Incremental Effort Estimation via Use Case Analysis

An Empirical Study of Parallel Agile Projects

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Early project effort is essential for various software management decisions.

- Control project scope
  - Avoid the risks of being over-schedule & budget
- Make project plans
- Resource allocation
Applicability of Existing Models over SE Process
Use Case Points

Use Case Points (UCPs) (Karner, 1993):

- Use case centric
- Measure software functional size
- Early applicability
- Empirically validated correlated with project effort (Anda, 2001)(Silva, 2008)
- Many variants were proposed to improve the estimation accuracy
Example of Counting Use Case Points

Step 1:

<table>
<thead>
<tr>
<th>UC Name</th>
<th>Search Inventory Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Course</td>
<td><strong>User</strong> Inputs the keywords and clicks the search buttons. <strong>System</strong> validates the input keywords. <strong>System</strong> queries from the catalog by the keywords. <strong>System</strong> displays the returned list of items.</td>
</tr>
<tr>
<td>Alternative Courses</td>
<td><strong>AC1</strong> – <strong>Input keywords invalid.</strong> <strong>System</strong> displays “Invalid Input” message <strong>AC1 - No matched inventory items found.</strong> <strong>System</strong> displays “Not found” message</td>
</tr>
</tbody>
</table>

Step 2: Use Case Weighting Schema

<table>
<thead>
<tr>
<th>Complexity</th>
<th>Number of Transactions</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td>≤3</td>
<td>5</td>
</tr>
<tr>
<td>Average</td>
<td>4 to 7</td>
<td>10</td>
</tr>
<tr>
<td>Complex</td>
<td>&gt;7</td>
<td>15</td>
</tr>
</tbody>
</table>

Step 3:

\[
UCPs = \left( \sum_{c \in C} w_1(c) + \sum_{a \in A} w_2(a) \right) \times TCF \times EF
\]
The Issues with UCPs

The complexity levels of the original UCPs are abrupt (Nassif et al., 2016).

The weighting schema was based on Karner’s working experience at Objectory Systems in 1990’s (Karner, 1993).

Divergence on the experiences of how use cases should be weighted – Many different weighting schemas were proposed.

  • Extra levels were added to the original use case weighting schema to represent wider ranges (Mudasir et al., 2015) (Nassif, 2012).
  • Original complexity levels were discretized into more levels (Fan et al., 2009)(Nassif et al., 2016).
  • Calibrate the use case complexity weights using empirical datasets.(Nassif et al., 2014).
The underlying method of classifying use cases need to be adjusted.

- Heavily skewed distribution of use cases (1 : 5.9 : 5.3).

The influences from the different use case complexity levels tend to be non-linearly increasing (1 : 1.6 : 3.3).

- As opposed to the linear relationship (1 : 2 : 3) proposed by original UCPs.
The use case driven approach of software engineering (Jacobson, 1992)
- Capturing functional requirements
- Driving architectural decisions

Three models are generated to capture system specifications
- Use case model (use case diagram, use case narratives)
- Analysis model (object analysis diagram)
- Design model (class and sequence diagram)

Parallel Agile utilizes the use case analysis techniques to parallelize use cases for rapid delivery (Doug & Barry, 2017)
Transactions are as flows of actions of activity diagrams.

Transactions are as independent paths of object analysis diagrams.

Transactions are as sequences of messages of sequence diagrams.
## The Proposed Functional Software Sizing Model

<table>
<thead>
<tr>
<th></th>
<th>Transaction-centric sizing model</th>
<th>Use case centric sizing model (UCPs)</th>
</tr>
</thead>
</table>
| **Software Functional Size** | The sum of the weighted transactions:  
\[ \text{Software Size} = \sum_{t \in T} w_t \] | The sum of the weighted use cases:  
\[ \text{Software Size} = \sum_{c \in C} w_c \] |
| **Components**   | Transaction: A sequence of operations of system components to realize a user-system interaction, which defines a basic unit of system functionality. | Use Case: A set of interactions between actors and a system to achieve a goal. |
| **Weighting Method** | Data elements, components, operations, etc | Transactions |
Transactional Complexity:

- **Operational complexity - Transaction Length (TL)**
  - The number of operations that compose a transaction

- **Structural complexity - Transaction Degree (TD)**
  - The average number of service methods of the components

- **Data complexity - Data Element Types (DETs)**
  - The number of data element types
Phase-based Software Size Analysis

Three phases + three software size metrics:

• Requirements elicitation phase (Use case narratives/activity diagrams) - EUCP [STC’17]:

\[
\text{Software Size} = \sum_{t \in T} t
\]

• Analysis phase (Object analysis diagrams) - EXUCP [STC’17]:

\[
\text{Software Size} = \sum_{t \in T} w^*_t = \sum_{t \in T} w^*(TD(t), TL(t))
\]

• System design phase (Sequence and class diagram) - DUCP [MISE’18]:

\[
\text{Software Size} = \sum_{t \in T} w^{**}_t = \sum_{t \in T} w^{**(TD(t), TL(t), DETs(t))}
\]

The generic form of the effort estimation models:

\[
\text{Project Effort} = \alpha \sum_{t \in T} \sum_{i=1}^{|W|} (W_i \ast I_i(f_{\text{cmplx}}(t)))
\]

, where

\( \alpha \) is effort adjustment factor,
\( T \) is the set of transactions,
\( W \) is the set of weights assigned to the \(|W|\) levels of complexity,
\( I_i(x) \) is the indicator function,
\( f_{\text{cmplx}}(t) \) classifies a transaction into a level of complexity
Automated Design Artifact Analysis

1. Bridging modeling platforms with our analysis tool using XMI files.
2. Use User-system Interaction Model (USIM) [MISE 2018] as the data structure for indexing, connecting, and organizing design objects.
3. Automated transaction identification and classification.
4. Design metrics calculation and profiling.
Data Set:

- The projects are of different types: web applications, mobile applications, mobile games, scientific tools, etc.
- The projects: 3-9 people, 4-12 months, 1-20 KSLOC, 1-50 use cases.
- Effort Data: weekly effort reports & Jira.
- Transaction data: class and sequence diagrams (6157 transactions, 1610 use cases) [MISE’18].
Error-based Classification Optimization

1. Discretization and classification.
2. Bayesian analysis to determine the complexity weights.
The calibrated models (parameterized by the classification function, weighting schema, and effort adjustment factor).

\[
\text{Project Effort} = \alpha \times \sum_{t \in T} \sum_{i=1}^{W} (W_i \times I_i(f_{\text{cmplx}}(t)))
\]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>EUCP</th>
<th>EXUCP</th>
<th>DUCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha)</td>
<td>{7.02, 0.12}</td>
<td>{1.29, 0.02}</td>
<td>{1.33, 0.02}</td>
</tr>
<tr>
<td>(f_{\text{cmplx}}(t))</td>
<td>(f_{\text{cmplx}_1}(t) = 1)</td>
<td>(TL = {0, 4.0, 5.3, 6.9, Inf})</td>
<td>(TL = {0, 4.5, 6.3, Inf})</td>
</tr>
<tr>
<td>(f_{\text{cmplx}_2}(t) = TL(t) + TD(t) - 1)</td>
<td>(TD = {0, 3.2, 4.8, 6.7, Inf})</td>
<td>(TD = {0, 3.7, 6.0, Inf})</td>
<td></td>
</tr>
<tr>
<td>(f_{\text{cmplx}_3}(t) = TL(t) + TD(t) + DETs(t) - 2)</td>
<td>(DET_s = {0, 5.4, 11.2, Inf})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(W)</td>
<td>(w_1 = {1.01, 0.20})</td>
<td>(w_1 = {1.07, 0.22})</td>
<td>(w_1 = {1.17, 0.32})</td>
</tr>
<tr>
<td>(w_2 = {1.18, 0.20})</td>
<td>(w_2 = {1.18, 0.20})</td>
<td>(w_2 = {1.21, 0.21})</td>
<td></td>
</tr>
<tr>
<td>(w_3 = {2.01, 0.11})</td>
<td>(w_3 = {2.01, 0.11})</td>
<td>(w_3 = {2.01, 0.11})</td>
<td></td>
</tr>
<tr>
<td>(w_4 = {3.01, 0.13})</td>
<td>(w_4 = {3.01, 0.13})</td>
<td>(w_4 = {3.01, 0.11})</td>
<td></td>
</tr>
<tr>
<td>(w_5 = {5.06, 0.48})</td>
<td>(w_5 = {5.06, 0.48})</td>
<td>(w_5 = {5.08, 0.46})</td>
<td></td>
</tr>
<tr>
<td>(w_6 = {7.53, 1.07})</td>
<td>(w_6 = {7.53, 1.07})</td>
<td>(w_6 = {7.84, 1.07})</td>
<td></td>
</tr>
<tr>
<td>(w_7 = {8.00, 1.30})</td>
<td>(w_7 = {8.00, 1.30})</td>
<td>(w_7 = {7.91, 1.16})</td>
<td></td>
</tr>
</tbody>
</table>

11/13/18
Out-of-sample Accuracy Evaluation Results

MMRE, PRED(15%), PRED(25%), and PRED(50%) using 10-fold cross validation

<table>
<thead>
<tr>
<th>Model</th>
<th>MMRE</th>
<th>P.(15%)</th>
<th>P.(25%)</th>
<th>P.(50%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUCP</td>
<td>0.94</td>
<td>7.3%</td>
<td>29.1%</td>
<td>54.5%</td>
</tr>
<tr>
<td>EXUCP</td>
<td>0.61</td>
<td>20.0%</td>
<td>34.5%</td>
<td>58.2%</td>
</tr>
<tr>
<td>DUCP</td>
<td>0.52</td>
<td>25.5%</td>
<td>41.8%</td>
<td>63.6%</td>
</tr>
<tr>
<td>UCP</td>
<td>1.63</td>
<td>5.5%</td>
<td>14.5%</td>
<td>29.1%</td>
</tr>
</tbody>
</table>
The estimated project effort are decomposed into three categories ($l \in \{M, V, C\}$):

$$Effort_l = \frac{\sum_{c \in l} NOM(c)}{\sum_{c \in C} NOM(c)} \times Project Effort$$
## The MVC Effort Estimation Results for PA Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Year</th>
<th>Model (PH)</th>
<th>View (PH)</th>
<th>Control (PH)</th>
<th>Total (PH)</th>
<th>Actual (PH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBA</td>
<td>2014-2015</td>
<td>307(8.4%)</td>
<td>1739(47.7%)</td>
<td>1603(43.9%)</td>
<td>3649</td>
<td>3680</td>
</tr>
<tr>
<td>PicShare</td>
<td>2015</td>
<td>263(12.3%)</td>
<td>673(31.6%)</td>
<td>1198(56.1%)</td>
<td>2133</td>
<td>2016</td>
</tr>
<tr>
<td>CarmaCam</td>
<td>2016-2018</td>
<td>131(11.5%)</td>
<td>249(21.9%)</td>
<td>759(66.7%)</td>
<td>1138</td>
<td>1392</td>
</tr>
<tr>
<td>Tiki</td>
<td>2017-2018</td>
<td>157(17.3%)</td>
<td>212(23.4%)</td>
<td>460(50.8%)</td>
<td>905</td>
<td>737</td>
</tr>
</tbody>
</table>
Incremental Effort Estimation
  Continuous effort estimation over the process

Data-driven Software Management
  Prioritization of development tasks
  Resource allocation
  Feasibility analysis
  Productivity measurement
The Tool Implementation

- Web-based tool for easy access of the analytical results: design metrics, size metrics, effort estimates, etc.
- Support typical UML diagrams for modeling use cases: activity, object analysis, sequence, and class diagrams.
Specifying available resources for feasibility analysis

### Resource Estimation

**Personnel**
- Number of team members
- Estimate the available personnel. If it is unlimited, leave it blank.

**Schedule (Months)**
- Months
- Estimate the available schedule in months. If it is unlimited, leave it blank.

**Hours/Month**
- Hours/Month
- Estimate the average number of working hours per month for team members. For example, 160 hours for full-time members, 20 hours for part-time developers, etc.

### Project model file and documents

- **Model File** (file types: xml are supported)
  - Choose File: No file chosen

- **Other Documents** (file types: zip, rar, tar are supported)
  - Choose File: No file chosen

- **Select Estimator**
  - EUOC
### Feasibility/Risk Analysis

<table>
<thead>
<tr>
<th>Model</th>
<th>Effort (PH)</th>
<th>Schedule (Months)</th>
<th>PH/Month</th>
<th>EUCP</th>
<th>Personnel (FT Developers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>eucp_lm</td>
<td>969.76</td>
<td>5.04</td>
<td>40</td>
<td>138.79</td>
<td>5</td>
</tr>
</tbody>
</table>

### Use Case Prioritization

<table>
<thead>
<tr>
<th>Number</th>
<th>Use Case</th>
<th>Effort (PH)</th>
<th>EUCP</th>
<th>Schedule (Months)</th>
<th>Personnel (FT Developers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>BasicSearch</td>
<td>6.66</td>
<td>1.01</td>
<td>0.99</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Cancel submitted reservation</td>
<td>33.32</td>
<td>5.07</td>
<td>1.67</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Confirm Reservation Request</td>
<td>26.86</td>
<td>4.05</td>
<td>1.56</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Decline Reservation Request</td>
<td>46.85</td>
<td>7.10</td>
<td>1.87</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Login</td>
<td>53.32</td>
<td>8.12</td>
<td>1.95</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Make Payment</td>
<td>39.99</td>
<td>6.09</td>
<td>1.78</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Manage Users</td>
<td>38.99</td>
<td>6.09</td>
<td>1.78</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Modify User Role</td>
<td>33.32</td>
<td>5.07</td>
<td>1.67</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Post Surgical Slot</td>
<td>59.98</td>
<td>9.13</td>
<td>2.03</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Search Surgical Slot</td>
<td>79.98</td>
<td>12.18</td>
<td>2.23</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Setup reminder</td>
<td>33.32</td>
<td>5.07</td>
<td>1.67</td>
<td>1</td>
</tr>
</tbody>
</table>

### Resources/Personnel Allocation

Tool Demo:
http://18.223.102.195:8081/estimationPageDemo
Future Directions

• Collect more data points to further calibrate the models
  * We appreciate your support for the research with software project data (requirements, use cases, design artifacts, source code, effort data). Please contact me at: kqi@usc.edu.

• Show statistical significance of the accuracy improvements.

• Empirical evaluation of the models and the tool.
Thank You!

Q&A