Quantitative release planning in Extreme Programming

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Introduction

- Traditional plan-driven software development methodologies (e.g. waterfall) cannot cope with changing user requirements, that are present in almost all projects.
- Agile methodologies replace the strict plan-driven development process with values and practices proven to work well together.
- Extreme Programming (XP) is one of the most agile software development methodologies.
- The development in XP is guided by user stories, that are small pieces of visible functionality with added value for the customer.
Release planning in XP

- The development team elicits user stories from the customer, who consequently prioritizes them.
- Implementation complexity of stories are evaluated on the scale \( \{1, 2, 3, 5, 8\} \).
- Related stories can be grouped into themes that represent related functionality.
- In each iteration, a velocity estimate amount of story points worth stories is selected for implementation.
Problems in XP

1. **Customer availability**: the “whole team” practice requires constant presence of the customer

2. **Prioritization stress**: 
   - in case of velocity change the customer might need to re-prioritize stories
   - customer might not perceive value in constantly prioritizing the stories
Our planning model

- We evaluate stories in addition to the implementation complexity with respect to their business value on scale \( \{1, 2, 3, 4, 5\} \)
- We incorporate themes to model synergy effects between stories. Theme valuation is difficult, as they have to be in the same scale with the story business values. Ordinal evaluation and value-free approaches (different functional forms) can be applied.
- We incorporate precedence constraints (e.g. story \( x \) needs to be completed before story \( y \))
- We assume availability of a velocity distribution
- We produce “must have” (green), “should have” (yellow), and “could have” (red) lists
Cut-off points $d_i$ for the green ($b_1$), yellow ($b_2$) and red ($b_3$) lists

Figure: Complementary cumulative velocity distribution.
Let us define a set of stories $S = \{1, \ldots, n\}$ and a set of themes $T = \{n+1, \ldots, n+m\}$. All stories and themes have a business value $u_i$, and stories additionally have an implementation complexity $c_i$:

$$u_i \in \mathbb{N} ; i \in S \cup T$$
$$c_i \in \mathbb{N} ; i \in S$$

Define a nested set of knapsacks $K = \{1, \ldots, \ell\}$ corresponding to the $\ell$ story lists, each with a discount factor (cut-off point) $d_k$ and a budget $b_k$:

$$d_k \in \mathbb{R} ; k \in K$$
$$b_k \in \mathbb{N} ; k \in K$$

$K$ is ordered according to the discount factors that satisfy:

$$d_i > d_j ; \forall i < j$$
Define the decision variables of first including story $s$ and theme $t$ in knapsack $k$ as $x_{s,k}$ and $y_{t,k}$, respectively:

$$x_{s,k} \in \{0, 1\} ; s \in S, k \in K$$
$$y_{t,k} \in \{0, 1\} ; t \in T, k \in K$$

Now, we optimize the following objective function:

$$\max \sum_{k \in K} \sum_{s \in S} x_{s,k} d_k u_s + \sum_{k \in K} \sum_{t \in T} y_{t,k} d_k u_t$$

s.t. $\sum_{s \in S} \sum_{j=1}^{k} c_s x_{s,j} \leq b_k \ \forall k \in K$

and $\sum_{k \in K} x_{s,k} \leq 1 \ \forall s \in S$
Completing themes is modeled through a dummy decision variable

\[ z_{t,k} \in \{0, 1\} ; t \in T, k \in K \]

that is true iff all stories in theme \( t \) are completed in knapsack \( k \) or any knapsack preceding \( k \):

\[
\left( \sum_{s \in S} \sum_{j=1}^{k} a_{s,t} x_{s,j} \right) - e_t z_{t,k} \geq 0 ; \forall k \in K \forall t \in T
\]

\[
\left( \sum_{s \in S} \sum_{j=1}^{k} a_{s,t} x_{s,j} \right) - z_{t,k} \leq e_t - 1 ; \forall k \in K \forall t \in T
\]

Where \( a_{s,t} = 1 \) if story \( s \) is included in theme \( t \) and \( a_{s,t} = 0 \) otherwise, and \( e_t = \sum_{s \in S} a_{s,t} \), the number of stories in theme \( t \).
Then, we make sure that $y_{t,k}$ is true iff $z_{t,k}$ is the first (in terms of $k$) for which $z_{t,k} = 1$:

\[
y_{t,1} = z_{t,1} \quad \forall t \in T
\]
\[
y_{t,k} = z_{t,k} - z_{t,k-1} \quad \forall t \in T \forall k \in \{K-1\}
\]

The precedence relations, $i \prec j$ ($i$ precedes $j$), are represented as follows:

\[
x_{j,k} - \sum_{l=1}^{k} x_{i,l} \leq 0 \quad \forall i \prec j \forall k \in K
\]
If we have $\geq 5$ velocity observations, the iteration velocity can be estimated through maximum likelihood with

$$V_I \sim \log \mathcal{N}(\hat{\mu}, \hat{\sigma}^2)$$

where $\hat{\mu}$ is the mean of the log-transformed observations $\ln(v)$ and $\hat{\sigma}^2$ is the sample variance $\text{sd}(\ln(v))^2$. 
Velocity estimation heuristic: release

To estimate release velocity, release is viewed as a collection of $n_R$ independent iterations. Release velocity is the sum of $n_R$ log-normal distributions, and can be estimated using the (very accurate) Fenton-Wilkinson 2-moment approximation simplified for equal mean and variance:

$$V_R \sim \log \mathcal{N}(\mu_R, \sigma_R^2)$$

$$\sigma_R^2 \approx \ln(\exp(\hat{\sigma}^2) - 1 + n_R) - \ln n_R$$

$$\mu_R \approx \hat{\mu} + \ln n_R + \frac{1}{2}(\hat{\sigma}^2 - \sigma_R)$$
Velocity estimation heuristic

- Velocity estimate is overly precise in the beginning of a project, so we use the following weighted sum (approximating an inverse-Gamma prior with prior df=2):

\[
\hat{\sigma} = \frac{\sigma_0 + n\text{sd}(\ln(v))}{1 + n}
\]

where \( n \) is the number of observations and \( \sigma_0 \) is an prior belief of sample error that has a weight equal to one observation of true velocity.

- Prior belief \( \sigma_0 \) has to be specified!
Rules of thumb for uncertainty in velocity

<table>
<thead>
<tr>
<th>Phase</th>
<th>Suggested CI</th>
<th>$\sigma_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements Known *</td>
<td>$[\hat{\mu}/2.0, \hat{\mu} \times 2.0]$</td>
<td>0.42</td>
</tr>
<tr>
<td>Requirements Analyzed *</td>
<td>$[\hat{\mu}/1.75, \hat{\mu} \times 1.75]$</td>
<td>0.34</td>
</tr>
<tr>
<td>&lt; 2 Iterations Completed</td>
<td>$[\hat{\mu} \times 0.60, \hat{\mu} \times 1.60]$</td>
<td>0.29</td>
</tr>
<tr>
<td>Preliminary Design *</td>
<td>$[\hat{\mu}/1.40, \hat{\mu} \times 1.40]$</td>
<td>0.21</td>
</tr>
<tr>
<td>Detailed Design *</td>
<td>$[\hat{\mu}/1.25, \hat{\mu} \times 1.25]$</td>
<td>0.14</td>
</tr>
<tr>
<td>2 Iterations Completed</td>
<td>$[\hat{\mu} \times 0.8, \hat{\mu} \times 1.25]$</td>
<td>0.14</td>
</tr>
<tr>
<td>3 Iterations Completed</td>
<td>$[\hat{\mu} \times 0.85, \hat{\mu} \times 1.15]$</td>
<td>0.08</td>
</tr>
<tr>
<td>&gt; 3 Iterations Completed</td>
<td>$[\hat{\mu} \times 0.90, \hat{\mu} \times 1.10]$</td>
<td>0.06</td>
</tr>
</tbody>
</table>

With * are from NASA SEL guidelines (1990), others from Cohn (2005).
Velocity estimates vs observed velocity

Figure: $F_C(v)$ estimated for release 2 (from release 1 velocity) and release 3 (from release 2 velocity). Due to higher variability during release 2, the estimated velocity is much less certain. The ○ shows the velocity that was actually achieved.
Computational tests
Conclusions

- Release planning in XP can cause prioritization stress for the customer and is impractical in larger projects.
- We developed an optimization model that enables XP for larger projects and for those with a less available customer.
- The velocity distribution required for application of the model can be (easily) estimated with the provided heuristic, that corresponds well to velocity observed in a real-life development project.
- Problems with up to 6 themes and 50 stories can be solved in less than an hour.

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