CSCM10/CSCM10J Research Methodology

Research Models & Scientific Methods

Dr Scott Yang

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Scope

- Research Process Models
- Research Model: another view

- Scientific Methods
- An alternative pathway

Reasearch Process

Research Process

- Research involves a **systematic** process
- Four common views of the research (Dawson (2005), Baxter (2001)):
  - <u>Sequential</u>
  - <u>Generalised</u>
  - <u>Circulatory</u>
  - <u>Evolutionary</u>

Research process: Sequential

- Research process
  - Series of activities
  - Performed one after another (sequentially)
  - A fixed, linear series of stages

Model 1:

Research process model of Greenfield (1996):

1. Review the field
2. Build a theory
3. Test the theory
4. Reflect and integrate

Research process: Sequential cont.

Model 2:

Sharp et al. (2002):

1. Identify the broad area of study
2. Select a research topic
3. Decide on an approach
4. Plan how you will perform the research
5. Gather data and information
6. Analyse and interpret these data
7. Present the result and findings

Research process: Sequential cont.

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Research process: Sequential cont.

Problems with the sequential process model:

1. Stages not subject specific
2. No repetition or cycles
3. Starting point and order fixed

Research process: Generalised

The stages of the research process highly depending on the subject and nature of the research undertaken:

- Data gathering and data analysis play less significant role for research in pure mathematics and some parts of computer science
- Instead, researchers make conjectures which they prove mathematically
- Or, researchers explore the experimental outcomes and make conjectures based on the evidence
- Each route is still sequential

Research process: Generalised cont.

Example:

1. Identify the broad area of study
2. Select a research topic
3. Decide on an approach
4. Plan the research
5. Gather data and information
6. Analyse and interpret these data
7. Present the result and findings

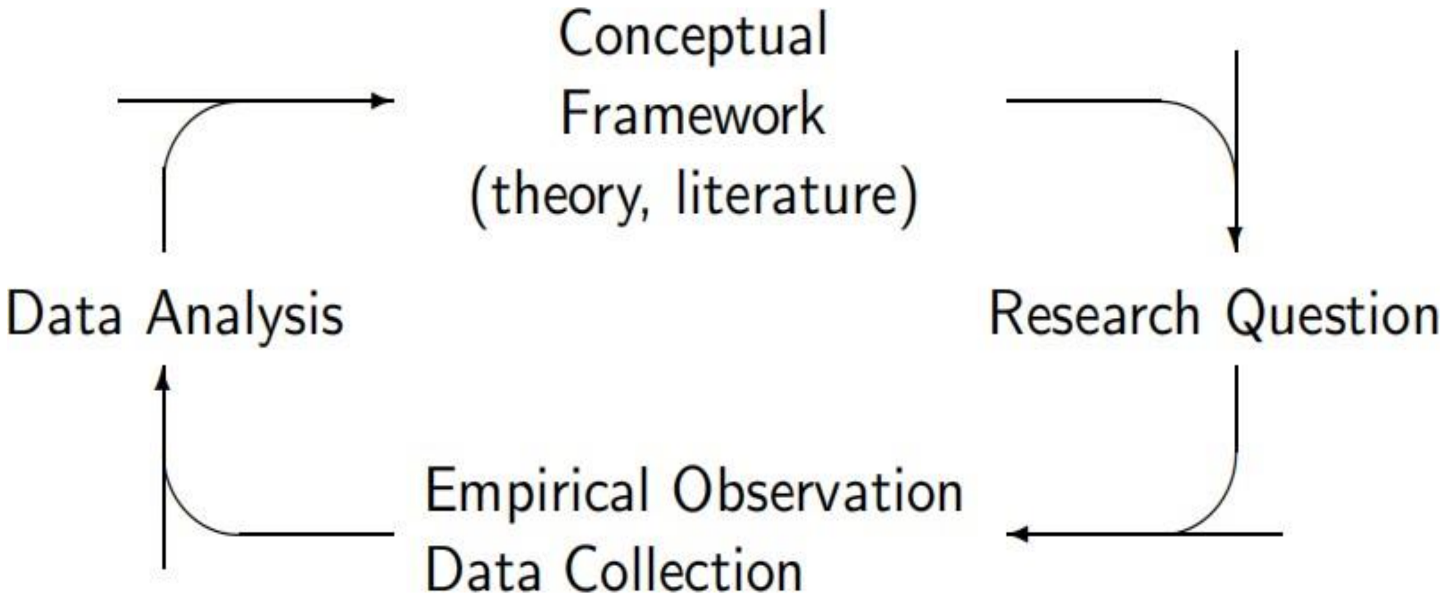
Problems with the generalised process model:

- No repetition or cycles
- Starting point and order fixed

Research process: Circulatory

It recognises that any research is part of a continuous cycle of discovery and investigation that **never ends**

- It allows the research process to be joined at any point
- One can revisit (go back to) earlier stages



Research process: Evolutionary

It recognises that research (methods) itself evolve and change over time

Over time our concept of

- What research questions are admissible
- What extend and methods of data collection are possible, necessary, ethical, or reliable
- What methods and data analysis are available
- What constitutes sufficient evidence for a hypothesis
- What we mean by a systematic approach to research changes

Research process: Evolutionary cont.

As an example, we can consider research in mathematics, its use of computers

- With respect to mathematical proofs we can make the following distinctions:
    1. Proofs created solely by humans: typically ‘sketchy’, omitting steps that are considered ‘obvious’
    2. Computer-aided mathematical proofs: Structure and deductive steps still provided by humans, but certain computations are delegated to a computer
    3. Computer generated and validated proofs: Every step of a proof is conducted and validated by a computer, possibly under guidance by humans

Conclusion

Among the four common views of the research process

- Sequential
- Generalised
- Circulatory
- Evolutionary

- Evolutionary research process model best describes the ‘**Real World**’ research process
- While the evolutionary research process model allows for the ‘rules of the game’ to change over time, this does not imply there are not any rules

Another View

Research models: another view

There is no common agreement on the classification of research models

- Physical models
- Mathematical models
- Mechanical models
- Theoretical models
- Symbolic interactionist models

Physical Models

- It is a physical object shaped to look like the represented phenomenon, usually built to scale e.g., atoms, molecules, skeletons, organs, animals, insects, sculptures, small-scale vehicles or buildings, life-size prototype products
- It can also include three-dimensional alternatives for two dimensional representations e.g., a physical model of a picture or photograph

Mathematical Models

- It refers to the use of mathematical equations to depict relationships between variables, or the behaviour of persons, groups, communities, cultural groups, nations, etc.
- It is an abstract model that uses mathematical language to describe the behaviour of a system
- They are used particularly in the natural sciences and engineering disciplines but also in the social sciences
- Examples include time series, stochastic and path models
- Applications include models of population and economic growth, weather forecasting etc.

Mechanical Models

- They are often an extension of mathematical models
- Mechanical (or computational) models tend to use concepts from the natural sciences, particularly physics, to provide analogues for behaviours
- Many computer-simulation models have shown how a research problem can be investigated through sequences of experiments (pipeline)
- e.g., game models; simulation models; models for predicting storm or tracking a hurricane

Theoretical Models

- It is used loosely to refer to any theory phrased in formal, speculative or symbolic styles
- It generally consist of a set of assumptions about some concept or system
- Often formulated, developed and named on the basis of a system (or a set of systems) that it describes
- They are considered an approximation that is useful for specific purpose(s)
- Theoretical models are often used in biology, chemistry, physics and psychology

Symbolic Models

- These models are used to untangle meanings of symbols that used by individuals
- They are generally simulation models, i.e., they are based on artificial situations, or structured concepts that correspond to real situations
- They are characterised by symbols, change, interaction and empiricism and are often used to examine human interaction in social settings
- It is somewhat against the current trend

Advantages of Modelling

- The determination of **factors** or variables that most influence the behaviour of phenomena
- The ability to **predict**, or forecast the long-term behaviour of phenomena
- The ability to predict the behaviour of the phenomenon when changes are made to the factors influencing it
- They allow researchers to **simplify** the complex processes

Advantages of Modelling cont.

- Allow the study of mathematically intractable problems
- They can be explicit, detailed, consistent, and clear (but that can also be a weakness)
- They allow the exploration of different parameter settings
- Models validated for a category of systems can be used in many different scenarios e.g., reusable in different scenarios
- Models enable researchers to generate unrealistic scenarios as well as realistic ones

Disadvantages of modelling cont.

- Difficulties in validating models
- Difficulties in assessing the accuracy of models
- Models can be very complex and difficult to explain
- Models do not "provide proof"

Scientific Methods

Scientific methods

- Scientists use **observations** and **reasoning** to develop technologies and propose explanations for natural phenomena in the form of **hypotheses**
- Predictions from these hypotheses are tested by **experiment** and further **technologies** developed
- Once it has been established that a hypothesis is sound, it becomes a **theory**
- Sometimes scientific development takes place differently, with a theory first being developed, then gaining support based on its logic and principles

Elements of a scientific method

The essential elements of a scientific method are with the following order:

- Characterisations

Quantifications, observations and measurements

- Hypotheses

Theoretical, hypothetical explanations of observations and measurements

- Predictions

Reasoning including logical deduction from hypotheses and theories

- Experiments

Tests of all of the above

Both characterisations and experiments involve data collection

Intellectual discovery

Knowing what the elements of a scientific method are, does not tell us how to come up with the right instances of these elements

- What predictions does a theory make?
- What is the right hypothesis in a particular situation?
- What is the right experiment to conduct?

These are commonly derived by a process involving

- Deductive reasoning
- Abductive reasoning
- Inductive reasoning

Intellectual discovery: Deduction (1)

Deductive reasoning proceeds from our knowledge of the world (theories) and predicts ‘likely’ observations

Example:

- Assume we know that A implies B.
- A has been observed.
- Then we should also obverse B.

Useful for experiment generation for theories

Example:

Newton’s theory of gravity versus Einstein’s theory of relativity

- Largely make the same predictions
- Both predict that the sun’s gravity should bend rays of light
- However, Einstein’s theory predicts a greater deflection
- Correctness of Einstein’s prediction confirmed by observation in 1919

Intellectual discovery: Deduction (2)

Deductive reasoning is often said not to lead to new knowledge

Note: This implies pure mathematicians largely waste their time:-)

- Seriously underestimates the computational effort involved in the process of deductive reasoning
- Most theories are undecidable
- Thus, establishing that a statement follows from a theory extends our knowledge

Intellectual discovery: Abduction

Abductive reasoning proceeds from observations to causes

Example:

- The phenomenon X is observed.
- Among hypotheses A, B, C, and D,
  only A and B are capable of explaining X.
- Hence, there is a reason to assume that A or B holds.
  - Requires a theory linking A, B, C, D to X

Useful for hypothesis generation

- Hypotheses must then be confirmed / eliminated through further observation
- It is not easy from the outside to decide whether someone uses deduction or abduction
  - **The two are often intertwined**

Intellectual discovery: Induction

Inductive reasoning proceeds from a set of observations to a general conclusion

Example:

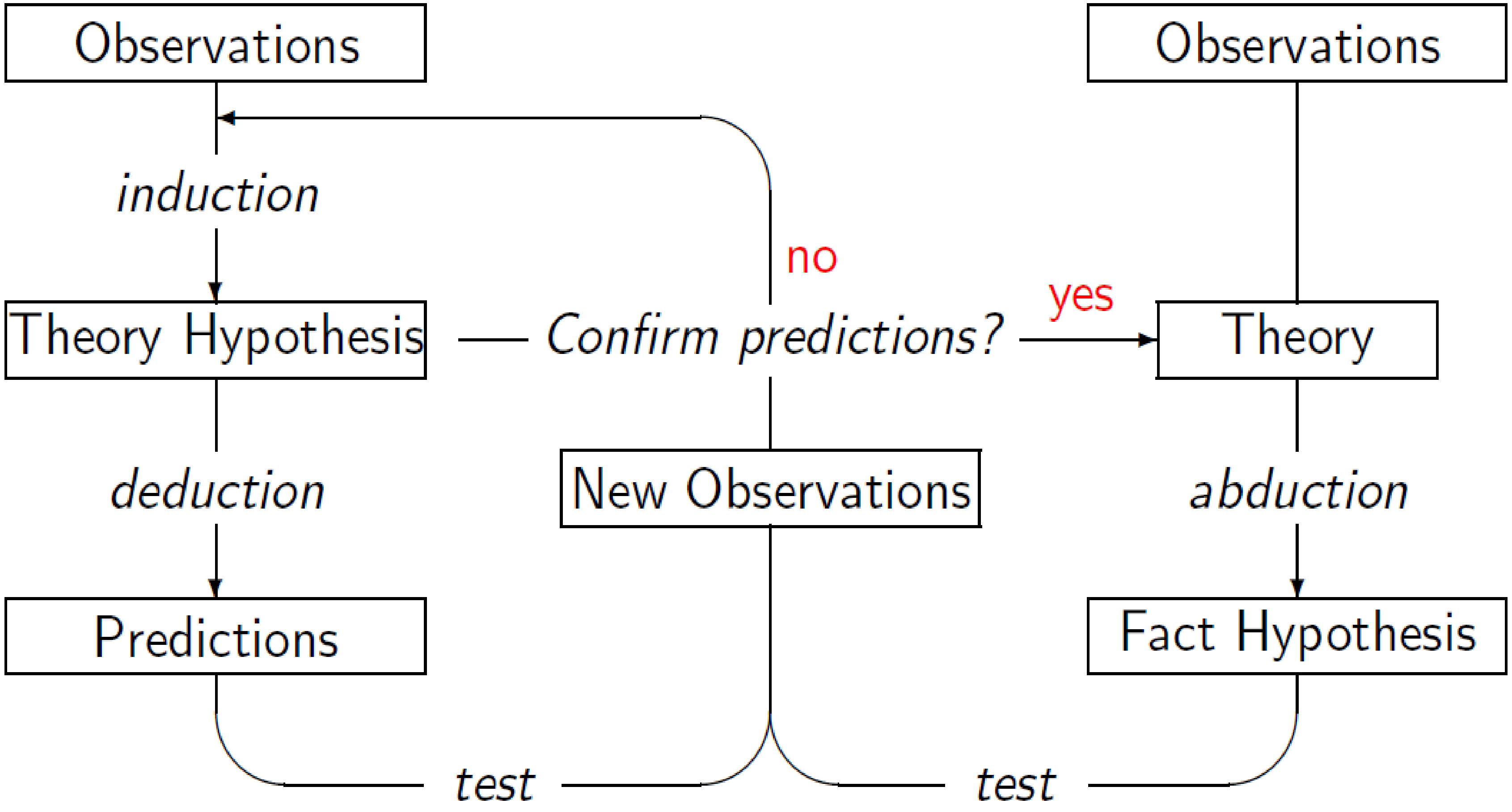
- Tycho Brahe, a 16^{th} century astronomer, collected data on the movement of the Mars
- Johannes Kepler analysed that data which was consistent with Mars moving in an elliptic orbit around the sun

Inductive conclusion:

Mars, and all other planets, move in elliptic orbits around the Sun, with the Sun at one of the focal points of the ellipse

- **A primary tool for theory formation**

A Model



Observations
induction
Theory Hypothesis
deduction
Predictions
test
Confirm predictions?
no
yes
New Observations
test
Observations
Theory
abduction
Fact Hypothesis

Yet Another View

Quantitative vs. Qualitative

Quantitative research methods

- Quantitative research methods
  - Methods associated with measurements (on numeric scales)
  - Stemming from **natural sciences**
  - Used to test hypotheses or create a set of observations for inductive reasoning
  - Accuracy and repeatability of vital importance

Qualitative research methods

- Qualitative research methods
  - Methods involving case studies and surveys
  - Stemming from **social sciences**
  - Concerned with increasing understanding of an entity, rather than an explanation
  - Repeatability usually a problem

Examples

Action research:

- Pursues action (or change) and understanding at the same time
- Continuously alternates between action and critical reflection, while refining methods, data and interpretation in the light of the understanding developed in the earlier cycles

Example: Reflective teaching

Case study:

- In-depth exploration of a single situation
- Usually generates a large amount of (subjective) data
- Should not merely report the data obtained or behaviour observed but attempt to generalise from the specific details of the situation observed

Example: Case study of open-source software development

Examples cont.

Survey:

- Usually undertaken using questionnaires or interviews
- Questionnaire and interview design
- Determination of sample size and sample elements

Experiment:

- Investigation of causal relationships using test controlled by the researcher
- Usually performed in development, evaluation and problem solving projects

Example: Evaluation of processor performance

Summary

- Research Models
  - Two categorizations

- Scientific Methods
  - Two classifications