Lecture 3

The HD Method and Bayesianism

What is Truth?

- In an obvious way science is about finding truths. But what is truth? There is at least two different types of truth:
- Correspondence Truth.
- Coherence Truth.
- The two types of truth are related to two ways of finding truths:
- Check observations of reality.
- Prove statements with logical methods.

The general method

- A general method for handling observations is the Hypothetico-Deductive Method (The HD Method).
- The HD Method and the way of thinking connected to it is a central theme in scientific thinking.
- But not all researchers agree.
- Physics, astronomy, chemistry and biology seem to be the most natural areas for the method.

How it works

- Let us assume that we have a hypothesis H. We want to know if it is true or not.
- H can be a single fact or a general law.
- We have different observations E1, E2, …, En.
- (The observations can be generated by an experiment. They can also exist before H.)
- Does the observation *confirm* or *disconfirm* the hypothesis H?
- The HD Method is a way to find an answer to that question.

A special case: Induction

- Goodman's problem: What hypothesis is supported by the induction?
- We first decide which hypothesis we want to test. (Goodman's problem doesn't occur.).
- A common form: H says that "All objects of type has property B".
- The observations are of the type: E1 = "Object O1 that is of type A has property B", and so on.

The HD Method used for falsification

- We have a hypothesis and want to show that it is false.
- We have a set of observations E1, E2, …, En.
- Assume that there is an observation Ei such that H => not Ei.
- Then Ei falsifies H.

The falsification of The Phlogiston Theory

- Let H be The Phlogiston Theory.
- A consequence of The Phlogiston Theory must be that burning objects get lighter.
- But we can find certain metals that get heavier after burning. Let us call this observation E.
- Since H => not E, we have falsified H.

Supporting hypotheses

- It might not be possible to prove H => not E *directly.* We might need a supporting hypothesis A such that H&A => not E.
- A could be all our *background knowledge.* (Kuhn would call it the paradigm.)
- Eg: H = "The illness is caused by bacteria".
- A = “Penicillin kills bacteria".
- E = “The illness is not cured by penicillin".

Ad hoc hypotheses

- Supporting hypotheses should be well established and secure. Sometimes they are not:
- If H => not E and E has been observed, someone might want to *save* H.
- This can maybe be done by assuming that the implication has the form (H&A=> not E). Then one substitutes A1 for A and get (H&A1 => E).
- If A1 seems very unlikely, if considered by itself, we call A1 an ad hoc hypothesis.

Example: The Phlogiston Theory

- Let H = The Phlogiston Theory.
- E was the observation of a metal getting heavier after burning.
- We can argue that the implication is H&A => not E, where A is "The phlogiston has positive weight".
- We can replace A with A1 = "The phlogiston in the metal has negative weight". Then H&A1 => E!
- But how probable is A1?

A more critical example: Uranus and Neptune

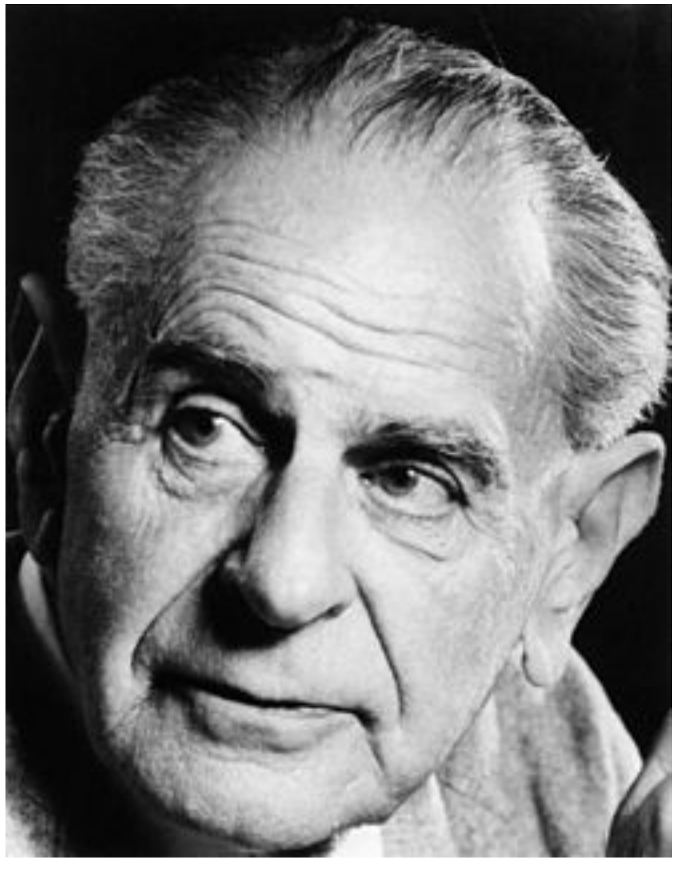
- The planet Uranus was discovered with telescope in 1781.
- In the beginning of the 19th century it was observed that Uranus didn't move in the way Newton's laws predicted.
- Call this observation E and Newton's laws H. Then we have H => not E.
- So Newton's laws were falsified!?
- But wait! The implication is really H&A => not E where A, amongst other thing contained the statement that there are seven planets.
- But if we replace A with A* where A* says that there are unknown planets we don't get a falsification.
- and in 1846 Neptune (the eight planet) was observed!
- So A* wasn't really an ad hoc hypothesis (or?).

The HD Method for falsification. Summary.

- We have a hypothesis and want to test if it is false.
- We use a supporting hypothesis A and deduce H&A => not E.
- We then observe E.
- We have then falsified H.

This is what Popper believed in

- The HD-Method can be used for falsification
- But in some cases we feel that a theory can be *confirmed* by positive experiments
- Popper denied this but the logical positivists thought so
- A simple example is induction
- Now let’s look at a more advanced form of induction



The HD Method used for verification

- Assume that we have a hypothesis H and observations E1, E2, ... , En.
- When can we say that the observations confirm H?
- One possibility is that E1&E2&…&En => H. In that case H is verified.
- But let us assume that this is not the case.

Observations that confirm

- We have H and E1, E2, ..., En.
- Assume that they are all rather improbable.
- Assume that we have a hypothesis A that we already believe is true and that H&A => E1&E2&…&En.
- Then the observations confirm H.

Arguments for and against a hypothesis

- Assume that we have observations E1, E2, ... ,En and a hypothesis H.
- Some of the observations confirm H if they together with a supporting hypothesis Ai gives H&Ai => Ei.
- Other observations disconfirm H if they together with a supporting hypothesis Bk H&Bk => not Ek. Observe that we don't know if Bk is true. We have not falsified H with absolute certainty.

Making a decision

- We form a type of weighted average. If the supporting hypotheses Ai are more natural than the Bk we say that H is strengthened, otherwise it is weakened.
- This works best if we can use probability theory.

A third form of the HD-Method. To chose between hypotheses.

- If we have a set of observations E1, E2, … ,En and a hypothesis H we can try to find supporting hypotheses Ai such that H&Ai => Ei for all i.
- If another hypothesis H* can do the same thing with more natural supporting hypotheses Bi (that is H*&Bi => Ei), then we say that H* is a better hypothesis.

We use probability

- The previous methods were qualitative.
- We now try to do a probabilistic analysis of when observations confirm a hypothesis.
- So we have this problem: Given a hypothesis H and an observation E, when can we say that the observation confirms H?

An important formula

Thomas Bayes 1702-1761

He found an important formula connecting different types of conditional probabilities.

This formula is the basis for so called Bayesian Statistics.

Bayes' formula

- We want to know what the conditional probability P(H|E) is.
- Bayes' formula:
  P(H|E) = P(E|H)P(H) / ((P(E|H)P(H) + P(E| not H)P(not H))
- Alternatively, we can write P(H|E) = P(E|H)P(H) / P(E)
- Which form we use depends on whether we know what P(E) is or not.

Example: Test of medicine

- Let us assume that we have a certain medicine that is supposed to cure a disease. Call the hypothesis that the medicine works H.
- We make an observation. It is that a sick Patient gets well after been given the medicine. Call this observation E.
- Can we decide to what degree E confirms H?

Test of medicine II

- We want to find P(H|E).
- We need to estimate some probabilities in Bayes' formula.
- P(E|H) = 1 seems reasonable.
- P(E| not H) is more complicated. Let us assume that we have the probability 0.25.
- P(H) is even more complicated. Let us start with the guess P(H)=0.5.
- That gives us P(H|E) = 0.8.

Test of medicine III

- Let us now assume that we have the guess $P(H) = 0.1$.
- That gives us $P(H|E) = 0.36$.
- In both cases we find that $P(H|E) > P(H)$.
- We can use this this relation to define strengthening.

Definition of strengthening

- We have a hypothesis H and an observation E.
- We say that E strengthens H if $P(H|E) > P(H)$.
- and we say that it weakens H if $P(H|E) < P(H)$.

Other ways of putting it

- We assume that $0 < P(E) < 1$.
- E strengthens H if $P(E|H)/P(E) > 1$, i.e. $P(E|H) > P(E)$.
- E weakens H if $P(E|H)/P(E) < 1$, i.e. $P(E|H) < P(E)$
- Or we can say it like this:
- E strengthens H if $P(E|H) > P(E|\text{not } H)$.
- E weakens H if $P(E|H) < P(E|\text{not } H)$.

Different views of probability

There are three different ways in which probability can be interpreted.

- Axiomatic: We postulate a set of equally probable *elementary events.* Every other events is expressed as a combination of these events.
- Frequency: The probability for an event is roughly the frequency with which the event will occur in repeated experiments.
- Subjective: We give a measure for the ”probability” of events without giving a formal basis for this measure.

It seems as if the Bayesian view of verification relies on an extensive use of subjective probability. This is a problem since subjective probability is not universally accepted as a stringent scientific concept.

Some more history

Early botany and natural philosophy

von Linné

Early botany and natural philosophy

- Botany becomes a science around mid 17th century.
- It is realized that species probably have *evolved.*
- and fossils seem to indicate that the Earth is probably much older than the Bible says.
- Carl von Linné: Describes the sexual system for the reproduction of plants.
- He creates a system of classification of species that is still in use.
- He places Man close to the apes in the system!
- He proposes a theory that says that the Earth is much older than previously believed and that it has once been totally covered with water.

Early botany and natural philosophy II

- There are continued speculations about the the age of the Earth.
- A model is created where it is assumed that the Earth has once breaked free from the Sun.
- At what rate is the Earth cooling down? An estimate shows that the Earth must be at least 75 000 years old. (A modern estimate is 4,5 billion years old, (miljarder in Swedish).)
- the first theories of evolution.
- Lamarck: Acquired properties can be inherited.

The second revolution: Geology and evolution

Lyell

Darwin

Geology and evolution

- Charles Lyell is considered the father of modern geology.
- He presents the thery of *uniformism* that says that the Earth has developed during a very long time by slow processes which are still at work today.
- Charles Darwin makes his famous journey with *Beagle* during the years 1831-1836.
- In 1859 he publishes *On the Origin of Species.*

Details

- During his trip Darwin becomes convinced the the species have developed.
- Other thinkers, for instance Lamarck, had already come to the same conclusion.
- Darwin found an explanation how and why they had evolved.
- *Natural Selection!*
- But objections where not late to arrive: For instance, a process governed by natural selection would take to much time.
- The discussion continues …