Probabilistic Computation and Emotion as Self-Regulation

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Introduction

- A common framework for discussing processes on the neuronal level to the level of conscious thought and reasoning would be useful for reasoning about complex decision-making architectures
- Emotion is often presented as “irrational”, and thus detrimental to the logic-based computational view of cognition, implying a problem for AI
- We will argue that a probabilistic view of computation allows emotion to be viewed as a necessary form of computational self-regulation in complex cognitive architectures

The Bayesian Brain

- The brain needs to make sense of overwhelming amounts of unreliable information
- Observe hidden state of the environment, update belief distributions
- Goal: minimise surprise
- Free energy upper bound on surprise; minimise free energy
- Free energy also upper bound on cost in reinforcement learning

Role of Emotion

- Complex decision-making architectures
  - Information overload, unreliable and conflicting information
  - Different subsystems may produce conflicting output
- Emotion is not thought to directly control decision-making, but is better seen as a higher-level regulatory system
- Coordination of cognitive and physiological subsystems
- Perception, learning, attention, decision-making, memory...

Evolution of Emotion

- Nesse[1] claims the first emotion was simple arousal: heightens awareness, improve reaction time
  - Increased weight to uncertain observations
  - Lowered exploration rate
- More refined emotions followed
- Social emotions relatively new

[1] Nesse, R.M. 1990. Evolutionary explanations of emotions. *Human Nature*. 1, 3 (1990), pp. 261–289.

Emotion and Learning

- Dopamine, acetylcholine, noradrenalin and serotonin have been demonstrated to control learning parameters in the brain[2]
  - Exploration rate, discounting, reward, learning rate
- Expected/unexpected uncertainty
- Bayesian tree search to produce behaviour from conflicting subsystems[3]

[2] Doya, K. 2008. Modulators of decision making. *Nature neuroscience*. 11, 4 (Apr. 2008), 410–6.

[3] Daw, N., Niv, Y. and Dayan, P. 2005. Uncertainty-based competition between prefrontal and dorsolateral striatal systems for behavioral control. *Nature neuroscience*. (2005).

Appraisal Theory

- Appraisal of the situation along a number of objective dimensions gives rise to (some) emotions
- Predictability, Outcome probability and Discrepancy from expectation relate directly to surprise
- Control and Power: probability distributions over action outcomes
- Conduciveness: value in reinforcement learning
  - Probability to reach a state of high value

Conclusion

- A living organism has a complex architecture with often conflicting subsystems that need to work together to produce useful behaviour
- Emotion serves to coordinate and direct cognitive and physiological subsystems
- Appraisal theory presents emotion in a statistical framework, which ties in well with the Bayesian Brain hypothesis
- There is much inspiration to be drawn from how biological cognitive systems use emotion to orchestrate large composite decision-making architectures