Calibrating the COCOMO II Post Architecture Model

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On behalf of:
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ICSE ‘98

http://sunset.usc.edu/cocomoII/docs/cse98.ps
Outline

♦ Brief History of COCOMO
♦ Modeling Methodology
♦ COCOMO II Calibration Approaches
  – COCOMO II.1997 Calibration
    ♦ Process
    ♦ Prediction Accuracies
  – COCOMO II.1998 Calibration
    ♦ Simple Cost Model Bayesian Prototype
    ♦ Status
COnstructive COSt MOdel (COCOMO)

♦ COCOMO published since 1981
♦ Commercial implementations of COCOMO
  ♦ CoCoPro, CB COCOMO, COCOMOID, COSTMODL, GECOMO Plus, SECOMO, etc.
♦ Other models based on COCOMO
  ♦ REVIC, Gulezian
♦ COCOMO II
  ♦ Research effort started in 1994 to develop a 1990’s-2000’s software cost model
  ♦ Address new processes and practices
  ♦ COCOMO II.199Y/200Y
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The Seven-Step Modeling Methodology

1. Analyze Existing literature
2. Perform Behavioral Analysis
3. Identify Relative Significance
4. Perform Expert-Judgment, Delphi Assessment
5. Gather Project Data
6. Determine Bayesian A-Posteriori Update
7. Gather more data; refine model
Literature, Behavioral Analysis (Steps 1-3)

Language and Tool Experience (LTEX)

Productivity Range = \( \frac{\text{Highest Rating}}{\text{Lowest Rating}} \)
Results of Delphi (Step 4)

Productivity Range = Highest Rating / Lowest Rating

A-priori Experts’ Delphi

Literature, behavioral analysis

Language Tool and Experience (LTEX)
Results of Sampling Data (Step 5)

Productivity Range = Highest Rating / Lowest Rating

Language and Tool Experience (LTEX)
Results of Bayesian Update: Using Prior and Sampling Information (Step 6)

Language and Tool Experience (LTEX)
Bayes’ Theorem

\[ g(\beta \mid y) = \frac{f(y \mid \beta) g(\beta)}{f(y)} \]

\[ g(\beta \mid y) \propto l(\beta \mid y) g(\beta) \]

posterior information \( \propto \) sample information X prior information

| A-Priori Information | + | Sampling Data | = | A-Posteriori Model |
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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
Consolidated Highly Correlated Parameters

TIME  1.0000  0.6860  -0.2855  -0.2015
STOR  0.6860  1.0000  -0.0769  -0.0027
ACAP -0.2855 -0.0769  1.0000  0.7339
PCAP -0.2015 -0.0027  0.7339  1.0000

TIME    STOR    ACAP    PCAP

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

• Needed linear model for regression:

\[ Y = B_0 + B_1 X_1 + B_2 X_2 + \cdots + B_p X_p \]

• COCOMO II Post-Architecture is non-linear

\[ Y = B_0 X^{B_1} \]

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

• Distributed the Scale Factors

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

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

Log Transformed COCOMO:

\[ \ln(PM_{est}) - \ln(Size)^{1.01} = \ln(A) + SF_1 \ln(Size) + \cdots + \ln(EM_{15}) \]

• Regression analysis derived the coefficients, \(B_i\), for each factor
COCOMO II.1997 Calibration

♦ 83 projects
♦ Multiple Linear Regression
  – 10% weighted average between a-priori values and data-determined values

Develop for Reuse (RUSE)
# Accuracy Results

## Effort Prediction

<table>
<thead>
<tr>
<th>Effort Prediction</th>
<th>Before Stratification By Organization</th>
<th>After Stratification By Organization</th>
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</thead>
<tbody>
<tr>
<td>PRED(.20)</td>
<td>46%</td>
<td>49%</td>
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<tr>
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</tr>
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## Schedule Prediction

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COCOMO ‘81 & COCOMO II.1997

♦ COCOMO ‘81: Pred (.20) = 68%
♦ COCOMO II.1997: Pred (.20) = 46%
  – Challenges faced in calibrating COCOMO II
    ♦ GUI builders, COTS, 4GL’s, reuse, requirements breakage
      – Need to rethink size metrics
    ♦ Distributed interactive applications
      – Web-based, object-oriented, event-based
      – Middleware effects
    ♦ New process models (evolutionary, incremental, spiral)
      – Phases overlap
      – Where are cost measurement endpoints?
  ♦ Lack of good data
    – not enough data (i.e. very little degrees of freedom)
    – lack of dispersion
    – heteroskedasticity
Multiple Linear Regression Well-Suited When...

♦ lot of data is available
♦ no data items are missing
♦ there are no outliers
♦ the predictor variables are not highly correlated
♦ the predictor variables have an easy interpretation when used in model

most are violated by current software engineering data
COCOMO II Calibration Approaches

1.07  Data

1.45  A-Priori
COCOMO II Calibration Approaches

1.07  Data

1.41  1.45

COCOMO II 1997 Posteriori
(10% weighted average approach)

A-Priori
COCOMO II Calibration Approaches

1.07  \( \text{COCOMO II 1998 posteriori (weight determined by prior and sample variance)} \)

1.26

1.41  \( \text{COCOMO II 1997 Posteriori (10\% weighted average approach)} \)

1.45

Data

A-Priori
### Prediction Accuracies - COCOMO II.1997 and Provisional COCOMO II.1998

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COCOMO II Research Group’s Aim

- 100% Data Driven
- 100% Expert Driven

Number of projects used in calibration:
- 83 datapoints - COCOMO II.1997 version
- ~200 datapoints - Bayesian model

COCOMO II research group’s aim