Lecture 22: Software Measurement

Basics of software measurement

- metrics
- predictive models
- validity

Some example models

- *COCOMO* (for effort and time estimation)
- Function Points (for estimating software size)
- Reliability Models
- Cyclomatic Complexity

Basics of Software Measurement

Definitions

Source: Adapted from Pfleeger 1998, p465-470

Metric - a quantifiable characteristic of software

Measurement - the process of mapping from real world attributes to a mathematical representation

Model - a mathematical relationship between metrics

- e.g. between quality factors and available metrics

Validity - Does the metric accurately measure what it purports to measure

Prediction system - a set of metrics and a model that can be used to predict some attribute of a future entity.

- Deterministic predictions give the same result for the same inputs
- Stochastic predictions provide a window of error around the actual value

Difficulties with software measurement

We are not measuring repeatable, objective phenomena

Software development is so complex that all models are weak approximations

- models that work for one project or team don't work for others
- local contingency factors may be more important than the metrics in the model

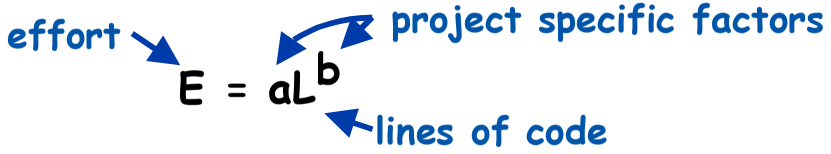
Example model: COCOMO

Source: Adapted from van Vliet, 1999, section 7.3.2

COnstructive COst Model (COCOMO)

Used to predict cost of a project from a measure of size (lines of code)

Basic model is:



Modeling process

Establish type of project (organic, semidetached, embedded)

- this gives sets of values for a and b

Identify the component modules, and estimate L for each module

Adjust L according to how much is reused

- COCOMO has a model for adjusting according to how much design, code and integration data is reused

Compute effort for each module using $E = aL^b$

Adjust E according to difficulty of the project

- COCOMO identifies 15 effort multipliers to take into account
- Product attributes: eg required reliability, complexity, database size
- Computer attributes: eg execution time constraints, storage constraints, etc.
- Personnel attributes: eg capability & experience of analysts and programmers,
- Project attributes: eg use of CASE tools, programming language, schedule

Compute time using $T = cE^d$

- c and d provided for different project types like a and b were

Example model: Function Points

Source: Adapted from van Vliet, 1999, section 7.3.5

Function Points

used to caculate size of software from a statement of the problem

tries to address variability in lines of code estimates used in models such as *COCOMO*

e.g. because SLOC varies with different languages

Originally for information systems, although other variants exist

Basic model is:

metric from problem statement

$$FP = a_1 I + a_2 O + a_3 E + a_4 L + a_5 F$$

weighting factor for this metric

Example

Sets of weightings (a_i) provided for different types of project

Measure properties of the problem statement:

I = number of user inputs (data entry)

O = number of user outputs (reports, screens, error messages)

E = number of user queries

L = number of files

F = number of external interfaces (to other devices, systems)

Example calculation:

$FP = 4I + 5O + 4E + 10L + 7F$

Example model: Reliability growth

Source: Adapted from Pfleeger 1998, p359

Motorola's Zero-failure testing model

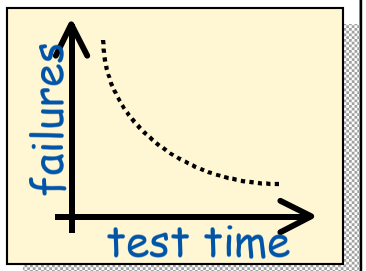
Predicts how much more testing is needed to establish a given reliability goal

basic model:

empirical constants

$$failures = a\, e^{-b(t)}$$

testing time



Reliability estimation process

Inputs needed:

- fd = target failure density (e.g. 0.03 failures per 1000 LOC)
- tf = total test failures observed so far
- th = total testing hours up to the last failure

Calculate number of further test hours needed using:

$$\frac{\ln(fd/(0.5 + fd)) \times th}{\ln((0.5 + fd)/(tf + fd))}$$

Result gives the number of further failure free hours of testing needed to establish the desired failure density

- if a failure is detected in this time, you stop the clock and recalculate

Note: this model ignores operational profiles!

Example model: Cyclomatic Complexity

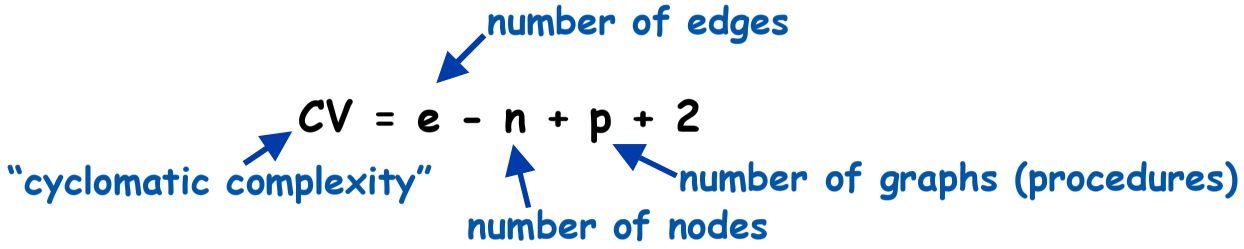
Source: Adapted from van Vliet, 1999, pp308-311

McCabes' complexity measure

This is a measurement model, not a predictive model

It measures complexity as a function of the number of paths through a program

Basic model is:



Application

Draw each module as flowchart

Convert each flowchart to a graph

- nodes show statements, edges show control paths
- branches (IF, WHILE, etc) have multiple edges coming out of them

Count edges and nodes in each graph

CV also corresponds to the number of linearly independent paths in the graph

CV > 10 is usually taken as an indicator that a module is overly complex

But the validity of this measure is hotly disputed!

But software measurement is hard

Key problems for software measurement:

- Most attributes of interest cannot be measured directly
- Most metrics are very hard to validate
- Most models are at best vague approximations
  - The validity of each of the models described is disputed
  - Models usually have to be adapted to a particular organization
  - Need to collect data over a long period to validate and adapt the models
- The technology keeps changing
  - parameters for these models are derived from past projects which might be unlike future projects

Predictive models can be self-fulfilling

- Predictive model is used to generate effort and time estimates
  - …which are used to generate a project plan
  - …which is used by managers to manage the project to
  - …so the project ends up having to conform to the estimate!

But you cannot control it if you cannot measure it

- poor models may be better than no models at all
- predictions will need to be continuously revised as the project proceeds

References

van Vliet, H. "Software Engineering: Principles and Practice (2nd Edition)" Wiley, 1999.

Chapter 6 has some introductory comments about measurement of various different things in software engineering, especially with respect to any attempt to measure software quality. Various metrics are introduced throughout the book, at appropriate places. For example, cost estimation (*COCOMO*, Function Point Analysis, etc) is in chapter 7; measurement of design complexity (Halstead, McCabe, …) is in chapter 11; measurement of testing (test coverage, test adequacy criteria) is in chapter 13; and reliability estimation is in chapter 18. This is of course appropriate – measurement should be an integrated part of software engineering, not something you bolt on afterwards!

Pfleeger, S. L. "Software Engineering: Theory and Practice" Prentice Hall, 1998.

Pfleeger's research area is software measurement, so she gives it a very strong treatment throughout her book.