Research Methods in Computer Science
Lecture 4: Research process models

Ullrich Hustadt

Department of Computer Science
University of Liverpool
Previously . . .

7 Investigation

8 Knowledge

9 Originality
   - Areas of originality

10 Gain

11 What is ‘Research’?
   - Summary
Research process models

- Sequential
- Generalised
- Circulatory
- Evolutionary
All definitions agree that research involves a systematic or methodical process.

Dawson (2005), following Baxter (2001), identifies four common views of the research process:

- Sequential
- Generalised
- Circulatory
- Evolutionary
Research process models: Sequential (1)

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

Example:
Research process model of Greenfield (1996):
1. Review the field
2. Build a theory
3. Test the theory
4. Reflect and integrate
Example:
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 models: Sequential (3)

Greenfield (1996):
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What do you think about this research process model?
What is wrong with it?

(7 minutes group discussion)
Research process models: Sequential (4)

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Problems with the sequential (and generalised) process model:
1. Stages not subject specific
2. No repetition or cycles
3. Starting point and order fixed
The **generalised research process model** recognises that the stages of the research process depend on the **subject** and **nature** of the research undertaken.

**Example:**
Data gathering and data analysis play no role for research in pure mathematics and large parts of computer science. Instead researchers make conjectures which they prove mathematically.

The **generalised research process model** provides alternative routes depending on the **subject** and **nature** of the research undertaken.

But each **route** is still **sequential**.
Research process models: Generalised (2)

Example:

(1) Identify the broad area of study
(2) Select a research topic

In natural sciences:
(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

In mathematics:
(3’) Make a conjecture
(4’) Prove the conjecture

Problems with the generalised process model:

1. No repetition or cycles
2. Starting point and order fixed
The circulatory research process model 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 also revisit (go back to) earlier stages.
Research process models: Evolutionary (1)

- The evolutionary research process model recognises that research (methods) itself evolve and change over time.

That is, 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 are data analysis are available
- What constitutes sufficient evidence for a hypothesis
- What we mean by a systematic approach to research changes
The evolutionary research process model recognises that research (methods) itself evolve and change over time.

As an example, we can consider research in mathematics, in particular, 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. Fully formal, computer generated and validated proofs
   - Every step of a proof is conducted and validated by a computer, possibly under guidance by humans
The **evolutionary research process model** recognises that research (methods) itself **evolve** and **change over time**

**Computer-aided mathematical proofs (1)**

Four colour theorem

*Any planar map can be coloured with at most four colours in a way that no two regions with the same colour share a border.*

Conjectured in 1852 by Guthrie. Proved in 1976 by Appel and Haken. Proof involves a case analysis of about 10,000 cases for which the help of a computer was used.

Proof seems generally accepted, but not by all Mathematician
The evolutionary research process model recognises that research (methods) itself evolve and change over time

Computer-aided mathematical proofs (2)

Sphere packing theorem

Close packing is the densest possible sphere packing.

Conjectured in 1611 by Kepler. Hayes published a proof plan in (1997). Execution of the plan involved solving about 100,000 linear optimisation problems using a computer. The computer files for the related programs and data requires more than 3GB of space

At one point it was suggested that the proof will be published with a disclaimer, saying that it is impossible for a human to check its correctness
Among the four common views of the research process:

- Sequential
- Generalised
- Circulatory
- Evolutionary

the evolutionary research process model best describes the ‘real’ research process.

While the evolutionary research process model allows for the ‘rules of the game’ to change over time, this does not imply there aren’t any rules.

For a young researcher it is best to follow the current established research process.