Neural Computational Models for One-Shot Learning

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Outline

- Learning Mechanism
  - Biological Neural mechanism
  - Learning in the cortical sheet
  - One-Shot Learning
- Motivation and Background
- Computational One-Shot Learning Models and Implementation
- Future of One-Shot Learning Models

Learning Mechanism

- Biological Neural Mechanism
  - Dendritic computation
  - Neuromodulation
- Learning in the Cortical Sheet
  - Specific architectural features of 6-layered cortical sheet
  - Unsupervised learning via prediction

Learning Mechanism (contd.)

- One-Shot Learning
  - Faster than Associative learning
  - Human learning in single exposure to stimulus
  - Instead of gradient descent training, continuous weight updates of object templates
  - Implement Bayesian Learning

Motivation and Background

- Survival instinct
- Fast mapping in word learning
- Object Categorization

Computational One-Shot Learning Models and Implementation

- Challenges:
  - Representation: How to model and Categorize?
  - Learning: How many models we acquire?
  - Detection: How do we detect a new image?
- Complexities:
  - Diverse shape and appearance
  - Highly variable appearance
  - Complex model features
  - Almost impossible to model class variability

Computational One-Shot Learning Models and Implementation (contd.)

- Bayesian Model (*Li Fei Fei et al.*)
  - Learning and recognition of categories
  - Limited training examples
  - Ability to learn with minimal supervision
  - Captures features (shape and appearance) of object categories

Computational One-Shot Learning Models and Implementation (contd.)

- Bayesian Model

$$R = \frac{p(\mathcal{O}_{fg}|\mathcal{I},\mathcal{I}_t)}{p(\mathcal{O}_{bg}|\mathcal{I},\mathcal{I}_t)} = \frac{p(\mathcal{I}|\mathcal{I}_t,\mathcal{O}_{fg})\ p(\mathcal{O}_{fg})}{p(\mathcal{I}|\mathcal{I}_t,\mathcal{O}_{bg})\ p(\mathcal{O}_{bg})}$$

$$R \propto \frac{\int p(\mathcal{I}|\boldsymbol{\theta},\mathcal{O}_{fg})p(\boldsymbol{\theta}|\mathcal{I}_t,\mathcal{O}_{fg})\ d\boldsymbol{\theta}}{\int p(\mathcal{I}|\boldsymbol{\theta}_{bg},\mathcal{O}_{bg})p(\boldsymbol{\theta}_{bg}|\mathcal{I}_t,\mathcal{O}_{bg})\ d\boldsymbol{\theta}_{bg}}$$

$$= \frac{\int p(\mathcal{I}|\boldsymbol{\theta})p(\boldsymbol{\theta}|\mathcal{I}_t,\mathcal{O}_{fg})\ d\boldsymbol{\theta}}{\int p(\mathcal{I}|\boldsymbol{\theta}_{bg})p(\boldsymbol{\theta}_{bg}|\mathcal{I}_t,\mathcal{O}_{bg})\ d\boldsymbol{\theta}_{bg}}.$$

I: Object to be categorized
I_t: Training set
O_{fg}: Foreground Category
O_{bg}: Background Clutters
Θ: Parameter for foreground category
$Θ_{bg}$: Parameter for foreground category

Fei-Fei, Li, Rob Fergus, and Pietro Perona. "One-shot learning of object categories." *IEEE transactions on pattern analysis and machine intelligence* 28.4 (2006): 594-611.

Computational One-Shot Learning Models and Implementation (contd.)

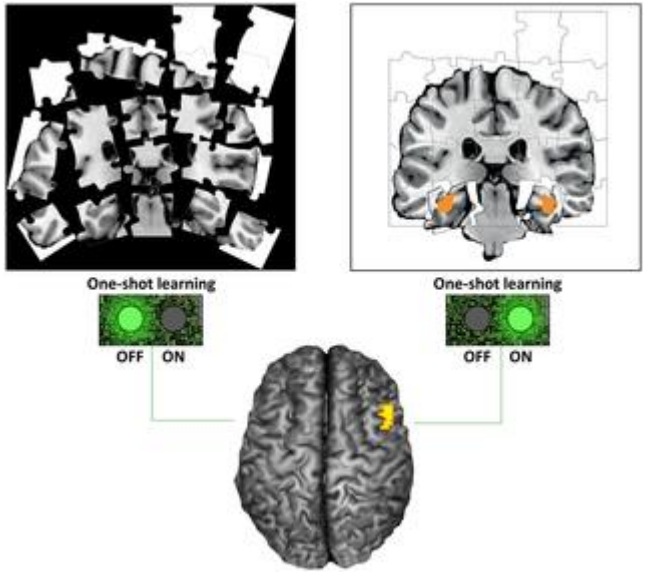
- Learning in Bayesian Model
  - Shape and appearance means are set to the means of the training data itself
  - Learning is halted when the largest parameter change per iteration falls below a certain threshold
  - Background images are not used in learning except for one instance
  - Learning a category takes roughly less than a minute on a 2.8 GHz machine

Computational One-Shot Learning Models and Implementation (contd.)

- Uncertainty in Causal Relationship model of Caltech
  - The relationship between the outcome and the stimulus
  - The more uncertainty in causal relationship between a stimulus and an outcome, the higher the learning rate to resolve the uncertainty
  - The hippocampus is selectively switched on when one-shot learning is predicted to occur, and the ventrolateral prefrontal cortex may act as a switch to turn on and off one-shot learning as required

Computational One-Shot Learning Models and Implementation (contd.)

- Uncertainty in Causal Relationship model of Caltech
  - Researchers analyzed behavioral data and functional magnetic resonance imaging (fMRI)
  - Results revealed that the uncertainty was associated with increased activation of PFC with hippocampus



Weaver, Janelle. "How one-shot learning unfolds in the brain." *PLoS Biol* 13.4 (2015): e1002138.

Future of One-shot Learning Models

- Future of AI combined with machine learning
- Substantial implications for real-world situations such as medical diagnoses, lawsuit cases, and psychiatric diseases, such as schizophrenia
- Memory Augmented Neural Network (MANN) to quickly retrieve data from new inputs

Thank You