Course "Softwaretechnik"
Book Chapter 4
Requirements Elicitation (Anforderungserhebung)

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- Requirements and Requirements Engineering
- Kinds of requirements
- Requirements and modeling
- Hard and soft systems

- Requirements Elicitation
  - identify problem & opportunity
- Elicitation techniques
  - Conventional
  - Representation-based
  - Social
  - Knowledge elicitation

Where are we?: Taxonomie "Die Welt der Softwaretechnik"

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Welt der Problemstellungen:

- **Produkt (Komplexitätsprob.)**
  - **Anforderungen (Problemraum)**
  - Entwurf (Lösungsraum)
- Prozess (psycho-soziale P.)
  - Kognitive Beschränkungen
  - Mängel der Urteilskraft
  - Kommunikation, Koordination
  - Gruppendynamik
  - Verborgene Ziele
  - Fehler

Welt der Lösungsansätze:

- Technische Ansätze ("hart")
  - Abstraktion
  - Wiederverwendung
  - Automatisierung
- **Methodische Ansätze ("weich")**
  - **Anforderungsermittlung**
  - Entwurf
  - Qualitätssicherung
  - Projektmanagement

Where are we?: Anforderungsermittlung

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- Einsicht: Man darf sich nicht auf intuitiven Eindruck darüber verlassen, was gebaut werden sollte
  - sondern sollte die Anforderungen systematisch ermitteln
- Prinzipien:
  - **Erhebung** der Anforderungen bei allen Gruppen von Beteiligten
  - **Beschreibung** in einer Form, die die Beteiligten verstehen
  - **Validierung** anhand der verschriftlichten Form
  - **Spezifikation**: Übertragung in zur Weiterverarbeitung günstige Form
  - **Trennung von Belangen**: Anford. möglichst wenig koppeln
  - **Analyse auf Vollständigkeit**: Lücken aufdecken und schließen
  - **Analyse auf Konsistenz**: Widersprüche aufdecken und lösen
  - **Mediation**: Widersprüche, die auf Interessengegensätzen beruhen, einer Lösung zuführen (Kompromiss oder Win-Win)
  - **Verwaltung**: Übermäßige Anforderungsänderungen eindämmen, Anforderungsdokument immer aktuell halten

Definitions: Requirement

- What is a Requirement?
  - Something that someone needs in order to solve a problem or achieve an objective:
    - *"A condition or capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification, or other formally imposed document.*
      The set of all requirements forms the basis for subsequent development of the system or system component". [IEEE Std]
  - Note 1: Often, the "formally imposed document" does not exist, but there is still *somebody* wishing to be satisfied.
    - Informal requirements
  - Note 2: Often, what is written down in the "formally imposed document" will not really *satisfy* the system user
    - Invalid/incorrect requirements
  - Note 3: Requirements are definitions, **not facts**.
  - Note 4: "System" can be a computer system (**system req's**) or a socio-technical system (**user requirements**)

Definitions: Types of Requirements

- Functional requirements:
  - What the system does: the interactions between the system and its environment; independent from implementation
- Nonfunctional requirements:
  - Observable aspects of the system that are not directly related to functional behavior
  - e.g. performance or reliability aspects, etc.
- Safety/security requirements ("shall not" properties)
  - A kind of nonfunctional requirement:
    Behavior the system must never exhibit
  - e.g. "must be impossible to apply reverse thrust in mid-flight"
- Constraints ("Pseudo requirements"):
  - Imposed by the client or environment in which the system operates
  - Often concern the technology to be used (language, operating system, middleware etc.)

nonfunctional requirements

Definitions: Requirements Engineering (RE)

- Requirements Elicitation is part of Requirements Engineering

- Requirements Engineering (RE):

  "[...] **Requirements Engineering** is the branch of systems engineering concerned with real-world goals for, services provided by, and constraints on software systems. Requirements Engineering is also concerned with the relationship of these factors to precise specifications of system behaviour and to their evolution over time and across system families..." [Zave94]

  "[...] RE is concerned with identifying the purpose of a software system, and the contexts in which it will be used." [RE'01 CfP]

Requirements Engineering process

1. Understand the problem
   - Requirements Elicitation
   - understand the context and the goals in the user's terms

2. Formally describe the problem
   - Requirements Specification
   - describe what the SW must do to reach the goals

3. Attain agreement on the problem
   - Requirements Validation
   - find gaps, mistakes, and inconsistencies in the requirements
   - includes conflict resolution, negotiation

4. Maintain the agreement
   - Requirements Management
   - negotiate and decide on changes of the specification

Source: *Adapted from Loucopoulos & Karakostas, 1995, p20 and Blum, 1992* [5]

Conflict is natural and ubiquitous

- Even the most cooperative stakeholders ("Beteiligte") will inevitably have conflicts
- Conflict resolution is a core activity of RE

Requirements Validation

- Even without conflict, requirements validation is a critical step in the development process
  - after requirements engineering or requirements analysis
  - and again at delivery
- Requirements validation criteria:
  - Correctness:
    - The requirements accurately represent the client's view.
  - Completeness:
    - All possible scenarios in which the system can be used are described, including exceptional behavior by the user or the system
  - Consistency:
    - No functional or nonfunctional requirements contradict one another
  - Feasibility/Realism:
    - Requirements can realistically be implemented and delivered
  - Traceability:
    - It will be possible to trace each system function to a corresponding (set of) functional requirement(s)

Requirements Management

- Problem with requirements validation:
  Requirements change during and after elicitation

- Large projects need tool support to manage requirements:
  - Store requirements in a shared repository
  - Provide multi-user access
  - Automatically create a system specification document from the repository
  - Allow change management
  - Provide traceability throughout the project lifecycle

- e.g. IBM Rational DOORS
- e.g. an appropriate Wiki tool (for not-so-huge projects)

Requirements, domain properties, specifications

- **Domain Properties** are properties in the problem domain that are true whether or not we ever build the proposed system
- **Requirements** are properties in the problem domain that we wish to be made true by delivering the proposed system
- **A specification** is a description of the behaviors of the program in the solution domain that the program must have in order to meet the requirements
  - The system specification (system requirements), not to be confused with a statement of the requirements themselves, the requirements specification (user requirements)

Source: *Adapted from Jackson, 1995, p170−171*

Validation vs. Verification

- Verification checks the equivalence of different formal representations
- Validation checks if a system fulfills the actual expectations in the real world

- **Verification** criteria:
  - Does the Program running on a particular Computer satisfy the Specification?
  - perhaps also (but usually not): Does the Specification, in the context of the given Domain properties, satisfy the *stated* Requirements?

- **Validation** (of requirements) also checks:
  - Did we understand all the important Requirements?
  - Did we understand all the relevant Domain properties?

Validation example

- Requirement R:
  - "Reverse thrust shall only be enabled when the aircraft is moving on the runway"
- Domain Properties D:
  - Wheel pulses are on if and only if wheels are turning
  - Wheels are turning if and only if aircraft is moving on runway
- Specification S:
  - Reverse thrust is enabled if and only if wheel pulses are on
- S + D imply R
  - But what if the domain model D is wrong?

(Do you recognize the example?)

Source: *Adapted from Jackson, 1995, p172*

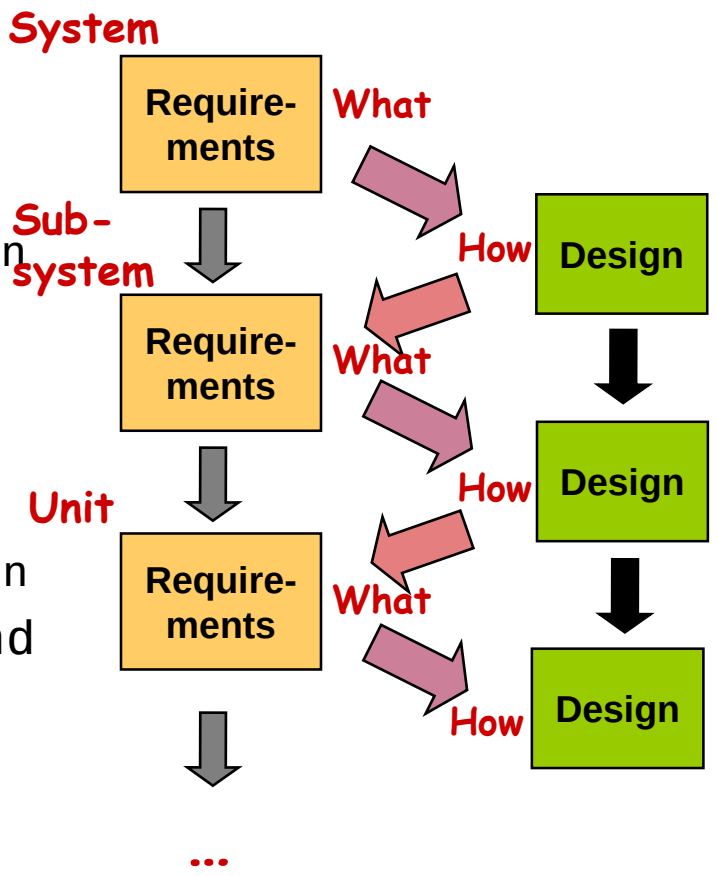
Another validation example

- Requirement R:
  - "The database shall only be accessible by authorized personnel"
- Domain Properties D:
  - Authorized personnel have passwords
  - Non-authorized personnel do not have passwords
- Specification S:
  - Access to the database shall only be granted after the user types an authorized password
- S + D imply R
  - But what if the domain assumptions are wrong?

Source: *Adapted from Jackson, 1995, p172*

What vs. How

- "Requirements should specify **what** without specifying **how**"
  - But this is not always easy to distinguish:
    - What does a car do vs. a bike?
      - (Don't mention the motor: 'how'!)
      - The 'how' at one level of abstraction forms the 'what' for the next level
- A suitable distinction
  - 'What' refers to a system's purpose
    - it is **external** to the system
    - it is a property of the application domain
  - 'How' refers to a system's structure and behavior
    - it is **internal** to the system
    - it is a property of the solution domain



Source: *Adapted from Jackson, 1995, p207*

What is a System?

Definition of a System:

- Some part of reality that can be observed to interact with its environment
  - Separated from its environment by a boundary
    - Boundary may be difficult to decide: "soft" system
  - A system receives inputs from the environment and sends outputs to the environment
  - Many systems have a control mechanism
  - Most systems have interesting emergent properties

- Examples:
  - cars, cities, houseplants, rocks, spacecraft, buildings, weather,...
  - operating systems, DBMS, The Sims, Instagram, the Internet
- Non-examples (there aren't many!):
  - numbers, truth values, letters

Source: *Adapted from Wieringa, 1996, p10*

Most systems are "soft"

- The software we will eventually write is not **"the system"** with respect to requirements engineering
  - The software is the system only in the solution domain
  - but not in the problem domain
- Rather, other things are also part of the system in the problem domain:
  - the people using the software,
  - the ways in which they use it,
  - many other environmental factors
- This larger system we need to understand during requirements elicitation
  - Rule of thumb: If people are involved in any way, never confuse the software with the system
  - Remember "Auswirkungen d. Informatik"?: underground train with taped-down "GO" button?
    - Very simple software, but a surprising system

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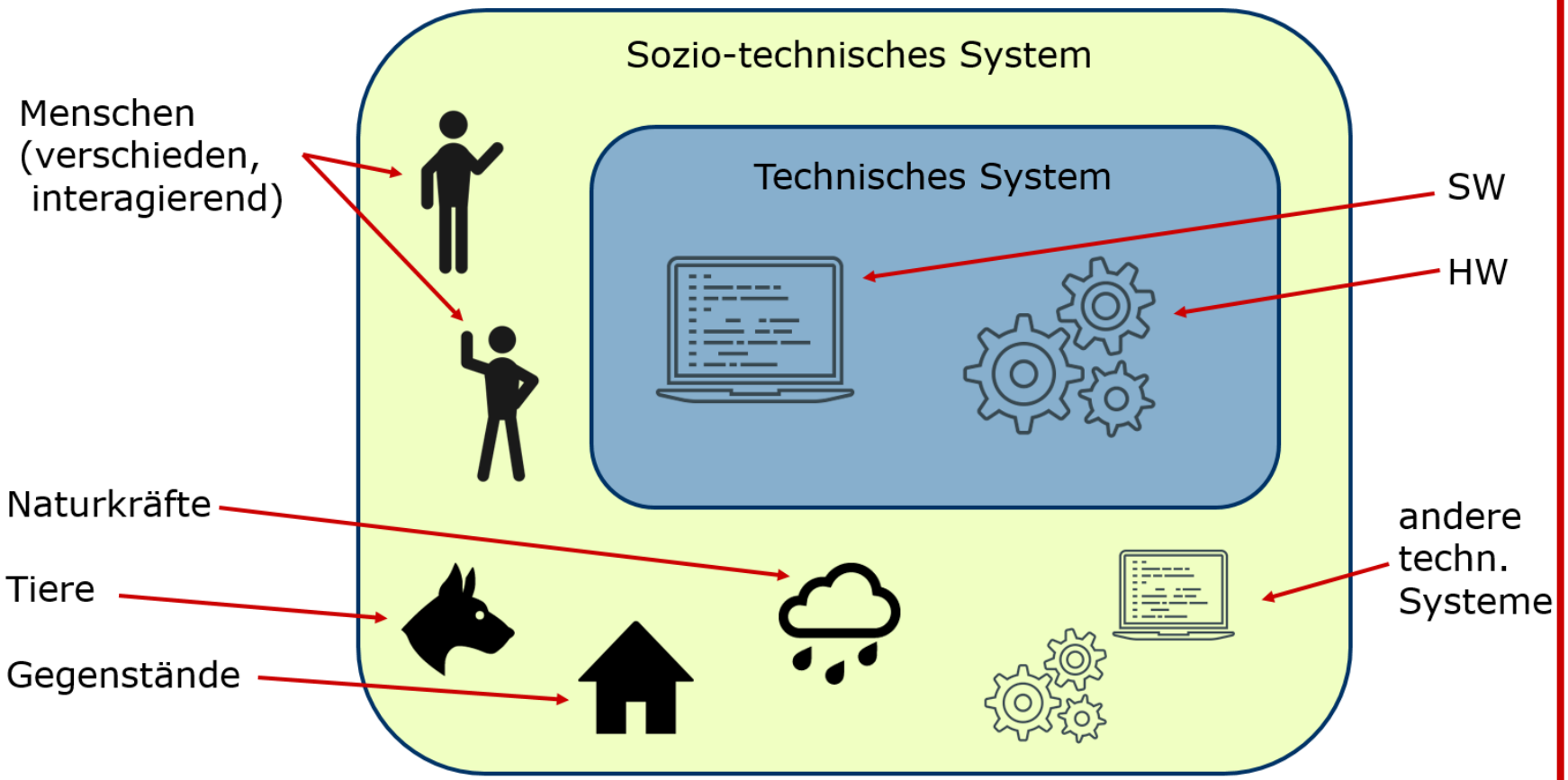
Sozio-Technisches System



Requirements Elicitation

- Starting point: Some notion that there is a "problem" that needs solving
  - e.g. dissatisfaction with the current state of affairs
  - e.g. a new business opportunity
  - e.g. a potential saving of cost, time, resource usage, etc.

- The requirements engineer must:
  - become enough of an expert in the problem domain to
  - identify the problem and opportunity and
  - elicit enough knowledge to analyze requirements for
  - validity, consistency, and completeness

W6H

The journalist's technique:

What?
Where?
Who?
Why?
When?
How?
(Which?)

Identifying the problem and opportunity

- Which problem needs to be solved?
  - identify problem Boundaries
- Where is the problem?
  - understand the Context/Problem Domain
- Whose problem is it?
  - identify Stakeholders (Betroffene, Beteiligte)
- Why does it need solving?
  - identify the stakeholders' Goals
- How might a software system help?
  - collect some Scenarios
- When and how does it need solving?
  - identify Development Constraints
- What might prevent us solving it?
  - identify Feasibility and Risk

Very useful slide

W6H

The journalist's technique:

What?
Where?
Who?
Why?
When?
How?
(Which?)

Difficulties of Elicitation (1)

- **Limited observability**
  - The problem owners might be too busy solving it in its current form
  - Presence of an observer may change the problem
- **Bias**
  - People may not be free to tell you what you need to know
    - Political climate & organizational factors
  - People may not want to tell you what you need to know
    - The outcome will affect them, so they may try to influence you (hidden agendas)
- There will be **conflicts** between different sources
  - People have conflicting goals
  - People have different understandings
- **Thin spread of domain knowledge**
  - It might be distributed across many sources
  - Is rarely available in explicit form

Difficulties of Elicitation (2): Tacit knowledge

- **Tacit knowledge**
  (The "say-do" problem)
  Three stage model of learning:
  1) cognitive – verbal rehearsal of tasks
  2) associative – with repetition, verbal mediation disappears
  3) autonomous – no conscious awareness of performance.
  ➔ Experts are not aware of what they know and cannot introspect reliably

- **Representational Problems**
  - Experts don't have the language to describe their knowledge
    - Spoken language lacks necessary precision
    - Knowledge Engineer and Expert must work together to create a suitable language and representation formalism
  - Different knowledge representations are good for different things

- **Brittleness**
  - Knowledge is created, not extracted: incomplete, overly simplified

Difficulties of Elicitation (3): **Distortions**

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Sender-related:

- Social pressure
  - Response to verbal and non-verbal cues from an interviewer
- Group think
  - Response to reactions of other experts
- Impression management
  - Response to imagined reactions of managers, clients, etc.
- Wishful thinking
  - Response to hopes
- Availability
  - Some data are easier to recall than others
- Underestimation of uncertainty
  - Tendency to underestimate by a factor of 2 or 3

Receiver-related:

- Misinterpretation
  - due to lack of knowledge
- Misrepresentation
  - Expert cannot accurately fit a response into the requested response mode
- Anchoring
  - Contradictory data is ignored once an initial solution is available

Sender- and receiver-related:

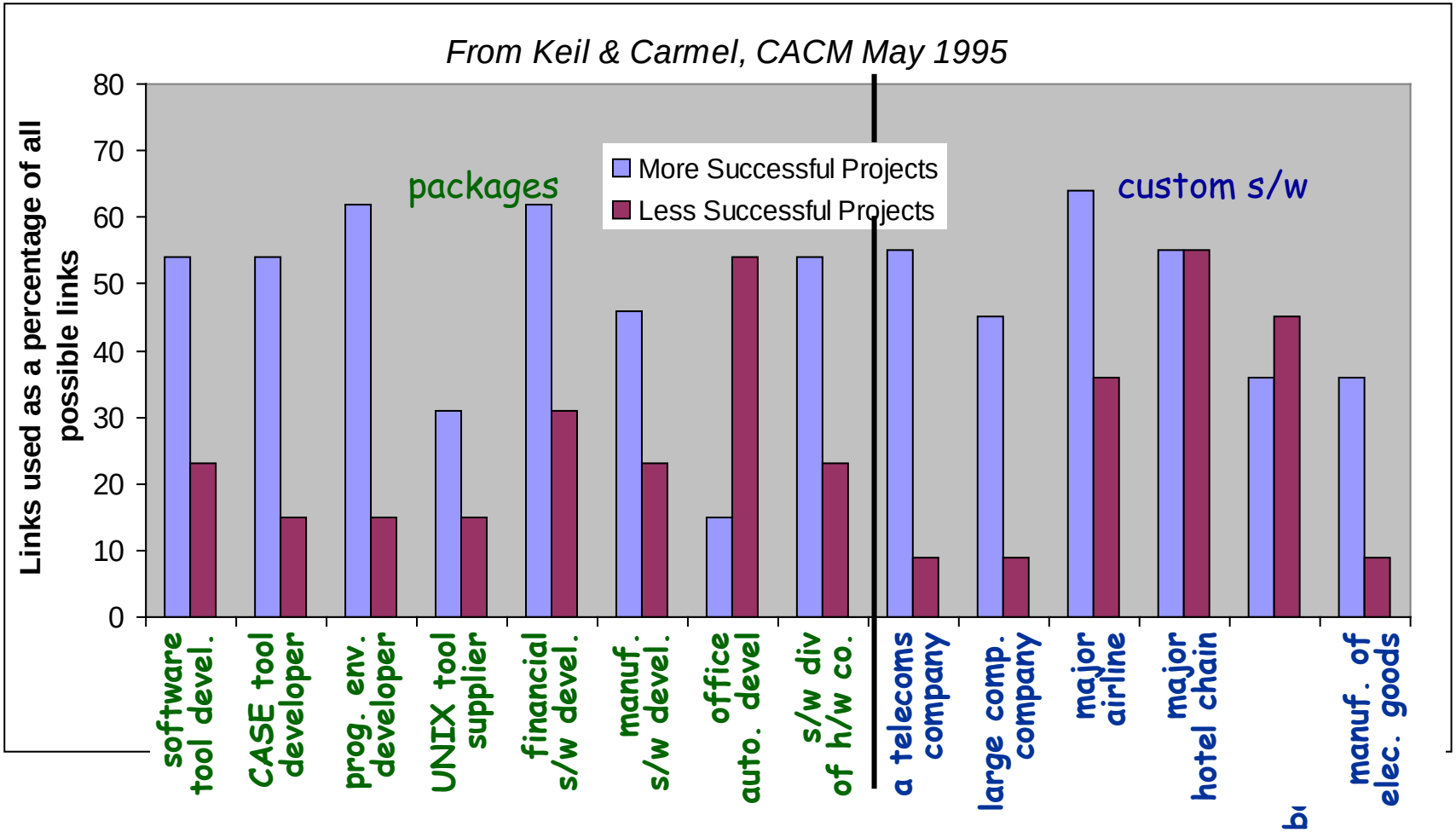
- Inconsistency
  - Statements made earlier are forgotten

Difficulties of Elicitation (4)

- **Personal** and interpersonal **factors**

Importance of links with customer(s)

- Successful projects tend to have more customer links



Source: *Adapted from Keil and Carmel, 1995, p37*

Elicitation Techniques

- Traditional Approaches
  - Introspection
  - Existing Documents/Data
  - Interviews
    - Open-ended
    - Structured
  - Surveys/Questionnaires
  - Group elicitation
    - Focus Groups
    - Brainstorming
    - JAD/RAD workshops
  - Prototyping
- Representation-based approaches
  - Goal-based
  - Scenario-Based
  - Use Cases

- Contextual (social) appr.
  - Ethnographic techniques
    - Participant Observation
    - Ethnomethodology
  - Discourse Analysis
    - Conversation Analysis
    - Speech Act Analysis
  - Participatory Design
  - Sociotechnical Methods
    - Soft Systems Analysis
- Cognitive approaches
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    - Repertory Grids
    - Proximity Scaling

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Method: Introspection

- Just sit down and think what the requirements may be
  - Very popular with software engineers
  - But then often in the form:
    Just sit down and think up some requirements

- Advantages
  - Simple, quick, cheap, no misunderstandings

- Disadvantages
  - Often not applicable ("I have no idea")
  - **Can be extremely misleading**
    - The mantra of usability people is: "Users are not like us!"

Method: Existing documents and data

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- Identify Collections of existing Hard Data
  - Facts and figures, financial information,...
  - Reports used for decision making,...
  - Survey results, marketing data,...
- Advantages
  - Can be quick and cheap
  - Sometimes offers very detailed information
- Disadvantages
  - **Most often not applicable**
  - Data may be biased
  - Data may be outdated

Method: Interviews

- Types:
  - Structured – agenda of fairly open questions
  - Open-ended – no pre-set agenda
- Advantages
  - Rich collection of information
- Disadvantages
  - **Interviewing is a difficult skill to master**
  - Large amount of qualitative data can be hard to analyze
  - Hard to compare different respondents
- Watch for
  - Tacit knowledge (and post-hoc rationalizations)
  - Removal from context
  - Influence from interviewer's attitude

Source: *Adapted from Goguen and Linde, 1993, p154.*

Method: Questionnaires

- Advantages
  - Can quickly collect info from large numbers of people
  - Can be administered remotely
  - Can collect attitudes, beliefs, characteristics

- Disadvantages
  - Simplistic (presupposed) categories provide very little context
    - No room for users to convey their real needs

- Watch for:
  - Bias in sample selection (especially with self-selection)
  - Too-small sample size
  - Suggestive questions → answers will be biased
  - Ambiguous questions → not everyone answers the same question
    - Questionnaires MUST be prototyped and tested

Source: *Adapted from Goguen and Linde, 1993, p154.*

Methods: Group Elicitation Techniques

- Types:
  - Joint/Rapid Application Development (JAD/RAD) Workshops
  - Focus Groups
  - Brainstorming
- Advantages
  - More natural interaction between people than formal interview
  - Can gauge group reaction to mock-ups, storyboards, etc.
- Disadvantages
  - May create unnatural groups (uncomfortable for participants)
  - **Danger of Groupthink**
  - May only provide superficial responses where detail is needed
  - Requires a highly trained facilitator
- Watch for
  - Sample bias
  - Dominance and submission

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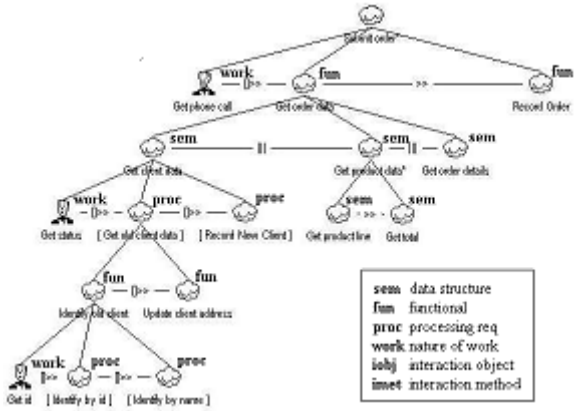
  - Sociotechnical Methods
    - Soft Systems Analysis
- Cognitive approaches
  - Task analysis
  - Protocol analysis
  - Knowl. Acquisition Techniqs
    - Card Sorting
    - Laddering
    - Repertory Grids
    - Proximity Scaling

Goal-based approaches

- Approach
  - Focus on why systems are constructed
  - Express the 'why' as a set of stakeholder goals
    - The top-level goal is often "save money" or "make money"
    - Use goal refinement to arrive at specific requirements
  - Goal analysis: document, organize and classify goals
  - Goal hierarchies show refinement and obstacle relationships between goals
- Advantages
  - Reasonably intuitive
  - **Sound basis for conflict resolution**
- Disadvantages
  - Hard to cope with evolution of goals
  - **Either very complex goal hierarchy** (can lead to analysis paralysis) **or lack of detail**



Source: *Adapted from Anton, 1996.*

Method: Scenarios

- Scenarios
  - Specific sequence of interaction between actor and system
    - typically between 3 and 7 steps
  - May be:
    - positive (i.e. required behavior)
    - negative (i.e. an undesirable interaction)
  - Often used as a first step when writing use cases
- Advantages
  - Very natural: stakeholders tend to use them spontaneously
  - Easy to understand (low level of abstraction)
- Disadvantages
  - Lack of structure: need use cases or task models to provide higher-level view

Source: *Adapted from Dardenne, 1993.*

Method: Use Cases

- What is a use case?
  - A description of a sequence of actions that a system performs that yields an observable result of value to a particular actor
    - i.e. a description of a set of possible concrete scenarios that have a common purpose
  - Typically written in natural language

UC_23 - eVerordnung_erstellen_Abschnitt_3	
Beschreibung	Die Informationen für eine eVerordnung werden zusammengestellt und signiert. Die eVerordnung wird auf eGK oder VODD verschoben.
Anwendungsumfeld	Institution des Akteurs Arzt (z. B. Arztpraxis, Krankenhaus)
Vorbedingungen	• Rechtmäßige Nutzung der eGK ist überprüft. • technisch nutzbare eGK liegt vor (gemäß [gemFK_CMSeGK_Nutz]). • Zugriffsauthentisierung durch Akteure ist erfolgt.
Auslöser	Eine eVerordnung soll erstellt werden.
Eingangsdaten	VSD_eGK / VOD_AM / Signaturdaten
Ergebnisse	Die eVerordnung wurde auf VODD oder eGK gespeichert.
Nachbedingungen	Die eVerordnung steht auf VODD oder eGK bereit zur weiteren Verwendung.
Beteiligte Akteure	- Arzt - Mitarbeiter medizinische Institution]:
Geschäftsobjekte	eVerordnung
Standardablauf	1 [Arzt oder Mitarbeiter medizinische Institution]: Informationen für die eVerordnung zusammenstellen 2 [Arzt]: Informationen der eVerordnung anzeigen (zur Signatur) 3 [Arzt]: Informationen der eVerordnung signieren

- Advantages
  - Easy to write, easy to understand (natural representation)
  - Helps in drawing system boundary

- Disadvantages
  - Use cases do not represent nonfunctional requirements
  - **Use cases do not capture domain knowledge**
  - Sometimes confused with a precise specification

Source: *Adapted from Rumbaugh 1997, p123-124*

Note: Beware of natural language!

- Natural language is easy-to-use, natural, and often appropriate for describing requirements
- But it is rarely precise!
- Example:

  "Buffalo once roamed the plains in large numbers"

Elicitation Techniques

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- Cognitive approaches
  - Task analysis
  - Protocol analysis
  - Knowl. Acquisition Techniqs

The ethnomethodologist's view

Requirements elicitation is a social activity

- Because it involves people-to-people communication
  - through discussions, observation, etc.
- Because it involves negotiation in bringing about consensus when there is disagreement.
- Because it affects and changes human activity systems

The domain of application is often a social world

- Need techniques that uncover the order of the social world
  - Social order might not be immediately obvious or describable
  - Social order cannot be assumed to have an *a priori* structure
- Social order can only be understood through **immersion**
  - Social order is constructed by the participants' actions
  - Need to witness the unfolding of social phenomena
  - **Cannot just collect data using pre-given categories**

Ethnomethodology

- Assumptions
  - Social world is ordered
  - We cannot know the order a-priori
  - To understand it, we need to immerse in its natural setting
- Categories
  - Most conventional approaches assume preexisting categories
    - This may mislead the observer (appropriation)
  - Ethnography attempts to use the subjects' own categories
    - Related to postmodern deconstruction: "there is no grand narrative"
- Measurement
  - There is no scientific objectivity about social phenomena
  - We need to use the subjects' own measurement theory

Source: *Adapted from Goguen and Linde, 1993, p158.*

Method: Participant observation ("teilnehmende Beobachtung")

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- Approach
  - Observer spends time with the subjects, joining in, long enough to become a member of the group

- Advantages
  - Highly contextualized and relatively reliable
  - Reveals details that other methods cannot
- Disadvantages
  - **Extremely time consuming!**
  - Resulting 'rich picture' is hard to analyze
  - Cannot say much about the results of proposed changes
- Watch for
  - going native!

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  - Task analysis
  - **Protocol analysis**
  - **Knowledge Acquisition Techniques**
    - **Card Sorting**
    - Laddering
    - Repertory Grids
    - **Proximity Scaling**

Method: Protocol Analysis

- Based on protocols created from vocalizing behavior
  - either "think-aloud" or retrospective
- Analyze protocols to reveal requirements
- Advantages
  - Direct verbalization of cognitive activities
  - Embedded in the work context
  - Good at revealing interaction problems with existing systems
- Disadvantages
  - **Interpretation requires introspection, hence unreliable**
  - No social dimension

Source: *Adapted from Hudlicka, 1996.*

Method: Proximity Scaling Techniques

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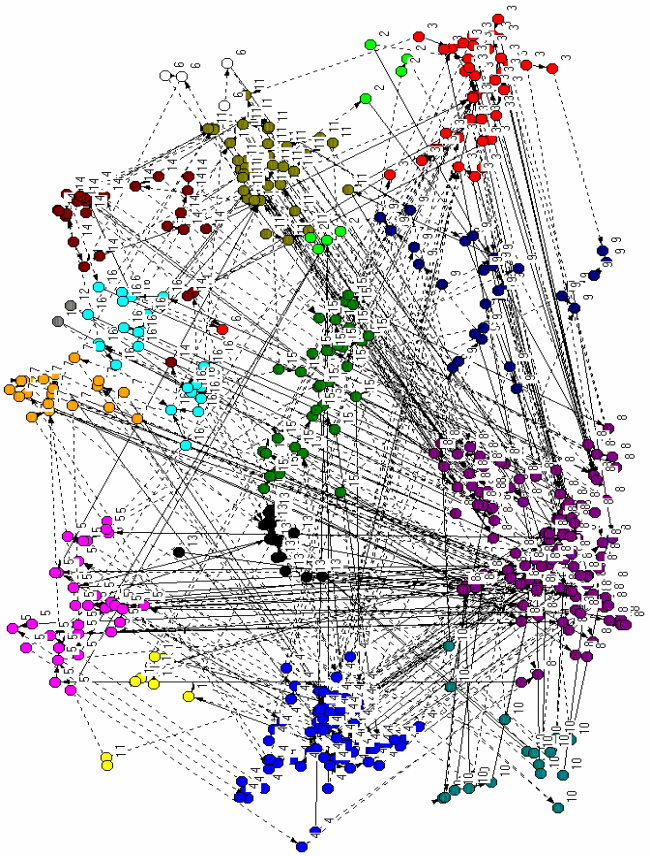
- Given some domain objects, derive a set of dimensions for classifying them:
  - Step 1: pairwise proximity assessment among domain elements
    - captures tacit knowledge of expert
  - Step 2: automated statistical analysis to build multi-dimensional space to classify the objects

- Advantages
  - Helps to elicit mental models where complex multivariate data is concerned
  - **Good for eliciting tacit knowledge**

- Disadvantages
  - Requires an agreed-upon set of objects
  - Only models classification knowledge, **not performance knowledge**



Method: Card sorting

- For a given set of domain objects, written on cards:
  - Expert sorts the cards into groups...
  - ...then says what the criterion was for sorting, and what the groups were
- Advantages
  - Simple, amenable to automation
    - Elicits classification knowledge
  - **Good for eliciting tacit knowledge**
- Disadvantages
  - Requires an agreed-upon set of objects
  - Only models classification knowledge, **not performance knowledge**

Data from CASA

Summary

- Requirements represent the goals to be reached via a software system
- A specification describes what the software must do in order to fulfill the requirements
  - assuming certain domain properties are met
- Requirements elicitation is the basic step of Requirements Engineering
  - others are Req. Specification, Req. Validation, and Req. Management

- Requirements Eliciation must overcome many recurring problems
- Many different elicitation techniques should be combined

Literature

- James Robertson, Suzanne Robertson: "Mastering the Requirements Process: Getting Requirements Right", 3rd ed., Addison-Wesley 2012

- Donald Gause, Gerald Weinberg: "Exploring Requirements – Quality before Design", B&T, 1989
  - auf deutsch: "Software Requirements: Anforderungen erkennen, verstehen und erfüllen", (vergriffen)
  - http://www.geraldmweinberg.com

Thank you!