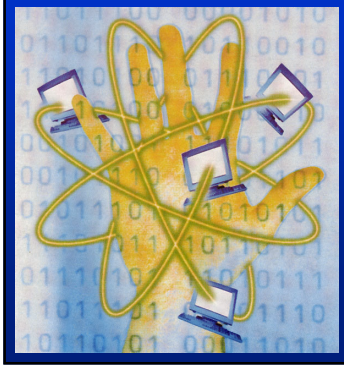
HUMAN-COMPUTER INTERFACE DESIGN

University of Essex



Course EE212 / CE653

Part 1, Section 2

modelling

human capabilities

Computing & Electronic Systems

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and Edward Tsang

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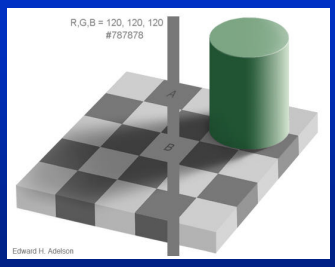
What is machine vision?

- Not just image processing
  - more than image enhancement, restoration and compression
- Not just pattern recognition / classification
  - Vision is concerned with generating descriptions of 3-D scenes
- Automatic deduction of structures and properties of a possibly dynamic 3-D world from a set of 2-D images
- Main concerns:
  - Computability,
  - Robustness
- Difficulties:
  - Computationally expensive

HUMAN SENSES
- more on visual illusion

http://web.mit.edu/persci/people/adelson/checkershadow_illusion.html



Is A darker than B ?

surprisingly, no

they have identical pixel values

- Our vision is BETTER THAN a biological kind of camera
  - optimised for distinguishing object-boundaries from surface textures
  - this is a difficult task in computer vision, complicated by lighting.

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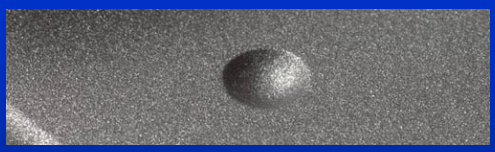
VISUAL INTERPRETATION
- more than is 'in' the picture



Is this a bump or a dent ?

the image, on its own, is ambiguous

information about the light source is needed to answer the question

- Our vision is BETTER THAN a biological kind of camera
  - It is not easy to *infer* light sources from image

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Hidden Dog

A challenge for machine vision

PERCEPTUAL EFFECTS IN 2-D IMAGES

- Our visual system is ever-keen to detect objects
  - even when there are very few appropriate edges in the image
- Our mental expectations can affect what we see …

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PERCEPTUAL EFFECTS IN 2-D IMAGES

- Images with little information can be ambiguous -
  our visual system can construct more than one plausible model of reality

Source: BORING, E.G. (1942). Sensation and Perception in the History of Experimental Psychology. New York: D. Appleton-Century

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Knowledge about the bio-system

- We know much about:
  The hardware:
  the eye, the optical mechanism
- We don't know much about:
  What happens in the brain:
  how does it process images?

General-purpose Vision System

- Image taken from a 3-D World
- Edge detection
- Constraint generation
  Line drawing, shading, texture, stereo, motion
- Simultaneous constraint satisfaction, 3-D segmentation and aggregation
- Recognition, prediction, navigation, etc.

Note: Interpretation of images is very important, but it is not as extensively studied as, say, edge detection.

HUMAN SENSATION
- inter-sensory effects

- Auditory illusions
  sounds can be attributed to the visual location of a plausible source
- Perceptions of audio-visual quality, from cinema history
  better sound slightly improves the rating of picture quality
  a brighter picture slightly improves the audience rating of sound quality
  the opposite happens too !
- Implications …
  cross-connections in brain, between hearing, sight and understanding
  precedence is given, in brain processing, to visual information
  'cognitive fusion' of the whole experience plays a strong role

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HUMAN SENSES
- touch, taste and smell

- For most people :
  the sense of touch is less important than senses of sound and sight
- For visually-impaired people :
  the sense of touch is enormously important - eg. reading by Braille
- Tactile communication and feedback can be very useful
  in noisy rooms - eg. vibrating call alert in pagers and mobile phones
  for greater realism - eg. in computer games and virtual-worlds,
  to create sensations of motion, pressure or surface texture
  for improved speed and accuracy in mouse or keyboard input
- Taste and smell are not (yet ?) used in HCI design

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HUMAN OUTPUT CHANNELS
- physiological motor control

- Speaking :
  maximum intelligible rate is about 180 to 400 words per minute
  (language dependent)
- Pushing buttons :
  with one finger, maximum speed about 400 actions per minute
  with both hands (piano playing), max. action speed 1,000 per minute
  with both feet (trained organist), max. action speed 600 per minute
- Most complex common control task is driving a car
- Most complex control task of all is flying a helicopter
  eyes, ears (balance and acceleration) and touch are input channels
  fingers, wrists, arms, legs, feet are output channels

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THE PURPOSE OF HUMAN SENSES
- to understand the world

- Five channels - hearing, vision, touch, taste, smell
  - not accurately,
  - not independent
- Our senses make an integrated system :
  - physical and brain-processing (psychological and cognitive) parts
  - aimed at extracting significant features about the source of the signal
  - we hear voices, words, instruments and notes
  - we see objects, relative speed, distance and threat / opportunity
- Useful information is embedded in sense-channel signals
  - human sensory processing aims to construct a mental model of what is happening around us
  - throwing away information that is perceived irrelevant

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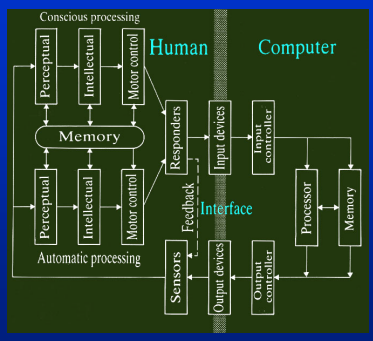
MODELLING THE HUMAN SYSTEM
- entire system is engineering plus human



- Human processing is one half of closed-loop feedback system

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MODELLING THE HUMAN SYSTEM
- incomplete knowledge

- HCI requires human modelling
  - What does the user know?
  - How would the user act?
- where do the models come from ?
- Models based on physiological and psychological experiment
  - experiments are slow and difficult to do
  - hard to interpret the (conflicting) results
  - Easier to predict collective behaviour
  - but not detailed, individual behaviour

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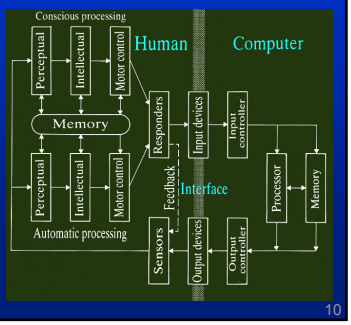
MODELLING THE HUMAN SYSTEM
- incomplete knowledge

- Typical model is process-based :
  - views the human system as three interacting sub-systems -
    - perceptual sub-system
    - cognitive sub-system
    - (also called intellectual)
    - motor control sub-system



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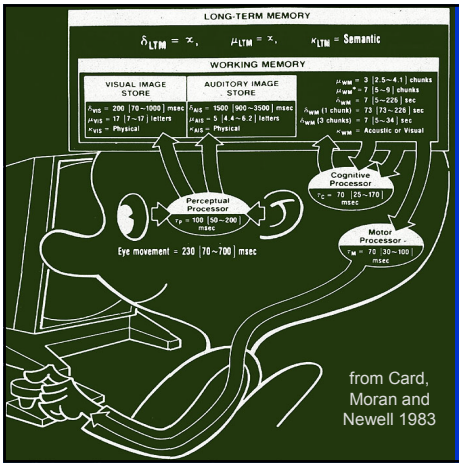

from Card, Moran and Newell 1983

measure parameters for each process

- Look for a simpler model …

Related: Doug Lenat's quest in the Cyc Project, trying to model common sense (see Wikipedia)

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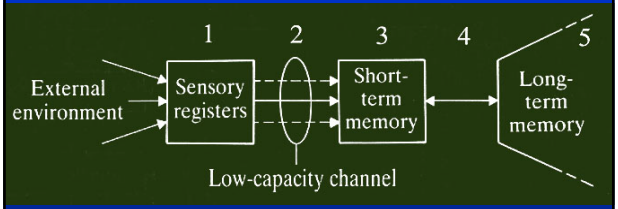
SIMPLER MODEL OF HUMAN BRAIN
- focus on perception and memory systems



- Modelling the information flow between senses and memory
  - (devised by Atkinson & Schiffrin 1968 and Kidd 1982)
  - five levels for analysis and description
  - intellectual processing, or conscious thought, is assumed but not shown
  - allows for different representations at different levels within the brain
  - each level has different characteristics and properties

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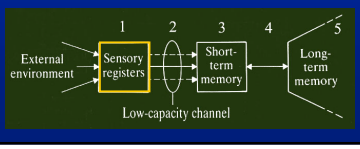
SIMPLE MODEL OF HUMAN BRAIN - sensory registers

- Can be thought of as temporary buffers
  - store a physical representation of the data output of sensory organs
  - no processing or decoding of data, stored in raw physical form
    - storage time for vision - about 200 millisecond (persistence of vision)
    - storage time for hearing - about 2 seconds
  - this level has a limited amount of subconscious (automatic) feedback
    - eg. saccadic (discontinuous, sporadic, jerky) eye movements, to maintain stimulation of the retina



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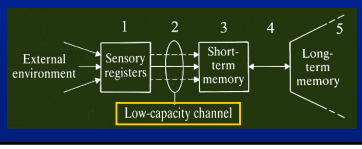
SIMPLE MODEL OF HUMAN BRAIN - low capacity channel

- Models our limited attention capacity
  - we can't pay full attention to many simultaneous rapidly changing inputs
  - under both subconscious and conscious control
  - bandwidth of the consciously-determined data flow is small, subconsciously, data-flow bandwidth is much larger
  - acts as more than just a channel - because information seems to be automatically coded or converted to a symbolic kind of representation
  - these conversions may explain why the channel data-rate is limited



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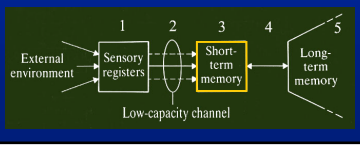
SIMPLE MODEL OF HUMAN BRAIN - short-term memory (STM)

- Can be thought of as *further* temporary buffers
  - short-term memory (STM) properties have been thoroughly investigated
  - long-term memory (LTM) is harder to investigate or analyse and is therefore less well understood than STM
  - information has been partly processed, and is stored in STM as symbols
  - storage duration about 20 to 30 seconds (rehearsal can increase this)



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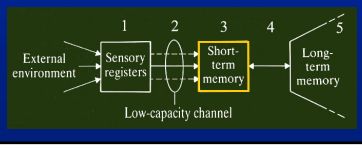
SIMPLE MODEL OF HUMAN BRAIN - short-term memory (STM)

- Is not like electronic memory …
  - Miller (1956) has shown that STM can store between 5 and 9 'chunks'
    - a 'chunk' is a meaningful unit, such as a word or a symbol
  - the equivalent number of 'bits per chunk' has no detectable limit, so that with training, a chunk can be a group of numbers, words or objects
  - the equivalent limit in electronic memory is address space - but electronic memory has a 'bits per address' limit, STM does not



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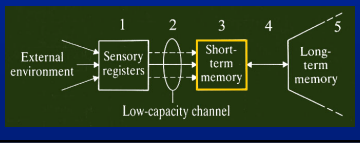
SIMPLE MODEL OF HUMAN BRAIN - short-term memory (STM)

- Effectively a bottle-neck in performance - information overload
  - STM is used in two different ways :
    - as memory storage
    - as input registers for cognitive tasks (decision-making)
  - limited chunk capacity means that these roles interfere with each other
  - we stumble over cognitive tasks if we're given too much data to recall
  - very important issue in design of complex HCI systems (eg. military) - better to 'recode' information into a smaller number of bigger chunks
    - use familiar, meaningful chunks and simplify decision-making



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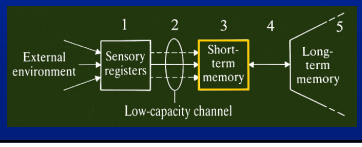
SHORT-TERM MEMORY - strategies for best performance

- Closure
  - users have strong motivations to finish and complete tasks in hand - allows STM to be 'cleared' - discarding old data
    - makes room for new data, new processing and new decisions
  - motive for closure is so strong that it feels pleasant and satisfying
  - inexperienced users prefer multiple small tasks, with frequent closure
  - experienced users can handle larger tasks, with slower closure



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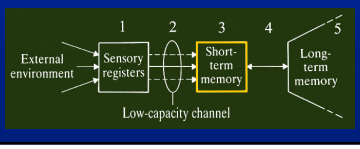
SHORT-TERM MEMORY
- strategies for best performance

- User attitude and anxiety (Shneidermann 1980)
  - an uncertain or negative user attitude means that learning is slower
  - anxiety (eg. a fear of failure) reduces STM 'chunk' capacity
  - STM overload can create anxiety - so that a vicious circle might develop
  - 'friendly and forgiving' is a better design strategy for non-stressful use



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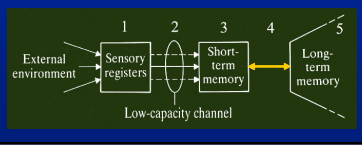
SIMPLE MODEL OF HUMAN BRAIN
- transfer from short-term to long-term memory

- Not like an communication channel in engineering …
  - not under conscious control, transfer is automatic but indirect
  - asymmetric - 'fast conscious read, slow unconscious write'
    - information goes in slowly, without our control or knowledge
    - putting much information in needs repetition or practice
  - therefore difficult to use LTM as working storage for decision-making
- Compare to reinforcement learning in computing



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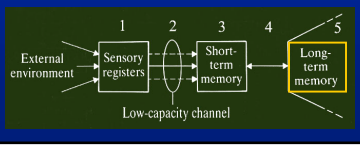
SIMPLE MODEL OF HUMAN BRAIN
- long-term memory

- Is even less like electronic memory …
  - seems to have no limit to its capacity
  - stores information semantically (by its meaning and significance)
  - information is accessed associatively (using links to other information)
    - associative access is effective, but can go wrong
  - speed and accuracy of access is strongly dependent on :
    - frequency of access, number of associative links, time since last use
- Refer to neural network and semantic network in computing



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HUMAN BEHAVIOUR
- for good design, essential to remember …

- Human beings are not fixed or static in performance
  - we are, by deeply-ingrained nature, very adaptable
  - we like to learn
  - the user's desire to control the interface will increase with familiarity
  - naive users become experienced users, some become experts
- Allow for a change of situation -
  - at first, the computer takes the initiative
  - eventually, users take initiatives
  - if these changes are blocked, users get frustrated and resentful

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HUMAN MODELLING
- summary

- Hearing and vision have limited resolution and non-linear behaviour
- Reaction time is ≥ 200 milliseconds
- Be wary of sensory memory
- Perception can be ambiguous and is often influenced by expectations
- The total input capacity is strictly limited
- Users always wish, and like, to clear Short term memory (closure of a task)
- Conscious processing is flexible but slow
- Subconscious processing is fast but inflexible and hard to change
- Long term memory has huge capacity, is associative and context-dependent
- People have a wide spread of performance and capabilities
- People put their own bounds on problems, often without knowing

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