COCOMO II.1997: Calibration and Plans

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USC-CSE

12th International Forum on COCOMO
Oct 9, 1997

Presentation Outline

→ COCOMO calibration
   → Calibration process
   Results to date
• Software Tool Status
• Other Ongoing Research and Plans
• Information Sources
COCOMO II Calibration Process

- Began with expert-determined a-priori model parameters
  - Iterated with Affiliates (Result => Original Post Architecture Model)
- Collected Data
- Identified and consolidated highly correlated model parameters
- Statistically determined estimates of consolidated model parameters from data
  - Using logarithms to linearize regression
- Used data determined model parameters to adjust a-priori model parameters
  - Experimented with weighting factors

Data Collection

- Defined the data needed (to completely describe the Post Architecture Model)
- Collected data with a paper form or a computer software tool
- Affiliate Organizations provided majority of data
  - Historical - whole project
- Site visits or phone interviews to record data
- Entered the data into the repository
  - Data is labeled with generic id
  - Stored in locked room
  - Limited access by researchers
- Did Data Consistency checking and conditioning
Consolidated Highly Correlated Parameters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Ratio (Max/Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME</td>
<td>1.0000</td>
<td>0.6860</td>
<td>-0.2855</td>
</tr>
<tr>
<td>STOR</td>
<td>0.6860</td>
<td>1.0000</td>
<td>0.0027</td>
</tr>
<tr>
<td>ACAP</td>
<td>-0.2855</td>
<td>-0.0769</td>
<td>1.0000</td>
</tr>
<tr>
<td>PCAP</td>
<td>-0.2015</td>
<td>0.7339</td>
<td>1.0000</td>
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</table>

• What do we do? Combine:
  TIME & STOR to give RCON (Resource Constraints)
  ACAP & PCAP to give PERS (Personnel Factors)

Thus, 15 effort multipliers instead of 17 for calibration.

Statistical Data Analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Ratio (Max/Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFFORT</td>
<td>6</td>
<td>11400</td>
<td>1900</td>
</tr>
<tr>
<td>SIZE</td>
<td>2.6</td>
<td>1282.8</td>
<td>497</td>
</tr>
</tbody>
</table>

Thus, we took log transforms to normalize the response variable.
Also, we took log transforms to linearize the parametrized model.
COCOMO Calibration Model

- Needed linear model for regression:
  \[ Y = B_0 + B_1X_1 + B_2X_2 + \cdots + B_pX_p \]

- COCOMO II Post-Architecture is non-linear
  \[ Y = B_0X^B_1 \]

- What did we do?
  - Expanded COCOMO model
  - Transformed products with logarithms to produce sums

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Expanded COCOMO

- Distributed the Scale Factors
- Resulted in 21 predictor variables i.e. 15 Effort Multipliers + 5 Scale Factors + \((\text{Size})^{1.01}\)

\[ PM = h \cdot (\text{Size})^{1.01} \cdot (\text{Size})^2 \cdot (\text{Size})^3 \cdots \cdot EM_1 \cdots EM_5 \]

Log Transformed COCOMO:

\[ \ln(PM_{\text{log}}) - \ln(\text{Size})^{1.01} = \ln(A) + SF \cdot \ln(\text{Size}) + \cdots + \ln(EM) \]

- Regression analysis derived the coefficients, \(B_i\), for each factor

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RUSE Effort Multiplier

- Example of the effect of a negative coefficient

Distribution of RUSE
Evolving Model Values

100% Data Driven

100% Expert Driven

Number of projects used in calibration

Evolution of Parameter Values

A-Priori Model Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIOR</td>
<td>0.001</td>
</tr>
<tr>
<td>FLEX</td>
<td>0.002</td>
</tr>
<tr>
<td>TD</td>
<td>0.003</td>
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<tr>
<td>BM</td>
<td>0.004</td>
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Data-Determined Model Parameters

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Model Parameters with Weighted factors

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chart 11

chart 12
Overview

- 83 Observations from different Industrial categories including Commercial, Aerospace, FFRDC
- Log transformations of Original Post Architecture Model to achieve linearity for linear regression analysis
- 21 predictor variables i.e. 15 Effort Multipliers +5 Scale Factors + Coefficient A
- Forecast accuracy measured with proportional error:

\[ PE = \begin{cases} 
0.5(PM_{est} + PM_{act}) - 1, & (PM_{est} - PM_{act}) \geq 0 \\
0.5(PM_{act} + PM_{est}) + 1, & (PM_{est} - PM_{act}) < 0 
\end{cases} \]
### Accuracy Results

<table>
<thead>
<tr>
<th>Effort Prediction</th>
<th>Before Stratification By Organization</th>
<th>After Stratification By Organization</th>
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<tbody>
<tr>
<td>PRED(20)</td>
<td>46%</td>
<td>49%</td>
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<tr>
<td>PRED(25)</td>
<td>49%</td>
<td>55%</td>
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<tr>
<td>PRED(30)</td>
<td>52%</td>
<td>64%</td>
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<table>
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<th>Schedule Prediction</th>
<th>Before Stratification By Organization</th>
<th>After Stratification By Organization</th>
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<tbody>
<tr>
<td>PRED(20)</td>
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<td>52%</td>
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<td>PRED(25)</td>
<td>54%</td>
<td>61%</td>
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<tr>
<td>PRED(30)</td>
<td>61%</td>
<td>62%</td>
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### Conclusions: Calibration Results

- Regression technique can be used to calibrate COCOMO locally using completed project data.
- New cost drivers can be added and calibrated without destroying the structure of the COCOMO model.
- COCOMO calibrated to local organization is more accurate than using generic COCOMO II model.
- More project data is required to facilitate better calibration of generic COCOMO II model.
- '990's software data presents more challenges:
  - Non-sequential processes: where are end-points?
  - Incremental development: how to separate the increments?
  - COTS, reuse, breakage, mixed language levels: what is size?
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COCOMO II Software Status

- USC COCOMO II available for MS Windows, Sun OS, and Java
  - Has new calibrated values
  - Confidence ranges
  - 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 and X is the version within that year)
- Commercial COCOMO II tools
  - COSTAR version currently available
  - COST*XPERT - will be available shortly
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Ongoing Research (PhD topics)

- Effects of Process Maturity on Effort (Brad Clark - presented earlier)
- COTS Model (Chris Abts - present after lunch)
- Cost/Quality Tradeoff Model (Sunita Devnani-Chulani)

Future Work

- Stratify data based on Language Level and Application Type
- Effort distribution based on activities
- Enhancement of COCOMO II database to continuously update the model
Cost/Quality Tradeoff Model: Extension to COCOMO II

Defect Data Reporting Scheme

<table>
<thead>
<tr>
<th>Type of Artifact</th>
<th>Requirements</th>
<th>Design</th>
<th>Code &amp; Unit Test</th>
<th>SW Integ. and Test</th>
<th>SW Acceptance Test</th>
<th>System Implementation and Test</th>
<th>Post-Operational</th>
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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