

Intelligent Software Engineering

Requirements Engineering

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September 29, 2025



Outline

- 1 Introduction
- 2 Assisting Requirements Engineering with LLM
- 3 Bridging RE and Prompt Engineering
- 4 Use Case Example with PlantUML
- 5 Requirements Specification
- 6 Best Practices and Methodology
- 7 Conclusion and Future Directions



Definition of Requirements Engineering

Requirements engineering is an interdisciplinary function that mediates between the domains of the acquirer and supplier or developer to establish and maintain the requirements to be met by the system, software or service of interest. Requirements engineering is concerned with discovering, eliciting, developing, analyzing, verifying (including verification methods and strategy), validating, communicating, documenting and managing requirements¹.

¹ISO/IEC/IEEE 29148 Systems and software engineering —Life cycle processes – Requirements engineering ▶



As Proposed by the Project Sponsor



As Specified in the Project Request



As Designed by the Senior Systems Analyst



As Produced by the Programmers



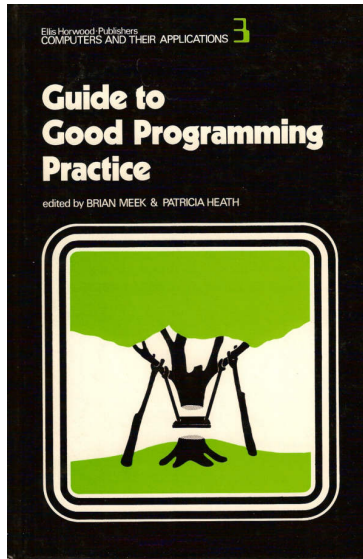
As Installed at the User's Site



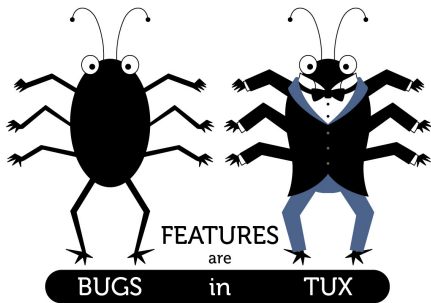
What The User Wanted



Guide to Good Programming Practice, 1979



bug or feature?




The First Computer Bug

Photo # NH 96566-KN (Color) First Computer "Bug", 1947

9/9

0800 Antan started
 1000 " stopped - antan ✓ { 1.2700 9.037 897 025
 13.02 (032) MP - MC 1.926 9.037 896 995 convt
 (033) PRO 2 2.13047645 9.615925059(-2)
 convt 2.13047645
 Relays 6-2 in 033 failed speed test
 in relay " 11,000 test. Relay
3145
Relay 3370

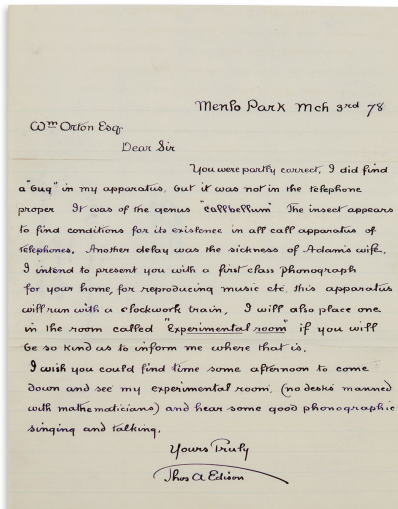
1100 Started Cosine Tape (Sine check)
 1525 Started Multi-Adder Test.

1545  Relay #70 Panel F
 (Math) in relay.

First actual case of bug being found.
 1630 Antan started.
 1700 closed down.



The First Computer Bug



Combo in Fighting Games was originally a Bug

Combos were a design accident; lead producer Noritaka Funamizu noticed that extra strikes were possible during a bug check on the car-smashing bonus stage. He thought that the timing required was too difficult to make it a useful game feature, but left it in as a hidden one².



Figure 1: Street Fighter 2

²[https://en.wikipedia.org/wiki/Combo_\(video_games\)](https://en.wikipedia.org/wiki/Combo_(video_games))



Hidden Features aka Easter Egg



Figure 2: The Konami Code

Finding the game too difficult to play through during testing, he (Konami developer) created the cheat code, which gives the player a full set of power-ups... The code was meant to be removed prior to publishing, but this was overlooked and only discovered as the game was being prepared for mass production. The developers decided to leave it there, as removing it could result in new bugs and glitches³.

³https://en.wikipedia.org/wiki/Konami_Code



Hidden Features aka Easter Egg



Figure 2: The Konami Code



Finding the game too difficult to play through during testing, he (Konami developer) created the cheat code, which gives the player a full set of power-ups... The code was meant to be removed prior to publishing, but this was overlooked and only discovered as the game was being prepared for mass production. The developers decided to leave it there, as removing it could result in new bugs and glitches³.

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Be Careful with Putting Easter Egg in Software

Why does man print "gimme gimme gimme" at 00:30?

Asked 7 years, 10 months ago Modified 30 days ago Viewed 563k times

2011

We've noticed that some of our automatic tests fail when they run at 00:30 but work fine the rest of the day. They fail with the message

```
gimme gimme gimme
```

in `stderr`, which wasn't expected. Why are we getting this output?

date man

Share Improve this question Follow

edited Jul 15, 2021 at 10:55
Admin AdminBee
user 23.8k 25 54 77

asked Nov 20, 2017 at 14:19
Jaroslav Kucera
38.9k 5 17 30

(a) Test Failure due to man

2672

Dear @colmacuati, I think that if you type "man" at 0001 hours it should print "gimme gimme gimme". #abba
#manamanel - 3 November 2011

er, that was my fault, I suggested it. Sorry.

1000

Pretty much the whole story is in the commit. The maintainer of man is a good friend of mine, and one day six years ago I jokingly said to him that if you invoke man after midnight it should print "gimme gimme gimme", because of the Abba song called "Gimme gimme gimme a man after midnight".

Well, he did actually [put it in](#). A few people were amused to discover it, and we mostly forgot about it until today.

(b) The Root Cause

Figure 3: Bug Caused by an Easter Egg



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What is Requirements Engineering?

Definition

Requirements Engineering (RE) is the process of defining, documenting, and maintaining requirements in the engineering design process.

- **Elicitation:** Discovering requirements from stakeholders
- **Analysis:** Refining and modeling requirements
- **Specification:** Documenting requirements unambiguously
- **Validation:** Ensuring requirements meet stakeholder needs
- **Management:** Managing requirements changes throughout project lifecycle

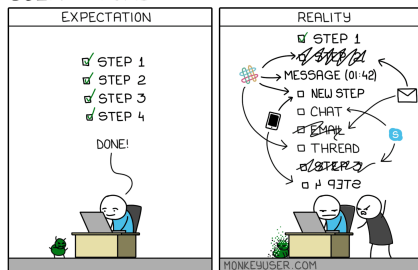


Traditional RE Challenges

Common Issues:

- Incomplete requirements
- Changing requirements
- Communication gaps
- Ambiguous specifications
- Stakeholder conflicts

USER STORY



What is PlantUML?

- **Core Idea:** Uses simple, human-readable Domain Specific Language (DSL)
- **Foundation:** Java-based tool for layout
- **Philosophy:** Focus on content rather than manual layout

"PlantUML is a versatile component for quickly and directly creating diagrams."



Key Advantages

Advantage	Description
Version Control Friendly	Text files work with Git - enables change history, diffing, collaboration
Efficiency & Speed	Faster than manual graphical editing, especially for complex diagrams
Maintainability & Consistency	Easy updates and consistent styling with themes
Automation & Integration	Integrates with documentation pipelines, build systems, CI/CD



UML Diagrams Supported

- Sequence Diagram
- Use Case Diagram
- Class Diagram
- Activity Diagram
- Component Diagram
- Deployment Diagram
- State Diagram
- Object Diagram

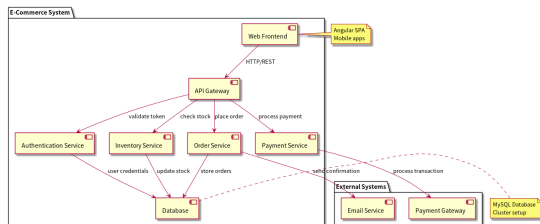


Figure 4: Component Diagram Example



Beyond UML Diagrams

- Architectural Diagrams (C4 model)
- Entity Relationship Diagrams (ERD)
- Wireframes / UI Mockups (salt library)
- Gantt charts for project management
- Mind Maps for brainstorming
- JSON/YAML visualization
- Network diagrams



How PlantUML Works

- 1 **Write:** Create text file (.puml) with PlantUML syntax
- 2 **Process:** Java processor parses text
- 3 **Render:** Layout engine generates final image
- 4 **Output:** Get image in desired format (PNG, SVG, etc.)

Text → **PlantUML** → **Diagram**



Syntax Example: Sequence Diagram

```
1 @startuml
2 actor User
3 participant "Web Browser" as Browser
4 participant Server
5
6 autonumber
7 User -> Browser: Enter URL
8 Browser -> Server: HTTP Request
9 Server -> Server: Process Request
10 Server --> Browser: Return HTML
11 Browser --> User: Display Page
12 @enduml
```

- @startuml/@enduml: Diagram boundaries
- actor, participant: Element declarations
- ->, -->: Solid/dashed arrows
- autonumber: Automatic message numbering

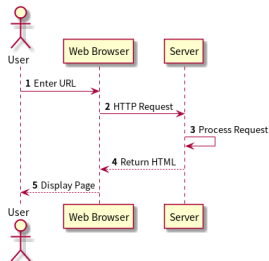


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9 Server -> Server: Process Request
10 Server --> Browser: Return HTML
11 Browser --> User: Display Page
12 @enduml

```



Syntax Example: Use Case Diagram

```
1 @startuml
2 left to right direction
3 actor "Library User" as User
4 usecase "Borrow Book" as Borrow
5 usecase "Search Catalog" as Search
6
7 User --> Borrow
8 User --> Search
9 @enduml
```

- left to right direction: Layout control
- actor, usecase: Actor and use case definitions
- -->: Connection arrows



Syntax Example: Use Case Diagram

```
1 @startuml
2 left to right direction
3 actor "Library User" as User
4 usecase "Borrow Book" as Borrow
5 usecase "Search Catalog" as Search
6
7 User --> Borrow
8 User --> Search
9 @enduml
```



Getting Started with PlantUML

Online Servers (Quick Start):

- Official server: plantuml.com
- Community site: planttext.com
- No installation required

Local Installation (Recommended):

- Prerequisites: Java JRE + Graphviz
- IDE Plugins: VSCode, IntelliJ, Eclipse
- Command Line: Use `plantuml.jar`



Summary & Key Takeaways

- **Why PlantUML?** Version control, automation, efficiency
- **Text-Based:** Simple, readable language for diagrams
- **Wide Support:** Comprehensive UML + additional diagram types
- **Easy Integration:** Fits modern development workflows
- **Quick Start:** Online editors local integration

Embrace efficient diagram creation and maintenance!



What is Prompt Engineering?

Definition

Prompt Engineering is the practice of designing and optimizing inputs (prompts) to effectively communicate with AI models to generate desired outputs.

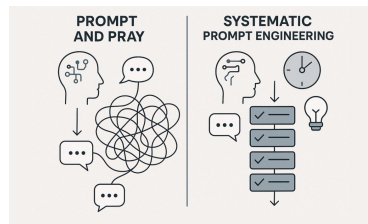
- **Precision:** Crafting clear, specific instructions
- **Context:** Providing relevant background information
- **Structure:** Organizing information logically
- **Iteration:** Refining based on model responses
- **Validation:** Ensuring output meets requirements



Prompt Engineering Techniques

Key Techniques:

- Zero-shot vs. Few-shot prompting
- Chain-of-Thought reasoning
- Role-playing scenarios
- Template-based prompts
- Iterative refinement



Zero-shot vs. Few-shot Prompting

Zero-shot Prompting

Providing no examples - the model must understand and respond based solely on the instruction

RE Example - Zero-shot

```
"Generate functional requirements for a user login system"
```



Zero-shot vs. Few-shot Prompting

Few-shot Prompting

Providing several examples to demonstrate the desired pattern or format

RE Example - Few-shot

"Here are examples of good requirements:

1. The system shall validate user credentials
2. The system shall encrypt passwords

Now generate requirements for user registration"



Zero-shot vs. Few-shot: Practical Examples

Zero-shot Example:

```
Create a use case for
"password reset" functionality
```

Few-shot Example:

```
Example 1: Use case for login
- Actor: User
- Precondition: Valid account
- Steps: Enter credentials...
```

```
Example 2: Use case for logout
- Actor: User
- Precondition: Logged in
- Steps: Click logout...
```

```
Now create for "password reset"
```

Pros:

- Quick and simple
- Good for straightforward tasks
- Less context needed

Pros:

- Better quality output
- Consistent formatting
- Handles complex patterns



Chain-of-Thought Reasoning

Definition

Breaking down complex problems into intermediate reasoning steps, mimicking human problem-solving

RE Application

Instead of asking for complete requirements, guide the AI through logical steps:

- 1 Identify stakeholders
- 2 Define high-level goals
- 3 Break down into features
- 4 Specify detailed requirements
- 5 Validate completeness



Chain-of-Thought: Requirements Example

Benefits for Requirements Engineering:

- Reduces ambiguity in complex domains
- Ensures logical consistency
- Helps identify missing requirements
- Improves traceability

Let's design requirements for an online payment system:

Step 1: Identify main stakeholders

- Customers, merchants, payment processors, banks

Step 2: Define core functionality needed

- Payment processing, security, fraud detection

Step 3: For payment processing, consider:

- Payment methods (credit card, digital wallets)
- Transaction flow (initiation, validation, completion)
- Error handling (declined payments, timeouts)

Step 4: Security requirements:

- Data encryption, PCI compliance, authentication

Step 5: Now generate detailed functional requirements for the payment processing component...

Listing 1: Chain-of-Thought for Payment System



Role-playing Scenarios

Concept

Asking the AI to adopt a specific persona or role to generate more context-appropriate responses

RE Roles Examples

- **Product Owner:** "Act as a product owner for an e-commerce platform..."
- **System Architect:** "You are a system architect designing a microservices architecture..."
- **Quality Assurance Engineer:** "As a QA engineer, create test scenarios for..."
- **End User:** "From the perspective of a novice user, what features would you need..."

Advantages:

Role-playing in Requirements Elicitation

Without Role-playing:

```
List requirements for  
a project management tool
```

With Role-playing:

```
Act as a project manager with  
10 years experience in agile  
environments. What requirements  
would you prioritize for a  
project management tool?
```

Specific Role Examples:

```
Role: Security Auditor
```

```
"Identify security requirements for a healthcare app handling patient data, considering HIPAA  
compliance"
```

```
Role: Accessibility Specialist
```

```
"Generate accessibility requirements for a banking application to ensure WCAG 2.1 AA compliance  
"
```



Template-based Prompts

Definition

Using structured templates to ensure consistent, comprehensive outputs across different requirements

Common RE Templates:

- Use Case Template
- User Story Template
- Functional Requirement Template
- Non-functional Requirement Template
- Acceptance Criteria Template

Benefits

- Standardized format across the project
- Easier validation and review
- Better integration with RE tools
- Consistent quality of generated content

Template Examples for Requirements Engineering

```
USE CASE TEMPLATE:
[System Name] - [Use Case Name]

ID: [Unique Identifier]
Primary Actor: [Role]
Secondary Actors: [Optional Roles]

Preconditions:
- [Condition 1]
- [Condition 2]

Main Success Scenario:
1. [Step 1]
2. [Step 2]
3. [Step 3]

Alternative Flows:
- [A1]: [Description]
- [A2]: [Description]

Postconditions:
- [State 1]
- [State 2]

Exceptions:
- [E1]: [Error condition]
```

Listing 2: Use Case Template



Functional Requirements Template

REQUIREMENT TEMPLATE:

Requirement ID: [FR-001]

Type: [Functional/Non-functional]

Priority: [High/Medium/Low]

Description:

[Clear, unambiguous description of what the system shall do]

Source:

[Stakeholder/Business Need/Regulation]

Rationale:

[Why this requirement is needed]

Acceptance Criteria:

1. [Criterion 1 - testable condition]
2. [Criterion 2 - testable condition]
3. [Criterion 3 - testable condition]

Dependencies:

- [Related requirement IDs]

Constraints:

- [Technical/business constraints]

Status: [Proposed/Approved/Implemented]

Listing 3: Structured Requirements Template

Iterative Refinement

Concept

Starting with broad requirements and progressively refining them through multiple iterations of feedback and clarification

Iterative Process:

- 1 **First Pass:** High-level requirements and scope
- 2 **Second Pass:** Detailed functional requirements
- 3 **Third Pass:** Non-functional requirements and constraints
- 4 **Final Pass:** Validation and acceptance criteria

RE Application

- Start with epic-level user stories
- Break down into features
- Refine into detailed user stories
- Add technical specifications

Iterative Refinement Example

Iteration 1: High-level

Create requirements for
user authentication system

Iteration 2: More specific

Add multi-factor
authentication support

Iteration 3: Detailed

Specify timeout policies
and password complexity rules

Iteration 4: Validation

Add error handling for
failed authentication attempts

Benefits of Iterative Approach:

- Catches ambiguities early
- Allows for stakeholder feedback at each stage
- Reduces rework
- Builds comprehensive requirement sets



Complete Iterative Refinement Workflow

```
// Stage 1: Scope Definition
"Define the high-level scope for a customer relationship management system"

// Stage 2: Feature Identification
"Based on the scope, identify key features needed for lead management"

// Stage 3: Detailed Requirements
"For the lead management feature, specify functional requirements including lead capture,
assignment, and tracking"

// Stage 4: Validation Criteria
"Add acceptance criteria and test scenarios for lead assignment functionality"

// Stage 5: Edge Cases
"Identify and specify requirements for edge cases like duplicate lead detection and lead
expiration"
```

Listing 4: Multi-stage Refinement Process



Technique Selection Guide

Technique	Best For	RE Phase
Zero-shot	Simple, well-understood requirements	Initial scoping
Few-shot	Consistent formatting, complex patterns	Detailed specification
Chain-of-Thought	Complex domains, logical decomposition	Analysis and modeling
Role-playing	Stakeholder perspective, conflict resolution	Elicitation and validation
Template-based	Standardization, tool integration	Specification and documentation
Iterative refinement	Complex systems, evolving requirements	All phases, especially management

Table 1: Selecting the Right Prompt Engineering Technique

Combination Approach:

- Start with role-playing for stakeholder perspective
- Use chain-of-thought for complex analysis
- Apply templates for consistent documentation
- Iterate based on feedback



Case Study: Applying Multiple Techniques

Scenario: Healthcare Patient Portal

Developing requirements for a secure patient portal with medical records access

Applied Techniques:

- 1 **Role-playing:** "Act as a healthcare compliance officer concerned with HIPAA"
- 2 **Chain-of-Thought:** Break down security requirements step by step
- 3 **Template-based:** Use standardized requirement templates
- 4 **Few-shot:** Provide examples of good medical software requirements
- 5 **Iterative refinement:** Multiple rounds of stakeholder review



Summary: Prompt Engineering for RE

Key Takeaways:

- Different techniques serve different RE needs
- Techniques can and should be combined
- Start simple, add complexity as needed
- Always validate AI-generated requirements
- Document your prompt strategies for reproducibility

Next Steps:

- Practice each technique with sample RE scenarios
- Develop organizational prompt templates
- Establish validation processes for AI-generated content
- Integrate with existing RE workflows



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Parallels Between RE and Prompt Engineering

Requirements Engineering	Prompt Engineering
Stakeholder needs analysis	Understanding user intent
Requirements elicitation	Prompt design and formulation
Use case modeling	Scenario specification
Requirements specification	Clear instruction crafting
Validation and verification	Output evaluation and refinement
Change management	Prompt iteration

Table 2: Comparative Analysis



AI-Assisted Requirements Engineering

The New Paradigm

Using prompt engineering techniques to enhance traditional requirements engineering processes

- **Automated Requirements Generation:** AI can help draft initial requirements
- **Requirements Analysis:** AI can identify inconsistencies and gaps
- **Use Case Development:** AI can generate and refine use cases
- **Specification Writing:** AI can help create clear, unambiguous specifications
- **Validation Support:** AI can simulate scenarios and identify edge cases



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Sample Prompt for Use Case Generation

Effective Prompt Structure

Act as a requirements engineer. Generate a use case diagram for an online banking system including: authentication, balance check, funds transfer, and transaction history. Use PlantUML syntax.

- **Role specification:** "Act as a requirements engineer"
- **Context:** "online banking system"
- **Specific requirements:** listed functionalities
- **Format specification:** "Use PlantUML syntax"



Generated Use Case Diagram (PlantUML Code)

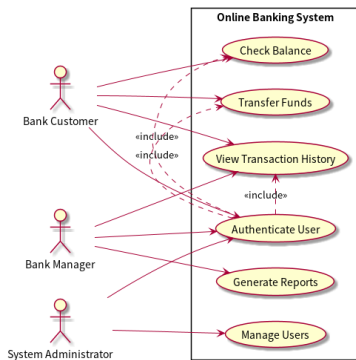
```

1 @startuml
2 left to right direction
3 actor "Bank Customer" as Customer
4 actor "Bank Manager" as Manager
5 actor "System Administrator" as Admin
6
7 rectangle "Online Banking System" {
8     usecase "Authenticate User" as UC1
9     usecase "Check Balance" as UC2
10    usecase "Transfer Funds" as UC3
11    usecase "View Transaction History" as UC4
12    usecase "Generate Reports" as UC5
13    usecase "Manage Users" as UC6
14 }
15 Customer --> UC1
16 Customer --> UC2
17 Customer --> UC3
18 Customer --> UC4
19 Manager --> UC1
20 Manager --> UC4
21 Manager --> UC5
22 Admin --> UC1
23 Admin --> UC6
24 UC1 ..> UC2 : <<include>>
25 UC1 ..> UC3 : <<include>>
26 UC1 ..> UC4 : <<include>>
27 @enduml

```

Listing 5: Online Banking System Use Case Diagram

Expected Use Case Diagram Output



Key Components:

- Actors: Customer, Manager, Administrator
- Use Cases: Authentication, Balance Check, Funds Transfer, etc
- Relationships: Associations and «include» dependencies



Use Case Specification Prompt

Detailed Use Case Prompt

Expand the 'Transfer Funds' use case with:
primary actor, preconditions, main success scenario,
alternative flows, and postconditions. Format as a
structured use case specification.

Expected Output Structure:

- Use Case Name and ID
- Primary Actor
- Preconditions
- Main Success Scenario (steps)
- Alternative Flows
- Postconditions



Generated Use Case Specification

Use Case: Transfer Funds

ID: UC-003

Primary Actor: Bank Customer

Preconditions:

1. User is authenticated
2. User has at least one active account
3. Sufficient funds available for transfer

Main Success Scenario:

1. User selects "Transfer Funds" option
2. System displays transfer form
3. User enters recipient details and amount
4. System validates transfer details
5. System processes transfer
6. System displays confirmation
7. System updates transaction history

Alternative Flows:

- A1: Insufficient funds - System shows error
- A2: Invalid recipient - System validates and rejects

Postconditions:

1. Funds deducted from source account
2. Funds credited to recipient account
3. Transaction recorded in history

Listing 6: Transfer Funds Use Case Specification



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From Use Cases to Formal Specifications

Specification Generation Prompt

Convert the 'Transfer Funds' use case into functional requirements specifications. Include: unique ID, description, priority, acceptance criteria, and dependencies.

Specification Components:

- Requirement ID (e.g., FR-001)
- Description (clear, unambiguous)
- Priority (High/Medium/Low)
- Acceptance Criteria (testable conditions)
- Dependencies (related requirements)



Sample Requirements Specification Output

Requirement ID: FR-001

Description: The system shall allow authenticated users to transfer funds between their own accounts or to other registered users.

Priority: High

Acceptance Criteria:

1. User must be successfully authenticated
2. Source account must have sufficient funds
3. Transfer amount must be positive numerical value
4. Recipient account must be valid and active
5. System must display transfer confirmation
6. Transaction must be recorded in audit log
7. Both accounts must reflect updated balances

Dependencies:

- FR-010: User Authentication
- FR-011: Account Balance Check
- FR-012: Account Validation

Status: Approved

Version: 1.0

Listing 7: Functional Requirements Specification



Non-Functional Requirements Example

```
Requirement ID: NFR-005
Description: The funds transfer functionality
shall meet specific performance and security standards.

Category: Performance & Security

Performance Requirements:
- Response time for transfer processing: < 2 seconds
- System availability: 99.9% uptime
- Maximum concurrent users: 10,000

Security Requirements:
- All transfers must be encrypted (TLS 1.2+)
- Two-factor authentication for transfers > $1,000
- Audit trail maintained for 7 years
- Fraud detection mechanisms in place

Compliance: PCI DSS, GDPR, SOX

Testing: Load testing, security penetration testing
```

Listing 8: Non-Functional Requirements



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Prompt Engineering Patterns for RE

Effective Patterns:

- **Template-based:** Use structured templates
- **Iterative refinement:** Build complexity gradually
- **Context provision:** Include domain knowledge
- **Example-driven:** Provide similar examples
- **Validation requests:** Ask for verification

Antipatterns:

- Vague or ambiguous terms
- Overly complex single prompts
- Assumed domain knowledge
- Open-ended without constraints
- Inconsistent terminology



Effective Prompt Template

```
[ROLE] Act as a [specific role, e.g., senior requirements engineer]

[CONTEXT] For a [domain/system type, e.g., healthcare management system]

[TASK] Generate [specific artifact, e.g., use case diagram]

[REQUIREMENTS] That includes:
- [Feature 1, e.g., patient registration]
- [Feature 2, e.g., appointment scheduling]
- [Feature 3, e.g., medical records access]

[CONSTRAINTS] With the following constraints:
- [Constraint 1, e.g., HIPAA compliance]
- [Constraint 2, e.g., mobile-first design]

[FORMAT] Present the output in [format, e.g., PlantUML syntax]

[VALIDATION] Also include [validation request, e.g., acceptance criteria]
```

Listing 9: Structured Prompt Template for RE



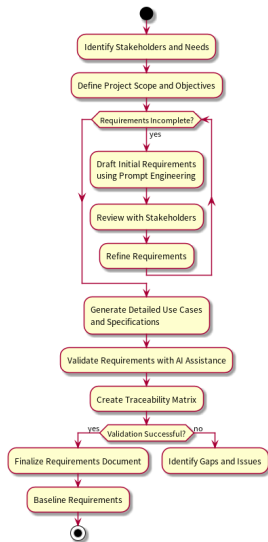
RE-PE Integration Workflow

```
1 @startuml
2 start
3 :Identify Stakeholders and Needs;
4 :Define Project Scope and Objectives;
5
6 while (Requirements Incomplete?) is (yes)
7   :Draft Initial Requirements\nusing Prompt Engineering;
8   :Review with Stakeholders;
9   :Refine Requirements;
10 endwhile
11
12 :Generate Detailed Use Cases\nand Specifications;
13 :Validate Requirements with AI Assistance;
14 :Create Traceability Matrix;
15
16 if (Validation Successful?) then (yes)
17   :Finalize Requirements Document;
18   :Baseline Requirements;
19   stop
20 else (no)
21   :Identify Gaps and Issues;
22   detach
23 endif
24 @enduml
```

Listing 10: Requirements Engineering Workflow



RE-PE Integration Workflow



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Key Takeaways

- **Synergy:** Prompt Engineering enhances traditional Requirements Engineering
- **Efficiency:** AI can accelerate requirements development and validation
- **Quality:** Structured prompts lead to better requirements specifications
- **Accessibility:** Visual models (like PlantUML) improve stakeholder understanding
- **Iterative Nature:** Both RE and PE benefit from continuous refinement

The Future

AI will become an integral partner in requirements engineering, with prompt engineering as the essential interface between human intent and machine capability.

References and Further Reading

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- [2] Wiegers, K. & Beatty, J. (2013) [Software Requirements](#)
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Thank You!
Questions?

