*International Journal of Internet, Broadcasting and Communication Vol.14 No.3 258-269 (2022)*
*http://dx.doi.org/10.7236/IJIBC.2022.14.3.258*

**IJIBC 22-3-30**

# On the Untact ICT based New Concept Storage Device Design by Interworking SysML and CAD Data to Improve the Development Efficiency

Myung Sung Kim*, Jae Min Park**, Young Min Kim***†

*** M.S. Candidate, Department of Systems Engineering, Ajou University, 206, World cup-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do, Korea*
*audtjddl200@ajou.ac.kr*

*** Ph. D. Candidate, Department of Systems Engineering, Ajou University, 206, World cup-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do, Korea*
*jm86@ajou.ac.kr*

**** Associate professor, Department of Systems Engineering, Ajou University, 206, World cup-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do, Korea*
*pretty0m@ajou.ac.kr*

***Abstract***

*In these days, innovative functions are required to unmanned parcel delivery lockers. As non-face-to-face transactions become the center due to the recent COVID-19 pandemic, many problem occurs in society such as theft crimes and lack of loading space. Therefore, New concept storage device is developed in korea. It has the functions that minimizes empty spaces by using the internal transport device to enable efficient space loading and refrigerate goods such as foods. In order to systematically approach the system design of the unmanned parcel delivery lockers which is the new function is applied, We applied model-based system engineering to improve the development efficiency and use a system modeling language to express the system. We conducted interworking research of CAD data including system modeling and design data. it is expected that this method will increase the effective development efficiency such as maintenance traceability and reduction of development period and cost.*

***Keywords:*** *Systems Engineering, Systems Modeling Language, MBSE, Unmanned Parcel Delivery Lockers, CAD*

## 1. Introduction

### 1.1 Background

In today's modern society logistics transportation systems are providing convenience to many people. In particular, As a pandemic due to COVID-19 is declared in 2020, [1] non-face-to-face transactions have become spreaded in customers who avoid face-to-face transactions which is visit in person to purchase goods. instead of this, customers tend to buy goods in internet shopping and receive goods via parcel delivery service. Figure

Manuscript Received: July. 22, 2022 / Revised: July. 25, 2022 / Accepted: July. 27, 2022
Corresponding Author: pretty0m@ajou.ac.kr(Young Min Kim)
Tel: +82-31-219-3949, Fax: +82-31-219-2334
Professor, Department of Systems Engineering, Ajou University, Korea

1 shows the trend of sales in the domestic delivery market of CJ Logistics Corporation, one of the large companies in the Korea delivery industry. Looking at this graph, it can be seen that sales have increased by about 2.5 times of the current courier sales in 2012 [1].

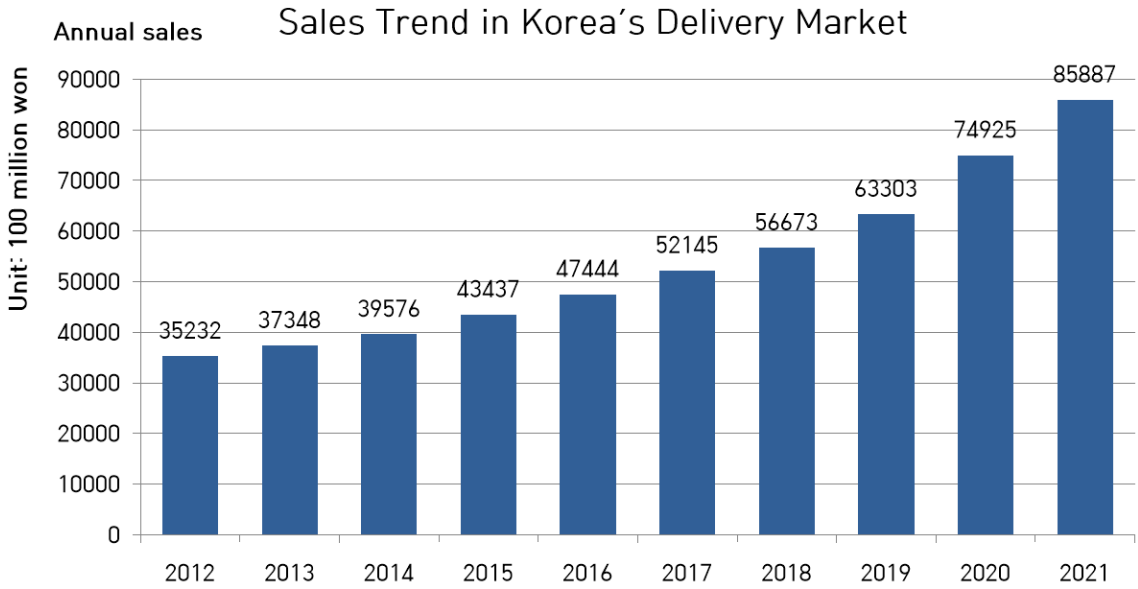


**Figure 1. Trends in Korea Delivery market sales**

With the emergence of many consumers in the delivery industry, problems such as restrictions on the provision of non-face-to-face parcel delivery services, various theft crimes, and poor utilization due to development that does not consider user requirements are occurring at this time. To solve this problem, unmanned parcel delivery lockers were manufactured by public or private companies and installed in subway stations or building lobby. However, there are functional limitations such as insufficient loading space and food which is needs to be stored in refrigerated, Therefore, innovative functions required to unmanned parcel delivery lockers.

Therefore, Republic of Korea developing a "Untact ICT based new concept storage device applied with cold chain-based active loading technology" that can be refrigerated and efficiently loaded. With the addition of new functions, the complexity of unmanned storage device is increasing, and development in consideration of this should proceed in the process of system development. As in this case, this paper proposes an efficient system development plan by applying a methodology called model-based systems engineering (MBSE) for the design of highly complex systems emerging in modern society. This model-based systems engineering [2] facilitates seamless communication between all stakeholders with a Interdisciplinary approach and reduces errors that may occur in the development phase. Therefore, model-based system engineering enables efficient design during the system development process in the early stages of conceptual design. Model-based system engineering can be represented through the system modeling language [3] and has been studied through SysML4Mechatronics, as concept that applies the system modeling language to the design of Mechatronics [4].

### 1.2 Problem Definition

In order to design the entire system with model-based systems engineering, it is necessary to go through an integrated development stage through communication between fields as a whole, rather than focusing on one area of the system. In general, there is a limitation of interworking in developing a system for any purpose. The biggest problem in system engineering implementation is that communication difficulties arise due to differences in expertise between jobs in each field. In particular, design information used in detailed design development can be difficult to understand by officials in other fields due to high technical terms and information. For example, the operational and planning departments and the design departments are structures that are prone to great communication difficulties [5]. The new concept of unmanned delivery storage device is a system which is more complicated and applied an autonomous robot unit for efficient loading parcels than the existing storage device. In order to carry out development that meets the purpose and requirements of the system, the application of model-based system engineering should be modeled through the system modeling language, mechanical design CAD data should be mapped to improve system understanding and communication as mapping CAD & systems modeling language. this method proposed through this study. Figure 2 shows this process.

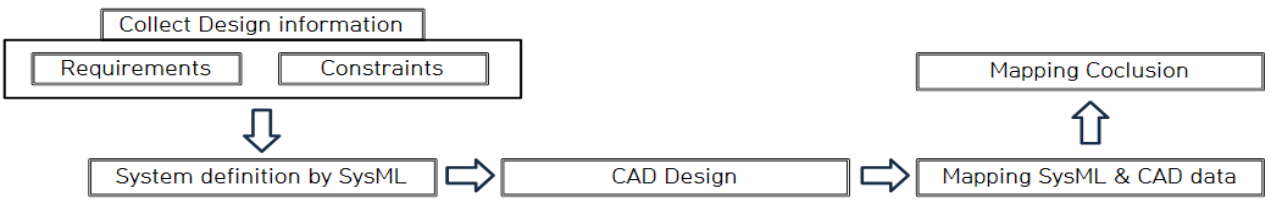


**Figure 2. Scope and purpose**

### 1.3 Related study

SysML4Mechatronics is an extended concept of the system modeling language that defines the criteria for modeling mechatronics systems into SysML. Based on this study, many studies linking SysML and Mechatronics have been derived [4]. This study did not use specific methodology or CAD information. A study was conducted to enable simultaneous development processes through mutual exchange and synchronization with AutomationML (AML), a data exchange format, for system engineering and CAD data between engineering tools in different fields [6]. However, this study did not consider the behavioral viewpoint of the system modeling language. Another study proposed a methodology for modeling plant automation machines as SysML4Mechatronics from each perspective of design/functional/required/behavioral [7]. This study modeled the structure and behavior of the system in a system modeling language, but did not include information on CAD.

Previous studies conducted in the past have succeeded in machine system modeling based on system modeling language, but there is a lack of definition of CAD data and properties of system modeling language. Therefore, in order to supplement the previous studies, this study suggested a plan to increase the efficiency of the development stage by selecting the robot system of the new concept unmanned delivery storage device as the research target and linking CAD data and system modeling language.

### 1.3 Composition of the paper

This study consists of the following. Chapter 2 presents an overview and research method and procedure of new concept unmanned delivery storage device and system modeling language, Chapter 3 shows an example of mapping CAD data to structural/behavioral diagrams by modeling new concept unmanned delivery storage device in system modeling language, and provides a table of properties of CAD data mapping to system modeling. Finally, Chapter 4 presents conclusions on this paper.

## 2. New Concept Unmanned Delivery Storage Device and CAD & SysML Interworking Design Overview

### 2.1 Introduction of New Concept Unmanned Delivery Storage Device

The ICT-based parcel storage system with active technology described in this paper, classifies the items according to the size shape and minimizes empty spaces by using the internal transport device to enable efficient space loading. In addition, it is a newly improved parcel storage device that is equipped with a refrigerated storage function and can be used for storing food requiring refrigerated storage. As shown in Figure 3, this device is divided into several sub-assemblies, the robot system was selected as the target to be modeled in the system modeling language in this paper.

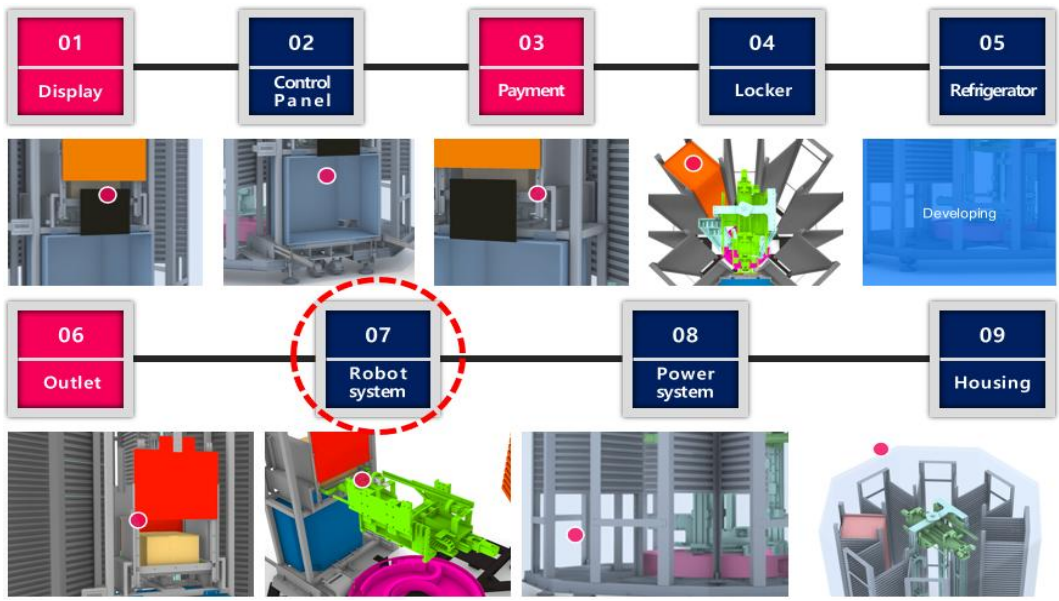


**Figure 3. Sub-assemblies in The ICT-based parcel storage device with active technology**

### 2.2 Introduction of SysML

The system modeling language consists of nine diagrams, which can be hierarchically subdivided in analyzing the system [8]. It's helping to build specifications and system specifications related to model-based

system engineering [9]. This can reduce errors and failures that may occur in the development or operation of the system. Table 1 illustrates the properties of a system modeling diagram to be mapped to CAD data.

**Table 1. System modeling language diagram properties**

| SysML Diagram | | Property |
|---|---|---|
| Requirements | | Based on the documents such as the proposal of the concept presented first, the requirements diagram contains the direction and goal of the design before entering the detailed design stage, and includes precautions and restrictions. |
| Structural viewpoint | Package | Structural diagrams are effective for designing assembly structures of CAD data by modeling mechatronic structures with SysML. |
| | Block Definition | |
| | Internal block | The internal block diagram is easy to represent one part as a detailed structural diagram. For example, it is possible to express elements such as mechanical parts (eg screws, springs, etc.) in detail. |
| | Parametric | Parameter diagram is a diagram to enable analysis of system performance and reliability using assembly. Parameter diagram is useful to indicate the properties of parts. (ex. motor speed value) |
| Behavioral viewpoint | Activity | Activity diagram is a diagram that expresses the behavior of a system using control, data flow, and activity. It is mainly used to express the control flow between objects. |
| | Sequence | The sequence diagram can be identified according to the order of operations and service types according to the passage of time. The sequence diagram can analyze the interaction of mutually sequential actions and the form of sequential service provision, and shows the instance where the message/call sequence and the horizontal message are transmitted according to the vertical-occurrence time sequence. |

### 2.3 Presentation of Research Methods and Procedures

#### 2.3.1 Methods of Interworking Design

In order to conduct the interworking design of CAD and system modeling language, a data medium for data exchange is required, and there are many ways to perform the integrated design by linking data. The commonly used measures can be classified into two methods: using an integrated design program and using an AML file extension. Syndeia, one of the integrated design programs, is a software platform for integrated model-based engineering (MBE), which allows system architecture models (SysML) to manage PLM, CAD, ALM, project management, requirement management, and simulation [10]. AutomationML (AML) is a data exchange format that enables lossless information exchange between engineering tools in different fields [6].

### 2.3.1 CAD & SysML Interworking Design Procedure

This paper presented a plan to optimize requirement management in the development process by applying a requirement diagram first for ICT-based parcel storage devices. And from a structural point of view, a block definition diagram was applied to model the structure of the robot part of the parcel storage device. In addition, in order to represent quantitative figures related to the linkage, a parametric diagram was applied to model the property values of the components. By applying behavioral perspective diagrams such as activity diagrams and sequence diagrams, 3D CAD data simulation and SysML structural/behavioral perspective diagrams were mapped. Figure 4 shows a diagram of the system modeling language to map CAD data according to the procedure. design of CAD and system modeling language, a data medium for data exchange.

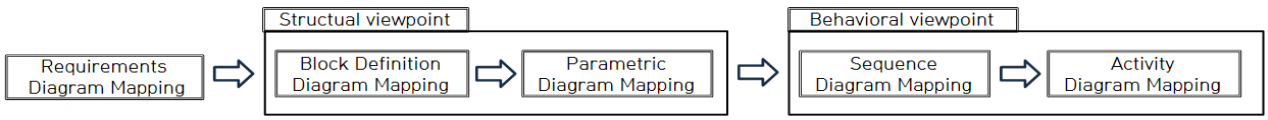


**Figure 4. System modeling diagram procedure to apply mapping of CAD Data**

## 3. CAD & SysML Interworking Design to The Robot System of New Concept Unmanned Parcel Storage Device

### 3.1 Interworking Design Process

Figure 5 is a diagram illustrating the properties of CAD data mapped to various diagrams of the system modeling language. In this paper, in order to perform an interworking design as an example of the robot system of a new concept parcel storage device, a 2D blueprint was mapped to the requirement diagram. The structural viewpoint diagrams mapping assembly and part data, and surface roughness and tolerance information. In the diagrams from a behavioral viewpoint, animation of 3D modeling and simulation information through Simulink were mapped.

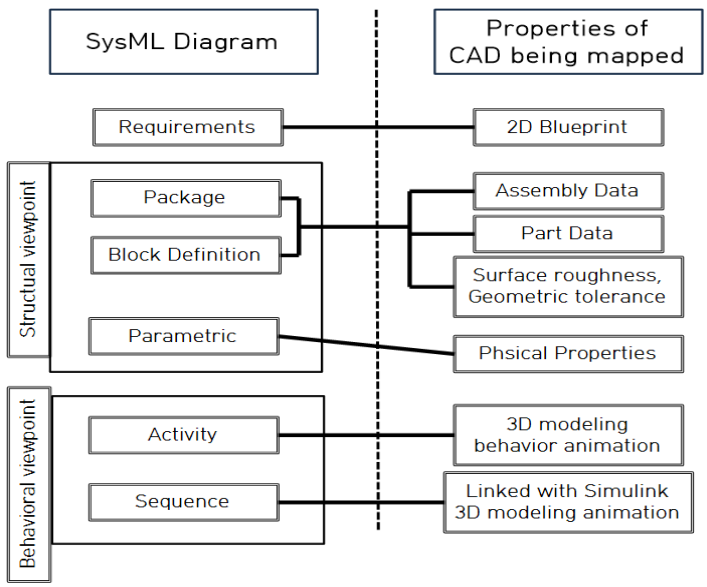


**Figure 5. CAD properties that map to the system modeling diagram**

### 3.2 SysML Diagram based Interworking Design

#### a. Requirements Diagram

The requirements diagram defines the objectives of the design and the concept of the system before designing CAD data, and includes precautions and constraints when designing the system. By applying the requirements diagram, designers can clearly identify physical constraints and stakeholder requirements before design process [11].

Figure 6 shows the results of hierarchically defining all requirements of the robot system. Mapping CAD design drawing data to the corresponding block in the requirement diagram. It can be mapped anywhere to help stakeholders understand the diagram, such as module/part/system/interface requirements. By mapping in this way, it is possible to verify and verify the CAD drawing data by comparing it with the requirement diagram.

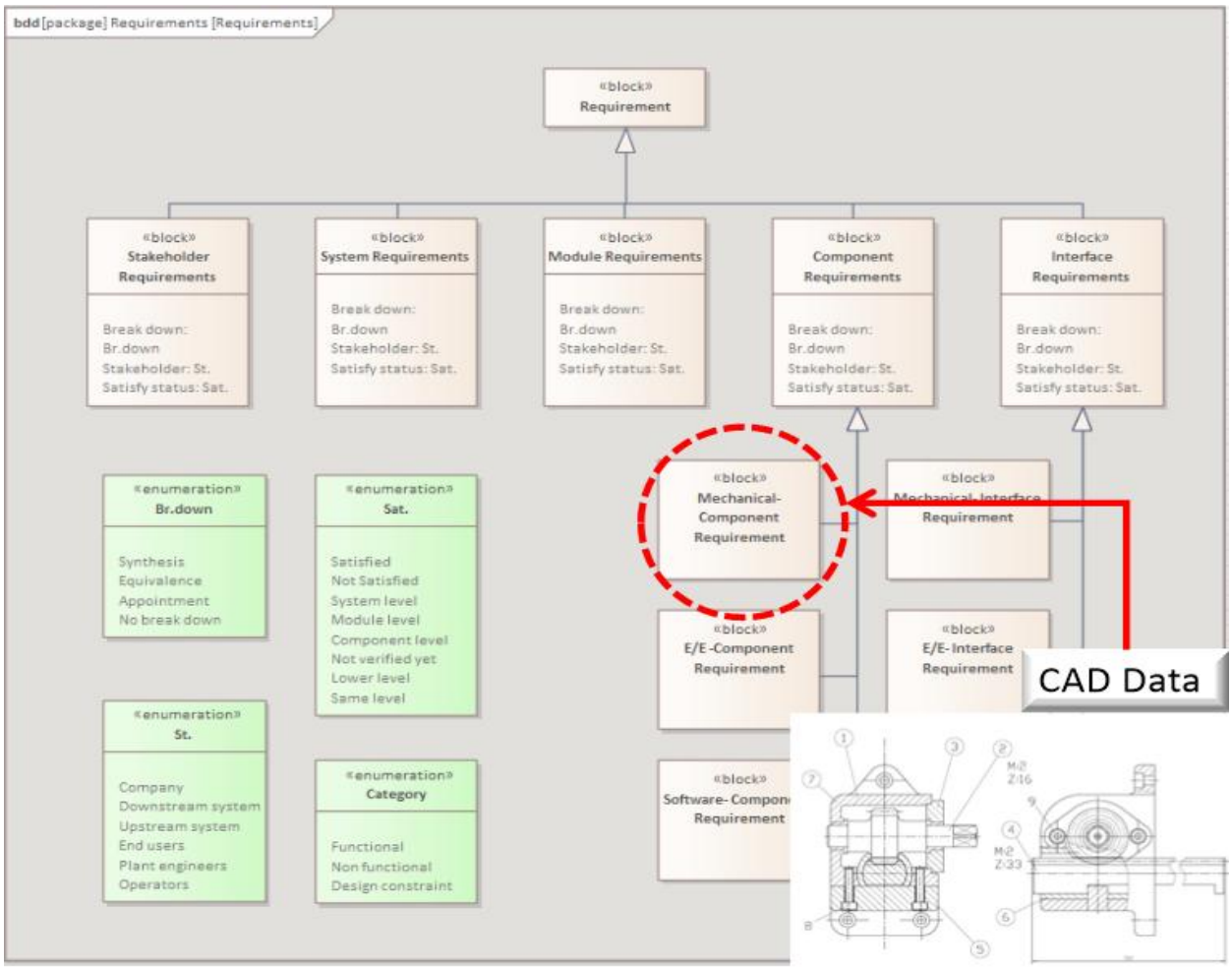


**Figure 6. Mapping 2D blueprints to systems requirements of The robot system**

### a. Structural Diagram

Figure 7 is the result of applying a block definition diagram hierarchically illustrating the structure of the system. This facilitates the traceability of the design/development phase and future maintenance by mapping assembly data to upper assembly blocks and mapping part data to part blocks. The data to be mapped were design blueprints and 3d modeling data. In addition, information on CAD design data such as surface roughness and geometric tolerances was also indicated as attributes of the block.

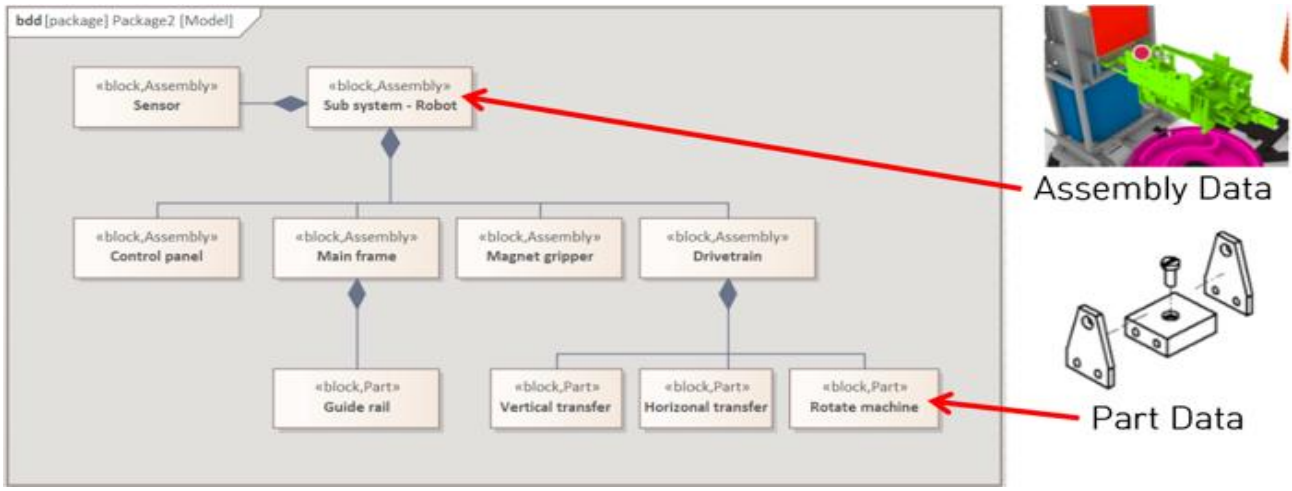


**Figure 7. Mapping 3D modeling data to system structure of Unmanned parcel storage device**

The parametric diagram may represent quantitative properties (material properties, numerical values representing performance, etc.) of each part constituting the system. In addition, it is possible to analyze quantitative figures such as system performance and reliability. From the operational point of view of the system, the system engineer should track the various states of key parameters/attributes of interest, based on the requirements built in the early stages of the system. In other words, it should be systematically managed so that the quantitative requirements required by stakeholders can be reflected in the development at the design conceptual stage of the parcel storage system, which is the subject of this paper. Figure 8 shows the concept of mapping the actual weight, volume, and performance numerical values of the robot system calculated by 3D modeling simulation to the values defined at the time of design.

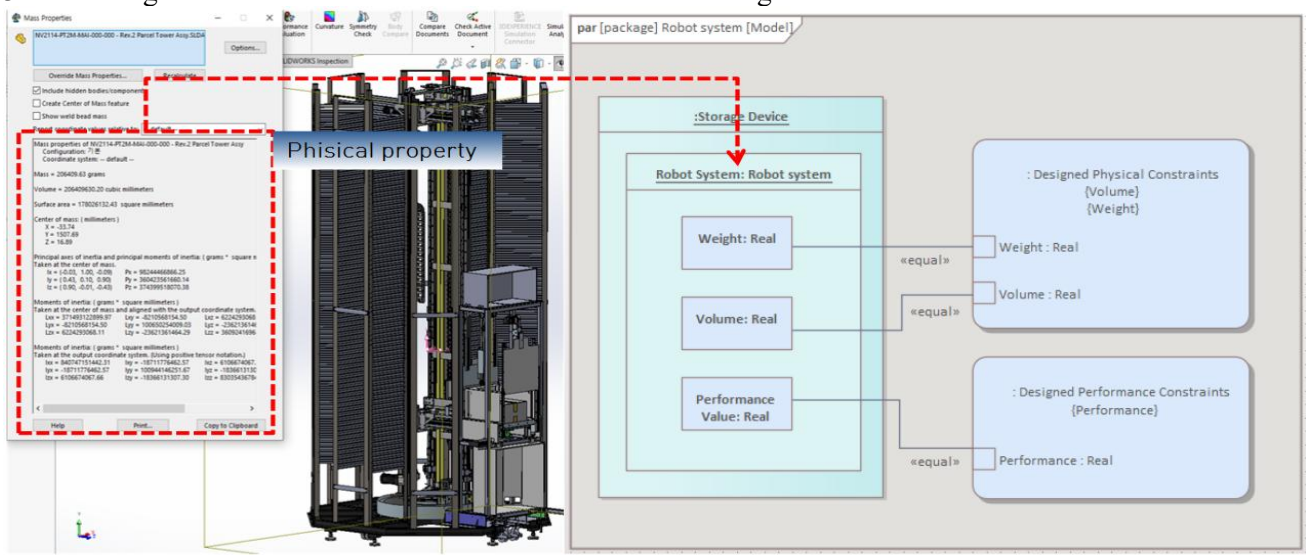


**Figure 8. Mapping the physical properties of the robot system to SysML parametric diagram**

### a. Behavioral viewpoint Diagram

The diagram from a behavioral viewpoint can model the function/action of the system to simulate 3D CAD data to verify and verify whether the correct behavior can be implemented. Activity diagrams are mainly used to represent control flows between objects, and in the design of each part and assembly structure, each part and component is mapped through simulation/animation to see how the assembly works. Figure 9 illustrates the concept of applying 3D modeling animation to an activity diagram.

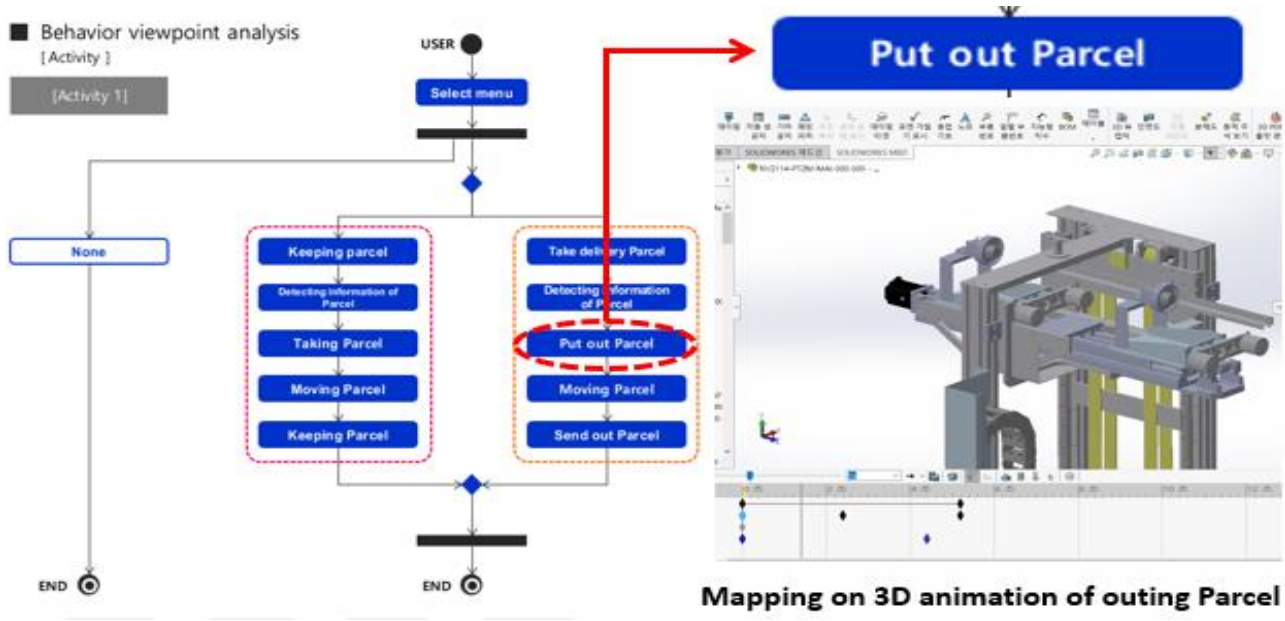


**Figure 9. Mapping the 3D modeling animation to SysML activity diagram**

Sequence diagrams enable interaction of mutual sequential behavior and analysis of sequential service provision forms. Indicates a message/call sequence according to the vertical-occurrence time order and an instance in which a horizontal-message is transmitted [12]. We map 3D CAD data to an instance of activity performed on these sequence diagrams with tools such as Simulink. Accordingly, the designer may efficiently track simulation information related to each function. Figure 10 illustrates the concept of this.

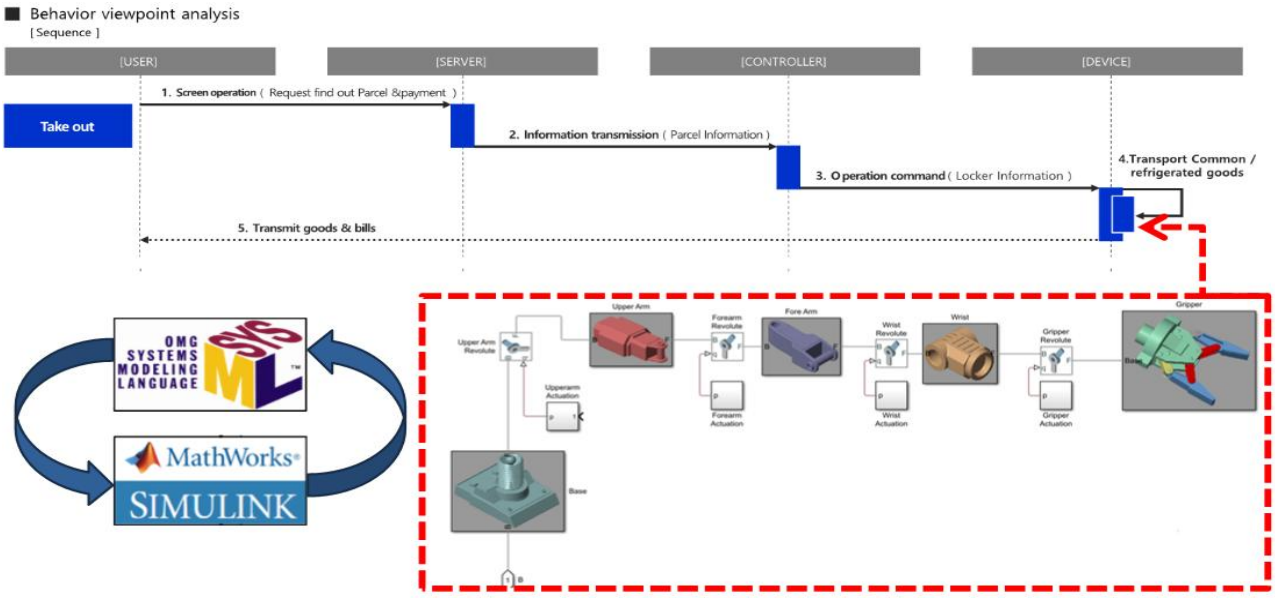


**Figure 10. Mapping the 3D modeling animation to SysML activity diagram**

### 3.3 Presenting the Interworking of SysML & CAD

According to the process described, CAD data can be mapped to SysML diagrams to improve the traceability of assembly/part information of the system, and design information can be checked and simulation & animation can be mapped to diagrams to help understand SysML modeling. simulation can be verified through Simulink tools. Table 2 derives the attributes of CAD data associated with the attributes of the SysML diagram performed earlier.

**Table 2. Presentation of attribute-based associations between SysML diagrams and CAD data**

| SysML Diagram | | Properties of CAD being mapped | Implications derived from interworking design between CAD and SysML |
|---|---|---|---|
| Requirements | | 2D blueprint | By mapping CAD design data to the related blocks of the requirements diagram, it can be mapped anywhere to help the stakeholders who view the diagram, such as module/part/system/interface requirements, for understand system.<br>Before designing, the designer understands the constraints and requirements in advance, and the design is entered in a recognized state, so errors and corrections can be reduced.<br>After all designs are completed, CAD data can be mapped to the requirements diagram to verify and confirm whether the requirements are properly implemented.. |
| Structural viewpoint | Package / | Assembly data | In a diagram from a structural point of view, assembly data is mapped to upper assembly blocks and part data is mapped to part blocks so that design data according to each hierarchical structure can be checked at a glance. |

| | | | |
|---|---|---|---|
| | Block Definition | Part data | SysML diagram (package, block definition, internal block structure) from a structural point of view is mapped with the structural diagram in designing the MCAD (Mechatronics CAD) data representing the mechanical structure and the ECAD data representing the electrical/electronic circuit structure. It is also easy to traceability of future maintenance. |
| | | Surface roughness, geometric tolerance | Information of CAD design data such as surface roughness and geometric tolerance can also be expressed as attributes of blocks. You can check this information in advance. It facilitates product process design. |
| | Parametric | Physical properties | It is also possible to substitute the material properties of 3D CAD data, so the designer can look at the properties of the part and consider properties such as volume mass and stiffness. |
| Behavioral viewpoint | Activity | 3D modeling behavior animation | The diagram from the behavioral point of view models the function/operation of the system and simulates 3D CAD data to verify and confirm whether the correct operation is possible.<br>In the design of each part and assembly structure, what action each part and component should perform in the design of each part and assembly structure is mapped to the control flow activity block between objects in the activity diagram. CAD data that can be a reference for diagrams from a behavioral point of view includes drawings and 3D modeling, but it is possible to check how the assembly works by mapping the simulation/animation of 3D modeling according to each function. |
| | Sequence | Linked with Simulink 3D modeling simulation | When 3D CAD data is imported with a tool such as Simulink, it is possible to design by referencing or mapping the drive flow structure diagram modeling of SysML when performing simulation of model-based diagrams in Simulink<br>Mapping the motion information animation of the machine corresponding to the function in the sequence diagram to the sequence diagram It is easy for the designer to track the information of the parts related to each function. |

## 4. Conclusion

Recently, demand for parcel delivery services has been increasing due to the COVID-19 pandemic. As non-face-to-face transactions become the center, the demand for unmanned delivery boxes is also increasing significantly, but new functions are required for unmanned storage lockers due to the functional limitations of unmanned storage lockers. The unmanned parcel storage device is a new concept of logistics system, and in general, there is a limit to interworking in developing a system for some purpose. However, the biggest problem in system engineering implementation is that communication difficulties arise due to differences in expertise between jobs in each field. In particular, design information used in detailed design development can be difficult to understand by officials in other fields due to high technical terms and information. Previous studies conducted previously succeeded in modeling SysML-based machine systems, but CAD data and SysML properties need to be defined. Therefore, in order to supplement the previous studies, We suggested a plan to increase the efficiency of the development stage by selecting the robot system of the parcel storage device as the research target and linking CAD data and SysML. We suggested that CAD data can be mapped to SysML diagrams to improve the traceability of assembly/part information of the system, and design

information can be checked and simulated drive animation can be mapped to diagrams to help understand SysML modeling, and simulation can be verified through Simulink tools. In this paper, a study on the linkage between CAD and SysML was conducted to improve the development efficiency of the parcel storage device.

## Acknowledgement

This work was supported by a grant from R&D program of the Korea Evaluation Institute of industrial Technology(20014664)

## References

[1] S. L. Ju, H. J. Kang and S. H. Oh, "Correlation analysis between COVID-19 cases and emergency alerts service," in Ploc. *The Journal of The Institute of Internet, Broadcasting and Communication (IIBC),* Vol. 21, No. 5, pp.1-9, Oct. 31, 2021

[2] S. W. Hwang, J. U. Kim, J. M. Park, S. M. Lee, M. T. Jo, M. J. Kim and Y. M. Kim, " On the derivation for logistics technology implementation based on underground urban railway," in Ploc. *2021 Autumn Conference & Annual Meeting of the Korean Society for Railway*, pp. 272-272, Nov.11-13, 2021.

[3] H. S. Yang, J. D. Jang, H. Jung, S. W. Choi, H. J. Lee and S. Y. Lee, "A Study on Requirements Development Process Using Model Based Systems Engineering Approach," *Journal of the Korea Society of Systems Engineering (J.KOSSE)*, Vol.13, No. 1, pp. 51-56, Jun. 2017.
DOI: https://doi.org/10.14248/JKOSSE.2016.13.1.051

[4] T. H. Kim, An Approach to System Specification Design of SoCs based on the Systems Engineering Method and SysML,Ph. D. Thesis. Ajou University, KR, 2007.

[5] Kernschmidt, K. E. T., "Interdisciplinary structural modeling of mechatronic production systems using SysML4Mechatronics," Ph.D. Thesis. Technische Universität München, DE, 2019.
DOI: http://mediatum.ub.tum.de/?id=1453653

[6] Defense Acquisition Program Administration, Systems Engineering guide book Version 1.0, Gwacheon-si : Defense Acquisition Program Administration, 2007, pp. 3-5.

[7] Li H., Tian L. and Vogel-Heuser B., "Automatic synchronization of mechanical CAD models and a SysML-based mechatronic model using AutomationML," in Proc. *IEEE International Conference on Systems, Man and Cybernetics (SMC)*, pp. 3343-3350, Oct.06-09, 2019.
DOI: https://doi.org/10.1109/SMC.2019.8913908

[8] Barbieri G., Kernschmidt K., Fantuzzi C. and Vogel-Heuser B., "A SysML based design pattern for the high-level development of mechatronic systems to enhance re-usability," in Ploc. *IFAC Volumes*, pp. 3431-3437, Aug.24-29, 2014.
DOI: https://doi.org/10.3182/20140824-6-ZA-1003.00615

[9] T. Weilkiens, Systems Engineering with SysML/UML, Burlington, MA, USA: Morgan Kaufmann, 2006, pp. 6-16.

[10] T. K. Lee, J. M. Cha, J. Y. Kim, Shelly S., "SysML-based Document Modeling Case," *Journal of the Korea Society of Systems Engineering (J.KOSSE)*, Vol.14, No. 2, pp. 8-15, Dec. 2018.
DOI: https://doi.org/10.14248/JKOSSE.2018.14.2.008

[11] Bajaj M., Cole B. and Zwemer D., "Architecture to geometry-integrating system models with mechanical design," in Proc. *AIAA SPACE 2016*, pp. 5470, Sep.13-16, 2016.
DOI: https://doi.org/10.2514/6.2016-5470

[12] Brahmi R., Hammadi M., Aifaoui N. and Choley J. Y. "Interoperability of CAD models and SysML specifications for the automated checking of design requirements," in Proc. *31st CIRP Design Conference*, pp. 259-264, May.19-21, 2021.
DOI: https://doi.org/10.1016/j.procir.2021.05.064

[13] Apvrille L., Saqui-Sannes P. and Vingerhoeds R. "An educational case study of using sysml and ttool for unmanned aerial vehicles design," *IEEE Journal on Miniaturization for Air and Space Systems*, Vol.1, No. 2, pp. 117-129, Jul. 2020.
DOI: https://doi.org/10.1109/JMASS.2020.3013325