OPTIMIZATION METHODS FOR SOFTWARE RELEASE PLANNING

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• Created in July 2001 at the University of Calgary
• Research team of 13 researchers (2 undergraduate, 3 graduate, 6 PhD students, and 2 profs)
• Research topics: Decision support (systems) for
  – Software release planning
  – Project management
  – Staffing
  – Effort estimation
  – COTS selection
• Research approach:
  – Interdisciplinary
  – Both fundamental and applied research
  – Empirical validation of results
• University spin-off company: Expert Decisions
Agenda

1. Decisions in release planning
2. Strategic release planning: Randomized versus deterministic
3. Operational release planning: Deterministic AND randomized
4. When-to-release decisions
5. Ongoing research
Release planning – What it is?

Feature and change request repository

Amount of functionality

Amount of suggested changes

Releases

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Release decisions

- Which features should be offered in the next release(s)?
- Which features should not be offered in the next release(s)?
- When is the best time for a product release?
- How to adjust to change for a given release?
  - When to re-plan?
  - How much to re-plan?
  - Which formerly planned features should be replaced by new ones?
  - How often re-planning can be done?
Release planning - Why efficient search is needed?

Hard and soft constraints on:
- Time
- Effort
- Quality
- Resources

Multiple objectives:
- Usability
- Value
- Time-to-market
- Frequency of use
- Risk

Information is:
- Uncertain
- Inconsistent
- Incomplete
- Fuzzy

Decision space:
- Large size
- High complexity
- Dynamically changing

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1. Decisions in release planning
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3. Operational release planning: Deterministic AND randomized
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“The mere formulation of a problem is far more essential than its solution, which may be merely a matter of mathematical or experimental skills. To raise new questions (and), new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advances in science.”

(Albert Einstein, 1879-1955)
Optimized release planning – How it began


What constitutes a release plan?

\[
\text{Max}\{ F(x, \alpha) = (\alpha - 1) F1(x) + \alpha F2(x) \text{ subject to } 0 \leq \alpha \leq 1, x \text{ from } X \}\]

Stakeholders
Weightings for stakeholders
Scores of stakeholders towards urgency (F1) and value (F2)
\( X \) composed of
- effort constraints
- coupling and precedence constraints (between features)
Optimized release planning – How it began

F1(x) is a penalty function defined for plan x describing the degree of violation of the monotonicy property between all pairs of features.

F2(x) is a benefit function based on feature scores of the stakeholders and the actual assignment of the feature according to the plan under consideration.

\[
value(n,p) = value\_score(n,p)(K - x(n) + 1)
\]
Empirical analysis

• EVOLVE was initially based on genetic search offered by Palisade’s RiskOptimizer
• Early industrial feedback (Corel, Siemens)
• Development of our own GA (emphasis on avoiding premature convergence)
• Empirical studies with 200 to 700 requirements comparing the GA with running ILOG’s CPLEX
• Better solutions for LP solver in reasonable time
• Known level of optimality
• Development of our own solution method utilizing open source optimization combined with knapsack-type of heuristic for B&B
• New approach more flexible model and with higher level of diversification among top solutions.
Stakeholder-centric release planning – Method EVOLVE II
Maximization of stakeholder feature points

- **Features**
  - score(n,p,q)
- **Stakeholder**
  - weight
  - Score(n,q)
- **Criteria**
  - weight
  - SCORE(n)
- **Releases**
  - weight
  - sfp(n,x)
- **Plan x**
  - TSFP(x)

.functions:
- Score(n, p, q)
- weight
- Score(n, q)
- weight
- SCORE(n)
- weight
- sfp(n, x)
- TSFP(x)
Resource constraints

- Resource class 1: A resource type $r$ belongs to class 1 if the feature related consumption of the resource is limited to exactly the release in which the feature is offered. Resources of this class are called local based on its spending mode.

$$\text{Consumption}(k, r, x) = \sum_{n: x(n) = k} \text{consumption}(n, r) \leq \text{Capacity}(k, r)$$
Resource constraints

• Resource class 2: A resource type \( r \) belongs to class 2 if the feature related consumption of the resource can be distributed across different release periods. Resources of this class are called global based on its spending mode.

\[
\sum_{n=1..N} w_x(n,k,r) \text{ consumption}(n,r) \leq \sum \text{ Capacity}(k,r) \quad \text{for all releases } k = 1 \ldots K
\]

\[0 \leq w_x(n,k,r) \leq 1 \quad \text{for all } n,k,r\]

\[
\sum_{k=1..K} w_x(n,k,r) = 1 \quad \text{for all } n,r
\]
The diversification principle

A single solution to a cognitive complex problem is less likely to reflect the actual problem when compared to a portfolio of qualified solutions being structurally diversified.
Diversified release plans

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https://www.releaseplanner.com/rp/wpp?mod=rpRequirements&Id=414512
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Operational planning: Data related to a feature \( f(n) \)


Assignment of developers to tasks of features

Developer dev(1)
productivity vector = (1.4, 2, 1.2)

Developer dev(2)
productivity vector = (1, 0, 2)

Developer dev(3)
productivity vector = (1, 2, 1)
Sample Gantt Chart of operational planning
RASORP modeling (1/3)

- $N$ - number of features under consideration,
- $K$ - number of releases considered for planning,
- $Q$ - number of tasks to be performed for each feature,
- $D$ - number of developers available for assignment to tasks,
- $t(k)$ - due date of release $k$ ($k = 1..K$), and
- $v(n,k)$ - value obtained by assigning feature $n$ to release $k$ ($n = 1..N, k = 1..K$)
- $x(n,k)$ - delivery of features $f(n)$ at release $k$
- $u(d,t,n,q)$ – assignment of developer $d$ at time $t$ to task $q$ of feature $f(n)$
RASORP modeling (2/3)

• Maximize \( F(x) = \sum_{n=1..N} \sum_{k=1..K} v(n,k) \cdot x(n,k) \) subject to \((u,x) \in UX\) where \(UX\) is the set of all feasible combination of staffing and release plans \((u,x)\).

• \( \sum_{k=1..K} x(n,k) \leq 1 \) for \( n = 1..N \)

• \( x(n_1,k) = x(n_2,k) \) for all coupled features \( C(n_1,n_2) \) for \( k = 1..K \)

• \( \sum_{k=1..K} (K+1-k)(x(n_1,k) - x(n_2,k)) \geq 0 \), for all pairs of features being in precedence relationship \( P(n_1,n_2) \)

• \( \sum_{t=t1..t2} \sum_{n=1..N} \sum_{q=1..Q} u(d,t,n,q) = 0 \) for \( d = 1..D, \ l = 1..L(d) \), and \( \text{twind}(d,l) = [t1,t2] \)

• \( \sum_{n=1..N} \sum_{q=1..Q} u(d,t,n,q) \leq 1 \) for \( d = 1..D \) and \( t = 1..t(K) \)
RASORP modeling (3/3)

- $\sum_{t=1..t(K)} u(d,t,n,q) \leq t(K) * z(d,n,q)$ for $d = 1..D$, $n = 1..N$ and $q = 1..Q$
- $\sum_{d=1..D} z(d,n,q) \leq 1$ for $n = 1..N$ and $q = 1..Q$
- $\sum_{d=1..D} \sum_{t=1..t(k)} u(d,t,n,q) * \text{prod}(d,q) \geq w(n,q) * \sum_{k1=1..k} x(n,k1)$ for $k = 1..K$, $n = 1..N$ and $q = 1..Q$
- $\sum_{d=1..D} \sum_{t1=1..t} u(d,t1,n,q) \geq \sum_{d=1..D} \sum_{t1=1..t} u(d,t1,n,q+e)$ for $t = 1..t(K)$, $n = 1..N$, $q = 1..Q-1$, $w(n,q)$, $w(n,q+e) > 0$ and $w(n,q*) = 0$ for all $q* = q+1..q+e-1$
- $\sum_{d=1..D} \sum_{t1=t..t(K)} u(d,t1,n,q+e) \geq \sum_{d=1..D} \sum_{t1=t..t(K)} u(d,t1,n,q)$ for $t = 1..t(K)$, $n = 1..N$, $q = 1..Q-1$, $e = 1..Q - q$, $w(n,q)$, $w(n,q+e) > 0$ and $w(n,q*) = 0$ for all $q* = q+1..q+e-1$
RASORP algorithm - Phase 1 (packaging)

• Step 1.1
Consider a simplified problem formulation RASORP* by ignoring the precedence constraints between the tasks implementing the features (just looking at $t = t(k)$’s).

• Step 1.2
Apply branch and bound techniques in combination with linear programming (solving the relaxed problem without integrality constraints) to generate upper bounds and using a greedy heuristic to solve the sub-problem at each node of the branching tree.

• Step 1.3
Obtain an optimized solution $x_1$ which is taken as an input for Phase 2 to define a reduced search space.
RASORP algorithm Phase 2 (scheduling)

- **Step 2.1**: Consider the complete problem RASORP.
- **Step 2.2**: Apply genetic algorithms to a reduced search space of permutations called $\prod^*$ (focused search) defined by the solution $x_1$ from Phase 1.
  - Population size = 100,
  - Maximal number of generations = 500,
  - Probability of mutation = 1%,
  - Termination: If there is no improvement after 100 consecutive generations or the maximum number of generations is reached,
  - Percentage of new random solutions in each new generation = 10%,
  - Number of generations indicating that the population is stuck at a local optimum = 50, and
  - Proportion of new individuals when the population is stuck at a local optimum = 80%.
- **Step 2.3**: The resulting solution $x_2$ has a degree of optimality of at least $F(x_2) / F(x_1)$.  

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## Empirical analysis: Definition of groups

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Comparison between FS, UFS and greedy search

- $x_1$ = optimized plan at the end of Phase 1
- $x_2$ = plan received from application of focused search FS
- $x_3$ = plan received from application of unfocused search UFS
- $x_4$ = plan received from application of greedy search
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When-to-release decisions for features with time-dependent value functions


- Value functions are continuous functions of time.

\[ TNV(n, t) = \int_{t}^{T} \text{DailyGrossIncome}(n, t) \, dt \]
When-to-release decisions for features with time-dependent value functions

- Actual release dates are no longer fixed but can be varied in some pre-defined interval.

\[
\text{Consumption}(k,r,x) = \sum_{n : x(n) = k} \text{consumption}(n,r) \leq \text{Capacity}(k,r,t^*(k)) \text{ for } r = 1\ldots R \text{ and } k = 1\ldots K
\]

\(t^*(k)\) being from the interval \([r_{d1}(k), r_{d2}(k)]\)

- Value\((x, RD,T) = \sum_{k=1\ldots K} \sum_{n : x(n) = k} TNV(n, r_d(k))\)
- Risk\((x, RD) = \sum_{k=1\ldots K} \alpha(k) [r_{d2}(k) - r_{d}(k)]^{\beta(k)}\)

- Calculation of trade-off solutions balancing the risk of early release with the potential additional value.

  Trade-off \([\{\text{Value}(x, RD,T) , \text{Risk}(x, RD)\}]\) according to \(x \in X(RD)\), \(RD = (r_{d}(1)\ldots r_{d}(k))\) with \(r_{d}(k) \in [r_{d1}(k), r_{d2}(k)]\) for all \(k = 1\ldots K\)
Risk-value trade-off solutions
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Topics of ongoing and future research

- Release planning with logical constraints
- Planning and mining for software releases
- Planning for multiple products
- Release decisions in consideration of the impact of uncertainty
- Release decisions in consideration of functional and non-functional requirements
A bit of self advertisement

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Empirical Software Engineering International Week (ESEIW) is comprised of six conferences/events:

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<td>ESEM</td>
<td>Link</td>
<td>International Symposium on Empirical Software Engineering and Measurement</td>
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<td>ISERN</td>
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<td>International Software Engineering Research Network</td>
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<td>Link</td>
<td>International Doctoral Symposium on Empirical Software Engineering</td>
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<td>IASESE</td>
<td>Link</td>
<td>International Advanced School on Empirical Software Engineering</td>
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<tr>
<td>PROMISE</td>
<td>Link</td>
<td>International Conference on Predictive Models in Software Engineering</td>
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<tr>
<td>RESER</td>
<td>Link</td>
<td>International Workshop on Replication in Empirical Software Engineering Research</td>
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<tr>
<td>MetriSec</td>
<td>Link</td>
<td>International Workshop on Security Measurements and Metrics</td>
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The schedule for ESEIW is as follows:

September 2011

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<th>Mon 19</th>
<th>Tue 20</th>
<th>Wed 21</th>
<th>Thu 22</th>
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The bigger picture

Source: http://www.softwareproductmanagement.org/
Discussion

• It is more important to solve the right problem instead of solving a problem right
• Modeling is more influential than solving
• “Traditional” optimization has advantages, too
• Huge gap in transferring research results into industry
• More evidence for usefulness is needed