Welcome to SENG 371 Software Evolution Spring 2013

A Core Course of the BSEng Program

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Announcements

- Marking
  - Midterm will be returned on Thu in class
  - A1 graded
  - Mon office hours reserved for marking questions —1:30-2:30 ECS 660
- Course website
  - http://www.engr.uvic.ca/~seng371
  - Lecture notes posted
  - Lab slides and activities are posted
- Assignment 2
  - Due March 11 — revised
  - Reverse engineering and program understanding
    - Part I—Summarize three papers
    - Part II—Define terms
    - Part III—Reverse engineer a C program (gawk)
    - Rigi demo on Monday
  - Cite your sources
  - Submit by e-mail to seng371@uvic.ca

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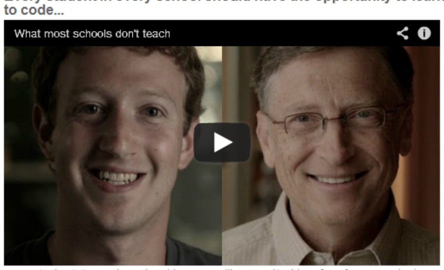
Video of the Week

https://www.youtube.com/watch?feature=player_embedded&v=nKIu9yen5nc

Every student in every school should have the opportunity to learn to code...



At the 2:21 mark on the video, you will see an iPad interface for a sound mixer written by UVic alumni at LOUD technologies(Acuma Labs) in Victoria. (http://www.mackie.com/products/dlseries/)

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Midterm Question 1
Some basic definitions

- *Software* — the programs, documentation, and operating procedures by which computers can be made useful to humans
- *Software evolution* — a process of continuous change from a lower, simpler to a higher, more complex, or better state
- *Software maintenance* — modification of a software product after delivery, to correct faults, to improve performance or other attributes, or to adapt the product to a modified environment
- *Maintainability* — the ease with which maintenance can be carried out

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Midterm Question 2
Scale Changes Everything

- Characteristics of ULS systems arise because of their scale
  - Decentralization
  - Inherently conflicting, unknowable, and diverse requirements
  - Continuous evolution and deployment
  - Heterogeneous, inconsistent, and changing elements
  - Erosion of the people/system boundary
  - Normal failures
  - New paradigms for acquisition and policy

These characteristics may appear in today's systems, but in ULS systems they dominate.
These characteristics undermine the assumptions that underlie today's software engineering approaches.

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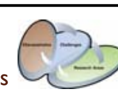
Midterm Question 2
ULS Systems Operate More Like Cities



- Built or conceived by many individuals over long periods of time (Rome)
- The form of the city is not specified by requirements, but loosely coordinated and regulated—zoning laws, building codes, economic incentives (change over time)
- Every day in every city construction is going on, repairs are taking place, modifications are being made—yet, the cities continue to function
- ULS systems will not simply be bigger systems: they will be interdependent webs of software-intensive systems, people, policies, cultures, and economics

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Midterm Question 2
Decentralized Ecosystems

- For 40 years we have embraced the traditional centralized engineering perspective for building software
  - Central control, top-down, tradeoff analysis
- Beyond a certain complexity threshold, traditional centralized engineering perspective is no longer sufficient and cannot be the primary means by which ultra-complex systems are made real
  - **Firms** are engineered—but the structure of the **economy** is not
  - The protocols of the **Internet** were engineered—but not the **Web** as a whole
- **Ecosystems** exhibit high degrees of complexity and organization—but not necessarily through engineering

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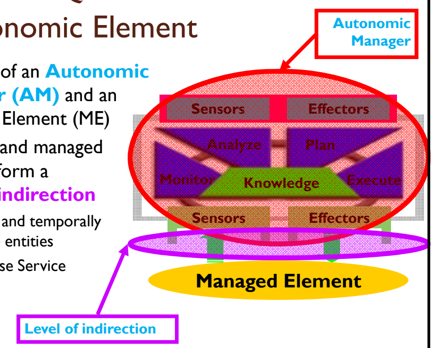
Midterm Question 3
Autonomic Element

- Consists of an **Autonomic Manager (AM)** and an Managed Element (ME)
- Manager and managed element form a **level of indirection**
  - Spatially and temporally separate entities
  - Enterprise Service Bus



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Monitor
- Senses the managed process and its context
- Collects data from the managed resource
- Provides mechanisms to aggregate and filter incoming data stream
- Stores relevant and critical data in the knowledge base or repository for future reference.

Analyzer
- Compares event data against patterns in the knowledge base to diagnose symptoms and stores the symptoms
- Correlates incoming data with historical data and policies stored in repository
- Analyzes symptoms
- Predicts problems

MAPE-K Loop
Midterm Question 3

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Planner
- Interprets the symptoms and devises a plan
- Decides on a plan of action
- Constructs actions
  - building scripts
- Implements policies
- Often performed manually

Execute Engine
- Executes the change in the managed process through the effectors
- Perform the execution plan
- Often performed manually

MAPE-K Loop
Midterm Question 3

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Midterm question 4
Definitions

- ***Ecosystem***
  - In biology, an ecosystem is a community of plants, animals, and microorganisms that are linked by energy and nutrient flows interacting with each other and with the physical environment.
  - Rain forests, deserts, coral reefs, grasslands, and a rotting log are all examples of ecosystems
- ***Socio-technical ecosystem***
  - An ecosystem whose elements are groups of people together with their computational and physical environments
  - ULS systems can be characterized as *socio-technical ecosystems*
- ***ULS system***
  - A system whose dimensions are of such a scale that constructing the system using development processes and techniques prevailing at the start of the 21st century is problematic.
  - ULS system characteristics
    - Decentralization
    - Conflicting, unknowable, and diverse requirements
    - Continuous evolution and deployment
    - Heterogeneous and changing element
    - Erosion of the people/system boundary
    - Normal failures of parts of the system

cf. Glossary in ULS Book

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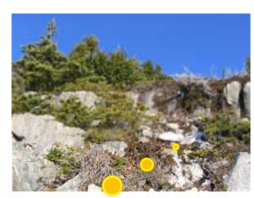
Midterm Question 4
Evolution of Software System

- Legacy systems
- Systems of Systems



Ultra-Large-Scale (ULS) Systems
Socio-Technical Ecosystems

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Midterm Question 4
Change of Perspective

- From satisfaction of requirements through traditional, top-down engineering

The system shall do this
… but it may do this …
as long as it does this …

- To satisfaction of requirements by regulation of complex, decentralized systems

How?

With adaptive systems
and feedback loops ☺

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Midterm Question 4
Socio-Technical Ecosystems

- **Socio-technical ecosystems include people, organizations, and technologies at all levels with significant and often competing interdependencies.**
- In such systems there is
  - Competition for resources
  - Organizations and participants responsible for setting policies
  - Organizations and participants responsible for producing ULS systems
  - Need for local and global indicators of health that will trigger necessary changes in policies and in element and system behavior

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Midterm Question 5
Self-Adaptive Systems

- A self-adaptive system continuously adjusts its behaviour at run-time in response to its perception of its environment and its own state in the form of fully or semiautomatic self-adaptation.
- H. Giese, Y. Brun, J. Serugendo, C. Gacek, H. Kienle, H. Müller, M. Pezzè, M. Shaw.: Engineering Self-Adaptive and Self-Managing Systems, LNCS 5527, Springer, 2009.

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Midterm Question 5
Key Questions

- How often should adaptation be considered?
  - Policies range from continuous (proactive) adaptation to as-and-when necessary (reactive)
  - Adaptation can also be opportunistic—exploiting resources such as CPU time when it is not being used for other tasks
  - "Go green" adaptation
- What kind of information must be collected to make adaptation decisions
  - Data can be gathered continuously
    - This provides precise and up-to-date observations, but incurs relatively high cost
  - Data can be gathered less often with the resulting samples being approximations of environment activity; this approach imposes less overhead
  - Trust issues

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Midterm Question 5
Key Questions

- Under what circumstances is adaptation cost-effective?
- The benefits gained from making a change must outweigh the costs associated with making the change
- Costs include:
  - Performance and memory overhead of monitoring system behaviour
    - Monitoring is necessary to make adaptation decisions
    - Memory may be limited on, particularly if adaptive software runs on embedded devices
  - Decision making—interpreting data gathered from monitoring may be computationally expensive
  - Executing the actions to actually change a system configuration
    - Changes involving physically distributed systems must be coordinated which itself incurs additional overhead

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Reading assignments

- Chikofsky, Cross: Reverse Engineering and Design Recovery: A Taxonomy, IEEE Software 7(1):13-17 (1990)
  http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=43044
- Kienle, Müller: Rigi—An Environment for Software Reverse Engineering, Exploration, Visualization, and Redocumentation, *Science of Computer Programming* 75(4):247-263, Elsevier, Apr. 2010.
  http://www.sciencedirect.com/science/article/pii/S016764230900149X
- Müller, Jahnke, Smith, Storey, Tilley, Wong, Reverse Engineering: A Roadmap, in *The Future of Software Engineering, ICSE 2000 Millennium Celebration*, 2000.
  http://dl.acm.org/citation.cfm?id=336526

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Lehman and Belady's System Classification

- S-type programs
  - Can be specified formally.
- P-type programs
  - Cannot be specified.
  - An iterative process is needed to find a working solution.
- E-type programs
  - Are embedded in the real world and become part of it, thereby changing the real world.
  - This leads to a feedback system where the program and its environment evolve in concert.

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Laws of software evolution

1. Law of Continuing Change (1974)
   - "E-type systems must be continually adapted or they become progressively less satisfactory."
   - Software which is used in a real-world environment must change or become less and less useful in that environment.
2. Law of Increasing Complexity (1974)
   - "As an E-type system evolves its complexity increases unless work is done to maintain or reduce it."
   - As an evolving program changes, its structure becomes more complex, unless active efforts are made to avoid this phenomenon.

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Laws of software evolution …

3. Law of Self Regulation (1978)
   - "E-type system evolution process is self regulating with distribution of product and process measures close to normal."
   - System attributes such as size, time between releases, and the number of reported errors are approximately invariant for each system release.
4. Law of Conservation of Organisational Stability
   - "The average effective global activity rate in an evolving E-type system is invariant over product lifetime."
   - Over a program's lifetime, its rate of development is approximately constant and independent of the resources devoted to system development.

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Laws of software evolution …

5. Law of Conservation of Familiarity (1978)
   - "As an E-type system evolves all associated with it, developers, sales personnel, users, for example, must maintain mastery of its content and behaviour to achieve satisfactory evolution. Excessive growth diminishes that mastery."
   - Over the lifetime of a system, the incremental system change in each release is approximately constant.
   - The average incremental growth of systems tends to remain constant or decline over time.
6. Law of Continuing Growth (1991)
   - "The functional content of E-type systems must be continually increased to maintain user satisfaction over their lifetime."
   - Functional capability must increase over the lifetime of a system to maintain user satisfaction.

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Laws of software evolution …

7. Law Declining Quality (1996)
   - "The quality of E-type systems will appear to be declining unless they are rigorously maintained and adapted to operational environment changes."
   - Unless rigorously adapted, quality will appear to decline over time.
8. Law of Feedback System (1996)
   - "E-type evolution processes constitute multi-level, multi-loop, multi-agent feedback systems and must be treated as such to achieve significant improvement over any reasonable base"
   - Evolution systems are multi-level, multi-agent, multi-loop feedback systems.

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Seven basic questions…[Erdos/Sneed]

A maintenance programmer must ask to be able to maintain programs that are only partially understood:

1. Where is a particular subroutine or procedure invoked?
2. What are the arguments and results of a particular function?
3. How does the flow of control reach a particular location?
4. Where is a particular variable set, used or queried?
5. Where is a particular variable declared?
6. Where is a particular data object accessed, i.e. created, read, updated, or deleted?
7. What are the inputs and outputs of a particular module?

What tools do you use to answer these questions?

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Learning objectives

- Understand differences between reverse engineering, forward engineering and reengineering
- Learn the concepts of design discovery/recovery and re-documentation
- Discuss the application of reverse engineering techniques to software maintenance problems
- Understand the weaknesses in reverse engineering techniques
- Learn about different tools to support reverse engineering

Software reverse engineering

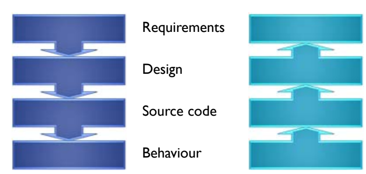
- Def. A two-step process
  - Information extraction
  - Information abstraction
- Def. A three-step process [Tilley95]
  - Information gathering
  - Knowledge organization
  - Information navigation, analysis, and presentation
- Def. Analyzing subject system [CC90]
  - to identify its current components and their dependencies
  - to extract and create system abstractions and design information
- The subject system is not altered; however, additional knowledge about the system is produced

Software reverse engineering …

- Feedback loops in life cycle models (e.g., waterfall or spiral model) are opportunities for reverse engineering
- Related terms
  - Abstraction and composition
  - Design recovery [Big89] and concept assignment [BMW94]
  - Redocumentation [WTMS95]
  - Inverse engineering [RBCM91]
  - Static and dynamic analysis
  - Summarizing resource flows and software structures
  - Change and impact analysis
  - Maintainability analysis
  - Migration analysis
  - Portfolio analysis
  - Economic analysis

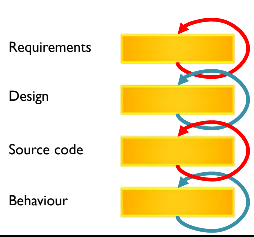
Forward engineering

- Traditional software process of moving from high-level abstractions and logical implementation-independent designs to the physical implementation of a system



Restructuring

- Transformation from one representation to another at the same relative abstraction level, while preserving the subject's system external behavior



The Horseshoe Model of Software Migration