HCI: Cognitive Architecture

Learning Objective

- There are three components in HCI - **H**uman, **C**omputer and **I**nteraction
- Among these components, human is the most important (human in design differentiates HCI from other fields)
- Design should take into account human (which resulted in user centered/participatory design approaches)

Learning Objective

- In the previous lectures, we learned the model-based approaches (to reduce the design time and effort)
  - We already seen how individual models of human factors are taken into account (Fitts' Law etc.)
  - Also discussed GOMS – a simple model of human behavior

Learning Objective

- However, human behavior is very complex
  - We need more complex approaches, taking into account different components of human behavior
  - Such complexities are to be captured in integrated cognitive architectures (CA), which are very useful in HCI
- In this lecture, we shall discuss the CA used in HCI

Human/User

- A user can be viewed as an information processing system
- Information i/o …
  - Input: Visual, Auditory, Haptic
  - Output: Movement/Motor Action
- Information Stored in Memory (Sensory, Short-/Long-term)

Human/User

- The information taken as input and stored are processed and applied in various ways
  - Reasoning
  - Problem Solving
  - Skill
  - Error
- Also, emotion influences human capabilities

Motivation

- We want to model these activities of Human Information Processor (HIP)
- Such (HIP) model can be used to:
  - Validate understanding of ourselves
  - Inform the design of better user interfaces
  - Develop robust automated design approaches

HIP Models

- There are broadly two approaches to model HIP
  - Computational – HIP can be modeled using the computer metaphors
  - Connectionist – Biological metaphor to model HIP; HIP as a neural network

HIP Models

- Our focus – Computational Approaches
- Computational HIP models can be of two types
  - Production Systems: the information processing behavior is implemented as a set of production (IF- THEN-ELSE) rules
  - Non-production Systems

Cognitive Architectures (CA)

- CA - a broad theory of human cognition based on a wide selection of human experimental data, and implemented as a running computer simulation program
- Essentially, CAs are computational HIP models taking into account all the components of cognition

Cognitive Architectures (CA)

- There are many CAs developed, most of them are production systems with few non-production systems
- Examples of CAs developed as production systems
  - Model Human Processor, Soar, EPIC, ACT-R/PM
- Example of non-production CAs – Integrated Cognitive Subsystems

CA and HCI

- CAs are relevant to usability
  - They can provide an engineering perspective to usability analysis
  - Can be used to develop HCI-related applications
  - Can serve an important role in HCI as a theoretical science

CA as Usability Engineering Tool

- Engineering requires quantitative predictions
  - Helps compare alternative designs & identify design problems
- Qualitative/quantitative guidelines may not be sufficient to compare two “nearly equally good” designs
  - Need some theory/model to “compute” certain “parameters” of the designs to compare them

CA as Usability Engineering Tool

- Usability engineering involves similar situation
- Every design must be subjected to usability test
  - UE experts mostly rely on intuition / experience / guidelines to do so

CA as Usability Engineering Tool

- Ex: intuition may say interface X is faster than Y, but how much? 10%, 20% or 30%.
  - Such quantitative data is required, as small savings in execution time may result in large financial savings
- Requires quantitative prediction theories
- Computational models based on CAs can provide such quantitative answers

CA as Usability Engineering Tool

- The models can predict many useful quantities such as
  - Execution Time
  - Error Rate
  - Transfer of Knowledge
  - Learning Rates
  - Memory Load
  - Many more Performance Measures

CA as Usability Engineering Tool

- Results may not be accurate but sufficient for comparison
- Models based on CA can be employed for evaluations in situations where traditional usability evaluation may be very costly or even impossible
  - For example, evaluation involving fighter pilots or astronauts

CA as Usability Engineering Tool

- CA based models can realistically mimic the human and act as "surrogate" user
- GOMS/cognitive walkthroughs etc. can also provide quantitative predictions
  - They are abstracted from some underlying architectures
  - CA based models can predict much more

CA Applications

- By definition, CAs are executables, making them suitable for several HCI-relevant applications
  - Intelligent Tutoring Systems
    - The Lisp Tutoring System (Anderson et al., 1989)
  - Populating Simulated Worlds/Situations
    - Training Fighter Pilots
    - Multi-party Game
    - Virtual Reality

CA - Issues

- Many aspects of human behavior are to be accounted for
  - Error Behavior
    - It is difficult to mimic such behavior, which sometimes is required to evaluate usability
  - Emotion
    - Recently some promising works are being done

CA - Issues

- Simulated agents (intelligent agents) usually interact with an interface using a specification of the system
  - An active research area is to enable simulated agents access interfaces in ways that approximate the richness and limitation of human perceptual-motor capabilities
- Understanding/implementing CAs requires specialization
  - Usability of CA specification languages needs improvements

Summary

- In the next lecture, we shall learn the MHP, which stands for the **M**odel **H**uman **P**rocessor, a production system, as a case study