Philosophical Perspectives

CS 6316 – Machine Learning
Fall 2017

OUTLINE

- Overview of Philosophy
- Acquisition of Knowledge and Inference
- Occam's Razor
- Popper's Falsifiability
- Bayesian Inference

Overview

Motivation: Why Philosophy is relevant?

- Relationship between reality (facts) and mental constructs (ideas)
- Epistemology and view of uncertainty
- Inference: from facts to models
- Truth vs utility
- Role of human culture /social structure

Observations, Reality and Mind

- Philosophy is concerned with the relationship between
  - Reality (Nature)
  - Sensory Perceptions
  - Mental Constructs

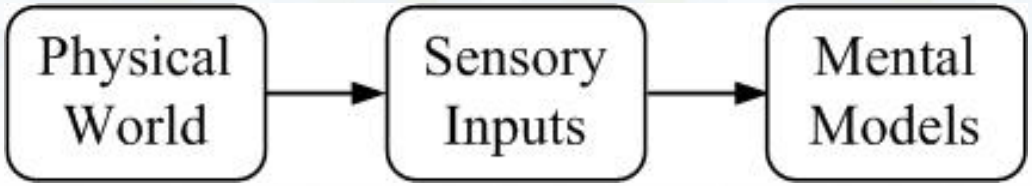
Observations, Reality and Mind

Three Philosophical Schools

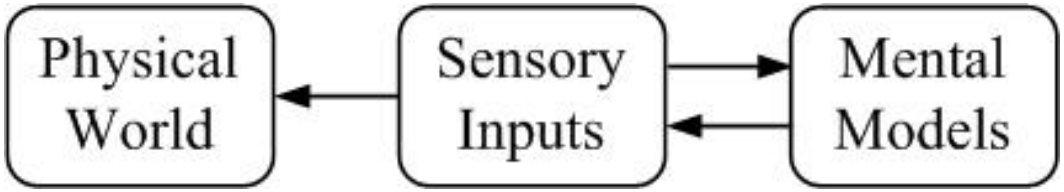
- REALISM
  - Objective physical reality perceived via senses
  - Mental constructs reflect objective reality
- IDEALISM
  - Primary role belongs to ideas (mental constructs)
  - Physical reality is a by-product of Mind
- INSTRUMENTALISM
  - The goal of science is to produce useful theories

Philosophical Schools

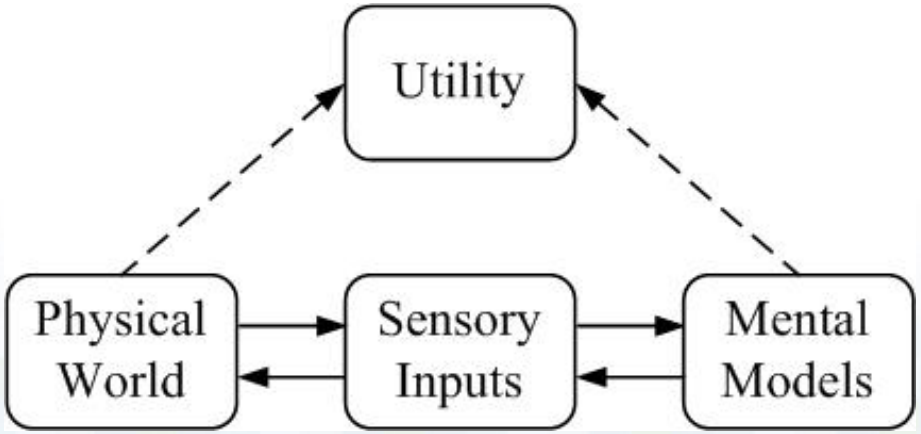
- Realism (materialism)



- Idealism

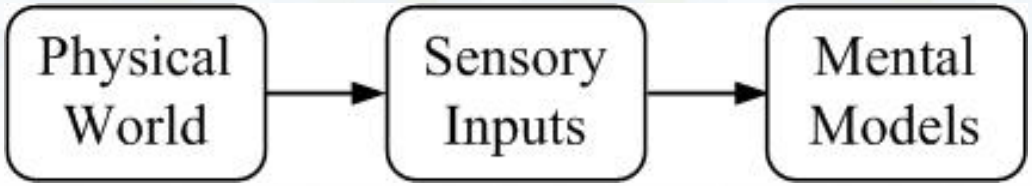


- Instrumentalism



Philosophical Schools: Realism

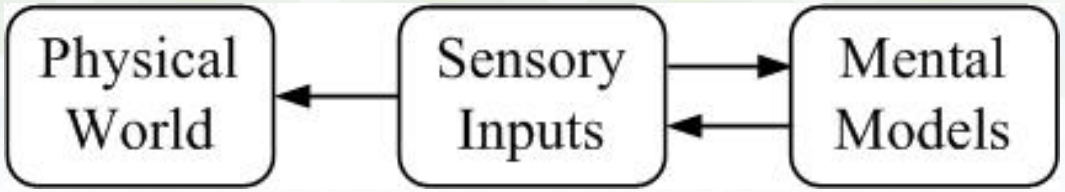
- Realism (materialism)



- Realism is essential to common sense, but *can not* be proven by logic arguments

Philosophical Schools

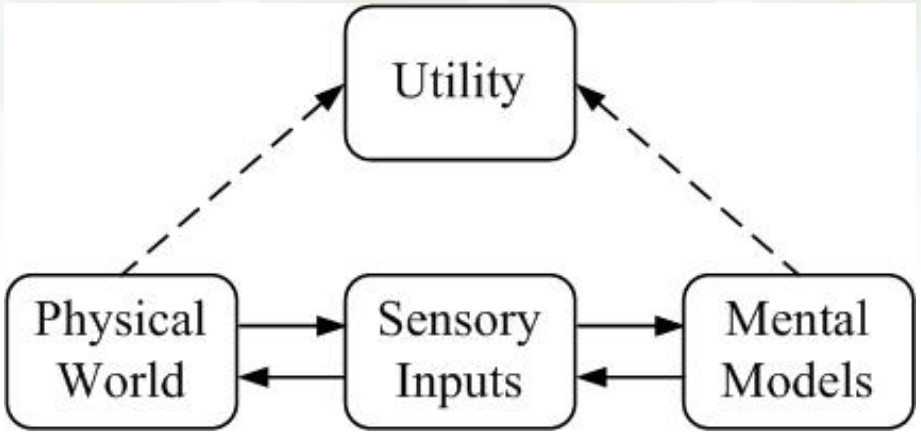
- Idealism



- Idealism states that only mental constructs exist:
- **R. Descartes**: Cogito ergo sum *"I think, therefore I am"*
- **I. Kant**: … *if I remove the thinking subject, the whole material world must at once vanish because it is nothing but a phenomenal appearance in the sensibility of ourselves as a subject, and a manner or species of representation*
- **Hegel** (1770-1831): Reality and Mind are parts of a system. *What ever exists (is real) is rational, and whatever is rational is real*

Philosophical Schools

- Instrumentalism



- Instrumentalist view:
  Whatever is useful is rational and (maybe) real

Science and Philosophy

Three Philosophical Schools

- REALISM
  - Adopted by most scientists and engineers
- IDEALISM
  - Should not be trivialized
- INSTRUMENTALISM
  - The goal of science is to produce useful theories

- Examples …

Realism

- You're looking at a computer screen. Pixels are glowing and changing before your eyes, creating patterns that your mind transforms into words and sentences. The sentences and ideas are in your mind (and mine, as I write them), but *the computer, the server, the pixels, and your eyeballs are all real objects in the real world*

- This is the position of philosophical **realism**: the view that *whatever we perceive is real, truly out there*. It's not an illusion, or "all in our minds"

Idealism

- **Idealism is in *contrast* to Realism**
- **Idealists** argue that the universe is *not* a collection of objects that human minds can perceive (**Realism**), but rather a collection of ideas that human minds can *grasp*. All physical objects, they say, are manifestations, or a kind of physical clothing on top of the idea

Idealism

- When you see a football arc through the air into the receiver's hands, it's following a mathematical trajectory called a parabola. Idealists would say that the ball's path is "manifesting" the abstract idea of a parabola, *so what's really "real" is not the ball or the air or the stadium, but the ideas that all these things represent*

Instrumentalism

- Is a view that the value of scientific concepts and theories is determined not by whether they are literally true or correspond to reality in some sense but *by the extent to which they help to make accurate empirical predictions* or to resolve conceptual problems
- i.e. this theory X exists not because it explains the real world *but because it is useful in helping to make accurate empirical predictions*

Instrumentalism

- Instrumentalism is thus the view that scientific theories should be thought of primarily as tools for solving practical problems rather than as meaningful descriptions of the natural world
- There may nevertheless be a sense in which the **instrumentalist and realist** positions are not as far apart as they sometimes seem. For it is difficult to say precisely what the distinction is between **accepting** the usefulness of a theoretical statement and actually **believing it** to be true

Acquisition of Knowledge and Inference

Acquisition of Knowledge & Inference

- **Inference** ~ the process of deriving a conclusion based on existing knowledge and/or facts (data)
- Inference involves interaction between mental constructs (ideas) and facts:

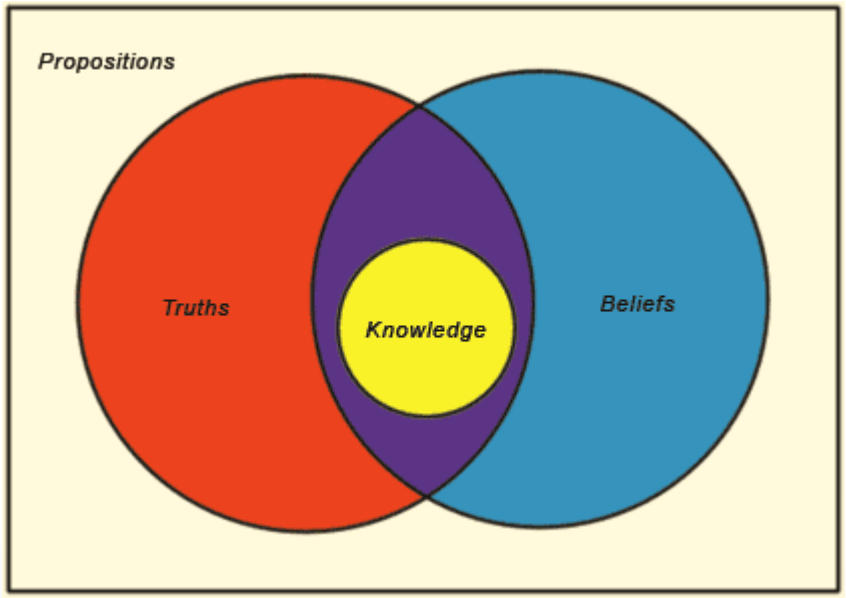
  - emphasis on **ideas** leads to logical inference (that dominated philosophical tradition much of human history)

  - emphasis on **facts** (experimental data) leads to empirical inference (that became popular only in 20th century)
- **Distinction** between logical and empirical inference is not clearly understood in philosophy
- **Predictive Learning** needs empirical inference

Logical Inference

- For idealists: knowledge corresponds to ideas (beliefs) that are consistent with true propositions.

- Plato: Knowledge is what is both true and believed



- Knowledge is justified true belief

Logical Inference and New Knowledge

- **Mathematical Induction** ~ method of proof for an infinite number of statements:

  - initial guess ~ belief

  - the proof (math induction) makes it justified

  Can new knowledge be obtained from existing knowledge alone (via logical reasoning)?

- **Scientific discovery** requires intelligent guessing (plausible reasoning) from observations ~ empirical inference

Inductive Inference

- **Scientific Method** had a major impact on philosophical understanding of **inference**:

  objectivity + repeatability → experimental data

- **Scientific Knowledge** constrained by two factors:

  - assumptions used to form an enquiry

  - empirical observations (experimental data)

- **Emphasis on assumptions** (concepts) leads to first-principle knowledge (deterministic laws)
- **Emphasis on empirical data** leads to extracting knowledge from noisy data, or empirical inference:

  - estimation of reliable models from noisy data

  - fits the **instrumental view**, i.e. the goal is to estimate useful models

Inductive Inference and Generalization

- Any scientific theory ~ **generalization** over finite number of observations (i.e., experiments used to confirm it)
- Impossible to logically justify new theory by experimental data alone

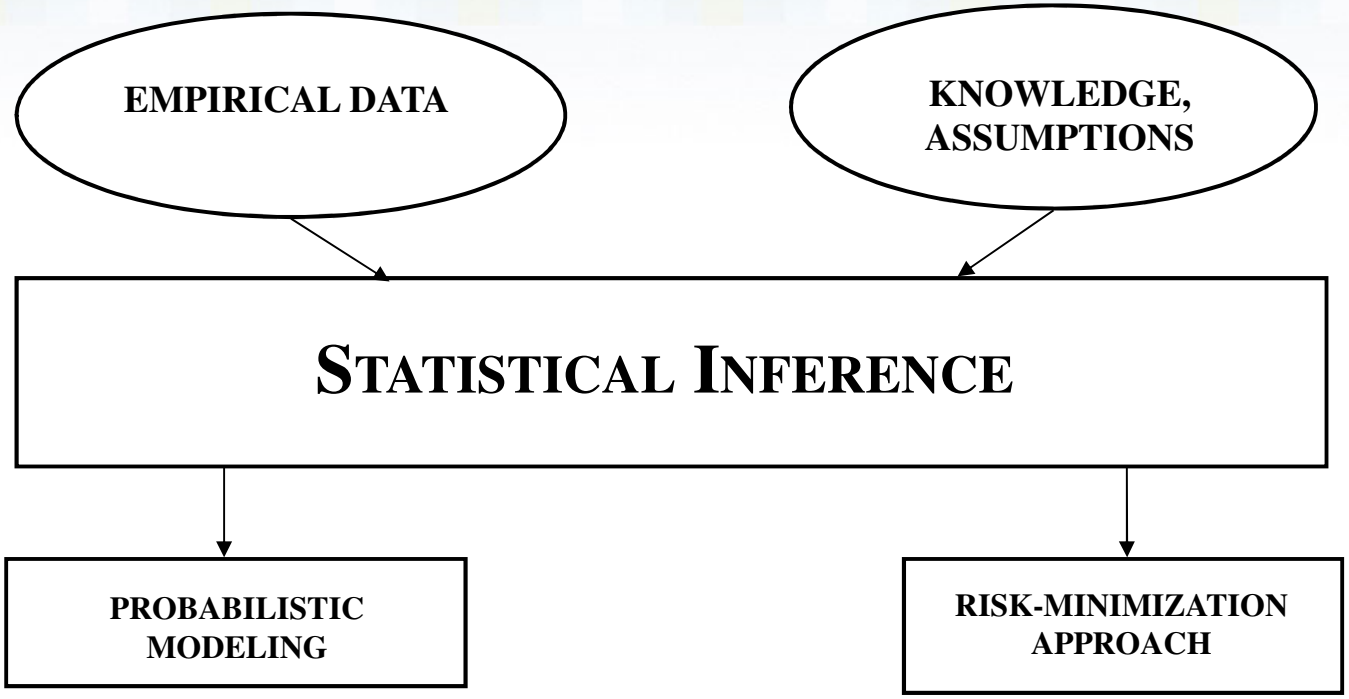
  → need philosophical principle known as
- **inductive inference** = generalization from repeatedly observed instances (observations) to some as yet unobserved instances (Popper, 1953).

  Similar to psychological induction (or learning by association – **Pavlov's** conditional reflex etc.)
- Philosophy of Science and Predictive Learning both are concerned with general strategies for obtaining good (valid) models from data

  - known as **inductive principles** in learning theory

Empirical Inference

- Two approaches to empirical or statistical inference



- General strategies for obtaining good models from data
  - known as **inductive principles** in learning theory

Occam's Razor

Occam's Razor

- Is the idea that more straightforward explanations are, in general, better

- Is often used as a heuristic guide in the development of theoretical models, rather than as a rigorous arbiter between candidate models

Occam's Razor

- Several known versions

1. William of Occam (14-th century):

   entities should not be multiplied beyond necessity

2. Isaac Newton:

   We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances

3. Modern version: **KISS** principle

   All things being equal, the simplest solution tends to be the best one

- Interpretation for model selection

Example Applications of Occam's Razor

Ptolemaic vs Copernican model

- Ptolemaic – *simplest explanation*
  - Earth center of the universe
  - Earth is stationary
  - Other planets travel in the most "perfect" paths – circle
- Copernican
  - No longer an earth-centered universe!

Example Applications of Occam's Razor

Diagnostic application of Occam's Razor in medicine

- A patient's symptoms include
  - Fatigue
  - Cirrhosis (of liver)

  →Most simple explanation (hypothesis) is a *drinking problem* – *simplest explanation*

- Is this the only explanation? Probably not….
  (What if the person doesn't drink?)

Limitations and Misuse of Occam's Razor

- In medicine: Hickam's dictum

- Hickam's dictum is a counterargument to the use of Occam's razor in the medical profession.
- While Occam's razor suggests that the simplest explanation is the most likely (implying in medicine that diagnostician should assume a single cause for multiple symptoms), **Hickum's dictum** is commonly stated: "*Patients can have as many diseases as they damn well please*"

Misuse of Occam's Razor

- If you really wanted to start from a small number of entities, use the letters of alphabet, since you could certainly construct the whole of human knowledge out of them (Galileo)

- Nature (and complex systems) may have its own notion of simplicity:

  'There are more things on earth, Horatio, than are dreamt of in your philosophy' (Shakespeare)

Statistical Applications

- Occam's Razor as a **principle for model selection**
  - Trade-off between fitting error and model complexity
    - Analytic model selection methods
    - Data Compression
    - Variable Selection (feature selection for dimensionality reduction)

- Limitations
  - Successful application requires common sense and good engineering

Famous Quote / Occam's Razor

$$E = MC^2$$

- This is probably the most famous equation ever written
- It also happens to be a fantastic example of Occam's Razor

Popper's Falsifiability

Popper's Falsifiability

- **Karl Popper** (1902 – 1994)
- Background: Vienna in early 20th century
  - New social theories (Marxism, socialism)
  - Psychoanalysis (Freud)
  - Theory of Relativity (Einstein)
- Demarcation Principle
  - A theory which is compatible with all possible empirical observations is unscientific. True theory can be falsified

Popper's Falsifiability

- Characteristic property of scientific method is falsifiability (rather than inductive inference)

- Instrumentalist view: a good theory cannot be regarded as absolute truth

Popper's Falsifiability

- **Popper** stresses the problem of **demarcation** – *distinguishing the scientific from the unscientific*— and makes **falsifiability** the demarcation criterion, such that what is unfalsifiable is classified as unscientific, and the practice of declaring an unfalsifiable theory to be scientifically true is pseudoscience

Falsifiability

- "All swans are white" can be proven false and is hence a falsifiable statement, since evidence of black swans proves it to be false, and such evidence can be provided.

Falsifiability

- For example, the universal generalization that "*All swans are white*" is **falsifiable** since it is logically possible to falsify it by observing a single black swan
- Thus the term **falsifiability** is sometimes synonymous to **testability** (although they are two different things)

- Some statements such as "*It will be raining here in one million years,*" are falsifiable in principle, but *not* in practice!

Conditions for Scientific Theories

Scientific hypothesis must satisfy two conditions:

- **Testability** via empirical data
- **Falsifiability**: it must be falsifiable by some conceivable event (fact)
- **New scientific theory** is a scientific hypothesis that also makes non-trivial (risky) predictions, not explained by old theories

Examples of Falsifiable Theories

- **Statement**: All ferrous metals are affected by magnetic fields – *How do you prove or disprove this?*

- **Newton's Law of Gravitation** (falsified by Einstein's Theory of General Relativity)

- How about pure math, i.e. **Pythagorean theorem**?
  - Non-falsifiable → metaphysical
  - If math is viewed as natural science, then math axioms reflect empirical evidence → may be falsifiable

Examples of Metaphysical Theories

- **Conspiracy theories**:
  - The absence of evidence is claimed as verification of the conspiracy
  - Example: in politics, every day life, social sciences
- **Psychoanalysis** → is not testable or falsifiable
- **Historicism**:
  - There exists a historical (or economic) law that determines the way in which historical events proceed → cannot be falsified

Statistical Use: Connection to Occam's Razor

- **Interpretation of Complexity**:
  complexity ~ degree-of-falsifiability
- Popper justifies Occam's Razor by a more general Principle of Falsifiability:

  For given data set, choose the model explaining this data well (testability) ***and*** having large falsifiability

- → **Discussion**: concepts '*testability*' and '*falsifiability*' lack quantitative meaning

Bayesian Inference

Bayesian Inference

Thomas Bayes(1702-1761)

How to update/ revise beliefs in light of new evidence

Scientific Method:

Collecting empirical evidence (data) E that may be consistent (or inconsistent) with the original hypothesis (model) H_0. Given prior probability P(H_0) calculate posterior probability as:

$$P(H_0|E) = \frac{P(E|H_0)\ P(H_0)}{P(E)}$$

$$P(H_0|E) = \frac{P(E|H_0)\ P(H_0)}{P(E)}$$

- $P(E \mid H_0)$ ~ the ***likelihood*** of observing E given hypothesis H_0

- $P(E)$ ~ the ***marginal probability*** of E, i.e. probability of observing new evidence under all mutually exclusive hypotheses, i.e.
  $P(E) = P(E/H_0)\ P(H_0) + P(E \mid not\ H_0)\ P(not\ H_0)$

- $P(H_0 \mid E)$ ~ the ***posterior probability*** of hypothesis $H0$ given E

Example: Medical Diagnosis

- A patient goes to see a doctor. A test is performed such that:
  - if a patient is sick, the test result is positive (with prob. 0.99)
  - if a patient is healthy, the result is negative (with prob. 0.95).

The patient tests positive.

Assuming that only 0.1 percent of all people in the country are sick,

what are the chances this patient is sick?

Hypotheses: Patient Sick ~ S; Patient Healthy ~ H

Evidence (Data): Test Positive (+); Test Negative (-).

Bayesian probabilities: prior probability P(S) = 0.001

likelihood P(+/S) = 0.99 likelihood P(-/H) = 0.95

The "chance that patient is sick" = the prosterior probability P(S/+):

$$P(S/+) = \frac{P(+/S)P(S)}{P(+)} \qquad P(+) = P(+/H)P(H) + P(+/S)P(S)$$

Calculations yield

$$P(S/+) = \frac{0.99 * 0.001}{0.05 * 0.999 + 0.99 * 0.001} \approx 0.02$$

Example: Bayesian Criminal Justice

Bayesian inference for jury trial: to incorporate the evidence for and against the guilt of the defendant.

Consider the following possible events:

G ~ the defendant is guilty

E ~ the defendant's DNA matches DNA found at the crime scene.

Also denote the following probabilities:

P(E | G) is the probability of observing E assuming G (that the defendant is guilty). This probability is usually taken to be 1.

P(G) is the prior probability: subjective belief of the jury that the defendant is guilty, based on the evidence other than the DNA match. This could be based on previously presented evidence. Let us assume that P(G) = 0.3

P(E) can be found as P(E) = P(G) P(E/G) + P(notG) P(E/notG)

where the probability that a person chosen at random would have DNA that matched that at the crime scene was 1 in a million, i.e., P(E/notG) = 10^^-6.