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Product Design Model by ArchiMate

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Abstract

Digital Transformation (DX) is the transformation of an existing organization into a competitive digital organization in a rapidly changing digital economy. Therefore, it is necessary to change the physical product design model so that it can correspond to the digital product design model. In this paper, we propose a method to represent the design element relationship diagram of the multi-spatial design model (M model) as the design model of the physical product in the graphic language ArchiMate of Enterprise Architecture. Next, the effectiveness of the proposed method is clarified by describing a concrete example of the M model in ArchiMate. Furthermore, the future research issues will be described.

Keywords: ArchiMate, Digital Transformation, Enterprise Architecture, M-Model

1 Introduction

With the spread of digital technology, the target of digitization is expanding to business models, and hardware products. Smart products that digitize hardware products require a design that integrates software services and products.

In the conventional design of artificial objects, a multi-spatial design model (M-Model) has been proposed, which targets a thinking space consisting of a psychological space and a physical space. However, in the spaces of the M model, digital services are not explicitly considered. With the progress of DX (Digital Transformation), it is necessary to transform the existing industry for manufacturing to the digital industry. Therefore, it is necessary to consider not only the physical space but also the design elements of the digital space.

EA (Enterprise Architecture) can comprehensively associate and model enterprise businesses, data, applications, technologies, and physical architectures. In this paper, we propose a method to express the M model for product design in the EA model language ArchiMate for the model for designing products and services using digital technology.

In order to meet the digitalization of the business environment and the needs of customers and companies, it is necessary to consider the integration of the product design model and the EA model.

In the following, the related research will be explained in Section 2. Next, Section 3 proposes a method for expressing the M model by ArchiMate, and Section 4 explains a concrete application example. Section 5 describes the discussion, and Section 6 describes the summary and future issues.

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2 Related Work

The related research will be explained below.

2.1 Multi Spatial Design Model

The multi-spatial design model (M model) [1][2][3] consists of a thinking space consisting of four types of spaces and a knowledge space that manipulates modeling within and between the spaces. There are psychological space and physical space in the thinking space. Psychological space has value space and meaning space. There are state space and attribute space in physical space. In the value space, various value design elements such as social, cultural, and personal values and their relationships are described. In the meaning space, design elements for functions and images are described. In the state space, we describe the design elements and their relationships regarding the mechanical, electrical, and chemical properties that depend on the usage environment of the artificial object as the design target, the user, and so on. The design elements of the attribute space have mechanical, geometric, and physical characteristics that are the characteristics of the design object that does not depend on the field.

According to Otsuki [4], the concepts of software engineering for (1) value, (2) meaning, (3) state, and (4) attributes of the M model are (1) customer value, (2) external characteristics (requirements), (3) internal characteristics (system and environment interaction), and (4) software architecture, and code.

2.2 Service Model

Spath and Fahnrich [5] define a service metamodel consisting of customers, goals, inputs, outputs, processes, human enabler, physical enabler, information enabler, and environment. By using goals, business, services, and customer expectations can be represented. Since the organization of the provider and the owner can be defined as a human resource, the business model can also be expressed by the interaction process with the customer.

Vink et al. [6] consider Purpose, Material, Process, and Actor as conceptual building blocks in the service design ecosystem. Goedkoop et al. [7] described products, services, and systems (PSS) as a system consisting of a player network and a support platform. Vasantha et al. [8] proposed a hierarchical PSS configuration consisting of products and services.

2.3 ArchiMate

ArchiMate is an EA modeling language standardized by The Open Group. ArchiMate1.0 was released in 2009. The latest version is ArchiMate 3.1, released at the end of 2019 [9]. ArchiMate is the most expressive visual business model language [10]. ArchiMate can describe the deliverables of all the processes of the Architecture Development Method (ADM) of TOGAF (The Open Group Architecture Framework) [11]. The most feature-rich EA framework is TOGAF [12].

3 M-Model by ArchiMate

In the M model, design elements and their relationships are described iteratively in four spaces consisting of values, meanings, states, and attributes. In each space, design elements and their relationships are described by the relationships between the nodes that node the elements. No explicit type is defined for the M model node. There are two types of node relationships: connection relationships with undirected lines and inclusion relationships between nodes and their internal nodes. There is also a connection relationship between nodes in different spaces. On the other hand, the ArchiMate diagram also has a node relationship with elements as nodes. Therefore, if the nodes of the M model diagram and their relationships can be associated with the nodes of the ArchiMate diagram and their relationships, the M model can be represented by ArchiMate.

Table 1 shows a comparison between the M model and ArchiMate. As can be seen from Table 1, the fact that the elements of the M model have no type and that they are undirected are the major differences from ArchiMate. Since ArchiMate also has an undirected relationship, if the ArchiMate element corresponding to the design element of the M model can be associated, ArchiMate can express the M model. However, the ArchiMate element has a well-defined type and must be properly selected.

Table 1: M-Model and ArchiMate

	M-Model	ArchiMate
Element	Type-less	Typed
Relationship	No directed, Type-less	Directed, typed
Layer	Value, Meaning, State, Attribute	Business, Application, Technology, Physical Architecture

Table 2 shows a comparison between elements of M-Model and ArchiMate according to Otsuki's mapping [4]. Here, the customer value and meaning of M-Model are represented by the motivation elements of ArchiMate.

Table 2: M-Model Elements of ArchiMate

M-Model	ArchiMate
Value	Value of motivation aspect
Meaning	Meaning of Motivation aspect
State	Business Architecture
Attribute	Technology, Physical Architecture

3.1 Representation of Value Space

As mentioned above, the value element of the M model can be expressed by the value of the motivation element of ArchiMate. The inclusion relationship of the value elements of the M model can also be expressed by ArchiMate.

3.2 Representation of Meaning Space

As mentioned above, the motivation element of ArchiMate also has a semantic element. Therefore, the value element of the M model can be expressed by the semantic element of ArchiMate. The inclusion relation of the semantic elements of the M model can also be expressed by ArchiMate. As for the meaning elements of the M model, there are no types, so you can freely describe the terms. For this reason, some terms in meaning space named as design elements may mean design goals. In this case, since the motivation element of ArchiMate has a goal element, it seems clearer to use the goal element instead of the semantic element. For example, in system requirements, objectivity and rationality are treated as non-functional requirements. In goal-oriented requirements engineering, non-functional requirements are defined as goals that the system should achieve. Therefore, among the design elements that are semantic elements in the M model, it is considered that there are elements that can be goal requirements in ArchiMate. Conversely, it can be said that the M model does not distinguish the semantic element from the goal element.

3.3 Representation of Meaning Space

As mentioned above, in the state space of the M model, the design elements and their relationships regarding the mechanical, electrical, and chemical properties that depend on the usage environment of the artificial object as the design target, the user, and so on are described. Therefore, the characteristics of the design object as a physical product are described. In this way, the state space of the M model does not consider software characteristics. Therefore, in addition to the objective characteristics of the product itself, the state space has user characteristics and product usage characteristics as design elements for the field. The policy of expressing these state-space elements with ArchiMate is as follows.

Since the user characteristics and use scenario can be treated as the information, business objects of ArchiMate is applied to represent these elements. Product characteristics are described by goal elements because they are non-functional requirements that the product should have.

3.4 Representation of Attribute Space

As mentioned above, the design elements of the attribute space of the M model are the mechanical, geometric, and physical characteristics of the field-independent design object. Mechanical characteristics include the required elements that the machine must meet and the elemental composition of the machine as equipment. Geometric properties include appearance elements such as shape and surface. Physical properties include physical requirements and material elements that meet them.

Table 3 summarizes the ArchiMate elements for the above elements.

Table 3: M-Model Attributes in ArchiMate

M-Model Attribute		ArchiMate
Machine characteristics	Machine requirement	Requirement
	Equipment	Equipment
Geometrical characteristics	Exterior	Requirement
Physical characteristics	Physical requirement	Requirement
	Material	Material
Processing method		Constraint

4 Case Study

Below, the ArchiMate expressions are explained for each space according to the M model example [13] of the new eyeglass design "eyewear".

4.1 Value Space Representation

There are two elements in the value space of the M model.

1) *Functional value[mobility]*
2) *Sensitivity value[beauty]*

Here, the notation X [Y] indicates that the element X includes the element Y.

The value elements are represented by ArchiMate as follows.

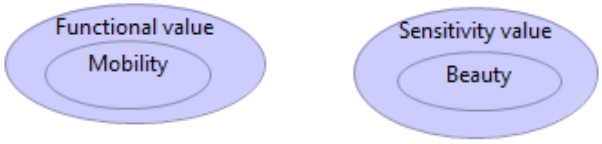

Figure 1: Value space representation in ArchiMate

4.2 Meaning Space Representation

There are five elements in the meaning space of the M model.

1) *Storability [Fits well, becomes compact,Foldable]*
2) *Rationality [Concise, clear, lean, continuity]*
3) *Mobility [Portable, can be used anywhere]*
4) *Variable[thinner, smaller]*
5) *Delicacy [smooth, sharp]*

Figure 2 shows the results of expressing mobility and storability with ArchiMate. At this point, note that the meaning elements included in the meaning space are described by the goal elements. For example, there is an element of "portable" in "mobility". In this case, "portable" is not a meaning, but the goal to be realized by the eyewear.

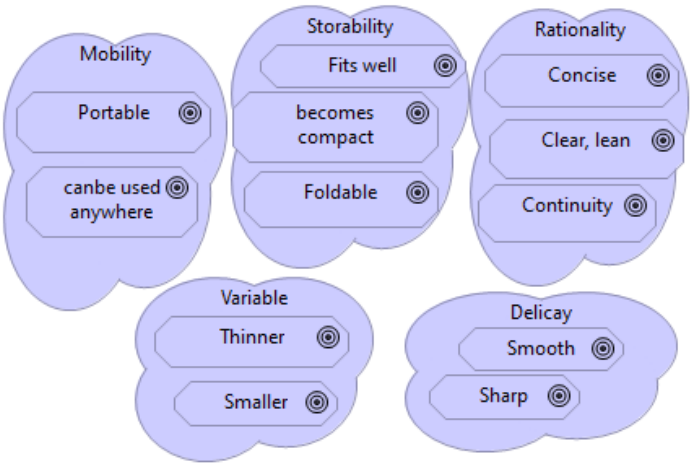

Figure 2: Meaning space representation in ArchiMate

4.3 State Space Representation

The user characteristics of state space elements in M Model of the eyewear are as follows.

1) *User characteristics [knowledge, age, preferences]*
2) *Lifestyle [Use daily, use occasionally]*
3) *Usage time*
4) *Non-use time*
5) *User fashion*
6) *Physical characteristics*

The product characteristics are as follows.

7) *Shape continuity*
8) *Freedom of movement*
9) *Parts characteristics [Stress of parts, friction of parts]*

The left part in Figure 3 shows ArchiMate's business objects that include not only knowledge, age, and taste, but also fashion and physical characteristics as user characteristics.

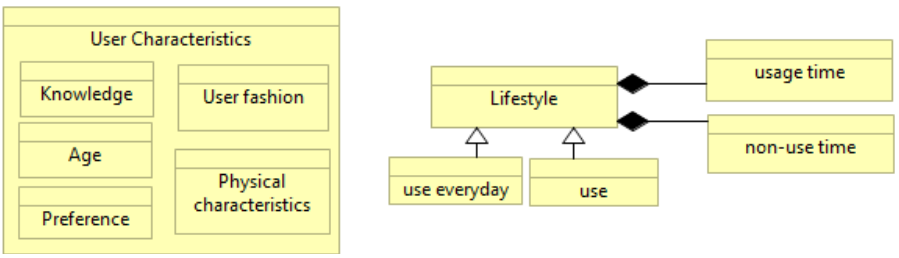

Figure 3: Example of User and Product Usage Characteristics in State space

Lifestyle as a usage characteristic is expressed by ArchiMate in the right part of Fig. 3. Here, the usage time and non-use time are described as lifestyle sub-objects, and whether or not they are used every day is described as the embodiment of lifestyle.

Assuming that product characteristics are goals that products must meet, in ArchiMate in Fig. 4, stress characteristics, friction characteristics, freedom of movement, and shape continuity are placed in the lower goals of the component characteristic goals.

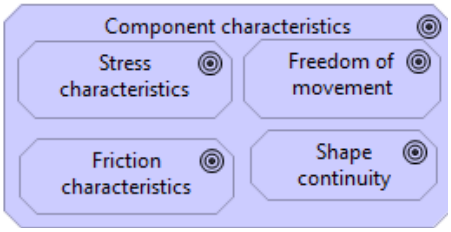

Figure 4: Example of Product Characteristics in State space

4.4 Attribute Space Representation

The attribute space elements of the M model for the eyewear are material, appearance, mechanism, parts, processing method, folding structure, hinge mechanism, and reason rotation hinge. Of these, the material, appearance, parts, and processing method have internal elements. Materials include metal, resin, and rubber. The material element can be described in the following ArchiMate diagram in Fig.5.

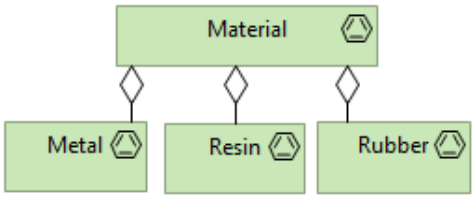

Figure 5: Example of Material elements in Attribute space

Next, regarding the appearance mechanism, parts, processing method, folding structure, hinge mechanism, and free rotation hinge, the following attribute space elements are described in the M model.

1) *Appearance [shape, color, finish]*
2) *Construction*
3) *Mechanism*
4) *Parts [lens, temple, rim, bridge, North head, hinge]*
5) *Processing method [Extrusion processing, bending processing, cutting processing]*
6) *Folding structure*
7) *Hinge mechanism*
8) *Free rotation hinge*

The left part of Figure 5 shows the appearance, folding structure, and free rotation hinge expressed by the requirement elements of ArchiMate. The right part of Figure 6 shows the constraint element representation of ArchiMate for the machining method [extrusion, bending, cutting].

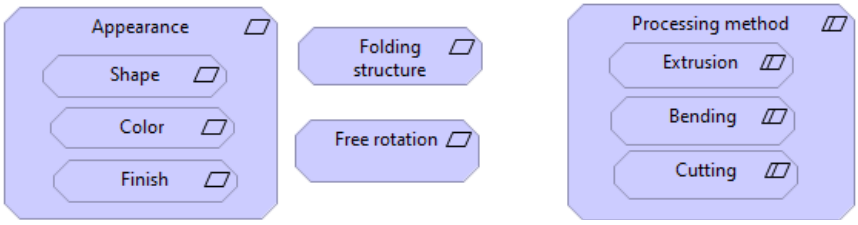

Figure 6: Attribute space representation in ArchiMate for requirements and constraints

Figure 7 shows the equipment element representation of ArchiMate for the component configuration. The "structural design element" is omitted. The reason for this is that the specific content of the structural attributes in the M model case of eyewear is unknown.

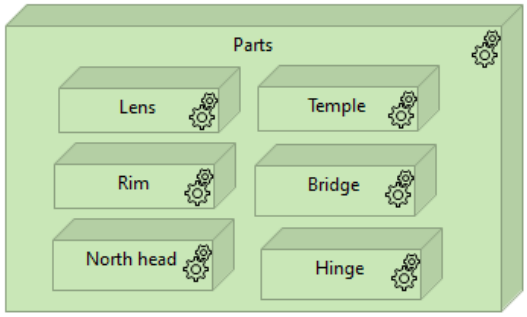

Figure 7: Attribute space representation in ArchiMate for equipment

4.5 Integration of the Design Model

The above-mentioned ArchiMate expressions are related and summarized in Fig. 8. The relationships of ArchiMate used in Fig. 7 are as follows.

[Influence relationship] Relationship between value elements

[Realization relationship] Lower elements realize the required elements

[Specialization] Element is specialized by lower elements

[Composition] Upper element consists of lower element

[Aggregation] Upper element consists of lower element

Here, in the composition relation, the lower element has an existence dependency that it cannot exist unless the upper element exists. There is no existence dependency in the aggregate relationship.

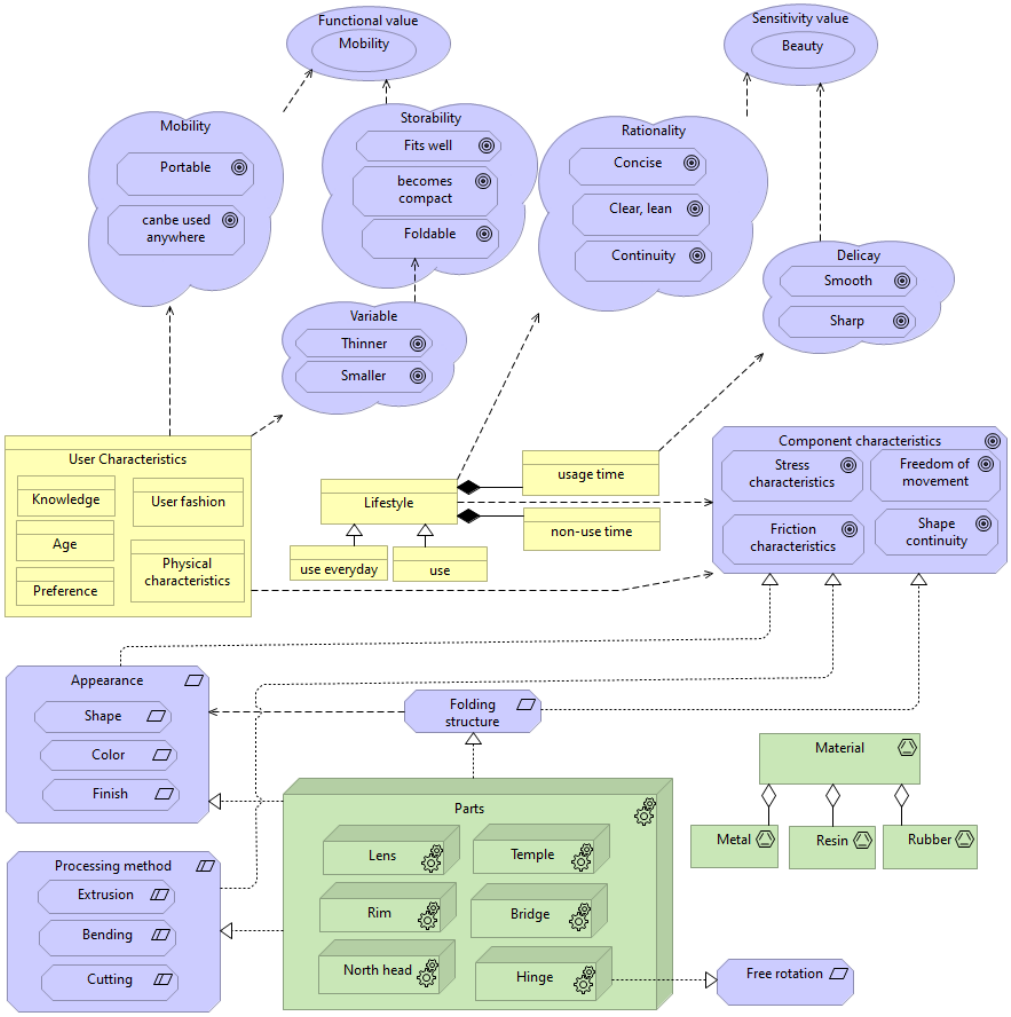

Figure 8:M model of “Eyeware” representation in ArchiMate

5 Discussion

In this paper, we proposed a method to represent M model, which is a general design model of product design, by using EA modeling language ArchiMate. Moreover, the effectiveness of the proposed method has been shown by applying it to specific product design cases. We focused on the design elements of the four spaces that make up the M model, selected the ArchiMate element, and clarified the conversion rules. These rules seem to be applicable to the represent various M model cases in ArchiMate.

In this paper, an existing design example of M model has been converted using ArchiMate, and the new design target M model is not represented by ArchiMate. In the future, it is necessary to clarify that this method can be used for designing with a new M model.

6 Conclusion

In this paper, we proposed a mapping method of expressing the M model in product design based on ArchiMate. As a result, the following was clarified.

(1) M model can be expressed by ArchiMate

(2) The ArchiMate element type can identify the design element of the M model for the product.

(3) Since the M model for product design could be expressed by ArchiMate, it became clear that the system development model ArchiMate may be able to integrate product design and system design.

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