Language Technology: Research and Development

Science and Research

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Course registration

- 30 credits advanced NLP courses required
- No students who do not fulfill this can take the course
- We will wait for MT and IR re-examination deadlines, but no longer

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- Already registrered students are assigned a research group, I will wait for MT results before assigning remaining students (at the latest tomorrow)

Research and Development

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- Development – applied knowledge (cf. engineering)

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A Very Short History of (Western) Science

- Philosophy as a precursor of modern science
  - Antiquity: natural philosophy, Aristotle (600–300 BC)
  - Middle ages: scholastic philosophy (1100–1500)
- The scientific revolution (1500–1750)
  - Copernicus, Kepler, Galileo, Newton
  - Observation and experimentation
  - Mathematical models of physical phenomena
- Modern science (1900–):
  - Explosion of new scientific disciplines
  - Natural, social and cultural sciences (arts, humanities)
  - Computational linguistics (1950s)

Philosophy of Science

- Study of scientific methods
  - What distinguishes science from pseudo-science?
  - What is the nature of scientific reasoning?
  - What is a scientific explanation?
  - How does science make progress?
- Two schools:
  - Prescriptive – what scientists should do
  - Descriptive – what scientists in fact do

Deduction and Induction

- Deductive inference

  All computational linguists are smart.
  Ann is a computational linguist.

  Therefore, Ann is smart.

  - Conclusion follows logically from premises
  - Characteristic of mathematical proofs

- Inductive inference

  All computational linguists I have met are smart.

  Therefore, all computational linguists are smart.

  - Conclusion does not follow logically from premises
  - Characteristic of empirical science (and everyday reasoning)

Induction in Science

- Newton's law of universal gravitation (1686)
  - Every point mass in the universe attracts every other point mass with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.
- Fleming's discovery of penicillin (1928)
  - Penicillium mold kills bacteria.
- Dürkheim's study of suicide (1897)
  - Suicide rates are higher in men than women.

Hume's Problem of Induction

- Induction presupposes "uniformity of nature"
- How can we rationally justify this assumption?
  - By deduction – safe but impossible
  - By induction – more plausible but circular
- Conclusion:
  - The principle of induction cannot be rationally justified!

David Hume
(1711–1776)

Verification and Falsification

Karl Popper
(1902–1994)

- Logical empiricism/positivism:
  - Scientific claims must be verifiable
  - Theories are verified inductively
  - Prefer the most probable of competing theories
  - Observations are objective and logically prior to theories
- Popper's alternative:
  - Scientific claims must be falsifiable
  - Theories are falsified deductively
  - Prefer the least probable of competing theories
  - Observations are theory-laden but must be replicable

The Hypothetico-Deductive Method

- Universal claims can be falsified (but not verified) deductively:

  Bob is a computational linguist.
  Bob is not smart.

  Therefore, not all computational linguists are smart.

  "No amount of experimentation can ever prove me right;
  a single experiment can prove me wrong" (Einstein)

- Given hypothesis H with consequence C:
  - If C does not agree with observations, H is rejected (falsified)
  - Else H is provisionally accepted (corroborated)
- Science:
  - Progress through repeated testing, falsification, revision
  - Knowledge fundamentally uncertain ("current best theory")

Inference to the Best Explanation (IBE)

- Another non-deductive inference type

  A window has been broken.
  A valuable painting is missing.

  A thief broke the window and took the painting.

  - Conclusion does not follow logically from premises
  - Alternative explanations are possible
- The principle of parsimony:
  - Prefer a simpler explanation (theory) over a more complex one
  - Darwin's theory of evolution
  - How can this principle be rationally justified?
  - Is IBE a form of induction (or the other way round)?

Probabilistic Reasoning

- Laws and theories involving the notion of probability
  - Every gene has a 50% chance of being inherited (genetics)
  - Suicide rates are higher in men than women (sociology)
  - 90% of all lung cancers are caused by smoking (medicine)
- Inductive inference:

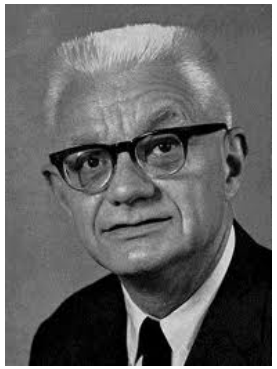
  80% of all computational linguists I have met are smart.

  Therefore, 80% of all computational linguists are smart.
- Deductive inference:

  80% of all computational linguists are smart.
  Ann is a computational linguist.

  Therefore, Ann has an 80% chance of being smart.

Scientific Explanation



Carl G. Hempel
(1905–1997)

- Structured like an argument:
  - A set of premises (explanans)
  - A conclusion (explanandum)

Why did the metal rod expand?

All metal objects expand when their temperature increases.
Fire increases the temperature of objects.
The metal rod was placed in the fire.

Therefore, the rod expanded.

- Hempel's covering law model of explanation:
  - Conclusion follows logically from premises (deduction)
  - Premises are true and include at least one general law

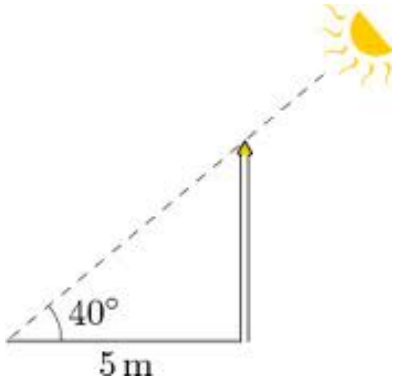
Problems with the Covering Law Model

- The problem of symmetry

  Why is the shadow 5 meters long?

  Light travels in straight lines.
  Laws of trigonometry.
  Flagpole is 4.2 meters high.
  Angle of evelation of the sun is 40°.

  Therefore, the shadow is 5 meters long.



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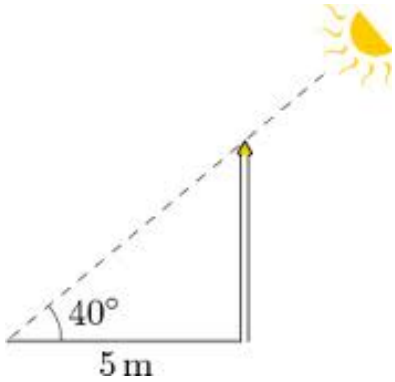

Problems with the Covering Law Model

- The problem of irrelevance

  Why didn't the man become pregnant?

  Anyone who takes birth control pills will not get pregnant.
  The man took birth control pills.

  Therefore, the man did not get pregnant.

- The problem of probabilistic laws

  Why did the man get lung cancer?

  90% of all lung cancers are caused by smoking.
  The man was smoking.

  Therefore, the man got lung cancer.

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  Why didn't the man become pregnant?

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  The man took birth control pills.

  Therefore, the man did not get pregnant.

- The problem of probabilistic laws

  Why did the man get lung cancer?

  90% of all lung cancers are caused by smoking.
  The man was smoking.

  Therefore, his lung cancer was probably caused by smoking.

Scientific Change

Thomas Kuhn
(1922–1996)

- Traditional view:
  - Science advances in a cumulative fashion
- Kuhn's notion of paradigm (normal science)
  - A set of shared theoretical assumptions
  - A set of accepted problems and methods ("puzzle solving")
- Scientific revolutions
  - Accumulation of anomalies lead to crisis and revolution
  - Old paradigm abandoned only if new paradigm available
  - Copernicus, Darwin, Einstein

Beyond Natural Sciences

- Hermeneutics
  - Natural sciences seek explanation
    Why? = What caused it to happen?
  - Social/human sciences seek understanding
    Why? = Why did the agents bring it about?
  - Causality vs. Meaning
- Design science
  - Sciences of the artificial
  - Constructs, models, methods, instantiations
  - Truth vs. Utility
- Is there a universal scientific method?

Hans-Georg Gadamer
(1900–2002)

Herbert Simon
(1916–2001)

Research Ethics

- Traditional view:
  - Scientific knowledge is neither good nor bad per se
  - But scientific knowledge can be used unethically
  - Where does the responsibility of scientists begin and end?
- Ethical considerations in research activities:
  - Experimentation with humans or animals
  - Intellectual dishonesty (fabrication of data, plagiarism)
  - Discrimination and harrassment
  - Many disciplines have specific ethical guidelines

Coming up

- Take home exam
  - Handed out September 22, in the student portal
  - Deadline: September 29
- Research groups
  - Posted on the web page (hopefully complete by tomorrow)
  - First meeting next Wednesday
  - Read the articles (everyone)
  - Prepare to introduce an article (assigned students)
- Only students who fulfill the prerquisites can follow the course! (after the IR deadline)