Software for Dependable Systems

EECS 4315

www.cse.yorku.ca/course/4315/

Daniel Jackson, Martyn Thomas, and Lynette I. Millett, editors. *Software for Dependable Systems: Sufficient Evidence?* The National Academies Press. 2007.

Daniel Jackson

- Professor at MIT.
- MA in Physics from Oxford University in 1984.
- PhD in Computer Science from MIT in 1992.

Source: people.csail.mit.edu/dnj

Martyn Thomas

- British independent consultant and software engineer.
- Visiting professor at the Oxford University.
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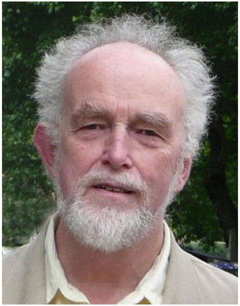
- Fellow at the Royal Academy of Engineering.



Source: Twitter

Lynette I. Millett

- Director of the Forum on Cyber Resilience at the National Academies.
- MSc in Computer Science from Cornell University.

Source: LinkedIn

Slides

The remaining slides are based on slides by Daniel Jackson which can be found at the `http://people.csail.mit.edu/dnj/talks/depcert07/depcert07.pdf`.

Concerns

- Growing role of mission-critical software,
- risks of undependable software,
- high cost of development, and
- uncertainty about value of certification.

A big question

How can software be made dependable in a cost-effective manner?

What We Know

Extent of failures to date:

- software has already resulted in critical system failures,
- leading to death, injury and major economic loss.

What We Know

Roots of failure:

- bugs in code account only for 3% of failures blamed on software,
- most failures blamed on interactions with operators and environment, and
- often poor understanding of requirements.

What We Know

Development strategies:

- building dependable software is difficult and costly,
- quality is highly variable,
- certification regimes and standards have mixed record, and
- organizational culture has dramatic effect.

What We Don't Know

Incomplete and unreliable data about:

- extent and frequency of software failures,
- efficacy of development approaches, and
- benefits of certification schemes.

What We Don't Know

Consequences:

- mandating particular process does not guarantee dependability,
- avoid being too prescriptive about particular tools or techniques,
- put in place mechanisms for collecting industry-wide evidence, and
- make evidence focus of dependable system development.

Notable Accidents

Injury and loss of life:

- Korean Air 747 in Guam, 200 deaths (1997),
- 30,000 deaths and 600,000 injuries from medical devices (1985-2005)
  perhaps 8% due to software?

Major economic loss:

- Code Red worm, \$2.75 billion in damage.

Near Misses

Critical application domains:

- Palmdale air-traffic control outage, 800 flights disrupted (2004), and
- blackout in Northeast (2003).

Widespread use of invasive devices:

- 200,000 pacemaker recalls due to software (1990-2000), and
- 23,900 Prius cars affected by software recall (2005).

Centralization leads to single point of failure:

- pharmacy database failure (Cook & O'Connor, 2005).

Certification Problems

In general:

- expensive and burdensome,
- certification $\neq$ fewer vulnerabilities, and
- limited focus on security components.

In avionics:

- study of code at levels A and B finds no difference, and
- modified condition/decision coverage testing rarely exposes errors.

In medicine:

- heavy reliance on testing and process,
- hasn't prevented accidents due to bad practice, and
- 17 deaths in Panama (2001), similar incident to Therac-25 (1985).

Why Certification Helps

Promotes safety culture:

- seriousness, attention to detail, and
- rigorous process.

Helps justify safety investment:

- balances hurry to get product to market.

Software for a Safer World

In medicine:

- 98,000 patients die annually from preventable errors,
- better tools for diagnosis and intervention, and
- effect of widespread IT on health would be major.

In avionics:

- detecting impending accidents,
- “controlled flight into terrain” responsible for most deaths,
- collisions during ground operations, and
- digital controllers to monitor engine performance.

In other areas:

- transportation: preventing car accidents,
- energy: monitoring generation and distribution, and
- telecommunications: better connectivity during emergencies.

Towards Dependable Software: the Three Es

Explicit:

- properties established,
- assumptions about domain and usage, and
- level of dependability.

Evidence:

- dependability case that properties hold,
- scientifically justifiable claims, and
- open to audit by a third-party.

Expertise:

- approach is technology-independent,
- demand for evidence stretches today's best practices, and
- deviate from best practice only with good reason.

Explicitness

Why be explicit?

- no system dependable in all respects, and
- so must choose, consciously or not.

What to make explicit?

- critical properties expected to hold,
- assumptions about environment and usage, and
- level of dependability claimed.

Radiotherapy example:

- property: emergency stop button turns off beam within 10ms,
- assumption: mechanical beam stop works, and
- level: 1 failure in 100 machines operating for 20 years.

Environmental Assumptions

What happened?

- Airbus A320, Warsaw 1993,
- aircraft landed on wet runway,
- aquaplaned, so brakes didn't work, and
- pilot applied reverse thrust, but disabled.

Why did that happen?

- reverse thrust disabled iff landing gears under compression.

Evidence

Dependability case:

- an auditable argument for dependability, and
- software $\wedge$ assumptions $\Rightarrow$ properties.

For each element of argument, use most effective technique, for example,

- type checker – independence of modules,
- static analysis – no buffer overflows,
- theorem proving – code meets specification,
- model checking – protocol doesn't deadlock and
- testing – environmental assumptions hold.

Process:

- to preserve chain of evidence, and
- deployed code = analyzed code.

Testing:

- tiny proportion of scenarios, so rarely justifies high confidence,
- sometimes exhaustive testing is possible, and
- automatic regression testing is an essential process practice.

Analysis:

- for local reasoning,
- formal and informal, but best if mechanized, and
- static analysis, model checking and theorem proving.

Justified claims:

- must state what inferences are drawn from analysis and testing, and
- bug finders are useful, but might not contribute much.

Role of Process

When to construct the case?

- too expensive to delay until system is complete, and
- construct hand-in-hand with system.

Chain of evidence:

- produced during development,
- preserved by careful checks and procedures, and
- leaves auditable records.

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Expertise

Approach is technology-independent:

- doesn't rely on particular tools, languages, methods,
- just following best practices is not good enough,
- but new approach demands expertise.

Examples of expertise required:

- prioritization and formalization of requirements,
- design of true data abstractions, not just lip service to OOP,
- substantive code standards: avoiding unsafe language features, and
- reflective bug tracking: back to origin.

Simplicity

No alternative:

- high confidence will require verification,
- cost of verifying entire code base too high, and
- therefore must design system with properties in mind.

Separation of concerns is key:

- establish critical properties in a few small modules,
- need independence arguments, and
- support with safe languages, virtual machines, etc.

Certification Regimes

Current regimes:

- few encompass the combination the book by Jackson et al. recommends.

In the future:

- certification = inspection and analysis of dependability case,
- by development organization, customer, or third-party, and
- no single regime for all circumstances.

Accountability:

- no fixed prescription,
- but must be clear at outset who's responsible for failure.

Culture Change Needed

Transparency:

- customers want to make informed judgments,
- criteria and evidence for claims must be transparent,
- publishing defect data boosts supplier's credibility, and
- certification process should be transparent (cf. e-voting).

Accountability:

- who is responsible if it fails?
- no fixed assignment, but must be clear.

Evidence and openness:

- dearth of evidence hampers technology and policy advances, and
- encourage collection, publication and analysis of failure data.

Education:

- demand for dependable software requires workforce,
- emphasis on software construction as systems building,
- high school: less on mechanism, more on problem solving, and
- university: more on security, usability, specification, argument.

Research:

- tools and techniques for constructing dependability cases,
- components and compositional dependability cases,
- how to bolster role of testing as evidence, and
- reasoning about fail-stop systems.

Now versus Future

	current	*future?*
requirements	massive informal list	a few critical properties
design	highly coupled	small trusted base
testing	expensive and unfocused	environmental assumption
analysis	in reviews, unrecorded	proof of no deadlock
best practices	specify commenting style	guarantee no buffer overflo
quality plan	long, unread, unchanging	succinct, known, responsiv
certification	testing and process checklist	audit of dependability case