Quantitative release planning in Extreme Programming

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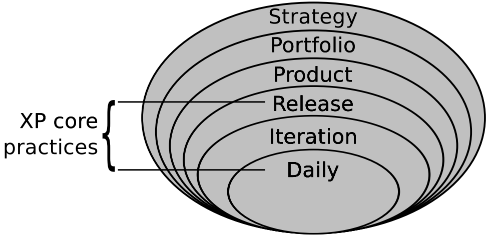
Introduction

- 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

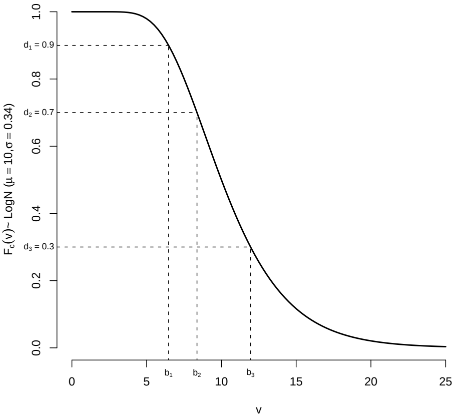


Figure: Complementary cumulative velocity distribution.

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 ℓ 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:

$$\max \sum_{k \in K} \sum_{s \in S} x_{s,k} d_k u_s + \sum_{k \in K} \sum_{t \in T} y_{t,k} d_k u_t$$
$$\text{s.t.} \sum_{s \in S} \sum_{j=1}^{k} c_s x_{s,j} \leq b_k \quad \forall_{k \in K}$$
$$\text{and} \sum_{k \in K} x_{s,k} \leq 1 \quad \forall_{s \in S}$$

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:

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

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

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 $z_{t,k} = 1$:

$$y_{t,1} = z_{t,1} \qquad \forall_{t \in T}$$

$$y_{t,k} = z_{t,k} - z_{t,k-1} \quad \forall_{t \in T} \forall_{k \in \{K-1\}}$$

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

$$x_{j,k} - \sum_{l=1}^{k} x_{i,l} \leq 0 \quad \forall_{i \prec j} \forall_{k \in K}$$

Velocity estimation heuristic: iteration

- If we have ≥ 5 velocity observations, the iteration velocity can be estimated through maximum likelyhood with

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

where $\hat{\mu}$ is the mean of the log-transformed observations $\ln(\mathbf{v})$ and $\hat{\sigma}^2$ is the sample variance $\mathrm{sd}(\ln(\mathbf{v}))^2$.

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:

$$\hat{\sigma} = \frac{\sigma_0 + n\mathrm{sd}(\ln(\mathbf{v}))}{1 + n}$$

where n is the number of observations and σ_0 is an prior belief of sample error that has a weight equal to one observation of true velocity.

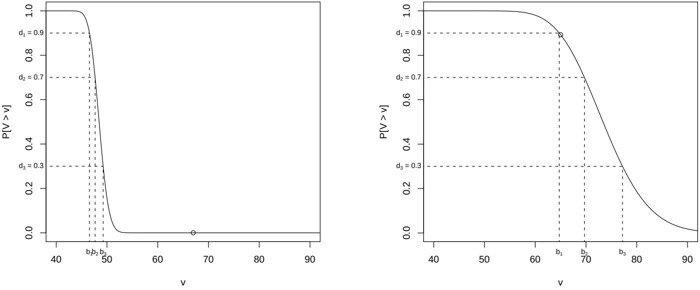
- Prior belief σ_0 has to be specified!

Rules of thumb for uncertainty in velocity

Phase	Suggested CI	σ_0
Requirements Known *	$[\hat{\mu}/2.0, \hat{\mu} * 2.0]$	0.42
Requirements Analyzed *	$[\hat{\mu}/1.75, \hat{\mu} * 1.75]$	0.34
$<$ 2 Iterations Completed	$[\hat{\mu} * 0.60, \hat{\mu} * 1.60]$	0.29
Preliminary Design *	$[\hat{\mu}/1.40, \hat{\mu} * 1.40]$	0.21
Detailed Design *	$[\hat{\mu}/1.25, \hat{\mu} * 1.25]$	0.14
2 Iterations Completed	$[\hat{\mu} * 0.8, \hat{\mu} * 1.25]$	0.14
3 Iterations Completed	$[\hat{\mu} * 0.85, \hat{\mu} * 1.15]$	0.08
$>$ 3 Iterations Completed	$[\hat{\mu} * 0.90, \hat{\mu} * 1.10]$	0.06

With * are from NASA SEL guidelines (1990), others from Cohn (2005).

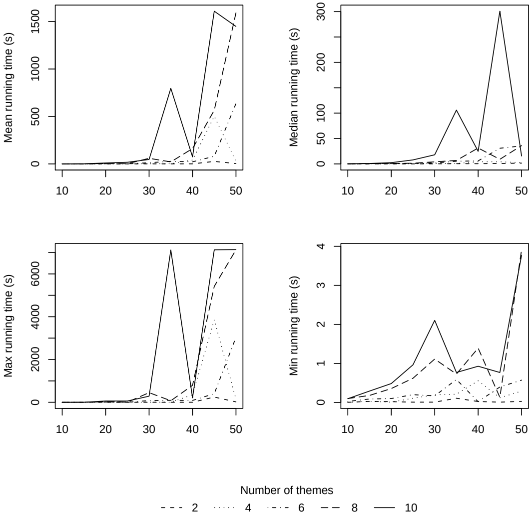
Velocity estimates vs observed velocity



(a) V_R for R2 (based on $\mathbf{v}_1$) (b) V_R for R3 (based on $\mathbf{v}_2$)

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 $\circ$ 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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