Cohesion and Coupling

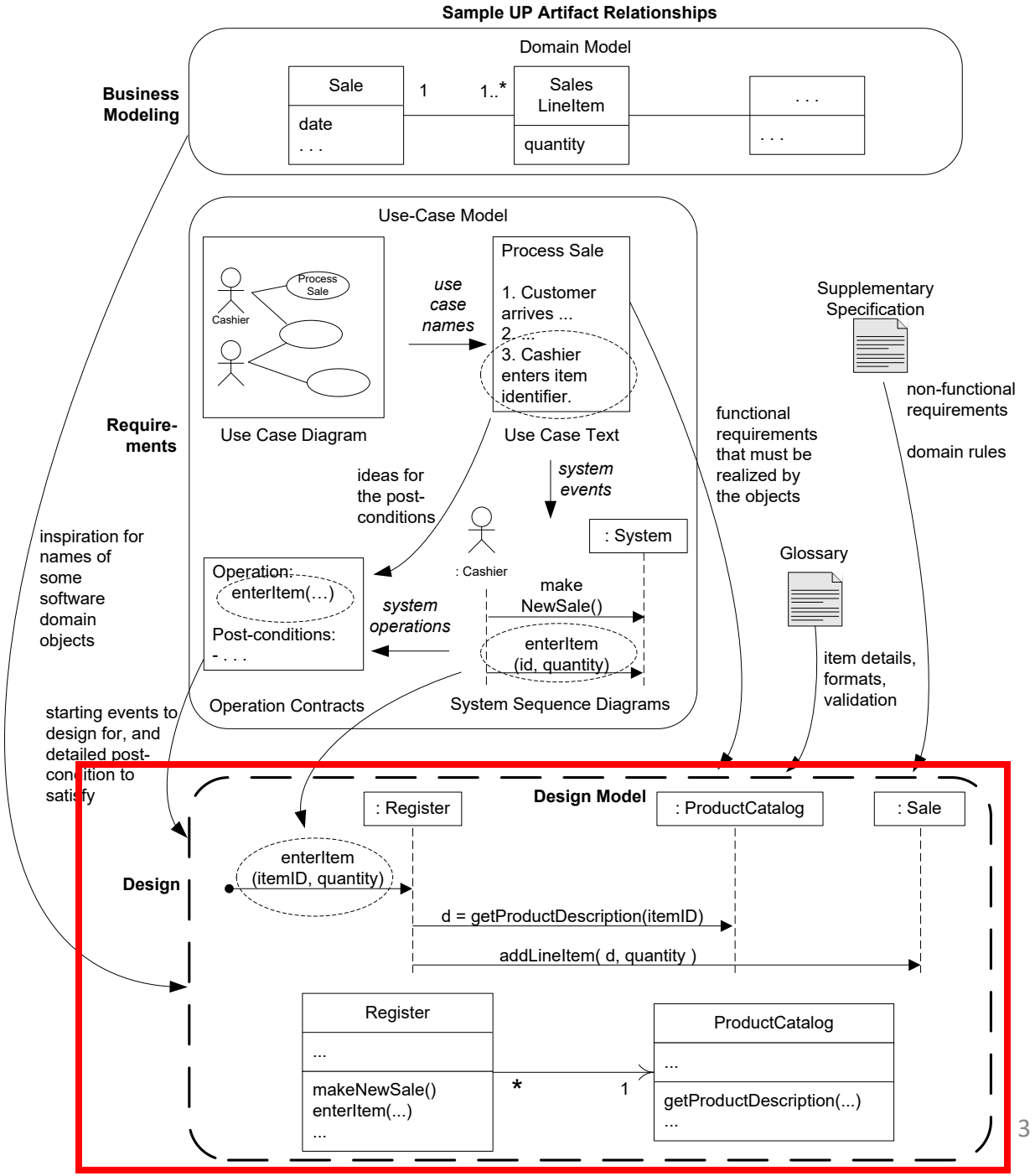
Promotion of Container Objects to Software Classes

ISEP / LETI / ESOFT

Topics

- Modularity
- Cohesion
- GRASP: High Cohesion
- Coupling
- GRASP: Low Coupling
- Types of coupling
- Promotion of Container Objects to Software Classes

Artifacts Overview



GRASP - General Responsibility Assignment Software Patterns (or Principles)

Recall previous lectures

- GRASP is a methodical **approach to OO Design**
  - Based on principles/patterns for **responsibilities assignment**
  - Helps to understand the fundamentals of object design
  - Allows to apply design reasoning in a methodical, rational, and understandable way

- In UML, the design of Interaction Diagrams (e.g. class and sequence diagrams) is a means to consider and represent responsibilities
  - When designing, you decide which responsibilities to assign to each object

GRASP

- Pure Fabrication
- Controller
- Information Expert
- Creator
- High Cohesion *
- Low Coupling *
- Polymorphism
- Indirection
- Protected Variation

* Patterns addressed in this slide deck

Modularity

Modularity

- “Modularity is the property of a system that has been decomposed into a set of **cohesive and loosely coupled** modules” [*Booch, 1994*]

- It is one of the most classic principles of software development

- It consist of **decomposing a product into smaller parts** (or modules) with clear responsibilities
  - SW System → Applications → Layers → Components → Classes
  - Layer examples: Presentation/UI layer, Domain layer

Poor/Bad Design → Low Modularity

- Rigidity
  - It is difficult to change because each change affects too many parts of the system
- Fragility
  - When a change is made, failures are (very) hard to predict
- Immobility
  - Difficult to reuse in other applications because it is difficult to disconnect from the original application
- **High Cohesion and Low Coupling promote modularity**

Cohesion

Cohesion (1/2)

- It is a measure regarding the **coherence of the responsibilities** assigned to an element of the system. E.g.:
  - **Classes (of software)**
  - Components
  - Modules
  - Applications

  Slightly addressed in ESOFT

- Typically, it is measured in:
  - High Cohesion → to be achieved
  - Low Cohesion → to be avoided

Cohesion (2/2)

- A class with High Cohesion
  - Has a relatively small number of operations
  - The operations are closely related to each other
  - Delegate or collaborate with other classes to perform more complex tasks
- A class with Low Cohesion
  - Is difficult to understand
  - Is difficult to reuse
  - Is difficult to maintain

GRASP

High Cohesion (HC)

High Cohesion

- **Problem**
  - How to maintain classes/objects with coherent and easy-to-understand functionalities?

- **Solution**
  - Assign responsibilities so that cohesion remains high
  - Features should be strongly related with each other
  - Prevent the same class/object from doing many different things
  - Cooperate with other classes
    - Tell other classes to do something about data they know
    - Do not ask other classes for data (avoid *getX* functions)

    } Tell, Don't Ask Principle
  - Delegate other responsibilities to other classes

Tell, Don’t Ask Principle

- Principle
  - **You should not ask** an object for its own data (*state*) and further act on that data to make some decisions
  - Instead, **you should tell** an object what to do, i.e. send commands to it

- Advantages
  - Promotes a clear separation of responsibilities
  - **Favors High Cohesion**
  - The solution becomes:
    - Easier to understand
    - Easier to maintain
    - Flexible enough to add new features

- Similar to Information Expert

Benefits of High Cohesion

- Greater **design clarity** and easier understanding
- **Maintenance** and improvements become simplified
- **Reuse** is facilitated because a class with high cohesion can be used for a clear specific purpose

- The higher the degree of cohesion, the better the quality of the software

Coupling

Coupling (1/2)

- It is a measure of **how strongly an element** is connected to, or has knowledge of, or **is dependent on other elements** of the system. E.g.:
  - **Classes (of software)**
  - Components
  - Modules
  - Applications

  Slightly addressed in ESOFT

- Typically, it is measured in:
  - Low Coupling → to be achieved
  - High Coupling → to be avoided

Coupling (2/2)

- A class with Low Coupling
  - Depends on few or no classes
  - Easy to understand
  - Easy to reuse
  - Easy to maintain
- A class with High Coupling
  - Depends on (many) other classes
  - Difficult to understand in isolation
  - Often needs to be changed by changes in related classes
  - More difficult to reuse

GRASP

Low Coupling (LC)

Low Coupling

- **Problem**
  - How to achieve low dependency, low impact on changes and increased reuse between classes/objects?

- **Solution**
  - Assign responsibilities to maintain a low coupling
  - Avoid unnecessary dependencies
  - Apply indirection mechanisms (Indirection Pattern) to assign the responsibility of mediation between two classes/objects to an intermediate class, thus ensuring decoupling (e.g. the controller classes play this role)

Benefits of Low Coupling

- It promotes **independence**, **modularity**, and **flexibility** of the code
- Classes are **simpler to understand** in isolation

- The lower the degree of coupling, the better the quality of the software

Types of Coupling

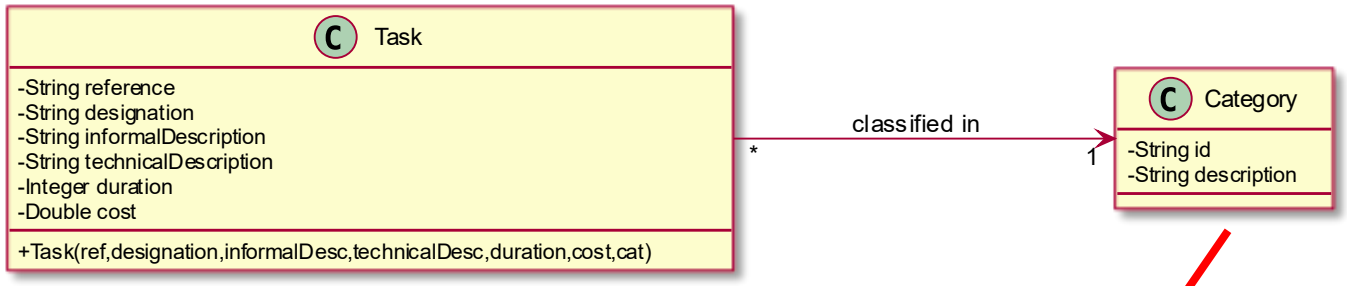
Types of Coupling

- An OO language, includes the following types of coupling:
  - **Loose Coupling**
    1. *TypeX* has an association to a *TypeY* object ***(Association: Aggregation / Composition)***
    2. *TypeX* has a function that references a *TypeY* object ***(Knowledge)***
  - **Medium Coupling**
    3. *TypeX* calls functions of a *TypeY* object ***(Function)***
    4. *TypeX* implements a *TypeY* interface ***(Implementation)***
  - **Strong Coupling**
    5. *TypeX* is (directly or indirectly) a *TypeY* subclass ***(Extension by Inheritance)***

- Each type of coupling has its own particularities and strengths
- Two classes can have several of these forms

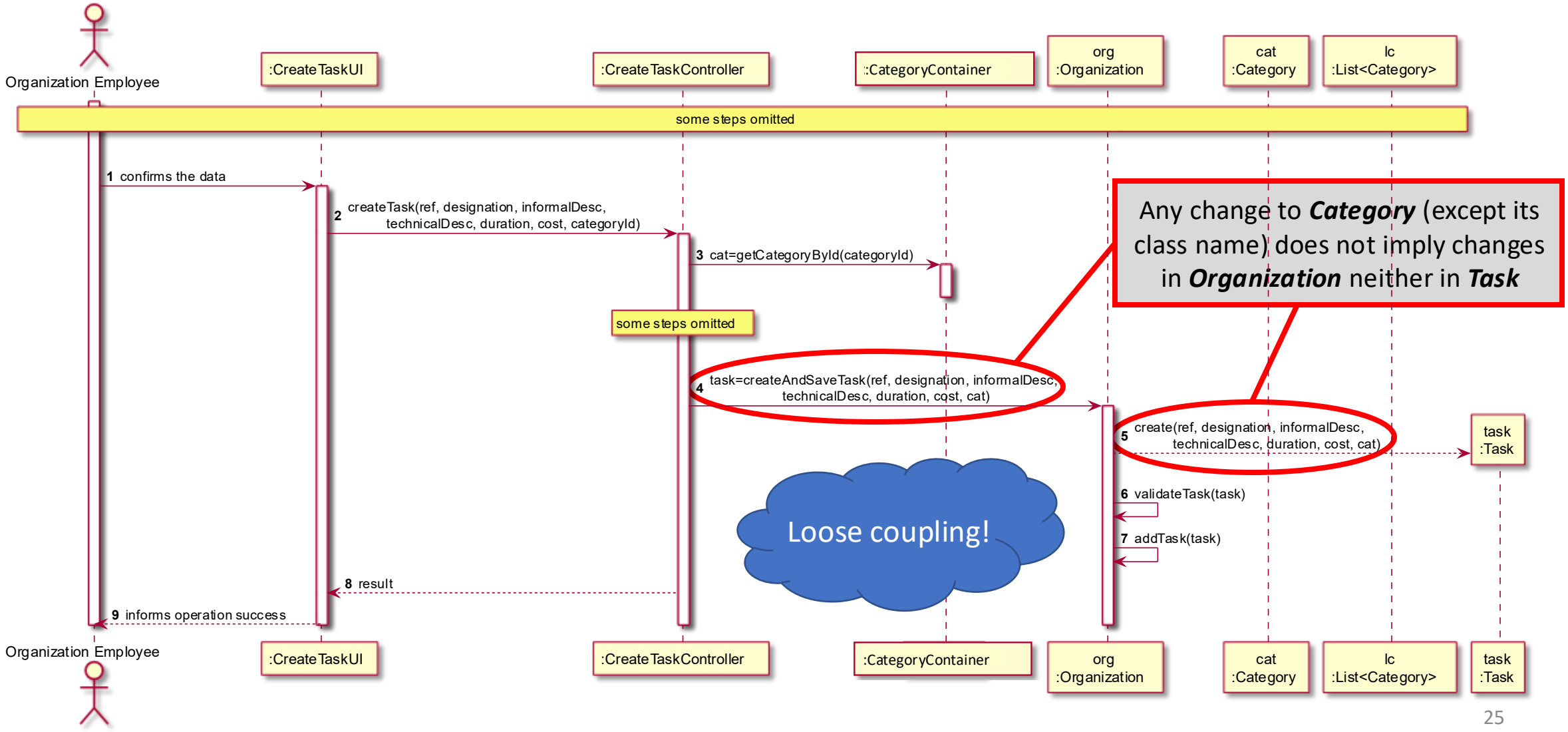
1. *TypeX* has an association to a *TypeY* object

Loose coupling!



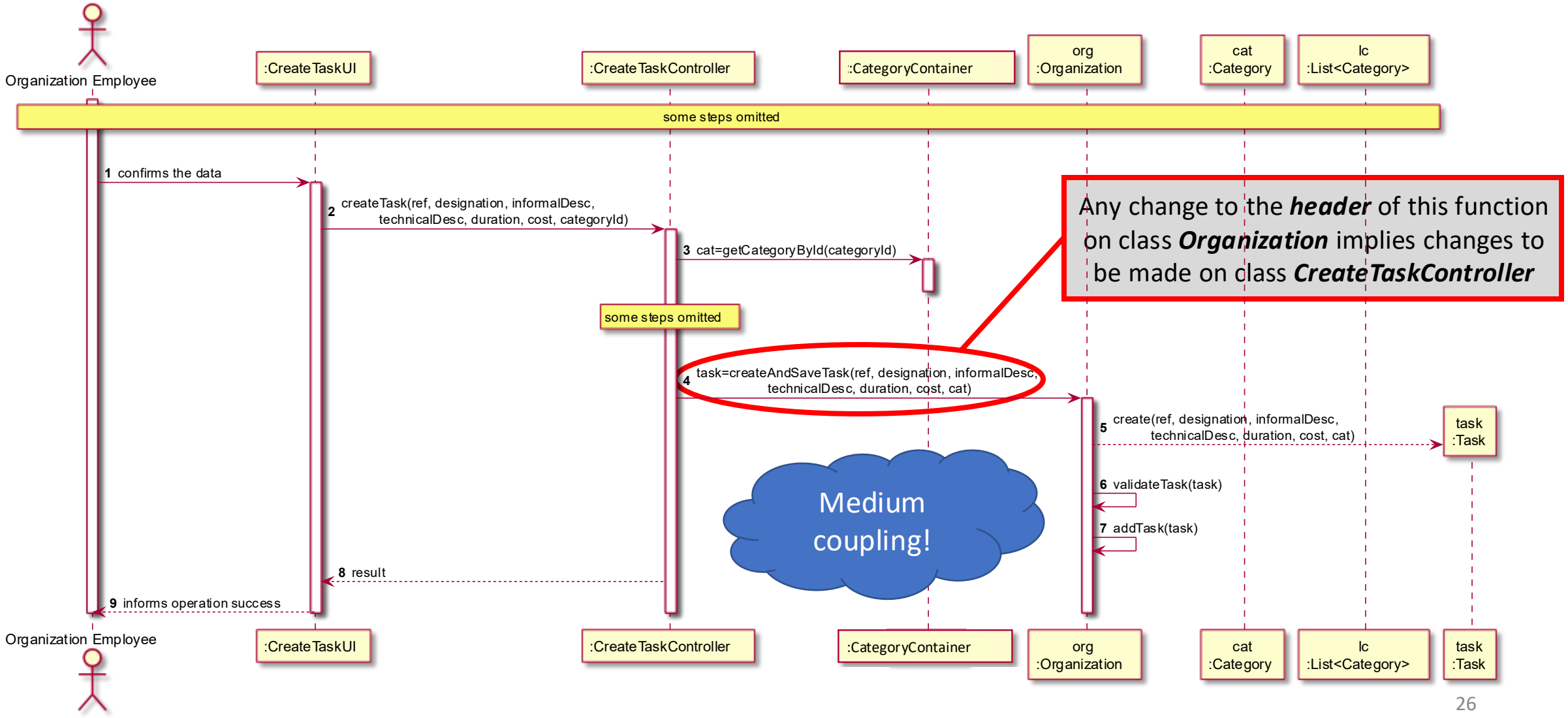
Any change to ***Category*** (except its class name) does not imply any changes in ***Task***

2. *TypeX* has a function that references a *TypeY* object



Any change to ***Category*** (except its class name) does not imply changes in ***Organization*** neither in ***Task***

3. *TypeX* calls functions of a *TypeY* object



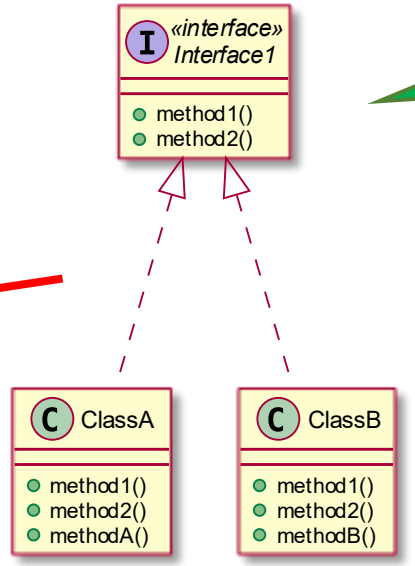
Any change to the ***header*** of this function on class ***Organization*** implies changes to be made on class ***CreateTaskController***

4. *TypeX* implements a *TypeY* interface

- The implementation mechanism establishes a contract between a class and the code that uses it
  - The interface describes what any class implementing the interface must do
  - E.g.: ClassA and ClassB must implement both `method1()` and `method2()`
- Form of polymorphism with a weaker coupling than with classes
- Verifiable at compile time

implements

```
ClassA implements Interface1
ClassB implements Interface1
```

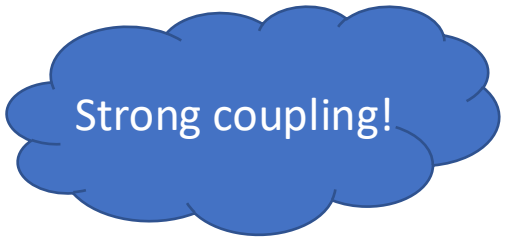


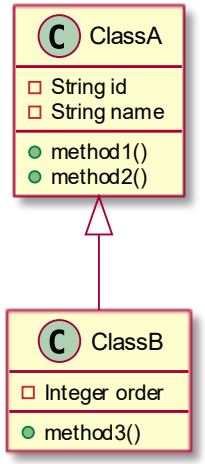
Interfaces are implemented in C++ by means of **Abstract Classes** whose functions are all **pure virtual**.

Medium coupling!

5. *TypeX* is (directly or indirectly) a *TypeY* subclass

- The subclass inherits all the public and protected members (attributes, operations and relations) from its superclass
  - New members can be added to the subclass
  - Existing members can be specialized by the subclass
- All instances of the subclass are also instances of the superclass
- Not all instances of the superclass are instances of the subclass





extends

`ClassB` is a subclass of **`ClassA`**
`ClassA` is a superclass of **`ClassB`**

Promotion of Container Objects to Software Classes

by applying High Cohesion, Low Coupling and Pure Fabrication

Motivating the Problem – Part I

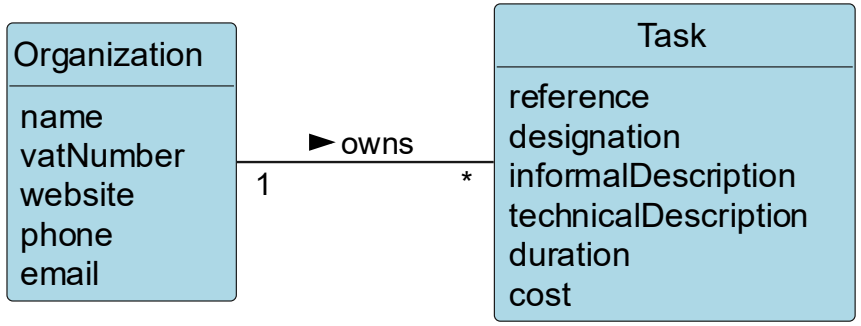
UC010 – List Organization Tasks

UC010 – List Organization Tasks

Platform for Outsourcing Tasks

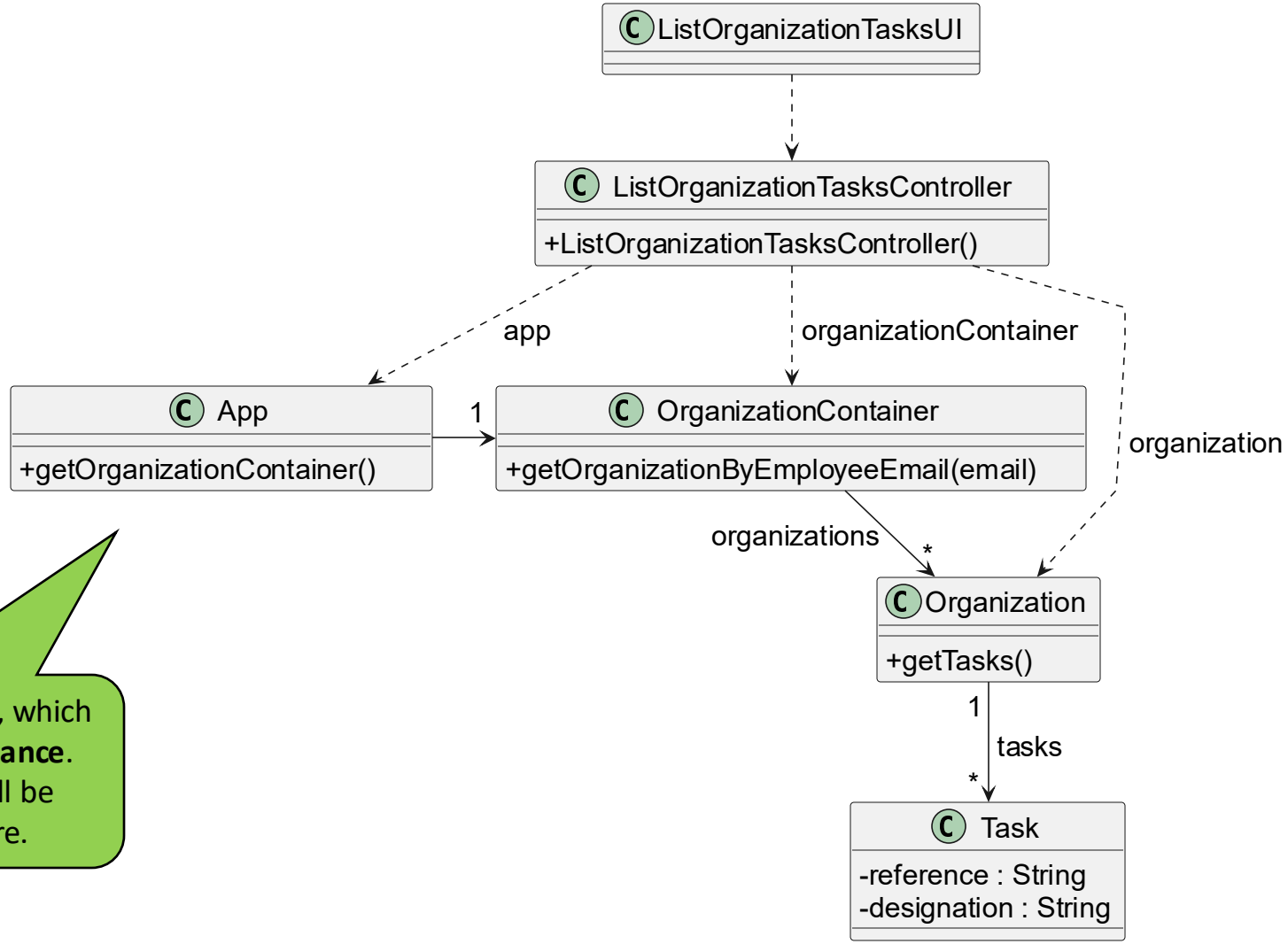
- As an Organization Employee, I want to list all tasks created by my organization.
  - AC1: The tasks must be sorted alphabetically by their designation.

- Relevant Domain Model excerpt



UC010 – Partial Class Diagram

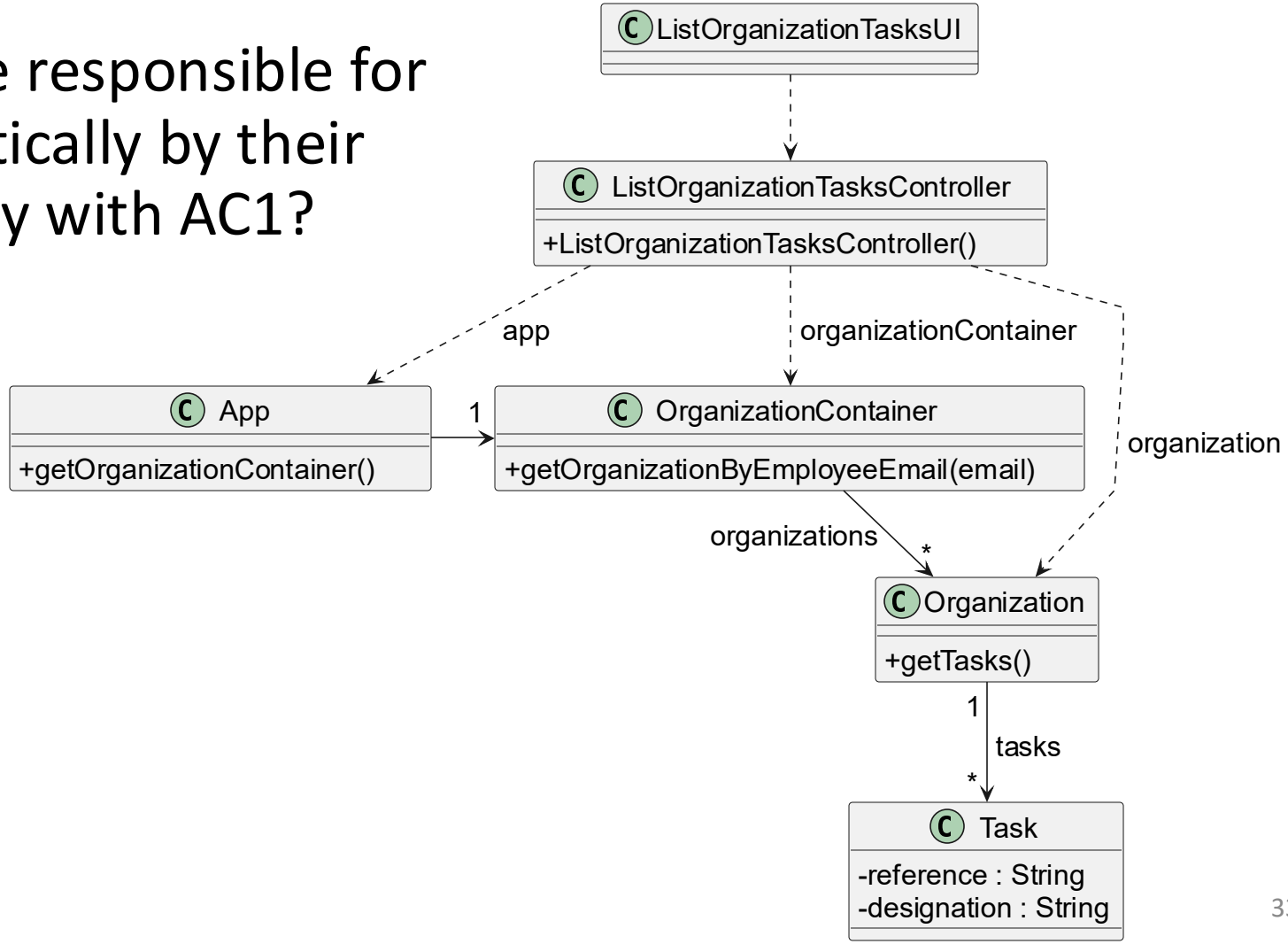
Platform for Outsourcing Tasks



The App class is a **singleton**, which means it has **only one instance**. The Singleton pattern will be address in a next lecture.

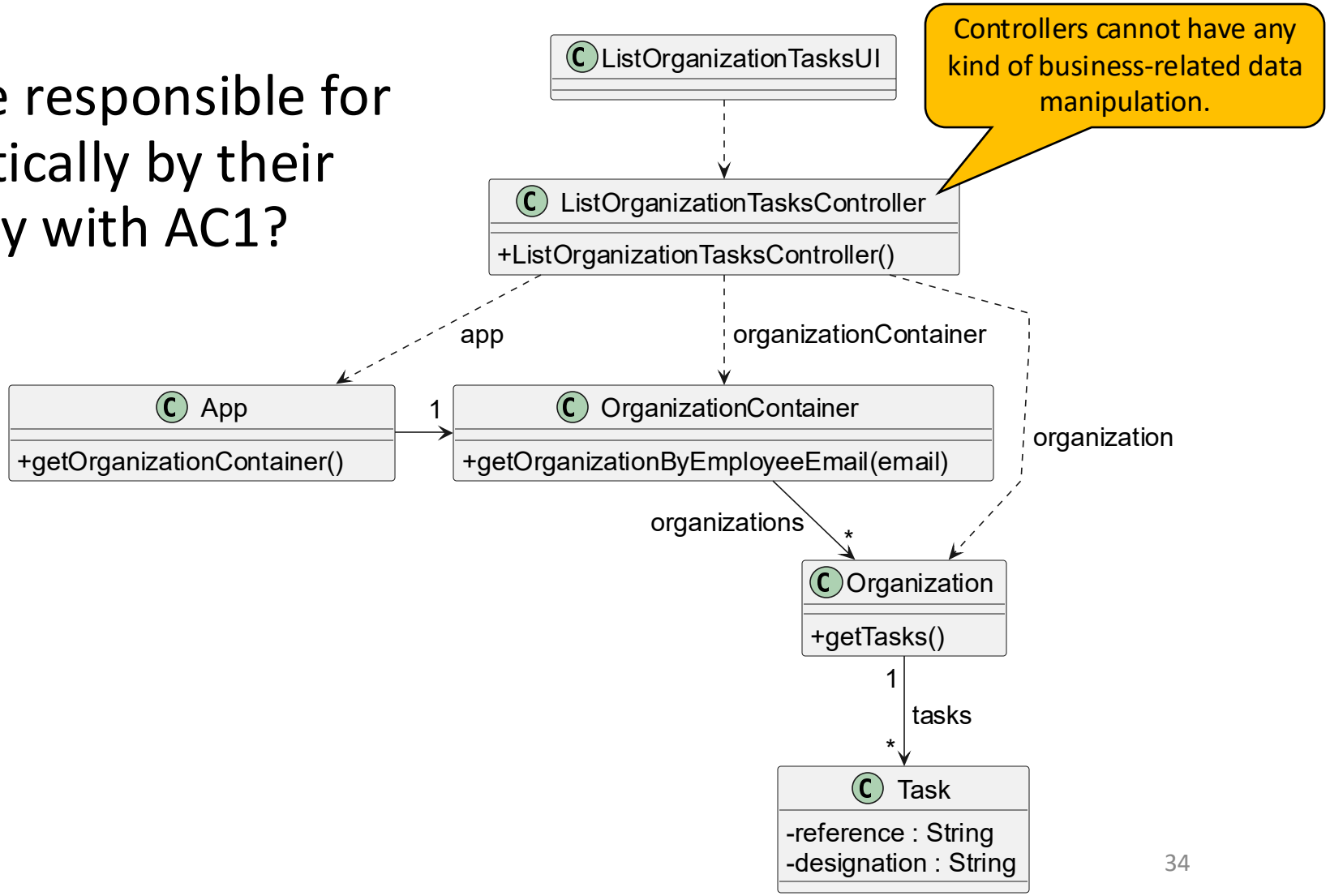
Complying with AC1: Sorting Tasks (1/5)

- Which class should be responsible for sorting tasks alphabetically by their designation, to comply with AC1?
  - UI?
  - Controller?
  - Organization?
  - Task?



Complying with AC1: Sorting Tasks (2/5)

- Which class should be responsible for sorting tasks alphabetically by their designation, to comply with AC1?
  - UI?
  - ~~Controller?~~
  - Organization?
  - Task?



Complying with AC1: Sorting Tasks (3/5)

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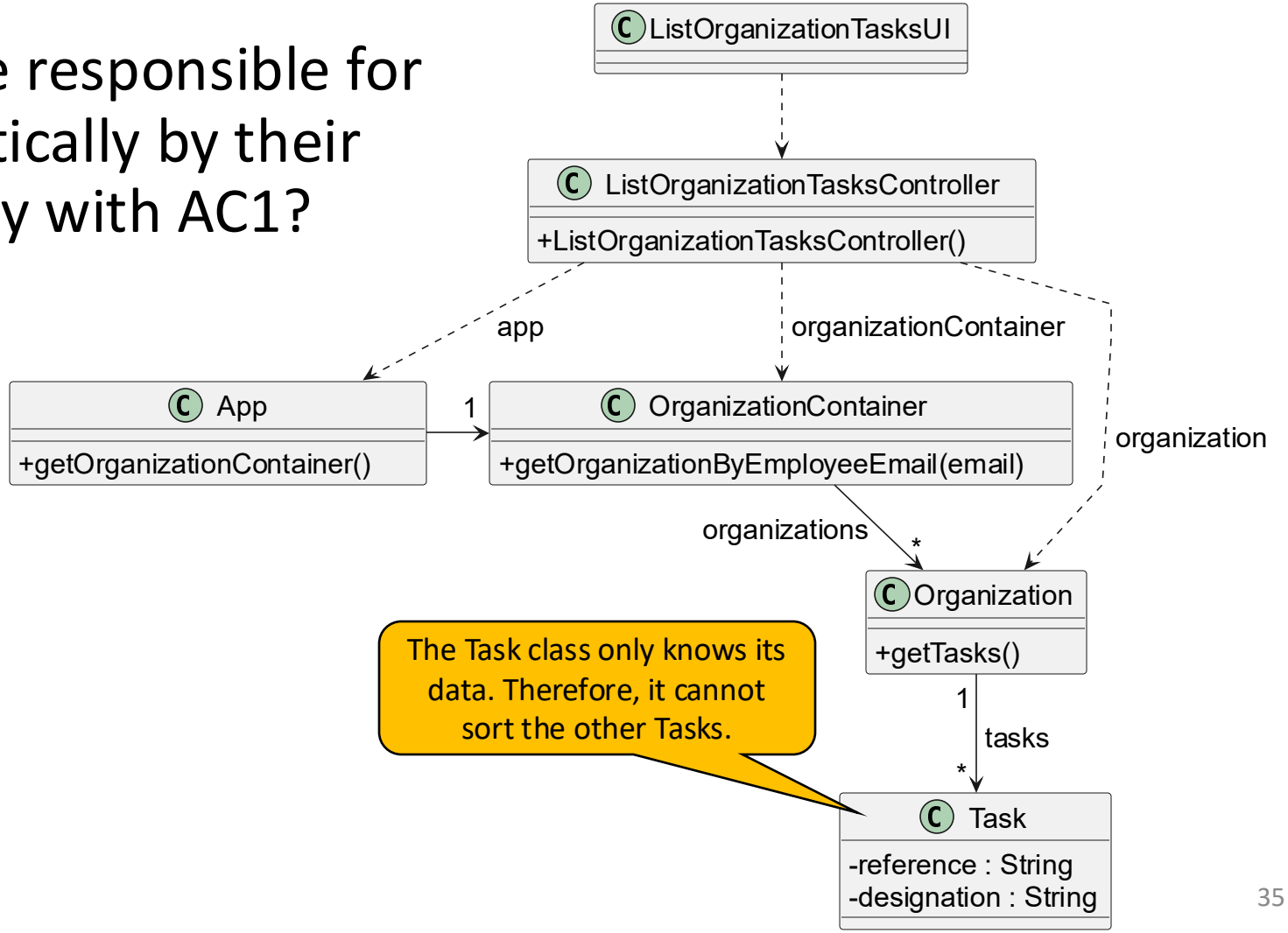

Complying with AC1: Sorting Tasks (4/5)

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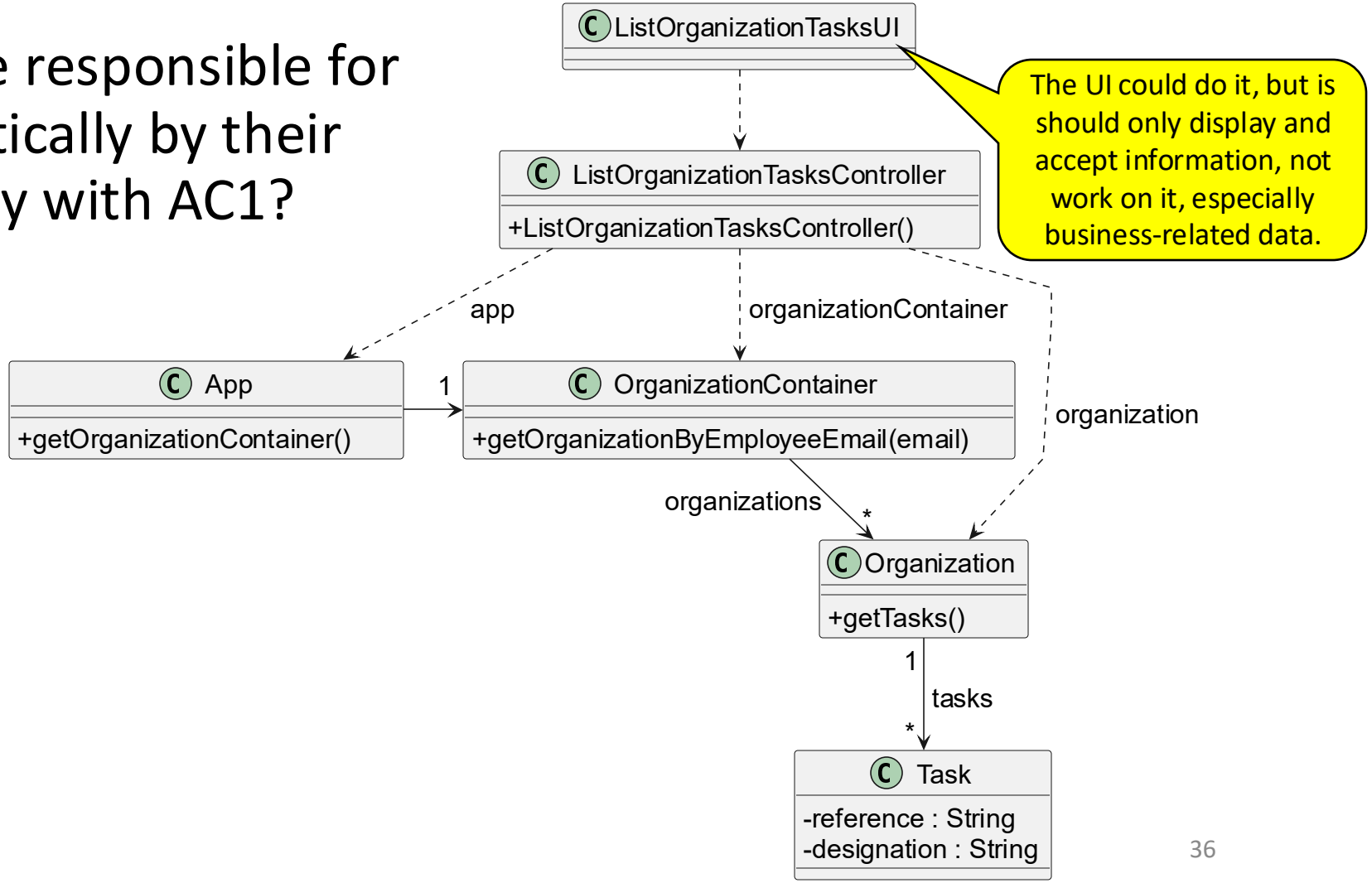

Complying with AC1: Sorting Tasks (5/5)

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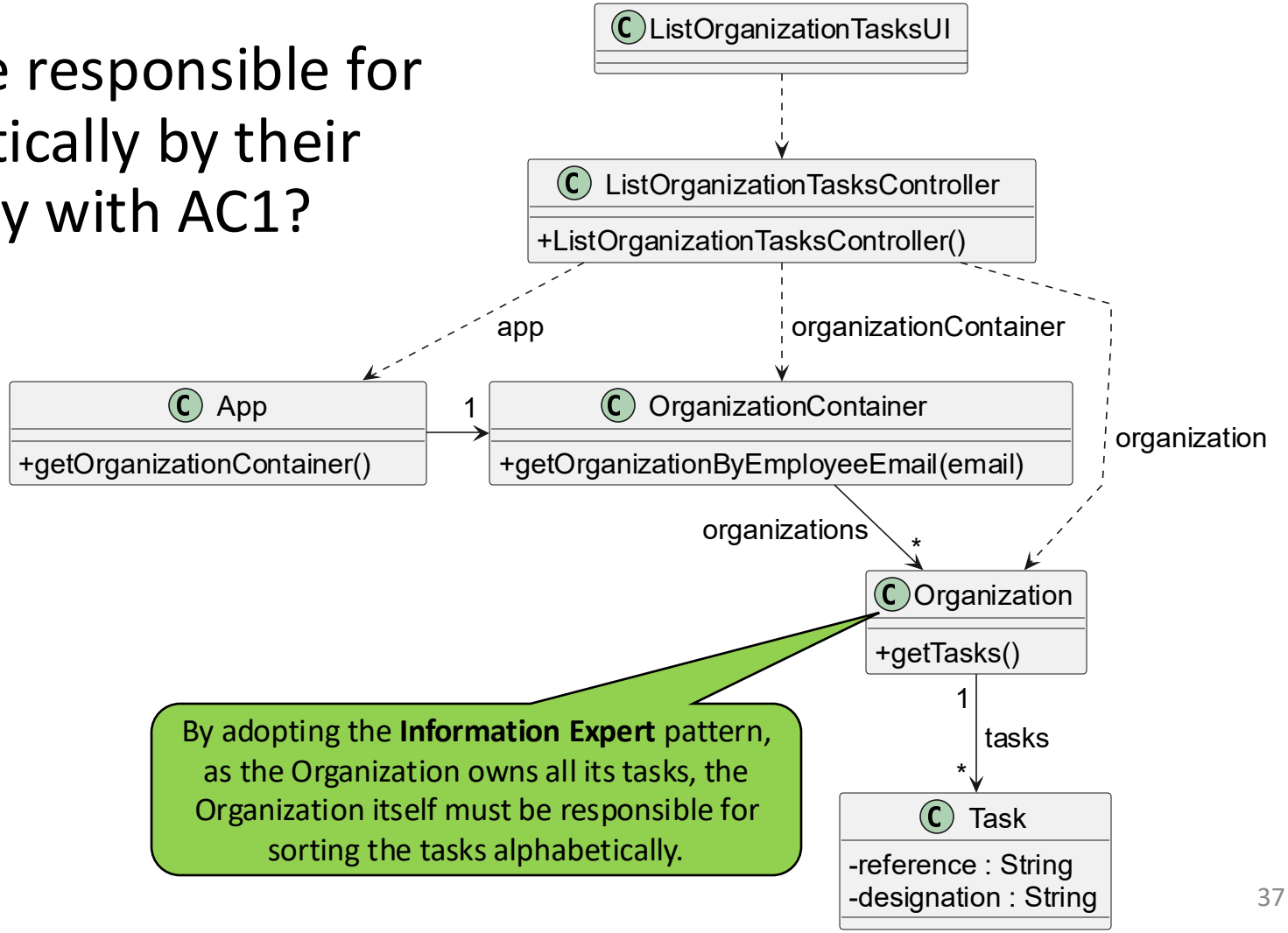

UC010 – AC1 Rationale (1/2)

- To comply with AC1 and according to Information Expert (IE), **the Organization class should be responsible for sorting the Tasks** because it holds the Tasks for the Organization
- The Organization class should implement the **getSortedTasks()** function
- While this makes sense, as a side effect, this approach:
  - **Increases Coupling** between Organization and Task
    - Remember the **"Tell, Don't Ask"** principle – how can the Organization have access to the **designation** attribute for comparison without a **getDesignation()** function in the Task class?
  - **Reduces Cohesion** of the Organization class
    - The Organization must not only hold the created Tasks, but also have the responsibility for sorting those Tasks

UC010 – AC1 Rationale (2/2)

Is this the best approach?
Let's consider another
Use Case…

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Motivating the Problem - Part II

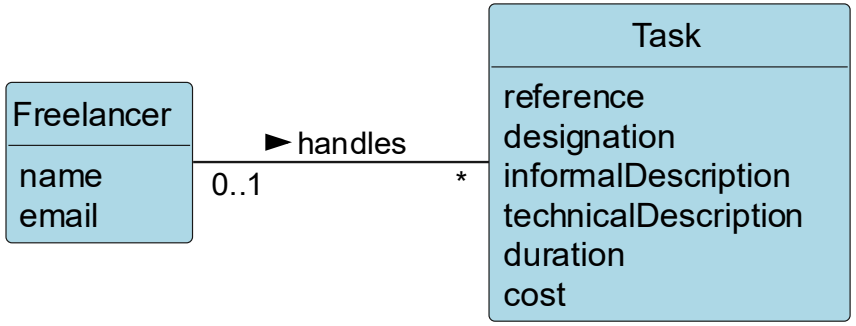
UC011 – List Freelancer Tasks

UC011 – List Freelancer Tasks

Platform for Outsourcing Tasks

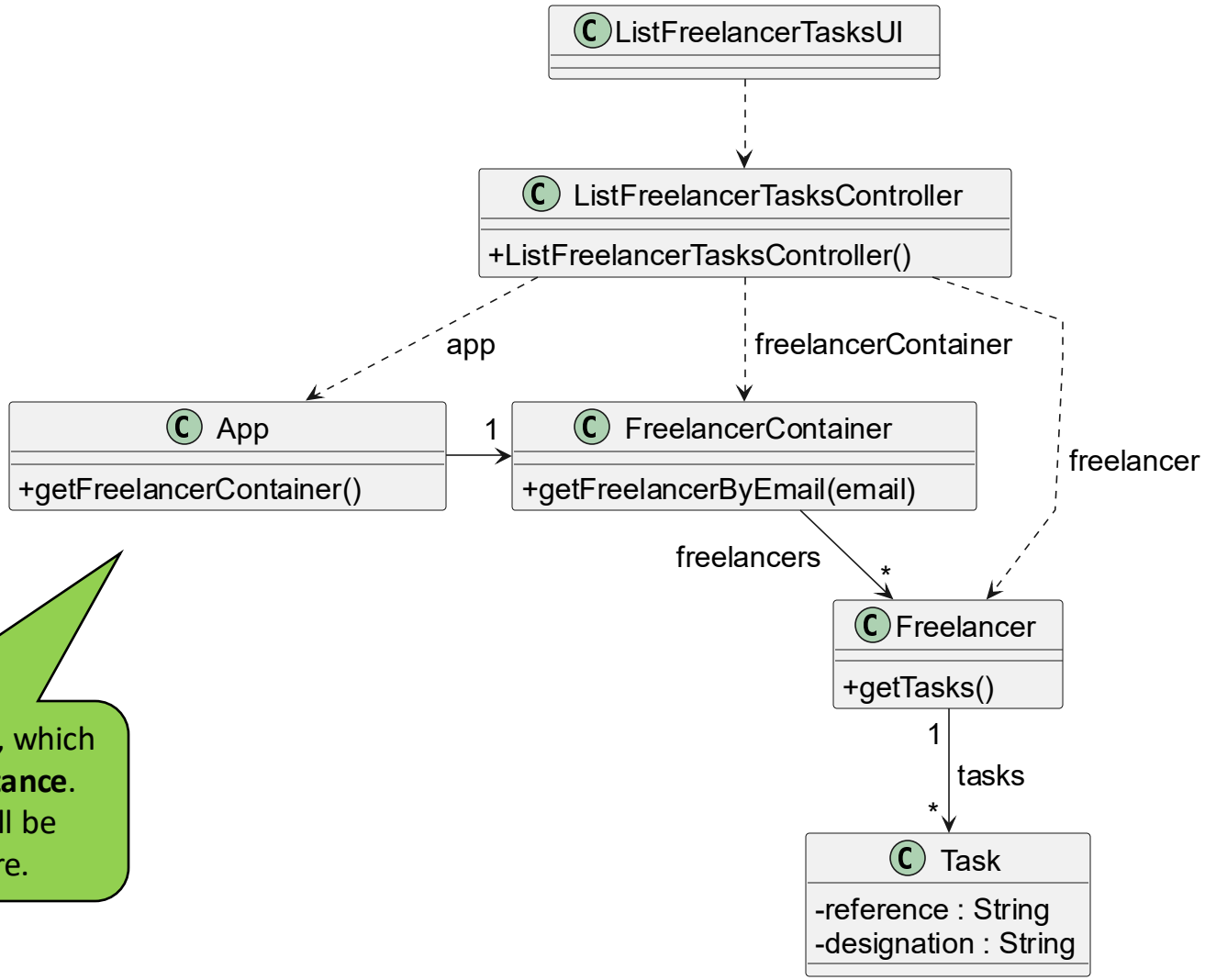
- As a Freelancer, I want to list all my assigned tasks.
  - AC1: The tasks must be sorted alphabetically by their designation.

- Relevant Domain Model excerpt



UC011 – Partial Class Diagram

Platform for Outsourcing Tasks



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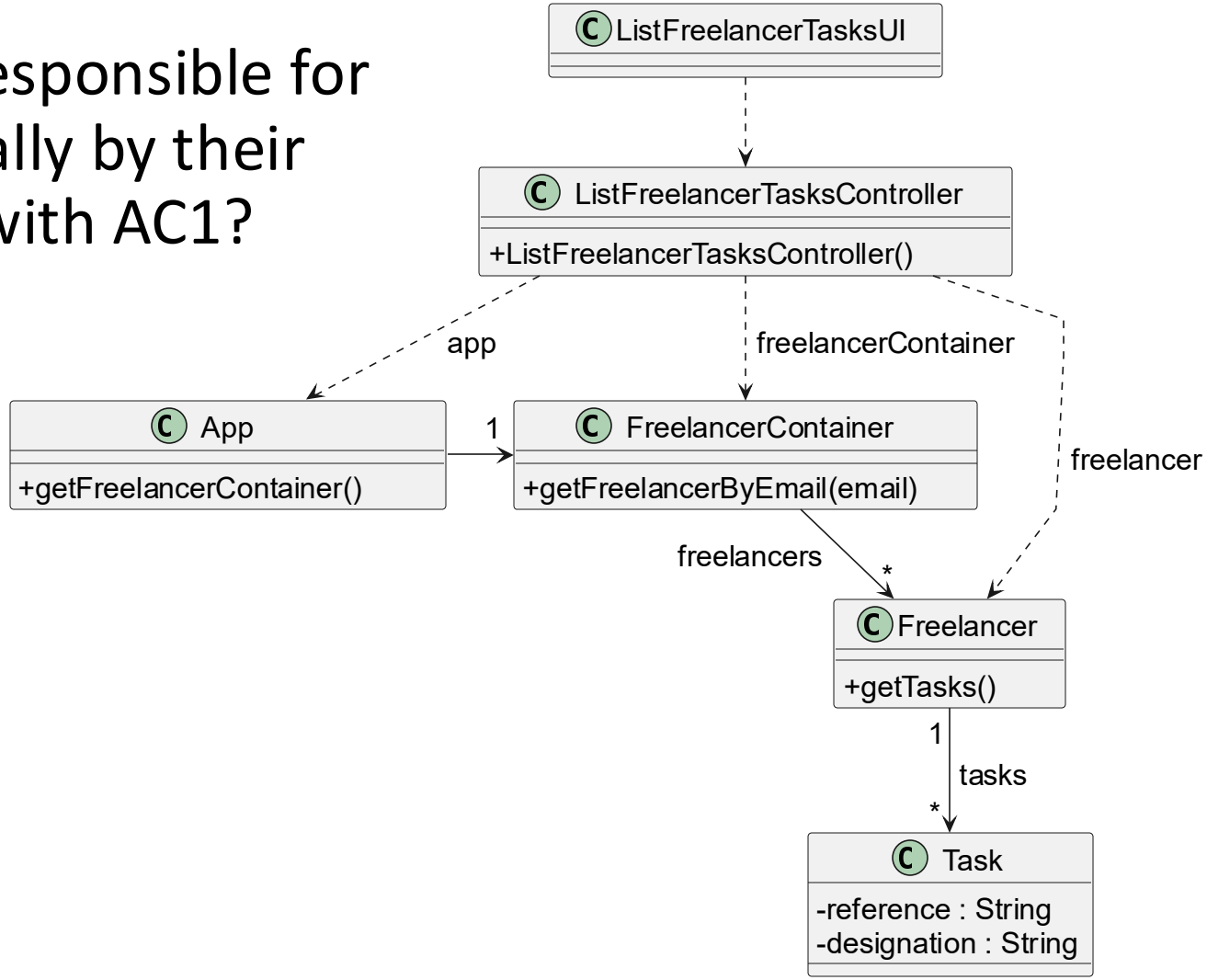

Complying with AC1: Sorting Tasks (2/5)

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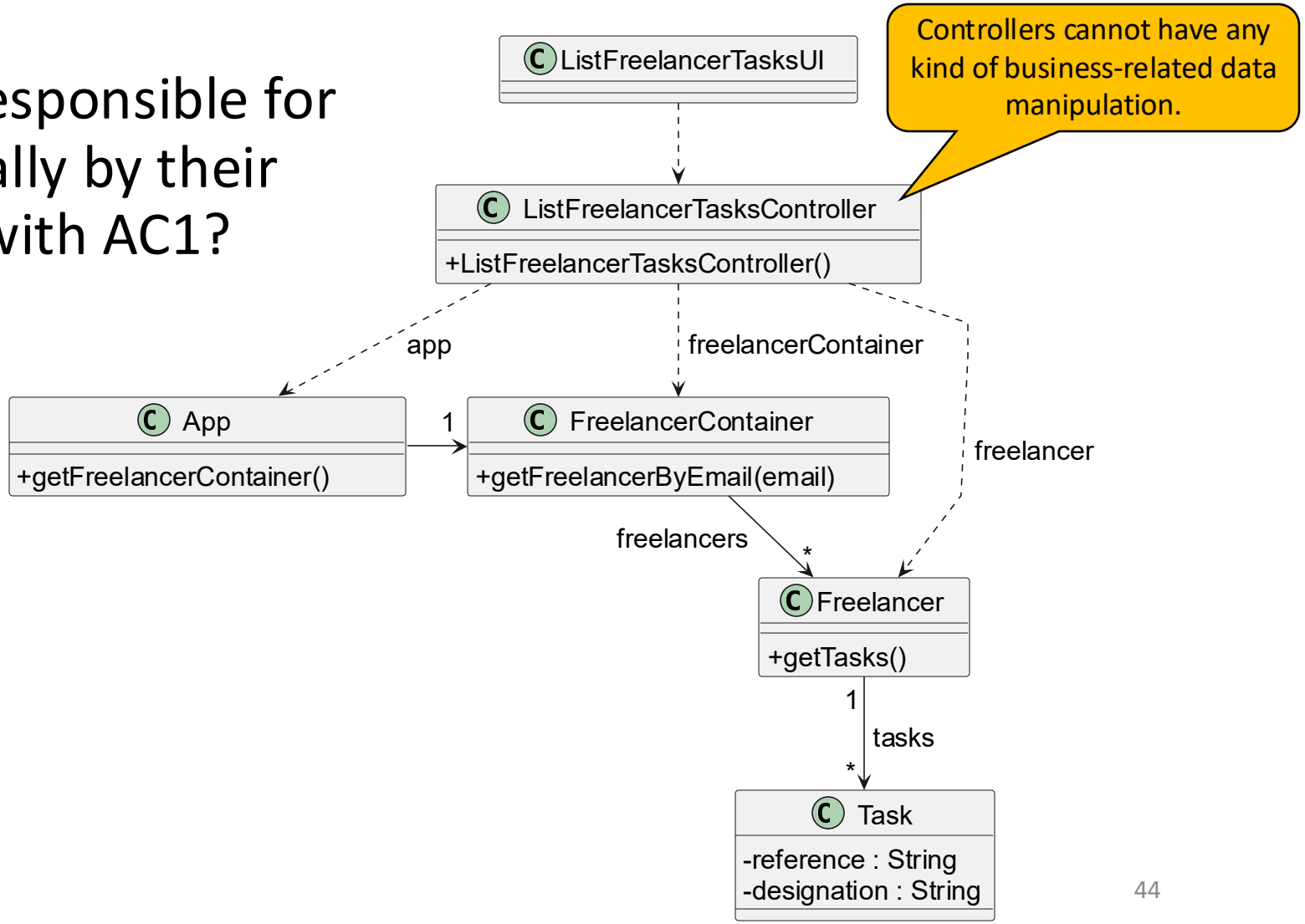

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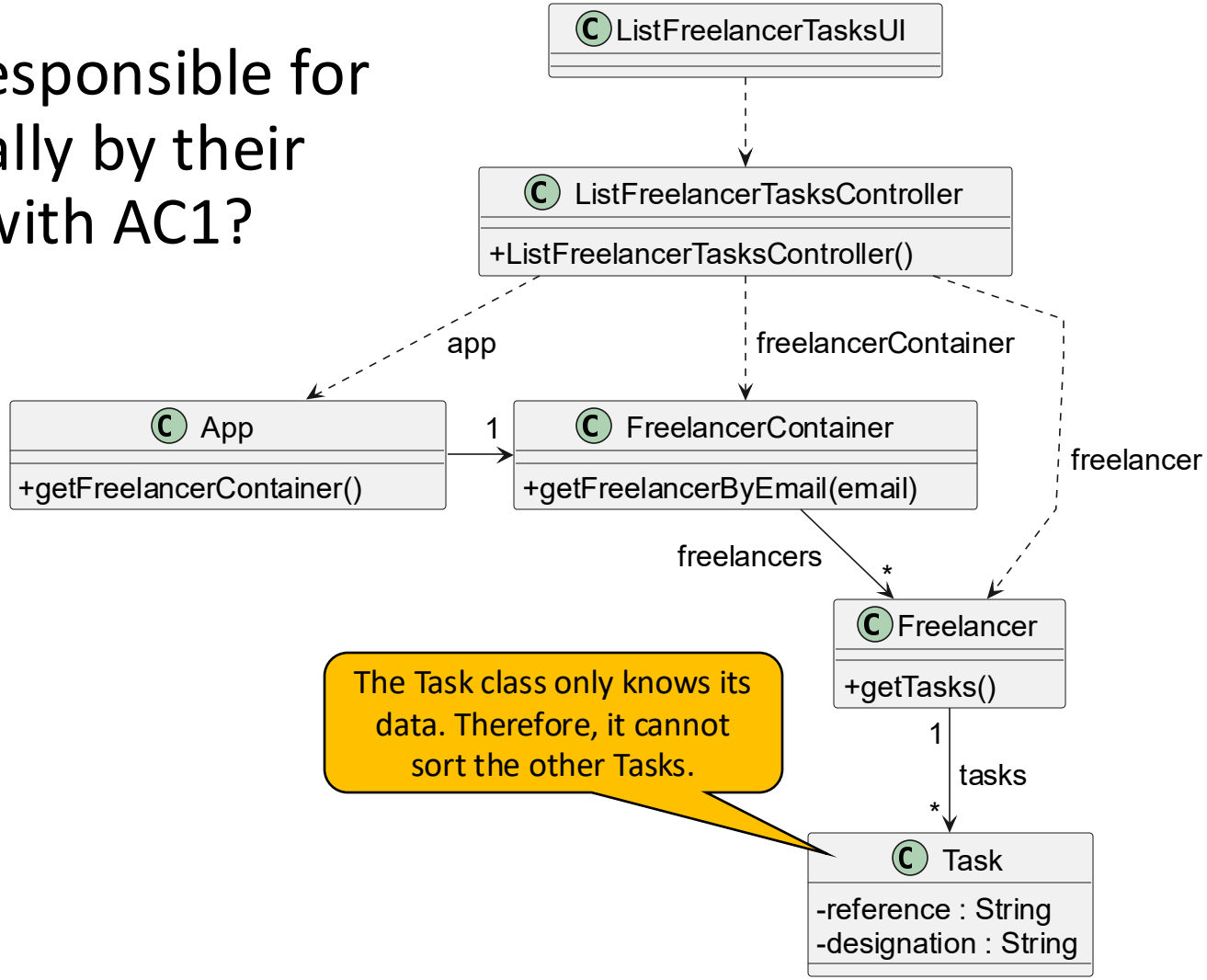

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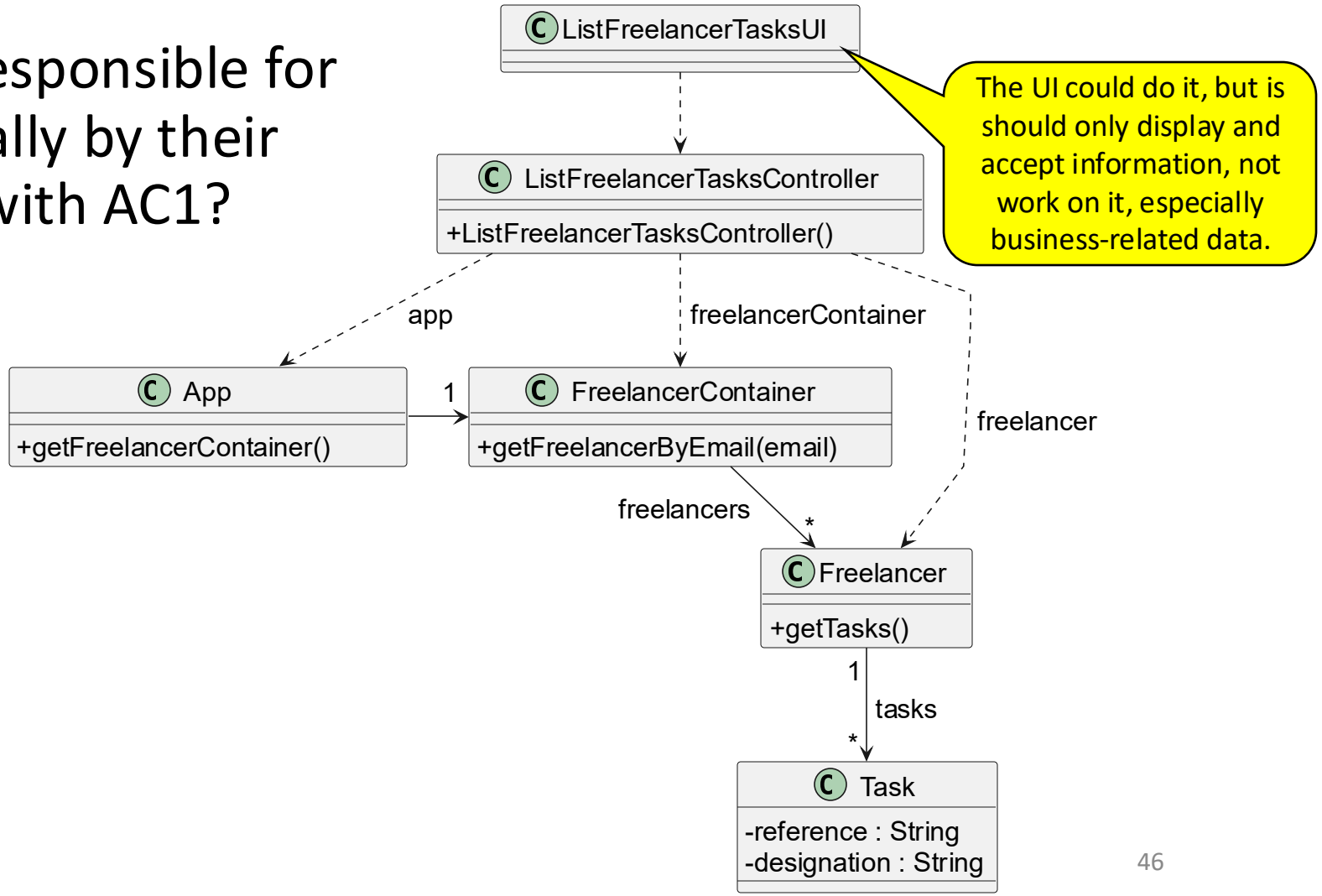

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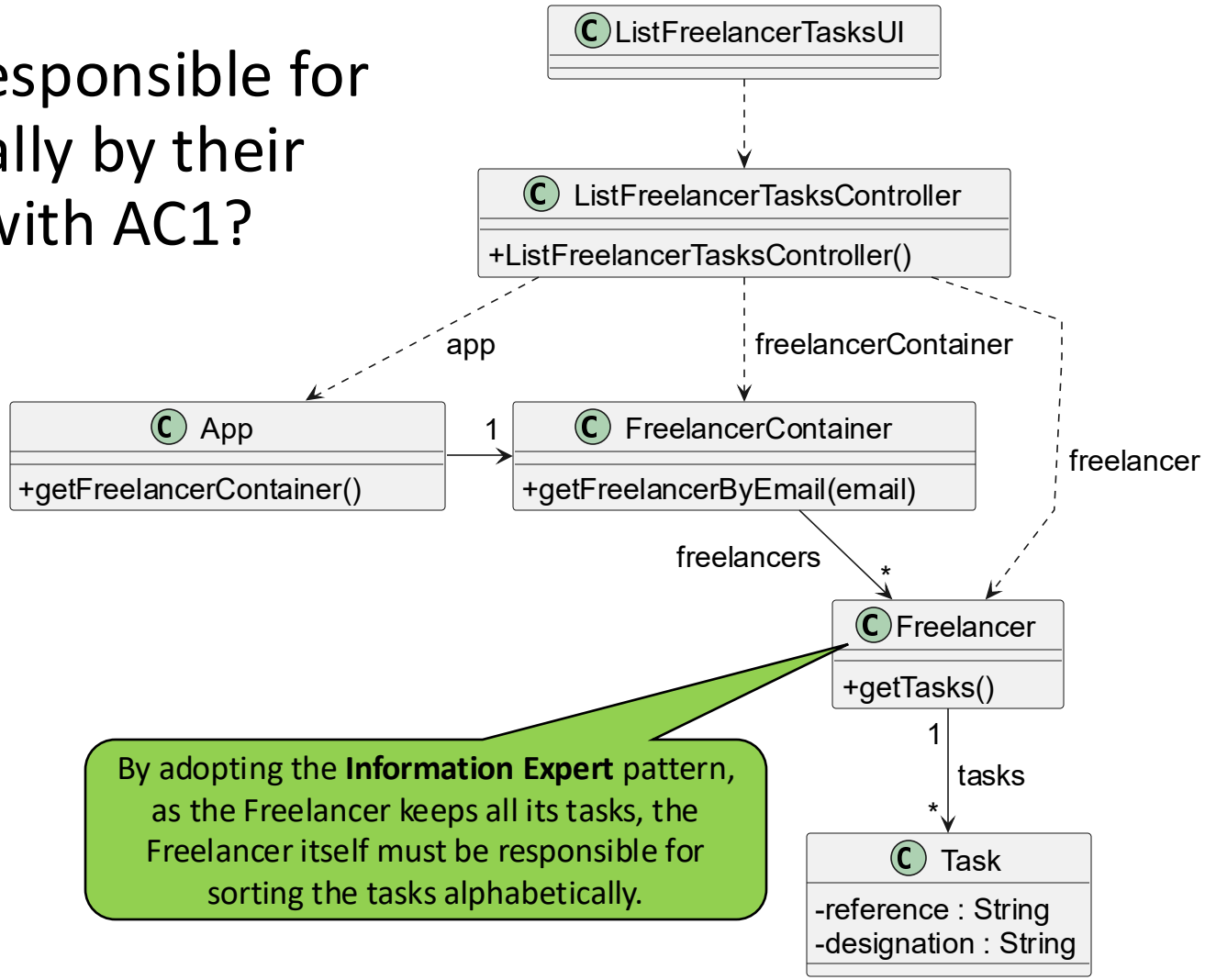

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UC011 – AC1 Rationale (2/5)

Doesn't this smell fishy and look like a repetition of what happened before?

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Haven't we increased, once again, the coupling of the Task class?

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HOW TO SOLVE THIS PROBLEM?

How to solve this problem? (1/2)

- Why not have both Organization and Freelancer classes **delegate the sorting responsibility to another class**?

- What responsibilities should that class have?
  - That class should be responsible for handling operations over a particular container object
  - In this case, the class would be handling responsibilities related to the tasks container

How to solve this problem? (2/2)

- **Keep using a Container object** (e.g. list) **if the association requires typical container functions only** (e.g. add, get, delete, iterator)

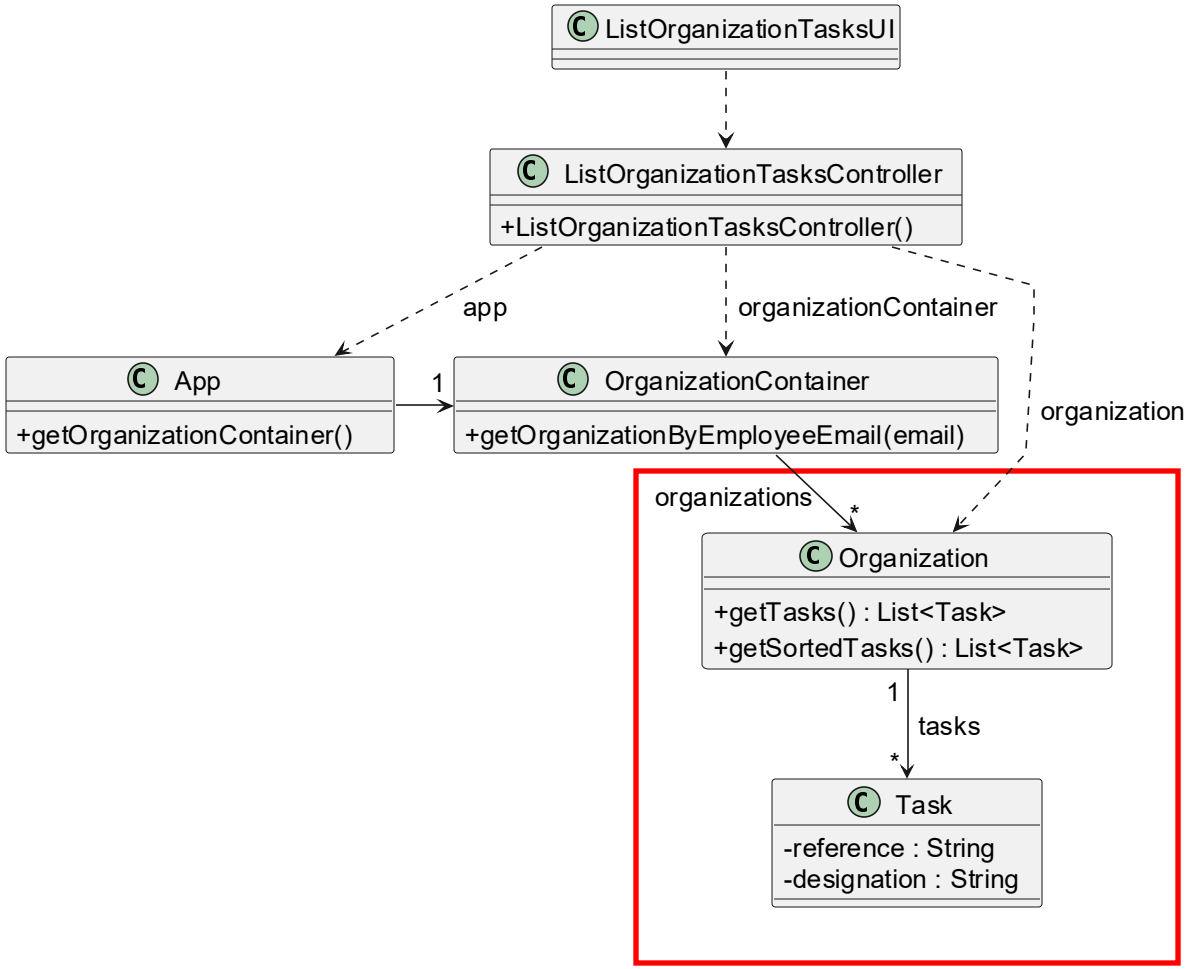
- **Promote the Container object to a New Class if**, in addition to the container functions, **specific functions are required**
  - E.g.: a sorting function like getSortedTasks()

How to name the new software class?

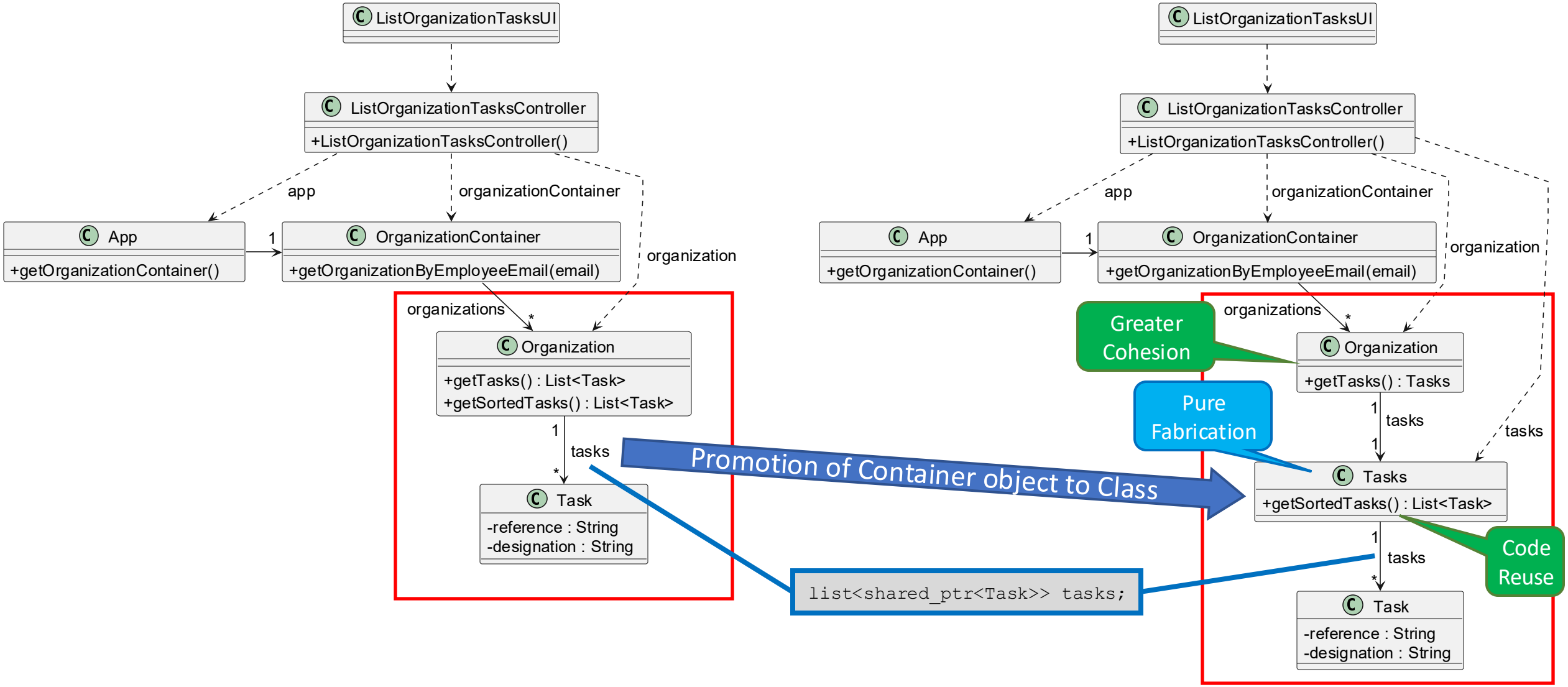
- When the New Class has a more **“global” scope** in the system, it might be named using as a suffix like, for example: Store, **Container** or Repository
  - E.g.: OrganizationStore, **OrganizationContainer**, OrganizationRepository

- When the New Class has a more **“local” scope** (i.e. restricted to a given instance), it might be named using a suffix like, for example: List (when of type List) or simply the name of the class **in plural**
  - E.g.: TaskList, **Tasks**

Changes to the UC010 design (1/2)



Changes to the UC010 design (2/2)



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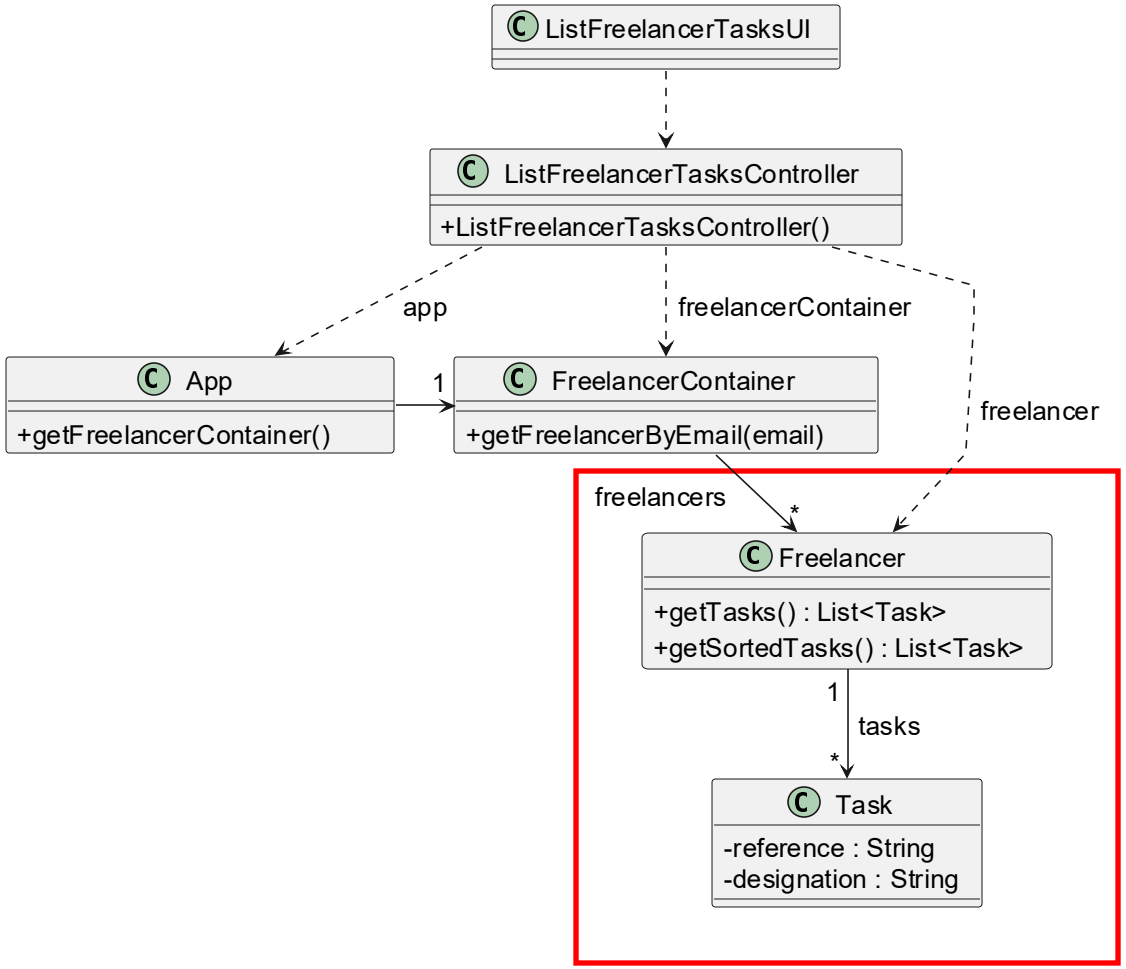
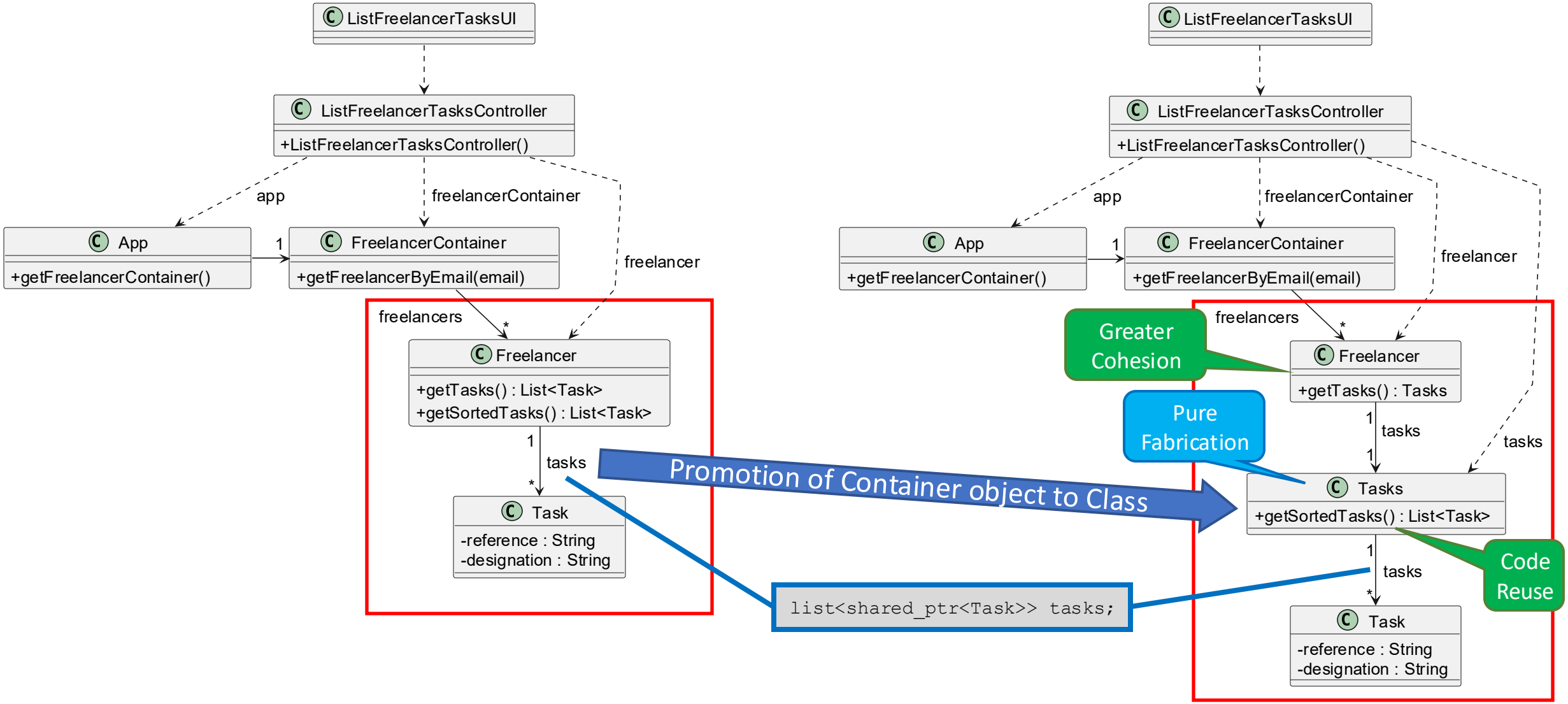


Changes to the UC011 design (2/2)



Summary (1/2)

- Combine High Cohesion and Low Coupling with other GRASP patterns to assign responsibilities to objects
- Evaluate design alternatives using High Cohesion and Low Coupling
- Adopt design alternatives favoring
  - Modularity
  - Reusability
  - Maintainability

Summary (2/2)

- High Cohesion and Low Coupling must be considered while designing
  - Not only to promote container objects to software classes
    - Pure Fabrication
  - But also, on other scenarios (e.g.: filter/sort a container object by some criteria) to evaluate plausible alternatives
    - Tell, Don’t Ask
    - Information Expert

- The Domain Model is used to inspire the creation of software classes (the Design Model), but the opposite is not true

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