the History of the Future of the Bayesian Brain

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Author

Karl J. Friston

- British neuroscientist
- Major in brain imaging
- Famous for *Statistical parametric mapping* (SPM)
Contents of paper

- Introduction
- The Bayesian brain
- Prehistory: functional integration club
- History: optimality, natural selection and value
- The Bayesian paradigm
- Bayesian brain & optimization
- Epilogue
Contents of paper

- Introduction
- The Bayesian brain
- Prehistory: functional integration club (1990)
- History: optimality, natural selection and value (1991)
- The Bayesian paradigm (1994)
- Bayesian brain & optimization
- Epilogue
Characters

Samir Zeki
Horace Barlow
Gerry Edelman
Graeme Mitchison

Peter Foldiak
Peter Dayan
Giulio Tononi
Olaf Sporns
Tim Shallice
Geffrey Hinton

Wooldice
Contents of presentation

- About paper
  - Author
  - Contents of paper
  - Character

- Background knowledge
  - Bayesian statistics
  - Bayesian optimal classifier

- Part I: The rise of Bayesian thinking
  - Functional segregation and integration of brain
  - The notion of optimality

- Part II: The Bayesian Brain
  - Optimal decision
  - Value learning
Background knowledge:
Bayesian statistics
Bayesian statistics

- Classical definition of probability
  - Frequency
  - \( P(\text{event}) = \lim_{n \to \infty} \frac{\text{number of the event}}{\text{number of trial}} \)
  - How to get \( P(\text{event}) \) when \( n = 1 \)?

- Bayesian probability
  - Calculate the probability using data, logic, and hypothesis

- Bayes’ theorem
  \[
  P(A|B) = \frac{P(B|A)P(A)}{P(B)}.
  \]
Bayesian optimal classifier

\[ y = \arg \max_{c_j \in C} \sum_{h_i \in H} P(c_j \mid h_i) P(T \mid h_i) P(h_i) \]

- \( C \_j = \text{class}, \quad h \_i = \text{Hypothesis}, \quad T: \text{training set} \)

- No other classifier can overcome Bayesian optimal classifier.

Bayesian optimal classifier

\[ y = \arg\max_{c_j \in C} \sum_{h_i \in H} P(c_j|h_i)P(T|h_i)P(h_i) \]

- \( C_j = \text{class}, \quad h_i = \text{Hypothesis}, \quad T: \text{training set} \)

Prior probability: \( P(h) \)

\[ y = \arg \max P(.) \]

Brain

B. Won

JS. Jung
Part I:
The rise of Bayesian thinking
Functional segregation / integration

- Regionally specific activations
  - Statistical parametric mapping

- Interactions mediated by effective connectivity
  - Dynamic causal modeling
Notion of optimality

- Brain is optimal in some sense.
  - What is optimized?
  - Information theory: Bayes optimal

- Bayes brain
  - Optimal decision theory
  - Value learning
Part II: The Bayesian brain
Bayesian brain

- **Information theory**
  - maximize the mutual information between sensory input & internal representations

- **Value learning /selection**
  - value or adaptive fitness

- **Free energy minimization**
  - marginal likelihood of a model

- All 3 processes are same thing

- Self organizing system (brain) minimize entropy
Further research of Bayesian brain

- Top-down predictions suppress errors of bottom-up prediction:
  example of minimizing free energy

Research of neuronal infrastructures:
  functional integration
effective connectivity
dynamic causal modeling
Bayesian evidence based modeling