SOFTWARE REQUIREMENT SPECIFICATION (v. 0.9)

Anomaly Management Platform for Manufacturing Plants

Software Platform for Detecting & Remedying Anomaly occurrences of Manufacturing Plants

March 2023

Due Dates

	Scope of AD	Due Date	Length Limit
Interim Report	Chapters 1, 2, 3	4/05(Wed), 9pm	20± Pages
Pre-Final Report	Chapters 4, 5	4/18(Tue), 9pm	50± Pages
Final Report	Chapters 6, 7	5/02(Tue), 9pm	70± Pages

CEP Instructor

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삼성전자 첨단기술아카데미

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Anomaly Management Platform for Manufacturing Plants

1. Purpose of the Document

The purpose of this document is to specify the requirement for developing the target system in this CEP. The requirement will become the basis for designing the software architecture of a target system, which is required as a fulfillment to acquire the Samsung Associate Architect (AA) certification.

2. Comprehensive Evaluation Project (CEP)

2.1. About Associate Architect (AA) Program

The Associate Architect Program of Samsung Electronics is to provide participants with two sets of software architecture design proficiency.

- **Body of Knowledge (BoK) on Software Architecture**

  This set includes the fundamental theories and methods for designing SW architecture.

- **Skillset for Designing SW Architecture**

  This set includes the practical skill for applying architecture design methods to a given SRS.

CEP is designed to fulfill the second set of AA program through an individual design project.

2.2. How is the CEP problem prepared?

The CEP problem is prepared by the instructor, based on the following principles.

- **Principle 1. Utilizing the Whole BOK of Software Architecture Design**
  - Utilizing Architecture Styles
  - Designing Architecture for multiple Views
  - Designing Architecture for Non-Functional Requirements
- **Principle 2. Handling the Complexity of Industrial Systems**

  The target system to design in CEP is an industry-level complex software system, i.e., not an academic problem appeared in books or literature.

- **Principle 3. Solution Not Available in Public**

  CEP problem is not a reproduction of already existing exercise problem in books, and hence the architecture design solution for the CEP problem is not available in public.

2.3. Architecture Design Reports in CEP

Each participant designs and submits the design of software architecture for the target system in an incremental manner.

- Interim Report
  This report includes the context analysis model and the skeleton architecture design of the target system.
- Prefinal Report
  This report includes the architecture design for multiple views of the system: functional view, information view, behavior view, and deployment view.
- Final Report
  This report includes the architecture design for non-functional requirements and the validation of the architecture design.

❑ **Weight Distribution of CEP Reports**

Interim Report	Prefinal Report	Final Report	TOTAL
25 points	35 points	40 points	**100 points**

2.4. Template for Architecture Design

A template for designing the software architecture in CEP is provided and hence participants can utilize the template in specifying the architecture design. The template is devised to be consistent with the architecture design methodology provided by the instructor.

❑ **Filename**

AA-2023-A2, CEP, AD Template.docx

3. Overview of the Target System

3.1. What is a Manufacturing Plant?

❑ Definition

A manufacturing plant is a facility or building where raw materials are transformed into finished target products through a series of production processes. The production of target products typically includes a combination of machinery, equipment, labor, and other resources.

Manufacturing plants play a critical role in the global economy, as they are responsible for creating the goods and products that we use every day. Therefore, they are found everywhere in the world.

❑ Variety of Manufacturing Plants

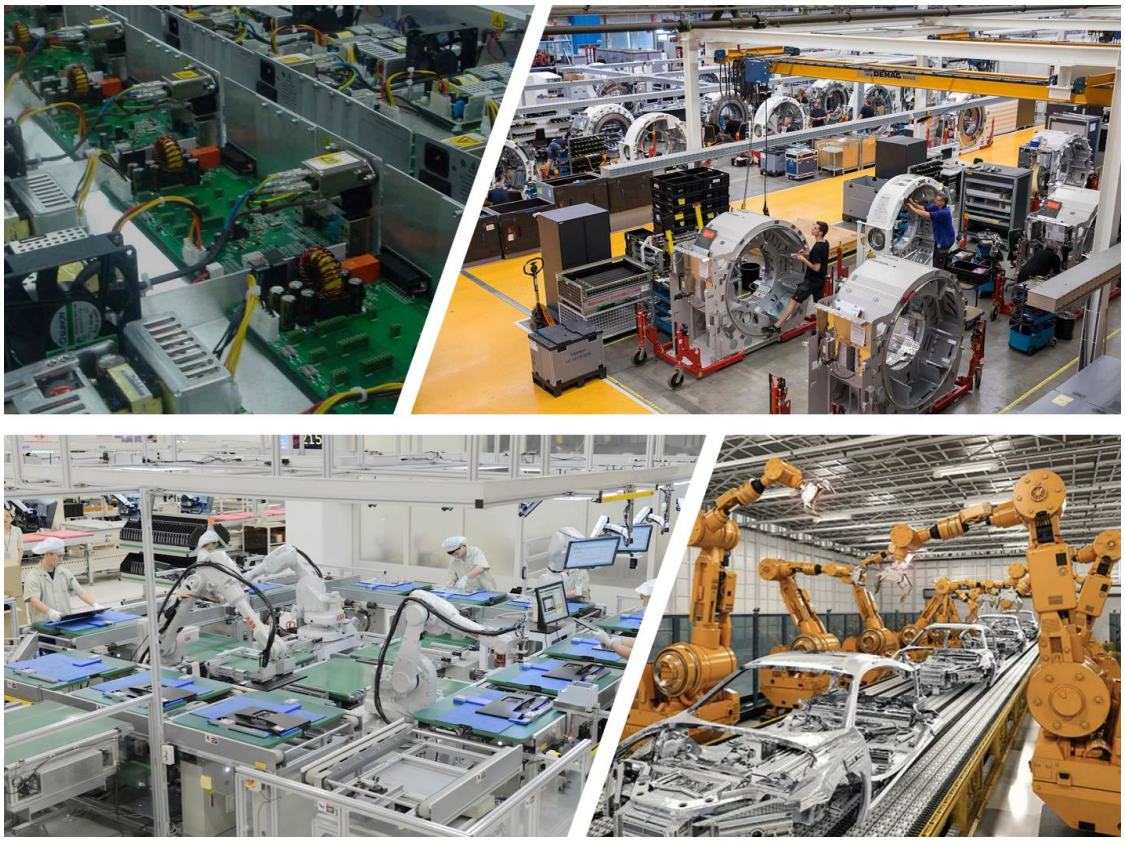
Manufacturing plants can produce a wide range of products, from consumer goods like clothing and electronics to industrial products like machinery and chemicals.

Manufacturing plants can vary in size, depending on the type of products being produced and the scale of the operation. Some plants may be relatively small and specialized, producing a single type of product, while others may be large and complex, producing multiple products and using advanced technologies.

Well-known large-scale manufacturing plants are the following.

- ❍ Automobile manufacturing plant
- ❍ Steel manufacturing plant
- ❍ Chemical manufacturing plant
- ❍ Pharmaceutical manufacturing plant
- ❍ Food and beverage manufacturing plant
- ❍ Electronics manufacturing plant
- ❍ Textile manufacturing plant
- ❍ Aerospace manufacturing plant
- ❍ Oil and gas refining plant
- ❍ Plastics manufacturing plant

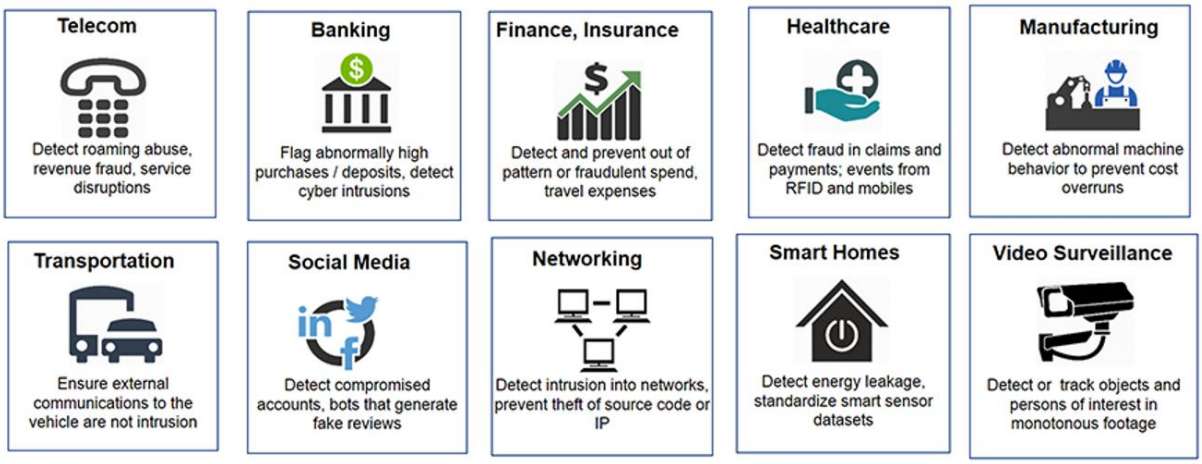
Some examples of the plants are shown in the following figure.



3.2. Anomaly Management for Manufacturing Plants?

❑ Anomaly in various Industrial Domains

Anomaly could occur in various industrial domains as shown in the following figure.



As different industrial domains introduce different types of anomaly, the design of anomaly management system depends on the application domain.

- **Anomaly in Manufacturing Domain**

  An anomaly in the manufacturing domain refers to any deviation or irregularity in the performance of a machine or a process that is unexpected or differs from the normal behavior or performance.

- **Consequence of Anomaly Occurrences**

  The consequence of anomaly occurrences could range between a minor inconvenience and a major significant critical failure. Some of the real examples are listed ere.

  - Equipment Failure (GM)

    In 2019, a major automobile manufacturer had to recall over 400,000 vehicles due to a potential defect in the engine. The issue was caused by a faulty part produced by a supplier, which led to the engine stalling or failing altogether.

  - Food Contamination (Jif)

    In 2022, a popular food manufacturer had to recall a number of its peanut butter products due to the potential presence of Salmonella bacteria.

  - Supply Chain Disruption

    The COVID-19 pandemic caused significant disruptions to global supply chains, including in the manufacturing industry. Many companies faced shortages of raw materials, transportation challenges, and delays in production, leading to widespread manufacturing plant anomalies.

- Chemical Leaks (LyondellBasell in Texas)

  In 2022, a chemical plant had a leak of 100,000lb (45,359kg) acetic acid, which can severely burn skin and are toxic if inhaled.

- Airplane Flight Grounding (Boeing 737 MAX)

  In 2017, a major airline manufacturer had to ground several of its planes due to a quality control issue related to a specific type of engine. The issue was caused by a human error in the manufacturing process, which led to a potentially dangerous situation for passengers and crew members.

There are many other incidents of anomaly occurrences in manufacturing plants.

- **Importance of Anomaly Management**

  It is essential for companies to have robust monitoring and control systems in place to identify and address the anomaly occurrences quickly to minimize their impact on operations and reputation. That is, it is important to detect and remedy anomalies in manufacturing plants as early as possible.

  Effective management of anomalies in manufacturing plants is essential for maintaining high product quality, reducing downtime, and ensuring that production processes run smoothly and efficiently.

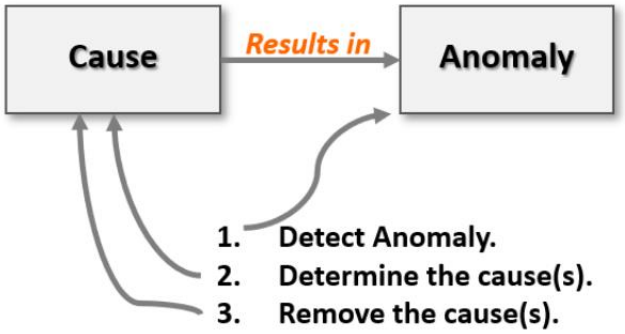
- **Causes for Anomaly Occurrences**

  Anomalies can occur due to various reasons such as mechanical failures, errors in the programming or control system, human error, or environmental factors.

The identification of the causes for an occurred anomaly is essential in determining the most effective method for remedying the anomaly occurrence.

❑ **Methods for Remedying Anomaly**

Anomaly can be managed in various techniques such as statistical process control, root cause analysis, and predictive/preventive maintenance. These techniques help to identify and diagnose the root cause of the anomaly and take corrective action to prevent it from reoccurring.



❑ **Prevention of Anomaly (Out of Scope in this CEP)**

Prevention is always better than handling anomaly. It is desirable to have a system that can help to prevent anomalies from affecting product quality, production efficiency, and safety.

3.3. What is Anomaly Management Platform for Manufacturing Plants?

The target system, Anomaly Management Platform for Manufacturing Plants, is a software planform that provides a comprehensive set of functionalities for detecting and handling various anomaly types in manufacturing plants.

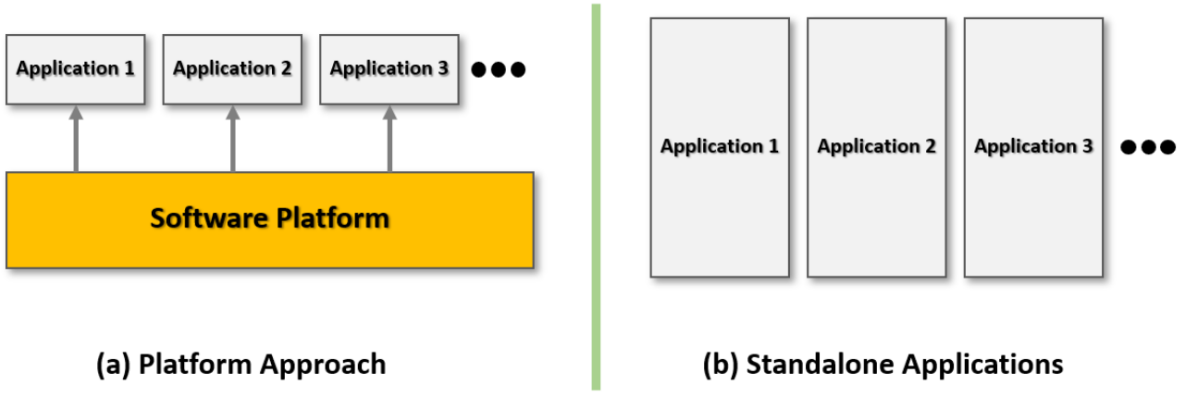
❑ **Software Platform**

Software platform can be defined as the underlying infrastructure that allows software applications to be developed, deployed, and run. It may include the operating system, programming libraries, frameworks, or tools that are necessary to create and run software applications. For example, Microsoft .NET platform provides developers with a framework and tools to create software applications for Windows operating system.

Software platform can also refer to online platforms that provide a set of services or tools for developing and deploying web applications, such as Amazon Web Services, Google Cloud Platform, and Microsoft Azure. These platforms provide developers with access to cloud-based infrastructure, databases, and other services to create scalable and reliable web applications.

- Difference between Software Platform and Software Application

  Software Platform itself is not an application; rather it provides the common functionality and services that can be utilized in developing software application. Hence, developing a software platform is considered to be more challenging than developing applications.



- **Key Functionality of the Anomaly Management Platform**
  - Registering Manufacturing Plants
  - Registering Hardware Devices
  - Registering Use Profiles
  - Registering Anomaly Types
  - Registering Remedy Methods
  - Detecting Anomaly Occurrences
  - Remedying Anomaly Occurrences
  - Generating Anomaly Management Reports
- **Process to Manage Anomaly Occurrences**

  The typical process to manage anomaly occurrences is the following.

  - Step 1. Initialize the hardware devices and check for their connectivity.
  - Step 2. Identify the data sources that can be used to detect anomalies. These may include data from sensors, production equipment, quality control systems, and maintenance logs.
  - Step 3. Acquire data from the sources. The data acquisition is done by utilizing effective data acquisition schemes such as pulling, pushing, register-notify-fetch, shared basket, and broadcasting.
  - Step 4. Preprocess data to ensure accuracy and validness by applying data cleaning, normalization, and noises filtering.
  - Step 5. Choose the appropriate method to detect anomaly occurrences. There can be several methods that can be used for anomaly detection including statistical methods such as Z-score and standard deviation, machine learning algorithms such as clustering

and decision trees, and deep learning algorithms such as autoencoders.

- Step 6. Upon an anomaly occurrence, choose the appropriate metho to remedy the anomaly. There can be several methods that can be used to handle anomaly occurrences. A remedy method may utilize the installed actuators to control machines and their environment, communication schemes such as SMS messages, phone calls, and posting on bulletin boards, and alarming.
- Step 7. Apply the selected remedy method and check for the result of the remedy action. This is to execute the remedy method.
- Step 8. Check the result of the remedy action. If the anomaly is not successfully handled, then report the incident to the system operator.
- Step 9. Repeat steps 3 through 8.

3.4. Deployment of the System

The platform can be utilized in 3 different ways, and hence their deployments will also vary.

- **As a Cloud Service**

  The platform can be designed and deployed as a cloud service that provides the common functionality to applications over network.

- **As a Programming Library (*)**

  The platform can be developed as a programming library, which can be imported in application programs. The type of deployment is adopted in this CEP.

4. Functional Requirements

The functionality of the system is organized as a set of functional categories.

4.1. Registering Manufacturing Plants

This functionality is to register the target manufacturing plant. It is done by entering descriptive information of the plant including the following attributes.

- Name and Location of the Manufacturing Plant
- Registration and/or Permit Numbers
- Industry Classification and Sub-classification
- Product Classification and Sub-classification
- Contact Information of Plant Managers
- Others

4.2. Registering Managed Objects

This functionality is to register the target objects that should be monitored and managed in the manufacturing plant. A managed object can be any participating machine, part-carrying vehicle, supply components, and any other resources needed for production. The target system manages the anomaly that occurred on the registered managed object.

Examples of managed objects can be the following.

- Machine
- Conveyor Belt
- Delivery Robots
- Electricity
- Raw Material as Supply
- Ground Shaking due to Thunderstorm
- Others

The classification of managed objects largely depends on the target manufacturing plant, and hence a tree-type hierarchical classification could be applied in specifying managed objects.

Each type of managed objects is specified in a Managed Object Profile.

4.3. Registering Hardware Devices

This functionality is to register hardware devices in the plant that are used to gather information about and control the managed objects.

- **Sensors**

  Sensors in manufacturing plants are used to gather information about the managed objects and its environment. Examples of them are temperature sensor, humidity sensor, pressure sensor, vibration sensor, light sensor, etc.

- **Cameras**

  Cameras in manufacturing plants play a key role in gathering the visual information of managed objects and its environment. The captured images and videos are utilized for detecting objects and their states with machine learning models such as CNN.

- **Actuators**

  Actuators in manufacturing plants are used to control the managed objects and its environment. They are utilized as means to remedy the occurred anomaly on managed objects.

The target system gathers information from sensors and cameras, detects anomaly occurrences, and performs remedy actions by utilizing the actuators and other means.

4.4. Registering Worker Profiles

This functionality is to manage the profiles of the workers who participate in the production process. The system maintains the identification, contact, login, and credit card information of the workers.

4.5. Registering Manager Profiles

This functionality is to manage the profiles of the staff members who manage the overall operation of the manufacturing plant. The system maintains the identification, contact, login, and credit card information of the workers.

4.6. Registering Anomaly Types

This functionality is to register the types of anomaly that could occur on the target manufacturing plant. Examples of anomaly in manufacturing domain are the following.

- Power Shortage due to Overload
- Stopped Machine
- Intra-network Disconnected
- Actuator Not Responding
- Excessive Noise on Delivery Vehicle
- Robot Malfunctioning
- Shortage of Raw Material Supply
- Others

Each type of anomaly is specified in an Anomaly Type Profile. This profile captures the meta-information of each anomaly type.

The classification of anomaly types largely depends on the target manufacturing plant, and hence a tree-type hierarchical classification could be applied in specifying anomaly types.

4.7. Registering Remedy Methods

This functionality is to register the set of remedy methods that can be applied to handle anomaly occurrences. A remedy method can handle one or more anomaly occurrences.

The classification of remedy methods depends on the target manufacturing plant such as Operating Actuator, Turning on Alarms, Shutting-off Operation, and Sending SMS messages. Hence, a tree-type hierarchical classification could be applied in specifying remedy methods.

Each type of remedy method is specified in a Remedy Method Profile. This profile captures the meta-information of each remedy method including the following descriptive attributes.

- ID and Name of Remedy Method
- Type of Remedy Method and its sub-type
- Types of Relevant Managed Objects
- Time to Apply, Time Duration to Apply
- Others

4.8. Detecting Anomaly Occurrences

This functionality is to detect the occurrence of anomaly on managed objects and its environment. Anomaly detection can be done by utilizing a variety of techniques including statistical analysis, pattern matching, and machine learning.

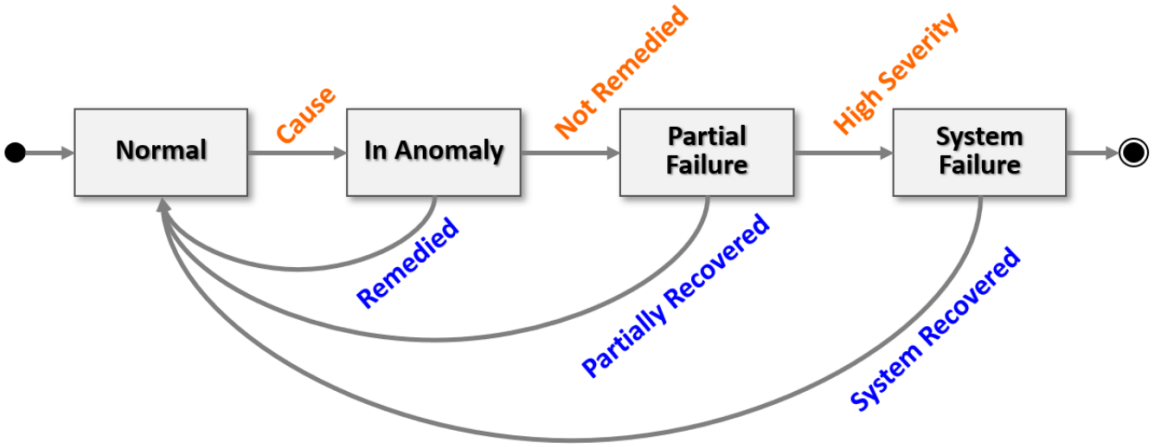
Each occurrence of anomaly is stored in an Anomaly Occurrence Profile, which includes the following attributes.

- Time Stamp
- Identification of Manufacturing Plant
- Managed Objects and their Locations
- Anomaly Type and Sub-type
- Anomaly Intensity
- Others

4.9. Remedying Anomaly Occurrences

This functionality is to perform remedy actions on anomaly occurrences by utilizing appropriate remedy methods. The system should first determine the remedy method(s) to apply for the occurred anomaly, perform the method(s), and store the results.

The following figure shows the different states of the manufacturing plant.



- **Normal**

  The system is in normal condition without any anomaly.

- **In Anomaly**

  Anomaly occurred on some managed objects in the platn.

- **Partial Failure**

  Some portions of the manufacturing plant failed due to the anomaly.

- **System Failure**

  The anomaly has not effectively been remedied, and the partial failure has not been recovered. If the anomaly is highly severe, the whole system could fail.

The figure also shows the actions of remedying anomaly and recovering the failure. The message from the figure is that the early detection of anomaly and remedying the anomaly effectively will be the most cost-effective approach.

4.10. Generating Operation Reports

This functionality is to generate comprehensive reports on anomaly management sessions. The report should include various efficiency measurements of anomaly management for a given period. The reports are further utilized in enhancing the system performance.

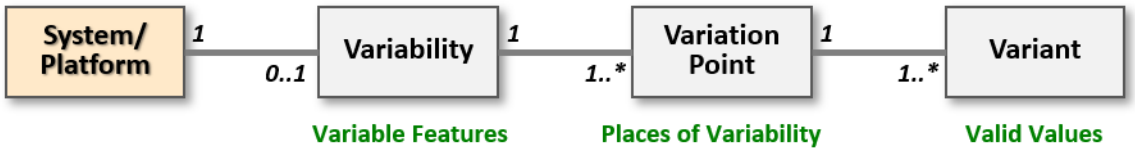
5. Non-Functional Requirements

There can be several non-functional requirements that are essential in the target system. For CEP, we consider only one NFR item.

5.1. NFR-1. High Configurability of the Anomaly Management Platform

Anomaly Management Platform is a software framework, which should be generic and configurable in developing various types of anomaly management systems for different manufacturing domains and plants. That is, the variability among the target application systems should be well-modeled in advance and the platform should be designed by considering all the essential variation points. Doing so, the platform can be widely applied to developing various target systems.

The relationship between variability, variation points and variants are here.



- A system may have a variability, which is defined as one or more variation points. Each variation point is associated with one or more variants, which is a valid value that can be bound to a variation point.

Configurability of the platform is the degree of effectiveness in customizing the platform for a target anomaly management application system. That is, the platform should be designed to handle all the essential variation points and effectively bind the application-specific variants on the variation points.

The key variation points to handle in the platform are the following.

- Heterogeneity on Manufacturing Domains
- Heterogeneity on Manufacturing Plants
- Heterogeneity on Target Products
- Heterogeneity on Hardware Devices
- Heterogeneity on Anomaly Types
- Heterogeneity on Methods to detect Anomaly Occurrences
- Heterogeneity on Remedy Methods
- Heterogeneity on Metrics to evaluate the Anomaly Management Performance
- Heterogeneity on Types of Reports

6. Guidelines for Conducting CEP

6.1. Guidelines for Designing the Architecture

Apply the following guidelines for writing CEP Reports.

- **Conformance to the given SRS**

  The submitted AD should conform to the given SRS.

- **Conformance to UML Standards**

  The submitted AD should conform to the notational and usage standards of UML.

- **Consistency among various Artifacts in AD**

  There should be a high consistency among various artifacts (such as diagrams) in the submitted AD.

- **Comprehensibility of Textual Description**

  The textual elaboration of the architecture design should be written in accurate, precise, and condensed way. Hence, the understandability of the AD becomes high. The textual description can be written in English, Korean, or their mixture.

- **Readability of Figures and Tables**

  The figures and tables should be easily readable by applying good formats, right font size and special effects on them. For example, a use case diagram with 100 use cases should be well structured and enlarged if needed.

- **Reasonable Details of Machine Learning design**

  The submitted AD would include a design for managing machine learning models. The description of the machine learning model generation should be written in reasonably details. The description typically includes machine learning algorithms utilized, training sets used, the details for designing the model generation components.

- **Originality of the AD**

  The submitted AD should be an individual work. Any same or highly similar solutions would get a score penalty.

6.2. Guidelines for Submitting Reports

Apply the following guidelines for writing CEP Reports.

- **Due Dates for Submission**

  The due dates and times for each CEP report are specified. The CEP reports should be submitted by the due. Late submissions of CEP reports are not accepted.

- **Format of the CEP Report**

  Use the word processor, MS Word, for formatting your CEP reports. Submit the word files, not the PDF files.

- **Submission**

  Submit your CEP report to the course manager, not to the instructor.

6.3. Evaluation Form for CEP Reports

The following form is used to evaluate the CEP report.

Evaluation of CEP Report

Name: 홍길동

Criteria	Max	Earned	
Ch.1, Introduction	2		
Ch.2, (A1) Architectural Requirement Refinement	3		
Ch.3, (A2) System Context Analysis			
System Boundary Context	5		
Functional Context	5		
Information Context	5		
Behavior Context	5		25
Ch.4, (A3) Skeleton Architecture Design			
Justification of Candidate Architecture Styles	6		
Integrating Selected Styles into Architecture	4		
Ch.5, (A4) Architecture with Views			
Applying Functional Viewpoint	7		
Applying Information Viewpoint	7		
Applying Behavior Viewpoint	7		
Applying Deployment Viewpoint	4		35
Ch.6, (A5) Architecture with Quality-driven Design			
Design for NFR #1, Applying Process	5		
Design for NFR #1, Quality Delivered	10		
Design for NFR #2, Applying Process	5		
Design for NFR #2, Quality Delivered	10		
Ch.7, (A6) Architecture Evaluation			
Intermediate Steps of applying Evaluation	5		
Correctness of the Evaluation	5		40
CEP Score	100		