Aalto University
School of Science

Research methods in product development

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Introduction to research and experimentation

Relying on existing research

- Concepts
  - Crucial to determine which definition of a concept is used in one's research in defining the thing that is to be found out.
  - For successful experimentation, testing, validating and construction you need to focus and start from fixed concepts
- Methods
  - Using methods beyond own research field and discipline is hazardous. You need an co-researcher from the other discipline to supervise and guide.
  - Using methods of own field is tough enough and requires review by others
- Utilize established concepts, methods and approaches as far as possible
  - Carefully study their prerequisites, constraints, limits as well as applicability in comparison with alternatives
  - Instead of using mixtures look for chances to divide problem for separate experimentations

Scientific method [Ketonen 1976]

- Scientific method allows explaining focused issue or focus areas
  - However, each solved problem leads to new open issues, i.e., not converging in relation to science as whole
- Each statement is given a justification that is published
  - Crucial difference from a method based on authority and intuition
  - Theory and its proof can be understood and repeated

Research process [Niiniluoto 2002, pages 25,28]

Simple schema of research stages:

1. Stating problem
2. Focusing of the problem and making research strategy
3. Collecting material/data
4. Describing/presenting the material
5. Analysis of the material
6. Making conclusions
7. Producing a paper or a report on the research
8. Publishing the results

Specific methods and tools have been developed for each field of science and research setting for stages 3-6.

Examples of methods and tools:

3. Theory of planning experiments, sampling, using sources, observation, interviews and questionnaires, measurements etc.
4. Qualitative classification, numeric data processing, statistical distribution and parameters, graphical presentations, system and graph theoretical presentations etc.
5. Statistical methods like estimation, correlation, variance analysis, regression analysis, factor analysis, multivariate methods etc.
6. Theory of statistical tests, analysis of causality, decision theory, error estimation etc.

Instrumentation of an experimentation as a research contribution

- Often expert is needed to contribute in constructing tools or conditions that are required for the experimentations of another researcher.
  - This makes software engineers popular indeed.
- Implementing a proper and reliable research system requires mastering software development including e.g.
  - Requirements engineering
  - Designing system for particular research conditions
  - Validation and software testing to verify reliability
- Computer science contribution and thesis
  - Construction of research system certainly fulfills and goes beyond the demands of a M.Sc. thesis – and of course B.Sc.
  - Doing the work properly reaches level of Ph.D. research. E.g. producing proof and measurements of required features.
  - Proper explication and analysis of computer science aspects is better approach than attempting to cover everything and confusing fields of science.

Experimentation plan and examination – study attainment of TMTK

- Planning an experimentation
  - Learning how to apply the chosen methods
  - Relating to other methods
  - Conditions of reliability, validity and applicability
- Examination is focused on the theory behind your experimentation plan
  - Send a list of references that you have will use for planning your experimentation
    - Text books, articles etc.
    - If you heed help for selecting sources, ask course staff
  - Questions will concern principles, feasibility and applicability of methods etc.
    - You may take the source material with you in the exam

Design classification

Design classification 1/2

- Routine designing, in computational terms
  - Designing activity which occurs when all the knowledge about the variables, objectives expressed in terms of those variables, constraints expressed in terms of those variables and the processes needed to find values for those variables, are all known a priori.
- Innovative designing, in computational terms
  - In terms of the design process, variable values outside the usual ranges have the potential to introduce unexpected as well as unintended behaviors that can only be brought into formal existence if additional knowledge capable of describing them can be introduced.
  - In terms of the artifact, innovative designing processes produce designs that recognizably belong to the same class as their routine progenitors but are also ‘new’.
- Creative designing, in computational terms
  - The designing activity that occurs when one or more new variables are introduced into the design.

Gero, JS (2002) Computational models of creative designing based on situated cognition, in T Hewett and T Kavanagh (eds), Creativity and Cognition 2002, ACM Press, New York, NY, pp. 3-10.

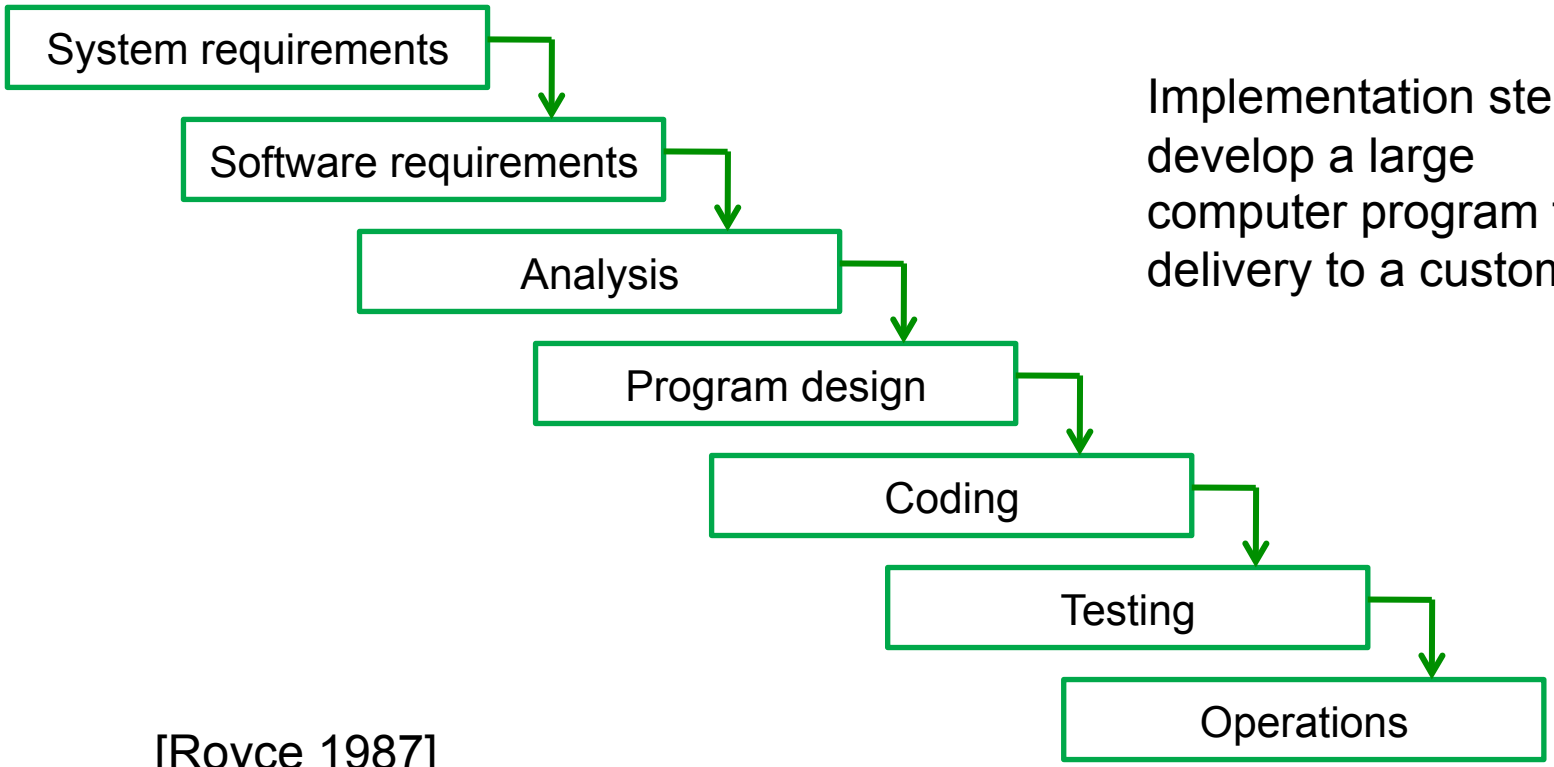
Design classification 2/2

- Routine designing
  - Designing variations and configurations
  - The process and factors are well known
  - Most of the designing falls into this class
  - Routine designing is not easy or straightforward
  - E.g. new models of mobile phones
- Innovative designing
  - Combining technologies and other enablers in new ways
  - Leads to new types of services and products that can profoundly affect how people do things
  - E.g. mobile phone and SMS were innovative
- Creative designing
  - Discovering completely new enablers and using them in completely new kinds of products and services
  - E.g. telephone, radio and aeroplane when they were first invented

Innovation prototyping – design classification

- Innovation prototyping is not for routine designing or creative designing
  - Both routine designing and creative designing have their own methodologies
- Innovation prototyping methodology has been developed specifically for innovative designing
  - Balanced brokering allows discovering new combinations and ways of applications of the enablers of different viewpoints
  - Modeling enforces the design work to be analytical and systematic to cope with the unexpected and unintended
  - Experimentation is where balanced brokering and modeling converge with real world. It gives the concrete justification and proof for the innovation to realized by the product development process.

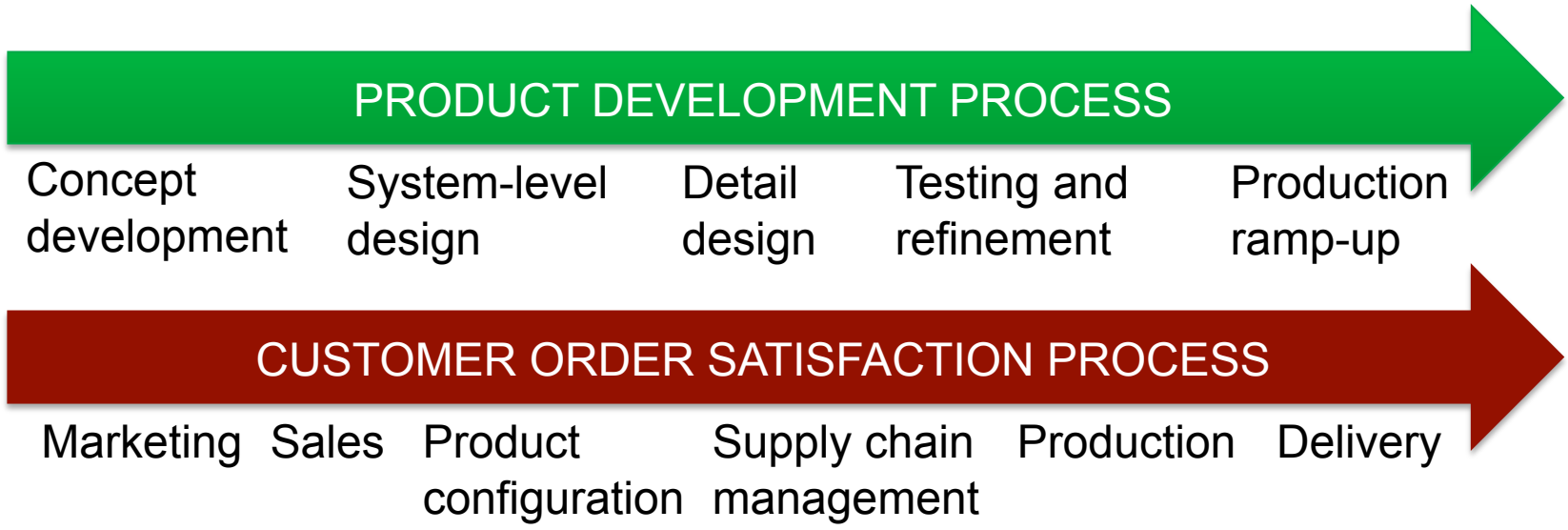
Software development



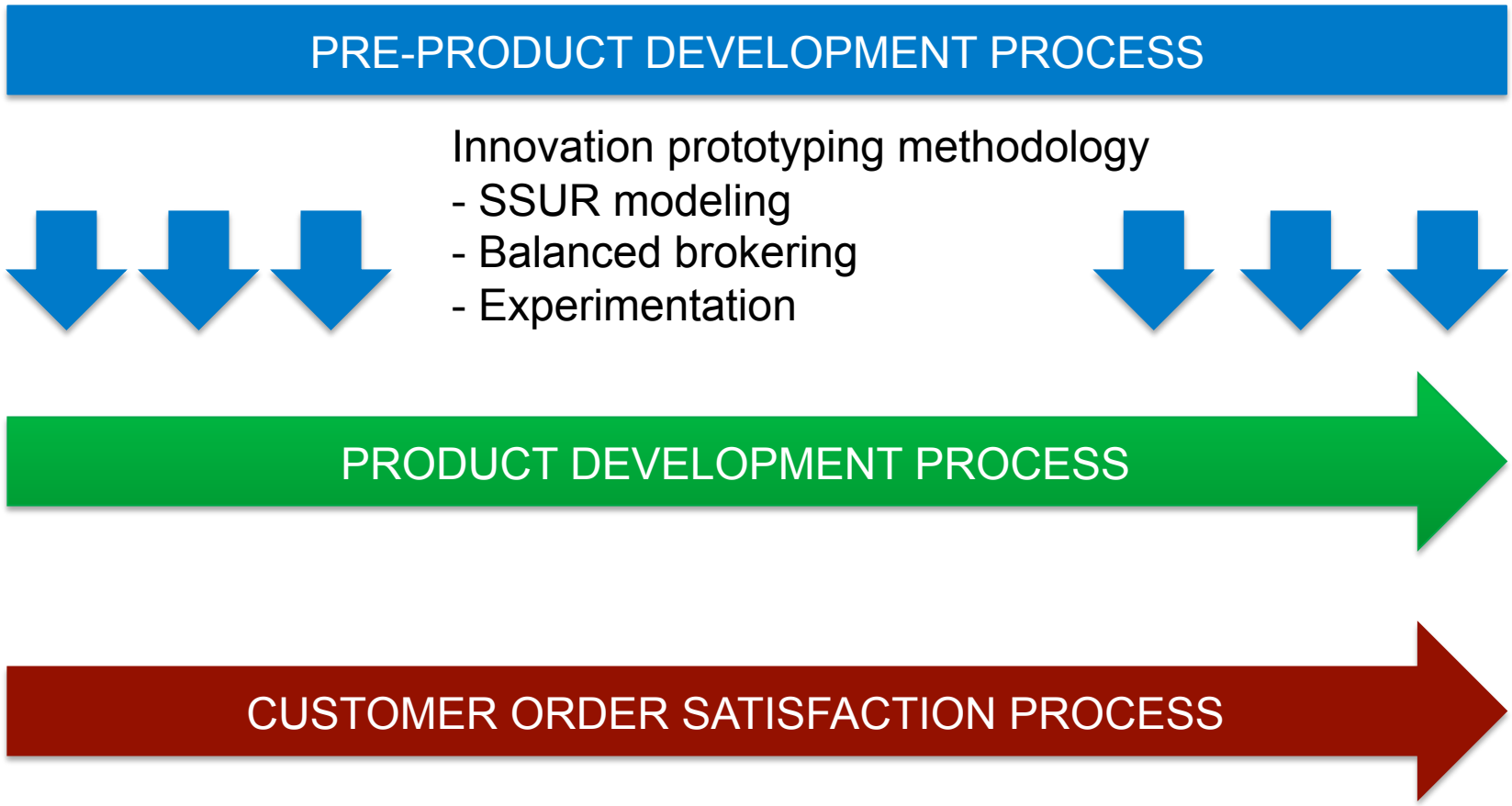
Implementation steps to develop a large computer program for delivery to a customer

[Royce 1987]

Three central processes



Three central processes



Problem orientation vs. solution orientation

INNOVATION PROTOTYPING		REQUIREMENTS ENGINEERING
Scenarios concretize services to reveal common denominators	SCENARIO	Scenarios or use cases are used for validating the user needs
Discovery of service features and design principles is the ultimate goal	SERVICE	A product has to fulfill the user requirements on the service
Use cases are components for reuse and they express, suggest and inspire new possibilities	USE CASE	Use cases or scenarios ensure a product matching user needs
Realizations are built to establish experiment settings for scenarios and services	REALIZATION	The right product is the ultimate goal
Problem orientation		Solution orientation

Innovation prototype vs. product prototype 1/2

	Innovation prototype	Product prototype
General description	A tool for experimenting and analyzing a service idea	A first version of a product for testing and analysis
Relation to the final product	Often different than any product	Similar to the final product
Functioning	A real prototype that works	A real prototype that works
	Ticks, flies, sparkles and has the attribute of jocularity	Operates and/or appears as close as possible like the final product
Origin of the concept definition	PM&RG – pre-product development of mobile and ubicomp services	Machine engineering – attribute 'product' added here for clarification

Innovation prototype vs. product prototype 2/2

	Innovation prototype	Product prototype
Scope	Focuses on certain service aspects that are to be experimented	Covers the whole product
Concurrency	Integration viewpoints of interaction, technology, profit...	Concurrent engineering, DFX= Design For Manufacturability/ Assembility...
Reuse	May allow experimenting several different services - design space	Used for improving and enhancing a particular product
	Modular and reusable for prototype builder	Modular and customizable for manufacturing
Process	Systematical flexible process	Systematical rigid process
	Next phase: service idea selection for product development	Next phase: planning the manufacturing
	Provides a pool of evaluated service ideas for product development	Applied for planning and enhancing manufacturing

Innovation prototyping vs. demonstration

	Innovation prototype	Demonstration
General description	A tool for focused experimentation of service ideas and services in pre-product development	A display, show or exhibition that presents the product in an illustrative manner.
Objective	Experimentation setting. Often applied for various tests or different services.	Illustrative presentation of proposed thing. Often an one-time show.
	Getting experimentation and test results to give a basis for specific evaluation	Proving and getting approval , usually not intended for specific experimentation
Scope	Focuses on certain service aspects	Wholeness. Usually unique, but components maybe reused
Results	Allows experimentation	Allows comprehension
	Modular and reusable for prototype builder	Typically fixed

Designing valid experimentation

Validity of an innovation prototype

- Without a well-designed experimentation, making a working prototype proves nothing
  - Two faceted problem
    - Validity of experimentation
      - Using well-known research, data gathering and analysis methods ensures the validity of the experimentation
      - For example qualitative and quantitative methods set different requirements
    - Validity of the prototype as an enabler of the experimentation
      - Using well-known software and hardware design techniques ensures that the prototype works as assumed in experimentation design
      - Examples are design patterns and standards
- Compare to software product development
  - Fulfilling customer requirements
  - Software testing
  - These are completely different problems

Designing an innovation prototype

1. Designing the experimentation
   - Deciding what is to be experimented
2. Designing what is to be implemented
   - Specifying the requirements and approach for implementation
3. Designing how to do the implementation
   - Choosing the way to implement

What a design of experimentation should contain? What is designed?

- Deciding what is to be experimented
  - Explicating research purpose for the experimentation
    - Hypothesis, research question
    - Research method, data to be collected, data analysis methods
    - Prototype as a means for instrumentation of the experimentation
  - Focus of experimentation
    - Explicating scope, restrictions, what is left for later stages
- SSUR models as means for planning and designing
  - Defining the assumed usage situations and enablers
  - Knowledge acquisition, analysis, trial runs and design

What is the design of an experimentation used for?

- Reaching common understanding
  - Brokering the viewpoints
  - Concreteness, consistency and coherency
  - Setting a common and fixed focus for the experimentation
- Narrowing focus improves feasibility and reliability
  - Focusing properly and focusing once more
  - Concreteness, consistency and coherency
  - Boundaries, what is left for later stages
- Capturing and keeping in mind the objective
  - Sticking to the relevant and avoiding all extra ingredients
  - Implementation must be based on the plan, planning cannot be driven by the implementation

What is gained by careful design of an experimentation?

- Designing to facilitate experimentation
  - Determines which factors are crucial for reliability of the experimentation
  - Without designing the experimentation the result ends up as a demonstration, i.e., proves nothing and lacks justification
- Coordination of a team and collaboration of teams
  - Brokering to match objectives, methods and implementations
- The success of next stages depends on this one
  - There is no certainty of validity of information gained from undesigned experimentation and the results cannot be used in product development
  - A prototype is not the primary objective, it is merely an enabler for doing experimentations
  - Without a well-designed experimentation, making a working prototype proves nothing

Common misunderstandings

- Non useful implies basic research Wrong
- No assumptions on results in advance Wrong
- Concepts are unambiguous Wrong
- Research = gallup = interview Wrong
- Creativity requires no work Wrong
- Qualitative research = without numbers = unreliable Wrong
- Quantitative = with numbers = reliable Wrong
- In constructive work, a failure is not a result Wrong

Definitions of research and development (from OECD)

- Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.
- Applied research is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.
- Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed to producing new materials, products or devices; to installing new processes, systems and services; or to improving substantially those already produced or installed.

Source: OECD. Glossary of statistical terms. http://stats.oecd.org/glossary/

Assumptions on results in advance

- Assumptions are essential for:
  - Focusing the research work
  - Justifying the relevance of the research
- Assumptions do no mean that the researchers would aim at making the assumptions look true.

Concepts are unambiguous

Wrong

- To understand in which sense a concept is used it is necessary to know research paradigm, field of science and research tradition.
- Even the researchers have their own specific interpretations of concepts.
- Research is required to built on existing knowledge and concept definitions. Never create new concepts unless absolutely necessary.
  - Research is not about trying to sell your work with hype words

Research = gallup = interview

Wrong

- Difference of using interviews as research method and newspaper interview and someone coming to ask you just some questions
- Interview as research requires considering e.g.
  - How to ensure that same questions are asked in same way
  - Confidentiality
  - Interpretation, structuring and analysis method
- Gallup results are useless for making any conclusions

Creativity requires no work

Wrong

- Creativity does not mean getting crazy ideas
- Analysis and taking the ideas to practice requires lots of heavy work
- Creativity requires thorough knowledge of methods and tools. Otherwise it is just useless.
- Do not be fooled by how easily gurus create magnificent theories and ideas. They have really done their homework.

Qualitative vs. quantitative research

- Qualitative researchers stress the socially constructed nature of reality…and the situational constraints that shape inquiry. They seek answers to questions that stress how social experience is created and given meaning.
- In contrast quantitative studies emphasize the measurement and analysis of causal relationships between variables, not processes.
  - [Denzin 1994]

Both qualitative and quantitative research are needed

- Qualitative research often prepares quantitative research…
- ...but may as well be needed to learn about anomalies in statistical studies
- keep in mind that the aim of research is to add knowledge: good research typically does that regardless of methods!
  - [Koskinen 2007, p. 3]

The numbers are the absolute truth

Wrong

- Remember to check the scale: nominal, ordinal, interval…
- Numbers without the context and interpretation are just numbers, nothing more.
- For more information check [Niiniluoto 2002]

In constructive work, a failure is not a result

Wrong

- Failure in constructive work is not a failure in the research
- Analyzing the failure is a source for research topics
- Science is about getting more knowledge, not about supplying a product
- Constructive work alone is never a sufficient proof in science, even if it was successful

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