

Biological Vision and Applications

Module 06-05: Symbolic & Emergent Systems



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Computational modeling of cognition

Two competing paradigms

- Symbolic approach
 - ▶ Motivated by AI research (symbolic logic)
 - ▶ Examples: Logic systems
 - ▶ Knowledge-driven (top-down) approach
- Emergent system approach
 - ▶ Motivated by neurosciences (neural networks)
 - ▶ Examples: Classifiers, Neural networks
 - ▶ Data-driven (bottom-up) approach

Symbolic approach is traditionally known as the “cognitive approach”

Comparison of symbolic and emergent system approaches

Knowledge representation & sharing

- Symbolic approach:
 - ▶ Explicit and formal representation of knowledge
 - ▶ Constructed from atomic symbols and their relations (model)
 - ▶ Humans can understand / contribute
 - ▶ Symbolic systems generally start with human implanted knowledge
 - ▶ Can work from day 1 (without training)
 - ▶ Knowledge can be easily shared across systems
 - ▶ Multiple agents can work with a common shared knowledge-base
- Emergent system approach:
 - ▶ Knowledge implicit in the states of the system (no explicit model)
 - ▶ Cannot be understood / contributed by humans
 - ▶ Knowledge is acquired through training (from data)
 - ▶ Knowledge is strictly private to the system
 - ▶ Can be shared only through explicit communication

Comparison of symbolic and emergent system approaches

Knowledge creation, maintenance & update

- Symbolic approach:
 - ▶ can be created / maintained by humans
 - ▶ Can be engineered in a modular way (knowledge partitions)
 - ▶ Representation is static
 - ▶ Update requires external intervention
 - ▶ Periodic knowledge update
- Emergent system approach:
 - ▶ Knowledge is implicit in the states of the system
 - ▶ Monolithic: Cannot be partitioned
 - ▶ Cannot be engineered
 - ▶ Knowledge gets updated in real-time with interaction with the environment
 - ▶ Continuous knowledge update

Comparison of symbolic and emergent system approaches

Generality and flexibility

- Symbolic approach:
 - ▶ Constructed from atomic symbols and their relations
 - ▶ Can combinatorially generalize (inductive generalization)
 - ▶ Experience “red apple” and “yellow banana”
 - ▶ Conceive the concepts of “yellow apple” and “red banana”
 - ▶ Lacks flexibility – cannot discover new concepts
- Emergent system approach:
 - ▶ Monolithic: cannot generalize
 - ▶ Flexible
 - ▶ Can find new / shifting patterns in data

Comparison of symbolic and emergent system approaches

Mode of reasoning

- Symbolic approach:
 - ▶ Deliberative
 - ▶ Follows a formal process
 - ▶ More reliable: Accuracy can be estimated
 - ▶ Less tolerance to noisy data: brittle
 - ▶ Explainable
 - ▶ Slow
- Emergent system approach:
 - ▶ Intuitive
 - ▶ No formal process
 - ▶ Less reliable: Accuracy cannot be estimated
 - ▶ More tolerance to noisy data: robust
 - ▶ Not explainable
 - ▶ Fast

See table 6.1 in book

How does the human mind work?

Dual process theory

- Symbolic approach: formal, knowledge driven, explainable, accurate, slow
 - ▶ More suitable for deliberations
- Emergent system approach: informal, data-driven, not explainable, inaccurate, fast
 - ▶ More suitable for reactive behavior
- Dual process theory: Human mind uses both the approaches
- How do they interact ?
 - ▶ Parallel model: fast and slow thinking occur simultaneously
 - ▶ ... and may conflict
 - ▶ Default-Interventionist model: fast thinking generates intuitive responses
 - ▶ Subsequent slow thinking processing may or may not deliberate on them

Dual process theory ...

How does the cognitive systems work?

- Most of cognitive systems till date are based on symbolic approach
 - ▶ ... Emergent approach is catching up fast
- Each approach has it's own advantages and disadvantages
 - ▶ Symbolic approach is more suitable for cognitive tasks
 - ▶ Emergent approach is more suitable for perceptual data processing
- A fusion between the two can be the key to build large practical cognitive systems
 - ▶ Bayesian reasoning is an amalgamation of knowledge-driven and data-driven reasoning
 - ▶ “Graph Networks” is yet another approach where neural networks use prior models

Quiz 06-05

End of Module 06-05