COCOMO II Status and Plans

Brad Clark, Barry Boehm
USC-CSE Annual Research Review
March 10, 1997
Outline

- COCOMO II Status: Brad Clark
  - Model calibration
  - Tool Status
  - Data Status

- COCOMO II Plans: Barry Boehm
  - Tool Plans
  - Model Plans
  - Training and data collection plans
Presentation Outline:

*Model Calibration*

- Calibration Procedures
- COCOMO II.1997 Model Parameters
- Accuracy Results
- USC COCOMO Software Status
- COSTAR Software Status
- Calibration Data Status
Model Calibration Status:

- Three models comprise COCOMO II:
  - Applications Composition
  - Early Design
  - Post-Architecture
- Post-Architecture model calibrated
- Early Design model will be derived from Post-Architecture
- Applications Composition: need data
Calibration Process:

- Begin with expert-determined apriori model parameters
- Collect Data
- Identify and consolidated highly correlated model parameters
- Statistically determine estimates of consolidated model parameters from data
- Use data determined coefficients to adjust apriori model parameters
- Experiment with weighting factors
Post-Architecture Model:

- Non-linear model:

\[
PM_{estimated} = A \cdot (\text{Size})^B \cdot \prod_{i=1}^{17} EM_i
\]

- A: Multiplicative calibration variable

- B: Captures relative diseconomies of scale. Consists of 5 scale factors:

\[
B = 1.01 + \sum_{j=1}^{5} SF_j
\]

- EM: Effort Multipliers to reflect characteristics of particular software under development.

- Size: Derived from either Source Lines of Code or Function Points. Includes reuse and breakage effects.
### Apriori Model Parameters:

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Data Collection:

- Define the data needed (to completely describe the Post Architecture Model)

- Collect data with a paper form or a computer software tool

- Affiliate Organizations providing majority of data.
  - Historical - whole project

- Site visits or phone interviews to record data

- Enter in data into the repository
  - Data is labeled with generic id
  - Stored in locked room
  - Limited access by researchers
  - Data Consistency checking and conditioning
Consolidated Highly Correlated Parameters:

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- Combined (for calibration purposes only):
  - TIME & STOR into RCON (Resource Constraints)
  - ACAP & PCAP into PERS (Personnel Factors)

- Thus, calibrated 15 effort multipliers instead of 17
Expanded Post-Architecture Model:

- Distribute the Scale Factors
- 21 predictor variables: 15 Effort Multiplier Coefficients + 5 Scale Factor Coefficients + overall A constant:

\[ PM_{est} = A \cdot (Size)^{1.01} \cdot (Size)^{SF_1} \cdot (Size)^{SF_2} \cdots EM_1 \cdots EM_{15} \]

Log Transformed Model:

- Regression analysis will derive the coefficients, \( A \) and \( b_i \), for each factor

\[ \ln(PM_{est}) - \ln(Size)^{1.01} = A + b_1 SF_1 \ln(Size) + \cdots + b_{20} \ln(EM_{15}) \]
Example of Applying Coefficients to Model Apriori Parameters:

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RUSE Effort Multiplier:

- Example of the effect of a negative coefficient
Distribution of RUSE:

![Bar Chart]

Frequency

RUSE
Evolving Model Values:

100% Data Driven

100% Expert Driven

Number of projects used in calibration
Aposteriori Model Parameters

- Using 10% of data-determined and 90% of apriori
- Effort constant, A: 2.45

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- Calibrated schedule constant, A: 2.66 (apriori value was 3.0)

\[
TDEV = [A \cdot (PM)^{(0.33+0.2 \cdot \sum SF_i)}] \cdot \frac{SCED\%}{100}
\]
Presentation Outline:

- Model Calibration
- Calibration Procedures
- COCOMO II 1997 Model Parameters

Analysis Results
- USC COCOMO Software Status
- COSTAR Software Status
- Calibration Data Status
Accuracy Results:

- Forecast accuracy measured with Proportional Error (PE):

\[
PE = \begin{cases} 
\left[ PM_{est} \div PM_{act} \right] - 1, & (PM_{est} - PM_{act}) \geq 0 \\
- \left[ PM_{act} \div PM_{est} \right] + 1, & (PM_{est} - PM_{act}) < 0
\end{cases}
\]

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<tr>
<td>PRED(.30)</td>
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</table>
Effort Proportional Error before Stratification

![Diagram showing Effort Proportional Error (PE) against Organization Number]
Effort Proportional Error after Stratification

- Projects

Organization Number

PE

0.00

-3.00

-2.00

-1.00

1.00

2.00

3.00
USC COCOMO Software Status:

- There is an initial version available for MS Windows, Sun OS, and Java
  
  - Has new calibrated values
  - Confidence ranges (optimistic, most likely, pessimistic)
  - User definable Cost Drivers: USR1, USR2
  - Schedule input is now project wide
  - New reference manual
  - New values can be manually input for all cost drivers
  - Version changed to COCOMO II.199Y.X
    (where Y is the year number and X is the version within that year)
USC COCOMO Future Work:

- Entry of actuals for periodic tracking of project and data submission
- Calibration of constant and exponent
- Incremental ratings between Very Low, Low, Nominal, High, Very High, Extra High
- Text entry for SU, AA, UNFM
- New Help file
COSTAR Software Status

- Commercialized version of COCOMO
- Beta version of COCOMO II model available
- New values will be put in the model soon
Calibration Data Status

- More project data is required to facilitate better calibration of the general COCOMO II Post-Architecture model.

- We hope the use of USC COCOMO software will facilitate collection and submission of data.

- If you calibrate the model to your local organization (constant and exponent) - we would like to have your observations in our repository to be used for full model calibration.

- We plan to make annual updates to the cost driver values and release them on a regular cycle.
Information Sources:

- Phone: 213-740-6470
- Email: cocomo-info@sunset.usc.edu
- Web site: http://sunset.usc.edu/COCOMOII/Cocomo.html

- Affiliate Prospectus
- Model Definition Manual (ver. 1.4)
- Data Collection Form (ver. 1.6)
- Java COCOMO
- Little Expert COCOMO Calculator
Outline

• COCOMO II Status: Brad Clark
  – Model calibration
  – Tool Status
  – Data Status

• COCOMO II Plans: Barry Boehm
  – Tool Plans
  – Model Plans
  – Training and data collection plans
Tool Plans: USC COCOMO II.1997.1

- Calibration to an organization’s data
  - Effort and/or schedule
  - Coefficient or also exponent
- Intermediate rating levels
- Updated Madachy risk assessment model
- Added reuse parameters: SU, AA, UNFM
Calibration

- Provide a way of capturing and retaining a set of projects.
- Capability of changing C (constant) and E (exponent) from cocomo equation.
- Provide users with 2 ways of using C and E.
  - Standard cocomo values
  - Calibrated values
Model Plans: Affiliate Priorities

14 • Activity distribution

13 • COTS integration costs

12 • Sizing improvements

5 • Cost/schedule/quality tradeoffs

5 • Life cycle tradeoff models
Effort Distribution by Activity

- Effort/FP varies by language level (LL)
  - But so does effort/SLOC!

- Proposed approach
  - SLOC, LL $$\Rightarrow$$ Effort:
    - Determine equivalent 3GL SLOC (3SLOC) via backfiring
    - Compute effort as $$F(3\text{SLOC})$$
    - Apply LL stage multipliers to obtain activity distribution, total effort
  - UFP, LL $$\Rightarrow$$ Effort
    - Determine 3SLOC by backfiring
    - Compute effort as $$F(3\text{SLOC})$$
    - Apply LL stage multipliers to obtain activity distribution, total effort
4GL Cost and Schedule Effects
[Verner-Tate, 1988]

- Correspondence school information system
- Estimated size: 15 KDSI ALL [4GL], 95 KDSI COBOL
- Actual size: 13.9 KDSI ALL, 93.6 KDSI equiv. COBOL
- Data on phase distribution of effort and schedule
## 4GL Estimates vs. Actuals

<table>
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<th>Quantity</th>
<th>COCOMO-COBOL</th>
<th>COCOMO-4GL</th>
<th>Actual</th>
<th>Recom. Use</th>
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Effort Distribution Relative to 3GL Development

Rapid App. Devel.

Spiral-type  Ev. Dev., Spiral

LCO, LCA  SAT

5GL  4  10  10

Sys Devel.

Spiral-type  Waterfall, Spiral-type  W'fall, IncDev, EvDev, Spiral, Design-to-Cost, etc.

LCO  LCA  Code, Integ., Test

Det. Design

4GL  6  9  13  21

3GL  7  17  25  58  100

2GL  8  19  27  154  200
Proposed UML-Based Sizing Model

- Rational’s Universal Modeling Language (Booch, Jacobson, Rumbaugh) approaching de-facto OOD standard
- A UML-based early sizing metric would address two major current short falls with Function Points
  - Automated counting
  - Object-orientation
- Rational (Walker Royce) is interested in pursuing such a project
- Would need some Affiliates to provide data
Model Elements

- **Class**
  - A set of objects that share a common structure and a common behavior

- **Use case/collaboration**
  - A named behavior involving the collaboration of a society of objects

- **State/operation**
  - The condition of an object; an activity

- **Interface**
  - The public part of an object

- **Thread**
  - An active class, capable of concurrent activity with other active classes

---

Model Elements (cont)

- **Component**
  - A reusable part, typically having both logical as well as physical aspects

- **Node**
  - A hardware device upon which software may reside and/or execute

- **Package**
  - A container of elements

- **Note**
  - A comment, explanation, or annotation
Diagrams

- Class diagram
- State machine diagram
- Sequence diagram
- Collaboration diagram
- Activity diagram
- Use case diagram
- Component diagram
- Deployment diagram

Architecture

- End-user Functionality
  - Logical View
- Analysts/Testers Behavior
  - Use Case View
  - Concurrency View
  - Deployment View
- Programmers Software management
  - Component View

- System Integrators
  - Performance
  - Scalability
  - Throughput
- System Engineering System topology
  - Delivery, installation
  - Communication

©1997 Rational Software Corporation The Unified Modeling Language
Training and Data Collection Plans

- USC COCOMO II.1997.1 or COSTAR/CALICO as data collection instruments
- Proposed role for Don Reifer
  - Meet broader need for COCOMO II training
  - Make data collection easier, more efficient
ROLE FOR DON REIFER

• Assist team in calibrating COCOMO-II
  – Use his databases, when applicable, to help calibrate the model
  – Run statistical tools to generate goodness of fit and other meaningful measures

• Provide ideas based on his extensive cost modeling experience

• Develop public training and help get data for the model’s continued refinement
WIN-WIN SITUATION

• USC and Affiliates get:
  – Calibration data and the results of an analysis of about 500 projects
  – Extensive knowledge base of experience of one of the leaders in field of parametric modeling
  – Public courseware when they need it

• Reifer Consultants (RCI) gets:
  – In-depth knowledge of COCOMO-II
  – Ability to consult and market COCOMO-II courseware and make a profit
USC/RCI AGREEMENTS

• RCI will not market COCOMO packages
  – Their focus will be training and consulting
• RCI will not market competing packages
  – Their agreement with Resource Calculations has been terminated
  – They have elected to discontinue support for their SoftCost product line in the future
• USC will cooperate and get data and feedback from the trained model users