a very simple model that remembers old examples
- No specific distinctions are needed
- Other example: word recognition vs. word completion

Conclusion

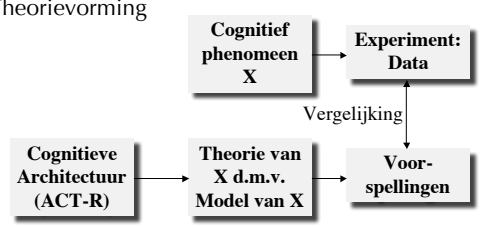
35

- In order to explain the Tulving experiment, it is not necessary to postulate two separate memory systems
- Similar models have been made of other implicit learning experiments, e.g. SugarFactory (Broadbent & Berry), and sequence learning

Wat is het nut?

36

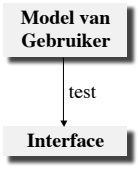
- Theorievorming



Wat is het nut?

37

- Theorievorming
- Cognitieve ergonomie



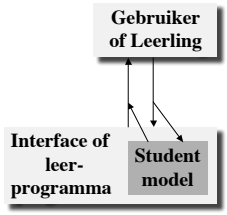
Carnegie Mellon

RuG

Wat is het nut?

38

- Theorievorming
- Cognitieve ergonomie
- Student/user models



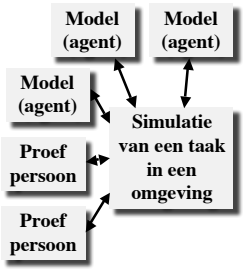
Carnegie Mellon

RuG

Wat is het nut?

39

- Theorievorming
- Cognitieve ergonomie
- Student/user models
- Simulatie van arbeidsituaties



Carnegie Mellon

RuG