Methodology of Science/Research

(Logic, Language, and Argumentation)

Michal Peliš

What is *methodology of science (research)?*

- Methods and/or techniques of a specific 'science'
- Philosophy of science

Methods and/or techniques of ...

- Depends on a branch (sociology, psychology, physics, mathematics, logic, philosophy, economy, biology, ...)
- Large variety in topics
- Will help: supervisor / consultant, reading of scientific papers

Philosophy of science

- Thomas Kuhn (normal science, paradigm, scientific revolution)
- Sociology of science (scientific community)
- Scientific **language** and **reasoning** (*logic* and argumentation)

Why we need logic?

- Basis of scientific language
- Analysis of (scientific) reasoning
- (Scientific) argumentation cannot be out of logic
- We need logic for writing a paper

Reasoning – basic forms

- Deduction
- Induction
- Abduction
- Informal reasoning (informal logic)

Deduction – example

Rule	All the beans from this bag are white
Case	These beans are from this bag
Result	These beans are white

Induction – example

Case	These beans are from this bag
Result	These beans are white
Rule	All the beans from this bag are white

Abduction – example

Rule	All the beans from this bag are white
Result	These beans are white
Case	These beans are from this bag

Reasoning – general form

P_1	1^{st} premise
P_2	2^{nd} premise
...	...
P_n	n^{th} premise
C	conclusion (conclusions)

Entailment relation (deductive reasoning)

premises

$\mathbf{P_1}$ and $\mathbf{P_2}$ and ... and $\mathbf{P_n}$

entail

a conclusion

C

Let us write: $\{\mathbf{P_1}, \mathbf{P_2}, \ldots, \mathbf{P_n}\} \mathbf{\models C}$

How to judge a (deductive) reasoning?

- It must be

if P_1 and ... and **P_n** are true, **then C** is true

- It cannot be

P_1 and ... and **P_n** are true **and C** is **not** true

- Any model of premises is a model of the conclusion.
- There is no model of premises that does not model the conclusion (*countermodel*).

How to judge an argument (a general rule)

- Try to find a counterexample (*countermodel*) where premises are valid (*true*) and a conclusion is not valid (*false*).
- If you were successful, the argument is not valid.

Deductive argument – propositional logic

P_1	**T**rue
P_2	**T**rue
...	...
P_n	**T**rue
C	**F**alse

- If premises can be true and a conclusion false, then
- we have a counterexample (countermodel), i.e.,
- the premises do not entail the conclusion (C), i.e., the argument is invalid.

Model and truth – examples of valid (deductive) arguments

1. If it is raining, then streets are wet.
2. It is raining.

Can be concluded

- Streets are wet.

1. If the Moon is from a cheese, then I am a mouse.
2. The Moon is from a cheese.

Can be concluded

- I am a mouse.

Atomic and structured propositions

- Atomic propositions:
  - It is raining.
  - Streets are wet.
- Structured propositions:
  - **If** it is raining, **then** streets are wet. (**implication**)
  - It is raining **and** streets are wet. (**conjunction**)
  - It is raining **or** streets are wet. (**disjunction**)
  - **It is not true that** streets are wet. (**negation**)

Exercise 1

- *Find (atomic) propositions and their connections and display the structure of the following argument:*

There are no chance factors in chess. If there are no chance factors in chess, then chess is a game of pure skill. Therefore, chess is a game of pure skill.

Reasoning

Deductive

- Conclusion does not deliver new info (in comparison with premises)
- *Monotonic*
- Can be formalized

Common

- Premises does not provide complete info
- The role of probability
- Non-monotonic
- Can be often formalized

Monotonicity

If

$$\{P_1 , P_2 , \ldots , P_n \} \models C$$

Then

$$\{P_1 , P_2 , \ldots , P_n , P_{n+1}\} \models C$$

(No matter what kind of proposition P_{n+1} is.)

Sherlock Holmes' argument

A dog was kept in the stalls, and yet, though someone had been in and fetched out a horse, he had not barked ... Obviously the visitor was someone whom the dog knew well...

(*The Adventure of Silver Blaze*)

Informal logic (very generally)

to give an *argument*

means

to offer a set of reasons or evidence in support of a conclusion

(scientific explanation is based on)

Scientific system

- Sets of premises (propositions of a theory, hypotheses, questions)
- Sets of conclusions

Thus:

A scientific system is full of arguments.

The task is:

Give arguments.

Verify them.

Composing of an argument – general rules

1. Distinguish premises and conclusion.
2. Present your ideas in a natural order.
3. Use concrete language (avoid abstract, vague, general terms).
4. Play fair.
5. Stick to one meaning for each term.

Exercise 2

Women and men are physically and emotionally different. The sexes are not *equal*, then, and therefore the law should not pretend that we are.

Examples of valid deductive arguments

(propositional logic)

Valid deductive arguments (I)

1. If A, then B.
2. A.

Therefore

- B.

(*see examples above*)

Exercise 3

- *Write the following argument in the form of modus ponens*:

Since optimists are more likely to succeed than pessimists, you should be an optimist.

Solution (Ex 3)

1. If optimists are more likely to succeed than pessimists, then you should be an optimist.
2. Optimists are more likely to succeed than pessimists.

Therefore

- You should be an optimist.

The meaning of if-then in PL

A	B	If A, then B.
True	True	True
True	False	False
False	True	True
False	False	True

Valid deductive arguments (II)

1. If A, then B.
2. Not B.

Therefore

- Not A.

Exercise 4

- Rewrite Sherlock Holmes' argument in the form of *modus tollens*.

Solution (Ex 4)

1. If the dog did not know the visitor well, then the dog would have barked.
2. The dog did not bark.

Therefore

- The dog knew the visitor well.

The meaning of negation in PL

A	Not A
True	False
False	True

Valid deductive arguments (III)

1. If A, then B.
2. If B, then C.

Therefore

- If A, then C.

1. If A, then B.
2. If B, then C.
3. If C, then D.

Therefore

- If A, then D.

(implication is *transitive*)

Example (*hypothetical syllogism*)

If you study other cultures, then you realize what a variety of human customs there is. If you realize what a variety of human customs there is, then you question your own customs. If you question your own customs, then you become more tolerant. Therefore, if you study other cultures, then you become more tolerant.

Valid deductive arguments (IV)

1. A or B.
2. Not A.

Therefore

- B.

The meaning of disjunction in PL

A	B	A or B
True	True	True
True	False	True
False	True	True
False	False	False

Exercise 5 (*disjunctive syllogism*)

The evils of the world are due to moral defects quite as much as to lack of intelligence. But the human race has not hitherto discovered any method of eradicating moral defects ... Intelligence, on the contrary, is easily improved by methods known to every competent educator. Therefore, ... the progress will have to sought by improvement of intelligence rather than of morals.

B. Russell, *Skeptical Essays*

The word **or** in *exclusive* sense

1. A or B.
2. A.

Therefore

- Not B.

- Exercise:

Give an example of exclusive **or**.

Valid deductive arguments (V)

1. A or B.
2. If A, then C.
3. If B, then D.

Therefore

- C or D.

Exercise 6 (a version of *dilemma*)

We should not build the new weapon system. Building the new system will either leave the balance of power unchanged, or it will be a huge waste of money.

Solution (Ex 6)

Building the new system will either leave the balance of power unchanged (**A**), **or** it will be a huge waste of money (**B**).

If building the new system will leave the balance of power unchanged (**A**), **then** we should not build it (**C**).

If building the new system will be a huge waste of money (**B**), **then** we should not build it (**C**).

Therefore,

we should not build it (**C**, in fact, **C or C**).

Exercise 7

- *Is the following a valid deductive argument? Display the structure of the argument.*

If the roads are icy, the mail is late. The roads are not icy. Therefore, the mail is not late.

Solution (Ex 7)

If A, then B.

Not A.

Therefore

Not B.

(*not valid*)

An example in natural language

1. If it is raining, then streets are wet.
2. It is **not** raining.

Therefore

- Streets are **not** wet.

Find a countermodel, resp. counterexample.
(Can be streets wet without raining?)

Exercise 8

- *Is the following a valid deductive argument? (You might meet it many times.)*

If you want to come at the meeting, you are interested in politics, but you do not want to come, therefore, you are not interested in it.

Exercise 9

- *Is the following a valid deductive argument? Display the structure of the argument.*

If the roads are icy, the mail is late. The mail is late. Therefore, the roads are icy.

Solution (Ex 9)

If A, then B.

B.

Therefore

A.

(*not valid*)

Fallacies

(1) Deductive fallacies

(see Exercises 7 – 9)

- Affirming the consequent (Ex 9)
- Denying the antecedent (Ex 7, 8)

(2) Generalization

- To draw conclusions from too little evidence
- Example: Every businessman is a thief. (Because I know two of them!)
- Problem of *induction – generalizing from incomplete information*
- Statistical induction (set of all units – sample)

Statistical inference

- Statistical methods enable to determine the reliability of observed differences and relationships so that we may make generalizations with a given degree of confidence.

(3) Appeal to ignorance

- Variant of (2)
- A claim is true because there is no evidence that it is not true.
- Example: There is not any concert of Rolling Stones in Prague (because I do not know about it).
- Successfully used in AI – close world assumption

Close world assumption in AI

- Question: *P(a)?*
- There is no file of property *P* belonging to an object *a* in a database, thus,
- Answer: *Not P(a)*.
- Example: Connection in public transportation.

(4) Circle

- Example:

God exists because it says so in the Bible, which I know is true because God wrote it.

(5) Complex question

- Examples:

Did you stop smoking?

Do you like cheese and milk?

- Exercise:

Describe presuppositions of both questions.
(Hint: Imagine positive as well as negative answers to the questions.)

(6) Overlooking alternatives

- Basic question:

To find a *correlation* of two (or more) events (variables)

- Specific question:

To find out *causality* of events (variables)

What is caused by what?

Exercise

There are two statistical results: our region has higher *unemployment* as well as *divorce rate*. Can we conclude a correlation (moreover, causality) from this info?

Causality – counterexamples

- At first sight, it seems that an event X causes an event Y; $X \rightarrow Y$.
- Let us think of another event Z correlated with X and Y.
- Thus, we try to find a counterexample to an alleged (pure) causal relationship of X and Y.

$$Z \rightarrow X \rightarrow Y$$

Evolutionary sequence

Example:

X:= violence in TV

Y:= murder

Z:= ?

X ← Z → Y

Pseudo correlation

(see previous Example)

$$X \rightarrow Z \rightarrow Y$$

Missing middle variable

Example:

X:= sex (male / female)

Y:= results in IQ tests

Z:= gender

$$X \rightarrow Y \leftarrow Z$$

Double cause

Example:

X:= education

Y:= property (financial)

Z:= job position

References

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