Softwaretechnik / Software-Engineering

Lecture 5: Procedure & Process Models

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Topic Area Project Management: Content

- Software Metrics
  - Properties of Metrics
  - Scales
  - Examples

- Cost Estimation
  - "(Software) Economics in a Nutshell"
  - Expert's Estimation
  - Algorithmic Estimation

- Project Management
  - Project
  - Process and Process Modelling

- Process Metrics
  - CMMI, Spice
Describing Software Development Processes

Over time, the following notions proved useful to describe and model (→ in a minute) software development processes:

- **role** — has responsibilities and rights, needs skills and capabilities. In particular: has responsibility for artefacts, participates in activities.

- **artefact** — all documents, evaluation protocols, software modules, etc., all products emerging during a development process. Is processed by activities, may have state.

- **activity** — any processing of artefacts, manually or automatic; solves tasks. Depends on artefacts, creates/modifies artefacts.

- **decision point** — special case of activity: a decision is made based on artefacts (in a certain state), creates a decision artefacts. Delimits phases, may correspond to milestone.

From Building Blocks to Process (And Back)

Building Blocks
Plan
Process
Process vs. Procedure Models
(Ludewig and Lichter, 2013) propose to distinguish: **process model** and **procedure model**.

- A **Process model** ('Prozessmodell') comprises
  1. **Procedure model** ('Vorgehensmodell')
     - e.g., “waterfall model” (70s/80s).
  2. **Organisational structure** – comprising requirements on
     - project management and responsibilities,
     - quality assurance,
     - documentation, document structure,
     - revision control.
     - e.g., V-Modell, RUP, XP (90s/00s).

- In the literature, **process model** and **procedure model** are often used as synonyms; there is not universally agreed distinction.

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**Procedure Models**

— Waterfall —
Waterfall or Document-Model— Software development is seen as a sequence of activities coupled by (partial) results (documents). These activities can be conducted concurrently or iteratively. Apart from that, the sequence of activities is fixed as (basically) analyse, specify, design, code, test, install, maintain. 

Ludewig & Lichter (2013)

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Ludewig & Lichter (2013)
The (In)famous Waterfall Model (Roose, 1967)

Procedure Models
— Spiral —

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Apart from that, the sequence of activities is fixed as (basically) analyse, specify, design, code, test, install, maintain. Ludwig & Lichter (2013)
The Spiral Model (Boehm, 1988)

Recall:

Quick Excursion: Risk and Riskvalue

- **risk** — a problem, which did not occur yet, but on occurrence threatens important project goals or results. Whether it will occur, cannot be surely predicted.

- **Ludewig & Lichter (2013)**

\[ \text{riskvalue} = p \cdot K \]

- \( p \): probability of problem occurrence,
- \( K \): cost in case of problem occurrence.

Note: risks can have various forms and counter-measures, e.g.,
- open technical questions (→ prototype?),
- lead developer about to leave the company (→ invest in documentation?),
- changed market situation (→ adapt appropriate features?),
- ...


Repeat until end of project (successful completion or failure):

(i) **determine** the set \( R \) of risks which are threatening the project:
- if \( R = \emptyset \), the project is successfully completed

(ii) **assign** each risk \( r \in R \) a risk value \( v(r) \)

(iii) for the risk \( r_0 \) with the **highest risk value**, \( r_0 = \max \{ v(r) \mid r \in R \} \),
- find a way to eliminate this risk, and go this way;
- if there is no way to eliminate the risk, stop with project failure

Advantages:
- We know early if the project goal is unreachable.
- Knowing that the biggest risks are eliminated gives a good feeling.
A concrete process using the Spiral Model could look as follows:

- investigate goals, alternatives, side conditions
- conduct risk analysis,
- develop and test the next product part,
- plan the next phase.

Content

- Procedure and Process Models
  - Procedure Model Examples
    - The (in)famous Waterfall model
    - The famous Spiral model
  - Procedure classification
    - linear / non-linear
    - prototyping
    - evolutionary, iterative, incremental
  - From Procedure to Process Models
  - Process Model Examples
    - Phase Model
    - V-Modell XT
    - Agile
      - Extreme Programming
      - Scrum
  - Process Metrics
    - CMMI, Spice
Procedure Model Classification

— Linear vs. Non-Linear —
**Linear vs. Non-Linear Procedure Models**

- **linear**: the strict Waterfall Model (no feedback)
- **non-linear**: basically everything else (with feedback between activities)

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**Procedure Model Classification**

--- By Treatment of Artefacts ---
Classification By Treatment of (Software) Artefacts

- Prototyping:

(Rapid) Prototyping

**Prototype** – A preliminary type, form, or instance of a system that serves as a model for later stages or for the final, complete version of the system.  
*IEEE 610.12 (1990)*

**Prototyping** – A hardware and software development technique in which a preliminary version of part or all of the hardware or software is developed to permit user feedback, determine feasibility, or investigate timing or other issues in support of the development process.  
*IEEE 610.12 (1990)*

**Rapid Prototyping** – A type of prototyping in which emphasis is placed on developing prototypes early in the development process to permit early feedback and analysis in support of the development process.  
*IEEE 610.12 (1990)*

Kinds of prototypes, distinguished by...
- **usage**: demonstration prototype, functional prototype, lab sample, pilot system, etc.
- **supported activity**: explorative prot.: support analysis; experimental prot.: support design; evolutionary prot.: → evolutionary procedure
• Prototyping:

• Evolutionary Development:

• Iterative Development:

Evolutionary and Iterative Development

**Evolutionary software development** – an approach which includes evolutions of the developed software under the influence of practical/field testing.

New and changed requirements are considered by developing the software in sequential steps of evolution.

Ludewig & Lichter (2013), flw. (Züllighoven, 2005)

**Iterative software development** – software is developed in multiple iterative steps, all of them planned and controlled.

Goal: each iterative step, beginning with the second, corrects and improves the existing system based on defects detected during usage.

Each iterative steps includes the characteristic activities analyse, design, code, test.

Ludewig & Lichter (2013)
Incremental Development

incremental software development – The total extension of a system under development remains open; it is realised in stages of expansion. The first stage is the core system. Each stage of expansion extends the existing system and is subject to a separate project. Providing a new stage of expansion typically includes (as with iterative development) an improvement of the old components. Ludewig & Lichter (2013)

Note: (to maximise confusion) IEEE calls our “iterative” incremental:

incremental development – A software development technique in which requirements definition, design, implementation, and testing occur in an overlapping, iterative (rather than sequential) manner, resulting in incremental completion of the overall software product. IEEE 610.12 (1990)

One difference (in our definitions):

iterative: steps towards fixed goal,
incremental: goal extended for each step; next step goals may already be planned.
Examples: operating system releases, short time-to-market (→ continuous integration).
Classification By Treatment of (Software) Artefacts

- **Prototyping:**
  ![Prototyping Diagram]

- **Evolutionary Development:**
  ![Evolutionary Development Diagram]

- **Iterative Development:**
  ![Iterative Development Diagram]

- **Incremental Development:**
  ![Incremental Development Diagram]

- **Staircase:** pipelined incremental
  ![Staircase Diagram]

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    - Extreme Programming
    - Scrum
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    - CMMI, Spice
Process Models

Process vs. Procedure Model

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  (ii) Organisational structure – comprising requirements on
      - project management and responsibilities.
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      - documentation, document structure.
      - revision control.
      e.g., V-Modell, RUP, XP (90s/00s).

- In the literature, process model and procedure model are often used as synonyms; there is not universally agreed distinction.
A process model may describe:

- steps to be conducted during development, their sequential arrangement, their dependencies (the procedure model)
- organisation, responsibilities, roles
- structure and properties of documents
- methods to be used, e.g., for gathering requirements or checking intermediate results
- project phases, milestones, testing criteria
- notations and languages
- tools to be used (in particular for project management).

Process models typically come with their own terminology (to maximise confusion?), e.g., what we call artefact is called product in V-Model terminology.
The Phase Model

- The project is planned by phases, delimited by well-defined milestones.
- Each phase is assigned a time/cost budget.
- Phases and milestones may be part of the development contract; partial payment when reaching milestones.
- Roles, responsibilities, artefacts defined as needed.

- By definition, there is no iteration of phases.
- But activities may span (be active during) multiple phases.

- Not uncommon for small projects (few software people, small product size), and small companies.
Process Models
— V-Model XT —
There are different "V-shaped" process models, we discuss the (German) "V-Modell".

"V-Modell":
- developed by company IABG in cooperation with the Federal Office for Defence Technology and Procurement ('Bundesministerium für Verteidigung'), released 1998
- (German) government as customer often requires usage of the V-Modell

2012: "V-Modell XT" Version 1.4 (Extreme Tailoring) (V-Modell XT, 2006)
V-Modell XT: Decision Points

V-Modell XT: Example Building Block & Product State

SW-Development (‘SW-Entwicklung’)
V-Modell XT: (Lots of) Disciplines and Products

V-Modell XT: (Lots of) Disciplines and Products
V-Modell XT: Activities (as many?!)
Project Roles:

Änderungssteuerungsgruppe (Change Control Board), Änderungsverantwortlicher, Anforderungsanalytiker (AG), Anforderungsanalytiker (AN), Anwender, Assessor, Ausschreibungsverantwortlicher, Datenschutzverantwortlicher, Ergonomieverantwortlicher, Funktionssicherheitsverantwortlicher, HW-Architekt, HW-Entwickler, Informationssicherheitsverantwortlicher, KM-Administrator, KM-Verantwortlicher, Lenkungsausschuss, Logistikentwickler, Logistikverantwortlicher, Projektkaufmann, Projektkoordinator, Projektmanager, Prozessingenieur, Prüfer, OS-Verantwortlicher, SW-Architekt, Systemarchitekt, Systemintegrator, Technischer Autor, Trainer.

Organisation Roles:

Akquiseur, Datenschutzbeauftragter (Organisation), Einkäufer, IT-Sicherheitsbeauftragter (Organisation), Qualitätsmanager.

What About the Colours?
V-Modell XT: Project Types

V-Modell XT considers four different project types:

- **AG**: project from the perspective of the customer
  (create call for bids, choose developer, accept product)
- **AN**: project from the perspective of the developer
  (create offer, develop system, hand over system to customer)
- **AG/AN**: customer and developer from same organisation
- **PM**: introduction or improvement of a process model

**Project type variants**: one/many customer(s); development/improvement/migration; maintenance

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V-Modell XT: Customer/Developer Interface
V-Modell XT: Development Strategies

V-Modell XT mainly supports three strategies, i.e. principal sequences between decision points, to develop a system:

- **incremental**
- **component based**
- **prototypical**
V-Modell XT: Discussion

Advantages:
- Certain management related building block are part of each project, thus they may receive increased attention of management and developers
- Publicly available, can be used free of license costs
- Very generic, support for tailoring
- Comprehensive, low risk of forgetting things

Disadvantages:
- Comprehensive, tries to cover everything; tailoring is supported, but may need high effort
- Tailoring is necessary, otherwise a huge amount of useless documents is created
- Description/presentation leaves room for improvement

Needs to prove in practice, in particular in small/medium sized enterprises (SME).

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    - CMMI, Spice
“Agile — denoting ‘the quality of being agile; readiness for motion; nimbleness, activity, dexterity in motion’ — software development methods are attempting to offer an answer to the eager business community asking for lighter weight along with faster and nimbler software development processes.

This is especially the case with the rapidly growing and volatile Internet software industry as well as for the emerging mobile application environment.” (Abrahamsson et al., 2002)

The Agile Manifesto (2001):

We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

| Individuals and interactions | over | processes and tools |
| Customer collaboration | over | contract negotiation |
| Working software | over | comprehensive documentation |
| Responding to change | over | following a plan |

that is, while there is value in the items on the right, we value the items on the left more.
Agile Principles

• “continuous / sustainable delivery”
  • Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.
  • Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
  • Agile processes promote sustainable development.
    The sponsors, developers, and users should be able to maintain a constant pace indefinitely.

• “simplicity”
  • Simplicity – the art of maximizing the amount of work not done – is essential.
  • Working software is the primary measure of progress.

• “changes”
  • Welcome changing requirements, even late in development.
    Agile processes harness change for the customer’s competitive advantage.

• “people”
  • The best architectures, requirements, and designs emerge from self-organizing teams.
  • Build projects around motivated individuals.
    Give them the environment and support they need, and trust them to get the job done.
  • Business people and developers must work together daily throughout the project.
  • The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.

Similarities of Agiles Process Models

• iterative: cycles of a few weeks, at most three months.
  • Work in small groups (6–8 people) proposed.
  • Dislike the idea of large, comprehensive documentation (radical or with restrictions).
  • Consider the customer important; recommend or request customer’s presence in the project.
  • Dislike dogmatic rules.

(Ludewig and Lichter, 2013)
Extreme Programming (XP) (Beck, 1999)

XP values:
- simplicity, feedback, communication, courage, respect.

XP practices:
- management
  - integral team (including customer)
  - planning game (→ Delphi method)
  - short release cycles
  - stand-up meetings
  - assess in hindsight
- team:
  - joint responsibility for the code
  - coding conventions
  - acceptable workload
  - central metaphor
  - continuous integration
- programming
  - test driven development
  - refactoring
  - simple design
  - pair programming
Scrum

First published 1995 (Schwaber, 1995), based on ideas of Takeuchi and Nonaka.
Inspired by Rugby (yes, the “hooligan’s game played by gentlemen”): get the ball in a scrum, then sprint to score.
Role-based; iterative and incremental: in contrast to XP no techniques proposed/required.

Three roles:

- **product owner:**
  - representative of customer,
  - maintains requirements in the product backlog,
  - plans and decides which requirement(s) to realise in next sprint,
  - (passive) participant of daily scrum,
  - assesses results of sprints

- **scrum team:**
  - members capable of developing autonomously,
  - decides how and how many requirements to realise in next sprint,
  - distribution of tasks self-organised, team decides who does what when,
  - environment needs to support communication and cooperation, e.g. by spatial locality

- **scrum master:**
  - helps to conduct scrum the right™ way,
  - looks for adherence to process and rules,
  - ensures that the team is not disturbed from outside,
  - moderates daily scrum, responsible for keeping product backlog up-to-date,
  - should be able to assess techniques and approaches
• **product backlog**  
  (maintained by product owner)  
  • comprises all requirements to be realised,  
  • priority and effort estimation for requirements,  
  • collects tasks to be conducted,

• **release plan**  
  • based on initial version of product backlog,  
  • how many sprints, which major requirements in which sprint,

• **release-burndown report**  
  • see sprint-burndown report

• **sprint backlog**  
  • requirements to be realised in next sprint,  
  taken from product backlog,  
  • more precise estimations,  
  • daily update (tasks done, new tasks, new estimations)

• **sprint-burndown report**  
  • completed/open tasks from sprint backlog,  
  • should decrease linearly,  
  otherwise remove tasks from sprint backlog,

• **sprint report**  
  • which requirements (not) realised in last sprint,  
  • description of obstacles/problems during sprint

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**Scrum Process**

**Daily Scrum:**  
• daily meeting, 15 min.  
• discuss progress, synchronise day plan, discuss and document new obstacles  
• team members, scrum master, product owner (if possible)

**Sprint:**  
• at most 30 days, usually shorter (initially longer)

**Sprint Review:**  
• assess amount and quality of realisations; product owner accepts results

**Sprint Retrospective:**  
• assess how well the scrum process was implemented;  
identify actions for improvement (if necessary)
Scrum: Discussion

- Has been used in many projects, experience in majority positive.
- Team size bigger 7–10 may need scrum of scrums.
- Competent product owner necessary for success.
- Success depends on motivation, competence, and communication skills of team members.
- Team members are responsible for planning, and for adhering to process and rules, thus intensive learning and experience necessary.
- Can (as other process models) be combined with techniques from XP.

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**Assessment and Improvement of the Process**

- **Idea** (for material goods): The quality of the (production) process influences **product quality**.

- **Plan**: Specify abstract criteria (metrics) to determine **good production processes** (e.g., to choose manufacturer).

- **Industry in general** (production!):
  - ISO 9001, ISO/TS 16949 (automotive), ...

- **Software industry** (development!):
  - CMM(I), SPICE

- **Note**: a good process does not stop us from creating **bad products**; (the hope is, that) bad products are less likely when using a good process, i.e. that there is a correlation:
**CMMI**

- 1991: Capability Maturity Model (CMM), DoD/SEI/CMU; superseded by
- 1997: **Capability Maturity Model Integration** (CMMI) ([Team, 2010](#));
  constellations: **CMMI-DEV** (development), CMMI-ACQ (acquisition), CMMI-SRV (service)
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**Goals:**
- applicable to all organisations which develop software.
- make strengths and weaknesses of the real process visible, to point out ways for improvement.
- neutral wrt. technology employed in project.
- levels: higher levels have lower levels as premise.
- be consistent with ISO 15504 (SPICE)

**Assumptions:**
- better defined, described, and planned processes have higher maturity.
- higher maturity levels require statistical control to support continuous improvement,
- higher maturity level yields:
  - better time/cost/quality prediction;
  - lower risk to miss project goals;
  - higher quality of products.

### CMMS Levels

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<th>level</th>
<th>level name</th>
<th>process areas</th>
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<td>1</td>
<td>initial</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>managed</td>
<td>REQM, PP, PMC, MA, PPQA, CM, SAM</td>
</tr>
<tr>
<td>3</td>
<td>defined</td>
<td>+ RD, TS, PI, VER, VAL, OPF, OPD, OT, IPM, RSKM, DAR</td>
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<tr>
<td>4</td>
<td>quantitatively managed</td>
<td>+ OPP, QPM</td>
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<tr>
<td>5</td>
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- **initial** – the process is not consciously designed, just evolved.

- **managed** (formerly: repeatable) – important areas of software development organised and prescribed to responsible people; each project may have own process

- **Areas**: requirements management (REQM), project planning (PP), project monitoring and control (PMC), measurement and analysis (MA), Process and Product Quality Assurance (PPQA), configuration management (CM), supplier agreement management (SAM)
CMMI General/Specific Goals and Practices

- CMMI certificates can be obtained via a so-called appraisal
- There are three levels of review methods A, B, C; A is most thorough (and expensive).
- A certificate authority checks, to what amount generic goals GG.1, ..., GG.3 with their generic practices are reached.
  Example: GG.2 (for level 2) includes
  - GG 2.1: create strategy for planning and installation of process
  - GG 2.2: plan the process
  - GG 2.3: allocate resources
  - ...
- Each area, like RD, has specific goals and specific practices, sometimes per level
  Example: RD (requirements development) includes
  - SG 1: develop customer requirements
  - SG 2: develop product requirements
  - SG 3: analyse and validate requirements
- That is, to reach CMMI level 2, an organisation has to reach GG.1, GG.2, and SG 1 and SG 2 for area RD.

CMMI: Discussion

- in CMMI, e.g. area RD requires that requirements are analysed, but does not state how – there are examples, but no particular techniques or approaches
- CMMI as such is not a process model (in the sense of the course)

- CMMI certificate is required by certain (U.S) government customers; may guide selection of sub-contractors (a certificate at least proves that they think about their process)
- CMMI can serve as an inspiration for important aspects of process models wrt. product quality

- Criticism:
  - CMM(I) assumptions are based on experience in specific projects; may not be present for all kinds of software.
  - CMMI certification applies to one particular state of process management; changed processes may require new (expensive) appraisal, in this sense CMMI certification may hinder innovation.
  - CMMI levels are chosen somewhat arbitrarily: "why is an area in level \( N \) and not already in level \( N - 1 \)?"
Software Process Improvement and Capability Determination

- similar to CMM(I): maturity levels, assessment, certificates
- maturity levels: 0 (incomplete), ..., 5 (optimizing);
  SPICE 0 corresponds to CMMI 1
- provides “process reference models”
  (in particular specific ones for automotive, aerospace, etc.)
- Literature: (Hörmann et al., 2006)

Tell Them What You’ve Told Them...

- Waterfall Model
  - very well-known, very abstract, of limited practical use.

- Spiral Model
  - iterated risk assessment, e.g., for very innovative projects.

- Classification of processes
  - prototyping: needs purposes and questions
  - evolutionary, iterative, incremental

- V-Model XT
  - slightly different vocabulary.
  - quite comprehensive.
  - may serve as inspiration for, e.g., definition of roles.
  - can be tailored in various ways

- Agile approaches
  - XP: proposes methods and approaches
  - Scrum: focuses on management aspects

- Measure process quality: CMMI, Spice
References


