TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Informatik, Institut für Software- und Multimediatechnik, Lehrstuhl für Softwaretechnologie

2. Software Development as Engineering Activity

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1. **Software Engineering Scenarios**
2. **A simple run through the life cycle**

Obligatory Reading

- Balzert Introduction
- Maciaszek/Liong Chap. 1
- Ghezzi Chap 5+7 or
- Pfleeger Chap 2+4
- Ed Seidewitz. What models mean. IEEE Software, 20:26-32, September 2003.
  - http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1231147&tag=1

References

- M. Pidd. Tools for Thinking. Modeling in Management Science. Wiley. Gives a good overview on modeling in general (soft and hard models)
- www.omg.org/mda Model driven architecture® is a process that structures refinement-based development, using UML
- Favre's papers on egyptology:
  - Jean-Marie Favre. Foundations of model (driven) (reverse) engineering: Models - episode I: Stories of the fidus papyrus and of the solarus. In Jean Bezivin and Reiko Heckel, editors, Language Engineering for Model-Driven Software Development, number 04101 in Dagstuhl Seminar Proceedings, Dagstuhl, Germany, 2005. Internationales Begegnungs- und Forschungszentrum für Informatik (IBFI), Schloss Dagstuhl, Germany.
  - Jean-Marie Favre. Foundations of meta-pyramids: Languages vs. metamodels- episode II: Story of thotus the baboon1. In Jean Bezivin and Reiko Heckel, editors, Language Engineering for Model-Driven Software Development, number 04101 in Dagstuhl Seminar Proceedings, Dagstuhl, Germany, 2005. Internationales Begegnungs- und Forschungszentrum für Informatik (IBFI), Schloss Dagstuhl, Germany.
- JR Abrial, Stephan Hallerstede. Refinement, decomposition, and instantiation of discrete models: Application to Event-B. Fundamenta Informaticae, 2007
  - http://dl.acm.org/citation.cfm?id=1365974&CFID=49627514&CFTOKEN=73132377

Scenario of Running Example

- You are a project manager in Hamann/Becker Car Radios, Inc, Karlsruhe, Germany
- Your boss comes into your office and says:
- "Our competitor Smith Car Radios has a new satellite radio. Their sales are growing, and our customers demand it, too. How quickly can you deliver me a satellite radio?"

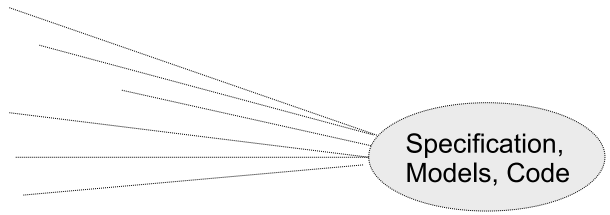
First Ideas

- How many people?
  - do we have the right ones?
- Which milestones (deadlines)?
- How many resources?
- What should the radio be able to do?
- Why will it better than the competitors? (competitive business edge)

- How can we go the way in a structured way towards the product?
- How can we engineer it?

What is Software Engineering?

- It teaches the production of software with engineering techniques (the engineer's toolkit)
- Model
- Analysis
- Prediction
- Construction
- Reuse
- Validation
- Improvement
- Sell



Software engineers model, measure, predict, build, validate, improve, and sell

The (Software) Engineer's Toolkit

- Model a reality (a domain or a system)
  - Describe or specify
  - World and problem modeling vs. system modeling
- **Analyze** (measure) a reality (a model or a system)
  - Identifying the problem (problem analysis, goal analysis, risk analysis)
  - Measuring (Software metrics)
  - Searching and finding
  - Controlling
- **Predict** features of a product from the model (form hypotheses, prove)
  - Specifying features and requirements of a system
  - Forming hypotheses about the system
- **Construct** a product (realize, develop, invent, build)
  - **Elaboration** (adding more details to the model to arrive at an implementation)
  - **Compose** a system from components
  - **Describing** the infinite and the unknown with finite descriptions
  - **Structure** a model (making the model more clear)
    - Refinement (making the model more precise and detailed)
    - Abstraction (leaving out detail, focusing on the essential)
    - Domain Transformation (changing representation of model)
  - **Reuse** parts of products
    - Engineer a *product line (product family)*

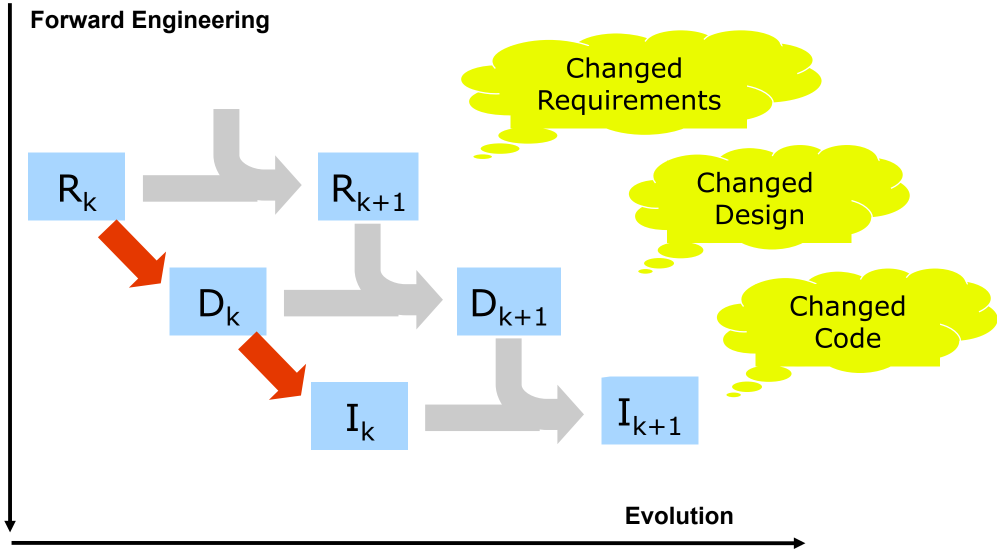
The (Software) Engineer's Toolkit

- **Validate** hypotheses on the product
  - Experimentation (empirical software engineering)
  - Checking (consistency, integrity, wellformedness, completeness, soundness)
  - Testing
  - Proving (formal software engineering, formal methods)
  - Statistics (not covered here)
- **Improve** the product
  - Reverse engineer
  - Restructure
  - Optimize with regard to a value model
- **Sell** the product(s)
  - The software engineer solves problems to earn money for his company and himself
  - How to come to products?
  - How to talk to customers?
  - How to see the problem of the customer?
  - How to reach a market with a product?
  - How to found a startup?
  - Often, engineers are good technicians, but fail to sell the products

Forward Engineering, Backward Engineering, Improvement, Round-Trip Engineering

2.1. SCENARIOS OF SOFTWARE ENGINEERING

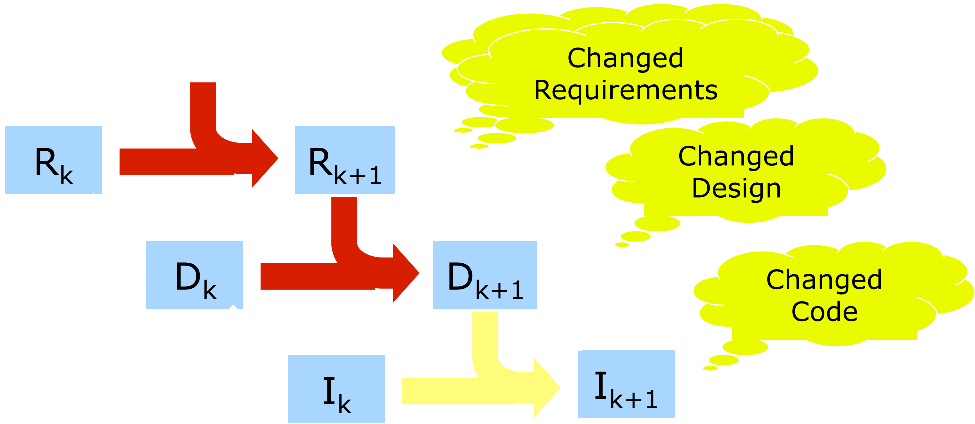
Forward Engineering and Evolution



With CASE tools, implementations can be generated from implementation models

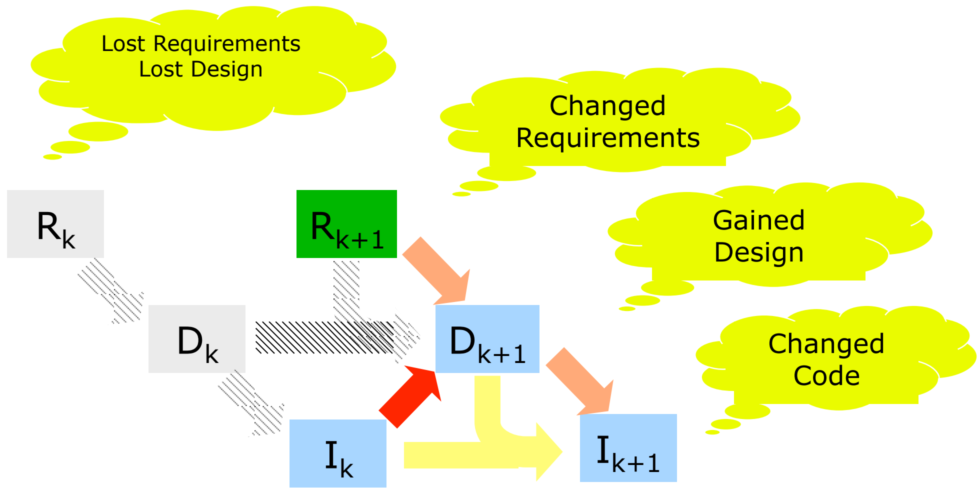
Software Evolution

- Changed requirements require refactoring and extensions



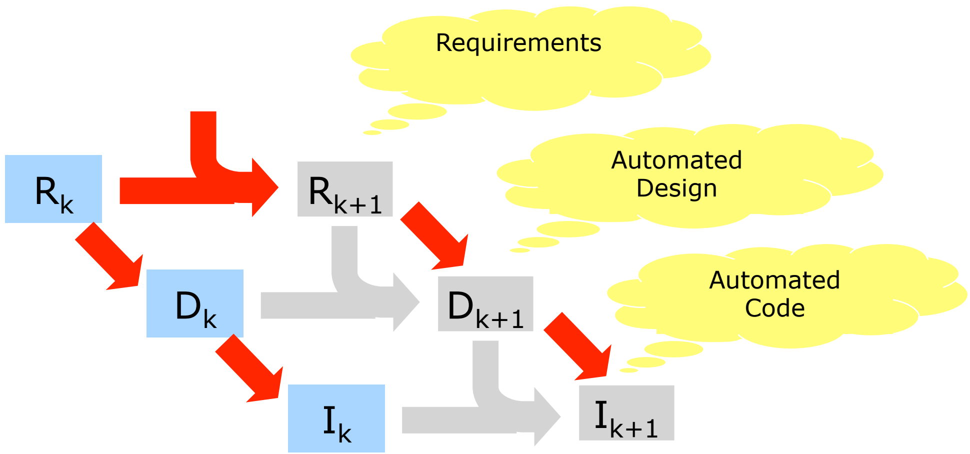
Software Reengineering

- **Reverse Engineering** attempts to recover design from code
- **Reengineering** uses the gained design for further forward engineering



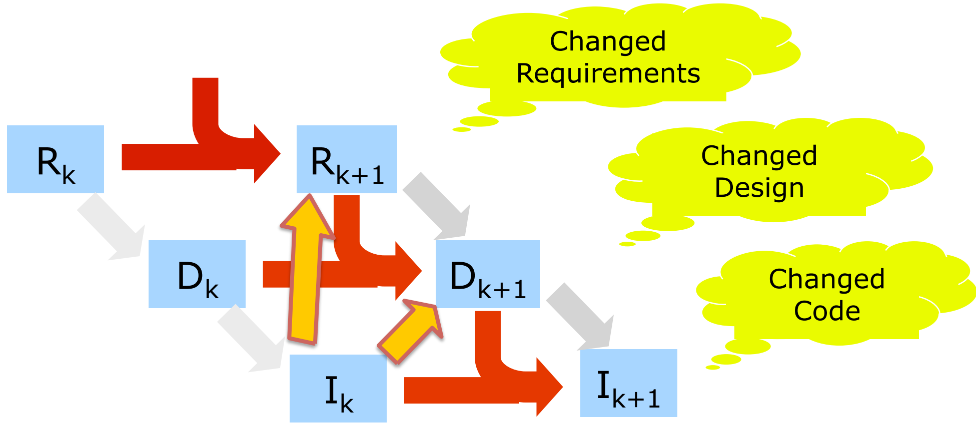
The Dream: Automated Programming

- **Automated programming (generative programming)** generates code from requirements automatically.
  - It will need planning and expert system support



Round-Trip Engineering (Forward and Backward)

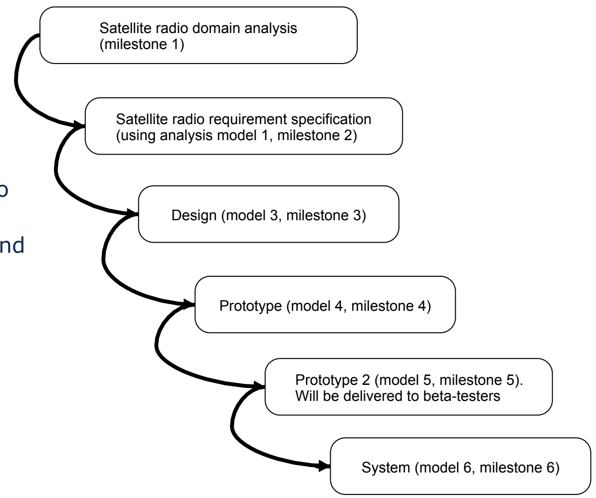
- **Round-trip engineering** combines forward and reverse engineering
  - It allows for editing on all levels, keeping all artefacts consistent



2.2 A RUN THROUGH AN ENGINEERING CYCLE

2.2.1 First Step: Analysis

- How do we arrive from the requirements at the product? Let's take an engineer's approach (Analysis steps):
  - Engineers analyze problems to understand what to do
  - Engineers specify a solution and realize (construct) it
  - For both activities, engineers model the world to master it
- Steps
  - We fix the requirements in a requirement specification (requirements models)
  - We go step by step through different design models
  - … until we arrive at the implementation model (which is the system)



But... What Is A Model?

- Pidd suggests a hierarchy of definitions:
  - *A model is a representation of reality*
  - A model is a representation of reality *intended for some definite purpose*
  - A model is a representation of reality intended *to be of use to someone charged with understanding, changing, managing, and controlling that reality*
  - A model is a representation of a part of reality *as seen by the people who wish to use it*
    - *To **understand** that reality*
    - *To **change, manage, and control** that reality*
- More simply:
  - A model is a representation of a part of a domain, or of a function of a system, its structure, or behavior
  - A model is an abstraction of a system
- A model is *partial*, i.e., *abstract*, and neglects some parts of the reality
- A descriptive model allows to understand a reality
- A prescriptive model allows to change, manage, and control a reality
- Question: what does this mean for the Satellite radio?

To Produce Software, We Model

- Software construction uses two kinds of models

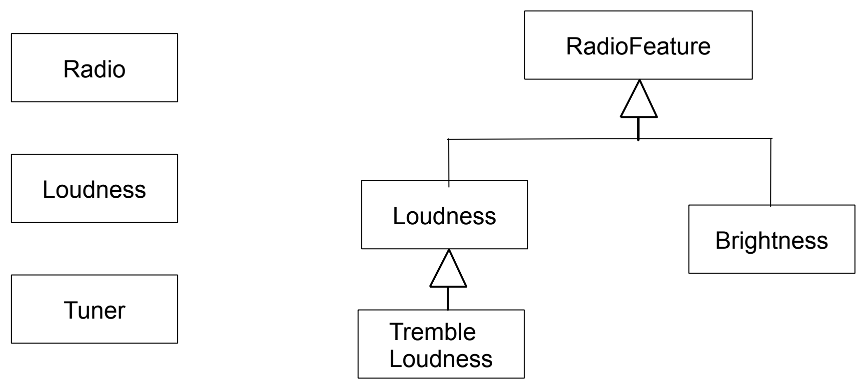
The World	Software Systems
Problem Domain	*System Domain*
Problem Analysis	*System Design*
What is the problem?	What is the solution?
Problem model	System model
(Analysis model)	(Design model)
Models the *problem reality*	Models the *system reality*
Descriptive (analytic) models	Prescriptive models (specifications)

The Satellite Radio as Example

The World	Software Systems
Problem Domain	*System Domain*
Problem Analysis	*System Design*
No FM in USA	Satellite Radio
Digital radio quality required everywhere	Software-controlled embedded system

Descriptive Models: Glossaries, Classifications and Taxonomies

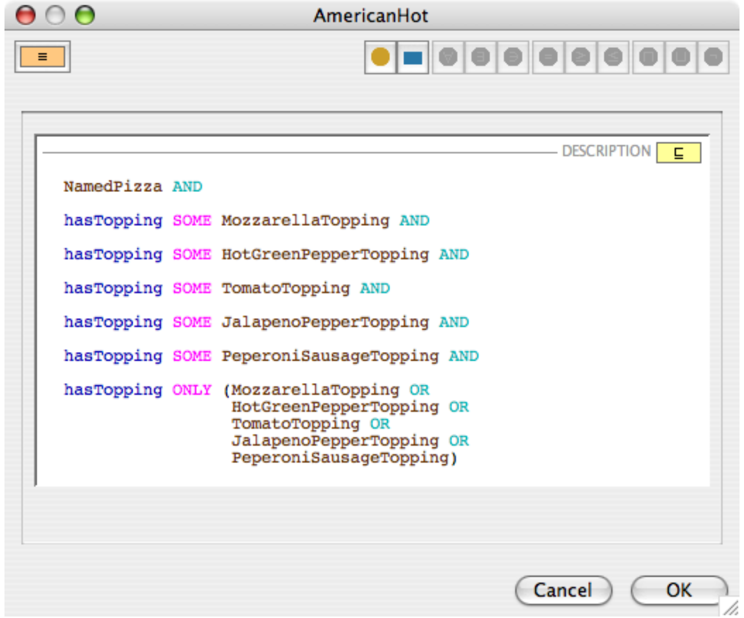
- A **glossary** is a set of explained terms
- A **classification** is a grouping of the concepts of a domain into classes
- A **taxonomy** superimposes a hierarchical or acyclic is-a relationship
  - Analyse similarity (commonality-variability analysis)



Ontologies as Standardized Domain Models

- A **(domain) ontology** is a shared, standardized model for a domain, consisting of a taxonomy and integrity constraints (consistency constraints) constraining the hierarchy
  - Rules to produce *derived parts* of the hierarchy. The derived parts are *intentionally* specified
- Ontologies are standardized domain models and play an important role in domain analysis
  - In general, a domain model need not necessarily be standardized
  - For many domains, domain modeling will start from these ontologies
  - *Domain engineers* produce domain ontologies
- Example:
  - Dublin Core ontology with concepts such as Date, Author, Comment
  - Medical ontologies, such as gopubmed.org
  - Upper ontologies (conceptual ontologies), such as SUO suo.ieee.org
  - Biochemical ontologies (Gene ontology www.geneontology.org)
- Ontologies in the Semantic Web
  - In 2003, the W3C has standardized the first ontology language for the web: OWL (web ontology language)

Ontology in OWL „Manchester Syntax"



What is a Specification?

- A ***specification*** is a prescriptive model (blue print) of the system, i.e., a precise description what a system
  - should deliver (service, delivery, postconditions, guarantees)
  - requires for the delivery (requirements, preconditions, assumptions)
  - "the truth lies in the model" (J.M. Favre)
- A specification must be *realized (implemented)*. An implementation can be *verified* with regard to a specification
  - showing that the implementation derives the delivery from the requirements
- A specification contains one or several *models* of the system
  - Models are abstract, partial representations of partial knowledge
- However, often, the word specification and model are used interchangeably (which is not precise)

Different Kinds of Specifications and Models

- Descriptive (Analysis) models
- Domain model:
  - Domain analysis is the process of identifying and organizing knowledge about the application domain
- "Real"-Problem model:
  - Usually, the requirement specification includes a problem model – to support description and solution of these problems
- Goal models
  - What do we want to achieve with the system?

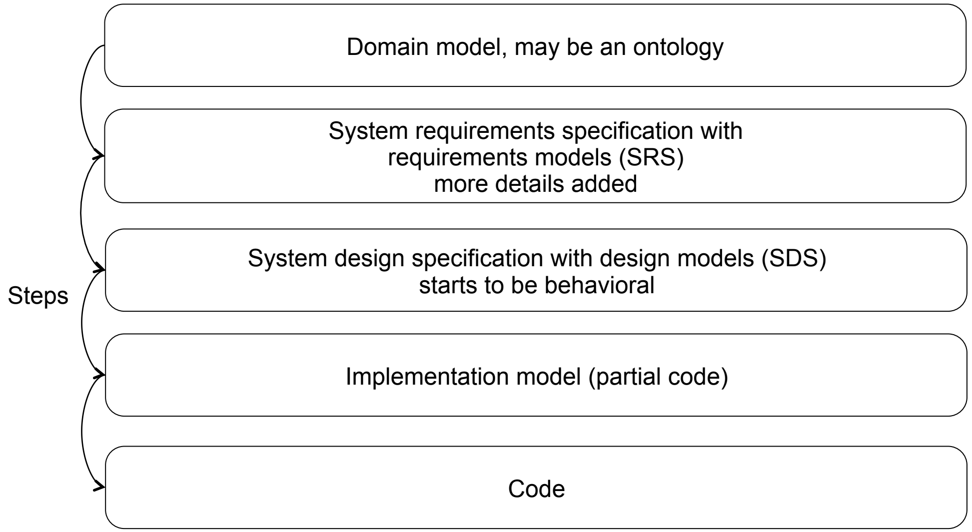
- System models (specifications)
  - From the analysis models, we derive the system models.
- Requirements specification (SRS):
  - the specification what the system should deliver.
  - Functional requirement model: system functions
  - Non-functional requirement model: system qualities
- Design models:
  - abstract representation of a system on the level of a design language
- Architecture models
  - Describing the software architecture
- Implementation models:
  - partial representation of the system on the level of an implementation language

Structural vs. Behavioral Models

- A structural model captures the structure of a reality
  - Integrity constraints for well-formedness
- A behavioral model captures its behavior
- A behavioral model uses a structural model and adds a model how a reality reacts
  - operations (functions, procedures, methods, ...)
  - event-condition-action rules,
  - a state space
- Objects have a state space, often represented by
  - Petri-nets (see later) and their specializations:
    - a finite state machine
    - a hierarchical state machine (state chart)
    - data-flow diagrams
  - Process algebra

Specifications and Models in Software Engineering

- From declarative to behavioral models



2.2.2 Second Step: Prediction

- Behavioral models allow for *prediction*.
  - Graph-based models can be consistency-checked with logic reasoners
    - Integrity constraints constrain the object sets (object extents) of the classes
    - Structural constraints (reducibility, layering)
  - Petri nets can be verified with matrix theory
    - Resource consumption (memory consumption)
    - Liveness of the processes
    - Fairness of the processes
    - Deadlocking processes
  - Statecharts can be checked with model checkers
  - Real-time statecharts can be time-checked with real-time model checkers
- This area is called *formal methods* of software engineering

How to come to the next model?

2.2.3 THIRD STEP: CONSTRUCTION

Construction with Refinement-Based Development

- The construction of systems starts off from Domain Model over Requirement Specification and Design Specification to Implementation Model to Code:
  - Develop the next specification, starting from the previous ones

- **Construction steps:**
- For every model, start with some simple form. Then, apply elaboration steps:
  - **Elaboration:** Elaborate more details – enrich with more semantics
  - **Refinement**: Refine an existing specification/model, by detailing an abstract concept
  - **Check:** Check consistency of models
  - **Measure** quality and quantity of models
  - **Compose** from components
  - We can distinguish several methods of development

Questions for the Methods of Development

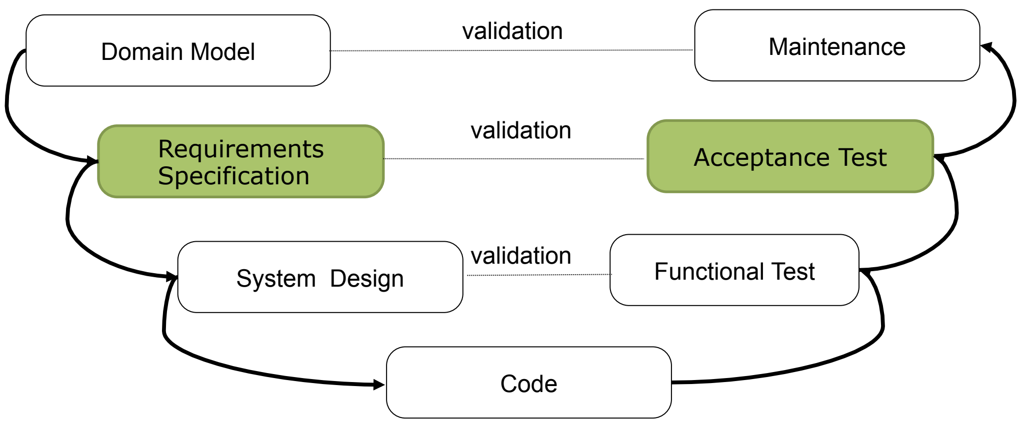
- Elaboration: Elaborate more details
  - Which Elaboration steps exist?
  - How do I know in which direction to elaborate?
- Pointwise Refinements (concretizations): detailing an abstract concept
  - With and without correctness proofs that the semantics of the abstract concept is provided by the refinement
- Rotations: Apply a semantics-preserving change
  - **Rotate:** Symmetry operations (semantics-preserving operations)
  - **Restructure (refactor)** (more structure, but keep requirements and delivery, i.e., semantics)
    - Which restructuring? (when is a specification too complex?)
  - **Transform Domains** (change representation, but keep semantics)
    - Which representation change? (which representations are appropriate for which purpose?)

Reuse of Models and Code in Construction

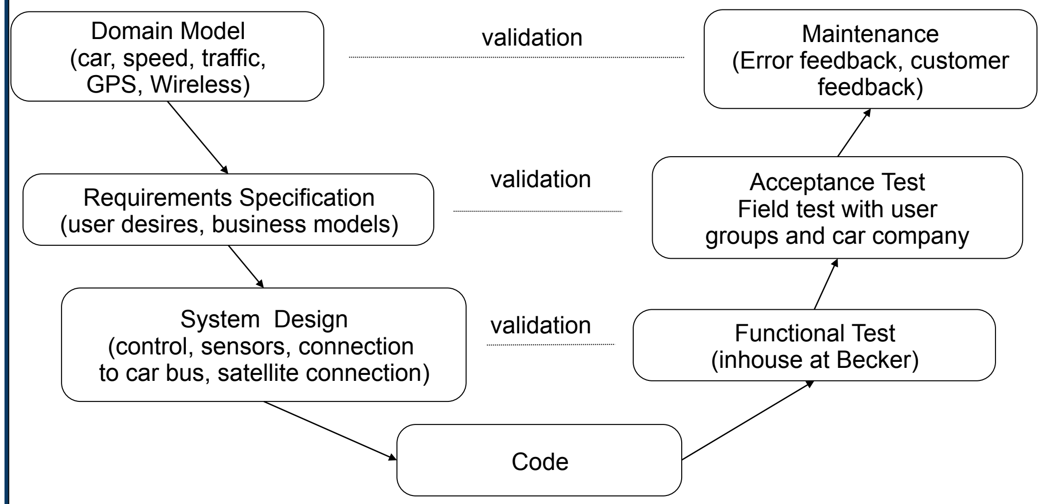
- Engineers try to reuse well-established solutions
  - Components (CBSE)
  - Design patterns
  - Models (model-driven architecture)
  - Best practives
- To simplify system construction
  - To save costs
  - To reduce testing effort

2.2.4. 4TH STEP: VALIDATION

- All specifications and models have to be validated or formally verified.
  - Detailed models against more abstract models
  - Implementations against specifications
- Result: A V-like software development process



Validation of the Satellite Radio in the V-Model



2.2.5 5TH STEP: IMPROVEMENT

5th Step: Improvement

- Done via iteration, and ad-hoc
  - Not in the focus of the course.
- Section "Product Lines" will treat some aspects of software evolution, namely when new products should be derived from an existing product or product family.
- Optimization means: Improve on the qualities of the system
  - Speed, reliability, resource consumption

Some aspects in section “Earning Money with Software”.

2.2.6 6TH STEP: SELLING SOFTWARE

The Best Seller Is...

- .. the one who solves a problem best
- .. the one who pretends to solve a problem best
- .. the one who solves a problem just good enough
- .. the one who solves a problem reliably

??

What Have We Learned?

- Specifications (complete representations of what the problem is or the system should do) consist of models (abstract representations of worlds)
  - Analysis models in the problem domain
  - System models in the system domain
- Engineers analyze, form hypotheses, construct, validate, improve, sell
  - Detailed models are validated against their more abstract ancestors
  - Implementations are validated against specifications
- The course is structured along these activities

Remark: Software and Systems Engineering

- Software Engineering is closely related to a twin, the Systems Engineering
  - Building software into a system (embedded system)
  - Many concepts can be used in both areas.
    - See study line “Distributed Systems Engineering (DSE)”.