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WHERE DOES CREATIVITY COME FROM? : CREATIVE DESIGN ANALYSIS USING INDIVIDUAL HUMAN KNOWLEDGE MODEL

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ABSTRACT:

Using Individual Human Knowledge Model (IHK model), which is designed focusing on the difference of each human's knowledge, we analyzed the results and design process of an application of Method of Object Extraction for Architecture (OEA method) to real house building project. OEA method is a new method aiming to realize an architecture free from the existing

building types through extracting user requirements from sufficient knowledge. IHK model possesses object libraries of episodic and semantic memory which comprise declarative knowledge.

The final results of OEA method are documents of semantic memory objects which are extracted from so-called *prospective episodic memory* objects constructed and written down in documents in its process. Not a really experienced, but an imagined and somewhat abstracted episode in the future is regarded as a prospective episodic memory.

We had a new view of research in creative design that the role of prospective episodic memory preceding the creative results is a key to the process.

1. INTRODUCTION

What is the role of human declarative knowledge in the process of creative design? In this paper we analyzed the creative design process and its results using Individual Human Knowledge Model (IHK model). IHK model is constructed by focusing on the differences between individuals, although in contrast, usual human knowledge models are constructed by generalizing human features for employing general purpose, as ACT-R of Anderson et al. (2004) typified.

IHK model possesses object libraries of episodic memory and semantic memory which construct declarative knowledge. The classification of episodic and semantic memory was advocated by Tulving (1972) in the resultant document of the conference of the study of memory and learning. Subsequently, various psychological experiments and clinical trials were performed on the classification and Tulving (1983) defined a more strict classification which was regarded as effectual for the study of memory. According to Tulving (1983), semantic memory is common knowledge about the world. It is common to everyone. Episodic memory is a dated unique memory for the rememberer. It is memory about concrete and personal experience. IHK model employed Tulving's classification.

In conventional methods of architecture, planning is done according to the building type, the framework of the past or existing buildings, with reference to the user requirement document which is provided by the users (Peña 1987; Nagamori 2004). However it is said that the architectures built according to the past building types cannot meet the requirements of

contemporary users which are specialized and diversified, and the revolution of the building types, therefore, is a big architectural purpose to be achieved (Hattori et al. 2002). There are regrets that few trials to put the viewpoint of the users into the process of architectural planning are done and the method for doing it is still one of groping (The Architecture Planning Committee 1989). To realize an architecture free from the building types, it is crucial to obtain user requirements sufficiently in order to be able to use them in the design process. OEA method is a new method to realize it using object technology. Its recursive process and visual diagrams help the users to recall their unconscious knowledge and generate new knowledge about the requirements for the building. As a result, OEA method extracts their knowledge thoroughly and makes it into documents effectively.

The final results produced in the process of OEA method were the declarative knowledge of the users about the building. Analyzing the declarative knowledge using IHK model, we could interpret it as a collection of *semantic memory* objects which were extracted from so-called *prospective episodic memory* objects. Though semantic memories are not always extracted from episodic memories (Tulving 1983), in this paper we are sure that the process of extraction of semantic memory objects from prospective episodic memory objects exists. We could have a new view of study in creative design that the role of the prospective episodic memory is important in the process.

2. PURPOSE

The purpose of the study was to explain the process and the results of creative design through an individually different human knowledge model which focuses on declarative knowledge. In this paper, *creative design* was defined as the design whose results are unique to an individual respectively. We understand that is because the results are created depending upon the knowledge of individual.

2. 1. INDIVIDUAL HUMAN KNOWLEDGE MODEL

First we prepared the human knowledge model which is for explaining the creative design. We named the model *Individual Human Knowledge Model* (IHK model). IHK model possesses two opinion libraries composed of objects: *Empirical Opinion Library* for episodic memory and *Real*

World Opinion Library (RWOL) for semantic memory. Both of them construct declarative knowledge (Fig. 2.1). The classification of episodic and semantic memory objects here is following Tulving (1983) and extended.

Here *opinion* is the word, presented by Deleuze and Guattari (1991), which represents each memory object is unique to individual human. Since an individual perceives objects in the real world using *perception* which works as one's own filter, and finds meaning of the perceived objects using *affection* which works as one's own abstraction (Deleuze and Guattari 1991), RWOL of each individual, therefore, is a unique map of the real world to each individual. N.B. the objects of the real world are not only real things but also imaginary things (e.g. Pegasus), thoughts, abstract concepts and so on.

Each object in the RWOL corresponds to a real world object, which, however, is as it were *coloured* by each person. It is different from the definition of semantic memory of Tulving (1983) who said it is common to everyone. May I ask if you like dogs? Some people love dogs while others hate dogs. Could they all have a common semantic memory of 'dog'? Imagining 'dog', you could have your own meaning (opinion) of 'dog' as well as the common meaning of 'dog' to communicate with others. We think the common 'dog' object is a kind of opinion 'dog' object. It means that the common object is extended from opinion object with redefining its elements. IHK model focuses the opinion objects to bring about the purpose of the study.

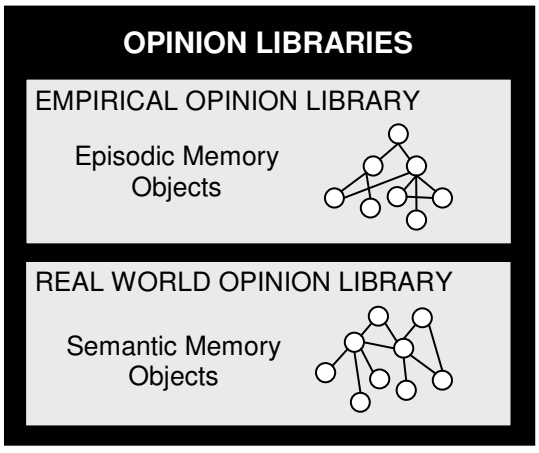


Figure 2.1: Opinion libraries of IHK model

2. 2. CREATIVE DESIGN AND IHK MODEL

We employ IHK model to understand the process of creative design through the usage of declarative human knowledge. Interactive Design Workshop for Science Knowledge (IDW for SK), the prototype system to support capacity building advocated by the International Council for Science (ICS), was developed and tested in our laboratory. ICS recognizes that the evolution from education to capacity building, which is to build personal and social utilization capacity of science knowledge, is an important challenge (Yoshikawa 2002; CSPR Assessment Panel 2006). IDW for SK is designed for high school students to investigate and construct knowledge through solving a design problem.

An experiment of IDW for SK[1] was held with the participation of three high school students conducted by primary author and observed by a high school teacher for 120 minutes each on 20 and 22 December 2006. The place was in Shuyukan High School, Fukuoka, Japan, one of the super science high schools designated by the Ministry of Education and Science of Japan.

IDW for SK system set each student testee a creative design problem: “Please create a new vehicle like a frog” and required the student to investigate frogs using the Internet to build scientific knowledge or a concept which was an object composed of three element categories: attributes, links and functions. IDW for SK system generated a key sentence by combining a randomly selected single element of ‘frog’ object and also randomly selected single vehicle object from many, which were prepared by the conductor and modified by the students. And the system showed the sentence to the student one by one as seen in Fig. 2.3. The key sentence was a mapping from domain concept *frog* to target concept *vehicle*.

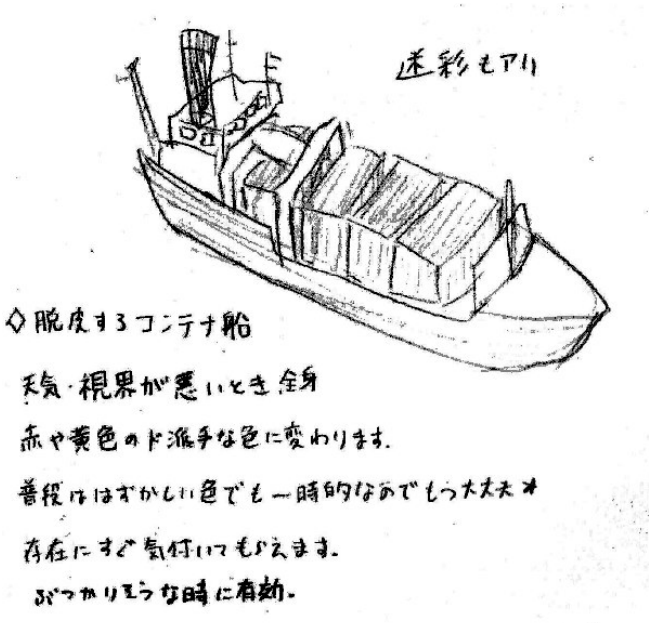
Container ship which *sheds its skin*
Tricycle which *breathes with lungs*
Bicycle which has *one more joint*
Ship which jumps

1 Both the language used in IDW for SK system and input by the students were Japanese, and translated into English in this paper. Please note that computer generated Japanese sentences used attributive form of the parts of the speech conjugation which I managed using a relative pronoun in translation. Japanese language also lacks a definite and indefinite article, and the third person singular present form. The transition of IDW for SK into English is an interesting subject but it is not the purpose of this study. Please ignore the grammatically unnatural part of the translation.

Cabin cruiser which has *developed muscle of hind legs*
Amphibious car which is *poikilotherm*
Airship which *moves towards light*

Figure 2.3: Generated key sentences (partial) by IDW for SK system

Referring the key sentence, the student designed a new creative vehicle that fulfilled the key sentence and drew it on a sketchbook with an explanation. Fig. 2.4 shows one of twenty-eight design results which was drawn and described by referring a key sentence: *Container ship which sheds its skin*. This is a concept abstraction in principle of similarity in taxonomical relations. It is one of three concept-synthesizing processes (Nagai and Taura 2006). Analogical reasoning and metaphor were used to synthesize two concepts. Here, *sheds its skin*, an element from functions of the domain concept *frog* is mapped to the target concept *Container ship*.



Translation of the description on the left picture:

- Container ship which sheds its skin

"When the weather is bad and the sight is obscured, the whole body will be changed into outstanding colour of red or yellow.

Please do not worry about the glaring colour, since it is just temporary.

You will be found easily.

Useful when you are in danger of colliding with another ship."

Figure 2.4: Design result of IDW for SK: Container ship which sheds its skin

Applying IHK model to the design process, the result Fig. 2.4 *Container ship which sheds its skin* is a semantic memory object as same as Frog and Container ship（see Fig. 2.5).

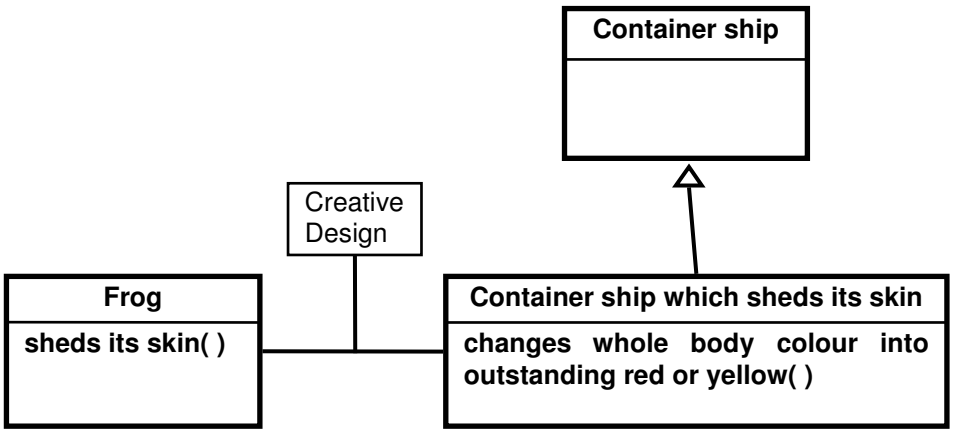


Figure 2.5: Semantic memory objects

Here, *Container ship which sheds its skin* is an extended object of Container ship object. Frog and *Container ship which sheds its skin* have a relationship of *Creative Design* which creates a new function of *changes whole body colour into outstanding red or yellow* for the extended Container ship mapped from the function of *sheds its skin* of Frog object.

What does the *Creative Design* relationship mean? The author interviewed the student after the experiment and confirmed the design process as follows:

1. The student remembered the old news on public media said, “When the weather was bad, big ships sometimes collide.”

2. Episodic thought of the student: “As the frog sheds its skin, the whole body colour of the container ship changes into outstanding red or yellow when the weather is bad in order not to collide with other ships.”

3. Semantic memory object *Container ship which sheds its skin* is extracted from the episodic thought.

First, the student remembered the episodic memory (EM) about a collision accident of big ships which is a parent or generalized object of container ship. The EM here was somewhat abstracted that there lacked concrete information of date and place. We think this happened through generalization of the EM objects built by media news. The news EM objects are abstracted into the object the student remembered and they have been forgotten. In this study, we treat this abstracted EM also as EM object of Empirical Opinion Library. Second, to avoid the accident the

student created a new episodic memory about the container ship. We regard this as a prospective episodic memory (PEM). The difference between the EM and the PEM is that the EM has taken place and the PEM has not taken place yet. Both of them are stored in Empirical Opinion Library of IHK model. Finally, the design result is extracted from PEM.

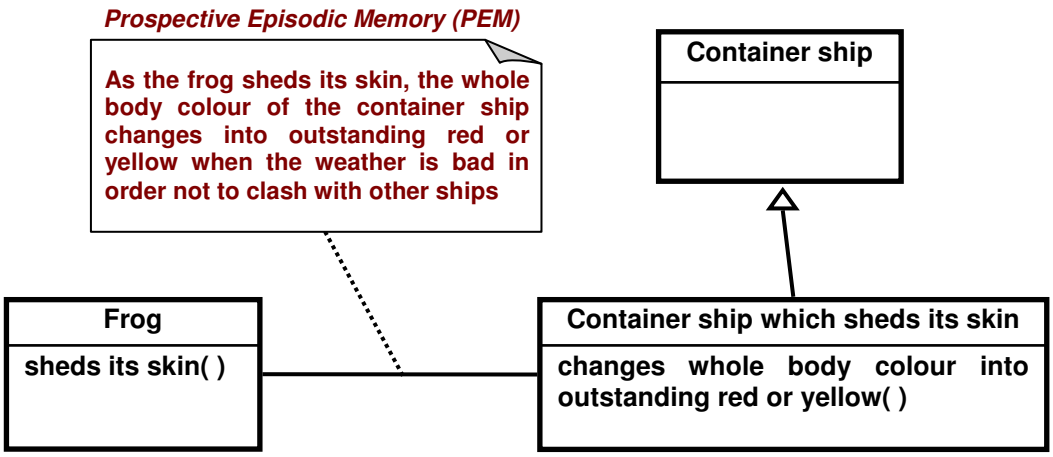


Figure 2.6: Semantic memory objects and PEM

We supposed it is PEM that relates to the creative design result. In this paper we analyze OEA method project to check if this hypothesis works effectively.

3. METHODS

3. 1. APPLICATION PROJECT OF OEA METHOD

In order to analyze the process and possess the results of creative design, we applied OEA method to the real house building project of F family carried out in Fukuoka Prefecture, Japan. Mr and Mrs F joined as users of the house and the primary author conducted the process. The application of the method was done through holding four interviews of about three hours each from September to December 2006. Also some homework was done by the users between the interview sessions. All of the resultant documents are sorted and written out fair by the conductor.

3. 2. PROCESS OF OEA METHOD

OEA method has three phases of analyses: Use Case Analysis, Scenario Analysis and Architectural Object Analysis.

Use Case Analysis is the phase where the users of the building think and find out who the real users of the building (actors) are and how the actors use the building (use cases). The purpose of this phase is to draw use case diagrams for the building according to the language specification defined by Object Management Group as a part of the UML specification (Object Management Group 2005), which is visual and easy to understand for both the users and architects. The resultant documents of the phase are *Use Case Diagrams* with descriptions of actors.

Scenario Analysis is for the users to think about concrete procedures (scenarios) of each use case found in the previous phase. Here step by step scenarios for regular cases and special cases are written by the users. The resultant document of the phase is *Scenarios*.

Architectural Object Analysis uses descriptions of all scenarios to extract all important objects which are used for or related to the building. We called the extracted objects *architectural objects*. The nouns of the scenarios are picked up and merged into architectural objects, their attributes or parts. After that the verbs related to the architectural objects are picked up to be their functions. All architectural objects are sorted into lists with the view of object relationships. The lists are categorized to the purpose. All objects are composed into Object Diagrams which represent logical views of the building with whole-part relationship. The resultant documents of the phase are *Lists of Architectural Objects and Object Diagrams*. Both are used to confirm that the physical design of the building fulfils the user requirements. An architect can use them as firm grounds for unique physical design independent of building types.

The process of OEA method is recursive. The users, therefore, can draw on their knowledge, which includes unconscious examples and one's not found yet, by referring to the resultant documents.

3. 3. VERIFYING THE HYPOTHESIS

We suppose that the resultant documents Use Case Diagram and Scenarios would be PEM objects, and List of Architectural Objects and Object Diagram, the creative design results, would be semantic memory objects of IHK model of the user. We look into the design process of OEA method, and verify if it is the PEM objects that are the source of extraction of the final design results, the semantic memory objects as seen in the IDW for SK project.

4. RESULTS

The resultant documents of the application project of OEA method were Use Case Diagrams, Scenarios, Lists of Architectural Objects and Object Diagrams which would be a logical design of the house.

4.1. USE CASE DIAGRAM

Fig. 4.1 is the main use case diagram of F family house. The biggest rectangle with bold line represents the house. The line drawing figures around it are actors. Ellipses on the diagram are use cases which represent how the actors use the house. The use case is connected to one or more actors by lines. The symbol of big and small combined rectangles is called *package* which represents that there is a collection of use cases. The *Visit* package at left side top is opened as seen in Fig. 4.2. The *Stay* package at centre top is opened as seen in Fig. 4.3. The *Live* package for family actors at right side middle is opened as seen in Fig. 4.4. These descriptions follow the UML specification of Object Management Group (2005).

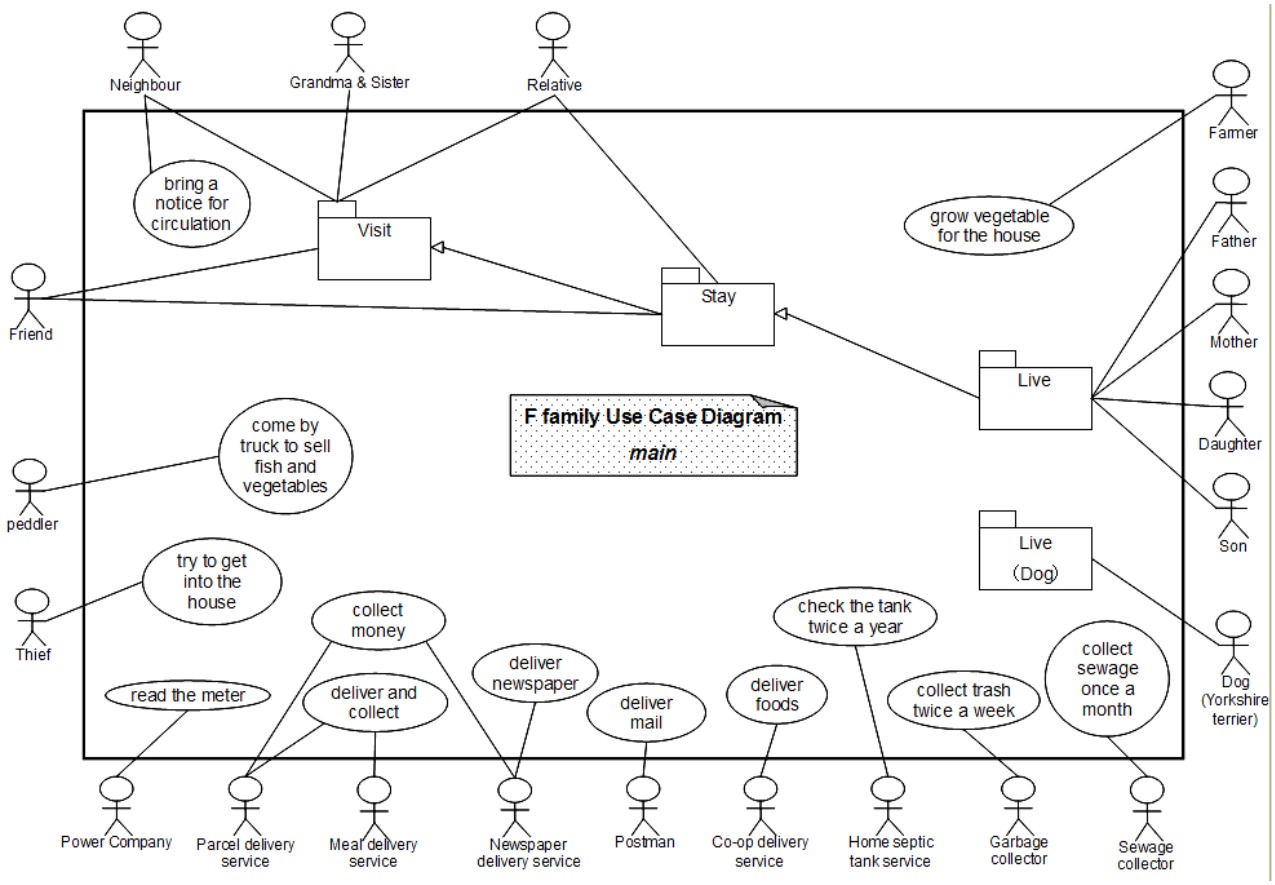


Figure 4.1: Use Case Diagram (main)

All actors and use cases were found by F family, the users. Interestingly they found *thief* as a negative actor who try to get into the house (left bottom in Fig. 4.1). They wrote scenario for the use case of the thief (see Fig. 4.6 later in 4.3. SCENARIO subsection) and it resulted outside object *Dark ground of house* (seen in Fig. 4.8 later in 4.4. LIST OF ARCHITECTURAL OBJECTS AND OBJECT DIAGRAM).

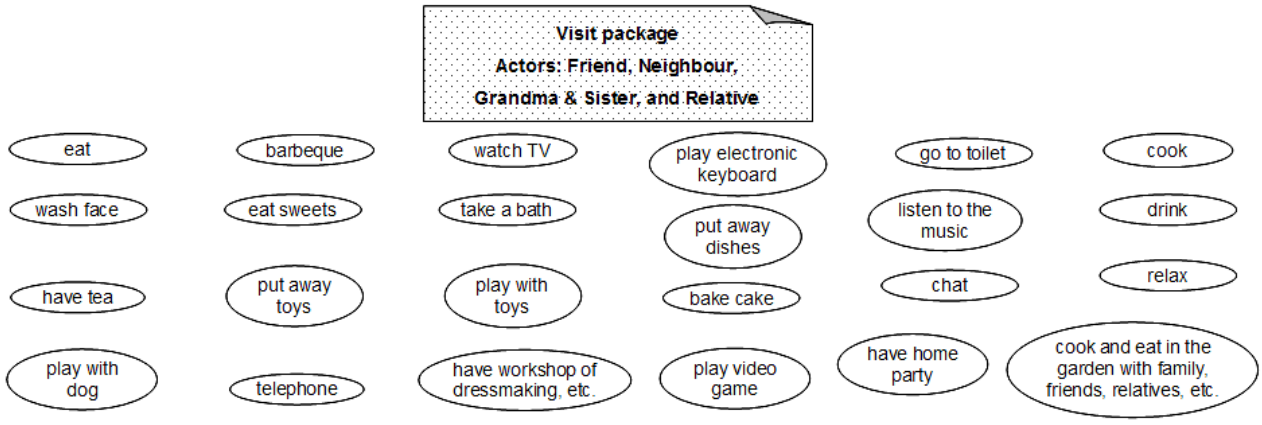


Figure 4.2: Use Case Diagram (Visit package)

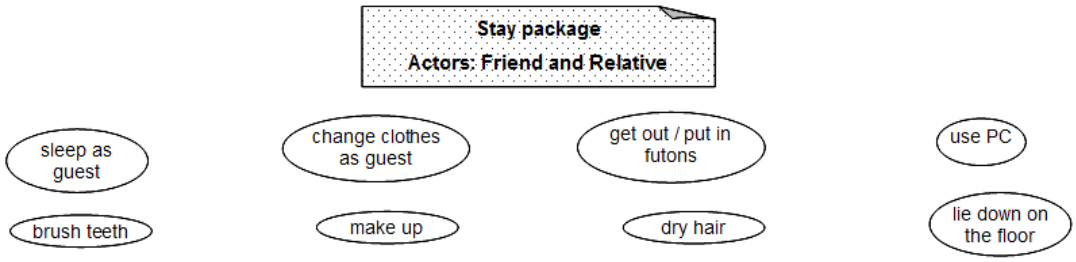


Figure 4.3: Use Case Diagram (Stay package)

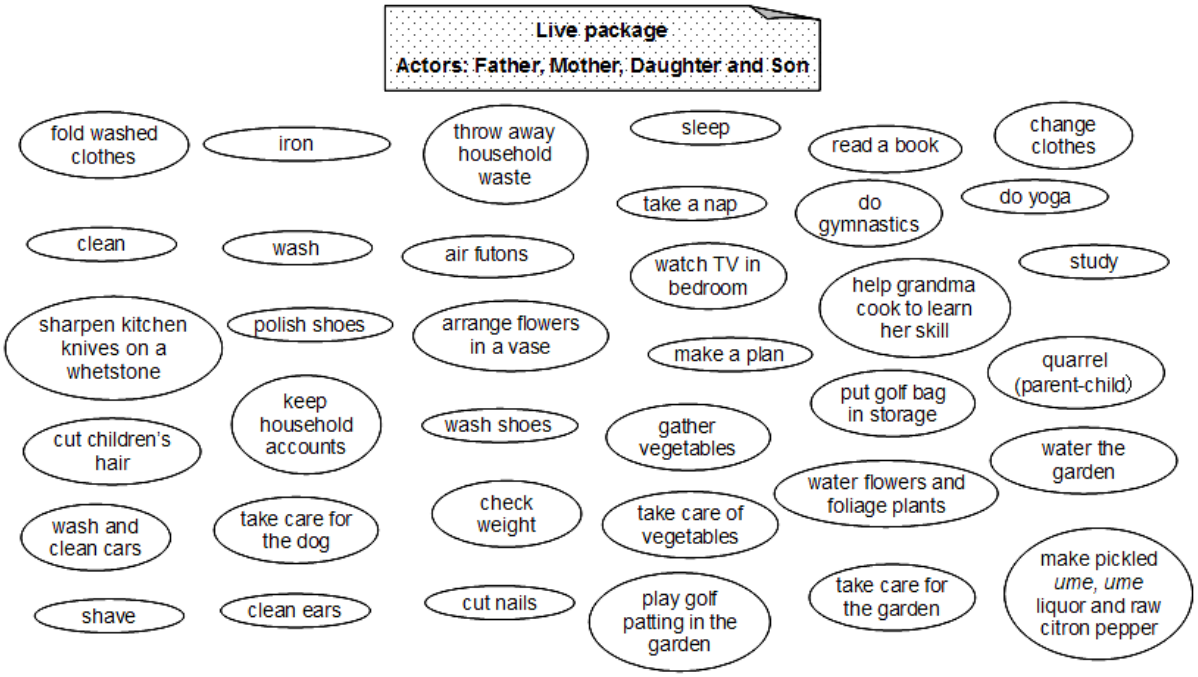


Figure 4.4: Use Case Diagram (Live package)

Visit, Stay and Live packages have relationship of inheritance. Live package is extended from Stay package which is extended from Visit package. That means if an actor connected to Live package, the actor has use cases of all three packages. We have found total eighty-two use cases for the house.

4.2. SCENARIOS

One or more typical step by step procedures were written for the use case respectively. Three scenarios related to the 'small kitchen' are seen in Fig. 4.5 below.

MAKE PICKLED *UME*, *UME* LIQUOR AND RAW CITRON PEPPER (from Live Package connected to Actors: Father, Mother, Daughter and Son)

1. Gather materials from parental home or vegetable garden.
2. Do preparation in the small kitchen at the back door under the eaves.

3-a. Put *umes* in bamboo sieves and dry them in foods-drying place which get a lot of sunshine and hide from a view from the entrance and living & dining room.

3-b. Open the door and get into the food storage area, which has a 4.5 *tatami* size floor, to make pickled *ume*, *ume* liquor and raw citron pepper.

GATHER VEGETABLES (from Live Package as above)

1. Gather vegetables from vegetable garden.
2. Wash muddy vegetables and put unnecessary leaves into compost bin in the small kitchen.

3-a-1. Take off the shoes at the taking-off-shoes place to when you enter the food storage area.

3-a-2. Put the vegetables in the food refrigerator in the food storage area.

3-b. Dry onions and persimmons in food-drying place which get a lot of sunshine.

BARBECUE (from Visit Package connected to Actors: Friend, Neighbour, Grandma & Sister and Relative)

1. Get materials from the kitchen to barbecue table in the garden.
2. Get charcoal, a folding table and chairs, a gridiron, etc. from the garage.
3. Barbecue.
4. After barbecue, wash gridiron, etc. in the small kitchen.
5. Put burning charcoal into the charcoal pot. Dig in the garden and bury the ashes.

Figure 4.5: Scenario of Use Case related to Small kitchen object

The example below is a use case *try to get into the house* of the *thief* whom the users found as a negative actor. The scenario shows that the house has function that the thief failed to get into the house.

TRY TO GET INTO THE HOUSE

a-1. Try to get into the house through dark ground of the house.
a-2. The dark ground of the house is covered with security gravel, which makes sounds, and made frightened and run away.
b-1. Try to get into the house but slide shutters are closed and locked; consequently, failed.

Figure 4.6: Scenario of Use Case 'try to get into the house' of Thief actor

4.3. LIST OF ARCHITECTURAL OBJECTS AND OBJECT DIAGRAM

Architectural objects picked up and sorted from the scenarios are categorized and composed into the List of Architectural Objects. Here are some examples for three categories *Room, Storage* and *Outside* (Table 4.1).

Object	Usages / Contents	Comments
<<Room>>		
Small kitchen	Prepare to make *ume* liquor and pickled *ume*. Wash and cut vegetables to cook. Put unnecessary leaves into compost bin. Clear up the barbecue tools.	At the back door under the eaves
Special *tatami* room	Drink tea. Eat sweets. Eat at folding low table. Talk. Change closes (guests). Sleep (guests). Take out floor mats from *oshiire* storage. Take out futons from *oshiire* to air in the garden. Etc.	Six or eight mat room. At least four guests can stay overnight.
<<Storage>>		
Garage storage	Storage pole to air futons, barbecue tools, farm appliances.	
Oshiire storage	Storage guest futon sets, floor cushions.	in Special *tatami* room
<<Outside>>		
Parking	Visitors park cars (max. three). Wash and wax family car. Use vacuum cleaner plugging to the outdoor socket to clean inside of family car.	Parking in the car park of community centre is also possible if necessary.
Deck in the garden	Grandma cuts children's hair. Take a nap on the chair. Do table coordinates. Eat at the table. Drink tea. Eat snacks. Chat. Use telephone.	Seamlessly continued from living & dining.
Dark ground of house	Cover with security gravel which sounds when a thief try to get into the house.	

Table 4.1: List of Architectural Objects (partial)

All Usages / Contents and Comments are also picked up from the scenarios. This list is a kind of cross reference between objects and functions, i.e. nouns and verbs from the scenarios. We have found eighteen objects for room category, eleven objects for storage category, fourteen objects for outside category and 103 objects for the objects to put in rooms and outside. Total number of the objects was 146 which were all extracted nouns from the scenarios.

Fig. 4.7 and 4.8 are Object Diagrams which represent logical design of the house. Fig 4.7 diagram is composed of the eighteen of room category objects while Fig. 4.8 diagram is composed of fourteen of outside category objects.

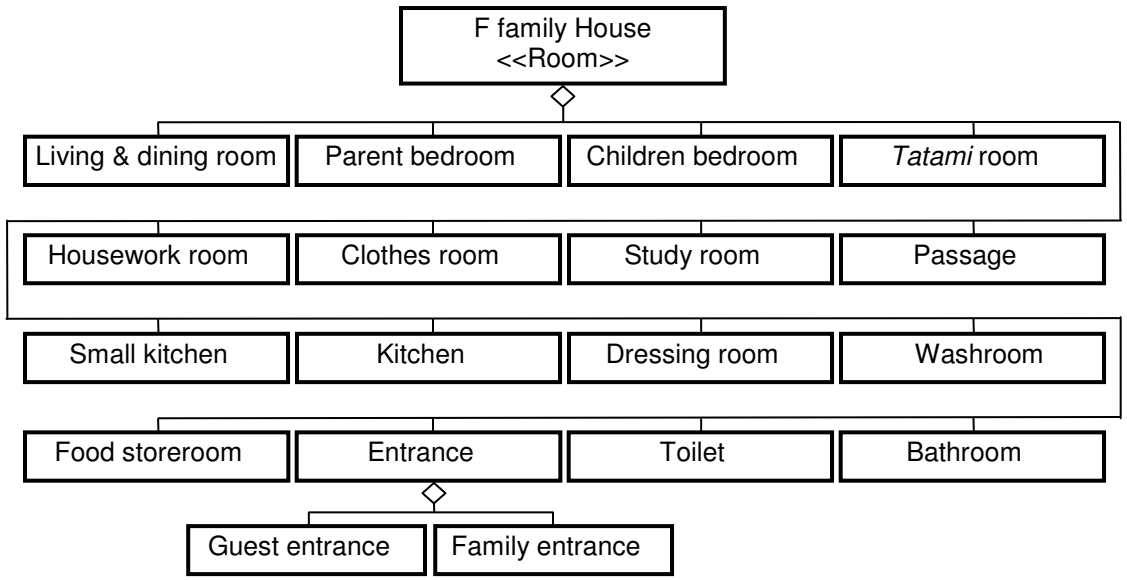


Figure 4.7: Object Diagram F family House <<Room>>

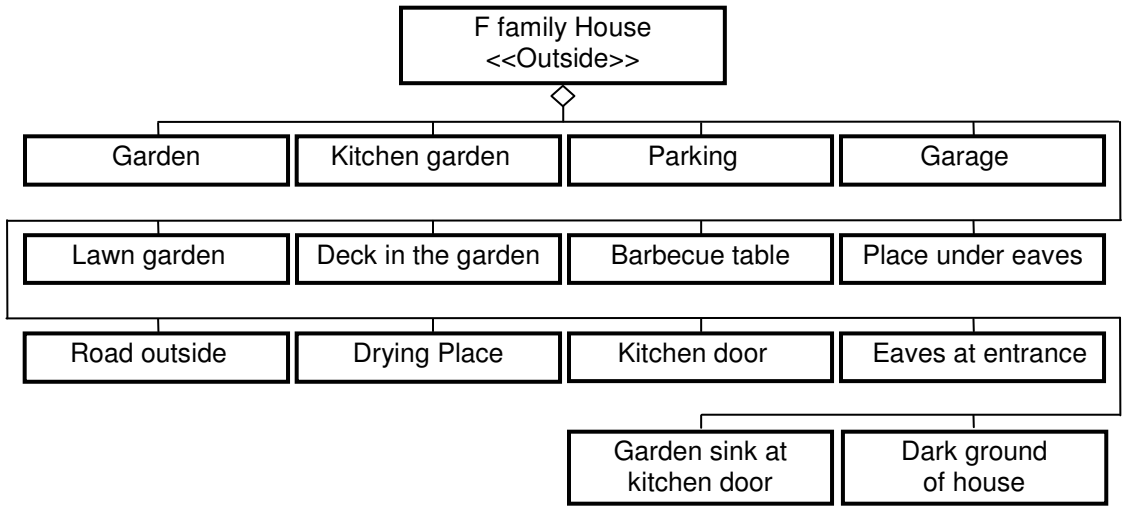


Figure 4.8: Object Diagram F family House <<Outside>>

5. DISCUSSION

Thinking about the episodic memories (EMs) of users related to their current house, the EMs are usually made through daily life experience such as how a family waked up, changed clothes and ate breakfast, or how relatives of husband visited and played Japanese chess in the living room, etc. These EMs are depending on the design of the house (Fig. 5.1). In contrast, a logical design of the future house was extracted from the prospective episodic memories (PEMs) of the users (Fig. 5.2) which are extracted in the process of OEA method.

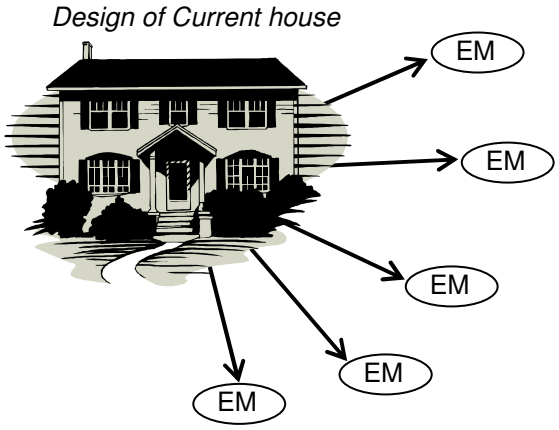


Figure 5.1: EMs and Current house

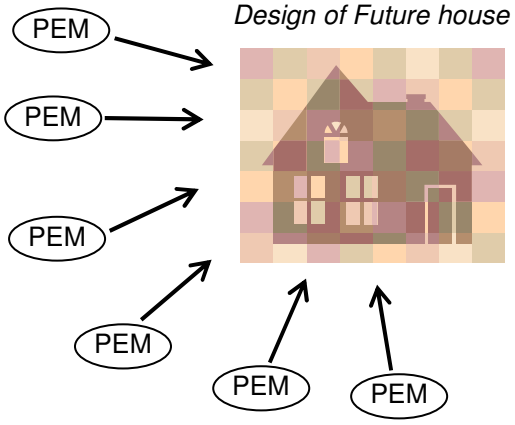


Figure 5.2: PEMs and Future house

According to IHK model, we regard Use Case Diagrams and Scenarios as PEM objects of Empirical Opinion Library since they are about episodes of the future house and have not yet taken place. They are the source of List of Architectural Objects and Object Diagram which we regard as semantic memory objects of RWOL.

5.1. OEA DOCUMENTS AS PEM AND EM

After we decided a noun ‘small kitchen’ found in the description of the Scenarios to be architectural object and categorized into Room, we picked up the related noun and verb to it from Scenarios in order to find attributes, functions or related parts of small kitchen object. The usage of ‘small kitchen’, which became functions of the ‘small kitchen’ object, was seen on Table 4.1 on page 14 as below:

1. Prepare to make *ume* liquor and pickled *ume*
2. Wash and cut vegetables to cook
3. Put unnecessary leaves into compost bin
4. Clear up the barbecue tools

These four functions were sought and extracted from three scenarios which had a noun 'small kitchen' as seen underlined in Fig. 4.5 on page 13 and so was the comment 'At the back door under the eaves' which is an attribute of the small kitchen object.

In this process three scenarios are PEM objects and small kitchen object is a semantic memory object extracted from PEM objects without any additional information. All architectural objects are extracted from Scenarios like this and that makes a logical design view and explanation of the building. The design results are not possibly the same for each user, since the episodes for the building are unique to each individual.

Formulating an equation ***LD = f(PEM)*** where ***LD*** is logical design or semantic memory objects of the building and ***PEM*** is PEM objects originated from declarative knowledge of users, we can say more clearly that it is PEM objects that determine logical design of the building as a logical consequence.

6. CONCLUSION

As a new point of view, we established a construction of the declarative knowledge unique to individuals and analyzed the process in which creative design was born. According to the study of the human development of memory system and amnesia cases, semantic memory is not always created from episodic memory (Tulving 1983), but in this study we found the process in which semantic memories which are the results of creative design are extracted from prospective episodic memories.

The knowledge of the users which was extracted in the recursive process of OEA method is for constructing prospective episodic memory (PEM). And the information of the List of Architectural Objects, the results of logical design of the house, is included in the PEM. Put another way, it is necessary to construct the PEM in order to create a List of Architectural Objects, and PEM

precedes the creative design results. The same process was also seen in IDW for SK project. Thus far we assume that the creative design results are not spontaneous but require the construction of PEM beforehand.

The relationship between PEM and creative design could be a new point of view which is useful to improve design research and to analyze the process of creation of creative design results.

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