Limiting factors of estimation accuracy and project risk
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Topics

1. Introduction and aims of the research
2. Integration of teaching risk & project estimation
3. Partitioning and reducing the variation
4. Some statistical aspects
5. Sources of the data
6. Results and analysis
7. Some useful outcomes
Can we measure the software process?

Or does any useful measurement get lost in the noise of:

- User fickleness
- Staff variation
- Communication problems
- Office politics
- Poor management?
Process improvement

The opposite of Quality is variation and inconsistency

To improve performance we must:

• Stabilise the process
• Implement a new strategy
• Measure size & direction of change
• Evaluate the optimum approach
**Significant problems in estimating project effort and duration**

Note previous comments on the relationship between risk and variance of the estimate.

There are several classifications [1] of the sources of bias and error of estimates.

Major areas are:

- Knowledge and definition of requirements
- Large variation in staff abilities (productivity)
- Changes in technological environment
- Managers do not adhere to process
- Shifting point of aim (project creep)
- End point of project is negotiated

These problems can be contained but not eliminated.
Aims of the research

Recent experiments have been designed to quantify the impact of the various sources of variation.

The aim is to partition the difference between Estimated and Actual effort into a series of issues that can be tackled individually.

Clearly, some areas give greater improvements in accuracy for less effort.
Assumptions of the work

1. There is a reasonably stable statement of requirements
2. The primary objective is completion of some deliverable within given quality constraints
3. There is a well-defined, measurable development process
4. There are procedures to ensure compliance with the process
5. All information on the project is openly available (no political or hidden agendas)
Process improvement as a two-stage process
Variation versus Bias

Error can be divided into bias (due to the estimator) and variation (due to the process)
Sources of variation

- Choice of Estimation method
- Bias in Historical; Data-base
- Personnel Turn-over
- Staff training
- Errors in Estimate of System size
- Errors with Productivity rate
- Management decisions
- Skills of Project team
- Changes In tools & techniques
- Estimates of Requirements creep
- Actual Requirements creep
- Variation in Estimation Process
- Variation in Project control
- Variation in Development Process
- Errors in Estimate of System size
- Errors with Productivity rate
- Management decisions
- Skills of Project team
- Changes In tools & techniques
- Estimates of Requirements creep
- Actual Requirements creep
- Variation in Estimation Process
- Variation in Project control
- Variation in Development Process
Sources of data

A series of exercises/experiments carried out in final-year software engineering classes at three West Australian universities over seven years.

- Development of a Personal Project Estimation Tool
- Estimation of the Spelling Checker [2]
- Group projects of a multiple elevator controller

Follow up within industry
Personal Project Estimation Tool (PPET)
Part of Estimation work-sheet

Have a look at the requirements for a spell checking system [Fenton, 1997] as specified by your tutor. The task is to estimate the amount of effort that would be needed to write the checker. Note that the standard dictionary of correct spellings is already complete and available but the personal dictionary will start as an empty file. Work together as a pair and agree upon each answer before filling in your own personal work sheet – which should be put in your portfolio.

2. How much effort would be required for your group to write such a system in Java? _______________(person-hours)

3. On what date do you think your group could deliver it, if you started today? _______________

8. The tutor will now provide a summary of the class’ estimates. In the light of the figures, you may wish to update the figure you gave in question two to ___________(person-days)
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8. The tutor will now provide a summary of the class’ estimates. In the light of the figures, you may wish to update the figure you gave in question two to ____________(person-days)
More of Estimation work-sheet

9. Assuming that all files in the Spelling Checker are of average complexity, produce a Function Point count:

Total (raw or unadjusted Function Points) = __________

10. Suppose that you have data from the last four Java projects, your group produced:

<table>
<thead>
<tr>
<th></th>
<th>40 FPs</th>
<th>60 FPs</th>
<th>90 FPs</th>
<th>160 FPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>45 Person-Days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>75 Person-Days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>115 Person-Days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>215 Person-Days</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Use this data to estimate how much effort it will take to produce the system based on your count from question nine: ____________ (person-days)
**Initial estimates (in days) by preferred time unit**

<table>
<thead>
<tr>
<th>Estimating Units</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours</td>
<td>5.6</td>
<td>4.7</td>
</tr>
<tr>
<td>Days</td>
<td>6.7</td>
<td>6.9</td>
</tr>
<tr>
<td>Weeks</td>
<td>14.2</td>
<td>10.9</td>
</tr>
<tr>
<td>Months</td>
<td>69.4</td>
<td>47.5</td>
</tr>
</tbody>
</table>
Comparison of two estimation units

<table>
<thead>
<tr>
<th></th>
<th>person-hours</th>
<th>person-weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (in person-days)</td>
<td>9.46</td>
<td>21.76</td>
</tr>
<tr>
<td>Standard Deviation (in person-days)</td>
<td>15.24</td>
<td>22.82</td>
</tr>
</tbody>
</table>

\[ t = 2.576 \text{ on } 31 \text{ df} \quad p < 0.01 \]
# Improvements due to education

*Estimates of the spelling checker (in days)*

<table>
<thead>
<tr>
<th></th>
<th>First exercise</th>
<th>After lectures</th>
<th>After project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minimum</strong></td>
<td>0.8</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>180</td>
<td>180</td>
<td>115</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>35.3</strong></td>
<td><strong>39.7</strong></td>
<td><strong>51.4</strong></td>
</tr>
<tr>
<td><strong>Standard Deviation</strong></td>
<td>46.3</td>
<td>42.7</td>
<td>34.5</td>
</tr>
<tr>
<td><strong>Coefficient of Variation</strong></td>
<td><strong>1.31</strong></td>
<td><strong>1.08</strong></td>
<td><strong>0.67</strong></td>
</tr>
</tbody>
</table>
Hypothesis

The hypothesis was that there would be substantial improvement possible in moving:

from ‘guesstimates’

to group expert opinion (with Delphi methods)

to algorithmic methods (such as COCOMO)

to estimation methods tailored to a particular organisation (calibrated with past project data)

and that size estimates in Function Points could be obtained consistently.
Reduction in variation due to choice of method & no of steps

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration (days)</td>
<td>13.06</td>
<td>15.12</td>
<td>1.157</td>
</tr>
<tr>
<td>Effort (person-days)</td>
<td>16.16</td>
<td>17.72</td>
<td>1.097</td>
</tr>
<tr>
<td>Delphi (person-days)</td>
<td>17.71</td>
<td>12.99</td>
<td>0.733</td>
</tr>
<tr>
<td>Analogy (person-days)</td>
<td>49.06</td>
<td>23.73</td>
<td>0.484</td>
</tr>
<tr>
<td>Size (Function Points)</td>
<td>42.61</td>
<td>16.22</td>
<td>0.381</td>
</tr>
</tbody>
</table>
Progressive accuracy of estimates

![Graph showing the progressive accuracy of estimates with lines for optimistic, pessimistic, and estimate scenarios. The x-axis represents the week of the project, and the y-axis represents the total hours estimated as needed. The graph indicates an increase in accuracy as the project progresses.]
Partitioning the variation (error) in project estimates

\[
\text{Var}(\text{actual} - \text{estimate}) = \text{Var}(\text{actual}) + \text{Var}(\text{estimate})
\]

iff the actual and estimate are independent variables

\[
(\text{actual} – \text{estimate})
= (\text{actual} – \text{actual}) + (\text{actual} – \text{estimate}) + (\text{estimate} – \text{estimate})
\]

Squaring both sides, summing over the n projects and dividing by n gives:

Mean Squared Error:

\[
= \text{Var}(\text{actual}) + \text{Bias} \text{ squared} + \text{Var}(\text{estimate}) + \text{Cross-Product}
\]
## Components of mean square error

<table>
<thead>
<tr>
<th></th>
<th>2001 project</th>
<th>2002 project</th>
<th>2002 calibrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Estimate</td>
<td>24.45</td>
<td>33.20</td>
<td>51.50</td>
</tr>
<tr>
<td>Mean Actual</td>
<td>51.50</td>
<td>45.84</td>
<td>45.84</td>
</tr>
<tr>
<td>Error or Bias</td>
<td>27.05</td>
<td>12.64</td>
<td>-5.66</td>
</tr>
<tr>
<td>Variance (estimate)</td>
<td>143.6</td>
<td>259.0</td>
<td>47.7</td>
</tr>
<tr>
<td>Variance (actual)</td>
<td>261.5</td>
<td>440.6</td>
<td>440.6</td>
</tr>
<tr>
<td>Bias squared</td>
<td>731.7</td>
<td>160.4</td>
<td>34.3</td>
</tr>
<tr>
<td>Cross Product</td>
<td>-165.0</td>
<td>4.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Mean Square Error</td>
<td>971.8</td>
<td>864.5</td>
<td>524.6</td>
</tr>
</tbody>
</table>
Limiting factors to estimation accuracy

![Bar chart showing bias squared and variance for different projects in 2001 and 2002, with a comparison to calibrated data.]

- Bias squared
- Var(estimate)
- Var(actual)
In Conclusion

These experiments have been used to:

1. demonstrate to students some issues in project estimation
2. illustrate to managers the sources and sizes of error in estimation
3. illustrate methods for process improvement experiments (PIEs)
4. obtain some measure of the relative size of sources of error - leading to a Theory of Constraints approach for the reduction of estimation error.
Acknowledgement

I would like to express my appreciation for the support, discussions and consideration given by Dr Gary Bundell, Dr Rachel Cardell-Oliver, Prof Geoff Roy and A/Prof Richard Thomas whose students, as well as my own, were involved in the various software engineering exercises.
References