Core Lecture 8: Advanced Interaction

TECHNOLOGIES FOR LEARNING

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Before the lecture

• Website:
  ◦ Missing slides
    ◦ Topic 6.1 (Collaborative learning support)
    ◦ Topic 6.5 (Argumentation-based learning systems)
  ◦ Time and place for poster presentations

• Course evaluation

• Project group meetings next week
  ◦ Don’t miss!

• Project reports
  ◦ Structure
    ◦ Introduction (problem description, motivation)
    ◦ Related work (..and what is missing)
    ◦ The approach
    ◦ The results
    ◦ Conclusion
  ◦ Language
Interface model in Intelligent Tutoring Systems

Interface Model
- Flexible Interface Component
- Virtual City Environment

Domain Model
- Pedagogical / Adaptation Model
- Student Model
Our cognitive architecture

• Interaction involves
  ◦ Perception and Attention
  ◦ Processing and Inference
  ◦ Memorization and Retrieval

• Long-term memory (LTM)
  ◦ Practically unlimited capacity and duration
  ◦ Knowledge are organized (schematic structures)

• Working memory
  ◦ Locust of conscious information processing
  ◦ Buffer between sensors and LTM
  ◦ Severe limitations in capacity and duration
“Cognitive economy’ principle

• Random search (Trial and error) < existing LTM schema < External guidance

• Better enhanced and frequently-activated LTM schemas are preferred
  ◦ Misconceptions during transfer
  ◦ Folk believes vs. Scientific knowledge
  ◦ Expert vs. novice thinking

• For novices, external guidance can be the only source of executive cognitive function

• Optimal: combination of existing LTM schemas and external guidance
  ◦ ZPD

• Too little guidance is bad for novices
  ◦ They do not have enough LTM schemas and have to engage the Trial and Error strategy

• Too much guidance is bad for experts
  ◦ Overlap between guidance and LTM can cause redundant mapping of external and internal structures and drain WM resources (expertise reversal effect)
HCI

• Design of efficient interactive learning environments should take into account main features and limitations of our cognitive architecture

• Effective design of interaction
  ◦ Promotes student-driven learning
  ◦ Triggers deep cognitive processes
  ◦ Result in active construction of new knowledge

• Ineffective Design
  ◦ Imposes redundant information processing
  ◦ Drains learner’s cognitive resources
  ◦ Hinders acquisition of knowledge
Cognitive Load Theory

- Our cognitive capacities are limited
- Some tasks are inherently difficult
- Design can be optimized to reduce bad cognitive load and free our resources for a good one

Three sources of Cognitive Load

- **Extraneous CL**: Imposed by the manner in which information is presented to learners
  - Should be decreased

- **Intrinsic CL**: Imposed by the learning task
  - Can be managed

- **Germaine CL**: Devoted to processing information, constructing & automating schemas
  - Should be induced

Inherent difficulty of a topic

\[ 2+2 \quad \text{vs} \quad f''-f'-30f=0 \]

Relation of a topic to existing knowledge, activation of long-term memory (Learning)
Sources of Extraneous CL

- **related elements** of information or representations that need to be processed simultaneously are separated in space and/or time

- **too many new elements** of information are introduced into WM and/or are introduced too fast to be successfully incorporated into LTM structures

- learners **do not have appropriate prior knowledge** to deal with the situation, and instruction does not provide sufficient external guidance thus forcing learners to use random search procedures

- learners have sufficient **prior knowledge that overlaps with provided external guidance** thus requiring learners to mentally coordinate different representations of the same information.
Multimedia Learning Theory

Three main assumptions:

- There are separate channels for processing information of different modalities
- Channels have limited capacity (only a few chunks can be processed at a time per channel)
- Learning is an active process of filtering, selecting, organizing, and integrating information

Richard Mayer (1990s)
Application: Principles for building Interactive Multimodal Learning Environments

- **multimedia** principle: *student understanding can be enhanced by engaging multiple channels (e.g., by the addition of non-verbal knowledge representations to verbal explanations)*

- **modality and verbal redundancy** principle: *verbal information should be presented in the auditory modality alone*

- **temporal contiguity and spatial contiguity** principles: *verbal and non-verbal information need to be synchronized in time and space*

- **feedback** principle: *students learn better with explanatory rather than corrective feedback alone (as it allows them to engage additional schemas to correct an error)*

...
Theory of Embodied Cognition

• many features of cognition, whether human or otherwise, are shaped by aspects of the entire body of the organism
  ◦ the motor system
  ◦ the perceptual system
  ◦ bodily interactions with the environment (situatedness)
  ◦ assumptions about the world that are built into the structure of the organism

• Pen experiment (face muscles influence processing of sentiments)

• Pendulum experiment (processing of “performable” sentences causes change in controlling a pendulum)

• Memory, reading, reasoning, solving math & science problem have been shown to relate to gestures and other motor activities
Application: CLT + EC

- Extraneous load from CLT has two components:
  - Sensorimotor load – motor & perceptual effort required to gather learning content
  - Processing load – effort required to construct a coherent mental representation of the content in WM
- Engaging multiple perception channels can make content gathering more effective (C)
- Inefficient interaction can make it less effective (D)
Haptic Interfaces

- A haptic interface is a system that allows a human to interact with a computer through bodily sensations (applied forces and vibrations) and movements.

- Haptic feedback:
  - Tactile feedback: sensation felt by skin
  - Force feedback: reproduction of directional forces (weight of an object, inertia, etc.)

- Interaction mechanically couples two controlled dynamical systems:
  - Haptic interface with a computer
  - Human user with a central nervous system
Applications – Immersive VR

Abdominal Aortic Aneurysms (AAA)
Tangible interface

- Interact with a digital information through physical environment
- Difference with haptic:
  - Tangible – physical objects help interacting with digital/virtual
  - Haptic – virtual objects interact with a human through physical senses
- Applications: Augmented reality environments

https://www.youtube.com/watch?v=m9lZfnRrM4Y
Game-based learning

- Effective games are characterized by:
  - Fantasy
  - Mystery
  - Control
  - Rules/Goals
  - Challenge
  - Sensory Stimuli

Stimulating Motivation & Affect
Supporting learning as an active process
Balancing Cognitive Load
Engaging multiple channels

Game-based learning from learning theory perspective
Pedagogical Agents

- virtual characters
  - Learning/teaching is a social process => a system needs a personality

- Benefits:
  - Increased motivation
  - Increased sense of comfort
  - Stimulation of essential learning behaviors
  - Enhanced flow of information and communication

- Diversity:
  - virtual vs. robotic
  - animated vs. static
  - teaching vs. teachable
  - Realistic vs. Cartoonish
Natural dialog

- NL-based interface is intuitive
- Human tutoring: learn through conversation
- Dialog can involve:
  - Asking questions
  - Answering questions
  - Giving feedback
  - Discussing a topic
  - Refinement of a statement
- Dialog can be:
  - text-based (usually is) or
  - verbal (technologies are improving)

Depending on a topic, verbal schema can be a more effective one.

Supporting learning as an active process
Stimulating Meta-cognition
Balancing Cognitive Load

In either case, verbal mode is used.