Schedule of Lectures

Week 01: Introduction to SE
Week 02: Requirements Engineering I
**Week 03: Requirements Engineering II**
Week 04: Analysis
Week 05: Development Infrastructure I
Week 06: Development Infrastructure II
Week 07: Architecture and Design
Week 08: No lecture
Week 09: Refactoring
Week 10: Verification and Validation I
Week 11: Verification and Validation II
Week 12: Agile/Lean Methods
Week 13: Software Quality Management
Week 14: no lecture
Week 15: Measurement / Course wrap-up, review and exam preparation
Week 16: no lecture
Labs Next Week

Make sure you submit your Lab 1 solution on time via your team project wiki on Bitbucket!

(double-check YOUR submission deadline: it’s at midnight before your lab takes place)

Penalties apply for late submission!
No exceptions will be allowed!
Labs Next Week

Lab 2 Assignment:
1. Project Planning
   - Refinement of requirements into Tasks
   - Prioritization of Tasks (P1, P2, P3, P4)
   - Responsibility assignment
   - Effort estimation
2. Five Use Case Descriptions
3. (Initial) Domain Model
Goal of this Lecture:
To give answers to the following questions …

What is ‘Requirements Engineering’?

Why is RE important?

Why is RE difficult?

Who is involved in RE?

What are ‘Requirements’?

What types of requirements exist?

What levels of requirements exist?

What process steps are involved in RE?

How to get started with RE?

How to elicit requirements?

How to represent/document requirements?

How to use requirements for project planning?
requirement spec. styles

- natural language (plus supporting tables and graphs)
- structured natural language / scenarios
  - e.g., use case descriptions, user stories, CRC cards, ...
- semi-formal notations
  - e.g., UML diagrams (use case diagrams, class diagrams, state diagram, sequence charts, etc.)
- formal notations (with formal semantics)
  - e.g., abstract model-based (VDM, Larch, B, ...) or algebraic (OBJ, OBJ, ACT-ONE, ...)

not covered in this course
Where do we want to take you? (by the end of this course)

Sample student software projects (Fall 2015)

- https://github.com/vladislavivanistsev/SuperCap/
- https://github.com/alajal/license-management/
Example: Home Access Control

Objective: Design an electronic system for:

- Home access control
- Locks and lighting operation
- Intrusion detection and warning

Please read: Ch 1.2 / 1.3.1 / 2.2
Ivan Marsic: Software Engineering, 2012
(http://www.ece.rutgers.edu/~marsic/books/SE/book-SE_marsic.pdf)
### Example NL Requirements

<table>
<thead>
<tr>
<th>Identifier</th>
<th>Priority</th>
<th>Requirement</th>
</tr>
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<tbody>
<tr>
<td>REQ1</td>
<td>5</td>
<td>The system shall keep the door locked at all times, unless commanded otherwise by authorized user. When the lock is disarmed, a countdown shall be initiated at the end of which the lock shall be automatically armed (if still disarmed).</td>
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*’shall’: mandatory (?)*

*’should’: optional (?)*
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"Compound" REQ: How test it?

Test?
Example NL Requirements

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'Compound' REQ: How test it?

For REQ3, the customer may suggest these test cases:
- Test with the valid key of a current tenant on his or her apartment (pass)
- Test with the valid key of a current tenant on someone else’s apartment (fail)
- Test with an invalid key on any apartment (fail)
- Test with the key of a removed tenant on his or her previous apartment (fail)
- Test with the valid key of a just-added tenant on his or her apartment (pass)
User Stories

As a tenant, I can unlock the doors to enter my apartment.

• Similar to NL requirements, but focus on the user benefits, instead on system characteristics (alone).

• Preferred tool in agile methods.
NL Requirements vs. User Stories

Traditional requirement – “shall” statements:

• “The system shall provide a user configurable interface for all user and system manager functions”

• “The user interface shall be configurable in the areas of:
  • Screen layout
  • Font
  • Background and text color

Corresponding “User Story”:

• “As a system user or system manager, …

• … I want to be able to configure the user interface for screen layout, font, background color, and text color, …

• … so that I can use the system in the most efficient manner”

who - what - why
## Example User Stories

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<tr>
<th>Identifier</th>
<th>User Story</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST-1</td>
<td>As an authorized person (tenant or landlord), I can keep the doors locked at all times. (... so I am safe)</td>
</tr>
<tr>
<td>ST-2</td>
<td>As an authorized person (tenant or landlord), I want the lock to be automatically locked after a defined period of time.</td>
</tr>
<tr>
<td>ST-3</td>
<td>As an authorized person (tenant or landlord), I can lock the doors on demand.</td>
</tr>
<tr>
<td>ST-4</td>
<td>As an authorized person (tenant or landlord), I can unlock the doors. <em>(Test: Allow a small number of mistakes, say three.</em>)</td>
</tr>
<tr>
<td>ST-5</td>
<td>As a landlord, I can at runtime manage authorized persons.</td>
</tr>
<tr>
<td>ST-6</td>
<td>As an authorized person (tenant or landlord), I can view past accesses.</td>
</tr>
<tr>
<td>ST-7</td>
<td>As a tenant, I can configure the preferences for activation of various devices.</td>
</tr>
<tr>
<td>ST-8</td>
<td>As a tenant, I can file complaint about “suspicious” accesses.</td>
</tr>
</tbody>
</table>

Note: 'Why' part is missing in the examples above.
INVEST Principles

<Actor/Role> As a user

... 

<Action> I want to narrow down people search results by location

... 

<Value> so I can find the right person more quickly

A good User Story is:
- Independent
- Negotiable
- Valuable
- Estimable
- Small
- Testable

INVEST
User Story and Acceptance Tests

<Actor/Role> As a user

... 

<Action> I want to narrow down people search results by location 

... 

<Value> so I can find the right person more quickly 

Acceptance test:

Given I am on the search screen
And 'Paula' is on the same indexed page with 'Tartu'

When I search for 'Paula'

Then I see 'Tartu' in the location section of the search results
Time Estimation with User Story Points

- Points assigned to individual user stories
- Total work size estimate:

\[
\text{Total size} = \sum \text{points-for-story}_i \quad (i = 1..N)
\]

- Velocity (= Productivity) estimated from experience
- Estimate the work duration:

\[
\text{Project duration} = \frac{\text{Total size}}{\text{Velocity}} \quad \text{[time unit]}
\]
## Example User Stories

<table>
<thead>
<tr>
<th>Identifier</th>
<th>User Story</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST-1</td>
<td>...</td>
<td>4 points</td>
</tr>
<tr>
<td>ST-2</td>
<td>...</td>
<td>3 pts</td>
</tr>
<tr>
<td>ST-3</td>
<td>...</td>
<td>6 pts</td>
</tr>
<tr>
<td>ST-4</td>
<td>...</td>
<td>9 pts</td>
</tr>
<tr>
<td>ST-5</td>
<td>...</td>
<td>10 pts</td>
</tr>
<tr>
<td>ST-6</td>
<td>...</td>
<td>6 pts</td>
</tr>
<tr>
<td>ST-7</td>
<td>...</td>
<td>6 pts</td>
</tr>
<tr>
<td>ST-8</td>
<td>...</td>
<td>6 pts</td>
</tr>
</tbody>
</table>

Sum: 50 User Story Points (USP)

Team: 3 persons

How long will it take?
Example Estimation

- Points assigned to individual user stories: 8 User Stories
- Total work size estimate:
  \[ \text{Total size} = \sum \text{points-for-story} \ i \quad (i = 1..N) \]
- Velocity (= Productivity) estimated from experience
- Estimate the work duration:

\[
\text{Project duration} = \frac{\text{Total size}}{\text{Velocity}} \quad \text{[time unit]}
\]

- 50 US Points
- Average Team Size: 6 persons
- Average Project Size: 600 USPs
- Average Project Duration: 30 days
- Average Velocity (6 pers): 20 USP/day
  \[ = 3.33 \text{ USP/person-day} \]

- 50 US Points & 3 Pers. Team:
  Duration: \( \frac{50}{(3 \times 3.33)} = 5 \text{ days} \)
Agile Project Estimation/Planning

Work backlog

1) ST-4: Unlock 2.7 day (9pts)
2) ST-2: Auto-Lock 0.9 day (3pts)
3) ST-1: Keep locked 1.2 day (4pts)
4) ST-5: Manage Users 3 day (10pts)
5) ST-6: View History 1.8 day (6pts)

Estimated work duration

assumes that 1 person works fulltime on this task without interruption

Items pulled by the team into an iteration

Priority

Work items

List prioritized by the customer

Time

1st iteration
2nd iteration
n-th iteration

Estimated completion date

5 days (40 hours)
20 days
Use Case Diagrams and Descriptions

Use Case Description:
Name of Use Case
Actors associated with Use Case
Pre-conditions
Post-conditions
Normal Flow of Events (Basic Scenario)
Alternative Flow of Events (Alternative Scenarios)
...

Use Case Model

Actors

Use Cases

Use-Case Descriptions
Use Cases

• For Functional Requirements Analysis and Specification

• A use case is a description of how a user will use the system-to-be to achieve business goals

  • Detailed use cases are usually written as usage scenarios or scripts, listing a specific sequence of actions and interactions between the actors and the system
Scenarios

• Scenario = real-life example of how a system can be used

• They should include
  • A description of the starting situation (state)
  • 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
Identifying Actors

• **Ask the following questions:**
  - Who will be a primary user of the system? (primary actor)
  - Who will need support from the system to do her daily tasks?
  - Who will maintain, administrate, keep the system working? (secondary actor)
  - Which hardware devices does the system need?
  - With which other systems does the system need to interact with?
  - Who or what has an interest in the results that the system produces?

• **Look for:**
  - the users who directly use the system
  - also others who need services from the system
Finding Use Cases

- For each actor, ask the following questions:
  - Which functions does the actor require from the system?
  - What does the actor need to do?
  - Does the actor need to read, create, destroy, modify, or store some kinds of information in the system?
  - Does the actor have to be notified about events in the system?
  - Does the actor need to notify the system about something?
  - What do those events require in terms of system functionality?
  - Could the actor’s daily work be simplified or made more efficient through new functions provided by the system?
Deriving Use Cases from System Requirements

REQ1: Keep door locked and auto-lock
REQ2: Lock when "LOCK" pressed
REQ3: Unlock when valid key provided
REQ4: Allow mistakes but prevent dictionary attacks
REQ5: Maintain a history log
REQ6: Adding/removing users at runtime
REQ7: Configuring the device activation preferences
REQ8: Inspecting the access history
REQ9: Filing inquiries

<table>
<thead>
<tr>
<th>Actor</th>
<th>Actor's Goal (what the actor intends to accomplish)</th>
<th>Use Case Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landlord</td>
<td>To disarm the lock and enter, and get space lighted up.</td>
<td>Unlock (UC-1)</td>
</tr>
<tr>
<td>Landlord</td>
<td>To lock the door &amp; shut the lights (sometimes?).</td>
<td>Lock (UC-2)</td>
</tr>
<tr>
<td>Landlord</td>
<td>To create a new user account and allow access to home.</td>
<td>AddUser (UC-3)</td>
</tr>
<tr>
<td>Landlord</td>
<td>To retire an existing user account and disable access.</td>
<td>RemoveUser (UC-4)</td>
</tr>
<tr>
<td>Tenant</td>
<td>To find out who accessed the home in a given interval of time and potentially file complaints.</td>
<td>InspectAccessHistory (UC-5)</td>
</tr>
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<td>To disarm the lock and enter, and get space lighted up.</td>
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<tr>
<td>Tenant</td>
<td>To configure the device activation preferences.</td>
<td>SetDevicePrefs (UC-6)</td>
</tr>
<tr>
<td>LockDevice</td>
<td>To control the physical lock mechanism.</td>
<td>UC-1, UC-2</td>
</tr>
<tr>
<td>LightSwitch</td>
<td>To control the lightbulb.</td>
<td>UC-1, UC-2</td>
</tr>
<tr>
<td>[to be identified]</td>
<td>To auto-lock the door if it is left unlocked for a given interval of time.</td>
<td>AutoLock (UC-2)</td>
</tr>
</tbody>
</table>

(Actors are often given, if working from user stories instead of ‘shall/should’-statements.)
### Traceability Matrix

Mapping: System requirements to Use cases

**Purpose:**
- Check all REQs are covered by Ucs
- Check no UC is added that doesn’t have a REQ
- Prioritize UCs

**PW = Priority Weight**

<table>
<thead>
<tr>
<th>Req’t</th>
<th>PW</th>
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<th>UC3</th>
<th>UC4</th>
<th>UC5</th>
<th>UC6</th>
<th>UC7</th>
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<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REQ2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>REQ3</td>
<td>5</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
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<td>REQ4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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</tr>
<tr>
<td>REQ5</td>
<td>2</td>
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<td>REQ6</td>
<td>1</td>
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<td>REQ9</td>
<td>1</td>
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Max PW: 5 5 1 1 1 2 5 2
Total PW: 16 9 1 1 2 2 9 5
Use Case Diagrams and Descriptions

Use Case Description:
Name of Use Case
Actors associated with Use Case
Pre-conditions
Post-conditions
Normal Flow of Events (Basic Scenario)
Alternative Flow of Events (Alternative Scenarios)
…
### Schema for Detailed Use Cases

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<th>Name / Identifier</th>
<th>[verb phrase]</th>
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<tbody>
<tr>
<td>Related Requirements</td>
<td>List of the requirements that are addressed by this use case</td>
<td></td>
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<tr>
<td>Initiating Actor</td>
<td>Actor who initiates interaction with the system to accomplish a goal</td>
<td></td>
</tr>
<tr>
<td>Actor's Goal</td>
<td>Informal description of the initiating actor's goal</td>
<td></td>
</tr>
<tr>
<td>Participating Actors</td>
<td>Actors that will help achieve the goal or need to know about the outcome</td>
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</tr>
<tr>
<td>Preconditions</td>
<td>What is assumed about the state of the system before the interaction starts</td>
<td></td>
</tr>
<tr>
<td>Postconditions</td>
<td>What are the results after the goal is achieved or abandoned; i.e., what must be true about the system at the time the execution of this use case is completed</td>
<td></td>
</tr>
</tbody>
</table>

**Flow of Events for Main Success Scenario:**

1. The initiating actor delivers an action or stimulus to the system (the arrow indicates the direction of interaction, to- or from the system)
2. The system's reaction or response to the stimulus; the system can also send a message to a participating actor, if any
3. ...

**Flow of Events for Extensions (Alternate Scenarios):**

What could go wrong? List the exceptions to the routine and describe how they are handled

1a. For example, actor enters invalid data
2a. For example, power outage, network failure, or requested data unavailable
...

The arrows on the left indicate the direction of interaction: → Actor's action; ← System's reaction
Use Case 1: Unlock

<table>
<thead>
<tr>
<th>Use Case UC-1:</th>
<th>Unlock</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Related Requirem’ts:</strong></td>
<td>REQ1, REQ3, REQ4, and REQ5</td>
</tr>
<tr>
<td><strong>Initiating Actor:</strong></td>
<td>Any of: Tenant, Landlord</td>
</tr>
<tr>
<td><strong>Actor’s Goal:</strong></td>
<td>To disarm the lock and enter, and get space lighted up automatically.</td>
</tr>
<tr>
<td><strong>Participating Actors:</strong></td>
<td>LockDevice, LightSwitch, Timer</td>
</tr>
<tr>
<td><strong>Preconditions:</strong></td>
<td>• The set of valid keys stored in the system database is non-empty. • The system displays the menu of available functions; at the door keypad the menu choices are “Lock” and “Unlock.”</td>
</tr>
<tr>
<td><strong>Postconditions:</strong></td>
<td>The auto-lock timer has started countdown from autoLockInterval.</td>
</tr>
</tbody>
</table>

**Flow of Events for Main Success Scenario:**

→ 1. **Tenant/Landlord** arrives at the door and selects the menu item “Unlock”
   2. include::AuthenticateUser (UC-7)

← 3. **System** (a) signals to the **Tenant/Landlord** the lock status, e.g., “disarmed,” (b) signals to **LockDevice** to disarm the lock, and (c) signals to **LightSwitch** to turn the light on

← 4. **System** signals to the **Timer** to start the auto-lock timer countdown

→ 5. **Tenant/Landlord** opens the door, enters the home [and shuts the door and locks]
Subroutine «include» UC-7

<table>
<thead>
<tr>
<th>Use Case UC-7:</th>
<th>AuthenticateUser (sub-use case)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Related Requirements:</strong></td>
<td>REQ3, REQ4</td>
</tr>
<tr>
<td><strong>Initiating Actor:</strong></td>
<td>Any of: Tenant, Landlord</td>
</tr>
<tr>
<td><strong>Actor’s Goal:</strong></td>
<td>To be positively identified by the system (at the door interface).</td>
</tr>
<tr>
<td><strong>Participating Actors:</strong></td>
<td>AlarmBell, Police</td>
</tr>
<tr>
<td><strong>Preconditions:</strong></td>
<td>• The set of valid keys stored in the system database is non-empty.</td>
</tr>
<tr>
<td></td>
<td>• The counter of authentication attempts equals zero.</td>
</tr>
<tr>
<td><strong>Postconditions:</strong></td>
<td>None worth mentioning.</td>
</tr>
</tbody>
</table>

**Flow of Events for Main Success Scenario:**

1. **System** prompts the actor for identification, e.g., alphanumeric key
2. **Tenant/Landlord** supplies a valid identification key
3. **System** (a) verifies that the key is valid, and (b) signals to the actor the key validity

**Flow of Events for Extensions (Alternate Scenarios):**

2a. **Tenant/Landlord** enters an invalid identification key
1. **System** (a) detects error, (b) marks a failed attempt, and (c) signals to the actor

   System (a) detects that the count of failed attempts exceeds the maximum allowed number, (b) signals to sound **AlarmBell**, and (c) notifies the **Police** actor of a possible break-in

2. **Tenant/Landlord** supplies a valid identification key
3. Same as in Step 3 above
Use Case Diagram: Device Control

First tier use cases

- UC1: Unlock
- UC2: Lock

Second tier use cases

- UC7: AuthenticateUser
- UC8: Login
- UC3: AddUser
- UC4: RemoveUser
- UC5: InspectAccessHistory
- UC6: SetDevicePrefs

System boundary

Actor:
- Tenant
- Landlord

Communication:
- Timer
- LightSwitch
- LockDevice
Use Case Diagram: Account Management

UC1: Unlock
UC2: Lock
UC3: AddUser
UC4: RemoveUser
UC5: InspectAccessHistory
UC6: SetDevicePrefs
UC7: AuthenticateUser
UC8: Login

Account Management Subsystem

Tenant

UC3: AddUser

UC4: RemoveUser

UC5: InspectAccessHistory

UC6: SetDevicePrefs

Landlord

UC8: Login
‘Login’ Use Case?

Novice developers frequently identify user login as a use case. Expert developers argue that login is not a use case in its own right.

Recall that use case is motivated by user’s goal; The user initiates interaction with the system to achieve a certain goal. You are not logging in for the sake of logging in—you are logging in to do some work, and this work is your use case.
Next Lecture

• Date/Time:
  • Friday, 23 Sep, 10:15-12:00

• Topic:
  • Analysis (Domain Modeling)

• For you to do:
  • Make sure you submit your Lab Task1 solution on time (double-check submission deadlines!)
  • Go to next lab → Second Assignment
Acknowledgements

Textbooks/Slides:
