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

- 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.*
- Eg: H = "The illness is caused by bacteria".
- A = “Penicillin kills bacteria".
- E = “The illness is not cured by penicillin”.

This is very important! If A is wrong then the argument does not work.

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

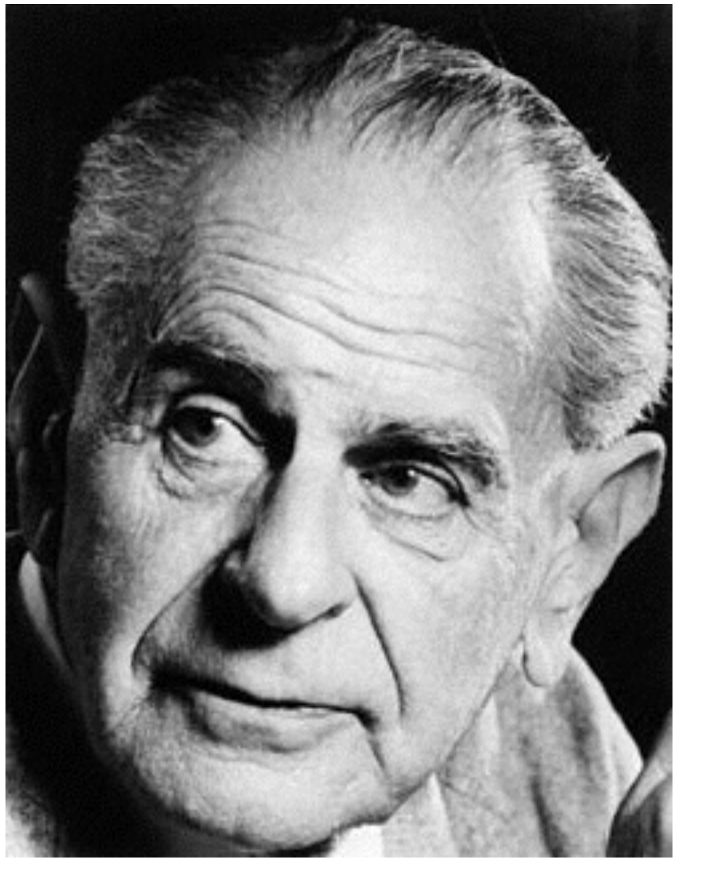
- The planet Uranus was discovered with telescope in 1781.
- In the beginning of the 19th century it was observed that Uranus didn't move in the way Newton's laws predicted.
- Call this observation E and Newton's laws H. Then we have H => not E.
- So Newton's laws were falsified!?
- But wait! The implication 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:
  $P(H|E) = P(E|H)P(H) / ((P(E|H)P(H) + P(E|\text{ not } H)P(\text{not } H))$
- 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.

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 …