Code Decay

Empirical Studies of Software Evolution
Threats to Validity

Today's Agenda

- Quiz (10 minutes)
- Code Decay
  - History (Myths?) of Code Decay
  - A study of Code Decay
  - Threats to Validity

A Model of Large Software Development

- L.A Belady and M.M Lehman
- 1976
- IBM OS/360
- Seminal empirical study paper in software evolution

Subject Program & Data

- OS/360
- 20 years old
- 20 user-oriented releases
- Starting with the available data, they attempted to *deduce* the nature of consecutive releases of OS/360

When observing software evolution, what can you measure?

Does it work? (True/False)

Tests

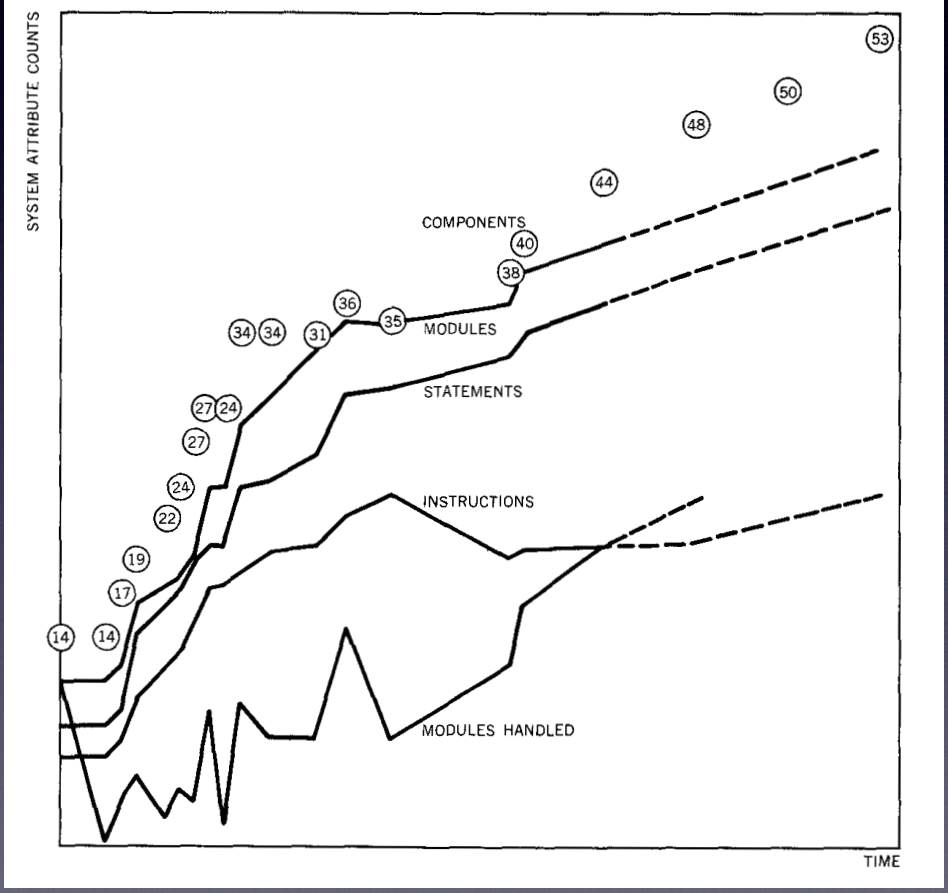
Features

$ Cost

Lines of Code

When observing software evolution, what can you measure?

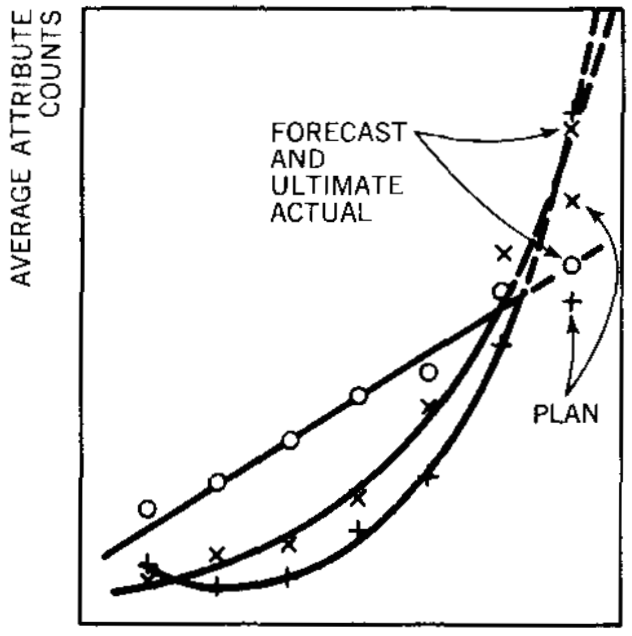
Growth Trends of System Attribute Counts With Time



What can you deduce from these graphs?

- It takes longer and longer to release the next release
- The size increases over time
- It requires modifying more and more modules per each release

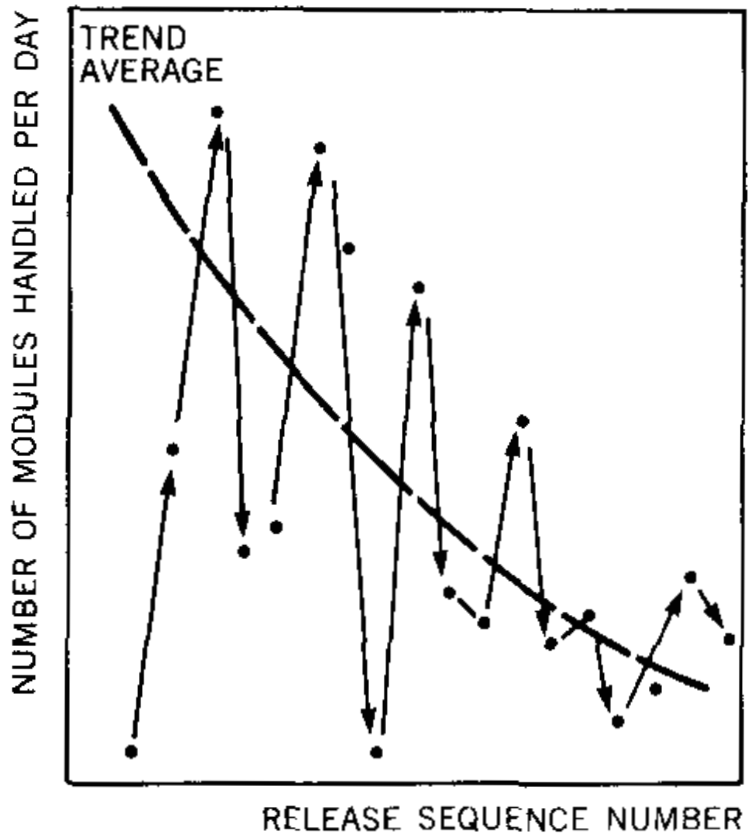
Figure 3 Average growth trends of system attributes compared with planned growth



What can you deduce from these graphs?

- Software changes involve fewer and fewer number of modules as the software evolves.

Figure 4 Serial and average growth trends of a particular attribute



Does Code Decay?

- Eick et al.
- TSE 2001 (almost 25 years after Belady & Lehman's Study)

Problem Definition

- What do the authors mean by "code decay?"
  - *it is harder to change than it should be*

Discussed Problem

- Check whether *code decay* is real: "Does Code Really Decay?"
  - how code decay can be characterized
  - the extent to which each risk factor matters
- **An Empirical Study* Paper*

Hypotheses

- What the authors are *trying or expecting to find*?
  - The span of files increases over time (age)
    changes
  - Effort has some relations to many measurable variables.
  - Modularity breaks over time
  - Fault potential has some relation to many measurable variables.

Hypotheses

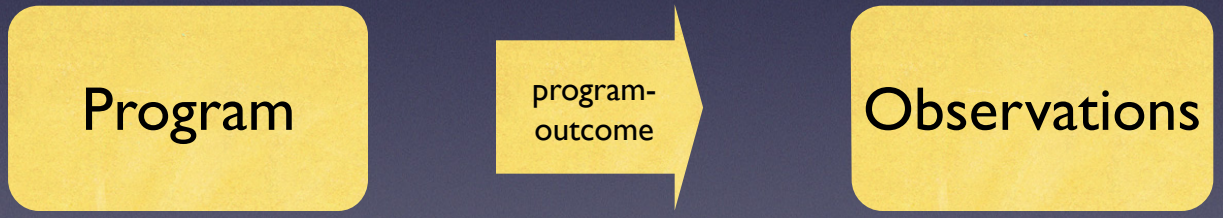
- What the authors are *trying or expecting to find*?
  1. The span of changes increases over time
  2. Breakdown of modularity increases over time
  3. Fault potential, the likelihood of changes to induce faults has some relations to ...
  4. Efforts has some relationship too
- Usually *good* empirical study paper either finds surprising empirical evidence that contradicts conventional wisdom or provides thorough empirical evidence that validates well known hypotheses.

Four types of threats to validity

- **External Validity**: Can we *generalize* to other situations?
- **Internal Validity**: Assuming that there is a relationship in this study, is the relationship a *causal* one?
- **Construction Validity**: Assuming that there is a causal relationship in this study, can we claim that the program reflected well our construct of the program and measure?
- **Conclusion Validity**: Is there a relationship between the cause and effect?

Another way of looking at Validity

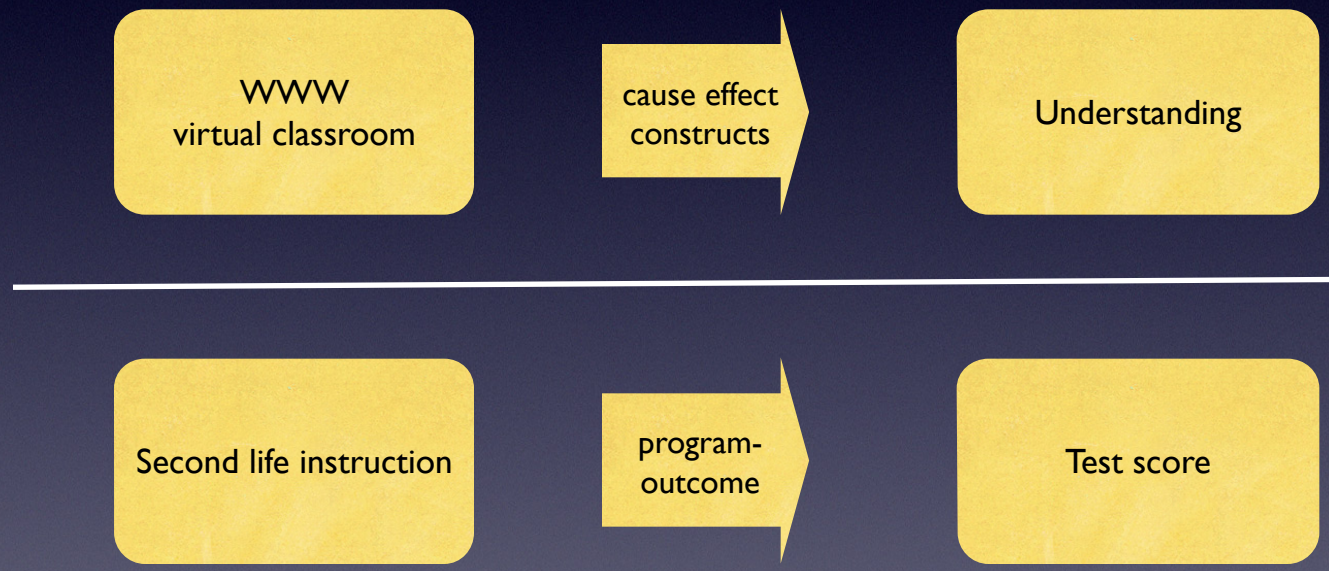
Theory: what you *think*



Observation: what you *test*

Example: WWW => Student Learning

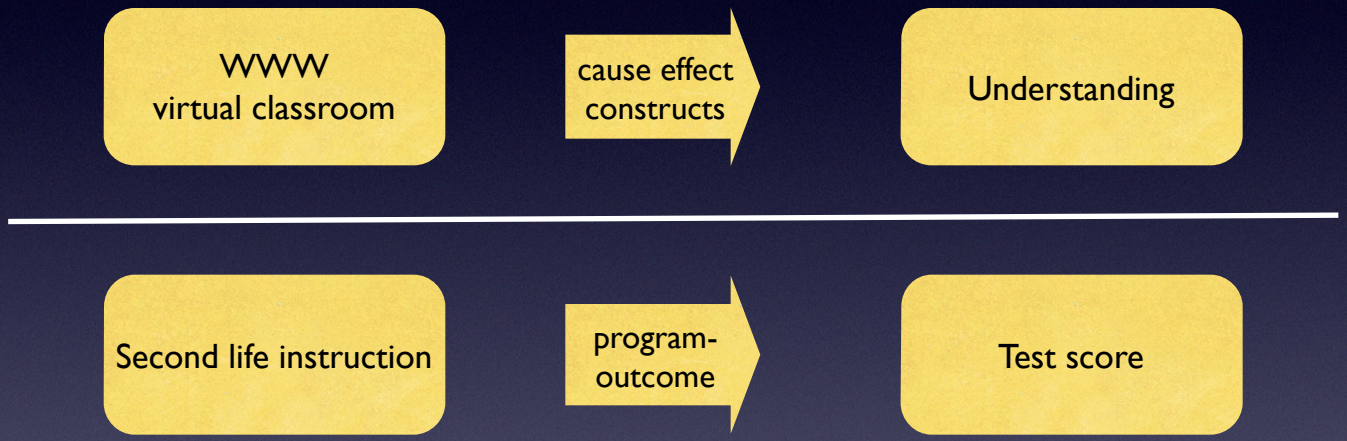
Theory: WWW virtual classroom improves student understanding of course materials



Observation: Let one half of EE382V to use second-life virtual class room and let the other half come to regular lecture. Compare their test scores at the end.

External Validity

Theory: WWW virtual classroom improves student understanding of course

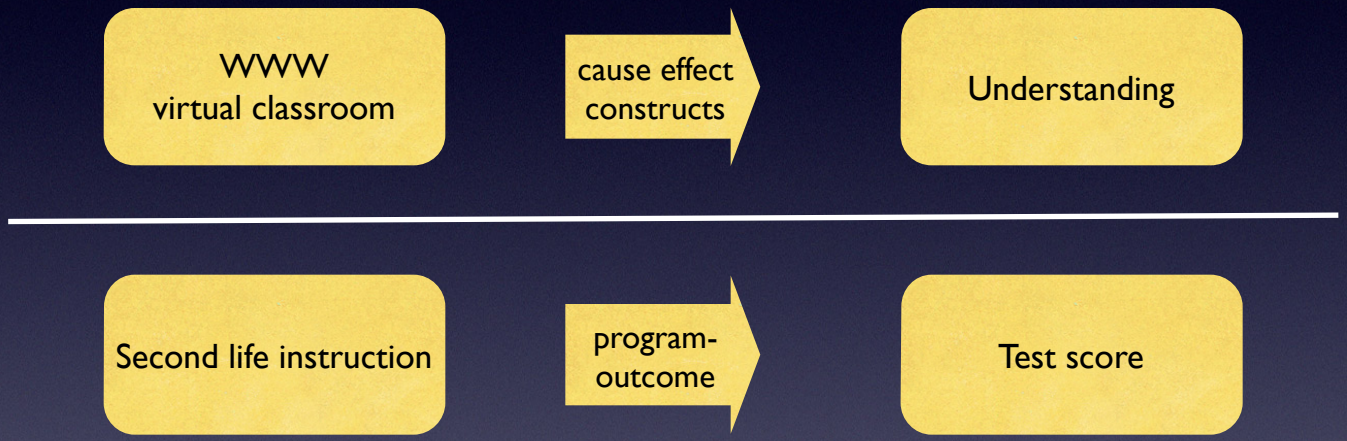


Observation: Let one half of EE382V to use www site and let the other half

External Validity: Does this study generalize to students of EE322c?

Internal Validity

Theory: WWW virtual classroom improves student understanding of course

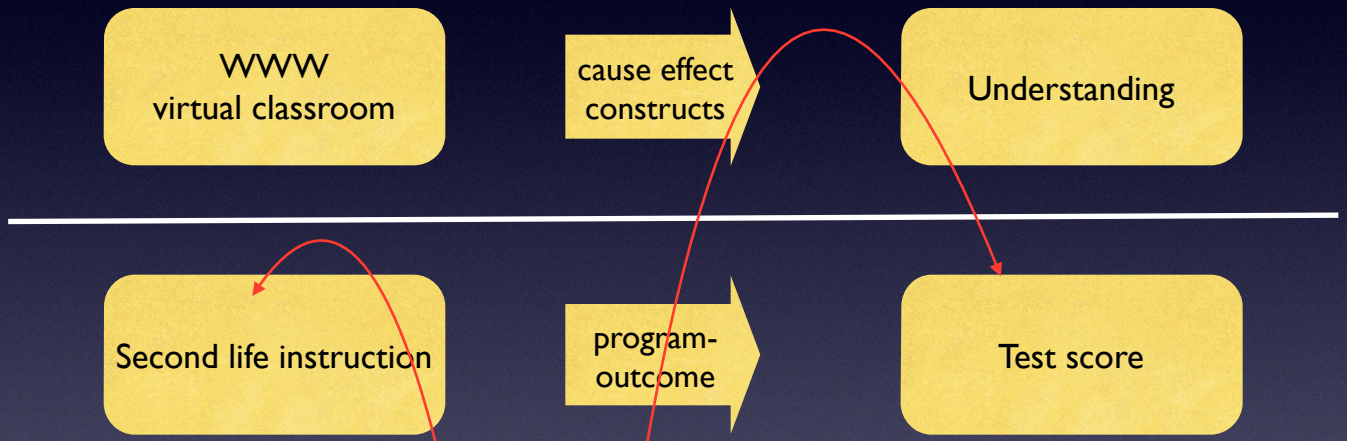


Observation: Let one half of EE382V to use www site and let the other half

Internal Validity: Assuming that students using WWW did better in their test, isn't it because these students have more money (apparently they have computers & high-speed internet) and rich students have more experiences with objective tests (due to their parents sending them to prep-schools.)

Construct Validity

Theory: WWW virtual classroom improves student understanding of course

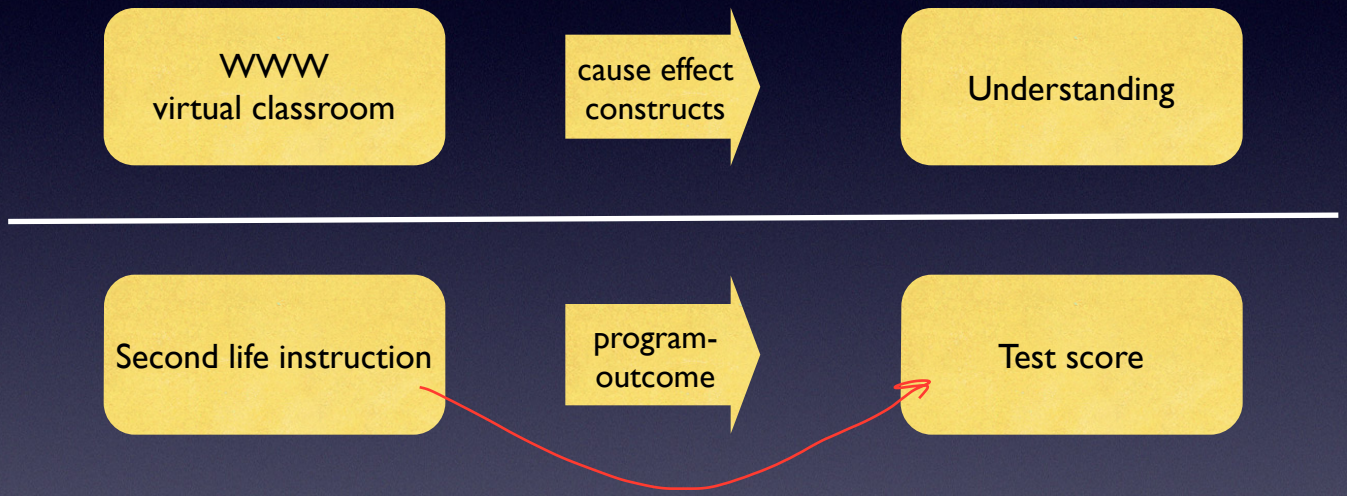


Observation: Let one half of EE382V to use www site and let the other half

Construct Validity: Is the operationalization method valid? Do objective test scores truly reflect students' understanding of core concepts? Don't students who are familiar with second life interface just test better?

Conclusion Validity

Theory: WWW virtual classroom improves student understanding of course



Observation: Let one half of EE382V to use www site and let the other half

Conclusion Validity: Are the correlation between second-life virtual classroom use and test scores significant?

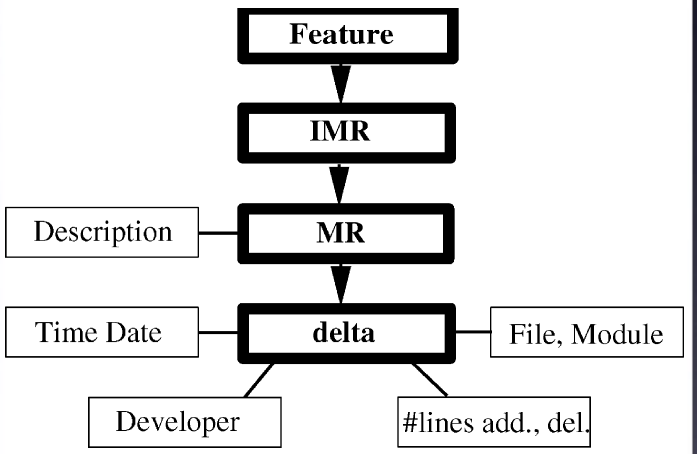
Study Approach

- Data selection
- Selection of measurement variables (so called independent variables)
- Study method that finds *relationships* among the measurement variables

Study Approach:
(1) Data Selection

- Rich data set
  - Telephone switching system
  - 100 million LOC
  - 5000 modules
  - 50 major subsystems
  - in C and C+

This system evolved by following a well-defined process.
Structured, manually labeled data
Easy to group related changes



Study Approach: (2) Measure Independent Variables

- c denotes changes (mostly a MR)
- Variables
  - DELTAS(c) = # of deltas associated with c
  - ADD(c) = # of lines added by c
  - DEL(c) = # of lines deleted by c
  - DATE(c) = the date on which c is completed
  - INT(c) = the interval of c (calendar time required to implement c)
  - DEV(c) = number of developers implementing c

Study Approach: (2) Measure Independent Variables

- Derived variables
  - FREQ(m, I) = $\sum_{c \rightsquigarrow m} 1\{\mathrm{DATE}(c) \in I\}$ / I
  - FILES(c) = # of files touched for change c
  - NCSL (m) = # of non-commentary source lines per module
  - AGE(m) = average age of its consequent lines

Study Approach:
(3) Finding Correlation or Visualization

- Statistical regression
  - This requires designing some template models

Study Approach: (3) Finding Correlation

- Fault Potential I. The number of faults that will have to be fixed in module m in the future. Change effects are dampened over time

$$\mathrm{FP_{WTD}(m,t)} = \gamma_1 \sum_{c \rightsquigarrow m,\ \mathrm{DATE(c)<t}} e^{-\alpha[t-\mathrm{DATE(c)}]} \times \log[\mathrm{ADD(c,m)} + \mathrm{DEL(c,m)}]$$

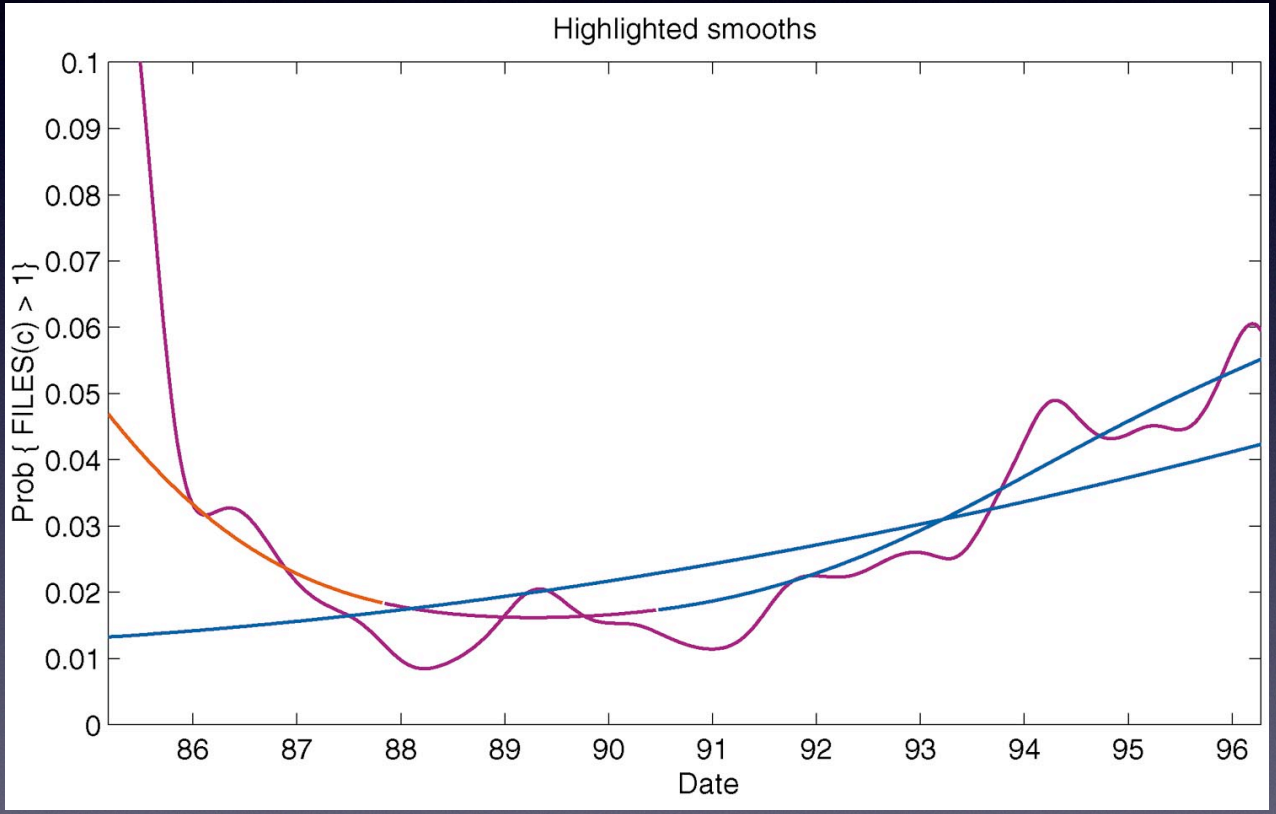
- Fault Potential II. The number of faults that will have to be fixed in a module in the future. Faults are less likely in older code (when beta is <1)

$$\mathrm{FP_{GLM}(m,t)} = \gamma_2 \times \sum_{c \in \Delta} \mathbf{1}\{c \rightsquigarrow m\} \times \beta^{\mathrm{AGE(m)}},$$

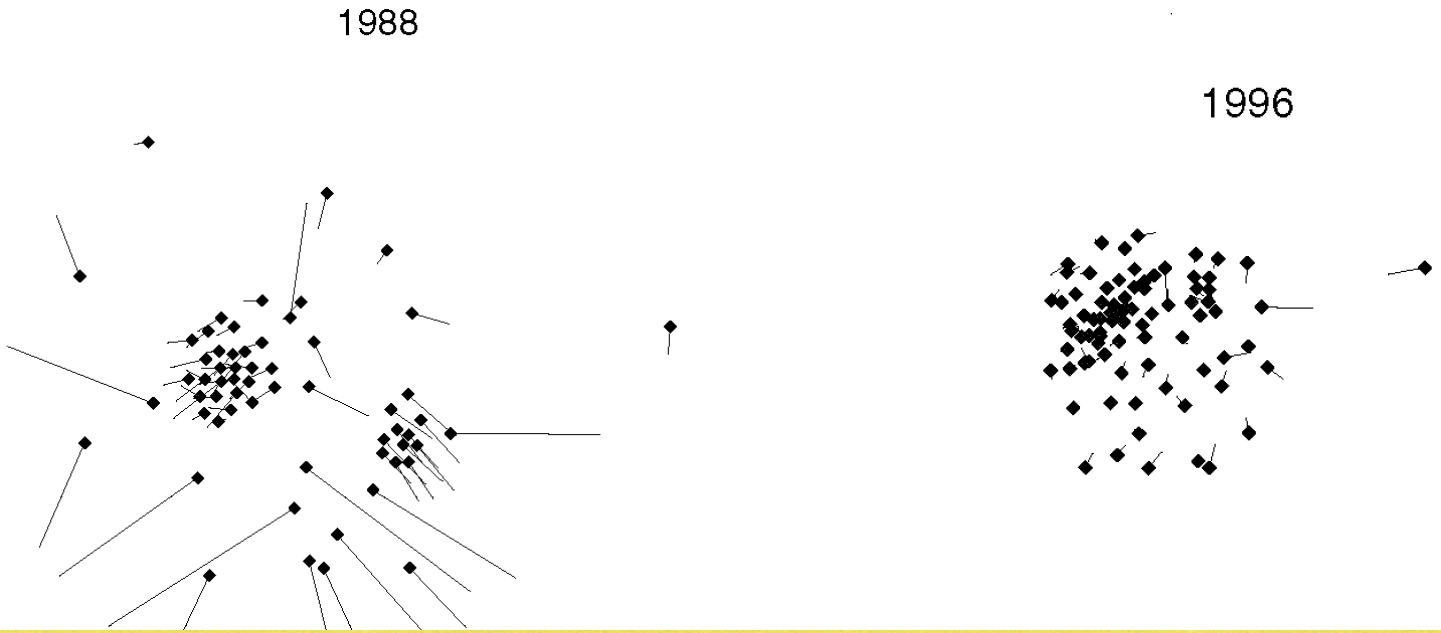
- Effort Model: predictors of the person-hours

$$\mathrm{EFF(c)} = a_0 + a_1 \mathrm{FILES(c)} + a_2 \sum_f 1\{c \rightsquigarrow f\}|f| + a_3 \mathrm{ADD(c)} + a_4 \mathrm{DEL(c)} + a_5 \mathrm{INT(c)} + a_6 \mathrm{DEV(c)}.$$

Results: (1) The span of changes increases over time?



Results: (2) Breakdown of modularity increases over time?



If modules have changed together as a part of the same MR, they were placed to close to each other.

Results: (3) Fault potential, the likelihood of changes to induce faults increases over time

$$\mathrm{FP_{WTD}(m,t)} = \gamma_1 \sum_{c \rightsquigarrow m,\ \mathrm{DATE(c)<t}} e^{-\alpha[t-\mathrm{DATE(c)}]} \times \log[\mathrm{ADD(c,m)} + \mathrm{DEL(c,m)}]$$

$$\mathrm{FP_{WTD}(m)} \propto \sum_{c \rightsquigarrow m} e^{0.75\times\mathrm{DATE(c)}} \times \log[\mathrm{ADD(c,m)} + \mathrm{DEL(c,m)}],$$

$$\mathrm{FP_{GLM}(m,t)} = \gamma_2 \times \sum_{c\in\Delta} \mathbf{1}\{c \rightsquigarrow m\} \times \beta^{\mathrm{AGE(m)}},$$

$$\mathrm{FP_{GLM}(m)} = .017 \times \sum_{c} \mathbf{1}\{c \rightsquigarrow m\} \times .64^{\mathrm{AGE(m)}}.$$

Large, recent changes add the most to fault potential.

Modules that have survived for a long time are less likely to have high faults. Modules that frequent changes are more likely to have high faults

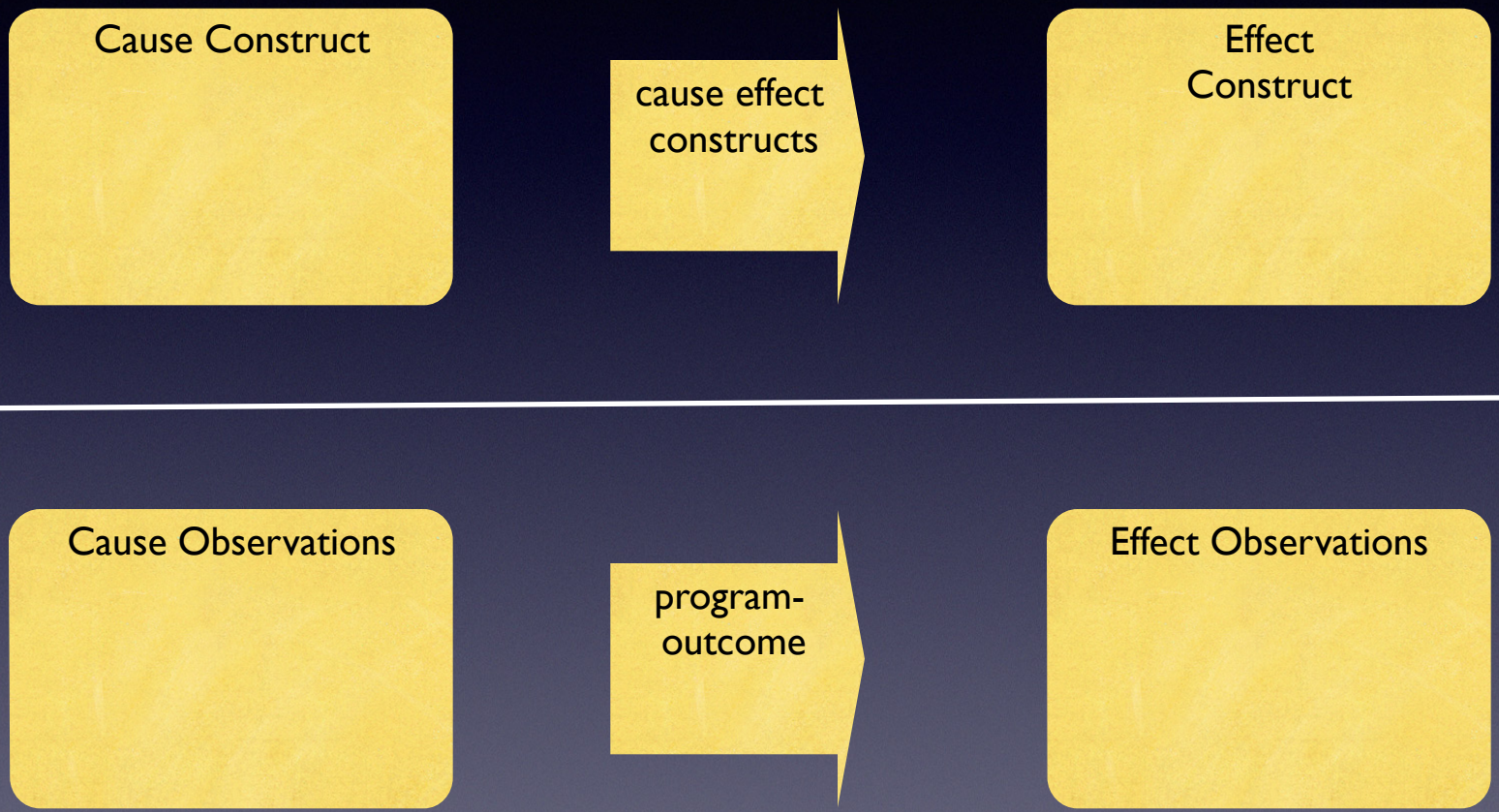
Results: (4) Prediction of efforts increases over time

$$\begin{aligned}\mathrm{EFF}(c) = a_0 &+ a_1 \mathrm{FILES}(c) + a_2 \sum_f 1\{c \rightsquigarrow f\}|f| \\ &+ a_3 \mathrm{ADD}(c) + a_4 \mathrm{DEL}(c) \\ &+ a_5 \mathrm{INT}(c) + a_6 \mathrm{DEV}(c).\end{aligned}$$

$$\begin{aligned}\log(1+\mathrm{EFF}(c)) = .32 &+ .13\ (\log[1+\mathrm{FILES}(c)])^2 \\ &- .09(\log[1+\mathrm{DEL}(c)])^2 \\ &+ .12 \log[1+\mathrm{ADD}(c)] \log[1+\mathrm{DEL}(c)] \\ &+ .11 \log[1+\mathrm{INT}(c)] \\ &- .47 \log[1+\mathrm{DELTAS}(c)].\end{aligned}$$

File span has positive correlation.
Large deletions are implemented rather easily.
Hardest changes require both additions and deletions.
Large number of editing changes are rather easy to implement.

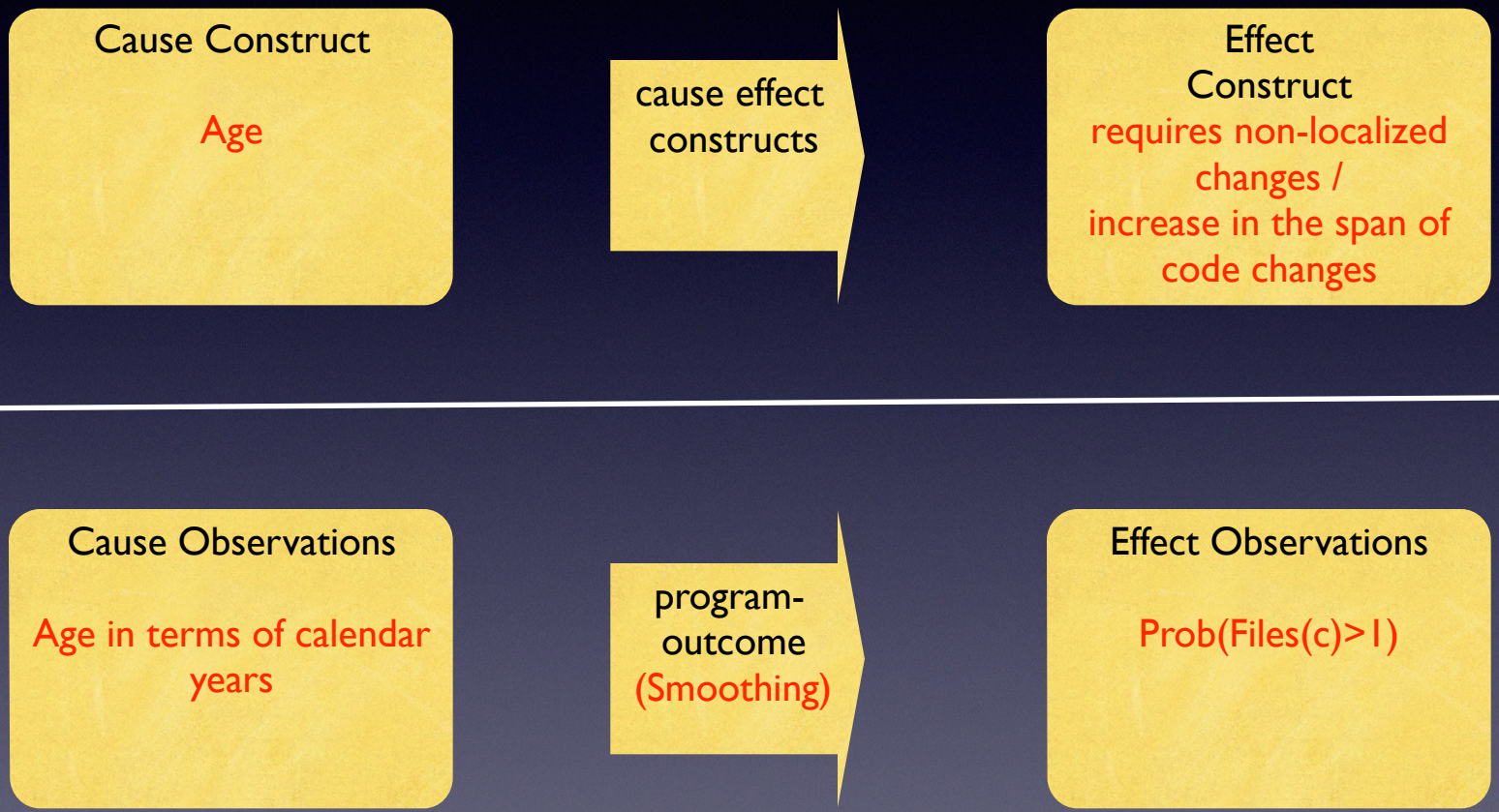
1. Temporal Behavior of the Span of Code Changes



1. Temporal Behavior of the Span of Code Changes

- External Validity
- Internal Validity
- Construct Validity
- Conclusion Validity

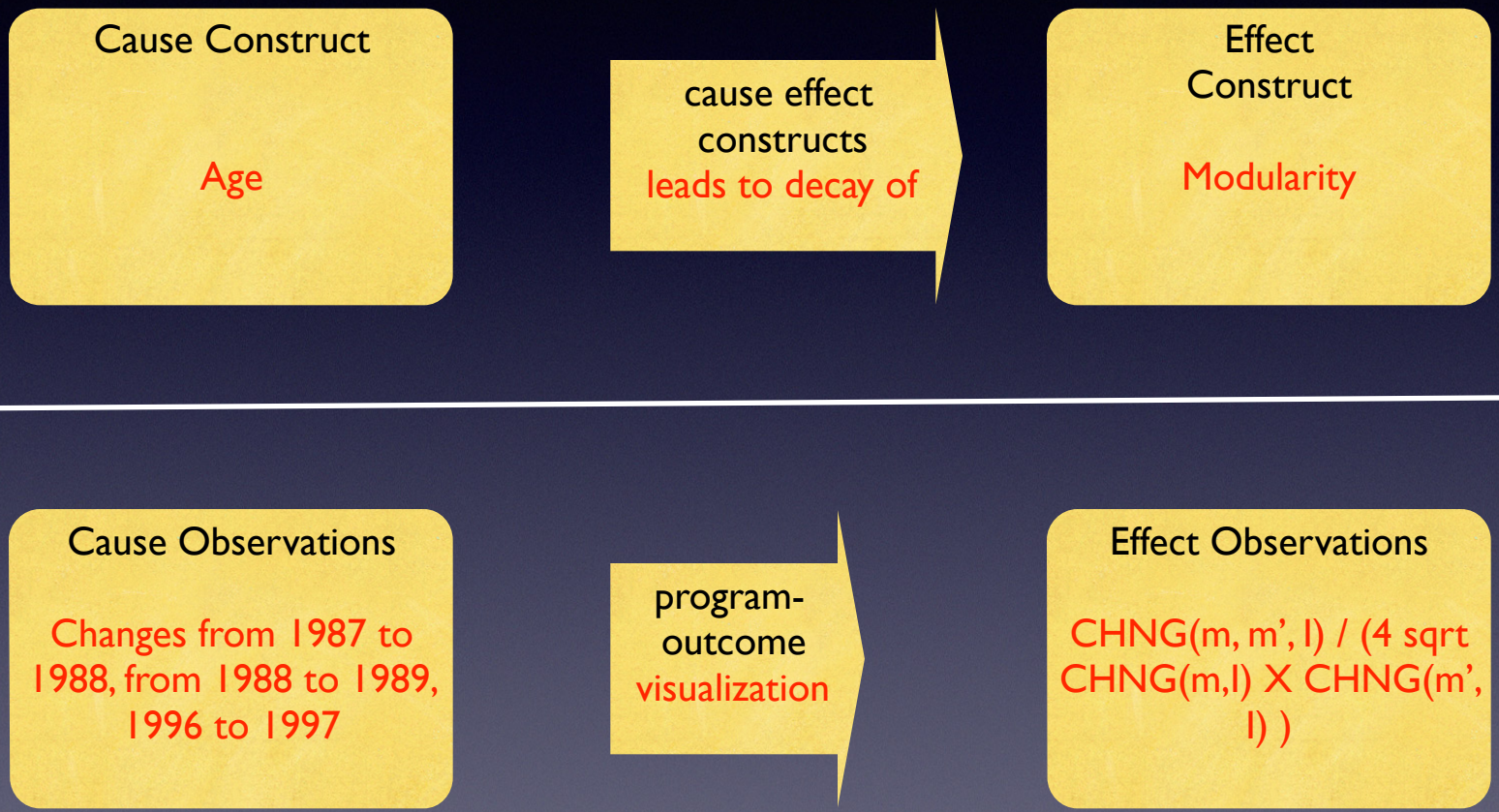
1. Temporal Behavior of the Span of Code Changes



1. Temporal Behavior of the Span of Code Changes

- External Validity: *what about systems other than 5ESS?*
- Internal Validity: *Perhaps the increase in the span of changes is caused by organizational changes.*
- Construct Validity: *Does the number of changed files correctly reflect the span of changes?*
- Conclusion Validity: *Does the Figure 3 lead to a conclusion that the span of code changes increase as software ages?*

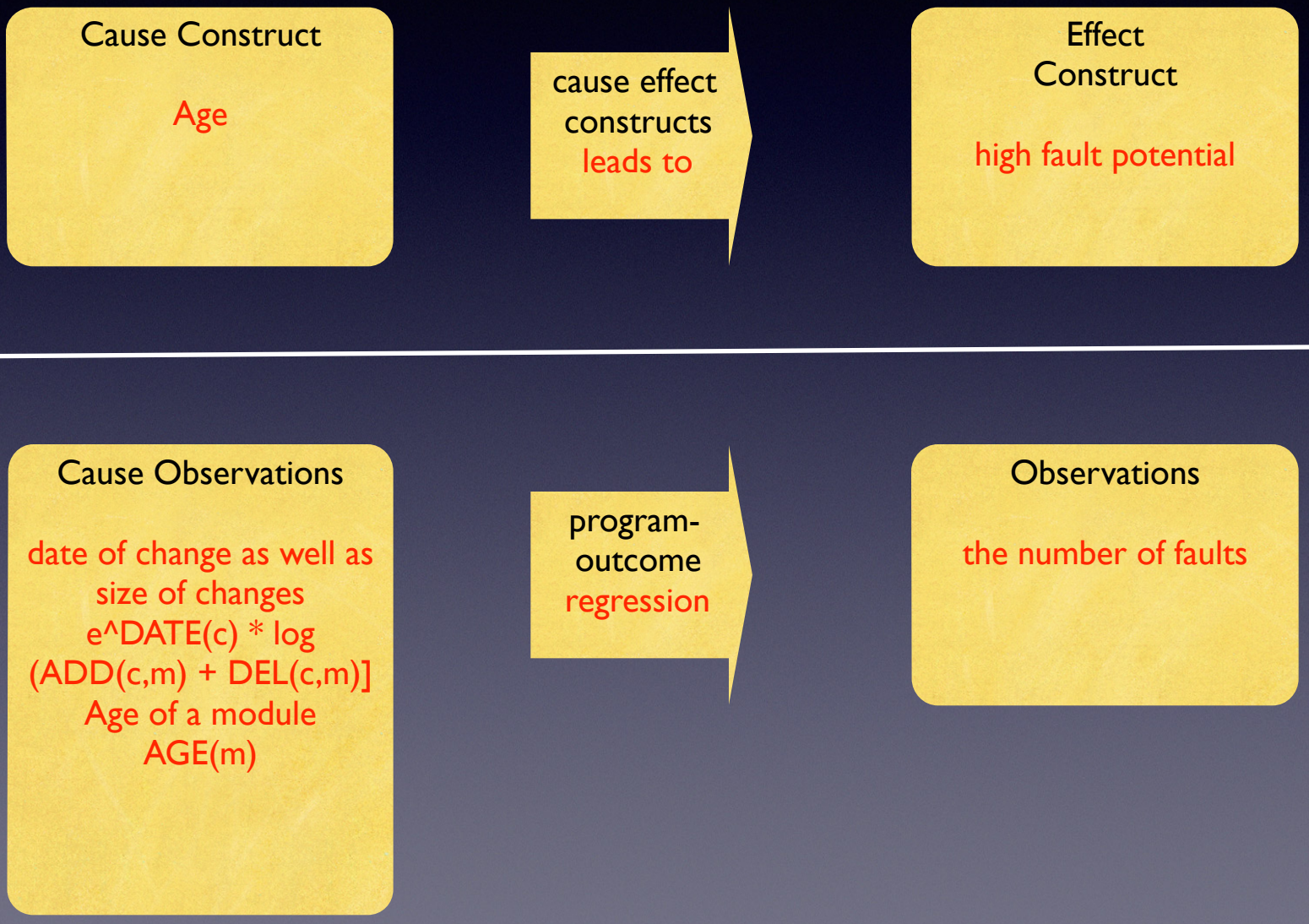
2. Time Behavior of Modularity



2. Time Behavior of Modularity

- External Validity: *what about systems other than 5ESS?*
- Internal Validity: *Perhaps the modularity decay is caused by organizational changes.*
- Construct Validity: *Does this distance metric,* CHNG(m, m', I) / (4 sqrt CHNG(m,I) X CHNG(m', I)) *represent modularity?*
- Conclusion Validity: *Can you conclude modularity decay from snapshots of visualizations?*

3. Prediction of Faults



3. Prediction of Faults

- External Validity: *What about systems other than 5ESS?*
- Internal Validity: *Perhaps the number of faults is different from the prediction of faults.*
- Construct Validity: *Perhaps the size changes in terms of added and deleted lines is not accurate.*
- Conclusion Validity: *Does the found positive coefficient indicate that fault potential increase over time?*

My general thoughts on Code Decay Paper

- Rich data set!!!
- Scientific research method
  - Identification of hypotheses => identify key variables and measure them = > create statistical models => statistical regression
- What do identified coefficients real mean?
- Can programmers use any of these findings for daily development activities?

Recap

- Code decay can be mapped to specific measured / derived variables.
  - e.g., span of changes => file span, non-localized changes => changes that spans module boundaries
- Early mining software repositories research in late 90s that is based on statistical regression analysis and visualization
- These types of research require having good insights.
  - e.g., weighted time dampened model
- Identified which factors do mater! => some surprising results that complexity metrics do not matter