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REPRESENTING PRODUCT-SERVICE SYSTEMS WITH PRODUCT AND SERVICE ELEMENTS

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ABSTRACT
This paper discusses the new Product-Service Systems (PSS) representation method which configures product and service elements. PSS is composed of a number of product elements and service elements, and they are complicatedly connected to each other to satisfy customer needs. Therefore, it is of much significance to appropriately represent product and service elements and their relations in PSS. In this paper, a new PSS representation scheme to effectively configure the product and service elements is proposed. In the proposed PSS representation scheme, the service elements can be modelled with stakeholders – service provider/receiver, activities and associated product elements. The product elements are included in the service element and serve as media for realizing PSS. To realize the specific function, several service elements can be connected with flows that were identified in PSS functional modelling. Those flows can also be used to connect associated product elements. Finally, case study is conducted to investigate the applicability of the proposed PSS representation method to the real PSS design project.

Keywords: Product-Service Systems (PSS), Product Element, Service Element, PSS Representation

1 INTRODUCTION
Recently, the researches on design and modelling of product-service systems (PSS) have been rapidly growing. PSS, which was firstly introduced by Goedkoop et al. in 1999 to deal with the environmental and economical challenges, have also been of central attention since PSS could satisfy consumers' needs more effectively by providing integrated solutions of products and services [1]. There have been a few meaningful definitions on PSS such as a system of products, services, supporting networks and infrastructure that is designed to satisfy customer needs and have a lower environmental impact than traditional business models and an integrated body of products and services and communication strategies that was conceived, developed and promoted by (a network of) actors to generate values for society [2, 3]. By the definitions given above, PSS usually has a number of diverse aspects such as stakeholders, activities, functions, product elements, service elements, and so forth. Therefore, appropriate representation scheme should be necessary for effective designing.
The research on the PSS modelling and representations could date back to 1980s. Shostack proposed the molecular modelling of service by introducing product elements, service elements, bond and essential evidence [4]. In his molecular modelling, the connection between product and service elements was made by a simple line – bond. He also proposed the service blueprint to identify and visualize the activities of customers and service providers and their relations during service process. In 1995, Congram and Epelman adopted the Structured Analysis and Design Technique (SADT) to represent services [5]. They claimed that SADT focused on activities which could be major building blocks of services and that SADT models could help employees at every level to understand what happens in delivering a service. In addition, SADT could describe who or what performed the activities and what guided or limited the activities.
More recently, Morelli has been among very active for researching systematic PSS design and modelling [6,7]. In his methodological framework for designing PSS, the major functions and requirements for the PSS were extracted, and they were then mapped to the elements of products and services in the case study of an urban tele-centre [5]. Morelli and Tollestrup studied various service representation methods such as the actor network mapping, motivation matrix, IDEF0, system platform and use cases [7].
Shimomura and his colleagues have been another active research group to study PSS design and modelling [8-11]. In their service engineering research, the service model containing several sub-

models such as flow model, scope model, view model and scenario model was proposed. They also introduced receiver state parameters (RSPs) to address customers' value and cost. Maussang et al. proposed the functional block diagram to correlate product unit and service unit in the PSS design process [12].

Although there have been some research works on PSS modelling and representation, the systematic and detailed framework to address product and service elements and their relations has not been substantially studied. Therefore, in this paper, a new PSS representation scheme involving product and service elements is proposed and its applicability is examined. The service element can be described with service provider/receiver and their activities. In addition, the product element can be considered as the media for service element to effectively and completely realize PSS. In this new PSS representation scheme, there are two different domains – service element domain and product element domain, and the mapping between service and product elements could be expressed in a 3-dimensional way. Multiple service elements can be connected by flows, which are usually identified in PSS function modelling. Those flows can further be decomposed and they connect several product elements in various ways. Sample case example on the clothes TakeIN PSS is studied to investigate the applicability of the proposed PSS representation method.

2 PRODUCT-SERVICE SYSTEMS DESIGN PROCESS [13]

We have previously proposed the systematic PSS design process, and it is composed of the following 6 phases: (1) Requirement Identification and Value Targeting, (2) Stakeholder Activity Design, (3) PSS Function Modelling, (4) Function-Activity Mapping and PSS Concept Generation, (5) PSS Concept Detailing and (6) PSS Concept Prototyping. Fig. 1 shows the schematic diagram of PSS design process. During PSS design process, alternative PSS concepts can be generated by correlating functions, stakeholders, activities and product/service elements. When generating PSS concepts, the activities and functions are linked in the modified service blueprint, and they should be mapped to appropriate product and service elements. In addition, those product and service elements should be properly connected together to effectively realize intended activities and functions. Therefore, it is necessary to develop a new representation scheme for PSS addressing mapping of product and service elements.

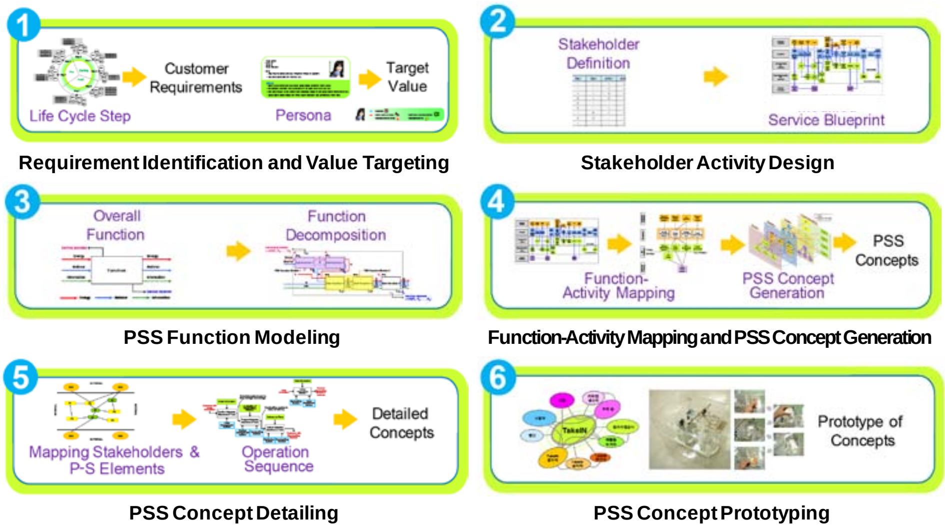


Fig. 1 Product-Service Systems (PSS) design process [13]

3 PSS REPRESENTATION METHOD

Major components composing a PSS concept are functions and related activities, and the functions should be mapped to appropriate product and service elements. When reviewing PSS function modelling in the PSS design process, a PSS function can be expressed as the block diagram which is given in Fig. 2. As can be seen in Fig. 2, the input and output to the function block are represented by three flows – energy, material and information, and they can also be used to logically connect multiple function blocks. In the function block, corresponding service provider and service receiver are expressed as folded nodes in upper left and lower right corners, respectively.

The overall function of PSS is decomposed into a number of sub-functions, and they are connected by flows based on causal and logical relations. The schematic representation of PSS function decomposition is given in Fig. 3. As can be seen in Fig. 3, the flows determine orders and connectivity of function blocks and play a significant role for building up critical functional modules. The service provider and receiver are also decomposed into sub-service providers and sub-service receivers, and they are assigned to each sub-function block.

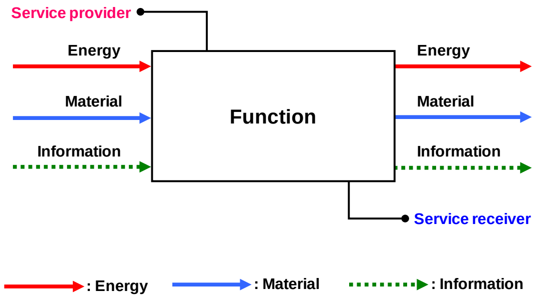


Fig. 2 Schematic of PSS function

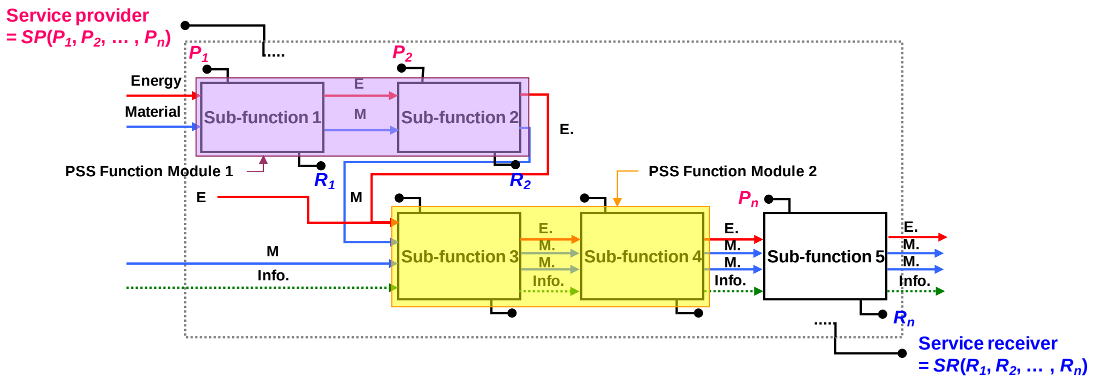


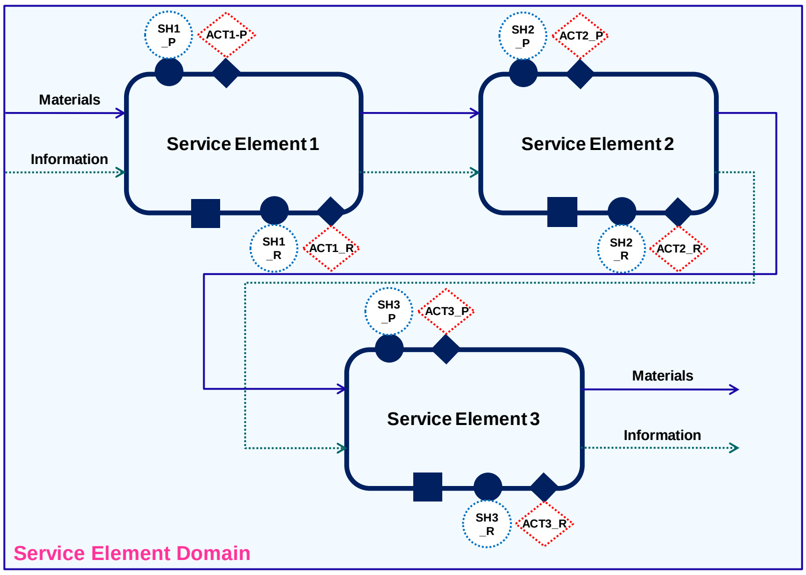
Fig. 3 PSS function decomposition

Each sub-function should be realized as sub-PSS. This sub-PSS is composed of a number of product elements and service elements, and they are connected together in order effectively to realize the corresponding function. Therefore, a proper new representation scheme describing product/service elements and their relationship are needed.

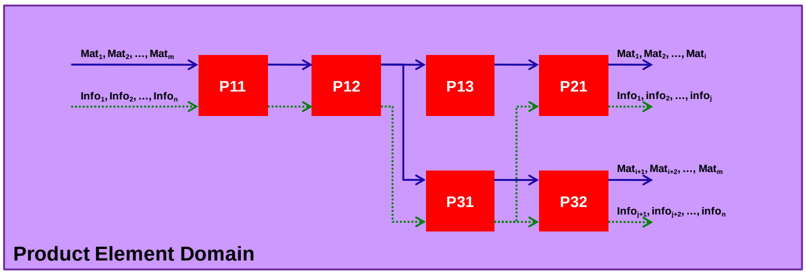
To represent a service element, stakeholders (who), activities (what) and product elements (how) were introduced. In general, service required specific providers and receivers, and their specific activities can also be followed. In addition, proper product elements should be accompanied as media to completely realize service elements. Fig. 4 shows the service and product elements, which are located in two different domains – service element domain and product element domain, respectively.

As can be seen in Fig. 4(a), the service element is represented with the block having service provider (SH_P), service receiver (SH_R) and their activities (ACT_P, ACT_R) in upper left and lower right corners, which is similar to the PSS function block. In addition, those service element blocks can be connected by flows of material and information which were already identified in PSS function modelling. The flow of energy can be used after more detailed attributes of product and service elements are determined. Meanwhile, as can be seen in Fig. 4(b), the associated product elements are also arranged and ordered via the flows of material and information. These product elements will be linked with the appropriate service elements to complete the sub-PSS. In the representation of the service element given in Fig. 4(a), the rectangular nodes have links with the product elements. The service and product elements represented in each domain should be appropriately connected, and 3D view of PSS representation is given in Fig. 5.

A single service element can have multiple product elements, and, on the other hand, a single product element can also be shared by a few service elements. For instance, in Fig. 5, the service element 1 has the product elements of P11, P12 and P13, and the product element of P13 can also be linked with the service element 2. In addition, the flows of material and information can be used to connect associated product elements.



(a) Service element representation



(b) Product element representation

Fig. 4 Representations of service elements and product elements connected with flows in service element domain and product element domain

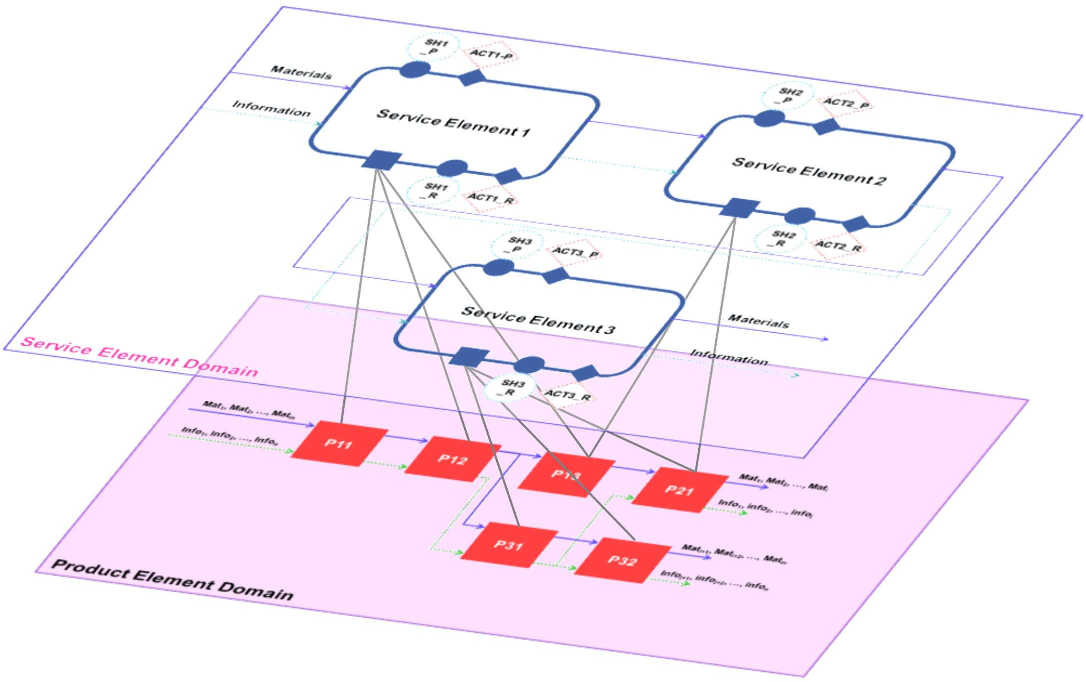


Fig. 5 3D view of PSS representation by mapping service elements and product elements

The patterns of connections among product elements can be different based on the attributes of selected product elements and flows. Besides, different service and product elements can be identified and configured to realize same function, and as a result, several alternative sub-PSSs can be generated and represented. In summary, the following formula can be hold for the proposed PSS representation scheme.

$$\text{Service Element}_i = SE_i\,(SH_i\_P, SH_i\_R, ACT_i\_P, ACT_i\_R, P_{ik}) \quad (1)$$

In formula (1), SH_i_P and SH_i_R represent stakeholders that serve as service provider and service receiver of the i-th service element SE_i respectively, and ACT_i_P and ACT_i_R mean corresponding activities of service provider and service receiver. In addition, P_{ik} represent product elements of the i-th service element SE_i.

4 CASE EXAMPLE – USED CLOTHES TAKEIN PSS

To demonstrate the applicability of the proposed new PSS representation scheme, the case example of clothes TakeIN PSS was studied. We have been using the name of *TakeIN* to denote PSS series for providing desirable reuse of products, indicating taking them back in use rather than throwing away. In this case example, the new scenario of clothes TakeIN PSS was developed by designing new activities and functions with the change of location context of a current used clothes bin. Fig. 6 shows the scenario of new used clothes TakeIN PSS. As can be seen in Fig. 6, the user (donator) repairs and cleans the used clothes, and he/she packages them at the clothes TakeIN station. The donated clothes can be properly stored in the clothes TakeIN station. Then, the stored clothes are collected by collectors and they are classified and properly kept in the warehouse. Afterwards, appropriate receivers are selected, and the donated clothes are delivered to them.

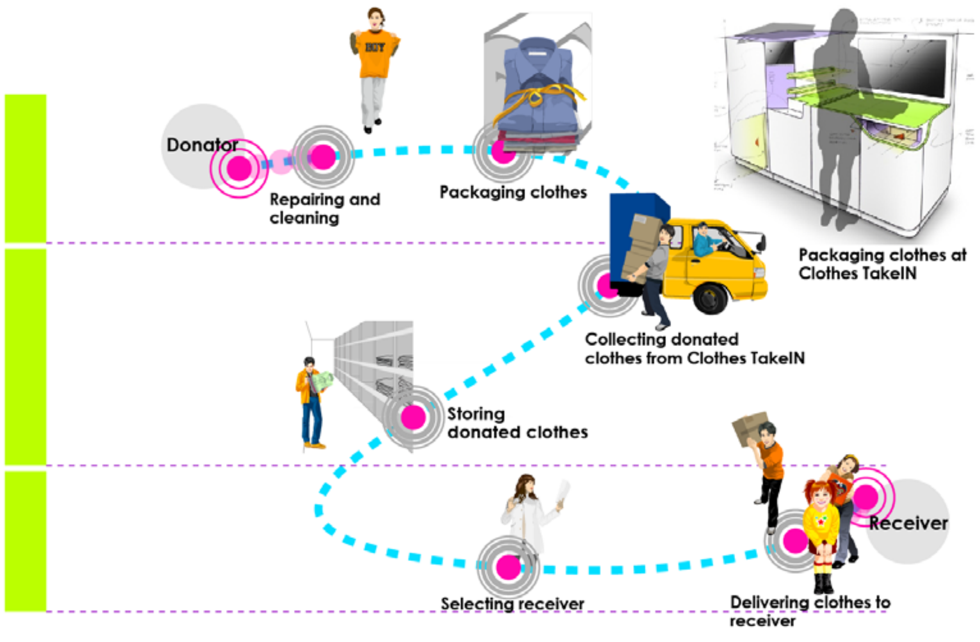
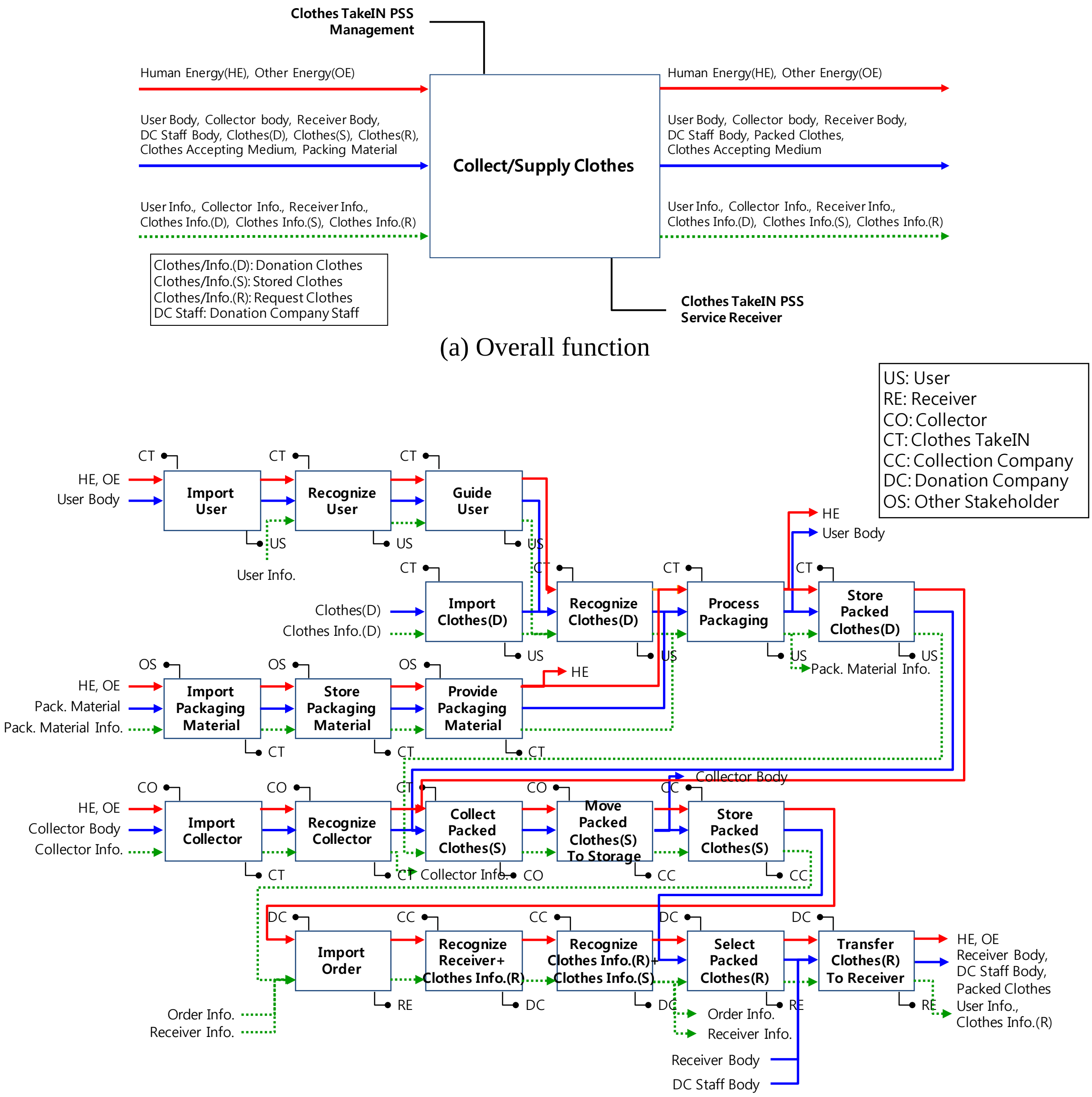


Fig. 6 Scenario of a new used clothes TakeIN PSS

In order realize the new used clothes TakeIN PSS given in Fig. 6, essential function requirements should be listed and properly arranged. Fig. 7 shows the overall function of the new used clothes TakeIN PSS and its corresponding function decomposition diagram. As can be seen in Fig. 7, the overall function of clothes TakeIN PSS was defined as “collect and supply clothes”, and total 27 sub-functions were identified. Those sub-functions were connected by flows based on their logical and causal relations. For each sub-function block, corresponding sub-service provider and sub-service receiver were assigned. Total 7 stakeholders were identified for sub-service providers and sub-service receivers for 27 sub-functions, as can be seen in Fig. 7(b).

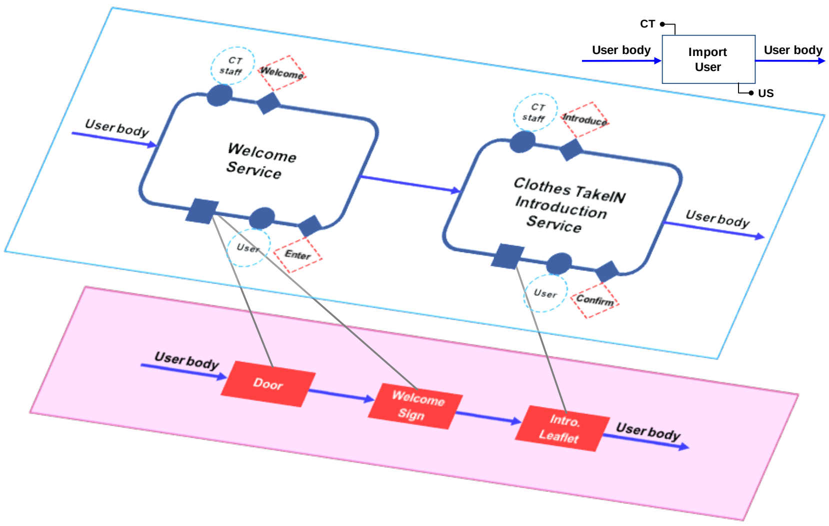


(a) Overall function

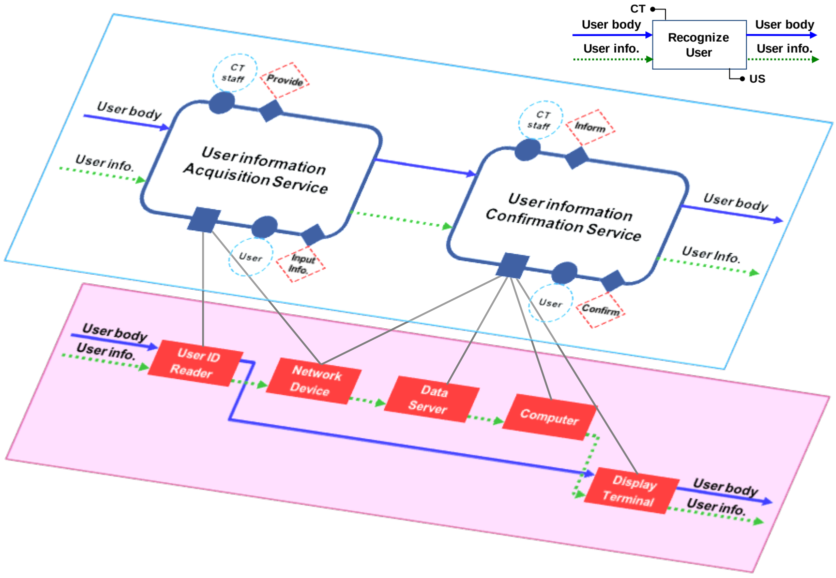
(b) Function decomposition diagram

Fig. 7 Function modelling of new used clothes TakeIN PSS

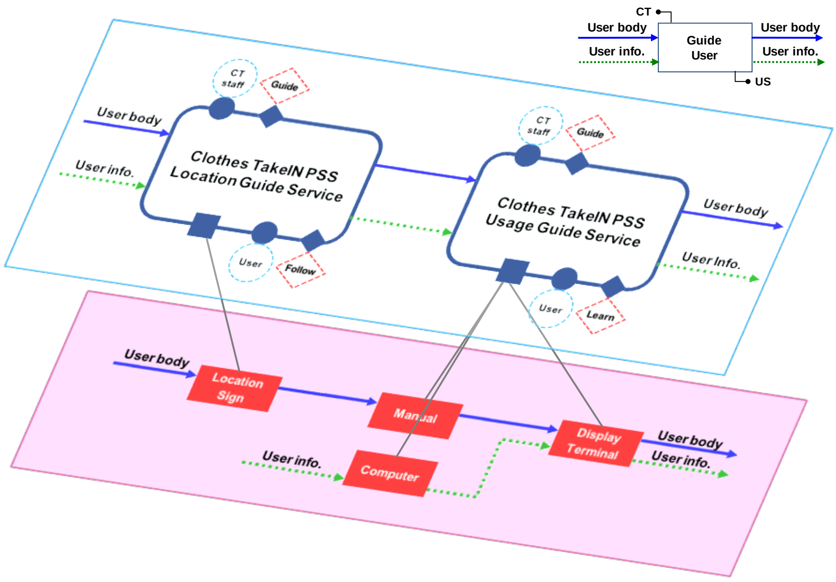
The proposed PSS representation scheme was applied to each function block, and service elements and product elements were defined and linked to each other to completely describe corresponding sub-PSS. Sample sub-PSS representations to a couple of sub-functions are given in Fig. 8. The first three sub-functions of "Import User", "Recognize User" and "Guide User" were considered for case study. As can be seen in Fig. 8(a), the service elements of "welcome service" and "clothes TakeIN introduction service" were selected and associated service provider/receiver and their activities were assigned. In the case of "welcome service", the user (service receiver) entered (activity) the clothes TakeIN PSS space when the CT staff (service provider) welcomed (activity) the user with the product elements of "door" and "welcome sign". Simiarly, in the case of "clothes TakeIN introduction service", the CT staff (service provider) introduced (activity) the clothes TakeIN PSS and the user (service receiver) confirmed (activities) it with the product element of "introduction leaflet". The material of flow of "user body" connected those product elements. Similar descriptions can also be made in the case of the function of "Recognize User", which is shown in Fig. 8(b). The service elements of "user information acquisition service" and "user information confirmation service" were come up with, and appropriate stakeholders and activities were assigned, as given in Fig. 8(b).



(a) Sub-PSS representation for function of "Import User"



(b) Sub-PSS representation for function of "Recognize User"



(c) Sub-PSS representation for function of "Guide User"

Fig. 8 Sample sub-PSS representations for some sub-functions of used clothes TakeIN PSS

The product elements of “user ID reader” and “network device” were connected to “user information acquisition service”, and the product elements of “network device”, “data server”, “computer” and “display terminal” were linked with “user information confirmation service”. As mentioned above, the product element of “network device” was shared by two service elements. There were two input flows of “user body” and “user information”, and only “user ID reader” and “display terminal” had the flow of “user body”. The flow of “user information” was run through all product elements. Therefore, it can be concluded that the product elements of “user ID reader” and “display terminal” had interactions with user, which could become service touchpoints for user. Fig. 8(c) denotes the sub-PSS representation for the function of “guide user”.

Three functions of “Import User”, “Recognize User” and “Guide User” can be grouped together to make the functional module. Consequently, associated service elements and product elements should also be linked together to realize the corresponding PSS module. Fig. 9 shows the PSS module representation corresponding to the group of three functions of “Import User”, “Recognize User” and “Guide User”.

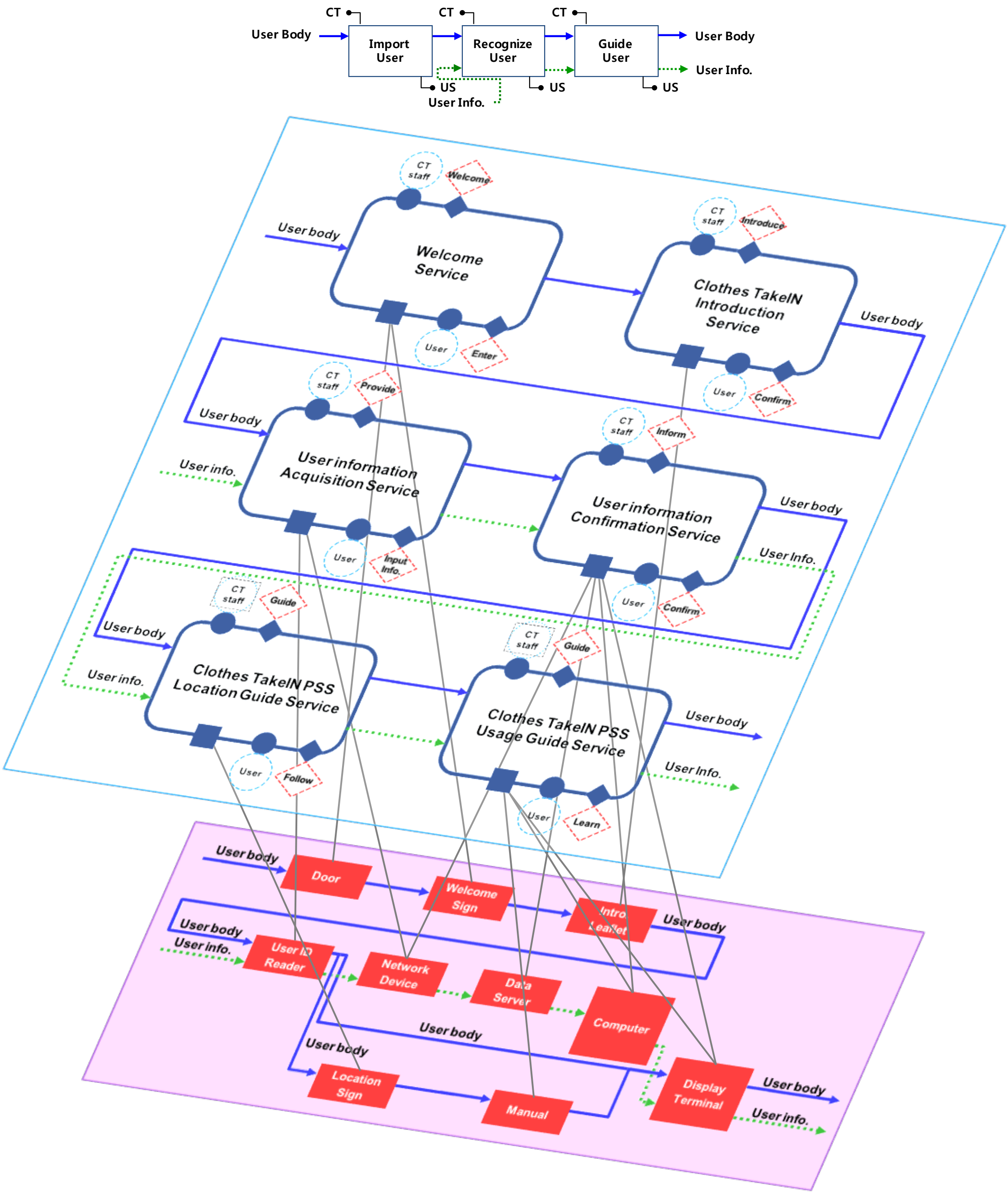


Fig. 9 PSS module representation corresponding to the function group of “Import User”, “Recognize User” and “Guide User”

As can be seen in Fig. 9, total six service elements were combined together via the flows of material and information, and associated product elements were arranged subsequently. In particular, the product element of “computer” and “display terminal” could be shared by two different service elements such as “user information confirmation service” and “clothes TakeIN PSS usage guide service”.

The proposed PSS representation scheme can help designers to effectively understand the relations among identified service elements and product elements with visual description. It is also possible to effectively display critical flows of material and information running through various product elements and service elements. Therefore, alternative arrangement and configuration of product/service elements can become much simpler and more effective. The assignment of stakeholders and activities to service elements also enables designers to effectively understand and show specific service providers and service receivers and their associated activities.

5 CONCLUDING REMARKS

This paper presented the new PSS representation method by modelling the product element and service element. To effectively represent the PSS, two different domains – service element domain and product element domain – were considered. The service element was modelled with service provider/receiver and their activities, and they were depicted as circular and diamond nodes at upper left and lower right corner of the service element block, respectively. In addition, the product element was included in the service element as a medium, and it could be connected with the service element block at the rectangular node. A single service element could have multiple product elements, and it was also possible for a single product element to be shared by several service elements. Multiple service elements were connected via the flows of material and information, which were usually identified in the PSS functional modelling. Similarly, the connection among the product elements could be made via the flows. These connections could differ when different product and service elements were identified, and as a result, alternative configurations of the product and service elements of the PSS realizing same functions could be generated and compared. Sample case study on the clothes TakeIN PSS was conducted, and the results demonstrated the applicability of the proposed PSS representation method. In the case study, several sub-PSS representations could be concatenated together based on the grouping of their corresponding functions, and the proposed method could also be applicable.

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