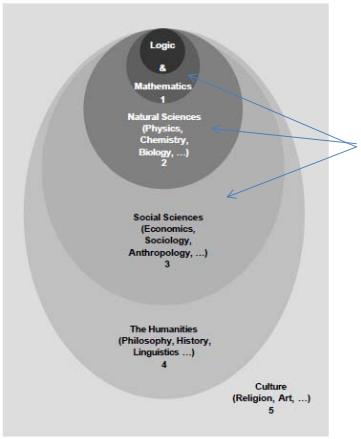
Research / Scientific Methods in Computer Science

Vera Goebel & Thomas Plagemann
Department of Informatics,
University of Oslo

Useful resources & readings:
- http://www.mrtc.mdh.se/publications/0446.pdf
- http://www.cs.iastate.edu/~honavar/research-methods-workshop.html

What is Science?



Sciences – Objects - Methods

SCIENCE	OBJECTS	DOMINATING METHOD
	Simple	*Reductionism (analysis)*
Logic & Mathematics	Abstract objects: propositions, numbers, ...	Deduction
Natural Sciences	Natural objects: physical bodies, fields and interactions, living organisms ...	Hypothetico-deductive method
Social Sciences	Social objects: human individuals, groups, society, ..	Hypothetico-deductive method + Hermeneutics
Humanities	Cultural objects: human ideas, actions and relationships, language, artefacts…	Hermeneutics
	Complex	*Holism (synthesis)*

The Scientific Method

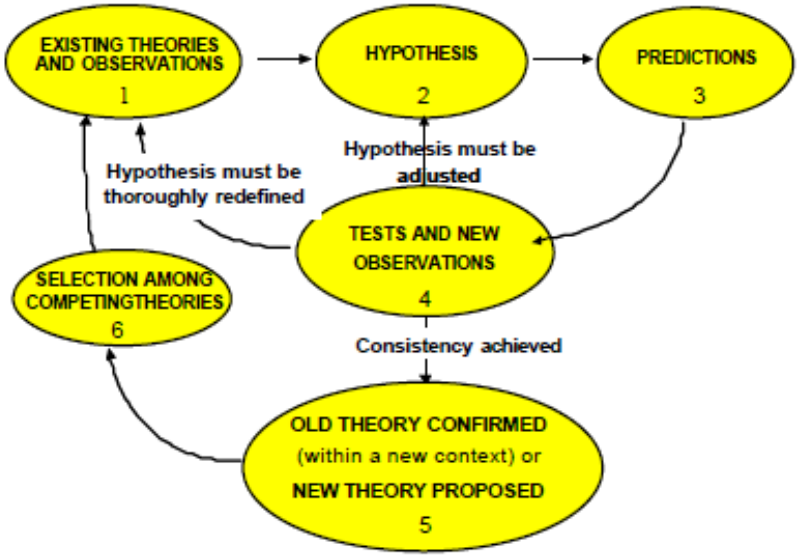
1. Pose the question in the context of existing knowledge (theory & observations).
   - new question that old theories are capable of answering (usually the case), or
   - question that calls for formulation of a new theory.
2. Formulate a hypothesis as a tentative answer.
3. Deduce consequences and make predictions.
4. Test the hypothesis in a specific experiment/theory field.
   The new hypothesis must prove to fit in the existing world-view .
   In case the hypothesis leads to contradictions and demands a radical change in the existing theoretical background, it has to be tested particularly carefully.
   The new hypothesis has to prove fruitful and offer considerable advantages, in order to replace the existing scientific paradigm.

Rule: loop 2-3-4 is repeated with modifications of the hypothesis until the agreement is obtained, which leads to 5. If major discrepancies are found the process must start from the beginning, 1.

5. When consistency is obtained the hypothesis becomes a theory and provides a coherent set of propositions that define a new class of phenomena or a new theoretical concept.
   The results have to be published.

Theory at that stage is subject of process of ”natural selection” among competing theories (6). A theory is then becoming a framework within which observations/theoretical facts are explained and predictions are made. The process can start from the beginning, but the state 1 has changed to include the new theory/improvements of old theory.

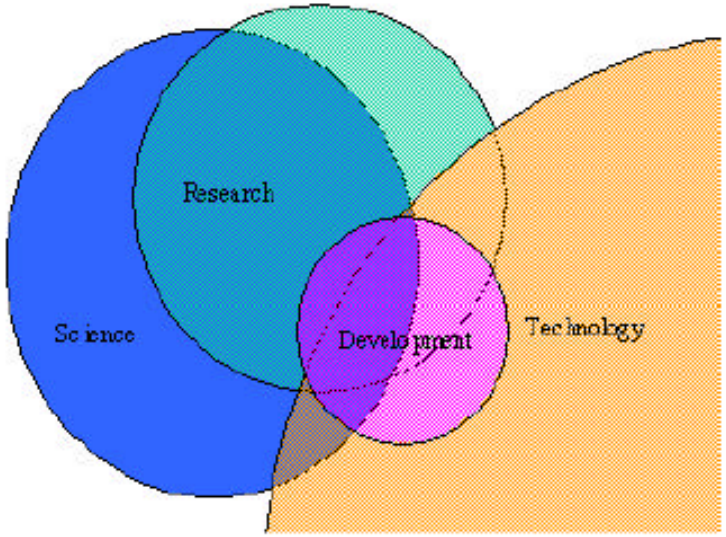
Diagram: Scientific Method



Science – Research - Technology

	Science	Technology
Object	unchangeable	changeable
Principle of motion	inside	outside
End	knowing the general	knowing the concrete
Activity	theoria: end in itself	poiesis: end in something else
Method	abstraction	modeling concrete (complex)
Process	conceptualizing	optimizing
Innovation form	discovery	invention
Type of result	law -like statements	rule-like statements
Time perspective	long-term	short-term

Relations: Science, Technology, ...



What is Computer Science?

Discipline of Computing: *Informatics?*

- Computer Science
- Computer Engineering
- Software Engineering
- Information Systems

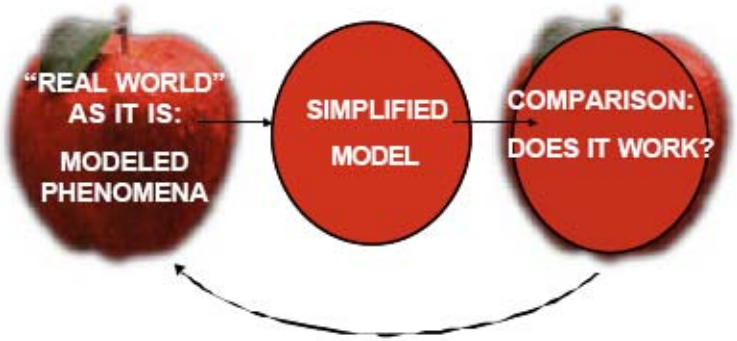
Definitions:

1. The discipline of Computing is the systematic study of algorithmic processes that describe and transform information: their theory, analysis, design, efficiency, implementation, and application.
2. Computer Science is the study of phenomena related to computers, Newell, Perlis and Simon, 1967.
3. Computer Science is the study of information structures, Wegner, 1968, Curriculum 68.
4. Computer Science is the study and management of complexity, Dijkstra, 1969.
5. Computer Science is the mechanization of abstraction, Aho and Ullman 1992.
6. Computer Science is a field of study that is concerned with theoretical and applied disciplines in the development and use of computers for information storage and processing, mathematics, logic, science, and many other areas.

Scientific Methods of Computer Science

- Modeling
- Theoretical Computer Science
- Experimental Computer Science
- Computer Simulation

Modeling - 1



"Real World"	Model
Program	Compiler theory
Artificial Neural Networks	Experiments testing ANN
Computer hardware	Simulation

Modeling - 2

- How to model?
  - What to take into account /neglect? -> features
- Is the model appropriate?
  - Purpose, resolution, level of abstraction
- Aspects of features / behavior?
- Difference to reality?
- Validation? Are the results valid?
- Special constraints

Theoretical CS

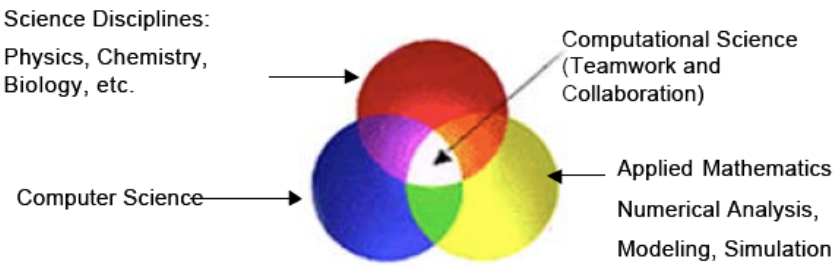
- Logic and Mathematics
  - Objects (axioms)
  - Operations (rules)
- Conceptualization, modeling, and analysis: data models, algorithms, complexity
  - Data model: values of data objects and operations
- Different levels of abstraction
- Efficiency
- Methodologies: iteration, recursion, induction

Experimental CS

- Information processes: formulate phenomena, explanations, testing
- Experiments: theory testing, exploration
  - Theoretical predictions <-> Reality
  - Edsger Dijkstra: "… an experiment can only show the presence of bugs (flows) in a theory, not their absence."

Computer Simulation - 1

- Computional Science



Computer Simulation - 2

- Investigations beyond current experimental capabilities
- Study phenomena that cannot be replicated in laboratories
- Guided by theory and experimental results (feedback loop)
- Simulate phenomena and processes

Thesis Proposal (multiple iterations, 10-15 pages)

6 essential questions that must be answered:

1. What is the problem? (Literature!)
   2 possibilities:
   - new problem -> find a solution
   - known problem & existing solutions -> find a better solution
2. What has been done (by others) already to solve this problem? (Literature!)
3. What is missing? What is not good in other approaches/solutions? (Literature!)
4. What are you planning to do?
5. What will be the result(s) in the end?
6. Rough idea (description) of the way to the end - finished PhD thesis (to reach the goal, i.e. solve the problem)
   includes time plan:
   - what has already been achieved
   - what has still to be done