Intelligent Control and Cognitive Systems

Perception and Memory in Cognitive Systems

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About the Course(work)

• Course was designed as MSc level.
• One of its deliverables is engaging you with research (both reading & writing.)
  • Informed public, citizen science.
• Exam a concession to final-year dissertations.
• …so, a bit about research (& coursework.)
Time Management and Degree Outcomes

- Most of you are writing dissertations.

- 100 hours/course / 10 weeks/course ⇒
  3 week/coursework ⇒ 21 hours/coursework

- 6 hours in lab; robots longest.
  - 3 hours/week lectures) * 3 week/coursework ⇒
  ~5 writing up ⇒

- 16 hours to hack and read!
Doing Research

- First you need to get your hands dirty.
  - Learn about the problem domain.
  - Check to see whether you have an approach that might work.
- Publishable projects are normally preceded by pilot projects.
What’s Worth Doing?

- By third week, you should run with something you have.

- Normally – look at literature for controversies you might take a side on. Test which side is right.

- Google Scholar – who cited a paper you’re interested in, and why?
Writing Up Research

Any paper can have only one point.

Point is in the Intro & Conclusion. Results prove the conclusion; Approach & Discussion explain the Results.

Pick a point / claim you think will be most promising to talk about, then examine it in detail.
Which Point?

- What surprised you? What did you need to learn to get your robot working?
- Is there something your robot does better than the others? Could you teach others to do it?
- Look for “tricks” / lessons learned; think about the Brooks contribution.
Intelligent Control and Cognitive Systems brings you...

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Sensing vs Perception

• First weeks: Sensing – what information comes in.

• This week: Perception – what you think is going on.

  • Perception includes expectations.

  • Necessary for disambiguating noisy and impoverished sensory information.
What Would Nature Do?

- Touch input
- Ear input
- Eye input

- Movement of muscles
- Primary motor cortex
- Perceptio of space and location of limbs
- Auditory perceptions and memories
- Visual perceptions and memories
- Temporal lobe
- Occipital lobe

Brain sections and functionalities explained with diagrams.
Basic Natural CPU

- Actually whole thing computes & senses.
- Signal takes time to propagate, one cell may get two messages from same axon.
- Many different types & configurations of nerve cells.
How Eyes Work

Basic Cross section of the Eye - Showing the Rods and Cones

- HUMAN EYE
- GANGLION CELLS
- SYNAPSI S
- RECEPTORS
- ROD
- NERVE FIBRES
- BIPOLAR CELLS
- CONE
- PIGMENTED CELLS

LIGHT
How (Vertebrate) Eyes Work

- Lens focuses world on back of eye.
- Rods & cones (receptors) respond to light falling on them.
- Bipolar cells combine information, detect edges & gradients.
- Gangliian cells aggregate bipolar cells.
Ganglians cells detect changes in colour, brightness. Send this information to the back of the brain.
Excitation, Inhibition & Feature Detection

c.f. Mann link
Information Projected and Accumulated

Visual cortex has retinotopic maps responding to different edges, motions.
Associative Cortices

- Features aggregated into objects.
- Still in maps, e.g. for pose.
- Different systems for what versus where.

Output of a pose sensitive cell.
Brain Expectations

Up until the Thalamus → Retina connection, there are as many axons going towards the eye as away from it.
Perception Requires Knowledge

- Sensing alone is impossible to discriminate.
- A whole lot of what the brain does is look for regularities (co-occurrences), then represent them.
- Nerve connections positively reinforced when both sides fire in sequence.
The Brain’s Job

Pattern Recognition

- Changing actions / developing skills,
- Discovering concepts / categories for contexts to apply actions,
- Optimising representations.
Cognitive Architecture: Modularity
Archetypical Real-Time AI Architecture

- Perception / action modules (bottom layer)
- Reactive (dynamic) plans to arbitrate between them.
- (Maybe) planner or at least goal arbitration at the top.

e.g. 3T, PRS, Soar
Goal Acquisition (smell)

Behaviour Patterns

Vertebrate (Fish)

Brain as 3-Layer Architecture

Output (spinal cord)
The Obvious Brain Modules are Functional

- **Long-term storage and category learning (neocortex/cerebrum)**
- **Routing (thalamus)**
- **Autonomic (midbrain)**
- **Smoothing (cerebellum)**
- **Episodic memory construction & use / RAM (hippocampus)**
Modules in Cognitive Systems

- Many AI cognitive architectures separate episodic or working memory from long term memory.

- Few have the process emphasis of brain e.g. smoothing, category learning, autonomic systems. Exceptions: Ymir (Thórisson 1996).

- Brooks’ sensing→action modules are almost ubiquitous in AI.
Non-Modular AI

- Some researchers try to solve all AI with a single learning function.
- Can get amazing skills together this way.
- Complete systems (e.g. driverless cars) need more structure.

Atkeson, Schaal & students 1997-2014
Modularity in Cognitive Science

- Fodor (1983) describes two kinds of modules:
  - **Vertical** (sensing or motor skills)
  - **Horizontal** (cross-task skills like language, reasoning.)

Perception in Nature

- Perception can be seen as both horizontally and vertically divided.
  - **Horizontal**: specialist mapping regions.
  - **Vertical**: Cone of perceptual processing leading to single “decision” cell coordinating descending cone of motor activation.
Vertical Modules

• Distributed across sensory-motor & pre-motor cortex – names are dated (Graziano 2010)

• Species-typical behaviour (again mapped); multi-modal stimuli.
Cone or Column?

- Individual neurons must be agnostic, can’t know whether they are the winner while processing.
- Winning candidates shift continuously with stimuli, posture.
- Local competitors inhibit each other (winner-take-all).
Retina again: Bipolar and Ganglion cells not only gather receptor information but locally inhibit.
Models of Cortical Maps
Built with Localised Excitation and Inhibition

Mexican hat function + Winner take all
c.f. Willshaw, Hinton.
References

• Mann’s Book (linked, on line).

• Carlson, *Physiology of Behaviour* (many editions in many years, great text book.)


  • Both in Library!
Q: Why put the visual cortex in the rear?

- More time-critical processing happens in midbrain.
- V1 also processes Braille.
- Light travels faster than sound: facilitates coincidence detection.

‘reptilian’ vision