Logic, Symbolic AI, and Cognitive Science

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Cognitive Neuroscience of Vision
Computational Problems in Object Recognition

• **Object perception** depends primarily on the analysis of the shape and form
  
  – cf) Cues such as color, texture, and motion certainly contribute to normal perception.

• Despite the irregularities in how these objects are depicted, we have little problem in recognizing them.

• We may never have seen pink elephants or plaid apples, but our object recognition system can still discern the essential feature.
Grandmother Cells and Ensemble Coding

- **Hierarchical coding hypothesis**
  - Elementary features are combined to create Gnostic units that recognize complex objects.

- **Ensemble coding hypothesis**
  - An object is defined by the simultaneous activation of a set of defining properties.
Holistic analysis

Analysis by parts
Episodic Encoding and Retrieval

Brain imaging:
Brain activation by episodic encoding & retrieval
Brain as Widely Distributed, Parallel, Interactive, Overlapping, Dynamic Relational Memory Networks

[Fuster, 2004]
Executive memory

Perceptual memory

Acts

Phyletic motor

Polysensory

Phyletic sensory

Actions (behavior, language)

Smell

Taste

Touch

Audition

Vision
Executive memory

Perceptual memory

Programs
Acts
Phyletic motor

Actions (behavior, language)

Episodic
Polysensory
Phyletic sensory

Smell
Taste
Touch
Audition
Vision
Executive memory

Perceptual memory

Conceptual
Plans
Programs
Acts
Phyletic motor

Actions (behavior, language)

Conceptual
Semantic
Episodic
Polysensory
Phyletic sensory

Smell
Taste
Touch
Audition
Vision
Whereas the cycle operates in series and in parallel through the environment, integrative working memory at the top operates by reentrant cortical integration (RCI).

Cognitive Neuroscience of Language
The Mental Lexicon (1/2)

- The mental lexicon is organized as information-specific.
- Three levels:
  - Lexeme level: sound level
  - Lemma level: grammatical properties
  - Conceptual level: semantic knowledge of words
- Organized according to meaningful relationships between words
- Close connected: More related

Fragment of a lexical network according to the Levelt model
The Mental Lexicon (2/2)

- Conceptual or semantic representation format
- Words are represented by conceptual nodes and are connected each other.
- The strength of the connection and the distance between the nodes are determined by the semantic relations or associative relations between the words.

An example of a semantic network. (Collins and Loftus, 1975)
Results of Brain Imaging Studies

• fMRI studies support the idea of category-specific semantic problem – separable neuronal circuits engaged

Locations of brain lesions that are correlated with selective deficits in naming persons, animals, or tools.
The Organization of Lexical Level

- Damasio proposed that the findings reflect the organization at the word (lexical) level.
- e.g. Patients having problems retrieving the name but its related properties.

Three levels of representation that are needed in speech production: semantic features, lexical nodes, and phonological segments.
Perceptual Analyses of the Linguistic Input

• What enables understanding of the linguistic input?
• Differences in spoken input analysis and written input analysis

Figure: Schematic representation of the components that are involved in spoken and written language comprehension. Notice that the flow of information is bottom up, from perceptual identification to “higher-level” word and lemma activation.
Written Input – Letter Recognition

• The pandemonium model: input is stored as iconic memory.
• A computational model: 3 levels of representation – feature/letter/word


Fragment of a connectionist network for letter recognition. (McClelland & Rumelhart, 1981)
Functional Neuroimaging of Language

- Metabolic correlates of aphasia
- Focal brain lesions from stroke – widespread changes in metabolism, extending to regions outside the lesion areas.

(a) Slice drawn from postmortem tissue
(b) 18-FDG PET

(a) Diagram of lesions and (b) PET scan showing regions of lowered metabolism in the brain of a stroke patient.
Electrophysiology of Language

- The N400: a brain wave related to linguistic processes.
- Increased when semantically mismatched

ERP waveforms differentiate between congruent words at the end of sentences (work) and anomalous last words that do not fit the semantic specifications of the preceding context (socks).
Synaptic Processing and ERP (1/2)

- P600/SPS (the syntactic positive shift): large positive component elicited by words after a syntactic violation

Figure: ERPs from frontal(Fz), central(Cz), and parietal(Pz) scalp recording sites elicited in response to each word of sentences that are anomalous versus those that are syntactically correct.
Syntactic Processing and ERP (2/2)

• LAN (left anterior negativity): negative wave over the left frontal areas when words violates the required word category in a sentence
  
• e.g. “the red eats,” “he mow”

ERPs related to semantic and syntactic processing.
IBM/DARPA Cognitive Computing Project

- SyNAPS
  - [http://www.youtube.com/watch?v=gQ3HEVe1BFY](http://www.youtube.com/watch?v=gQ3HEVe1BFY)
EU Human Brain Project (HBP)

• 1 Billion Euro Project for 10 Years (2013-2022)
  – http://www.youtube.com/watch?v=JqMpGrM5ECo
Cognitive Robot and AI
기호주의 인공지능

- Until roughly 1990, the vast majority of research in AI followed the symbolic paradigm.
- Symbols like *cat* are used to refer to things
- An explanation for this as intelligence was Newell's hypothesis that humans are symbol processing systems.
- Of course, our symbols are a lot more than just *cat*. (This relates to Searle's Chinese Room problem.)
- However, clearly, people do some complicated symbolic reasoning with math, language and logics among other things.
- Symbolic AI is still important to solve the Turing test, and it's still the most popular form of industrial AI.
연결주의 인공지능

- The central connectionist principle is that mental phenomena can be described by interconnected networks of simple and often uniform units.
  - E.g. units in the network could represent neurons and the connections could represent synapses.
Ecological Psychology

- Gibson emphasized the importance of environment and context in learning.
- The more chances they are given to perceive and interact with their environment, the more affordances they discover, and the more accurate their perceptions become.
- Gibson identified four important aspects of human behavior that develop:
  - Agency - self-control, intentionality in behavior
  - Prospectivity - intentional, anticipatory, planful, future-oriented behaviors
  - Search for Order - tendency to see order, regularity, and pattern to make sense of the world
  - Flexibility - perception can adjust to new situations and bodily conditions (such as growth, improved motor skills, or a sprained ankle)
Embodied Cognition

• The aspects of cognition include high level mental constructs (such as concepts and categories) and human performance on various cognitive tasks (such as reasoning or judgment).

• George Lakoff has developed several lines evidence that suggest that people use their understanding of familiar physical objects, actions and situations (such as containers, spaces, trajectories) to understand other more complex domains (such as mathematics, relationships or death).

• Lakoff argues that all cognition is based on knowledge that comes from the body and that other domains are mapped onto our embodied knowledge using a combination of conceptual metaphor, image schema and prototypes.
Common Coding Theory

• Common coding theory is a cognitive psychology theory describing how perceptual representations (e.g. of things we can see and hear) and motor representations (e.g. of hand actions) are linked.

• The theory claims that there is a shared representation (a common code) for both perception and action.

• More important, seeing an event activates the action associated with that event, and performing an action activates the associated perceptual event.

• One of the most direct evidence for common coding in the brain
  – Pattern classifiers that can differentiate based on brain activity whether someone has performed action A or B can also classify, above chance, whether that person heard the sound of action A or B, thereby demonstrating that action execution and perception are represented using a common code.
Perceptual Symbol System

• L. Barsalou
• The nature of human knowledge, and its roles in perception, memory, language, and thought.
• The human conceptual system is grounded in the brain’s modality-specific systems.
Cognitive Robotics

- Cognitive robotics is concerned with endowing a robot with intelligent behavior by providing it with a processing architecture that will allow it to learn and reason about how to behave in response to complex goals in a complex world.
Shakey: Mobile Robot

• Shakey was the first general-purpose mobile robot to be able to reason about its own actions.
• Shakey was developed at the Artificial Intelligence Center of Stanford Research Institute (now called SRI International) in 1966 through 1972.

http://vimeo.com/5072714
Issues and Learning Techniques

• Perception and action and the notion of symbolic representation are core issues to be addressed in cognitive robotics.

• A cognitive robot should exhibit:
  – informational attitudes such as knowledge and beliefs
  – motivational attitudes such as preferences and goals
  – cognitive capabilities such as revising mental attitudes, reasoning, decision making, planning, as well as observing and communicating
  – physical capabilities to move in the physical world, and to interact safely with objects in that world, including manipulation of these objects

• Learning Techniques
  – Learning by imitation
  – Autonomous knowledge acquisition
Personal Robots (PR2)

PR2 fetches beer from the refrigerator
- [https://www.youtube.com/watch?v=c3Cq0sy4TBs](https://www.youtube.com/watch?v=c3Cq0sy4TBs)

PR2 opens doors
- [http://www.youtube.com/watch?v=g-9Yt2570xI](http://www.youtube.com/watch?v=g-9Yt2570xI)
Big Dog (Boston Dynamics)

https://www.youtube.com/watch?v=cNZPRsrwumQ
Little Dog (Boston Dynamics)

http://www.youtube.com/watch?v=nUQsRPJ1dYw
Cogniron EU Project

RA1: Multi-modal dialogues (UniBi)
RA2: Detection and understanding of human activity (UniKarl)
RA3: Social Behaviour and Embodied Interaction (UH)
RA4: Skill and Task Learning (EPFL)
RA5: Spatial cognition and multi-modal situation awareness (UvA)
RA6: Intentionality and initiative (LAAS)

RA7: Systems level integration and evaluation (FhG-IPA)

KE1: Key Experiment 1
The Robot Home Tour (UniBi)

KE2: Key Experiment 2
The Curious Robot (LAAS)

KE3: Key Experiment 3
Learning Skills and Tasks (UniKarl/EPFL/IPA)

WP8: Innovation-related activities (LAAS)
WP9: Training and Mobility (LAAS)
WP10: Project Management (LAAS)
iCub Child Robot

http://bcove.me/yu5e7wpp
TUM James and TUM Rosie
Preparing Bavarian Breakfast

http://www.youtube.com/watch?v=_SIUCrmE8J0
TUM PR2 – Making Popcorn

http://www.youtube.com/watch?v=qxRGAFpbqb0
Cognitive Technical Systems (CoTeSvs) TU Munich + Max Planck + DLR
Cognitive Factory
Cognitive Kitchen
Pepper

https://www.youtube.com/watch?v=osD6O4LAcpo
Telepresence robot

https://www.youtube.com/watch?v=mZ22wi-nyfg
CHAPPIE

https://www.youtube.com/watch?v=HhNshgSYF_M