# Software modeling



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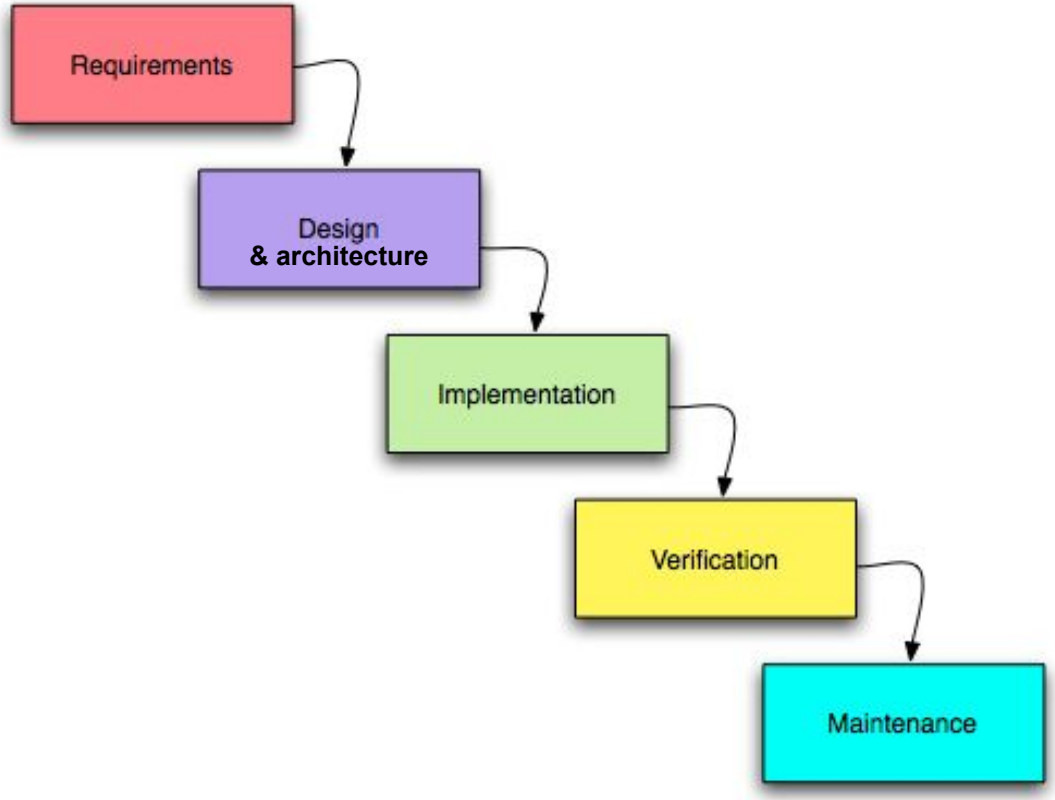
# SW development process



# Importance of pre-construction phases

**Classical research (waterfall)**

- Pressman[2001] - normal projects
  - 40% specifications & design
  - 20% building
  - 40 % testing
- Pressman[2001] - large projects
  - 3 % planning
  - 44,5% specifications & design
  - 17,5% building
  - 35 % testing
- Boehm[1987]
  - 60% specifications & design
  - 15% building
  - 25 % testing
- Brooks[1995]
  - 33% planning (including specifications & design)
  - 17% building
  - 25% component testing
  - 25 % system testing
- Schach[2007]
  - 39% specifications & design
  - 40% building
  - 21 % testing

**Effort distribution in Agile teams** - International Software Benchmarking Standards Group[2024]

- 20-30% planning and requirements - often does not include initial inception ot the requirements
- 10-20% design, architecture (+deployment)
- 50%+ development and testing - may include iterative design activities (e.g., OO design), which are difficult to separate from coding itself

# Requirements modeling
## (Deep dive)

# Example: E-commerce store requirements

**Business requirements** (Describe high-level objectives of the organization itself)

- Achieve a 20% increase in sales in first year
- Expand customer base by 15% in first year
- ….

**Stakeholder requirements** (Describe stakeholder/user needs)

- Users want to be able to search the products
- Users want to safely purchase selected products
- Sales dept. wants to be able to use flexible pricing strategies
- ….

**Solution (system) requirements** (Describe system's functions, services and operational constraints)

- The system shall allow the users to browse the products by category
- The system shall allow the users to search the products by name
- The system shall allow the users to add items to the shopping cart

} **Functional requirements**

- ….
- The system shall adhere to Payment Card Industry Data Security Standard (PCI DSS) compliance for handling and storing payment card information

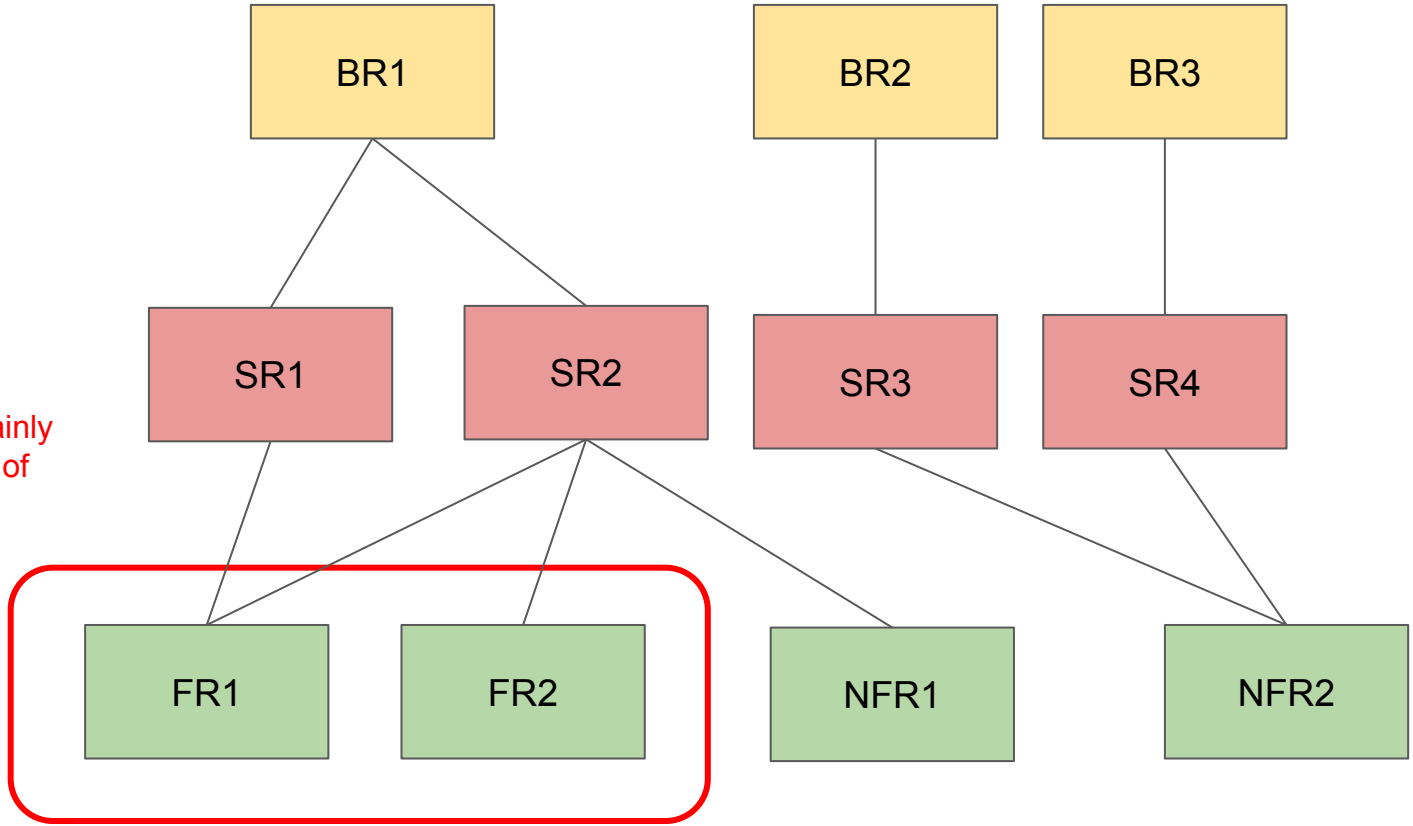
} **Nonfunctional requirements**

- ….

**Stakeholder:** an individual, group or organization who may affect or be affected by the result of the project

*(BABOK® Guide requirements classification schema)*

# Requirements traceability




We will focus mainly on the modeling of functional requirements

# Functional requirements

- Describes required functionality
- Input for next phases of SW development process (together with nonfunctional requirements)
- Typical form
  - Natural language text (free format, typically structured)
  - UML Use Case model
    - Use Case diagrams
    - Use Case and Actor descriptions
  - Dynamic UML diagrams - activity diagrams, state diagrams, ….
  - User stories and supporting documents
- Functional requirements are often supported by GUI models
  - Partially describes also non-functional requirements

A common problem: the stakeholders do not know UML … ☹

In GUI-centric applications it might be more convenient to use wireframes/mockups and their description instead of diagrams

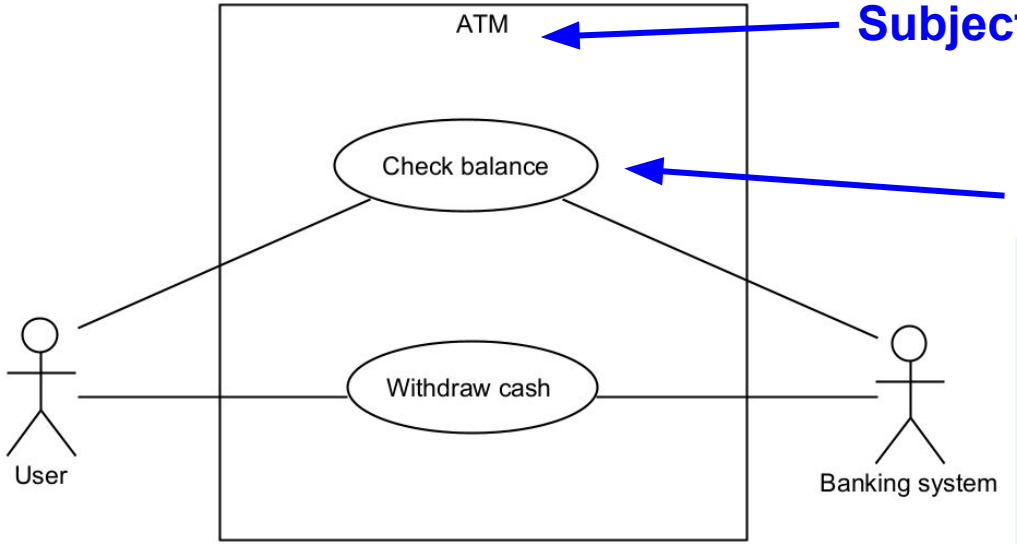
# UML Use Case model

- It is used less frequently in modern development
- However it is a concept that greatly helps to clarify key notions such as user roles, user goals, and system boundaries
- Later we will also map these notions to modern user stories

# Use Case Diagram

= behavioral UML diagram

- High-level view of the system: actors, use cases, subjects and their relationships
- Typically easy-to-understand for stakeholders



# Actors & Use cases

Actors are always placed outside the system.

Actor represents a role, it means

- A single physical instance may play the role of several different Actors

  *Example: An employee responsible for managing the attendance application has both a "user" and an "admin" account for that application. The "user" account is used to manage their own attendance.*

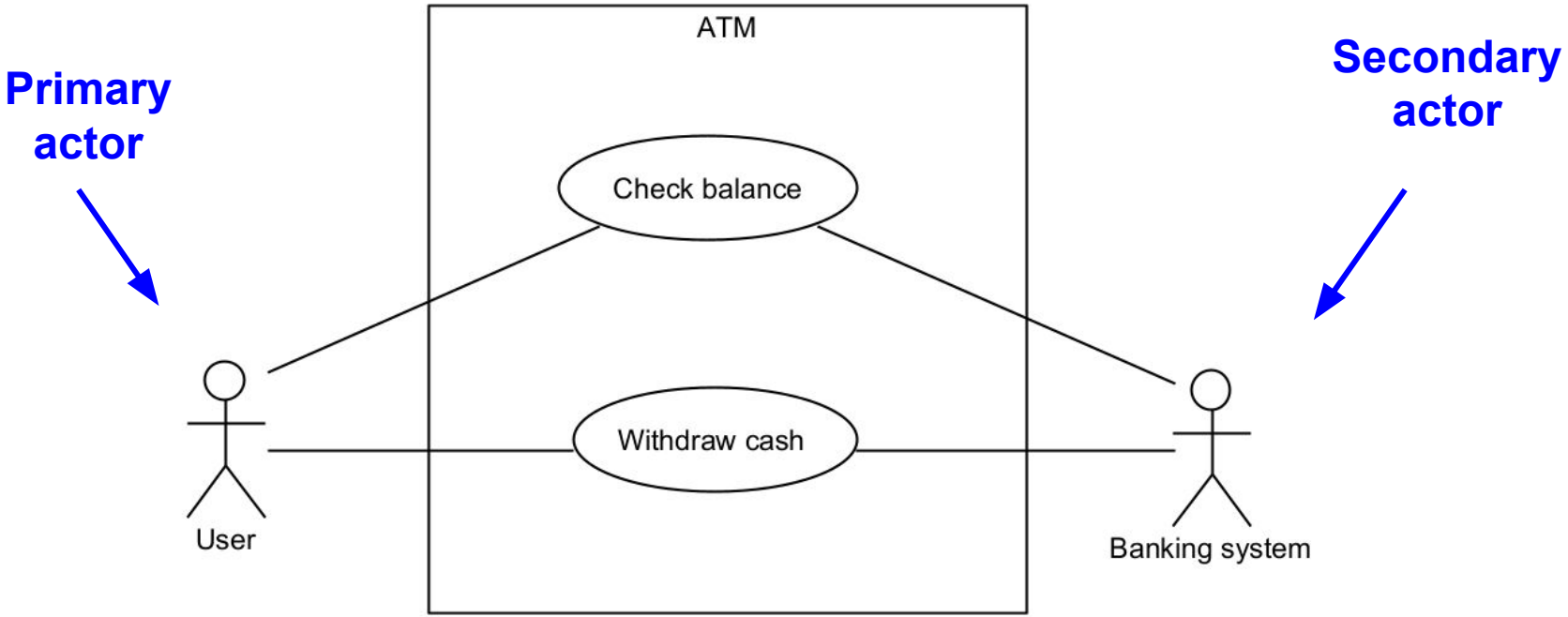
- A given Actor may be played by multiple different instances

  *Example: All employees have "user" account for the attendance application.*

Actors are further defined as follows *

- **Primary actor:** has a defined user goal that the system aims to fulfill. This actor initiates the corresponding use case.
- **Secondary actor:** provides a supporting role to complete the use case.

** Cockburn[2000]*


Primary actor
Secondary actor
ATM
Check balance
Withdraw cash
User
Banking system

# Relationships

## Actor - Actor

- Generalization

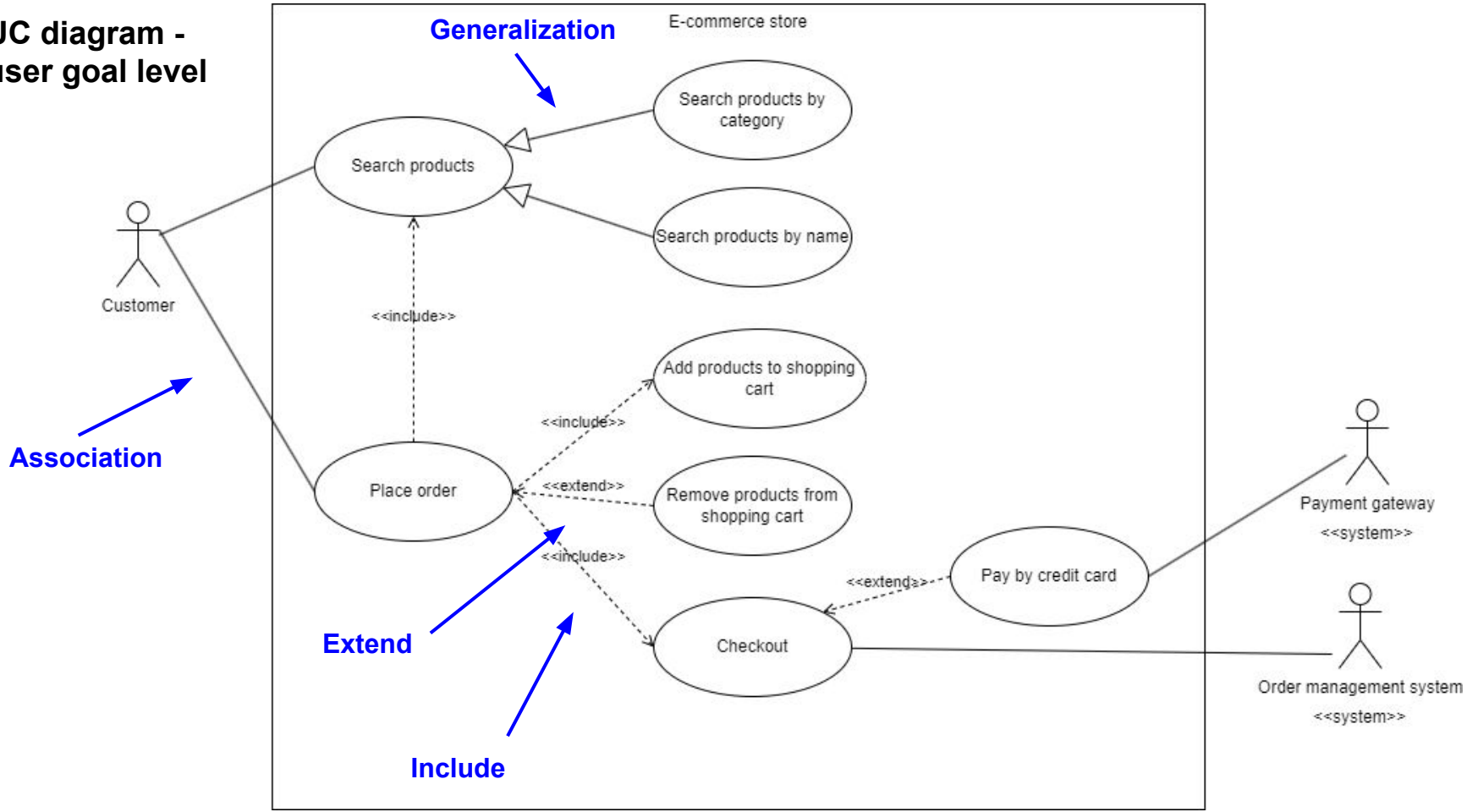
## Actor - Use Case

- Association
  - Represents interaction, associated Use case typically capture a user goal

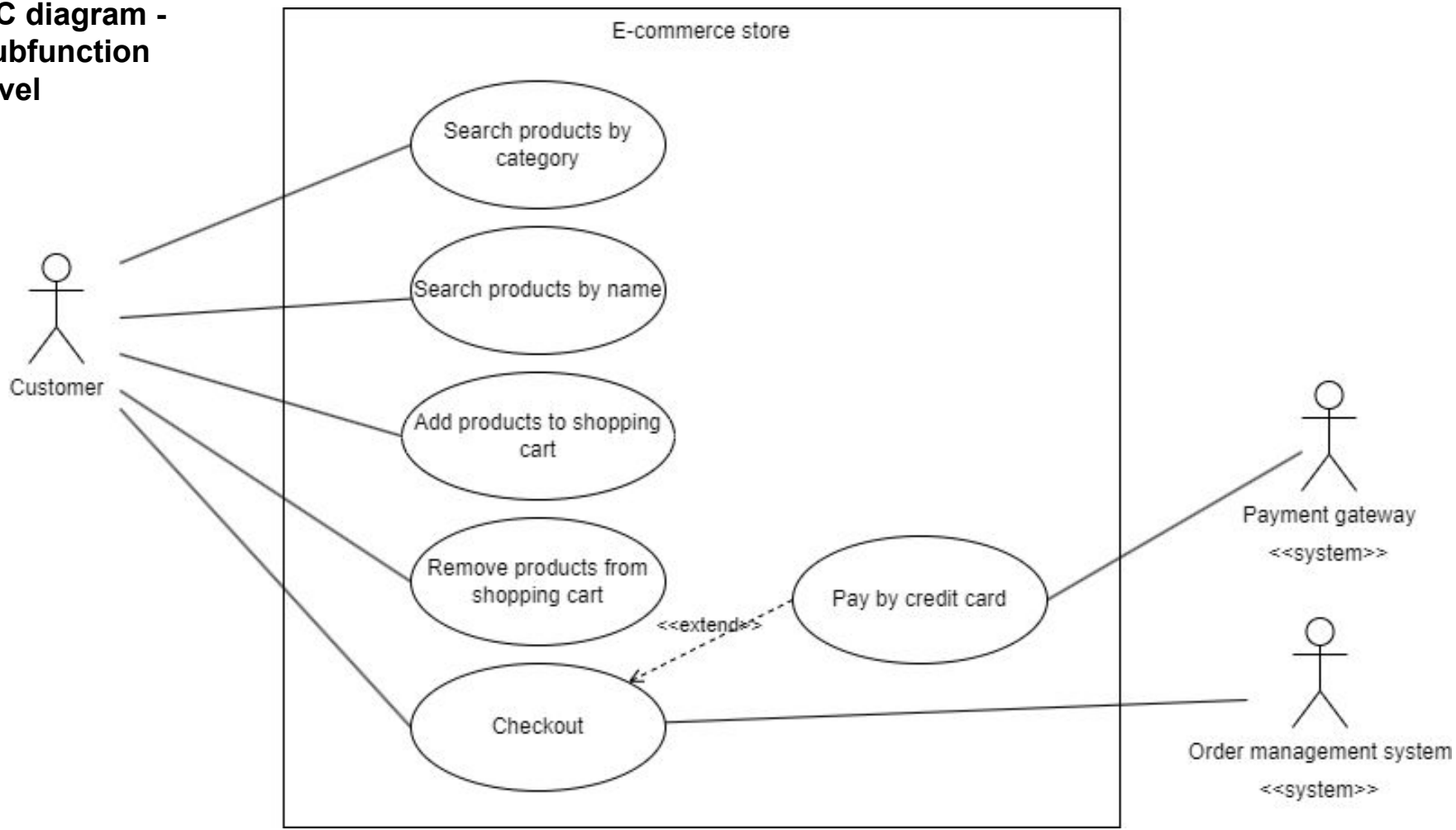
## Use Case - Use Case

- Generalization
- “Include” dependency
  - An including use case always contains the behavior defined in another, included (base), use case. Included use case can be seen as subroutine.
- “Extend” dependency
  - The behavior defined in the extending use case can be inserted into the behavior defined in the extended use case

# UC diagram - user goal level



**UC diagram - subfunction level**



# Best practices

- Actor name
  - Nouns, unified and understandable from business point of view
  - Example: Customer, Supplier, Printer
- Use case name
  - Should begin with the imperative form of the verb
  - Examples: **Open** order, **Print** order
- Common domain glossary across the model
  - Log in to **the system**, Log out from **the application** -> WRONG
  - Log in to **the system**, Log out from **the system**
- Take into account time sequence of Use Cases
  - The first UC on the top, another below it, etc.
  - It i not always possible to find such time sequence
- Primary vs secondary actors
  - Primary actors are placed on left-hand side, secondary actors on right-hand side of the corresponding use case
- Avoid GUI and implementation details
- Minimize usage of “extend” dependency and generalization between UCs
  - Semantic can be too complex and confusing
- Keep the diagram consistent within the chosen level (user goal level, subfunction level, …)

This should be followed throughout the specification

# Use case description

- UML use case diagram only provides a "big picture" of the interaction between actors and the system
- More details are typically provided by

  1. Text descriptions: Goal, Preconditions, Postconditions, Algorithm, …
  2. Behavioral UML diagrams - activity diagrams, state diagrams, …

- A detailed description of all use cases can lead to extensive documentation that is difficult to maintain. It can be reduced as follows:
  - Provide detailed description only for critical or complex use cases
  - Provide short description for simpler use cases, focusing on key aspects

Note: The concept of “use case” was introduced already in 1987 by Ivar Jacobson while UML (including Use Case modeling) was standardized in 1997.

# “Fully dressed” description

= detailed description, it typically contains the following elements:

1. Attributes
   - Name: use case name
   - Goal: a longer statement of the goal
   - Scope: subsystem, application, ...
   - Pre-conditions: state before use case execution
   - Post-conditions: state after use case execution
   - Trigger: action upon which is use case started
   - Primary actor
   - Secondary actors
2. Algorithm (flow of events)
   - Primary scenario, extensions and variations
3. Additional information
   - E.g., priority, related non-functional requirements, …

*The concept of fully dressed vs casual use case descriptions comes from Cockburn[2000]*

**Use case name:** Checkout
**Goal:** To order products in the shopping cart
**Preconditions:** Non-empty shopping cart
**Postconditions:** Successfully placed order for the products in the shopping cart or information about error in order processing

**Trigger:** Customer chooses an option to proceed to checkout.
**Primary actor:** Customer
**Secondary actor:** Order management system

GUI independent phrases

1. Customer chooses an option to proceed to checkout.
2. System displays the content of the shopping cart
3. Customer confirms that he/she wants to proceed to checkout.
4. Customer enters phone no. and e-mail.
5. System validates entered data.
6. If data is not valid, systems informs about detected errors and UC returns back to step 4.
7. Customer chooses one of the following delivery methods - delivery service or personal pickup.
8. If the chosen delivery method is “Delivery service”
   a. User enters the delivery address
   b. System validates entered data.
   c. If data is not valid, system informs about detected errors and UC returns back to step 8a.
9. Customer chooses one of the following payment methods - credit card or bank transfer.
10. If the chosen payment method is “Bank transfer”, system displays payment instructions.
11. If the chosen payment method is “Credit card”
    a. System calls **UC “Pay by credit card”.**
    b. If the payment by credit card failed, UC returns to step 9.
    c. System informs about successful payment.
12. Order management system registers the order.
13. If registering the order fails
    (steps 13a-13b happen in any order)
    a. System informs the customer about error in processing the order
    b. System sends notification to technical support
    c. Use Case terminates (failure)
14. System performs the following steps in parallel
    (steps 14a-14b happen in any order)
    a. System confirms that the order has been placed successfully
    b. System sends confirmation e-mail to the customer.
15. Use case terminates (success)

UC is still simplified, for example it is not mentioned what “display shopping cart” means, free delivery is assumed, …

# “Casual” description

= short description, the structure is not predefined

**UC Checkout**

Customer initiates checkout process. System displayed content of the shopping cart and customer confirms it. Customer

- Enters phone no. and e/mail
- Chooses delivery method (delivery service or personal pickup). In case of delivery service, he/she enters also delivery address.
- Chooses payment method (bank transfer, credit card). In case of credit card, UC Pay by credit card is called.

Order management system registers the order.

- In case of failure, system informs about error in processing order and if the order has been already paid, it ensures the customer that amount paid will be refunded to given credit card.
- In case of success, system informs that the order has been placed successfully. It provides payment instruction if the bank transfer was chosen. It informs that the order has been paid if the credit card was chosen and the payment was successful.

# Activity diagram

= behavioral UML diagram

- A visual means of describing algorithms / workflows

- **Action:** a specific unit of work or operation
- **Partition (swimlane):** a logical grouping of activities or actions
- **Special nodes**
  - **Initial node:** the starting point of the activity diagram
  - **Final node:** the ending point of the activity or process
- **Conditionals**
  - **Decision:** a point where a decision is made, the control flow can follow different paths based on conditions
  - **Merge:** a point where different control flows converge back into a single flow
- **Concurrency**
  - **Fork:** a point in the process where the control flow splits into multiple concurrent control flows
  - **Join:** a point where multiple concurrent control flows converge back into a single control flow
- **Objects and object flows**
- **Parameters**

# Log in, log out, register

- Are these use cases?

  Use case = “a set of behaviors performed by the system, which yields an **observable result** that is of **value** for actors or other stakeholders of the system”

# Log in, log out, register

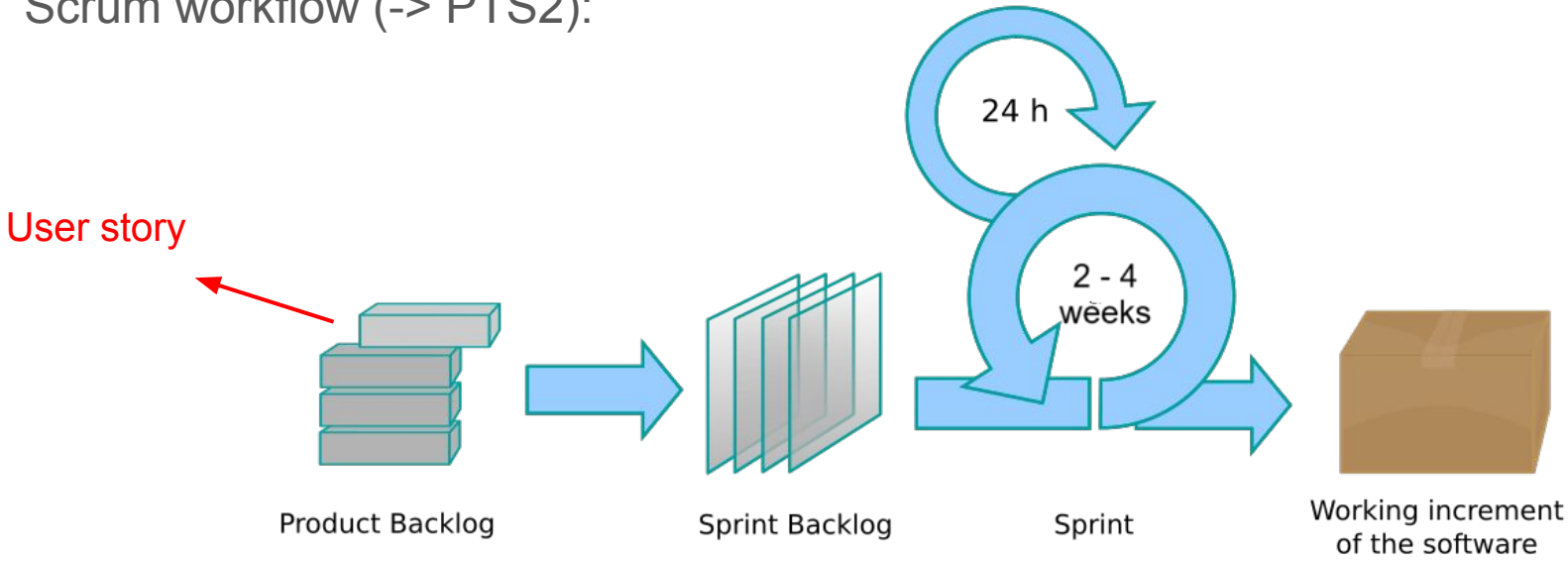
- “Technical” functions implementing non-functional requirements
  - Example NFR: “Data are accessible by authorized parties only”
- These are not use cases in the strictest sense
- No consensus on how to model them

Example solutions

- Login / logout / register are not modeled as use cases
  - UC diagram: Constraint “User is logged in”
  - UC descriptions: Precondition “User is logged in”
- Login / logout / register are modeled as use cases
  - UC diagram:  Separate use cases + constraint “User is logged in” / “User is registered”
  - UC descriptions: Precondition “User is logged in” / “User is registered”
  - Actor “User” may need to be differentiated into “Unregistered user” / “Registered user”
  - Could make sense at more technical level

# Agile analysis - SCRUM

Scrum workflow (-> PTS2):




Source: Wikimedia

# User stories

= an informal, general explanation of a software feature written from the perspective of the end user or customer

- Used especially in agile methodologies (e.g., Scrum)
- Common template

```
As a <role> I want to <capability>, so that <I receive benefit>
```

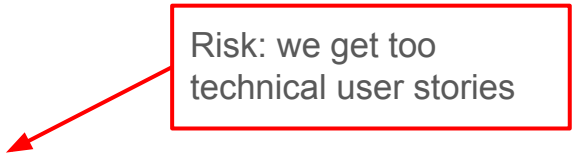
(“So that” part is optional)

- User stories are placeholders for further discussion, they can be split / refined to more detailed specification if needed
  - Sometimes they are even not considered to be true requirements
  - The granularity of user stories changes over time, the final user stories (those to be implemented) represent small piece of work that can be implemented within a short iteration
- Acceptance criteria
  - Conditions that the given feature must fulfill in order to be accepted by stakeholders
  - Provides more details about User story

# User story evolution

Scrum assumes the existence of a product backlog that is continuously filled with raw user stories, but does not prescribe how those stories are generated.

1. **Raw user stories**
   - Initial, unrefined stories
   - They capture the high-level goal but lack detailed acceptance criteria, context, or specific technical details
2. **Refined user stories**
   - Raw stories are typically refined during Story refinement / backlog grooming meetings - continuous process (partially during Sprint planning)
   - Raw user stories are
     - Further specified, prioritized
     - Broken down into smaller ones if needed
     - Supplemented by acceptance criteria
   - Refined stories are ready for implementation within a single sprint
3. **Even more refined user stories**
   - During sprint
   - A refined user story is further specified to facilitate design / implementation / testing



**As a** customer, **I want to** search for products by a product name **so that** I can easily find and select the products I want to buy.

Acceptance criteria:

- Given a customer's search criteria (partial product name), the system displays a list of products that match the specified search.
- If no products match the search criteria, the system shows a message informing the customer that no products were found.
- Each product in the list displays the following mandatory information:
  - Product name, Product code, Price per item, Stock quantity
- Each product in the list displays the following optional information (if available):
  - Product photo, Product description
- For each product with a stock quantity greater than 0, the customer can input a quantity (less than or equal to the available stock) and add the selected quantity to the shopping cart.

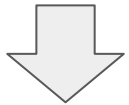
\+ Other specification, e.g. wireframes / mockups, algorithm, UML diagrams (activity, sequence, ..)

# Acceptance criteria

- Free text
- Or template: `Given … when … then …`

*Origin: Behavior-driven development [D.North]*

Given a customer's search criteria (partial product name), the system displays a list of products that match the specified search.



Given: The customer is on the product catalog page and enters a non-empty product name (partial or complete) as a search criterion.

When: The customer initiates the search for products.

Then: The system displays a list of products that match the specified search criterion

Preconditions

Trigger

Expected behavior

# User stories  vs use cases - standalone

Standalone User story vs standalone Use case (in UC  diagram)

| **User story (US)** | | **Use case (UC)** |
|---|---|---|
| Role | ~ | Primary actor |
| Capability | ~ | Use case name |
| Benefit | ~ | UC description / “Rationale” |

At requirements level, UCs primary actors typically overlap significantly with USs roles.

# USs acceptance criteria vs UCs postconditions

- **UCs postconditions**
  = the state of the system after the Use Case has been completed
- **USs acceptance criteria**
  = the conditions to be met so that the implementation of US is accepted by the stakeholders
  The may refer to the postconditions but also intermediate conditions / behaviors of the system.
  They may also contain feature-specific non-functional requirements.

# Example - password reset

**Use Case: "Reset password"**

Postconditions (success scenario):

- The user's password is updated.
- The password reset link becomes invalid after it is used.
- A success message is displayed to the user confirming the password reset.

**User Story: "As a user, I want to reset my password so that I can access my account if I forget my password."**

Acceptance criteria (success scenario):

Given the user is registered, when they choose the password reset option, then they receive a password reset email within 10 seconds.

Given the user receives the reset email, when they follow the unexpired reset password link then they are able to enter a new password.

Given the password reset link is expired, when the user opens it, then they are informed that the link is invalid.

Given the user enters a new valid password, when they confirm the password then the user's password is updated.

the password reset link becomes invalid and a success message is displayed confirming the password reset.

Given the user enters an invalid password, when they attempt to confirm it, then an error message is displayed.

Intermediate conditions / behavior

Postconditions

**As a** customer, **I want to** search products **so that** I can easily find and select the products I want to buy.

~ UC Search products

**As a** customer, **I want to** add products to shopping cart **so that** I can save the products before checkout.

~ UC Add products to shopping cart

**As a** customer, **I want to** remove products from shopping cart **so that** that I can update my selection before checkout.

~ UC Remove products from shopping cart

**As a** customer **I want to** checkout **so that** I can complete my purchase.

~ UC Checkout

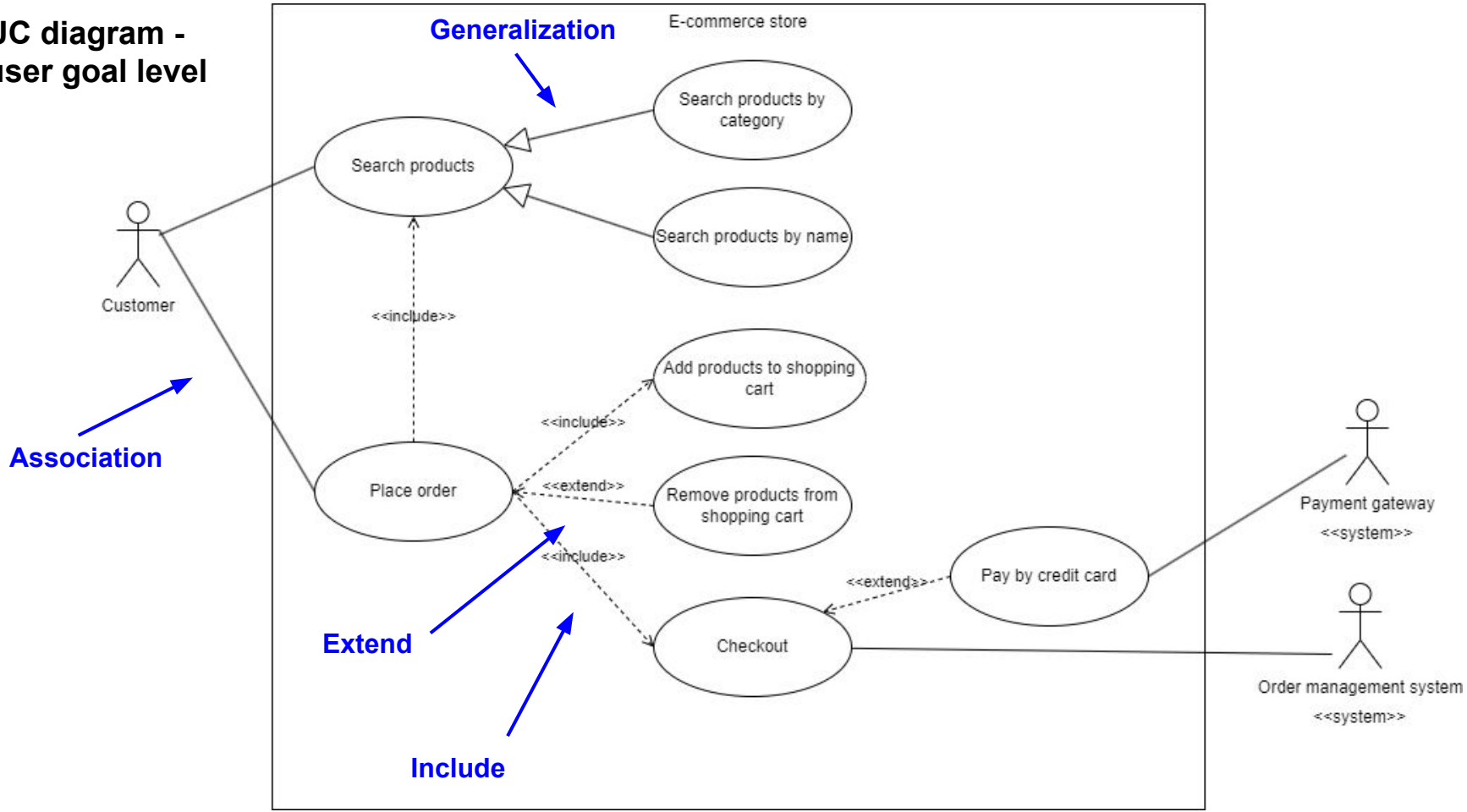
**As a** customer **I want to** pay by credit card **so that** I can finalize my order.

~ UC Pay by credit card

# User stories vs use cases - mutual relationships

- User stories
  - None or weak mutual relationships
    - Focus on agile development
  - Higher level stories -> lower level stories
    - Raw story -> Refined story: Scrum does not provide means how to handle original raw stories after refinement, context might be difficult to access or lost
    - Nowadays, so-called **epics** are often used to represent higher-level requirements (not part of original Scrum)
- Use cases
  - Several types of mutual relationships (include, extend, generalization)
    - Focus on waterfall / long iteration development
  - Higher level use cases -> lower level use cases
    - Multiple granularity levels in a specification
    - It is possible to keep the context (user-goal level)

# UC diagram - user goal level



## Epic: Product search

**As a** customer, **I want to** search products by category **so that** I can easily find and select the products I want to buy.

**As a** customer, **I want to** search products by name **so that** I can easily find and select the products I want to buy.

## Epic: Order placement

**As a** customer, **I want to** add products to shopping cart **so that** review and purchase them later.

**As a** customer, **I want to** remove products from shopping cart **so that** I can update my selection before checkout.

**As a** customer, **I want to** checkout **so that** I can complete my purchase.

**As a** customer, **I want to** pay by credit card **so that** I can finalize my order.

Extending Use Cases mostly map to separate User Stories

- Fixed 2-level hierarchy: Epics + User Stories
- In practice, “Order placement” epic would probably be split into more specific epics such as Cart management, Checkout, Payment

# User stories vs. use cases

**User cases**

(+) complex functionalities with many internal dependencies can be captured by single UC or a group of related UCs (typically at user goal level), then the context is not lost

(+) named user goals provide a summary of project's scope

(-) a single UC may represent a large chunk of work and thus be difficult to develop within a short iteration

UCs fully-dressed descriptions:

(-) a lot of writing for analysts, a lot of reading for stakeholders

(-) difficult to maintain

**User stories (refined)**

(+) short, easy to read, and understandable

(+) represent small increments of functionality that can be developed in short iterations

(+) refined just-in-time, avoiding too-early specificity

(+) easy to maintain

(-) they do not capture the larger context, thus they are not sufficient to perform a more complex analysis / design

(-) they do not provide summary of project scope

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