

RESEARCH PARADIGMS IN COMPUTER SCIENCE

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http://www.eden-study.org/articles/2007/three_paradigms_of_computer_science.pdf

Example: factorial function

// precondition: a non-negative integer (n) is ready to be specified

// postcondition: returns $n! = n \cdot (n-1) \cdot (n-2) \cdot \dots \cdot 1$, with $0! = 1$.

```
int factorial(int n) {  
    int prod = 1;  
    for (int i = n; i > 1; i--) {  
        prod *= i;  
    }  
    return prod;  
}
```

- Can we prove that this function is *correct*?
- What if the function is called with a negative number?
- What if the function is called with a very large number? How *reliable* is the function?

The Rationalist Paradigm

- Computer science is a branch of mathematics, treats programs on a par with mathematical objects, and seeks certain, a priori knowledge about their ‘correctness’ by means of deductive reasoning.
 1. Computers are mathematical machines.
 2. Computer programs are mathematical expressions....They describe with unprecedented precision and in every minutest detail the behavior, intended or unintended, of the computer on which they are executed. ...
 3. Programming is a mathematical activity...its successful practice requires determined and meticulous application of traditional methods of mathematical understanding, calculation and proof.
(Hoare 1986)

The Rationalist Paradigm

- The problem of program correctness: can correctness be defined and evaluated formally? In some cases, Yes:
 - The program finds the factorial of a positive integer
 - The program detects whether the face of person y appears in any given picture
 - The program takes a regular expression (a string of text) and returns a list of World Wide Web documents sorted by their 'relevance' to this expression

The Rationalist Paradigm

- The problem of program correctness: can correctness be defined and evaluated formally? In some cases, No:
 - <http://www.computerhistory.org/atcm/microsoft-word-for-windows-1-1a-source-code/>
 - Will the program never terminate unexpectedly?
 - Will the program restrict unauthorized persons from accessing sensitive data?
 - Will the program execute with visibly identical outcome regardless of the operating system used?
 - Will the program not cause the space shuttle to explode
 - Huh? <http://www.around.com/ariane.html>

The Technocratic Paradigm

- Computer science is a branch of engineering, and including aspects of software engineering, software design, software architecture, software maintenance and evolution, and software testing.
- Reliable knowledge about programs emanates only from experience, whereas certain, a priori 'knowledge' emanating from the deductive methods of theoretical computer science is either impractical or impossible in principle.

Technocratic Paradigm

- The argument of **complexity** demonstrates that deductive reasoning is impractical for large programs.
- "How then do engineers manage to create reliable structures? ... They have a mature and realistic view of what "reliable" means; in particular, the one thing it never means is "perfect." There is no way to deduce logically that bridges stand, or that airplanes fly, or that power stations deliver electricity." (DeMillo et. al 1979)
- Knowledge about programs (i.e., reliability) comes from testing
- Example: <http://www.computerhistory.org/atchm/microsoft-word-for-windows-1-1a-source-code/>

The scientific paradigm

- Computer science is a branch of natural sciences, on a par with “astronomy, economics, and geology” (Newell & Simon 1976).
- Since many programs are unpredictable, or even ‘chaotic’, the scientific paradigm holds that a priori knowledge emanating from deductive reasoning must be supplanted with a posteriori knowledge emanating from the empirical evidence by conducting **scientific experiments**.
- Since program-processes are temporal, non-physical, causal, metabolic, contingent upon a physical manifestation, and nonlinear entities, the scientific paradigm holds them to be on a par with mental processes.

The scientific paradigm

- Experiments with programs go beyond establishing reliability. Computer programs can also be used as tools in discovering and empirically establishing the laws of nature, e.g., through simulations and artificial intelligence
- In scientific paradigm, we test a hypothesis (claim)
 - Algorithm A has a faster running time than Algorithm B
 - Method A is better at identifying faces than Method B
 - Constructing a pillar that partially obstructs a door increases the number of individuals who safely exit a room in the case of a fire.

Research Questions in Software Engineering

- Method or means of development
 - How can we do/create (or automate doing) X? What is a better way to do/create X?
- Method for analysis
 - How can I evaluate the quality/correctness of X? How do I choose between X and Y?
- Design, evaluation, or analysis of a particular instance
 - What is a (better) design or implementation for application X?
 - What is property X of artifact/method Y?
 - How does X compare to Y?
- Generalization or characterization
 - What, exactly, do we mean by X?
 - What are the important characteristics of X?
 - What is a good formal/empirical model for X?
 - What are the varieties of X, how are they related?
- Feasibility
 - Does X even exist, and if so what is it like?
 - Is it possible to accomplish X at all?

Types of Research in Software Engineering

- Procedure or technique
 - New or better way to do some task
- Qualitative or descriptive model
- Empirical model
 - Empirical predictive model based on observed data
- Specific solution*
 - Solution to application problem that shows use of software engineering principles – may be design, rather than implementation
- Answer or judgment
 - Result of a specific analysis, evaluation, or comparison
- Report
 - Interesting observations, rules of thumb

Research articles vs. Review articles

- A *research* article describes an investigation that is centered around a specific hypothesis or an objective
- The hypothesis is tested or the objective is by designing a method or model, collecting and analyzing data, and drawing conclusions using an appropriate and reproducible methodology
- A research article has a reproducible method involving something other than "searching the literature"
- A *review* article is an article that summarizes what others have done in a way that often organizes findings according to specific methods or themes
- When exploring research topics, review articles can be great places to start

Research or Review article?

1. http://www.anefian.com/research/nefian99_embedded.pdf
2. <http://waset.org/publications/7912/face-recognition-a-literature-review>
3. <http://www.sciencedirect.com/science/article/pii/S0160738306001034>
4. <http://dl.acm.org/citation.cfm?id=2335358>