No Silver Bullet

CSCI 5828: Foundations of Software Engineering
Lecture 02 — 01/19/2012

Lecture Goals

- Introduce thesis of Fred Brook’s No Silver Bullet
    - Classic essay by Fred Brooks discussing “Why is SE so hard?”

No Silver Bullet

- "**There is no single** development, in either technology or management **technique**, **which by itself promises even one order-of-magnitude improvement within a decade in productivity, in reliability, in simplicity.**"
  - — Fred Brooks, 1986
- i.e. There is no magical cure for the "software crisis"

Why? Essence and Accidents

- Brooks divides the problems facing software engineering into two categories
  - **essence**: difficulties inherent, or intrinsic, in the nature of software
  - **accidents**: difficulties related to the production of software

- Brooks argues that **most techniques attack the accidents** of software engineering

An Order of Magnitude

- In order to improve software development by a factor of 10
  - first, the accidents of software engineering would have to account for 90% of the overall effort
  - second, tools would have to reduce accidental problems to zero
- Brooks doesn't believe that the former is true…
  - and the latter is nigh impossible because each new tool or technique solves some problems while introducing others

The Essence

- Brooks divides the essence into four subcategories
  - complexity
  - conformity
  - changeability
  - invisibility

- Lets consider each in turn

Complexity (I)

- Software entities are amazingly complex
  - No two parts (above statements) are alike
  - Contrast with materials in other domains
- Large software systems have a huge number of states
  - Brooks claims they have an order of magnitude more states than computers (i.e. hardware) do
- As the size of a system increases, both the number and types of parts increase exponentially
  - the latter increase is the most significant

Complexity (II)

- You can't abstract away the complexity of the application domain. Consider:
  - air traffic control, international banking, avionics software
- These domains are intrinsically complex and this complexity will appear in the software system as designers attempt to model the domain
  - Complexity also comes from the numerous and tight relationships between heterogeneous software artifacts such as specs, docs, code, test cases, etc.

Complexity (III)

- Problems resulting from complexity
  - difficult team communication
  - product flaws; cost overruns; schedule delays
  - personnel turnover (loss of knowledge)
  - unenumerated states (lots of them)
  - lack of extensibility (complexity of structure)
  - unanticipated states (security loopholes)
  - project overview is difficult

Conformity (I)

- A lot of complexity facing software engineers is arbitrary
  - Consider designing a software system to support an existing business process when
    - a new VP arrives at the company
    - The VP decides to “make a mark” on the company and changes the business process
  - Our system must now conform to the (from our perspective) **arbitrary changes** imposed by the VP

Conformity (II)

- Other instances of conformity
  - Having to integrate with a non-standard module interface
  - Adapting to a pre-existing environment
    - and if the environment changes (for whatever reason), you can bet that software will be asked to change in response
- Main Point: **It is almost impossible to plan for arbitrary change;**
  - instead, you just have to wait for it to occur and deal with it when it happens

Changeability (I)

- Software is constantly asked to change
  - Other things are too, however, manufactured things are rarely changed after they have been created
    - instead, changes appear in later models
      - automobiles are recalled only infrequently
      - buildings are expensive to remodel

Changeability (II)

- With software, **the pressure to change is greater**
  - in a project, it is functionality that is often asked to change and **software EQUALS functionality** (plus its malleable)
  - clients of a software project often don't understand enough about software to understand when a change request requires significant rework of an existing system
    - Contrast with more tangible domains
      - Imagine asking for a new layout of a house after the foundation has been poured

Invisibility (I)

- Software is by its nature invisible; and it is difficult to design graphical displays of software that convey meaning to developers
  - Contrast to blueprints: here geometry can be used to identify problems and help optimize the use of space
- But with software, its difficult to reduce it to diagrams
  - UML contains 13 different diagram types (!)
    - to model class structure, object relationships, activities, event handling, software architecture, deployment, packages, etc.

Invisibility (II)

- Hard to get both a “big picture” view as well as details
  - Hard to convey just one issue on a single diagram
  - instead multiple concerns crowd and/or clutter the diagram hindering understanding
- This lack of visualization deprives the engineer from using the brain's powerful visual skills

What about “X”?

- Brooks argues that past breakthroughs solve accidental difficulties
  - High-level languages
  - Time-Sharing
  - Programming Environments
  - OO Analysis, Design, Programming
  - …

Promising Attacks on the Essence

- Buy vs. Build
  - Don't develop software when you can avoid it
- Rapid Prototyping
  - Use to clarify requirements
- Incremental Development
  - don't build software, grow it
- Great designers
  - Be on the look out for them, when you find them, don't let go!

No Silver Bullet, Take 2

- Brooks reflects on No Silver Bullet‡, ten years later
  - Lots of people have argued that their methodology, technique, or tool is the silver bullet for software engineering
    - If so, they didn't meet the deadline of 10 years or the target of a 10 times improvement in the production of software
- Others misunderstood what Brooks calls “obscure writing”
  - e.g., “accidental” did not mean “occurring by chance”;
    - instead, he meant that the use of technique A for benefit B unfortunately introduced problem C into the process of software development

‡ This reflection appears in The Mythical Man-Month, 20th Anniversary Edition

The Size of Accidental Effort

- Some people misunderstood his point with the 90% figure
  - Brooks doesn't actually think that accidental effort is 90% of the job
    - its much smaller than that
- As a result, reducing it to zero (which is effectively impossible) will not give you an order of magnitude improvement

Obtaining the Increase

- Some people interpreted Brooks as saying that the essence could never be attacked
  - That's not his point; he said that **no single technique could produce an order of magnitude increase by itself**
  - He argues instead that **several techniques in tandem could achieve it but that requires industry-wide enforcement and discipline**
- Brooks states:
  - “We will surely make substantial progress over the next 40 years; an order of magnitude improvement over 40 years is hardly magical…”

Quiz Yourself

- Essence or Accident?
  - A bug in a financial system is discovered that came from a conflict in state/federal regulations on one type of transaction
  - A program developed in two weeks using a whiz bang new application framework is unable to handle multiple threads since the framework is not thread safe
  - A new version of a compiler generates code that crashes on 32-bit architectures; the previous version did not
  - A fickle customer submits 10 change requests per week after receiving the first usable version of a software system

Returning to SE Intro

- Lets continue our “Overview of Software Engineering” that was started in Lecture 1
  - This draws on material from Software Engineering: Theory and Practice by Pfleeger and Atlee
    - As such, some material is copyright © 2006 Pearson/Prentice Hall.

What is Software Engineering?

- Simply Put: It is **solving problems with software-based systems**
  - Design and development of these systems require
    - **Analysis**
      - decomposing large problems into smaller, understandable pieces
        - abstraction is the key
    - **Synthesis**
      - building large software systems from smaller building blocks
        - composition is challenging

Solving Problems (I)

- To aid us in solving problems, we apply
  - **techniques**: a formal “recipe” for accomplishing a goal that is typically independent of the tools used
  - **tools**: an instrument or automated system for accomplishing something in a better way, where “better” can mean more efficient, more accurate, faster, etc.

Solving Problems (II)

- To aid us in solving problems, we apply
  - **procedures**: a **combination of tools and techniques** that, in concert, **produce a particular product**
  - **paradigms**: a particular philosophy or approach for building a product
    - Think: “cooking style”: may share procedures, tools, and techniques with other styles but apply them in different ways
    - By analogy: **OO approach** to development vs. **the structured approach**
      - Both approaches use similar things:
        - reqs., design, code, editors, compilers, etc.
      - But think about the problem in fundamentally different ways

Software Engineering: The Good

- Software engineering has helped to produce systems that improve our lives in numerous ways
  - helping us to perform tasks more quickly and effectively
  - supporting advances in medicine, agriculture, transportation, and other industries
- Indeed, software-based systems are now ubiquitous

Software Engineering: The Bad (I)

- Software is not without its problems
  - Systems function, but not in the way we expect
  - Or systems crash, make mistakes, etc.
  - Or the process for producing a system is riddled with problems leading to a failure to produce the entire system
    - many projects get cancelled without ever producing a system
- One study in the late 80s found that in a survey of 600 firms, more than 35% reported having a **runaway development project**. A runway project is one in which the budget and schedule are completely out of control.

Software Engineering: The Bad (II)

- CHAOS Report from Standish Group
  - Has studied over 40,000 industry software development projects over the course of 1994 to 2004.
  - Success rates (projects completed on-time, within budget) in 2004 was 34%, up from 16.2% in 1994
  - Failure rates (projects cancelled before completion) in 2004 was 15%, down from 31% in 1994.
  - In 2004, “challenged” projects made up 51% of the projects included in the survey.
    - A challenged project is one that was over time, over budget and/or missing critical functionality

Software Engineering: The Bad (III)

- Most challenged projects in 2004 had a cost overrun of under 20% of the budget, compared to 60% in 1994
- The average cost overrun in 2004 was 43% versus an average cost overrun of 180% in 1994.
- In 2004, total U.S. project waste was 55 billion dollars with 17 billion of that in cost overruns; Total project spending in 2004 was 255 billion
  - In 1994, total U.S. project waste was 140 billion (80 billion from failed projects) out of a total of 250 billion in project spending

Software Engineering: The Bad (IV)

- So, things are getting better (attributed to better project management skills industry wide), but we still have a long way to go.
  - 66% of the surveyed projects in 2004 did not succeed!

Software Engineering: The Ugly (I)

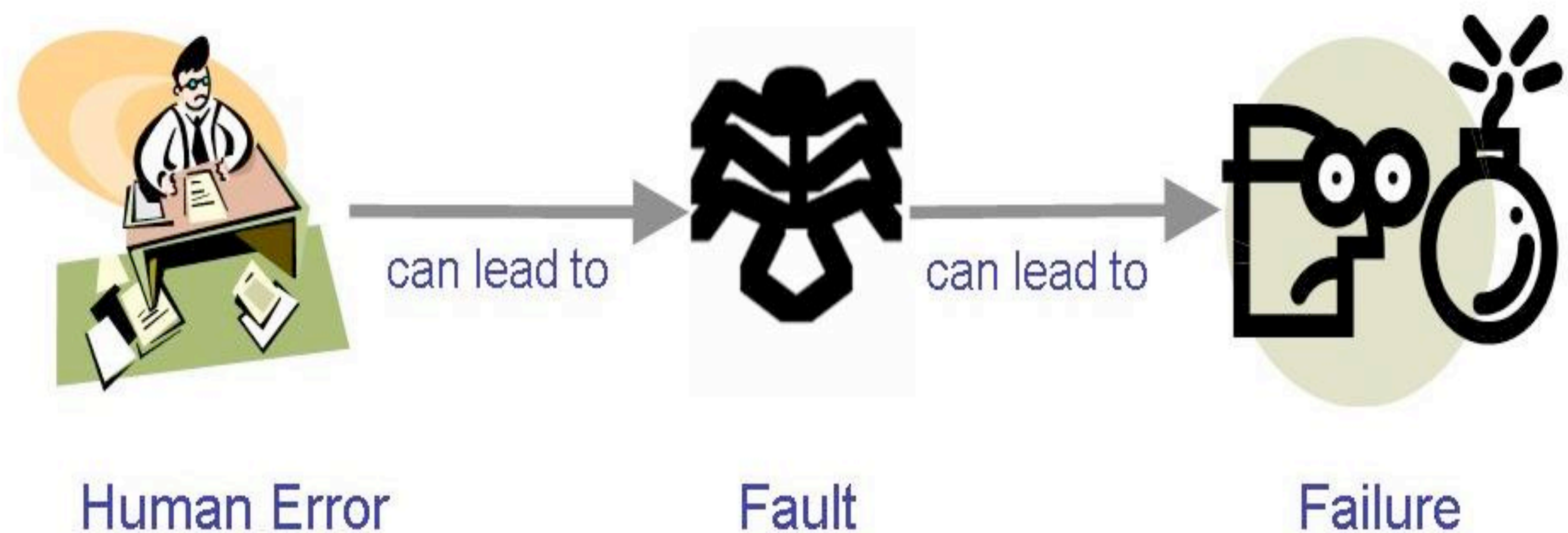
- Loss of NASA's Mars Climate Observer
  - due to mismatch of English and Metric units!
  - even worse: problem was known but politics between JPL and Houston prevented fix from being deployed
- Denver International Airport
  - Luggage system: 16 months late, 3.2 billion dollars over budget!
- IRS hired Sperry Corporation to build an automated federal income tax form processing process
  - An extra $90 M was needed to enhance the original $103 M product
  - IRS lost $40.2 M on interest and $22.3 M in overtime wages because refunds were not returned on time

Software Engineering: The Ugly (II)

- Therac-25 (safety critical system: failure poses threat to life or health)
  - Machine had two modes:
    - “electron beam” and “megavolt x-ray”
  - “megavolt” mode delivered x-rays to a patient by colliding high energy electrons into a “target”
    - Patients died when a “race condition” in the software allowed the megavolt mode to engage when the target was not in position
    - Related to a race between a “type ahead” feature in the user interface and the process for rotating the target into position

Terminology for Describing Bugs

- An error is a mistake made by a human
- A fault is the manifestation of the error in a software artifact
- A failure is a departure from a system's expected behavior



What is Good Software?

- “Good” is often associated with some definition of quality. The higher the quality, the better the software.
- The problem? Many different definitions of quality!
  - **Transcendental**: where quality is something we can recognize but not define (“I know it when I see it”)
  - **User**: where quality is determined by evaluating the fitness of a system for a particular purpose or task (or set of tasks)
  - **Manufacturing**: quality is conformance to a specification
  - **Product**: quality is determined by internal characteristics (e.g. number of bugs, complexity of modules, etc.)
  - **Value**: quality depends on the amount customers are willing to pay
    - customers adopt “user view”; developers adopt “manufacturing view”, researchers adopt “product view”; “value view” can help to tie these together

What is Good Software?

- Good software engineering must always include a **strategy for producing high quality software**
- Three common ways that SE considers quality:
  - The quality of the product (product view)
  - The quality of the process (manufacturing view)
  - The quality of the product in the context of a business environment (user view)
- The results of the first two are termed the “technical value of a system”; The latter is the “business value of a system”

The Quality of the Product

- Users judge a system on external characteristics
  - correct functionality, number of failures, types of failures
- Developers judge the system on internal characteristics
  - types of faults, reliability, efficiency, etc.
- Quality models can be used to relate these two views
  - An example is McCall's quality model
    - This model can be useful to developers: want to increase "reliability" examine your system's "consistency, accuracy, and error tolerance"

The Quality of the Process (I)

- Quality of the development and maintenance process is as important as the product quality
  - The development process needs to be modeled

The Quality of the Process (II)

- Modeling will address questions such as
  - What steps are needed and in what order?
  - Where in the process is effective for finding a particular kind of fault?
  - How can you shape the process to find faults earlier?
  - How can you shape the process to build fault tolerance into a system?

The Quality of the Process (III)

- Models for Process Improvement
  - SEI's Capability Maturity Model (CMM)
  - ISO 9000
  - Software Process Improvement and Capability dEtermination (SPICE)

Business Environment Quality (I)

- The business value being generated by the software system
  - Is it helping the business do things faster or with less people?
    - Does it increase productivity?
- To be useful, business value must be quantified

Business Environment Quality (II)

- A common approach is to use “return on investment” (ROI)
- Problem: Different stakeholders define ROI in different ways!
  - Business schools: “what is given up for other purposes”
  - U.S. Government: “in terms of dollars, reducing costs, predicting savings”
  - U.S. Industry: “in terms of effort rather than cost or dollars; saving time, using fewer people”
- Differences in definition means that one organization’s ROI can NOT be compared with another organization’s ROI without careful analysis

Software Engineering: More than just Programming

- It should now be clear that software engineering is more than just
  - programming, data structures, algorithms, etc.
- It takes advantage of these very useful computer science techniques but adds
  - quality concerns
    - testing, code reviews, validation and verification of requirements
  - process concerns
    - Are we using the right software life cycle? Are we monitoring our ability to execute the process? Are we consistent? Are we getting better?
  - reliance on tools, people, and support processes
    - debugging, profiling, configuration management, deployment, issue tracking

Summary

- In this lecture, we discussed
  - Brooks's definition of a silver bullet
    - A single tool or technique that by itself produces an order of magnitude improvement in the production of software
  - and his argument for why there is no silver bullet for software engineering
- We continued our introduction to the field of software engineering
  - Additional definitions and concerns
  - Challenges faced by the field
  - The importance of quality assurance and why it is difficult to define "quality" for software engineering

SE Conferences

- International Conference on Software Engineering (ICSE)
  - http://www.icse-conferences.org/
- International Symposium on the Foundations of Software Engineering (FSE)
- Automated Software Engineering
- Many, many more; See for instance
  - http://www.sigsoft.org/conferences/listOfEvents.htm
  -

Professional Societies

- For Computer Science in general
  - ACM: Association for Computing Machinery
    - http://www.acm.org/
  - IEEE Computer Society
    - http://www.computer.org/
- For Software Engineering
  - ACM Special Interest Group on Software Engineering (ACM SIGSOFT)
    - http://www.sigsoft.org/

SE Journals

- The Big Two
  - ACM Transactions on Software Engineering and Methodology
    - http://tosem.acm.org/
  - IEEE Transactions on Software Engineering
    - <http://www.computer.org/portal/web/tse>
- Papers are also available at ACM's and IEEE's digital libraries
  - ACM Digital Library: http://dl.acm.org/
  - IEEE Digital Library: http://www.computer.org/portal/web/csdl

SE-Related Sites/Blogs

- A great combination: **a good developer with a blog**
  - loudthinking.com; inessential.com; http://daringfireball.net/
  - http://joelonsoftware.com; http://ridiculousfish.com/blog/posts.html
  - http://www.tbray.org/ongoing/; scripting.com; http://blog.wilshipley.com/
  - http://jeff-vogel.blogspot.com/; http://notch.tumblr.com/
- More general: slashdot.org; stackoverflow.com; semat.org
- **Humor**:
  - xkcd.org, The Order of the Stick, thedailywtf.com
- Please send me others that you find useful

Coming Up Next

- Lecture 3: Introduction to Software Life Cycles
- Lecture 4: Introduction to Concurrency
  - Chapter 1 of the JVM book