INF 111 / CSE 121: Software Tools and Methods

Lecture Notes for Summer, 2008

Michele Rousseau

Lecture Note 10 – Effort Estimation

Announcements

- **Assignment #3 is due on Monday**
- **Quiz #3 regrades are due today**

Previously in INF 111/ CSE 121…

- **Effort Estimations**
  - Better Techniques

Today's Lecture

- **Effort Estimation**
  - Algorithmic Cost Modeling
    - COCOMO
- **Personal Software Process (PSP)**

Algorithmic Cost Modeling

- Cost and development time for a project is estimated from an equation
- Equations can come from research or industry
  - **Analysis of historical data**
  - **Work best if they are tailored using personal and organizational data**
    - **Adjust weights of metrics based on your environment**

Basic Equation

Constant: Organizational Dependent

Effort for Large Projects
Disproportionate

Estimate

$$E = (a + S^c)m(X)$$

Vector of cost factors (x1..xn):
Complexity of the product, Risk, resources, methods, tools, etc…

Size (LOC)

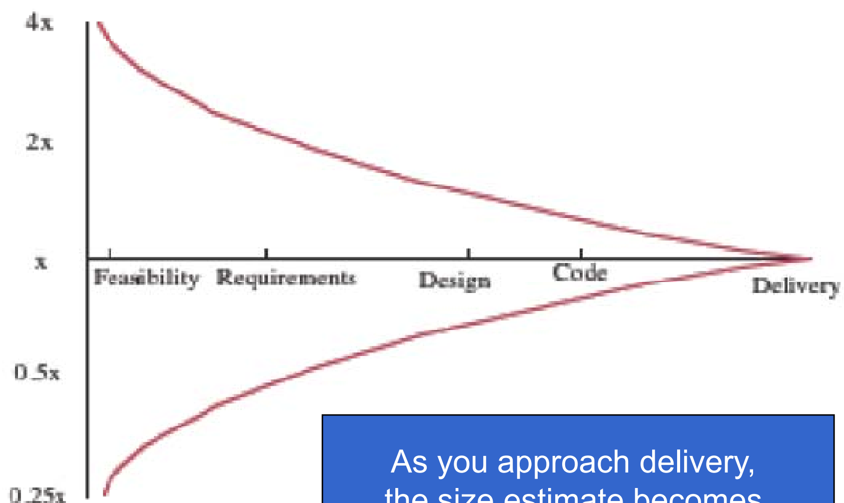
Multiplier:
Reflects product, process & people attributes

- Most commonly used product attribute for cost estimation is code size
- Most models are basically similar but with different values for a,c, & m

Problems with Algorithmic Estimation

- Effort estimates are based on size
  - **Highly inaccurate at start of project**
  - **Size is usually given in lines of code**
- Lines of code does not reflect the difficulty
  - **Some short programs are harder to write than long ones**
  - **Lines of code ≠ effort**
    - **Not all activities produce code**
  - **Programming Language: Java vs. assembler**
  - **Number of Components**
  - **Distribution of the system**
- Recall Brooks Chapter 2
  - **Effort ≠ progress**
  - **The B exponent is an attempt to account for communication and complexity costs, but basic problem remains**

Estimate Uncertainty



As you approach delivery, the size estimate becomes more accurate

Boehm: COCOMO

Constructive Cost Model (COCOMO)

- COCOMO is one of the most widely used software estimation models in the world
- An empirical model based on project experience
- Well-documented, 'independent' model which is not tied to a specific software vendor
- Long history from initial version published in 1981 (COCOMO-81)
- COCOMO II takes into account different approaches to software development, reuse, etc.
- predicts the effort and schedule for a software product development based on inputs relating to the **size** of the software and a number of **cost drivers** that affect productivity

COCOMO: Some Assumptions

- Primary cost driver ➔DSI
  - Delivered Source Instructions (DSI) developed by the project
  - Only code developed by staff
  - Excludes
    - Test drivers & other support code
    - Comments
    - Declarations
    - Code developed by application generators
  - SLOC => Single logical line of code → eg. If;then;else

COCOMO: More Assumptions

- COCOMO estimates assume that the project will enjoy good management by both the developer and the customer
- Assumes the requirements specification is not substantially changed after the plans and requirements phase

COCOMO: Three Models

- **3 Models reflect the complexity:**
  - the Basic Model
  - the Intermediate Model
  - and the Detailed Model

The Development Modes: Project Characteristics

- Organic Mode
  - developed in a **familiar**, stable environment,
  - **similar** to the previously developed projects
  - relatively **small** and requires little innovation
  - Eg. Payroll system
- Semidetached Mode
  - **intermediate** between Organic and Embedded
  - Eg. Banking System
- Embedded Mode
  - tight, **inflexible** constraints and interface requirements
  - The product requires **great innovation**
  - Eg. Nuclear power plant system

Basic COCOMO Model:

Estimates the software development effort using only a *single predictor variable* (size in DSI) and 3 development modes

- When Should You Use It ?
  - Good for quick, early, rough order of magnitude estimates of software costs

Basic COCOMO Model: Equations

Mode	Effort	Schedule
Organic	$E=2.4*(KDSI)^{1.05}$	$TDEV=2.5*(E)^{0.38}$
Semi-detached	$E=3.0*(KDSI)^{1.12}$	$TDEV=2.5*(E)^{0.35}$
Embedded	$E=3.6*(KDSI)^{1.20}$	$TDEV=2.5*(E)^{0.32}$

Basic COCOMO Model: Example

- We have determined our project fits the characteristics of Semi-Detached mode
- We estimate our project will have 32,000 Delivered Source Instructions (DSI).

Using the formulas, we can estimate:

- Effort = $3.0*(32)^{1.12}$ = 146 man-months
- Schedule = $2.5*(146)^{0.35}$ = 14 months
- Productivity = 32,000 DSI / 146 MM = 219 DSI/MM
- Average Staffing = 146 MM /14 months = 10 FSP

Comparison of Basic Formula

	Halstead	Boehm	Walston-Felix
KLOC	$E=0.7\ KLOC^{1.50}$	$E=2.4\ KLOC^{1.05}$	$E=5.2\ KLOC^{0.91}$
1	0.7	2.4	5.2
10	22.1	26.9	42.3
50	247.5	145.9	182.8
100	700.0	302.1	343.6
1000	22135.9	3390.1	2792.6

- Coefficients derived using actual project data
  - **Variability in project characteristics**
- At best, yield estimates that are at most 25% off, 75% of the time, *for projects used to derive the model*.

Basic COCOMO Model: Limitations

- Its accuracy is necessarily limited because of its lack of factors which have a significant influence on software costs
- Estimates are within a factor of…
  - **1.3** only **29%** of the time **&**
  - **2** only **60%** of the time

Take a break!

- **Get some Coffee**
- **Wakey-Wakey**

When we return…

- **More on COCOMO**

Intermediate COCOMO Model

Estimates effort by using fifteen cost driver variables besides the size variable used in Basic COCOMO

- When should you use it?
  - Can be applied across the entire software product for easy and rough cost estimation during the early stage
  - or it can be applied at the software product component level for more accurate cost estimation in more detailed stages

Cost Drivers

Four areas for drivers

- **Product Attributes**
  - Reliability, Database Size, Complexity
- **Computer Attributes**
  - Execution Time Constraint, Main Storage Constraint, Virtual Machine Volatility, Computer Turnaround Time
- **Personnel Attributes**
  - Analyst Capability, Applications Experience, Programmer Capability, Virtual Machine Experience, Programming Language Experience
- **Project Attributes**
  - Modern Programming Practices, Use of Software Tools, Required Development Schedule

Subjective Assessments

Intermediate Model: Effort Multipliers

- Table of Effort Multipliers for each of the Cost Drivers is provided with ranges depending on the ratings

Cost Driver	*Very Low*	*Low*	*Nom*	*High*	*Very High*	*Extra High*
Product Complexity	**0.70**	**0.85**	**1.00**	**1.15**	**1.30**	**1.65**

Intermediate Model: Equations

Mode	*Effort*	*Schedule*
Organic	$E=EAF*3.2*(KDSI)^{1.05}$	$TDEV=2.5*(E)^{0.38}$
Semi-detached	$E=EAF*3.0*(KDSI)^{1.12}$	$TDEV=2.5*(E)^{0.35}$
Embedded	$E=EAF*2.8*(KDSI)^{1.20}$	$TDEV=2.5*(E)^{0.32}$

COCOMO Effort Equation

Effort = 3.0 * EAF * (KSLOC)^{E}

- Result is in Man-months
- EAF → Effort Adjustment Factor
  - Derived from Cost Drivers
- E → Exponent
  - Derived from five scale drivers
    - Precedentedness
    - Development Flexibility
    - Architecture / Risk Resolution
    - Team Cohesion
    - Process Maturity

Intermediate Model: Example

- Project A is to be a **32,000 DSI semi-detached software**. It is in a mission critical area, so the **reliability** is high (RELY=high=1.15).

Then we can estimate:

- **Effort** = $1.15*3.0*(32)^{1.12}$ = 167 man-months
- **Schedule** = $2.5*(167)^{0.35}$ = 15 months
- **Productivity** = (DSI / MM) = 32,000 DSI/167 MM = 192 DSI/MM
- **Average Staffing** = = 167 MM/15 months
  MM/Schedule Months **=** 11 FSP

Intermediate Model: Limitations

- Estimates are within **20%** of the actuals **68%** of the time
- Its effort multipliers are phase-insensitive
- It can be very tedious to use on a product with many components

Detailed COCOMO Model: How is it Different?

- **Phase-sensitive Effort Multipliers**
  Effort multipliers for the cost drivers are different depending on the software development phases
- **Module-Subsystem-System Hierarchy**
  - The software product is estimated in the three level hierarchical decomposition.
  - The fifteen cost drivers are related to module or subsystem level

Detailed COCOMO Model: When Should You Use It?

- The Detailed Model can estimate
  - **the staffing, cost, and duration of each of the development phases, subsystems, modules**
- It allows you to experiment with different development strategies, to find the plan that best suits your needs and resources

Detailed Model: Equations

- Same equations for estimations as the Intermediate Model
- Uses a very complex procedure to calculate estimation.
  - **The procedure uses the DSIs for subsystems and modules, and module level and subsystem level effort multipliers as inputs**

Detailed Model: Limitations

- Requires substantially more time and effort to calculate estimates than previous models
- Estimates are within 20% of the actuals 70% of the time

COCOMO II

- **Modified for more current development**
- **3 increasingly detailed cost estimation models**
  - **Application composition**
    - **Prototyping efforts (UI Issues)**
    - **Used in a powerful CASE environment**
  - **Early Design**
    - **Focused on Architectural design phase**
  - **Post-Architecture model**
    - **Used during implementation phaseCOCOMO estimates assume good mgmt**
- by both the developer and the customer

- Assumes the requirements specification is not substantially changed after the requirements & design phase

- **http://sunset.usc.edu/research/COCOMOII/index.html**

So, what can you do?

- You
  - **Don't have a historical database**
  - **Are not an expert**
- Generate estimates using multiple models and compare based on your guesses or assumptions
  - **Similar to using the models as your personal experts in Delphi method**
  - **Candidate models:**
    - **Walston and Felix (simple and easy to use)**
    - **COCOMO 2 (complicated and detailed)**
    - **DeMarco (based on UI requirements)**
- Brooks, p. 20
  - **1/3 planning, 1/6 coding, 1/4 component tests and early system test, 1/4 system test**

Data Collection

- Regardless of the method or model used, data is needed for calibration
- Programmers need to know their own "constant adjustment factors"
  - **Goal of Personal Software Process to establish such a database**

Overview of PSP

The Personal Software Process (PSP)

- **PSP sets out the principal practices for defining, measuring and analysing an individual's own processes**
- **The main idea:**
  - understand how you work
  - analyze your performance
  - Improve your process
  - Develop an ability to define, measure and analyze your process

PSP

- **PSP applies a CMM-like assessment for individual work**
  - Measurement & analysis framework to help you characterize your process
    - Self-assessment and self-monitoring
  - Prescribes a personal process for developing software
    - defined steps
    - Forms
    - Standards
  - Assumes individual scale & complexity
    - Well-defined individual tasks of short duration

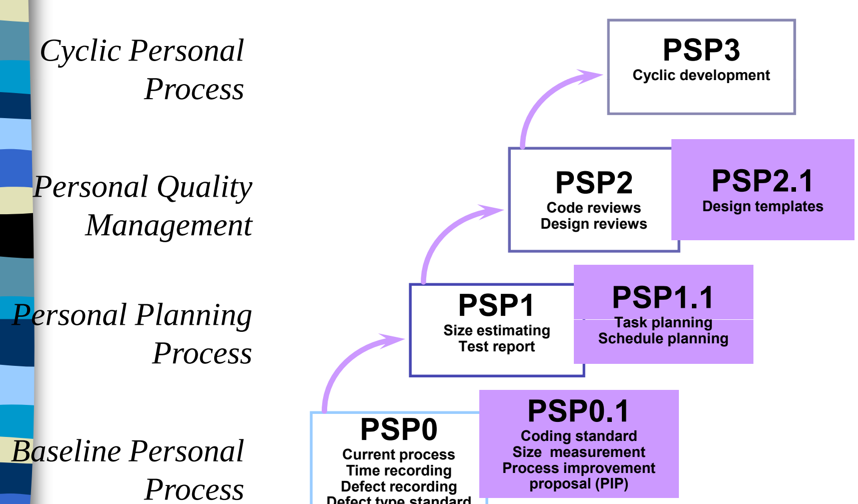
PSP - Steps

1. **Understand the current status of your development process or processes.**
2. **Develop a vision of the desired process.**
3. **Establish a list of required process improvement actions, in order of priority.**
4. **Produce a plan to accomplish the required actions.**
5. **Commit the resources to execute the plan.**
6. **Start over at step 1.**

PSP Overview

- **The PSP is introduced in 7 upward compatible steps (4 levels)**
- **Write 1 or 2 *small* programs at each step**
  - Assume that you know the programming language
- **Gather and analyze data on your work**
  - Many standard forms & spreadsheet templates
- **Use these analyses to improve your work**
  - Note patterns in your work

PSP Evolution



Why use PSP?

- demonstrates personal process principles
- assists engineers in making accurate plans
- determines the steps engineers can take to improve product quality
- establishes benchmarks to measure personal process improvement, and
- determines the impact of process changes on an engineer's performance

PSP Evaluation

- Humphrey has used in SE courses
  - Improvements in time-to-compile, quality and productivity
- Patchy, but promising use in industry
  - E.g. Nortel (Atlanta)
- Still immature
- Requires large overhead for data gathering
  - Not clear that you should use permanently or continually

PSP/TSP/CMM

CMM® Builds organizational capability

TSP℠ Builds quality products on cost and schedule

PSP® Builds individual skill and discipline