Software Evolution
Alexander Serebrenik
Organisation

• Quartile 3 and 4:
  • 2 hours lectures:
    – Wednesday:
      – Time: 7th and 8th hour (15:45-17:30)
      – Location: AUD 6 (Q3), AUD 13 (Q4)
• Master students: CSE, ES, BIS
• 5 ECTS = 140 hours
  • 140 – 2*16 = 108 hours
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  • 3595
  • HG 5.41
Learning objectives

• list important challenges associated with software evolution;

• discuss methods and tools addressing these challenges, their advantages and disadvantages;

• apply the methods and tools to existing software systems;

• interpret the results obtained in a scientifically responsible way.
Assignments

- [http://peach.win.tue.nl/](http://peach.win.tue.nl/)
- 8 assignments (on average: 2 weeks to complete)
- Some individual, some in small teams

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No exams!
A typical assignment

- **Report**
  - What problem will you study?
  - What system(s) will you study?
  - How did you design your experiment?
    - Design decisions and tools used to obtain, analyse and visualize data
  - What results have you obtained?
  - How do you interpret these results?
  - What might have affected validity of your results?
Software evolution and others...

- No formal prerequisites
  - “Generic language technology” is recommended but not mandatory

- Interest in analysis of software systems
- Basic programming skills
Reading material (mostly...)
What is this course about?
Software Evolution. In the beginning.


Where does the money go?

75-95%
Why is maintenance so expensive?!

- Software is crucial for modern society.

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Toyota Prius. 160,000 vehicles recalled.

Ariane 5. Launch failed.

Discussed in detail in "Architecture of Distributed Systems"
Change?

- GNOME project
  - Sarma, Maccherone, Wagstrom, and Herbsleb ICSE’09
  - 10 years, 1000 developers
  - 2.5 millions changes
- Mozilla
  - Lanza
  - 6 years, hundreds of developers
  - > 1 million changes

- Lots of small changes leading to a new behaviour…
Evolution is staged process of progressive change over time in the properties, attributes, characteristics, behaviour of some material or abstract, natural or artificial, entity or system.

Charles Darwin

Meir Manny Lehman
Evolution vs. Maintenance

Software evolution

maintenance activities

1.0

“Software development” (Royce 1970)

“Software maintenance” (Royce 1970)
Why do we want to study software evolution?

• Software = the weakest link (often)
• Evolution “in general” makes things more complex
  • Science:
    – What is the nature of software evolution?
      – Psychology, sociology and organization theory, economics, law…
  • Engineering:
    – Where did the things go wrong?
      – incorrect, too complex, out of sync with other artefacts
    – Where can/will the things go wrong?
      – prediction, week spot identification, …
    – What can we do to prevent the things from going wrong?
Three questions for today

• **What** software artefacts are subject to evolution?

• **Why** do they evolve?

• **How** do they evolve?
What does evolve?

Evolution of different artefacts should be consistent.

This is called the co-evolution problem.
Co-evolution is time-dependent!

- **Assumption:** files committed together are co-evolving.

D’Ambros, Gall, Lanza, and Pinzger. “Analysing Software Repositories to Understand Software Evolution”
Co-evolution: Points of discussion

• What should co-evolve?
  • Code and database table definitions
  • Code and design documentation
  • Code and tests
  • Code and programming language
  • Code and 3\textsuperscript{rd} party software
  • Different code elements (packages, modules, files…)
  • ...

• What constitutes inconsistency?
• How to detect inconsistencies?
• How to ensure absence of inconsistencies?
Why does software evolve?

Swanson 1976

• **corrective maintenance**: to address processing, performance or implementation failure;
• **adaptive maintenance**: to address change in the data or processing environments;
• **perfective maintenance**: to address processing efficiency, performance enhancement and maintainability

Which maintenance type tries to address the co-evolution problem?
How do the system evolve?

• Evolution in small: series of changes

• Each change has to be understood and confirmed: impact analysis

• Yau and Collofello 1980
Do all programs evolve?

- What about your student assignments?

- There is a specification
- Specification is complete and fixed
  - All that matters has been completely defined
  - Changed specification = new specification
- Correctness wrt the specification is all it matters
  - No “extra” requirements

- S-type systems [Lehman 1985a] = no evolution
- NB: Presence of specification: not enough for S-type
S-type systems

• Rarely observed in practice: Why?

• Important:
  • Some design approaches aim at improving formality
  • But implicitly assume absence of evolution
    - S-type systems definition clarifies shortcomings of such approaches (Acme ADL, …)

• Are S-type systems useless in practice?
P-type: Restricted evolution

- Problem [Lehman 1980] or paradigm [CHLW 2006]
- P-type systems = systems that should always be consistent with a single external paradigm:
  - Virgo: laws of physics
- Standards can be regarded as a paradigm

- What are the differences between a paradigm and a specification?

- In what way is the evolution of P-type systems restricted?
P-type systems and reuse

- Reuse techniques foster P-type solutions
  - Design patterns
  - “Stable intermediate forms” (Simon 1969)
    - Building blocks to construct more complex systems
E-type systems

- E-type systems = systems that operate in the real world (or address it)
- Should evolve since the real world evolves:
E-type systems

• “Unrestricted evolution”

• Lehman has observed 8 laws of software evolution
  • Experience-based
  • Some might sound obvious
  • Have been changed and reformulated a number of times…

• We will look at them one by one…
1. Continuing Change

• An E-type system must be continually adapted, else it becomes progressively less satisfactory in use

• Follows from:
  • E-type systems operate in the real world (or address it)
  • Real world changes

• Would you use today?
Step aside: is the continuous change always possible?

Loss of architectural integrity

Patches too costly?

Start thinking about migration or reengineering

• Bennett and Rajlich (2000)
2. Increasing complexity

- As an E-type system is changed its complexity increases and becomes more difficult to evolve unless work is done to maintain or reduce the complexity.

Number of internal dependencies in Eclipse: added, kept, kept from r1, deleted.

Wermelinger, Yu, Lozano, ICSM 2008
Increasing complexity

• How do we define complexity?
  • Dependencies, execution paths, inheritance, …
  • Metrics

• How do we detect trends, changes and outliers?
  • Visual inspection
  • Statistical analysis

• How we map the change points to recorded improvement activities?
  • Logbooks
  • Automatic detection of refactorings
3. Self Regulation

- Global E-type system evolution is feedback regulated.

- Computational procedures and algorithms
- Application concept
- Application domain
- Operational program
- Stakeholders’ views
- Evolving understanding and structure
- Theories, models procedures, laws of application and system domains

Program definition
Requirements analysis

M.M. Lehman: Software evolution as a feedback loop (simplified)
Feedback and Growth Pattern

- Feedback necessitates ability to react, i.e., control.
- Repeated cyclic pattern is typical for feedback.
- More?
  Ch. 17 of Lehman and Belady 1972, 1985
4. Conservation of Organizational Stability

• The work rate of an organization evolving an E-type system tends to be constant over the operational lifetime of that system or phases of that lifetime.

• Rather controversial: managers have no power?
  • Supported, e.g., by Gefen and Schneberger
  • No evidence found, e.g., by Lawrence

• “Phases of that lifetime” – discontinuity!
5. Conservation of Familiarity

- In general, the **incremental growth** (growth rate trend) of E-type systems is constrained by the need to maintain familiarity.

- Lehman: growth is linear
- Godfrey and Tu: not for Open Source (Linux)
- Wermelinger, Yu, Lozano: linear for architecture (Eclipse)
6. Continuing Growth

- The functional capability of E-type systems must be continually enhanced to maintain user satisfaction over system lifetime.

- In earlier versions the law talked about “size”.

![Graph showing total uncommented LOC over time](image-url)
6. Continuing Growth (cntd.)

- How to measure functional capability?
  - Is it reflected in # lines of code, modules, etc.?
- Measure of functionality: Function points
  - Usually require description to be calculated
  - Description ≠ functionality
- Continuing(?) growth

Staged growth: typical for Open Source Software?

Growth in Gaim (Ramil, Capiluppi 2004)
7. Declining Quality

- Unless rigorously adapted and evolved to take into account changes in the operational environment, the quality of an E-type system will appear to be declining.

- Again, would you use

- How would you define quality? Adaptation?
8. Feedback system

- E-type evolution processes are **multi-level multi-loop multi-agent feedback systems**.

- This process model is far too simplistic!

- **Agents**: corporate managers, process managers, product managers, SW architects, SW developers, SW testers, marketers, users, …

- **Loops**: document/code reviews

- **Levels**: granularity, parallel versions, …
In fact...

Theories, Models, Procedures, Laws of Application and System Domains

Program Definition

Requirements Analysis

Evolving Understanding and Structure

Exogenous Change

Application Concept

Operational Program

Views (Predictive)

Corporate Management

M.M. Lehman

Program

Computational Procedures and Algorithms

Project & Process Managers

Users User Support

Marketeers

User Support

In fact...
Laws of Software Evolution: Summary

1. Continuing change
2. Increasing complexity
3. Self-regulation
4. Conservation of organizational stability
5. Conservation of familiarity
6. Continuing growth
7. Declining quality
8. Feedback system
Laws of SW Evolution: Limitations and critique

- Applicability to “non-standard” software?
  - Open source, co-developed, based on dev. frameworks

- Applicability to “non-standard” languages?
  - Specification languages, process models, domain-specific languages

- Applicability to “non-standard” artefacts?
  - Requirements documents, architecture, test scripts?

- Empirical validation
  - Case studies conducted and more case studies needed
  - Statistical validity of the results?!

- Vagueness
Summary so far…

• Software usually undergoes numerous small changes ⇒ evolution
• What, why and how of software evolution
  • Why: types of maintenance
  • How: types of software systems:
    – S-type: fixed spec, no evolution
    – P-type: fixed paradigm, restricted evolution
    – E-type: the general case
      – Lehman’s laws of software evolution
Assignment 1

- Individual
- Deadline: February 9, 23:59

- Give an example of S-, P- and E-type systems or components: one example for each type.
- Briefly describe their functionality.
- Explain why do you think that these components are S-, P- or E-type.

- Your description should not exceed 2 A4 pages.
Topics for the coming lectures

• Requirements Evolution
• Reverse Engineering and Evolution of SW Architecture
• Code Duplication and Differencing
• Mining Software Repositories
• Code Measurement: Size and Complexity
• Controlling Evolution: Refactoring, Reengineering and Model Transformations

• Is there a topic not listed you are interested in?
  • Please let me know!
Software Evolution @ TU/e

- Domain specific languages and model transformations – MvdB
- Software metrics, aggregation and statistical analysis – AS
- Tooling, case studies – Serguei Roubtsov, Reinier Post, Joost Gabriels
- Requirements – Martijn Klabbers
- Evolution of Eclipse plugins – John Businge
- Model transformations, their quality and correctness – Marcel van Amstel, Luc Engelen
- Model differencing – Zvezdan Protic
- Parsing technology – Maarten Manders
- Software architecture – Yanja Dajsuren
- Program analysis – Arjan van der Meer

and also YOU!