IIT Jodhpur

Biological Vision and Applications

Module 03-01: Reasoning

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What is “reasoning”

- We “know” some facts
  - Supplied by others
  - Sensed by some sensors
- We infer unknown facts from the known facts

A simple example:

- Prior knowledge:
  - I need to go to the institute
  - Metro connects my home to the institute
- Inference:
  - Therefore, I take metro

Reasoning paradigms

- In human mind, reasoning is intuitive
- Formalizations
  - Knowledge driven (top-down)
    - Rule-based reasoning
    - Model-based reasoning
    - Case-based reasoning
  - Data driven (bottom-up)

Rule-based reasoning

- Apply some rules on the known facts to "deduce" unknown facts
- Formalized as logic
  - $\forall x : bird(x) \rightarrow fly(x), \forall x : parrot(x) \rightarrow bird(x)$
  - $\Longrightarrow \forall x : parrot(x) \rightarrow fly(x)$
- Also called "deductive" reasoning
- Many flavors
  - Propositional calculus, predicate calculus
  - First order logic, second order logic, ...
  - Descriptions logic
- See Norvig & Russell

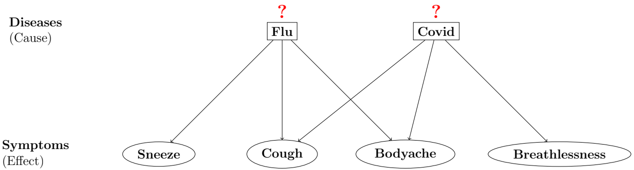
Rule-based reasoning

Strengths and weaknesses

- Major strength:
  - Reasoning is valid
  - If the premises are true, the consequence must be true.
    - Can be proved
- Major weaknesses:
  - Can discover fact implied by known facts
    - Cannot find "new" fact
  - Cannot handle uncertain sensory data
    - If premises are not known or incorrect, the reasoning breaks down

Model based reasoning

- Based on a mental model of the world (diseases and symptoms)
  - What symptoms are caused by a disease



- Doctor "observes" the symptoms (patient / lab reports)
- Doctor needs to infer the disease
  - Checks which model matches the observations

Why deductive reasoning cannot be used ?

- One could frame the rules
  - Sneeze $\wedge$ Cough $\wedge$ Body-ache $\rightarrow$ Flu
  - Cough $\wedge$ Body-ache $\wedge$ Breathlessness $\rightarrow$ Covid
- Why it does not work?
  - Uncertainty of effects: All symptoms for a disease may not appear in a patient
  - Noisy / incomplete data: The patient / lab reports may be incomplete or wrong
  - Degree of symptom: Symptoms may manifest in various degrees (strong/mild)

Matching a model

Exact match vs. approximate match

- Real-world is extremely complex – we lack knowledge
  - Creating an "exact" model of the real world is impossible
- A real-world scenario will seldom match a model
- Model that <u>best</u> explains the observations is accepted as the inference
  - There may be many different ways to define the "best" explanation
- Inferencing by best explanation is known as "abduction"

Abduction

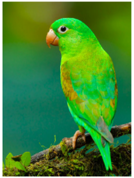
Strengths and weaknesses

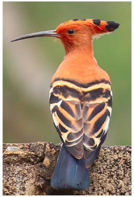
- Strengths
  - Robust against
    - Incomplete knowledge
    - Incomplete/erroneous data
  - Can generate “new” fact
    - Emergent knowledge
    - Observes symptoms – infers disease
- Weaknesses
  - The inference is not “valid”
    - Correctness of inference cannot be proven

Induction

Generalization from observations

- Example: Suppose you observe
  - Parrot is a bird; parrot can fly
  - Crow is a bird; crow can fly
  - Mynah is a bird; mynah can fly
  - ...
- Now we ask: Hoopoe is a bird; can it fly?
- From your earlier observations
  - You create a generalized model of a bird
  - You extrapolate the properties to a new species of bird
- You may get it wrong – penguins cannot fly





Properties of Abduction and Induction

- Abduction and induction result in new facts being generated
  - Not implied by existing knowledge
  - Inferred entities can be of different kind from the observed entities
- The inference of abduction and induction need not be valid
- Robust against uncertainties
  - In the model
  - In the observations
- Useful in processing sensory signals (essentially noisy)
- Induction is a special form of abduction

Case based reasoning

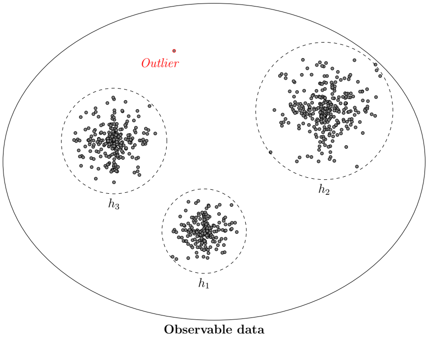
- Try to compare current scenario with scenario earlier observed
  - Infer based on earlier best-matched scenario
- Example
  - Earlier we have seen a winged thing – it could fly
  - We see a new winged thing – it should fly

- Apparently similar to induction
- Difference:
  - In induction, a generic model is formed (even without encountering a new scenario)
    - A new scenario is interpreted with the generic model
  - In CBR, no generic model is formed
    - A new scenario is compared with earlier cases
  - CBR can work with less experiential data

Data driven reasoning

Bottom-up approach

- Uses statistical similarity/associations to discover patterns
- We learn the models from data
- Flexible – no prior models
- Can't handle sparse and noisy data



Data driven reasoning

Example

	Sneeze	Cough	Body ache	Breathlessness
Patient 1	X	X	X	
Patient 2	X	X		
Patient 3		X	X	X
Patient 4		X	X	
Patient 5		X	X	X
Patient 6	X	X	X	
Patient 7		X		X
Patient 8	X		X	
Patient 9	X	X	X	
Patient 10			X	X

- No prior knowledge about diseases
- Patients 1, 2, 6, and 8 have similar symptoms $\rightarrow$ disease 1
- Patients 3,4,5,9 and 10 have similar symptoms $\rightarrow$ disease 2
- Patient 7 has Unique symptom
  - Observation error?
  - A new unknown disease?

- Pros: can discover new patterns (new models)
- Cons: inductive generalization not possible

Which one ?

- Which form of reasoning in used in the human mental processes ?
  - Probably all of them, depending on context
- Which form of reasoning in used in the human perception ?
  - Involves processing of sensory data (noisy)
  - Differences in visual appearance of object instances (uncertainties)
  - Incomplete model of the world (incomplete knowledge)
  - Model based abduction seems to be most appropriate
    - Inexact matching
    - Bayesian reasoning

Quiz

Quiz 03-01

End of Module 03-01