No Silver Bullet

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Lecture Goals

- Introduce thesis of Fred Brook's No Silver Bullet
  - Classic essay by Fred Brooks discussing "Why is SE so hard?"
  - Available at link below:
    - No Silver Bullet

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 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 for an existing business process and 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: Its 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

The Size of Accidental

- 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 argued 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: Its about **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
    - procedure for thickening a sauce without causing it to curdle
  - **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
    - Example: OO approach to development vs. the structured approach

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
  - How many computers do you have in your home?
  - How many times do you interact with a software-based system each day?

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

Software Engineering: The Bad (IV)

- 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
- So, things are getting better (attributed to better project management skills industry wide), but we've still got 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
- Leap-year bug
  - A supermarket was fined $1000 for having meat around 1 day too long on Feb. 29, 1988
- Denver International Airport
  - Luggage system: 16 months late, 3.2 billion dollars over budget!

Software Engineering: The Ugly (II)

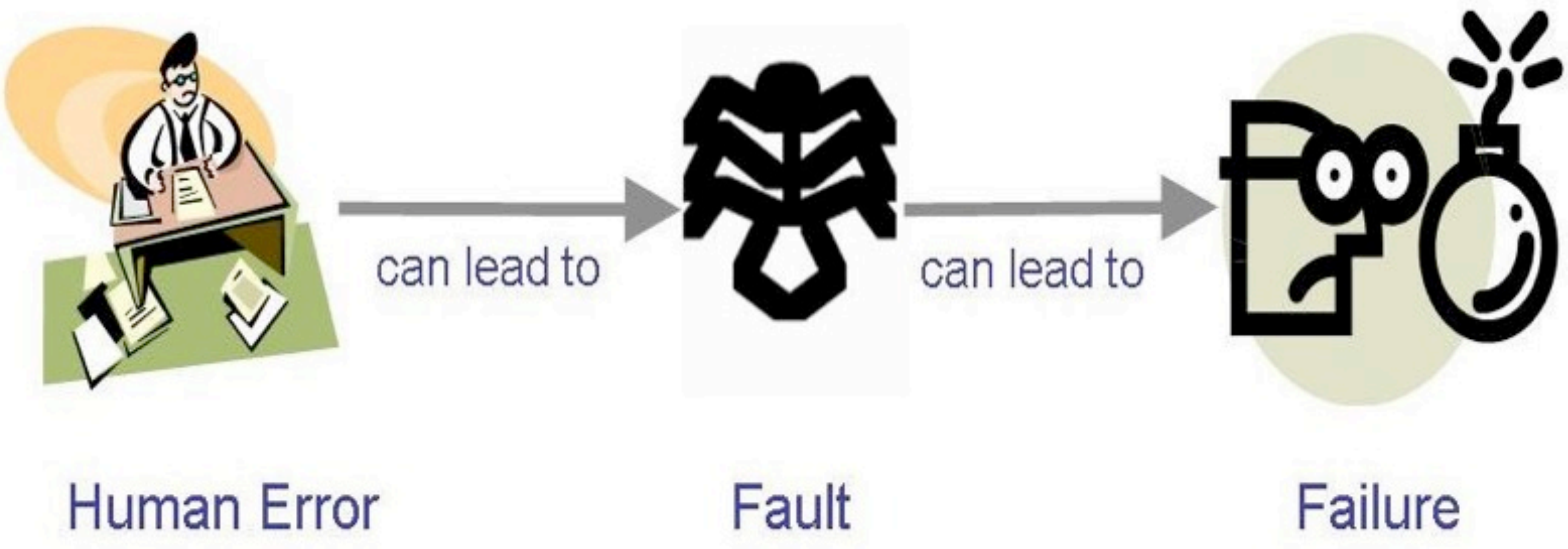
- IRS hired Sperry Corporation to build an automated federal income tax form processing process
  - An extra $90 M was needed to enhance the original $103 M product
  - IRS lost $40.2 M on interests and $22.3 M in overtime wages because refunds were not returned on time

Software Engineering: The Ugly (III)

- 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

What is Good Software?

- Many different definitions of quality!
  - **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

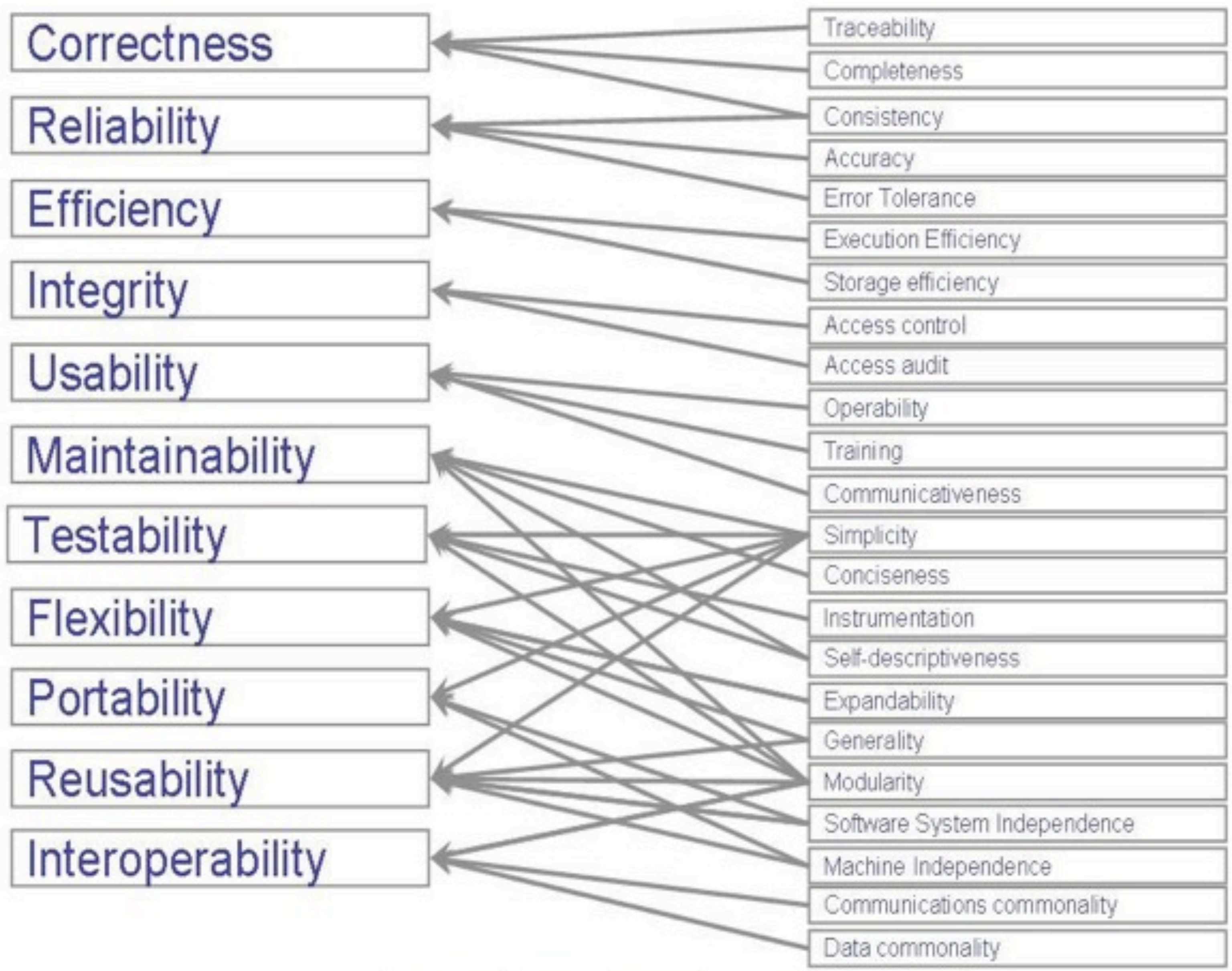
What is Good Software?

- 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”

McCall's Quality Model



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”

Business Environment Quality (III)

- Differences in definition means that one organization's ROI can NOT be compared with another organization's ROI without careful analysis

SE-Related Sites/Blogs

- slashdot.org; joelonsoftware.com
- http://www.tbray.org/ongoing/
- stackoverflow.com; loudthinking.com
- Humor:
  - xkcd.org, The Order of the Stick, thedailywtf.com
- Please send me others that you find useful

Coming Up Next

- Lecture 3: Pleasing Your Customer
  - Chapter 1 of Pilone & Miles
- Lecture 4: Introduction to Concurrency
  - Chapter 1 of Magee and Kramer