SOFTWARE ENGINEERING

Chapter 4 – Requirements Engineering

Topics covered

• Functional and non-functional requirements
• The software requirements document
• Requirements specification
• Requirements engineering processes
• Requirements elicitation and analysis
• Requirements validation
• Requirements management
Requirements engineering

- The process of establishing the services that the customer requires from a system and the constraints under which it operates and is developed.
- The requirements themselves are the descriptions of the system services and constraints that are generated during the requirements engineering process.

What is a requirement?

- It may range from a high-level abstract statement of a service or of a system constraint to a detailed mathematical functional specification.
- 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)

“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
  • Statements in natural language plus diagrams of the services the system provides and its operational constraints. Written for customers.

• System requirements
  • A structured document setting out detailed descriptions of the system’s functions, services and operational constraints. Defines what should be implemented so may be part of a contract between client and contractor.
User and system requirements

User requirement definition

1. The MHC-PMS 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 automatically 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, 20 mg, etc.) separate reports shall be created for each dose unit.
1.5 Access to all cost reports shall be restricted to authorized users listed on a management access control list.

Readers of different types of requirements specification

- **User requirements**
  - Client managers
  - System end-users
  - Client engineers
  - Contractor managers
  - System architects

- **System requirements**
  - System end-users
  - Client engineers
  - System architects
  - Software developers
Functional and non-functional requirements

• 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.

• Domain requirements
  • Constraints on the system from the domain of operation

Functional requirements

• Describe functionality or system services.
• Depend on the type of software, expected users and the type of system where the software is used.
• Functional user requirements may be high-level statements of what the system should do.
• Functional system requirements should describe the system services in detail.
Case study: MHC-PMS

- The MHC-PMS (Mental Health Care-Patient Management System) is an information system that is intended for use in clinics.
- It makes use of a centralized database of patient information but has also been designed to run on a PC, so that it may be accessed and used from sites that do not have secure network connectivity.
- When the local systems have secure network access, they use patient information in the database but they can download and use local copies of patient records when they are disconnected.

MHC-PMS goals

- To generate management information that allows health service managers to assess performance against local and government targets.
- To provide medical staff with timely information to support the treatment of patients.
The organization of the MHC-PMS

MHC-PMS key features

- **Individual care management**
  - Clinicians can create records for patients, edit the information in the system, view patient history, etc. The system supports data summaries so that doctors can quickly learn about the key problems and treatments that have been prescribed.

- **Patient monitoring**
  - The system monitors the records of patients that are involved in treatment and issues warnings if possible problems are detected.

- **Administrative reporting**
  - The system generates monthly management reports showing the number of patients treated at each clinic, the number of patients who have entered and left the care system, number of patients sectioned, the drugs prescribed and their costs, etc.
MHC-PMS concerns

• Privacy
  • It is essential that patient information is confidential and is never disclosed to anyone apart from authorised medical staff and the patient themselves.

• Safety
  • Some mental illnesses cause patients to become suicidal or a danger to other people. Wherever possible, the system should warn medical staff about potentially suicidal or dangerous patients.
  • The system must be available when needed otherwise safety may be compromised and it may be impossible to prescribe the correct medication to patients.

Functional requirements for the MHC-PMS

• 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 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, it is impossible to produce a complete and consistent requirements document.
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 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 MHC-PMS

**Product requirement**
The MHC-PMS 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 MHC-PMS 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

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

• The system’s operational domain imposes requirements on the system.
  • For example, a train control system has to take into account the braking characteristics in different weather conditions.
• Domain requirements be new functional requirements, constraints on existing requirements or define specific computations.
• If domain requirements are not satisfied, the system may be unworkable.

Train protection system

• This is a domain requirement for a train protection system:
• The deceleration of the train shall be computed as:
  • $D_{train} = D_{control} + D_{gradient}$
  • where $D_{gradient}$ is $9.81 \text{ms}^2 \times \text{compensated gradient/alpha}$ and where the values of $9.81 \text{ms}^2 /\text{alpha}$ are known for different types of train.
• It is difficult for a non-specialist to understand the implications of this and how it interacts with other requirements.
Domain requirements problems

- Understandability
  - Requirements are expressed in the language of the application domain;
  - This is often not understood by software engineers developing the system.

- Implicitness
  - Domain specialists understand the area so well that they do not think of making the domain requirements explicit.

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 requirements document

- System customers
  Specify the requirements and read them to check that they meet their needs. Customers specify changes to the requirements.

- Managers
  Use the requirements document to plan a bid for the system and to plan the system development process.

- System engineers
  Use the requirements to understand what system is to be developed.

- System test engineers
  Use the requirements to develop validation tests for the system.

- System maintenance engineers
  Use the requirements to understand the system and the relationships between its parts.

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

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>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.</td>
</tr>
<tr>
<td>Introduction</td>
<td>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.</td>
</tr>
<tr>
<td>Glossary</td>
<td>This should define the technical terms used in the document. You should not make assumptions about the experience or expertise of the reader.</td>
</tr>
<tr>
<td>User requirements definition</td>
<td>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.</td>
</tr>
<tr>
<td>System architecture</td>
<td>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.</td>
</tr>
</tbody>
</table>

## The structure of a requirements document

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>System requirements specification</td>
<td>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.</td>
</tr>
<tr>
<td>System models</td>
<td>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.</td>
</tr>
<tr>
<td>System evolution</td>
<td>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.</td>
</tr>
<tr>
<td>Appendices</td>
<td>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.</td>
</tr>
<tr>
<td>Index</td>
<td>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.</td>
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</tbody>
</table>
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

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

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

- 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 ($r_2$); the previous two readings ($r_0$ and $r_1$).

**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

<table>
<thead>
<tr>
<th>Condition</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar level falling ( (r2 &lt; r1) )</td>
<td>( \text{CompDose} = 0 )</td>
</tr>
<tr>
<td>Sugar level stable ( (r2 = r1) )</td>
<td>( \text{CompDose} = 0 )</td>
</tr>
<tr>
<td>Sugar level increasing and rate of increase decreasing ( ((r2 - r1) &lt; (r1 - r0)) )</td>
<td>( \text{CompDose} = 0 )</td>
</tr>
</tbody>
</table>
| Sugar level increasing and rate of increase stable or increasing \( ((r2 - r1) \geq (r1 - r0)) \) | \( \text{CompDose} = \text{round} \left( \frac{r2 - r1}{4} \right) \)  
  If rounded result = 0 then  
  \( \text{CompDose} = \text{MinimumDose} \) |

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 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*. 
Problems of requirements analysis

- 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.

Requirements elicitation and analysis

- 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.
The requirements elicitation and analysis process

Process activities

- Requirements discovery
  - Interacting with stakeholders to discover their requirements. Domain requirements 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.
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 change.

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.
Stakeholders in the MHC-PMS

- 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 MHC-PMS

- 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.
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 springboard question, a requirements proposal, or by working together on a prototype system.

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.
- 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.
Exercise - Context

• Some supermarket offers their customers credit cards (CC)
• A CC-approval department of this supermarket
  • receive postal and online CC applications from their customers
  • process applications and decide whether an application is approved or not
  • Issue CC or notify their customers
• An IT team is developing a computer-support system for this department
• The IT team interview staff of the department to do requirements elicitation

Exercise: Role playing games

• To make student groups of 5-6
• Students in each group play two main roles: supermarket staff and IT system analyst
• Students playing the role of system analyst interview students playing the role of staff
• Some points to consider
  • Supermarket staff may not want to honestly describe the way the process CC applications
  • What do the system analysts obtain after the interview?
Scenarios

• Scenarios are real-life examples of how a system can be used.
• They should include
  • A description of the starting situation;
  • A description of the normal flow of events;
  • A description of what can go wrong;
  • Information about other concurrent activities;
  • A description of the state when the scenario finishes.

Scenario for collecting medical history in MHC-PMS

Initial assumption: The patient has seen a medical receptionist who has created a record in the system and collected the patient’s personal information (name, address, age, etc.). A nurse is logged on to the system and is collecting medical history.

Normal: The nurse searches for the patient by family name. If there is more than one patient with the same surname, the given name (first name in English) and date of birth are used to identify the patient.

The nurse chooses the menu option to add medical history.

The nurse then follows a series of prompts from the system to enter information about consultations elsewhere on mental health problems (free text input), existing medical conditions (nurse selects conditions from menu), medication currently taken (selected from menu), allergies (free text), and home life (form).
Scenario for collecting medical history in MHC-PMS

What can go wrong: The patient’s record does not exist or cannot be found. The nurse should create a new record and record personal information.

Patient conditions or medication are not entered in the menu. The nurse should choose the ‘other’ option and enter free text describing the condition/medication.

Patient cannot/will not provide information on medical history. The nurse should enter free text recording the patient’s inability/unwillingness to provide information. The system should print the standard exclusion form stating that the lack of information may mean that treatment will be limited or delayed. This should be signed and handed to the patient.

Other activities: Record may be consulted but not edited by other staff while information is being entered.

System state on completion: User is logged on. The patient record including medical history is entered in the database, a record is added to the system log showing the start and end time of the session and the nurse involved.

Use cases

• Use-cases are a scenario based technique in the UML which 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.

• High-level graphical model supplemented by more detailed tabular description (see Chapter 5).

• 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 MHC-PMS

Ethnography

- A social scientist spends a considerable time observing and analysing how people actually work.
- People do not have to explain or articulate their work.
- Social and organisational factors of importance may be observed.
- Ethnographic studies have shown that work is usually richer and more complex than suggested by simple system models.
Scope of ethnography

• Requirements that are derived from the way that people actually work rather than the way in which process definitions suggest that they ought to work.
• Requirements that are derived from cooperation and awareness of other people’s activities.
  • Awareness of what other people are doing leads to changes in the ways in which we do things.
• Ethnography is effective for understanding existing processes but cannot identify new features that should be added to a system.

Focused ethnography

• Developed in a project studying the air traffic control process
• Combines ethnography with prototyping
• Prototype development results in unanswered questions which focus the ethnographic analysis.
• The problem with ethnography is that it studies existing practices which may have some historical basis which is no longer relevant.
Ethnography and prototyping for requirements analysis

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

• 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. Covered in Chapter 2.
• 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?
Testability

The system shall display the difference in salary between the client and the world wide average for the same trade

✗ -- can't be tested because the average mentioned cannot be determined (even though it exists).

Better:

The system shall display the difference in salary between the client and the estimated world-wide average for the same trade as published by the United Nations on its website www.... at the time of the display....

Ambiguity

The player can decide the qualities of Encounter characters.

✗ At any time? Probably not. Would have to test under all circumstances, many not intended, incurring unnecessary expense, and producing a wrong result.

Better version:

Whenever all foreign players are absent from the area containing the player's main character, the player may change the quality values of this character, keeping the sum total of the quality values unchanged. The PlayerQualityWindow, (see section 3.2.PQ) is used for this purpose. Changes take effect four seconds after the “OK” button is pressed.
Prioritizing D-requirements

• 1. Essential? [essential] Every game character has
• the same set of qualities.

• 2. Otherwise: [desirable] Each area has a set of
• preferred qualities

• 3. Optional? [optional] The player’s character shall age
• with every encounter. The age rate can be
• provided at setup time. Its default is one year
• per encounter.

Completeness

• Begin Requirements
  • The application shall display a video in stock when a title is entered at the prompt, or “OUT” when not in stock
  • The application shall display all of the store’s videos by any director whose last name is entered at the prompt.
    • 2.1 Sequencing shall be controlled by the forward arrow key.
  • The application shall display all of the store’s videos by any actor whose last name is entered at the prompt.
    • 3.1 Sequencing shall be controlled by the forward arrow key.

• End Requirements

• Incomplete: specify how to “display” a video!
Error Conditions Handling in Requirements

- Ex: How about illegal input (negative numbers, zero)?
  - A function that tells whether three numbers produce an equilateral triangle (whose sides are all equal), an isosceles triangle (containing exactly two equal sides) or a scalene triangle (a triangle which is neither equilateral nor isosceles).

- More complete:
  - A function that tells whether a triplet of numbers produces:
    - (1) an equilateral triangle (whose sides are all greater than zero and equal), in which case it outputs ‘E’ at the prompt, or
    - (2) an isosceles triangle (whose sides are greater than zero, exactly two of which are equal, and which form a triangle), in which case it outputs ‘I’ at the system, or
    - (3) a scalene triangle (whose sides are all greater than zero, which form a triangle, and which is neither equilateral nor isosceles), in which case it outputs ‘S’ at the prompt, or
    - (4) no triangle, in which case it outputs ‘N’ at the prompt.

Consistency

- Requirement 14. Only basic food staples shall be carried by game characters
- . . . . .
- Requirement 223. Every game character shall carry water.
- . . . . .
- Requirement 497. Flour, butter, milk and salt shall be considered the only basic food staples.
Write a Detailed Requirement

1. Classify requirement as functional or non-functional
   - IEEE SRS prompts for most non-functional
   - select method for organizing functional requirements

2. Size carefully
   - a functional requirement corresponds ± to a method
   - too large: hard to manage
   - too small: not worth tracking separately

3. Make trace-able if possible
   - ensure suitable for tracking through design and implementation

4. Make testable
   - sketch a specific test that establishes satisfaction

5. Make sure not ambiguous
   - ensure hard to misunderstand intention

6. Give the requirement a priority
   - e.g., highest (“essential”); lowest (“optional”); neither (“desirable”)

7. Check that requirement set complete
   - for each requirement, ensure all other necessary accompanying requirements are also present

8. Include error conditions
   - state what’s specifically required for non-nominal situations
   - include programmer errors for critical places

9. Check for consistency
   - ensure that each requirement does not contradict any aspect of any other requirement
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.

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

[Diagram showing the evolution of requirements over time]
Requirements management planning

- Establishes the level of requirements management detail that is required.
- Requirements management decisions:
  - 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. I discuss this process in more detail in the following section.
  - 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

Summary

• Requirements for a software system set out what the system should do and define constraints on its operation and implementation.

• Functional requirements are statements of the services that the system must provide or are descriptions of how some computations must be carried out.

• Non-functional requirements often constrain the system being developed and the development process being used.

• They often relate to the emergent properties of the system and therefore apply to the system as a whole.
Summary (cont.)

• The software requirements document is an agreed statement of the system requirements. It should be organized so that both system customers and software developers can use it.

• The requirements engineering process is an iterative process including requirements elicitation, specification and validation.

• Requirements elicitation and analysis is an iterative process that can be represented as a spiral of activities – requirements discovery, requirements classification and organization, requirements negotiation and requirements documentation.

Summary (cont.)

• You can use a range of techniques for requirements elicitation including interviews, scenarios, use-cases and ethnography.

• Requirements validation is the process of checking the requirements for validity, consistency, completeness, realism and verifiability.

• Business, organizational and technical changes inevitably lead to changes to the requirements for a software system. Requirements management is the process of managing and controlling these changes.