Evolution in Open Source Software: A Case Study

Michael W. Godfrey
Qiang Tu

Software Architecture Group
University of Waterloo

Overview

- What is software evolution?
  - Why should we care?
- Previous research
- A case study: The Linux OS kernel
- Observations, hypotheses, and future research

What is software evolution?

"Evolution is what happens while you're busy making other plans."

- Usually, we consider evolution to begin once the first version has been delivered:
  - *Maintenance* is the planned set of tasks to effect changes.
  - *Evolution* is what actually happens to the software.

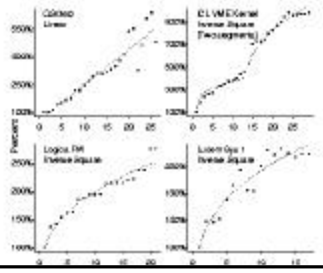
Previous research

- Lehman's laws
- Parnas on software geriatrics
- Eick *et al.* on code decay (10 MLOC telecom)
- Gall *et al.* (10 MLOC telecom)
- Munro, Burd *et al.* (2 MLOC gcc)

Lehman's Laws in a nutshell

- Observations:
  - (Most) useful software must evolve or die.
  - As a software system gets bigger, its resulting complexity tends to limit its ability to grow.
  - Development progress/effort is (more or less) constant; growth is *at best* constant.
- Advice:
  - Need to manage complexity.
  - Do periodic redesigns.
  - Treat software and its development process as a feedback system (and not as a passive theorem).

Lehman's examples



A case study in evolution: The Linux OS kernel

A case study in evolution: The Linux OS kernel

- It's Linux!
  - Large system, very stable, many releases over several years, many developers
  - Growing mainstream adoption
- Open source development model
  - Interesting phenomenon in itself
  - Easy to track, can publish results, many experts
  - Not much previous study

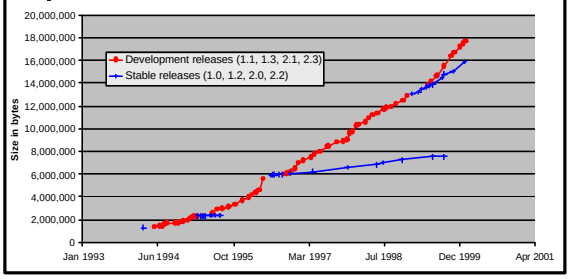
Linux background

- Linux kernel v1.0 released March 1994
  - 487 source files, 165 KLOC, i386 only
- Linux kernel v2.3.39 released January 2000
  - 4854 source files, 2.2 MLOC, 10 hardware architectures supported, over 300 developers credited
- Maintained along two parallel paths:
  - *development* and *stable*

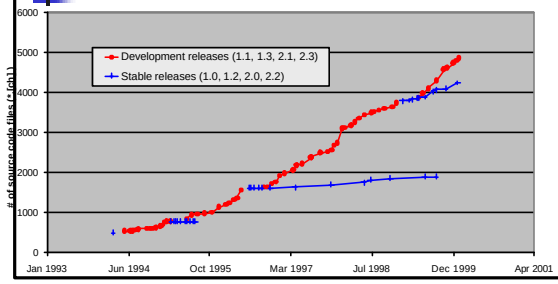
Methodology

- Examined 96 versions of Linux kernel
  - 34 of the 67 stable releases
  - 62 of the 369 development releases
- All measures considered only `.c/.h` files contained in the tarball
  - Counted LOC using "`wc -l`" and an `awk` script that ignored comments and blank lines
  - Counted # of fcns/vars/macros using `ctags`
  - Architectural model (SSs hierarchy) based on default directory structure
- We plotted growth against calendar time
  - Lehman suggests plotting growth against release number

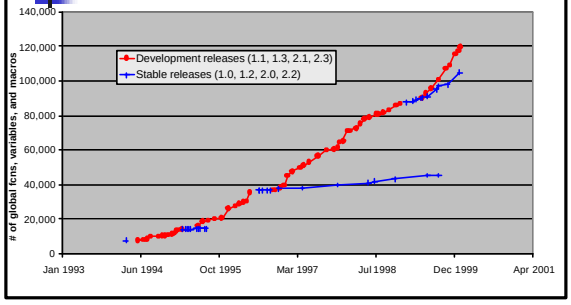
Growth of compressed tar file



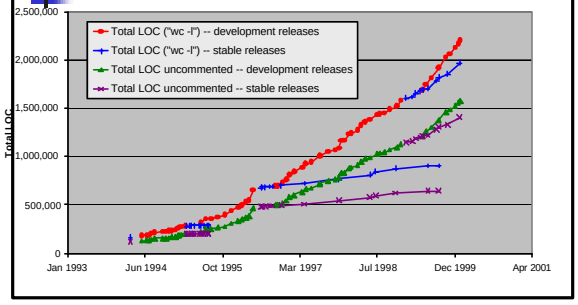
Growth of # of source files



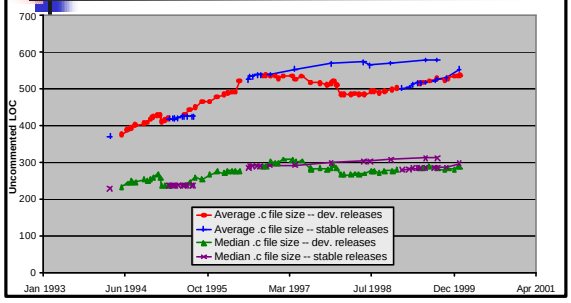
Growth of # of global fcns, variables, and macros



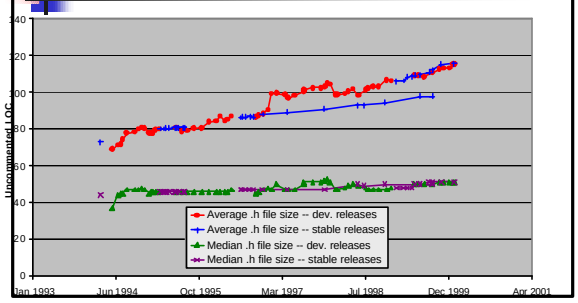
Growth of Lines of Code (LOC)



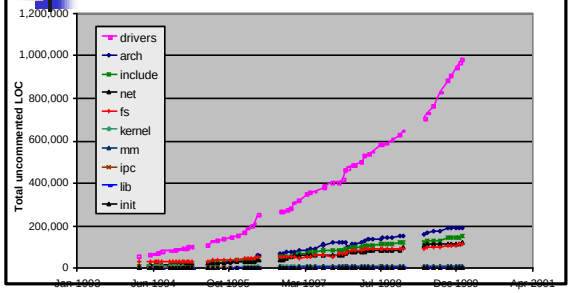
Average/median .c file size



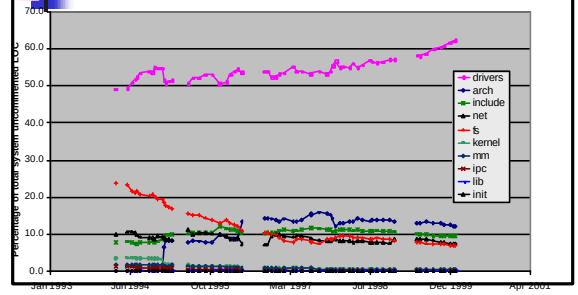
Average/median .h file size



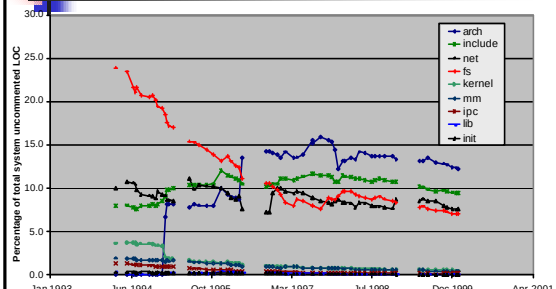
Growth of major SSs (dev. releases)



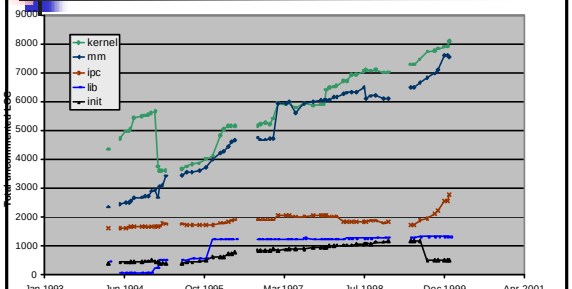
SS LOC as percentage of total system



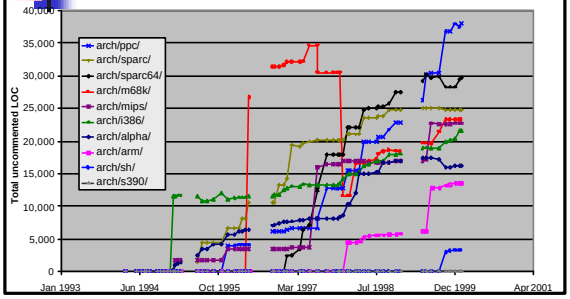
SS LOC as percentage of total system (ignoring drivers)



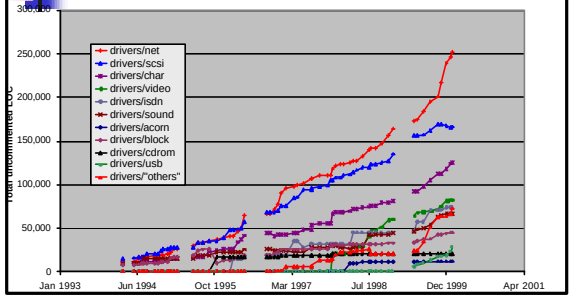
Growth of small core SSs



Growth of arch SSs



Growth of drivers SSs



Observations and hypotheses

- Growth along devel. path is super-linear

  y = .21*x^2 + 252*x + 90,055 r2=.997

  y = size in LOC
  x = days since v1.0
  r2 is "coefficient of determination" using least squares

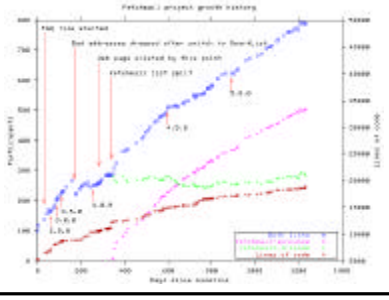
  [Lehman/Turski's model: y' = y + E/y^2
  < y0 + x*E/y0^2]

  - Linux's strong growth is continuing.
  - This is stronger growth at MLOC level than observed by others (Lehman, Gall), even for other OSs.

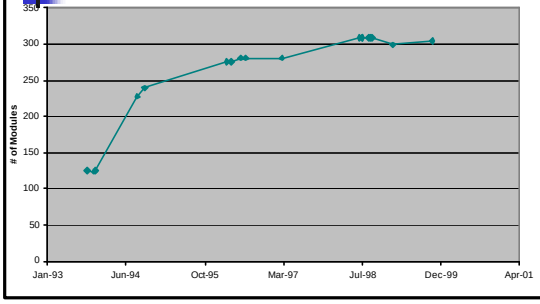
Why has Linux been able to continue its geometric growth?

- Core code quality is carefully maintained
- Architecture/problem domain
  - It's largely drivers
  - Much of the code is "parallel"
  - It's not as big as you might think
    - Vanilla configuration used only 15% of files
- Development model (OSD) and its sociology
  - Popularity and visibility has encouraged outsiders (both hackers and industry) to contribute

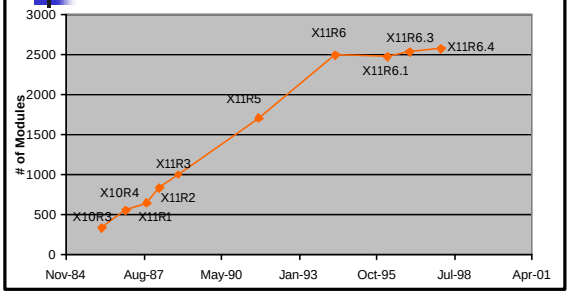
Growth of `fetchmail` [Raymond]



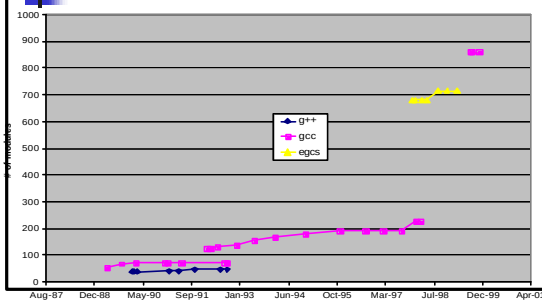
Growth of `pine` (email client)



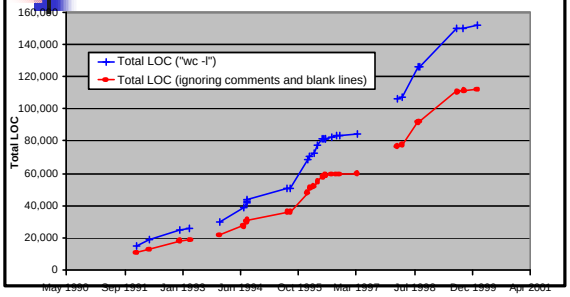
Growth of X Windows



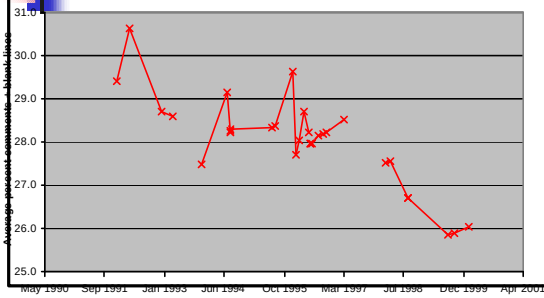
Growth of `gcc/g++/egcs`



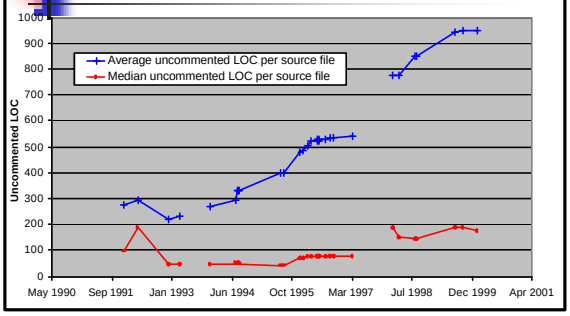
Growth of `vim` (text editor)



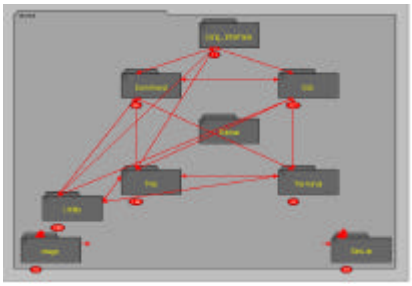
`vim` avg % comments and blank lines per file



vim avg/median file size



vim's architecture



Hypotheses

Factors affecting evolution include

- Size and age of system
- Use of traditional sw. eng. principles during development

PLUS

- Problem domain
  - Problem complexity, multi-platform, multi-features
- Software architecture
- Process model
- Sociology, market forces, and acts-of-God

Software evolution research: What next?

So far, we have examined only growth.

- More case studies needed
  - Qualitative and quantitative
  - Industrial and open source systems
  - Different problem domains, architectures
- Supporting tools to aid analysing, visualizing, and querying program evolution
  - More than just RCS and `perl`
  - Support for architecture repair
- Codified knowledge: Why and how does software change?
  - Build catalogue of *change patterns* and *evolutionary narratives*

Codified knowledge

- Mature engineering disciplines codify knowledge and experience.
- Arguably, this is lacking in software engineering.
  - Software architecture styles [Shaw]
  - Design patterns [GoF]
- Codified knowledge of how and why programs evolve:
  - *Evolutionary narratives* [Godfrey]
    - Long term, coarse granularity
  - *Change patterns*
    - Short term, fine granularity

Change patterns and evolutionary narratives

- Phenomena observed in Linux evolution
  - Bandwagon effect
  - Contributed third party code
  - "Mostly parallel" enables sustained growth
  - Clone and hack
  - Careful control of core code; more flexibility on contributed drivers, experimental features