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Lecture 2: Requirements and Specifications

Or: How do we decide what to build?

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Easter Term

The Danger of Perfection

"There is nothing quite so useless as doing with great efficiency something that should not be done at all."
– Peter Drucker

- Engineers love solving technical puzzles.
- Building a perfectly secure, infinitely scalable system is worthless if it doesn't solve the user's actual problem.
- We must separate the *Problem Space* from the *Solution Space*.

The Business Goals (The "Why")

The Problem Space

- Why are we funding this project?
- Example: "Our current warehouse packing process is too slow, causing delayed shipments and unhappy customers."
- The "Why" is purely focused on business value, user needs, and market realities. It is technology-agnostic.

The Technical Implementation (The "What")

The Solution Space

- What are we going to build to solve the "Why"?
- Example: "We will build a tablet-based barcode scanning app that calculates optimal walking routes for warehouse staff."
- The "What" introduces technology, architecture, and engineering constraints.

The Translation Gap

Bridging the Divide

- Stakeholders (business owners, clients) know the "Why", but often speak in vague, contradictory terms.
- Engineers know the "How", but often lack domain expertise in the client's business.
- **Requirements Engineering** is the formal process of bridging this gap.

Requirements Elicitation: Interviews

How do we find out what they want?

- **Interviews:** Sitting down with stakeholders.
- *Pros:* Good for initial scoping and understanding high-level business goals.
- *Cons:* Users often don't know what they actually want, or they describe a solution instead of their problem.
- "If I had asked people what they wanted, they would have said faster horses." – (Apocryphally attributed to Henry Ford)

Requirements Elicitation: Ethnography

Watching Users Work

- **Ethnography / Observation:** Embedding yourself in the user's environment.
- Why is this powerful? Users develop invisible workarounds.
- Example: You notice a nurse has a sticky note with passwords on her monitor because the current login system logs her out too fast.
- She wouldn't mention this in an interview because she considers it "normal."

The Problem with Natural Language

Ambiguity is the enemy of engineering.

- Human language is naturally ambiguous, context-dependent, and imprecise.
- Code is binary, deterministic, and merciless.
- If a requirement is ambiguous, the programmer will unconsciously make an assumption to fill the gap. That assumption is usually wrong.

Example: The Vague Requirement

Bad Requirement

"The search system should be fast and easy to use."

Why is this bad?

- What does "fast" mean? 100 milliseconds? 2 seconds?
- What does "easy to use" mean? How do you test that?
- If the client rejects the software saying "it's too slow," you have no contractual defense.

Example: The Testable Requirement

Good Requirement

"The system shall return search results for a database of 1 million records in under 500 milliseconds for 95% of queries under normal load."

Why is this good?

- It is quantifiable.
- It is testable (you can write an automated script to verify this).
- It sets a clear boundary for "done".

The Cost of Late Fixes

Boehm's Curve

- Fixing a misunderstood requirement during the *design phase* costs 1x.
- Fixing it during *coding* costs 5x.
- Fixing it during *testing* costs 10x.
- Fixing it *after deployment* (in production) costs 100x+.

Measure twice, cut once.

Defining Functional Requirements (FRs)

Functional Requirement

A statement of a specific action or behaviour the system must perform. It describes **what** the system should do.

- Think of these as the verbs of your system.
- They define the direct inputs, processing, and outputs.
- If the system doesn't do this, it is fundamentally broken.

Examples: Functional Requirements

Context: An E-Commerce Website

- "The system shall allow a user to add an item to a digital shopping cart."
- "The system shall calculate the total cost of items in the cart, including VAT."
- "The system shall send a confirmation email to the user upon successful payment."

Defining Non-Functional Requirements (NFRs)

Non-Functional Requirement

A constraint on the operation of the system. It describes **how well** the system should perform its functions.

- Think of these as the adjectives or adverbs of your system.
- They define quality attributes, performance bounds, and architectural constraints.
- Crucially, NFRs often dictate the architecture of the entire system.

The "-ilities" (NFR Categories)

NFRs are often colloquially referred to as the "-ilities":

- **Scalability:** Can it handle 10x the users?
- **Reliability:** How often does it crash?
- **Maintainability:** How hard is it to update the code?
- **Portability:** Can we move it from AWS to Google Cloud?
- **Usability:** Can a novice learn it in 5 minutes?

Performance Metrics as NFRs

Latency vs. Throughput

- **Latency:** How long does one operation take? (e.g., "Page load time must be < 2s").
- **Throughput:** How many operations can happen at once? (e.g., "System must process 5,000 transactions per second").
- You often have to design differently to optimize for one over the other.

Security as an NFR

Constraints on Data and Access

- Security is almost always an NFR, but it generates functional requirements.
- *NFR:* "The system must comply with GDPR data protection laws."
- *Resulting FR:* "The system shall provide a button for the user to delete their account and all associated data."

Usability as an NFR

Constraints on Human Interaction

- Usability metrics must be specific to be useful.
- "The system must be intuitive" is meaningless.
- "A new warehouse employee must be able to successfully scan and dispatch a package with less than 15 minutes of training." (Testable).

The Reality of Trade-offs

You cannot have it all.

- NFRs constantly fight each other. Engineering is the art of balancing them.
- **Security vs. Usability:** A 24-character password requirement with 2FA is highly secure, but terrible for user usability.
- **Performance vs. Maintainability:** Writing core logic in hand-optimized Assembly language improves performance, but destroys maintainability.

Documenting NFRs Testably

Fit Criteria Every NFR must have a "fit criterion"—a measurement to prove it was met.

- **Scale:** "Supports 10,000 concurrent websocket connections."
- **Availability:** "99.99% uptime per month (allows for $\approx$ 4.3 minutes of downtime)."
- **Accessibility:** "Complies with WCAG 2.1 AA standards for screen readers."

Class Exercise

Functional

or

Non-Functional?

Class Exercise: Q1

Context: University Library System

"The system shall allow a student to reserve a book that is currently checked out."

Class Exercise: Q1

Context: University Library System

"The system shall allow a student to reserve a book that is currently checked out."

Answer: Functional Requirement. (It describes a specific action the system performs).

Class Exercise: Q2

Context: University Library System

"The search functionality must return results in under 2 seconds, even with 500 concurrent users."

Class Exercise: Q2

Context: University Library System

"The search functionality must return results in under 2 seconds, even with 500 concurrent users."

Answer: Non-Functional Requirement. (Performance/Scalability constraint).

Class Exercise: Q3

Context: University Library System

"Database passwords must be stored using bcrypt hashing with a salt factor of 12."

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Context: University Library System

"Database passwords must be stored using bcrypt hashing with a salt factor of 12."

Answer: Non-Functional Requirement. (Implementation/Security constraint).

Why do we model?

The Power of Abstraction

- You cannot show a stakeholder 10,000 lines of Java code to explain how the system works.
- We use models to abstract away complexity and communicate architecture clearly.
- A good model hides exactly enough detail to make the core concept understandable.

Introduction to UML

Unified Modeling Language (UML)

- Developed in the 1990s as a standardized way to visualize system design.
- Contains 14 different diagram types (e.g., Use Case, Class, Sequence, State Machine).
- Historically, companies tried to generate entire codebases directly from highly detailed UML diagrams. (This largely failed).

Modern UML: Sketches vs. Blueprints

How we use UML today

- **As Blueprints:** Rarely used today. This means defining every single method, variable, and type before coding. Too rigid.
- **As Sketches:** The modern approach. Engineers use informal UML on whiteboards to explain architectural concepts, ignoring strict syntax rules in favor of speed and clarity.

Class Diagrams: Static Structure

Class Diagram

Shows the static structure of a system by outlining its classes, their attributes, operations (methods), and the relationships among objects.

- The backbone of Object-Oriented Design.
- Shows *what* exists in the system, not *when* things happen.

Class Diagrams: The Box

Anatomy of a Class Node

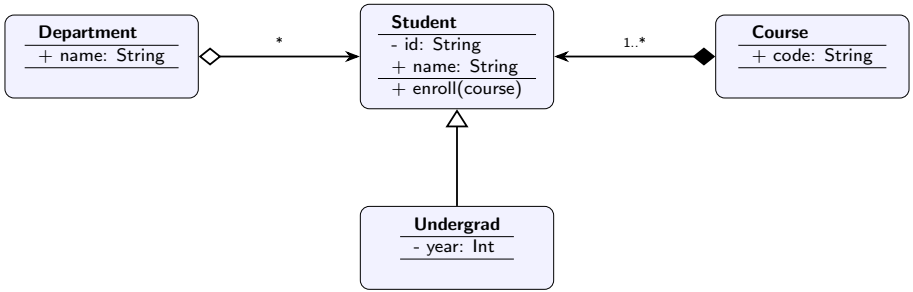
- **Top Compartment:** Class Name (e.g., `Customer`).
- **Middle Compartment:** Attributes / Variables (e.g., `+ email: String`).
- **Bottom Compartment:** Methods / Operations (e.g., `+ verifyPassword(pwd): Boolean`).
- *Visibility modifiers:* + (Public), – (Private), # (Protected).

Class Diagrams: Relationships

How classes interact

- **Association:** A general connection (Line).
- **Inheritance:** "Is-a" relationship (Arrow with hollow triangle). E.g., `Undergrad` inherits from `Student`.
- **Aggregation:** "Has-a" relationship (Hollow diamond). E.g., `Department` has `Professors`.
- **Composition:** Strict "Has-a" relationship where the child dies if the parent dies (Solid diamond). E.g., `Building` has `Rooms`.

Class Diagram: Visual Structure



Example: University Management System

Sequence Diagrams: Dynamic Behavior

Sequence Diagram

An interaction diagram that shows how processes operate with one another and in what order.

- Focuses on the message flow over time.
- Excellent for modeling network calls, API interactions, and authentication flows.

Sequence Diagrams: Components

Anatomy of a Sequence Diagram

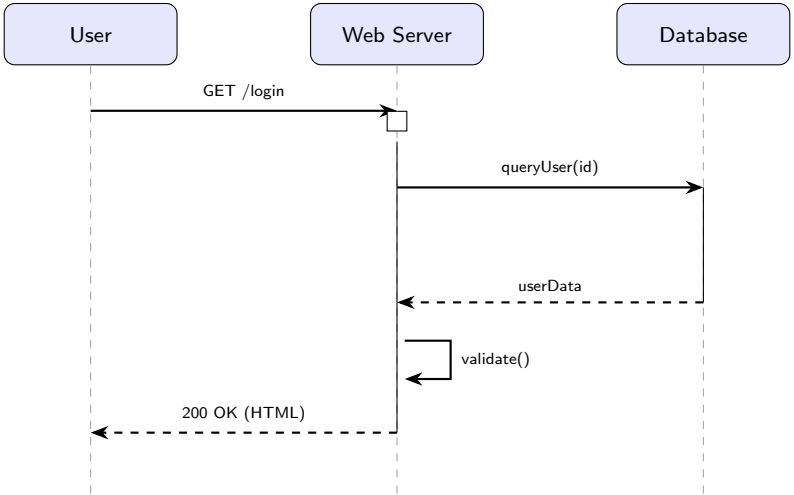
- **Lifelines:** Vertical dashed lines representing the lifespan of an object or actor.
- **Messages:** Horizontal arrows passing between lifelines (e.g., `HTTP GET /login`).
- Time flows from top to bottom.

Sequence Diagrams: Activation

Showing Processing Time

- **Activation Boxes:** Thin rectangles on lifelines indicating that an object is actively processing a task.
- **Return Messages:** Dashed arrows indicating a response (e.g., `200 OK` or a JSON payload).
- Perfect for mapping out asynchronous behavior or database queries.

Sequence Diagram: Visual Flow



Example: User Login Authentication Flow

When to use which diagram?

Use the right tool for the job.

- Need to show the database schema and entity relationships? → **Class Diagram**.
- Need to show how OAuth2 login works between the user, your server, and Google? → **Sequence Diagram**.
- Need to show what states a shopping cart can be in (Empty, Active, CheckedOut)? → **State Machine Diagram**.

Anti-pattern: Over-engineering Models

Beware of Analysis Paralysis

- Spending 3 weeks making the perfect UML diagram in Visio is usually a waste of time.
- By the time you finish the diagram, the requirements will have changed.
- **Rule of thumb:** If the diagram fits on a whiteboard and the team understands it, it is good enough. Start coding.

The Product Manager (PM)

Who manages the requirements?

- In modern software companies, requirements are driven by **Product Managers** (PMs).
- They are the intersection of Business, UX, and Technology.
- They own the "Why" and the "What". Engineers own the "How".

PM: Voice of the Customer

The PM's Responsibility

- Conduct user research and interviews.
- Analyze market trends and competitor software.
- Shield the engineering team from changing business whims by filtering requests.
- Prioritize features to maximize business value.

PM vs. Engineering Manager (EM)

A crucial distinction in industry

- **Product Manager (PM):** Decides that we need to build a new payment gateway to capture European customers. (Focuses on product value).
- **Engineering Manager (EM):** Decides which engineers will build it, oversees the code architecture, and manages the career growth of the developers. (Focuses on technical execution and team health).

Prioritization

We can't build everything.

- Stakeholders will always want 100 features. The budget only allows for 20.
- PMs and Engineers must work together to prioritize requirements.
- We need structured frameworks to avoid prioritizing based on "who shouts the loudest."

The MoSCoW Method

A common prioritization framework:

- **Must have:** The product is completely unviable without this. (e.g., Login system).
- **Should have:** Highly important, but we can launch a V1 without it if absolutely necessary. (e.g., Password reset email).
- **Could have:** Nice to have if we finish early. (e.g., Dark mode).
- **Won't have:** Out of scope for this release. Let's not talk about it right now.

The Product Requirements Document (PRD)

The Source of Truth

- The PRD is a living document (often in Confluence or Google Docs) authored by the PM.
- It contains the background, business goals, user personas, and the list of Functional and Non-Functional Requirements.
- Engineers read the PRD to understand what to build.

Requirement Traceability

How do we know we built what we promised?

- **Traceability:** The ability to trace a requirement from its origin (PRD) to its implementation (Code) to its verification (Test).
- Example: Requirement #42 $\rightarrow$ Pull Request #105 $\rightarrow$ Integration Test `test_req_42()`.
- Highly regulated industries (aviation, medical) require strict Traceability Matrices.

Summary of Lecture 2

- Understand the "Why" before designing the "What".
- Ambiguous requirements are the root of most software project failures.
- **Functional Requirements** are actions (verbs); **Non-Functional Requirements** are constraints and qualities (adverbs).
- Use UML (Class and Sequence diagrams) as whiteboard sketches to communicate architecture.
- PMs manage requirements; Engineers execute them.