Core Lecture 6: Advanced Interaction

TECHNOLOGIES FOR LEARNING

Sergey Sosnovsky
Interface model in Intelligent Tutoring Systems
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 into Trial and Error

- 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**: Should be decreased
  - Imposed by the manner in which information is presented to learners
  - Instructional design & interface design, information modality

- **Intrinsic CL**: Can be managed
  - Imposed by the learning task
  - Inherent difficulty of a topic
  - $2+2 \text{ vs } f''-f'-30f=0$

- **Germaine CL**: Should be induced
  - Devoted to processing information, constructing & automating schemas
  - Relation of a topic to existing knowledge, activation of long-term memory (Learning)

John Sweller (1980s)
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
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 systems 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