**Software Design Patterns**

Continuous Assessment Activity 1 – CAT1

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**Design Principles and Analysis Patterns**

Question 1

1. The proposed design does not satisfy the OCP principle.

To satisfy the OCP principle the classes should be open for extension but closed for modification, and the problem with this approach is that if we were to add a new type of employee that also doesn’t have a salary, we may need to modify the class Payroll.

In the Payroll class, the method calculateTotalPayroll() there’s a type check: if(!employee instanceof Intern). This is intended to check that Intern employees, that do not have a salary, are not included in the payroll calculation. But for example, if we must add a “volunteer” employee type that is also not having a salary, we will need to add a new check in the Payroll class:

// Example of code modification needed if we add a new employee subtype

if(!(employee instanceof Intern || employee instanceof Volunteer)) {

    totalSalary += employee.calculateSalary();

}

In summary, the Payroll class shouldn’t be modified every time we introduce a new type of employee. A better OCP approach will be to have each employee type class defining its own calculateSalary()method calculation logic, avoiding adding type checks in the Payroll class.

1. The proposed design is not fully satisfying the DRY principle.

This principle says that each piece of logic should appear only once, and as we can observe in our code, the logic to calculate the payroll is being repeated in multiple classes.

Also, the Intern class sets the salary to 0 via super(name, surname, 0) and then this logic is duplicated in the setSalary method when explicitly setting this.salary = 0.

Additionally, the Contractor class has a separate calculation method but also follows a repetitive logic when setting the salary to 0 via super(name, surname, 0).

In summary, we have multiple places to force salary = 0 for an Intern and the Contractor salary calculation following a repetitive pattern. This means that some pieces of logic are repeated and if any business rule changes, we will need to update multiple parts of the code. So, since we don’t have a clean way of avoiding duplicating the checks and the salary calculation, we can say that the DRY principle is not being satisfied.

1. The proposed design does not fully satisfy the High Cohesion principle.

The high cohesion principle states that every class should have a unique and clear responsibility and in our code the Payroll class in managing multiple logics.

The reason is that the Payroll class has to know about the specific implementation of the different employee types, assigning multiple responsibilities to this class and reducing cohesion.

1. To address all the issues mentioned, I will propose this design:

// Base employee class

public abstract class Employee {

    private String name;

    private String surname;

    public Employee(String name, String surname) {

        this.name = name;

        this.surname = surname;

    }

    public abstract double calculateSalary();

}

// Regular employees have a fix salary

public class RegularEmployee extends Employee {

    private double salary;

    public RegularEmployee(String name, String surname, double salary) {

        super(name, surname);

        this.salary = salary;

    }

    public void updateSalary(double newSalary) {

        this.salary = newSalary;

    }

    @Override

    public double calculateSalary() {

        return salary;

    }

}

// Interns do not have salary

public class Intern extends Employee {

    public Intern(String name, String surname) {

        super(name, surname);

    }

    @Override

    public double calculateSalary() {

        return 0;

    }

}

 // Contractors with salary calculation based on hours worked

public class Contractor extends Employee {

    private double hourlyRate;

    private int hoursMonth;

    public Contractor(String name, String surname, double hourlyRate, int hoursMonth) {

        super(name, surname);

        this.hourlyRate = hourlyRate;

        this.hoursMonth = hoursMonth;

    }

    @Override

    public double calculateSalary() {

        return hourlyRate \* hoursMonth;

    }

}

// Payroll only manages employees

public class Payroll {

    private List<Employee> employees;

    public Payroll() {

        employees = new ArrayList<>();

    }

    public void addEmployee(Employee employee) {

        employees.add(employee);

    }

    public double calculateTotalPayroll() {

        double totalSalary = 0;

        for (Employee employee : employees) {

            totalSalary += employee.calculateSalary(); // Polymorphism

        }

        return totalSalary;

    }

}

* In the proposed design, the Payroll class has only one responsibility, managing employees. Also, each subtype of employee handles its own salary calculation without affecting the rest of the system. **High Cohesion**
* If we create a new employee subtype, we don’t need to modify the current existing classes. **OCP**
* We don’t repeat checks for intern and there’s no repeated logic for salary. **DRY**
* Additionally, we improved the method to handle salary change for regular employees and we added the override decorator to make sure that each employee subtype salary calculation method correctly overrides the method from the Employee parent class, making the code easier to read and understand.

UML

A diagram of a computer

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Question 2

1. The initial design does not satisfy the LSP principle.

The LSP principle states that if we replace one class type with another, the system should still work properly, meaning that if a subclass changes the system’s behavior, then the LSP principle is not being satisfied.

In the original design, the Intern class breaks this rule by doing two different things:

1. Throwing an exception in calculateSalary() because any code expecting a number from this operation will make the system fail. This means the Intern class can be substituted for a regular Employee without changing how the system works, hence breaking the LSP principle:

public double calculateSalary() {

  throw new UnsupportedOperationException("Interns do not have salary");

  }

As we mentioned many times, the Payroll must manually exclude interns with the already explained check. So, this is a clear violation of the LSP principle since if Interns behave like any other Employee we wouldn’t need this check.

1. In our design, the Intern class is now returning 0 without throwing errors. So, now all the subclasses can be used the same way without breaking the code satisfying the LSP principle.

public double calculateSalary() {

        return 0;

    }

1. The clearest example of violation of the LSP principle is found in Intern class in the method calculateSalary() when throwing an exception. This prevents the Intern class from being used as a normal Employee, breaking the logic whenever the system assumes all employees can return a valid salary:

public double calculateSalary() {

    throw new UnsupportedOperationException("Interns do not have salary");

  }

So, if we replace a RegularEmployee with an Intern this will cause an error:

List<Employee> employees = new ArrayList<>();

employees.add(new RegularEmployee("Nico", "Dalessandro", 3000));

employees.add(new Intern("Juan", "Perez"));

// This will throw an exception breaking the LSP principle

for (Employee employee : employees) {

        double salary = employee.calculateSalary();

        System.out.println("Processing salary: " + salary);

}

For addressing this issue, we have modified the calculateSalary() method to return 0 instead of throwing an exception, making our Intern class available to be used interchangeably with other Employee types and making the Payroll available to process all employees without need of modification or extra checks:

public class Intern extends Employee {

    @Override

    public double calculateSalary() {

        return 0;

    }

}

1. Violating the LSP principle may have many consequences such as **unexpected errors or crashes at runtime** since the code expects some behavior from a base class but gets a different behavior from a subclass, as happened in our example from previous exercises.

Also, not following this principle may lead to **more manual checks and code complexity** as it happens in the instance type check for interns forced in the payroll class.

Finally, violating the LSP principle will result in **code that is hard to extend in the future**, as in our example, where we highlight that adding another employee type such as volunteers will require the modification of the payroll class.

Question 3

1. To design the proposed system, I will use the following patterns:

|  |  |
| --- | --- |
| **Pattern** | **Justification** |
| **Range Pattern** | The statement mentions that each device has a valid range (blood pressure between 90-140 mmHg, etc.), so, using the Range **Pattern will help to ensure that the values remain within the acceptable limits avoiding incorrect measurements**. |
| **Quantity Pattern** | The statement mentions that each measurement has a specific unit (75 bpm, 120 mmHg, 36°C, etc.), so, **using the Quantity Pattern will help to ensure that the values are stored with their units, avoiding mistakes and calculation errors**. |

In summary:

* **Because devices operate in a predefined range**, we will use the *Range pattern* to establish the limits for each device.
* **For storing measurements with its corresponding unit,** we will use *Quantity pattern* for associate values with units.

Requirements:

1. **MedicalDeviceType** will represent the type of medical device like the “CARDIOMAX” and it will have the attributes identifierName (example “CARDIOMAX) and description (example “Device that measures hear rate”).
2. **PhysiologicalParameter** will represent the physiological parameter that the device measure like “Heart Rate” and it will have the attribute parameterName (example “hear rate”).
3. **MeasurementUnit** will represent the unit of measure the physiological parameter is being measured and will have the attribute unitName (example “bpm”).
4. **Range** will represent the limits in which the device type can operate, and it will have the attribute minValue and maxValue (example 40-200)
5. Static AnalysisDiagram

A diagram of a device type

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**System constraints achieved with this design:**

* A MedicalDevice is linked to one PhysiologicalParameter to ensure devices measure a specific parameter.
* Each PhysiologicalParameter is measured in a specific MeasurementUnit to maintain the unit consistency.
* A MedicalDevice has a defined Range setting the operational limits and avoiding incorrect readings.
* Each PhysiologicalParameter is measured in a specific MeasurementUnit to maintain the unit consistency.
* A MeasurementUnit can be the same in different PhysiologicalParameter.

**Analysis Patterns applied in this design:**

* **Quantity Pattern**: Represented when linking the physiological measurements with its unit by PhysiologicalParameter and MeasurementUnit
* **Range Pattern**: Represented by the Range class associated with each device and when defining the minValue and maxValue.

**Example Implementation Code:**

public class MeasurementUnit {

    private String unitName;

    public MeasurementUnit(String unitName) {

        this.unitName = unitName;

    }

    public String getUnitName() {

        return unitName;

    }

    public void setUnitName(String unitName) {

        this.unitName = unitName;

    }

}

public class PhysiologicalParameter {

    private String parameterName;

    private MeasurementUnit unit;

    public PhysiologicalParameter(String parameterName, MeasurementUnit unit) {

        this.parameterName = parameterName;

        this.unit = unit;

    }

    public String getParameterName() {

        return parameterName;

    }

    public MeasurementUnit getUnit() {

        return unit;

    }

    public void setUnit(MeasurementUnit unit) {

        this.unit = unit;

    }

}

public class Range {

    private double minValue;

    private double maxValue;

    public Range(double minValue, double maxValue) {

        if(minValue > maxValue) {

            throw new IllegalArgumentException("minValue must be <= maxValue");

        }

        this.minValue = minValue;

        this.maxValue = maxValue;

    }

    public double getMinValue() {

        return minValue;

    }

    public double getMaxValue() {

        return maxValue;

    }

    public boolean isWithinRange(double value) {

        return value >= minValue && value <= maxValue;

    }

}

public class MedicalDeviceType {

    private String identifierName;

    private String description;

    private PhysiologicalParameter parameter;

    private Range operatingRange;

    public MedicalDeviceType(String identifierName, String description, PhysiologicalParameter parameter, Range operatingRange) {

        this.identifierName = identifierName;

        this.description = description;

        this.parameter = parameter;

        this.operatingRange = operatingRange;

    }

    public String getIdentifierName() {

        return identifierName;

    }

    public String getDescription() {

        return description;

    }

    public PhysiologicalParameter getParameter() {

        return parameter;

    }

    public Range getOperatingRange() {

        return operatingRange;

    }

}

public class Main {

    public static void main(String[] args) {

        // Measurement unit "bpm"

        MeasurementUnit bpmUnit = new MeasurementUnit("bpm");

        // Physiological parameter "Heart Rate" measured in "bpm"

        PhysiologicalParameter heartRate = new PhysiologicalParameter("Heart Rate", bpmUnit);

        // Range: from 40 bpm to 200 bpm

        Range cardiomaxRange = new Range(40, 200);

        // Medical device type "CARDIOMAX"

        MedicalDeviceType cardiomax = new MedicalDeviceType(

                "CARDIOMAX",

                "Device that measures heart rate.",

                heartRate,

                cardiomaxRange

        );

        // Clear demonstration

        System.out.println("Device Type: " + cardiomax.getIdentifierName());

        System.out.println("Description: " + cardiomax.getDescription());

        System.out.println("Measures: " + cardiomax.getParameter().getParameterName());

        System.out.println("Unit: " + cardiomax.getParameter().getUnit().getUnitName());

        System.out.println("Operating Range: from " + cardiomax.getOperatingRange().getMinValue() + " to " + cardiomax.getOperatingRange().getMaxValue() + " " + cardiomax.getParameter().getUnit().getUnitName());

    }

}

// Output of the code to demonstrate instantiation

Device Type: CARDIOMAX

Description: Device that measures heart rate.

Measures: Heart Rate

Unit: bpm

Operating Range: from 40.0 to 200.0 bpm

Question 4

1. To design the proposed system, I will use the following patterns:

|  |  |
| --- | --- |
| **Pattern** | **Justification** |
| **Historical Association** | The statement mentions that the measurements are recorded over time, meaning that we will need to store the past values. So, **using the Historical Association pattern will help to ensure that we maintain the corresponding history of measurements with its timestamp and the serial number** and to be able to answer questions like what the heart rate at 10:30 AM was, etc. |
| **Quantity Pattern** | The statement mentions that each measurement has a specific unit (75 bpm, 120 mmHg, 36°C, etc.), so, **using the Quantity Pattern will help to ensure that the values are stored with their units, avoiding mistakes and calculation errors**. |

In summary:

* **For storing historical record of the measurements,** we will use the Historical Association pattern allowing us to keep track them.
* **For storing measurements with its corresponding unit,** we will use *Quantity pattern* for associate values with units

Requirements:

1. **MedicalDevice** will represent the physical device that is an instance of the MedicalDeviceType defined in exercise 3 and it will have a unique serialNumber. It can realize many measurements.
2. **PhysiologicalParameter** will represent the physiological parameter that the device measure like “Heart Rate” and it will have the attribute parameterName (example “hear rate”).
3. **MeasurementUnit** will represent the unit of measure the physiological parameter is being measured and will have the attribute unitName (example “bpm”).
4. **MeasurementRecord** will represent the historical association within the specific device type instance (example CARDIOMAX #1234) and the specific physiological parameter (example “Heart Rate”) at an exact time (example January 1, 2025, at 10:30 AM). It has the Timestamp attribute and the numerical value measurementValue).

By storing the MeasurementUnit and the values we will be applying the **Quantity** pattern, similar as we did in exercise 3. For applying the **Historical Association** pattern, we will use the learning material and the example solutions given as a reference, where we have *many examples of class A, class B and a class Date*. In our specific case the “Date” is not independent but an attribute within the historical class **MeasurementRecord.** This means we don’t need to represent the date as an independent class but as an attribute. So, we have a binary association within device and parameter with a historical class association that will store the date and the numerical value:

**Medical Device (A)** ↔ **MeasurementRecord** ↔ **Physiological Parameter** **(B)**

A diagram of a diagram

AI-generated content may be incorrect.

* **Class A**: *Medical Device* (CARDIOMAX #1234).
* **Class B**: *Physiological Parameter* (Heart Rate).
* **Historical Class**: *MeasurementRecord* that stores date time and measurement value (75 bpm, on January 1, 2025, at 10:30 AM)

**System constraints achieved with this design:**

* A MeasurementRecord is connected to a specific MedicalDevice instance by the serial number to ensure traceability.
* A MeasurementRecord has a timestamp to avoid duplicates
* Each Measurement is stored with a PhysiologicalParameter, that has it corresponding MeasurementUnit ensuring consistency in measurement units.

So, by adding this to the previous exercise class diagram we can obtain the following UML:

**A diagram of a software

AI-generated content may be incorrect.**

**Example Implementation Code:**

public class MeasurementUnit {

    private String unitName;

    public MeasurementUnit(String unitName) {

        this.unitName = unitName;

    }

    public String getUnitName() {

        return unitName;

    }

}

public class PhysiologicalParameter {

    private String parameterName;

    private MeasurementUnit unit;

    public PhysiologicalParameter(String parameterName, MeasurementUnit unit) {

        this.parameterName = parameterName;

        this.unit = unit;

    }

    public String getParameterName() {

        return parameterName;

    }

    public MeasurementUnit getUnit() {

        return unit;

    }

}

public class Range {

    private double minValue;

    private double maxValue;

    public Range(double minValue, double maxValue) {

        this.minValue = minValue;

        this.maxValue = maxValue;

    }

    public boolean isValid(double value) {

        return value >= minValue && value <= maxValue;

    }

}

public class MedicalDeviceType {

    private String identifierName;

    private String description;

    private PhysiologicalParameter parameter;

    private Range range;

    public MedicalDeviceType(String identifierName, String description, PhysiologicalParameter parameter, Range range) {

        this.identifierName = identifierName;

        this.description = description;

        this.parameter = parameter;

        this.range = range;

    }

    public PhysiologicalParameter getParameter() {

        return parameter;

    }

    public Range getRange() {

        return range;

    }

    public String getIdentifierName() {

        return identifierName;

    }

}

public class MedicalDevice {

    private int serialNumber;

    private MedicalDeviceType deviceType;

    public MedicalDevice(int serialNumber, MedicalDeviceType deviceType) {

        this.serialNumber = serialNumber;

        this.deviceType = deviceType;

    }

    public int getSerialNumber() {

        return serialNumber;

    }

    public MedicalDeviceType getDeviceType() {

        return deviceType;

    }

}

import java.time.LocalDateTime;

public class MeasurementRecord {

    private LocalDateTime timestamp;

    private double measurementValue;

    private MedicalDevice device;

    public MeasurementRecord(LocalDateTime timestamp, double measurementValue, MedicalDevice device) {

        this.timestamp = timestamp;

        this.measurementValue = measurementValue;

        this.device = device;

    }

    public String getSummary() {

        return "Device: " + device.getDeviceType().getIdentifierName() + " #" + device.getSerialNumber() +

               "\nMeasured: " + device.getDeviceType().getParameter().getParameterName() +

               "\nValue: " + measurementValue + " " + device.getDeviceType().getParameter().getUnit().getUnitName() +

               "\nTimestamp: " + timestamp;

    }

}

import java.time.LocalDateTime;

public class Main {

    public static void main(String[] args) {

        // Unit (bpm)

        MeasurementUnit bpm = new MeasurementUnit("bpm");

        // Parameter (Heart Rate)

        PhysiologicalParameter heartRate = new PhysiologicalParameter("Heart Rate", bpm);

        // Valid Range (40 a 200 bpm)

        Range cardioRange = new Range(40, 200);

        // Device Type (CARDIOMAX)

        MedicalDeviceType cardiomaxType = new MedicalDeviceType(

            "CARDIOMAX",

            "Device measuring heart rate.",

            heartRate,

            cardioRange

        );

        // Specific device CARDIOMAX (#1234)

        MedicalDevice cardiomax1234 = new MedicalDevice(1234, cardiomaxType);

        // Historical Register (MeasurementRecord)

        MeasurementRecord record = new MeasurementRecord(

            LocalDateTime.of(2025, 1, 1, 10, 30),

            75.0,

            cardiomax1234

        );

        // Show Summary

        System.out.println(record.getSummary());

    }

}

// Output of the code to demonstrate instantiation

Device: CARDIOMAX #1234

Measured: Heart Rate

Value: 75.0 bpm

Timestamp: 2025-01-01T10:30