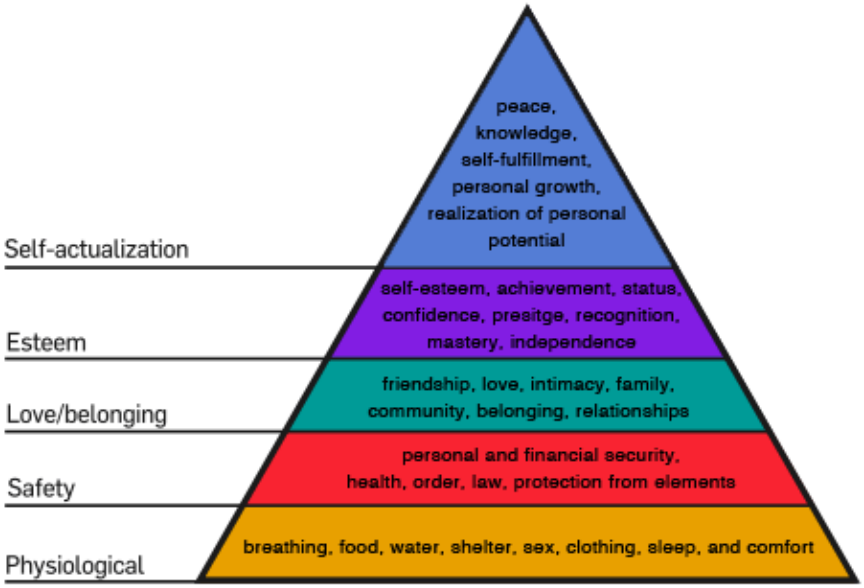
Requirements Engineering

Lt Col Muhammad Nazrul Islam, PhD
CSE Dept., MIST

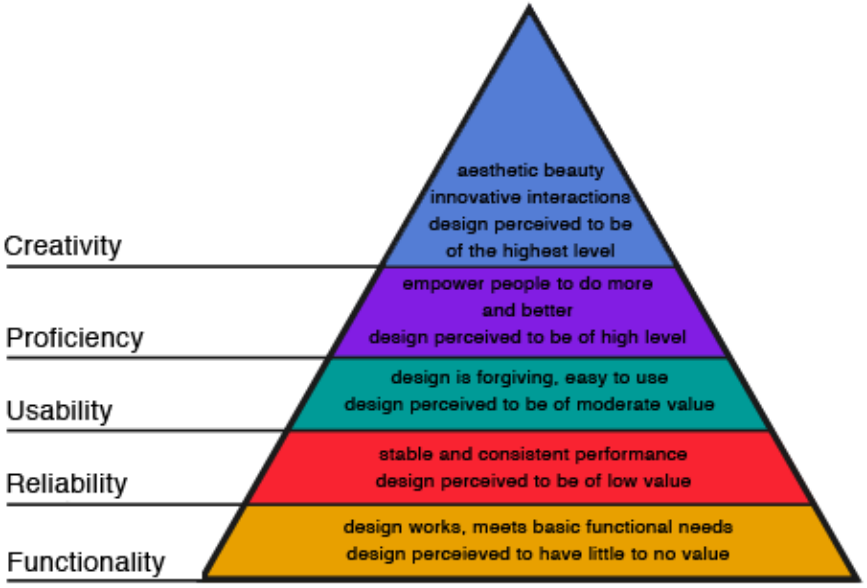
Topics covered

- ✧ Basic concepts on Requirements engineering
- ✧ Functional and non-functional requirements
- ✧ Requirements engineering processes
- ✧ Requirements elicitation
- ✧ Requirements specification
- ✧ Requirements validation
- ✧ Requirements change

What are needs?



Maslow's Hierarchy of Needs



Design Hierarchy of Needs

Requirements engineering

Establishing what the customer requires (NEEDS) from a software system

Requirements engineering

RE: The process of *finding out, analyzing, documenting, and checking* the services that a customer requires from a system and the constraints under which it operates.

The **system requirements** are the descriptions of the system services and constraints that are generated during the RE process.

Here, *SYSTEM → SOFTWARE SYSTEMS*

What is a requirement?

✧ Term ‘requirement’ is not used consistently in the SW industry.

✧ It may range from a high-level abstract statement of a service or of a system constraint to a detailed definition of a system function.

✧ This is inevitable as requirements may serve a dual function

- May be the basis for a bid for a contract - therefore must be open to interpretation;
- May be the basis for the contract itself - therefore must be defined in detail;
- Both these statements may be called requirements.

Requirements abstraction (Davis, 1993)

Davis explains why these differences exist:

"If a company wishes to let a contract for a large software development project, it must define **its needs** in a sufficiently abstract way that a solution is not pre-defined. The requirements must be written so that several contractors can bid for the contract, offering, perhaps, different ways of meeting the client **organization's needs**.

Once a contract has been awarded, the contractor must write a **system definition** for the client in more detail so that the client understands and can validate what the software will do. Both of these documents may be called the **requirements document** for the system."

Types of requirement

✧ User requirements

- To mean the high level abstract requirements
- Statements in natural language plus diagrams of the services the system provides and its operational constraints. Written for customers.

✧ System requirements

- To mean the detailed description of what the system should do.
- A structured document setting out detailed descriptions of the system's functions, services and operational constraints. Defines exactly what is to be implemented. It may be part of contract between the system buyer and the software developers.

User and system requirements

Example from a mental health care patient management system

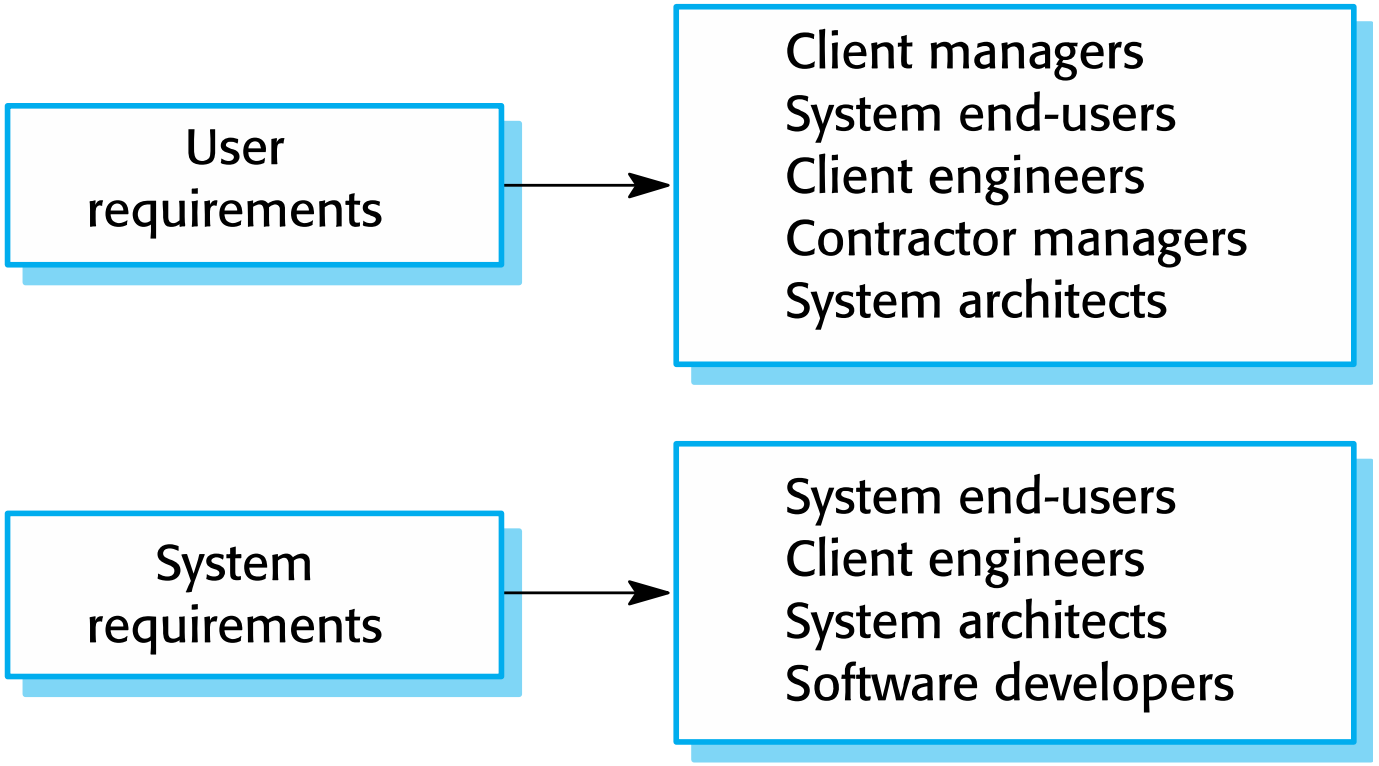
User requirements definition

1. The Mentcare system shall generate monthly management reports showing the cost of drugs prescribed by each clinic during that month.

System requirements specification

1.1 On the last working day of each month, a summary of the drugs prescribed, their cost and the prescribing clinics shall be generated.
1.2 The system shall generate the report for printing after 17.30 on the last working day of the month.
1.3 A report shall be created for each clinic and shall list the individual drug names, the total number of prescriptions, the number of doses prescribed and the total cost of the prescribed drugs.
1.4 If drugs are available in different dose units (e.g. 10mg, 20mg, etc) separate reports shall be created for each dose unit.
1.5 Access to drug cost reports shall be restricted to authorized users as listed on a management access control list.

Readers of different types of requirements specification



System stakeholders

- Any person or organization who is affected by the system in some way and so who has a legitimate interest

- Stakeholder types
  - End users
  - System managers
  - System owners
  - External stakeholders

Stakeholders in the Mentcare system

- ✧ Patients whose information is recorded in the system.
- ✧ Doctors who are responsible for assessing and treating patients.
- ✧ Nurses who coordinate the consultations with doctors and administer some treatments.
- ✧ Medical receptionists who manage patients' appointments.
- ✧ IT staff who are responsible for installing and maintaining the system.

Stakeholders in the Mentcare system

- A medical ethics manager who must ensure that the system meets current ethical guidelines for patient care.
- Health care managers who obtain management information from the system.
- Medical records staff who are responsible for ensuring that system information can be maintained and preserved, and that record keeping procedures have been properly implemented.

Agile methods and requirements

- Many agile methods argue that producing detailed system requirements is a waste of time as requirements change so quickly.
- The requirements document is therefore always out of date.
- Agile methods usually use incremental requirements engineering and may express requirements as ‘user stories’.
- This is practical for business systems but problematic for systems that require pre-delivery analysis (e.g. critical systems) or systems developed by several teams.

Functional and non-functional requirements

Functional and non-functional requirements

SW system requirements are often classified as :

- **Functional requirements**
  - Statements of services the system should provide, how the system should react to particular inputs and how the system should behave in particular situations.
  - May state what the system should not do.
- **Non-functional requirements**
  - Constraints on the services or functions offered by the system such as timing constraints, constraints on the development process, standards, etc.
  - Often apply to the system as a whole rather than individual features or services.

In reality, the distinction between these types of requirements is not as clear-cut!

Functional requirements

- ✧ Describe functionality or system services.
- ✧ Depend on the type of software, expected users and the type of organization where the software is used.
- ✧ In general, functional user requirements may be high-level statements of what the system should do.
- ✧ More specific functional system requirements should describe the system services in detail (e.g., input, output, exceptions, etc.).

Mentcare system: functional requirements

- A user shall be able to search the appointments lists for all clinics.
- The system shall generate each day, for each clinic, a list of patients who are expected to attend appointments that day.
- Each staff member using the system shall be uniquely identified by his or her 8-digit employee number.

Requirements imprecision

- Problems arise when functional requirements are not precisely stated.
- Ambiguous requirements may be interpreted in different ways by developers and users.
- Consider the term ‘search’ in requirement 1
  - User intention – search for a patient name across all appointments in all clinics;
  - Developer interpretation – search for a patient name in an individual clinic. User chooses clinic then search.

Requirements completeness and consistency

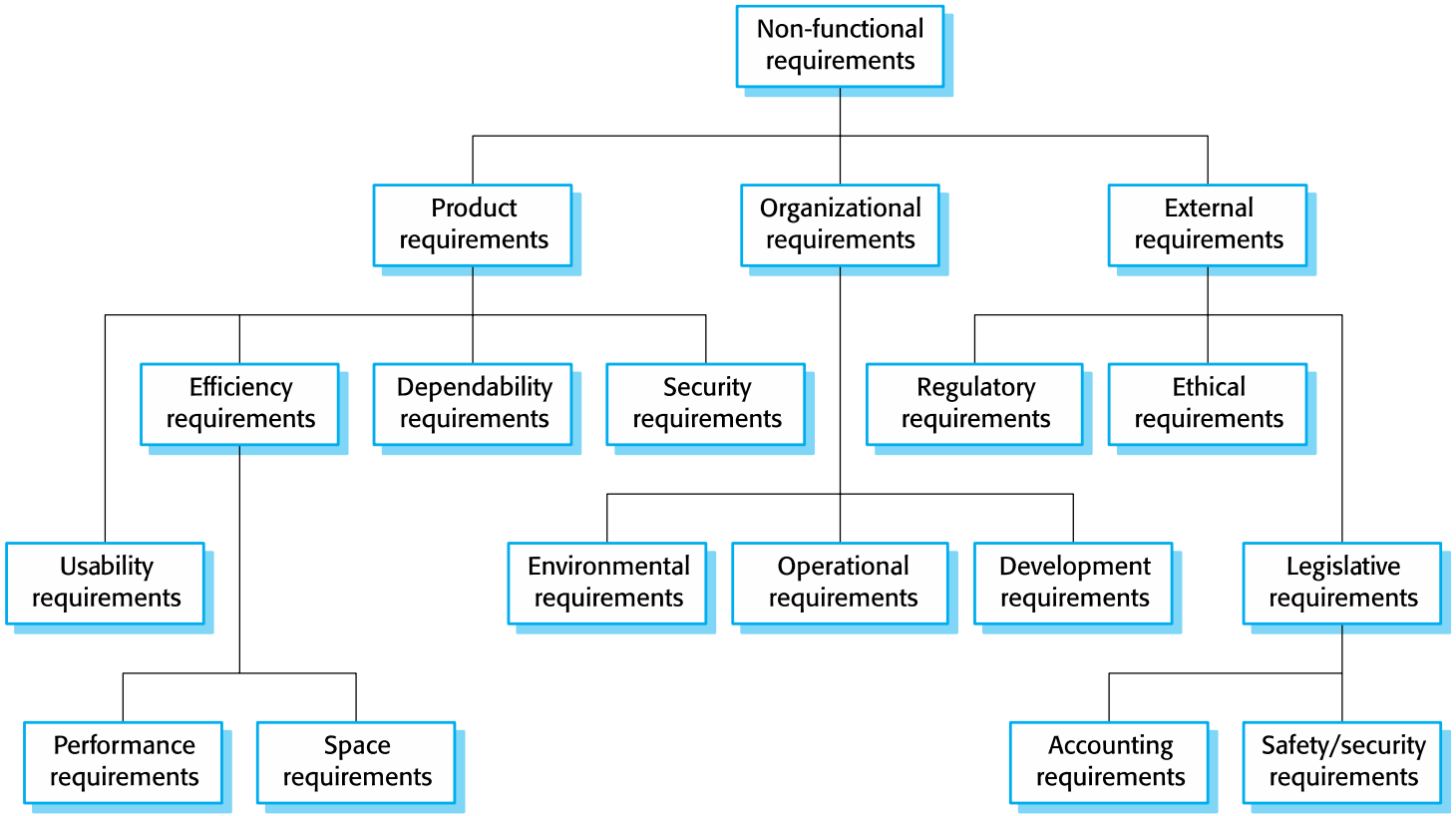
- In principle, requirements should be both complete and consistent.
- Complete
  - They should include descriptions of all facilities required.
- Consistent
  - There should be no conflicts or contradictions in the descriptions of the system facilities.

In practice, because of system and environmental complexity, it is impossible to produce a complete and consistent requirements document. E.g., due to mistakes/omissions, different stakeholders interests, etc.)

Non-functional requirements

- These define system properties and constraints e.g. reliability, response time and storage requirements. Constraints are I/O device capability, system representations, etc.
- Process requirements may also be specified mandating a particular IDE, programming language or development method.
- Non-functional requirements may be more critical than functional requirements. If these are not met, the system may be useless.

Types of nonfunctional requirement



Non-functional requirements implementation

- Non-functional requirements may affect the overall architecture of a system rather than the individual components.
  - For example, to ensure that performance requirements are met, you may have to organize the system to minimize communications between components.
- A single non-functional requirement, such as a security requirement, may generate a number of related functional requirements that define system services that are required.
  - It may also generate requirements that restrict existing requirements.

Non-functional requirements classifications

- ✧ Product requirements
  - Requirements which specify that the delivered product must behave in a particular way e.g. execution speed, reliability, etc.
- ✧ Organisational requirements
  - Requirements which are a consequence of organisational policies and procedures e.g. process standards used, implementation requirements, etc.
- ✧ External requirements
  - Requirements which arise from factors which are external to the system and its development process e.g. interoperability requirements, legislative requirements, etc.

Examples of nonfunctional requirements in the Mentcare system

Product requirement
The Mentcare system shall be available to all clinics during normal working hours (Mon–Fri, 0830–17.30). Downtime within normal working hours shall not exceed five seconds in any one day.

Organizational requirement
Users of the Mentcare system shall authenticate themselves using their health authority identity card.

External requirement
The system shall implement patient privacy provisions as set out in HStan-03-2006-priv.

Goals and requirements

- Non-functional requirements may be very difficult to state precisely and imprecise requirements may be difficult to verify.
- Goal
  - A general intention of the user such as ease of use.
- Verifiable non-functional requirement
  - A statement using some measure that can be objectively tested.
- Goals are helpful to developers as they convey the intentions of the system users.

Usability requirements

- ✧ The system should be easy to use by medical staff and should be organized in such a way that user errors are minimized. (Goal)
- ✧ Medical staff shall be able to use all the system functions after four hours of training. After this training, the average number of errors made by experienced users shall not exceed two per hour of system use. (Testable non-functional requirement)

Metrics for specifying nonfunctional requirements

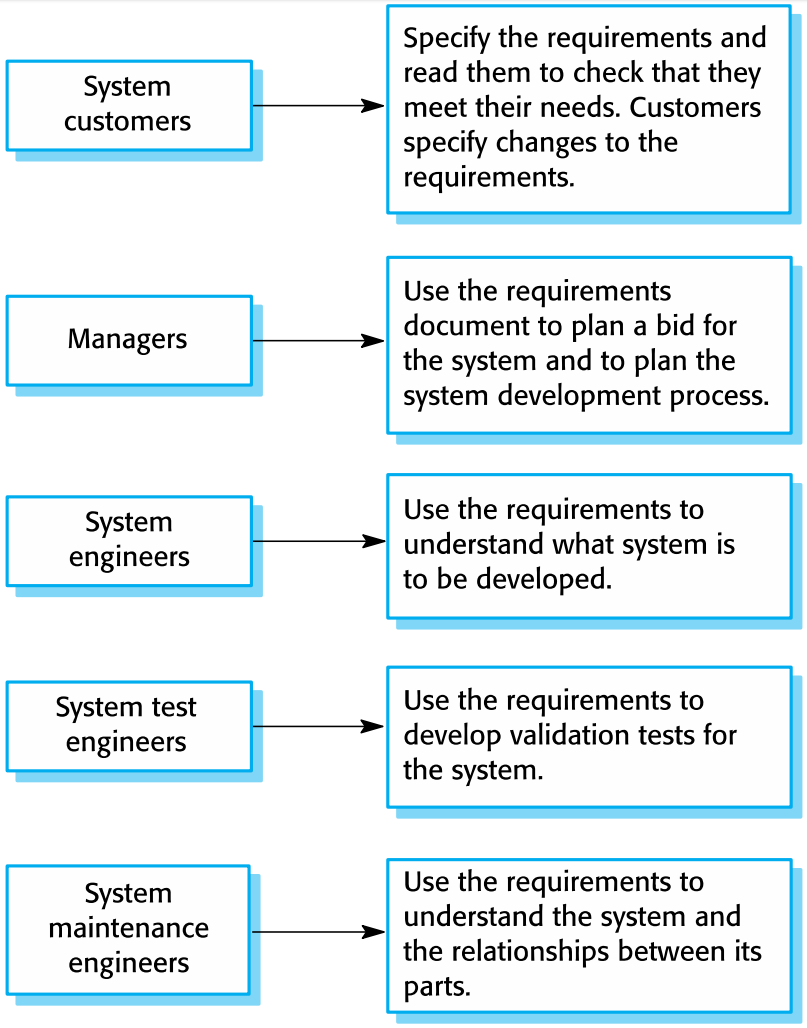
Property	Measure
Speed	Processed transactions/second User/event response time Screen refresh time
Size	Mbytes Number of ROM chips
Ease of use	Training time Number of help frames
Reliability	Mean time to failure Probability of unavailability Rate of failure occurrence Availability
Robustness	Time to restart after failure Percentage of events causing failure Probability of data corruption on failure
Portability	Percentage of target dependent statements Number of target systems

Software Requirements Document

The software requirements document

- The software requirements document is the official statement of what is required of the system developers.
- Should include both a definition of user requirements and a specification of the system requirements.
- It is NOT a design document. As far as possible, it should set of **WHAT the system should do** rather than HOW it should do it.

Users of a requirements document



Requirements document variability

- Information in requirements document depends on type of system and the approach to development used.
- Systems developed incrementally will, typically, have less detail in the requirements document.
- Requirements documents standards have been designed e.g. IEEE standard. These are mostly applicable to the requirements for large systems engineering projects.

The structure of a requirements document

Chapter	Description
Preface	This should define the expected readership of the document and describe its version history, including a rationale for the creation of a new version and a summary of the changes made in each version.
Introduction	This should describe the need for the system. It should briefly describe the system's functions and explain how it will work with other systems. It should also describe how the system fits into the overall business or strategic objectives of the organization commissioning the software.
Glossary	This should define the technical terms used in the document. You should not make assumptions about the experience or expertise of the reader.
User requirements definition	Here, you describe the services provided for the user. The nonfunctional system requirements should also be described in this section. This description may use natural language, diagrams, or other notations that are understandable to customers. Product and process standards that must be followed should be specified.
System architecture	This chapter should present a high-level overview of the anticipated system architecture, showing the distribution of functions across system modules. Architectural components that are reused should be highlighted.

The structure of a requirements document

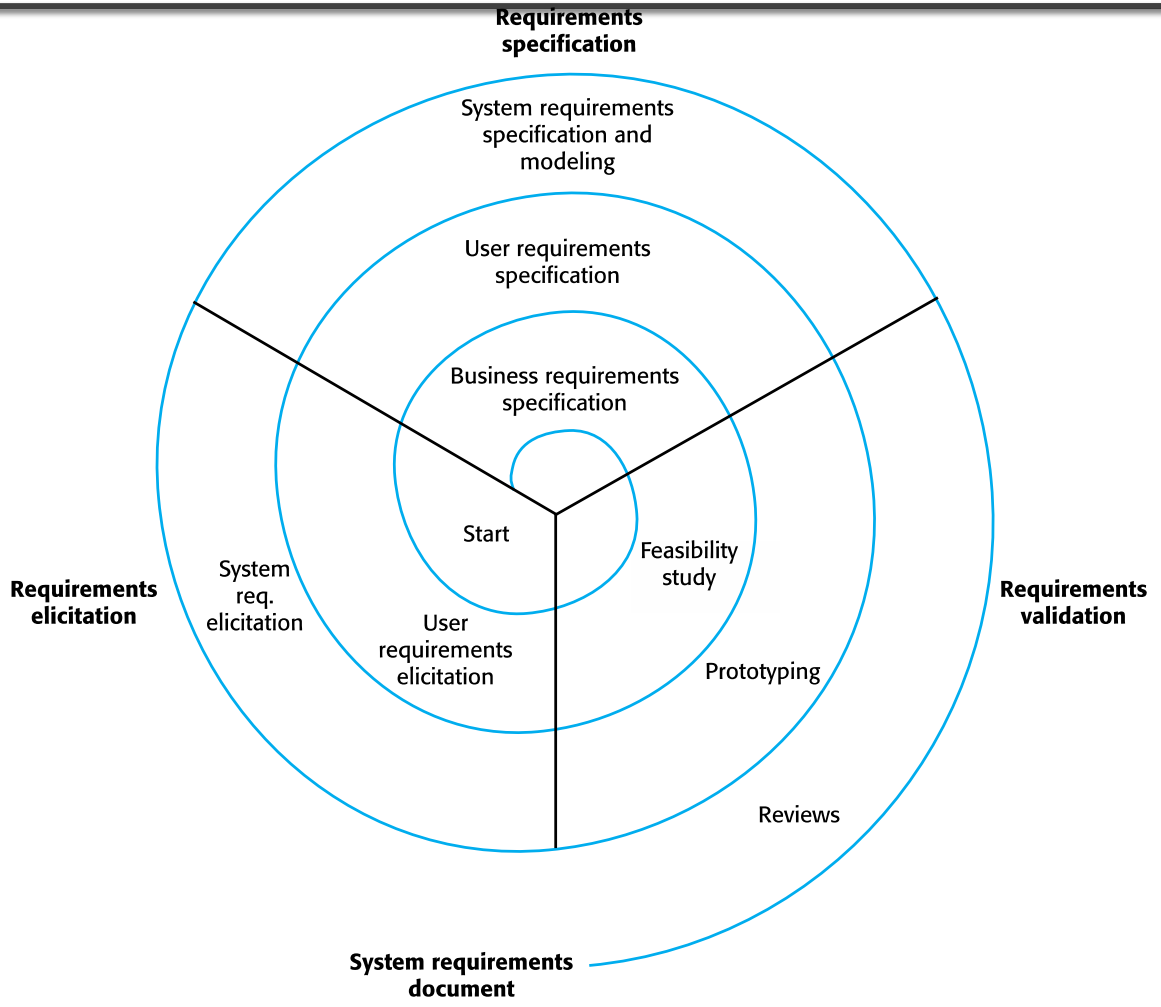
Chapter	Description
System requirements specification	This should describe the functional and nonfunctional requirements in more detail. If necessary, further detail may also be added to the nonfunctional requirements. Interfaces to other systems may be defined.
System models	This might include graphical system models showing the relationships between the system components and the system and its environment. Examples of possible models are object models, data-flow models, or semantic data models.
System evolution	This should describe the fundamental assumptions on which the system is based, and any anticipated changes due to hardware evolution, changing user needs, and so on. This section is useful for system designers as it may help them avoid design decisions that would constrain likely future changes to the system.
Appendices	These should provide detailed, specific information that is related to the application being developed; for example, hardware and database descriptions. Hardware requirements define the minimal and optimal configurations for the system. Database requirements define the logical organization of the data used by the system and the relationships between data.
Index	Several indexes to the document may be included. As well as a normal alphabetic index, there may be an index of diagrams, an index of functions, and so on.

Requirements engineering processes

Requirements engineering processes

- The processes used for RE vary widely depending on the application domain, the people involved and the organisation developing the requirements.
- However, there are a number of generic activities common to all processes
  - Requirements elicitation;
  - Requirements analysis;
  - Requirements validation;
  - Requirements management.
- In practice, RE is an iterative activity in which these processes are interleaved.

A spiral view of the requirements engineering process



Requirements elicitation

Requirements elicitation and analysis

- Sometimes called requirements elicitation or requirements discovery.
- Involves technical staff working with customers to find out about the application domain, the services that the system should provide and the system's operational constraints.
- May involve end-users, managers, engineers involved in maintenance, domain experts, trade unions, etc. These are called *stakeholders.*

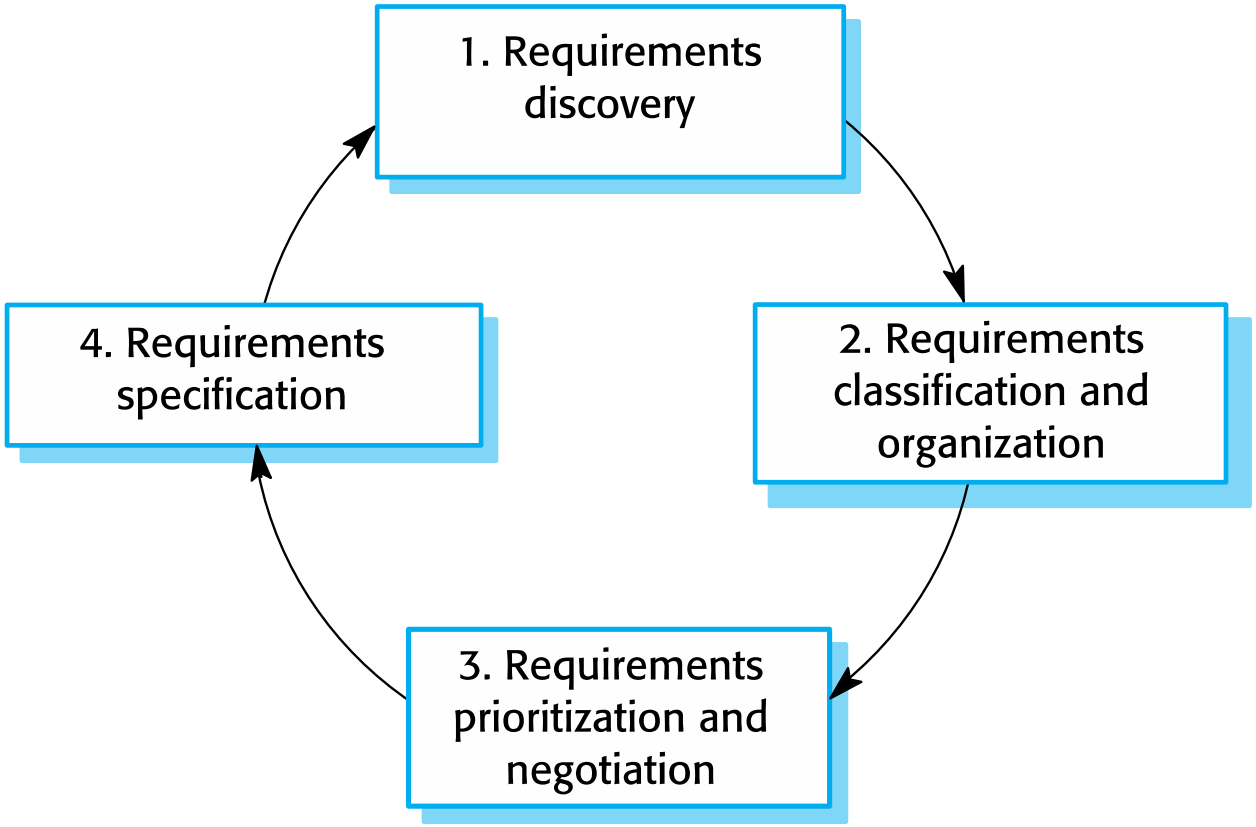
Requirements elicitation

- Software engineers work with a range of system stakeholders to find out about the application domain, the services that the system should provide, the required system performance, hardware constraints, other systems, etc.
- Stages include:
  - Requirements discovery,
  - Requirements classification and organization,
  - Requirements prioritization and negotiation,
  - Requirements specification.

Problems of requirements elicitation

- ✧ Stakeholders don’t know what they really want.
- ✧ Stakeholders express requirements in their own terms.
- ✧ Different stakeholders may have conflicting requirements.
- ✧ Organisational and political factors may influence the system requirements.
- ✧ The requirements change during the analysis process. New stakeholders may emerge and the business environment may change.

The requirements elicitation and analysis process



Process activities

- Requirements discovery
  - Interacting with stakeholders to discover their requirements. Domain requirements (constraints on the system from the domain of operation) are also discovered at this stage.
- Requirements classification and organisation
  - Groups related requirements and organises them into coherent clusters.
- Prioritisation and negotiation
  - Prioritising requirements and resolving requirements conflicts.
- Requirements specification
  - Requirements are documented and input into the next round of the spiral.

Requirements discovery

- The process of gathering information about the required and existing systems and distilling the user and system requirements from this information.
- Interaction is with system stakeholders from managers to external regulators.
- Systems normally have a range of stakeholders.

Interviewing

- Formal or informal interviews with stakeholders are part of most RE processes.
- Types of interview
  - Closed interviews based on pre-determined list of questions
  - Open interviews where various issues are explored with stakeholders.
- Effective interviewing
  - Be open-minded, avoid pre-conceived ideas about the requirements and are willing to listen to stakeholders.
  - Prompt the interviewee to get discussions going using a requirements proposal, or by working together on a prototype system.

Interviews

- ✧ Most important: representative target users
  - May be current users of similar system
  - Might be non-users
  - Lead users
  - Group interview
- ✧ E.g. design a bus companion system
  - Who would you interview?
  - How would you reach to them?

Interview questions to AVOID

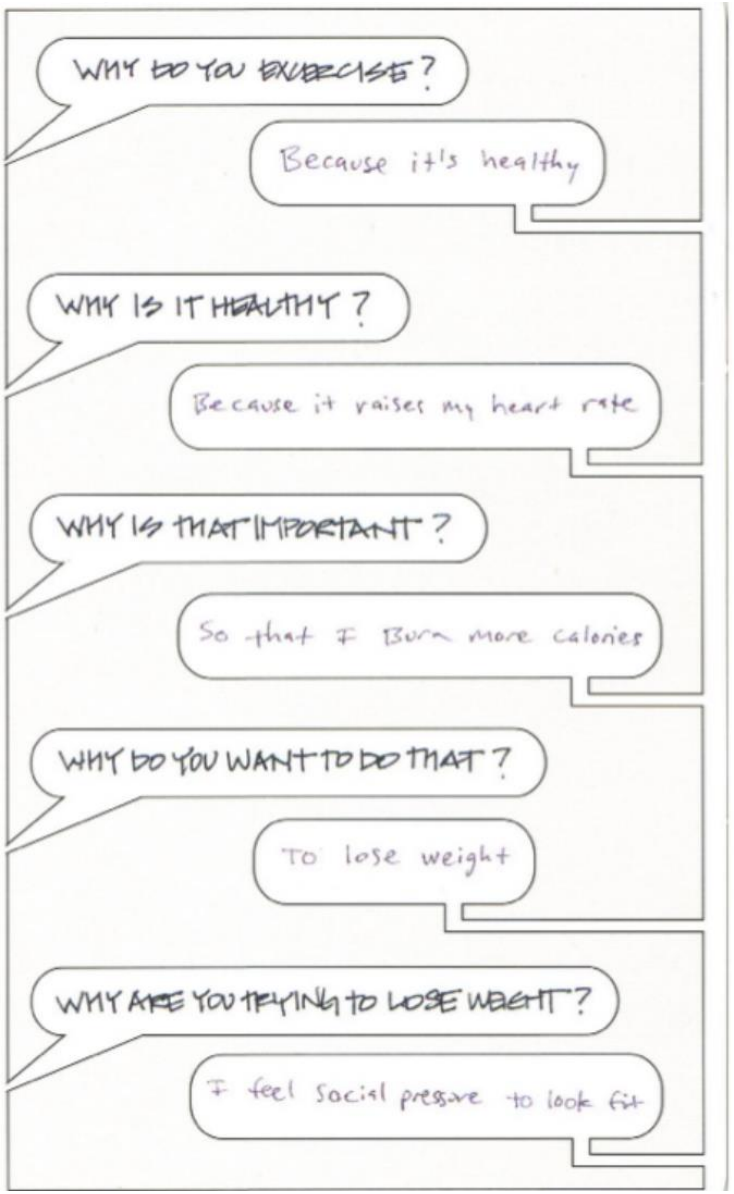
- ✧ Leading questions
  - E.g. do you think this is a good idea?
- ✧ People are experts in their own life, not design
  - E.g. what would you like in a tool?
- ✧ Hypothetical scenarios
  - E.g. what would you do/like/want if …
- ✧ Frequency questions
  - E.g. how often do you exercise?
- ✧ Scale rating questions
  - E.g. rate how much you like to do exercise
- ✧ Binary questions
  - E.g. do you like to exercise?

Interview questions

- ✧ The more open the question, the more interesting the answers you get
  - E.g. I see that you haven’t used the login. Why is that?, how do you like the…, what are you trying to do…, what are the reasons you prefer x over y?
- Be curious, needs are not obvious
  - Insights emerge from the expression
- ✧ A little bit of silence is golden

Interview questions

- ✧ Five whys?
  - Ask ‘why?’ questions in response to five consecutive answers
  - Force people to examine and express the underlying reasons for their behavior



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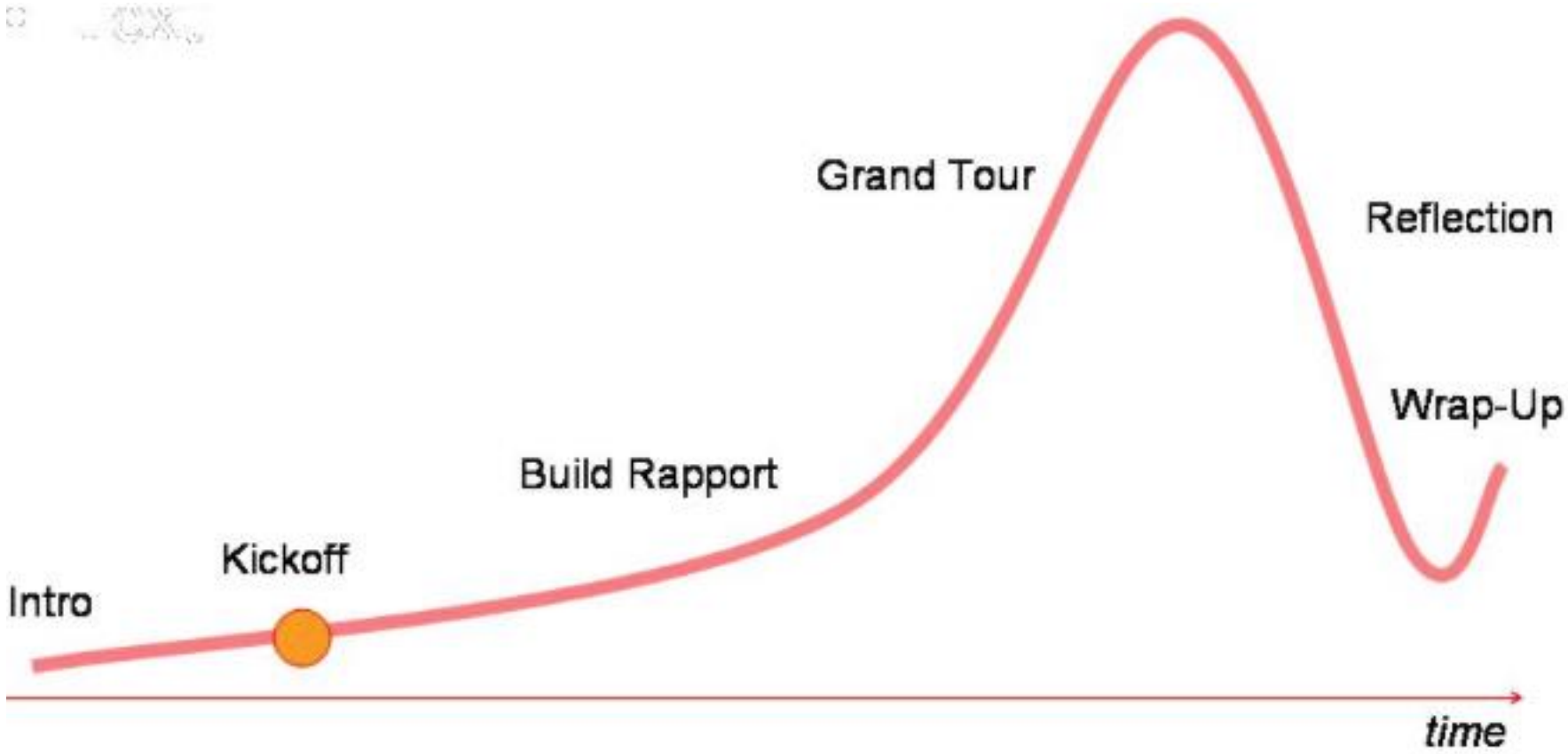
Interview process



Hasso Plattner, 2007

Interview process

- Introduction
  - “Hi, I’m a student studying wellbeing of people. I’m interested in hearing about your daily life and activities. There are no right or wrong answers, I just want to hear what you have to say.”
- Kick-off
  - “How do you feel today?”
- Build rapport
  - “What did you do today before coming here? How was it? Do you have a favorite daily activity?”
- Grand Tour
  - “Can you describe your most memorable activity experience? Why was it so unique? What happened?”
- Reflection
  - “If you were designing the ultimate device to support your daily activity based on your ideal experience. . .”

Adapted from Hasso Plattner, 2007

Interviews in practice

- Normally a mix of closed and open-ended interviewing.
- Interviews are good for getting an overall understanding of what stakeholders do and how they might interact with the system.
- Interviewers need to be open-minded without pre-conceived ideas of what the system should do
- You need to prompt the use to talk about the system by suggesting requirements rather than simply asking them what they want.

Problems with interviews

- Application specialists may use language to describe their work that isn't easy for the requirements engineer to understand.
- Interviews are not good for understanding domain requirements
  - Requirements engineers cannot understand specific domain terminology;
  - Some domain knowledge is so familiar that people find it hard to articulate or think that it isn't worth articulating.

Requirements specification

Requirements specification

- The process of writing down the user and system requirements in a requirements document.
- User requirements have to be understandable by end-users and customers who do not have a technical background.
- System requirements are more detailed requirements and may include more technical information.
- The requirements may be part of a contract for the system development
  - It is therefore important that these are as complete as possible.

Ways of writing a system requirements specification

Notation	Description
Natural language	The requirements are written using numbered sentences in natural language. Each sentence should express one requirement.
Structured natural language	The requirements are written in natural language on a standard form or template. Each field provides information about an aspect of the requirement.
Design description languages	This approach uses a language like a programming language, but with more abstract features to specify the requirements by defining an operational model of the system. This approach is now rarely used although it can be useful for interface specifications.
Graphical notations	Graphical models, supplemented by text annotations, are used to define the functional requirements for the system; UML use case and sequence diagrams are commonly used.
Mathematical specifications	These notations are based on mathematical concepts such as finite-state machines or sets. Although these unambiguous specifications can reduce the ambiguity in a requirements document, most customers don't understand a formal specification. They cannot check that it represents what they want and are reluctant to accept it as a system contract

Requirements and design

- In principle, requirements should state what the system should do and the design should describe how it does this.
- In practice, requirements and design are inseparable

Natural language specification

- Requirements are written as natural language sentences supplemented by diagrams and tables.
- Used for writing requirements because it is expressive, intuitive and universal. This means that the requirements can be understood by users and customers.

Guidelines for writing requirements

- ✧ Invent a standard format and use it for all requirements.
- ✧ Use language in a consistent way. Use shall for mandatory requirements, should for desirable requirements.
- ✧ Use text highlighting to identify key parts of the requirement.
- ✧ Avoid the use of computer jargon.
- ✧ Include an explanation (rationale) of why a requirement is necessary.

Problems with natural language

- ✧ Lack of clarity
  - Precision is difficult without making the document difficult to read.
- ✧ Requirements confusion
  - Functional and non-functional requirements tend to be mixed-up.
- ✧ Requirements amalgamation
  - Several different requirements may be expressed together.

Example requirements for the insulin pump software system

3.2 The system shall measure the blood sugar and deliver insulin, if required, every 10 minutes. *(Changes in blood sugar are relatively slow so more frequent measurement is unnecessary; less frequent measurement could lead to unnecessarily high sugar levels.)*

3.6 The system shall run a self-test routine every minute with the conditions to be tested and the associated actions defined in Table 1. *(A self-test routine can discover hardware and software problems and alert the user to the fact the normal operation may be impossible.)*

Structured specifications

- An approach to writing requirements where the freedom of the requirements writer is limited and requirements are written in a standard way.
- This works well for some types of requirements e.g. requirements for embedded control system but is sometimes too rigid for writing business system requirements.

Form-based specifications

When a standard form is used for specifying functional requirements, the following information should be included:

- ✧ Definition of the function or entity.
- ✧ Description of inputs and where they come from.
- ✧ Description of outputs and where they go to.
- ✧ Information about the information needed for the computation and other entities used.
- ✧ Description of the action to be taken.
- ✧ Pre and post conditions (if appropriate).
- ✧ The side effects (if any) of the function.

A structured specification of a requirement for an insulin pump

Insulin Pump/Control Software/SRS/3.3.2

Function Compute insulin dose: safe sugar level.

Description

Computes the dose of insulin to be delivered when the current measured sugar level is in the safe zone between 3 and 7 units.

Inputs Current sugar reading (r2); the previous two readings (r0 and r1).

Source Current sugar reading from sensor. Other readings from memory.

Outputs CompDose—the dose in insulin to be delivered.

Destination Main control loop.

A structured specification of a requirement for an insulin pump

Action
CompDose is zero if the sugar level is stable or falling or if the level is increasing but the rate of increase is decreasing. If the level is increasing and the rate of increase is increasing, then CompDose is computed by dividing the difference between the current sugar level and the previous level by 4 and rounding the result. If the result, is rounded to zero then CompDose is set to the minimum dose that can be delivered.
Requirements
Two previous readings so that the rate of change of sugar level can be computed.
Pre-condition
The insulin reservoir contains at least the maximum allowed single dose of insulin.
Post-condition r0 is replaced by r1 then r1 is replaced by r2.
Side effects None.

Tabular specification

- ✧ Used to supplement natural language.
- ✧ Particularly useful when you have to define a number of possible alternative courses of action.
- ✧ For example, the insulin pump systems bases its computations on the rate of change of blood sugar level and the tabular specification explains how to calculate the insulin requirement for different scenarios.

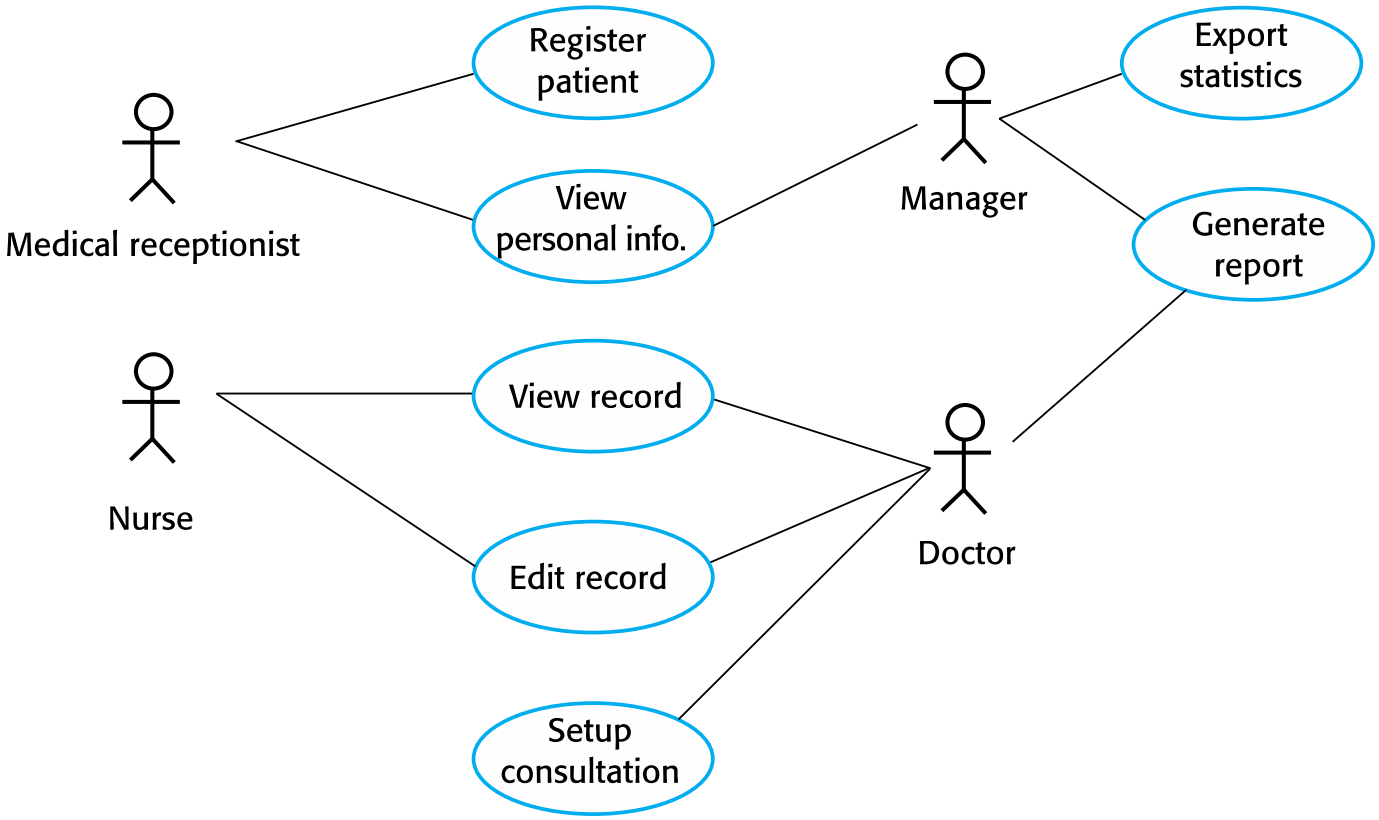
Tabular specification of computation for an insulin pump

Condition	Action
Sugar level falling (r2 < r1)	CompDose = 0
Sugar level stable (r2 = r1)	CompDose = 0
Sugar level increasing and rate of increase decreasing ((r2 – r1) < (r1 – r0))	CompDose = 0
Sugar level increasing and rate of increase stable or increasing ((r2 – r1) ≥ (r1 – r0))	CompDose = round ((r2 – r1)/4) If rounded result = 0 then CompDose = MinimumDose

Use cases

- Use-cases are a kind of scenario that are included in the UML.
- Use cases identify the actors in an interaction and which describe the interaction itself.
- A set of use cases should describe all possible interactions with the system.
- UML sequence diagrams may be used to add detail to use-cases by showing the sequence of event processing in the system.

Use cases for the Mentcare system



Requirements validation

Requirements validation

- Concerned with demonstrating that the requirements define the system that the customer really wants.
- Requirements error costs are high so validation is very important
  - Fixing a requirements error after delivery may cost up to 100 times the cost of fixing an implementation error.

Requirements checking

During the validation process, following checking should be carried out-

- ✧ Validity. Does the system provide the functions which best support the customer's needs?
- ✧ Consistency. Are there any requirements conflicts?
- ✧ Completeness. Are all functions required by the customer included?
- ✧ Realism. Can the requirements be implemented given available budget and technology
- ✧ Verifiability. Can the requirements be checked?

Requirements validation techniques

- ✧ Requirements reviews
  - Systematic manual analysis of the requirements.
- ✧ Prototyping
  - Using an executable model of the system to check requirements.
- ✧ Test-case generation
  - Developing tests for requirements to check testability.

Requirements reviews

- Regular reviews should be held while the requirements definition is being formulated.
- Both client and contractor staff should be involved in reviews.
- Reviews may be formal (with completed documents) or informal. Good communications between developers, customers and users can resolve problems at an early stage.

Review checks

- ✧ Verifiability
  - Is the requirement realistically testable?
- ✧ Comprehensibility
  - Is the requirement properly understood?
- ✧ Traceability
  - Is the origin of the requirement clearly stated?
- ✧ Adaptability
  - Can the requirement be changed without a large impact on other requirements?

Requirements change

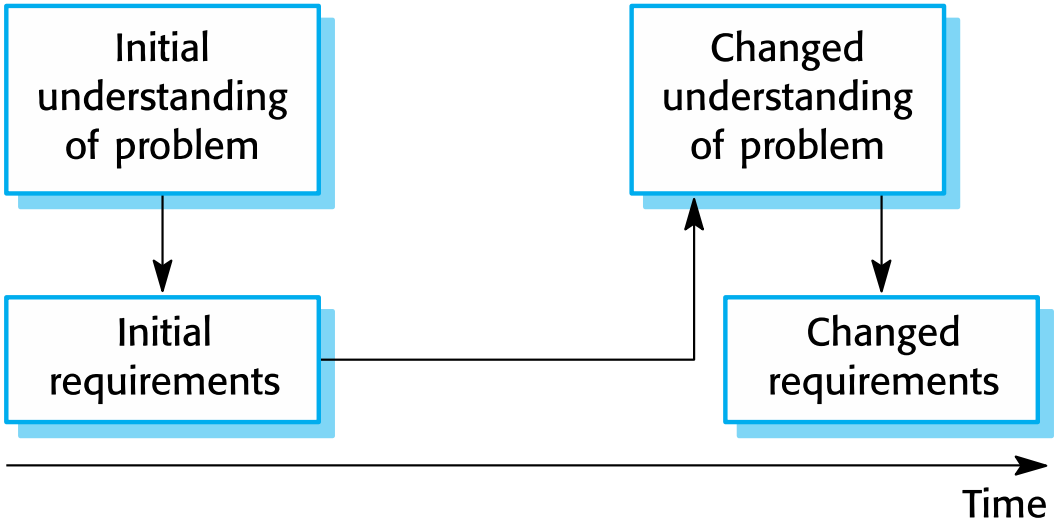
Changing requirements

- The business and technical environment of the system always changes after installation.
  - New hardware may be introduced, it may be necessary to interface the system with other systems, business priorities may change (with consequent changes in the system support required), and new legislation and regulations may be introduced that the system must necessarily abide by.
- The people who pay for a system and the users of that system are rarely the same people.
  - System customers impose requirements because of organizational and budgetary constraints. These may conflict with end-user requirements and, after delivery, new features may have to be added for user support if the system is to meet its goals.

Changing requirements

- Large systems usually have a diverse user community, with many users having different requirements and priorities that may be conflicting or contradictory.
  - The final system requirements are inevitably a compromise between them and, with experience, it is often discovered that the balance of support given to different users has to be changed.

Requirements evolution



Requirements management

- Requirements management is the process of managing changing requirements during the requirements engineering process and system development.
- New requirements emerge as a system is being developed and after it has gone into use.
- You need to keep track of individual requirements and maintain links between dependent requirements so that you can assess the impact of requirements changes. You need to establish a formal process for making change proposals and linking these to system requirements.

Requirements management planning

- Establishes the level of requirements management detail that is required.
- During the Requirements management stage, you have to decide on:
  - *Requirements identification* Each requirement must be uniquely identified so that it can be cross-referenced with other requirements.
  - *A change management process* This is the set of activities that assess the impact and cost of changes.
  - *Traceability policies* These policies define the relationships between each requirement and between the requirements and the system design that should be recorded.
  - *Tool support* Tools that may be used range from specialist requirements management systems to spreadsheets and simple database systems.

Requirements change management

✧ Deciding if a requirements change should be accepted

- *Problem analysis and change specification*
  - During this stage, the problem or the change proposal is analyzed to check that it is valid. This analysis is fed back to the change requestor who may respond with a more specific requirements change proposal, or decide to withdraw the request.
- *Change analysis and costing*
  - The effect of the proposed change is assessed using traceability information and general knowledge of the system requirements. Once this analysis is completed, a decision is made whether or not to proceed with the requirements change.
- Change implementation
  - The requirements document and, where necessary, the system design and implementation, are modified. Ideally, the document should be organized so that changes can be easily implemented.

Requirements change management