

Journal of Information and Telecommunication

ISSN: (Print) (Online) Journal homepage: <https://www.tandfonline.com/loi/tjit20>

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To cite this article: Thang Le Dinh, Thanh Thoa Pham Thi, Cuong Pham-Nguyen & Le Nguyen Hoai Nam (2022) A knowledge-based model for context-aware smart service systems, Journal of Information and Telecommunication, 6:2, 141-162, DOI: [10.1080/24751839.2021.1962105](https://doi.org/10.1080/24751839.2021.1962105)

To link to this article: <https://doi.org/10.1080/24751839.2021.1962105>



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Published online: 23 Aug 2021.



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A knowledge-based model for context-aware smart service systems

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ABSTRACT

The advancement of the Internet of Things, big data, and mobile computing leads to the need for smart services that enable the context awareness and the adaptability to their changing contexts. Today, designing a smart service system is a complex task due to the lack of an adequate model support in awareness and pervasive environment. In this paper, we present the concept of a context-aware smart service system and propose a knowledge model for context-aware smart service systems. The proposed model organizes the domain and context-aware knowledge into knowledge components based on the three levels of services: Services, Service system, and Network of service systems. The knowledge model for context-aware smart service systems integrates all the information and knowledge related to smart services, knowledge components, and context awareness that can play a key role for any framework, infrastructure, or applications deploying smart services. In order to demonstrate the approach, two case studies about chatbot as context-aware smart services for customer support are presented.

ARTICLE HISTORY

Received 15 April 2021
Accepted 27 July 2021



KEYWORDS

Smart services; smart service systems; knowledge component; context-aware; chatbot

1. Introduction

The advancement of the Internet of Things, big data, and mobile computing leads to the need for smart services, which enable the context awareness and the adaptability to their changing contexts. Consequently, the information technology paradigm shifts to a smart service environment, as ubiquitous technologies are used in the latest industry trend. The major features of smart services are high dynamism and heterogeneity of their environment and the need for context awareness (Oh et al., 2009).

Smart services are services that are capable of actively adapting and responding based on the circumstance of interests. A smart service, as is evident from its name, is a context-aware connected service (Geum et al., 2016). Consequently, the service context plays a key

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role that influences the service behaviors. From another perspective, smart services are considered as the suitable knowledge provided to consumers and smart objects based on their circumstances. Therefore, smart services and smart service systems have been an emerging research direction not only in the information systems discipline but also in marketing, computer science, industrial engineering, and business administration (Bev-erungen et al., 2017). However, designing a smart service system is a complex task due to the lack of an adequate model support in awareness and pervasive environment (Gu et al., 2005).

As a result, the paper focuses on context-aware smart service systems and presents a knowledge model for context-aware smart service systems, called the context-aware knowledge model. This approach aims at organizing the domain and context-aware knowledge related to smart service systems into knowledge components based on the three levels of services: Services, Service system, and Network of service systems (Le Dinh & Pham Thi, 2012).

The rest of the paper is organized as follows. Section 2 provides the theoretical background of contexts, service systems, smart service systems, and approaches of context-aware systems. Section 3 discusses context-aware smart service systems and presents our research design. Section 4 proposes a knowledge model for context-aware smart service systems. Section 5 illustrates our proposed approach with specific cases of context-aware smart services for software support. Section 6 deals with the evaluation of the proposed approach. Section 7 provides some conclusions and future research work.

2. Theoretical background

This section aims at presenting the key concepts and principles related to context, context-aware systems, service science, and smart service systems.

2.1. Context-aware systems

2.1.1. Context

Context is defined as *the situation within which something exists or happens, and that can help explain it* in the Cambridge dictionary.¹

In the information systems field, context is defined as *any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application* (Abowd et al., 1999). Contexts can be classified as computing context, physical context, time context, and user context (Chen & Kotz, 2000).

Contexts, from the ambient intelligence perspective, are grouped into user-centric context and environmental context (Feng et al., 2004). *User-centric context* includes the information about the user profile, agenda, body sensors, or emotional states. Meanwhile, *environmental context* relates to the physical, social and computational environment around users.

In the industrial engineering field, contexts are categorized into user context, environment, system, information retrieval and pattern recognition (Rosenberger & Gerhard, 2018). *User context* refers to all context related to users such as personal information, personal condition, and user location. *Environment* addresses all contexts

surrounding a user such as the date and time, workspace resources, resource condition, and physical condition like temperature, and humidity level. *System* refers to the context around the usage of a system such as a network, software, and devices. *Information retrieval* relates to the information provision context such as searchable data. *Pattern recognition* is context derived from historical contexts (Rosenberger & Gerhard, 2018).

In the context of business services, which is the focus of this paper, there are certain types of context that are, in practice, more important than others such as location, identity, activity and time. Those types of context are the primary context types for characterizing the situation of a particular entity and can be used to find the secondary context for that same entity as well as primary context for other related entities (Abowd et al., 1999). Consequently, the questions of who, what, when, and where are often used to identify other sources of contextual information.

2.1.2. Context-aware systems

A system is context-aware if it uses context to provide relevant information and/or services to the user, where the relevancy depends on the user's task (Abowd et al., 1999). A context-aware system refers to a general class of systems that can sense their environment, and adapt their behavior accordingly (Bellavista et al., 2012). The main features of context-aware systems are: (i) Presentation of information and services to users; (ii) Execution automatically of a service; and (iii) Tagging of context to information for later use.

Context-aware frameworks typically support context acquisition, representation, delivery, and reaction (Dey et al., 2001). Depending on the application domains and perspectives, a context has different types, and context information comes from different sources. Therefore, some standards for context modelling or context representation are needed to help the context-aware systems in using contextual information. A survey of various context-aware systems, projects and approaches is carried out by Perera et al. (2014), in which sixteen taxonomies are used to compare different approaches. The selected taxonomies relate to all levels of context-aware system development from modelling to implementation. At the modelling level of context-aware systems, the relevant taxonomies are context type, context representation, and knowledge management. Knowledge management refers to knowledge on sensors, domains, users, activities and many more (Perera et al., 2014). Recently, Irani et al. (2021) have reviewed several definitions of aware, awareness, conscious, and consciousness and identified the functionalities of computationally aware systems.

2.1.3. Context-aware approaches

According to Perera et al. (2014), the most popular context modelling techniques are key-value, markup schemes, graphical, object-based, logic-based, and ontology-based modelling. Table 1 presents some typical context-aware approaches.

In the **user-based approach**, a context is composed of user context, phone use context and environment context (Aaltonen et al., 2005): (i) *User context* includes social context, mental context, activity, and profile; (ii) *Phone use* context involves sensors, network services, current application, and the user interface; and (iii) *Environment* context deals with location, date time, season, people, light, temperature, and noise.

Table 1. Typical context-aware approaches.

Approach	Authors	Context type	Context representation	Knowledge management
User-based	Aaltonen et al. (2005)	<ul style="list-style-type: none"> • User context • Environment context 	• Key-value	• No
Sensor data based	Henricksen and Indulska (2006)	<ul style="list-style-type: none"> • Sensor data • Static context • User profile 	• Graphical modelling	• Relational model
User situation based	Mo et al. (2010)	<ul style="list-style-type: none"> • User data • User situation 	• Database	• Reasoning rules
Goal-based	Kim et al. (2012)	<ul style="list-style-type: none"> • Goal • Role • Action • Status • Location • Time 	• Ontology based model	• Knowledge base
Location-based	Dobson et al. (2016)	• Location context	<ul style="list-style-type: none"> • Object-based model • Space model 	<ul style="list-style-type: none"> • Knowledge base • Spatial knowledge
User location based	Schmidtke (2020)	• User location	<ul style="list-style-type: none"> • Ontology based • Network hierarchy 	• Context knowledge management

Moreover, concerning the knowledge representation, an additional context, called *file* context, contains context information in the form of key-value (Aaltonen et al., 2005).

In the **sensor data based approach** (Henricksen & Indulska, 2006), a context involves sensed data (e.g. sensor data), static context data, user profiled data and other derived data. The graphical model (including object type, fact types and their relationship) is used for context representation, and the relational model is used for context knowledge management. Indeed, the graphical model is mapped to the relational representation, which consists of a set of facts expressed in the form of database tuples.

In the **user situation based approach**, user data and user situations (such as time, location, and status) are used to define a context (Mo et al., 2010). Context data is stored in databases, having a data type and a context identifier. Knowledge is stored and used in the form of reasoning rules.

In the **goal-based approach** (Kim et al., 2012), a context is defined based on the information related to the goal (why), role (who), action (how), status (what), location (where), and time (when). Besides, ontology based model encoded context ontology for modelling context-aware environments, and for supporting logic based context reasoning.

In the **location-based approach**, the focus is the location context (Dobson et al., 2016). The context modelling technique is the object-based model, in which data in the space model is used to describe the relationship between an entity and a space. The space model is to describe relations between spatial entities, which are represented by coordinate points, geometric shape, and symbolic place or a relative location. The knowledge base is about spatial data and networked environment. Spatial knowledge is used for querying and reasoning on spatial data.

In the **user location based approach** (Schmidtke, 2020), a context is represented by the semantic information about user location, which is used to represent the hierarchical reasoning about location and sensor information. Semantic information is linked to locations with URLs and stored in an ontology for context knowledge management.

2.2. Services, service system and network of service systems

2.2.1. Services

In the service-dominant logic, services are defined as the use of an economic entity's specific competencies, such as knowledge, skills and technologies, for the benefit of another economic entity (Lusch et al., 2008). Services include all economic activities in which individuals, organizations and technologies work together, apply specialized competences and capabilities to co-create business value.

2.2.2. Service systems

Value creation occurs when a resource is turned into a specific benefit, called resourcing, that is performed by a service system. A service system is defined as a *value-coproduction configuration of people, technology, other internal and external service systems, and shared information* (Spohrer et al., 2007). Service systems have been getting smarter overtime as new trends, such as big data and business analytics, which have been used to generate information and automate business operations to create more value for customers.

2.2.3. Network of service systems

The traditional supply chain is re-conceptualized as a network of service systems, also called a service value creation network, which is a group of autonomous organizations working together to achieve not only their own goals, but also a collective goal (Le Dinh & Leonard, 2009; Lusch et al., 2008).

2.3. Smart services and smart service systems

2.3.1. Smart services

Services delivered to or through intelligent products, which feature the awareness and connectivity, are called 'smart services' (Lim & Maglio, 2018). Smart services are services that are capable of actively adapting and responding based on the circumstance of interests. A smart service, as is evident from its name, is a context-aware connected service (Geum et al., 2016).

Indeed, smart services are constituted by the accommodation of smart devices into a digital service system to integrate physical and digital competencies in a complex social-technical service system (Beverungen et al., 2017).

2.3.2. Smart service systems

A smart service system is a service system, which is *capable of learning, dynamic adaptation, and decision-making based upon data received, transmitted, and/or processed to improve its response to a future situation* (Medina-Borja, 2015). A smart service system can be considered as a service system equipped with smart devices that can amplify or augment *human capabilities to identify, learn, adapt, monitor and make a decision* (Beverungen et al., 2017).

Consequently, smart service systems are instrumented, interconnected, and intelligent (Spohrer, 2013). *Instrumented* means sensors that capture more real time and historical information that stakeholders need to make better decisions. *Interconnected* refers to people having easy access to information about a particular service system, as well as

others that interact with it. *Intelligent* relates to recommendation algorithms that provide stakeholders with the best choices. There are several types of smart service systems such as smart home, smart energy, smart building, smart transportation, smart logistics, smart farming, smart security, smart health, smart hospitality, smart education, and smart city and government (Lim & Maglio, 2018).

3. Context-aware smart service systems

This section begins with the context and motivation of the study and then continues with its research design.

3.1. Context and motivation

Context-aware smart service systems are one of the merging research directions, especially in the field of industrial engineering related to the Internet of Things, smart solutions and context-aware services. The following are some typical applications:

- *Smart life*: context-awareness is used to obtain information and gives proper services automatically (Mo et al., 2010).
- *Intelligent transport system*: various sensors have achieved large-scale deployment, and abundant data are generated and processed into useful information, and new services to benefit the driver and improve road safety (Chang et al., 2017).
- *Smart home*: ubiquitous computing is moving towards the creation of context-aware smart environments that users and things interact with in order to support the smart home domain (Aggeliki et al., 2016).
- *Context-aware web services*: web services are based on the context-aware techniques that can be employed in the future of services amongst others, mobile devices, web services, and pervasive environments (Truong & Dustdar, 2009).

Indeed, the field of context-aware smart service systems is still an emerging field that covers different new research topics (Lim & Maglio, 2018). However, there is still a little focus on the context-aware smart service systems in the context of information systems, especially in business services (Le Dinh & Pham Thi, 2012).

Moreover, one of the most important challenges faced today is the *design of context-aware smart service systems*, which addresses knowledge for the design of these systems, including design model, approach, and process (Lim & Maglio, 2018). In fact, there is an urgent need for IT artefacts that can be used to develop, interoperate, and deliver context-aware smart services (Beverungen et al., 2017).

For this reason, this paper addresses the challenge of designing a smart service system and presents a knowledge model for designing and building a context-aware smart service system with the focus on business services in the following sections.

3.2. Research design

3.2.1. Research question

This paper seeks to answer the following research question: *How to design a context-aware smart service system based on knowledge components?*

In order to respond to this question, the paper proposes the Context-Aware Knowledge model, called CAK model, which can be used to design and build context-aware smart service systems. The earlier version of this model was presented at the ICCCI conference in November 2020 (Le Dinh et al., 2020). This version is indeed an extended version with the focus on the context-aware business services.

A smart service system must be capable of learning, dynamic adaptation, and decision-making. Therefore, a smart service system needs a knowledge structure, including a knowledge management system for its operations as well as a knowledge development process to facilitate the transformation of data into information and then from information into knowledge (Le Dinh et al., 2014). The underlying research design consists of two phases. Firstly, the paper aims at the construction of the research artefacts of the proposed model and then continues with the subsequent evaluation and applicability check of these artefacts with the case studies.

3.2.2. Context definition

After reviewing the relevant thematic and methodological literature (Le Dinh et al., 2014), the paper considers a context is all the information that can be used to describe a situation of a smart service and its interactions with the environment. Based on the perspective of knowledge components (Le Dinh et al., 2014), a context is defined by a set of knowledge components, including know-with, know-who, know-where, know-when, know-what, know-how, and know-why.

A typical expression of a context is as the following: A « *stakeholder* » (know-who) performs « *operations* » (know-how) on « *objects* » (know-what) at « *time* » (know-when) in « *a location* » (know-where) because of « *a contract* » (know-with) to be consistent with « *a business rule* » (know-why).

3.2.3. Smart service and its context

The proposed approach considers that a service consists of three service elements: service proposal, service consumption, and service operation (Le Dinh & Pham Thi, 2012). At the Network of service systems level, the *service proposal* element uses the knowledge and understanding to create and increase the values of business services in a service value creation network by applying effective management practices. At the Service system level, the *service consumption* element aims at organizing services in a service system and supporting consumers in consuming services. At the Service level, the *service operation* element improves the quality of services. Accordingly, the focal points of the CAK model could involve different knowledge components (Le Dinh et al., 2014) at different levels of services (Table 2).

At the Network of service systems level, the Know-who and Know-with knowledge components aim at capturing knowledge about the relationship and interaction between stakeholders of the network and at determining the process of value proposition and co-creation. At the Service systems level, the Know-where and Know-when knowledge components focus on the knowledge about strategies and implementation of business services to create more value. At the Service level, the Know-what, Know-how and Know-why knowledge components concentrate on the knowledge related to the use of new technologies and knowledge to improve the quality of business services.

Table 2. Knowledge components of the CAK model.

Level	Objective	Knowledge components	Corresponding types of context
Network of service systems	Service proposal	Know-with Know-who	Secondary context Identity (primary context)
Service system	Service consumption	Know-where Know-when	Location (primary context) Time (primary context)
Service	Service operation	Know-what Know-how Know-why	Activity (primary context)

4. Knowledge-based model for context-aware smart service systems

This section presents the *CAK (Context Aware Knowledge)* model for designing context-aware smart service systems according to the three levels of business services: Network of service systems, Service system and Service levels.

4.1. CAK model at the network of service systems level

The Network of service systems level focuses on the service proposal, which aims at modelling services as a chain of value creation and exchange in which service systems coproduce common results (Le Dinh & Pham Thi, 2012). This level relates to the knowledge about the business ecosystem and relationships between its members, which is represented by the Know-who and Know-with knowledge components (Johnson et al., 2004; Le Dinh et al., 2014).

Know-who knowledge component refers to *a combination of knowledge and social relationship about resources such as individuals, groups, or organizations* that provide or consume a service (Le Dinh & Pham Thi, 2012). **Know-with** is the relational knowledge that concerns with the knowledge about the relationships between stakeholders inside a network of service systems such as knowledge about the interactions in partner relationships, knowledge about the management of supply chain functions, and knowledge about its external operating environment (Johnson et al., 2004; Le Dinh et al., 2014). Those two knowledge components facilitate the process of value co-creation in a network of service systems (Le Dinh & Pham Thi, 2012).

In the CAK model, know-who is represented by *Entity*; meanwhile, know-with is represented by *Contract*. Table 3 presents the concepts of the CAK model at the Network of service systems level.

In order to illustrate the concepts of our model, we use an example of a context-aware smart service for software support, including two case studies. The first case study, called **Adobot**, demonstrates the implementation of a smart service to support customers using the Adobe Photoshop (Tran Hien et al., 2020). The second case study, called **Smabot** shares the experiment of smart services to support customers for online sales of smartphone devices (Truc et al., 2020).

Concerning the first case study, Adobe Photoshop had been chosen to develop the service based on its popularity and available resources. A service is required and begun when a photographer, as a Photoshop's customer, wants to use an online image processing tool for his work. The service proposal value is to help him to complete the work with high quality. The entities included in the service are the photographer as a service consumer, Adobe and its partners are the service providers. This service disposes of some

Table 3. Concepts of the CAK model at the Network of service systems level.

Concept	Knowledge component	Definition
Entity	Know-who	A stakeholder of the network and has distinct goals.
Resource		Having the responsibility to carry out a contract related to a service.
Contract	Know-with	Defining what to offer and to whom, such as a SLA (service level agreement).

different resources such as the software itself, documentation, community forum, and customer support center. The photographer needs to buy a license to use the service. The license, which is associated with a price and a specific type of usage, is considered as a contract between the service consumer and the service providers.

4.2. CAK model at the service system level

The service system level concerns the service consumption that involves the configuration, implementation and use of business services provided by a service system. This level focuses on the knowledge that ensures all the services have adequate resources and sufficient technological support. The knowledge at this level determines what resources will be consumed, where and when it takes place, and who will be consumers. Firstly, **Know-where** indicates the locations related to resources of the service provider and the service consumer. **Know-when** indicates the time frame in which certain services are expected to offer or in which consumers are expected to consume services. According to the view of the service consumer, know-where and know-when help consumers find the right information in the right place at the right time.

In the CAK model, know-where is represented by *Location* and know-when is represented by *Time frame*. Table 4 presents the concepts of the CAK model at the Service system level.

Regarding our example about Adobot, in order to use the Image processing tool, the user needs to access the Adobe Photoshop link and sign in. The tool is available for 24/7. In relation to the Adobe’s support center and community forum, the service time frame is also 24/7 or the office hours 9–6 if the user wants to contact a support staff based on his location. On the other hand, the history of the usages of the service based on the location and time frame also helps the service provider to allocate their resources efficiently.

4.3. CAK model at the service level

The Service level, concerning the service operation, emphasizes what is provided to consumers and how it is provided (Le Dinh & Pham Thi, 2012). This level also concerns the governance so that a service is operated smoothly by enforcing a set of rules. There are three types of knowledge components at this level: know-what, know-how and

Table 4. Concepts of the CAK model at the Service system level.

Concept	Knowledge component	Definition
Location	Know-where	Situational knowledge about positional relationships of resources that indicates where to request and consume services.
Time frame	Know-when	Situational knowledge representing the period in which certain services are expected to offer or in which consumers are expected to consume services.

Table 5. Concepts of the CAK model at the Service level.

Concept	Knowledge component	Definition
Object	Know-what	A thing or product that consumers can use or consume
Attribute		A piece of information determining the properties of an object.
State		Conditions, modes or situations during which certain business activities are 'enabled' and others 'disabled'
Operation	Know-how	An operation of a service that is used to transit from a state to another state of an object.
Rule	Know-why	A rule represents the implementation of a business rule in a service system.

know-why (Le Dinh et al., 2014). **Know-what** refers to objects relating to a service. **Know-how** refers to the understanding of the operations constituting a service. **Know-why** refers to the understanding of the service quality.

In the CAK model, know-what is described by *Object*, know-how by *Operation*, and know-why by *Rule*. Table 5 presents the concepts of the CAK model at the Service level.

Some concepts related to the service operation in our example about Adobot are described as follows. Firstly, the main objects of Adobe Photoshop are Images and Video. The attributes of images are Color, Shape, Background, Texture, Brightness, and Contrast; meanwhile, the attributes of videos are Length, Size, File Format, Timeline, Motion, and Layer. Each object may have several states. For instance, the states of images are Original, Editing, Undone, and Finished. The operations are used to change the states of objects. Concerning the Image object, there are operations such as Edit, Undo, Set color, Crop, and Purge. In order to conform to the contract, some rules are required to help users get a high-quality image and a good experience during the image processing.

4.4. Elements of the CAK model and their interrelationships

Figure 1 presents the elements of the CAK model and the corresponding knowledge components using the UML notation (Rumbaugh et al., 1999).

Firstly, a service consists of the service proposal, service consumption and service operation. Economic entities (know-who) can engage in a service such as service providers or service consumers. A service proposal is based on a contract (know-with) that indicates the resources must be assumed by corresponding entities. Secondly, a service consumption is allowed based on a service proposal. A consumer can consume the services at one or different locations (know-where) at different time frames (know-when). Lastly, a service operation supports the process of service consumption. A service operation can be performed by a set of operations (know-how) on a set of objects (know-what). To guarantee the quality of the services, a set of rules (know-why) is taken into account. The scope of a rule covers a subset of relative objects, and the influence of a rule may lead to failing points of certain operations.

In our approach, context information is a categorized context, represented by an ontology that depicts concepts and connections from concepts to the corresponding knowledge components.

5. Chatbot as a context-aware smart service for customer support

To illustrate and evaluate the proposed approach, the paper has used the multiple-case study approach in which several instrumental bounded cases are selected to develop a

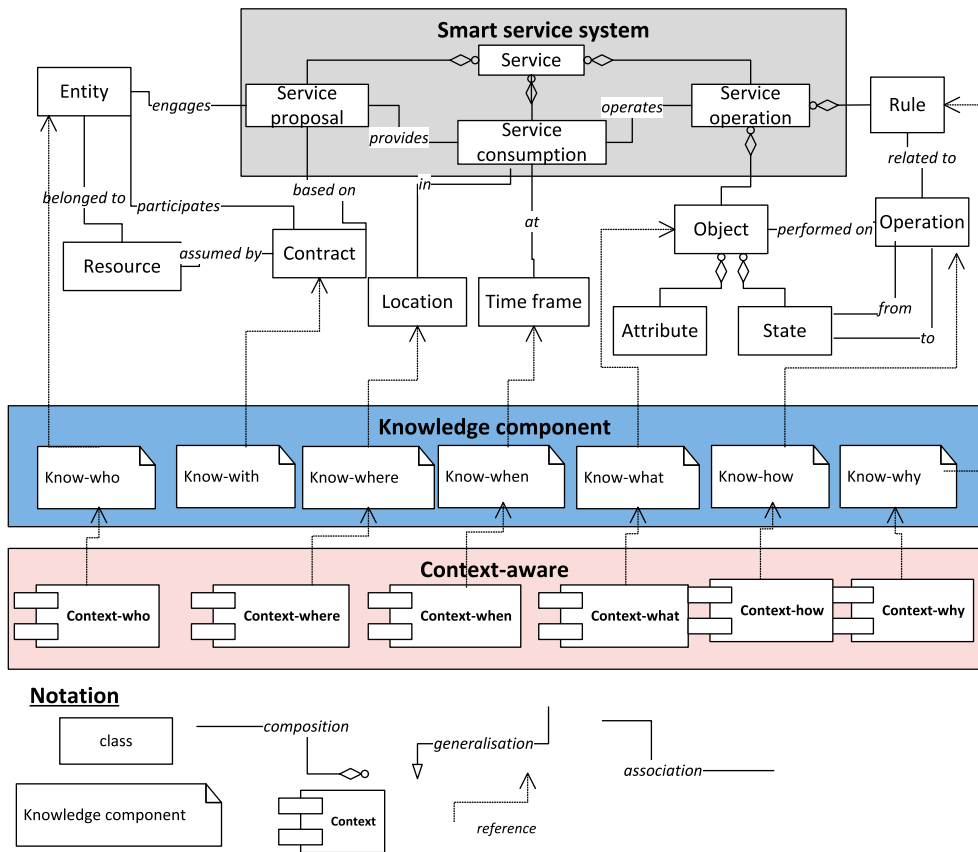


Figure 1. Elements of the CAK model and their interrelationships.

more in-depth understanding of the study. Adobot and Smabot, two case studies representing the instantiations of the CAK model, are presented as part of the applicability check. Both Adobot and Smabot have selected specific knowledge components of the CAK model that fit for their application domain and requirements.

In the case of Adobot, only the key knowledge components related to the customer support application are selected, including *know-what*, *know-how*, *know-where* and *know-when*, to support Photoshop’s users. In the case of Smabot, *know-what* (what, yes/no, what comparison), *know-how*, and *know-when* have been selected to build the knowledge base.

Concerning the service operation, both cases aim at building a chatbot-based interactive question-answering (QA) to provide technical support and to answer customers’ inquiries with the focus on what, yes/no, and how- questions.

Concerning the service consumption, the context information related to where and when are used to refine the responses by increasing the accuracy and quality when answering the users’ queries.

Concerning the service proposal, chatbots can be used as a new resource to provide customized services in order to improve customer experience and increase the customer

satisfaction. Moreover, the interaction between users and the service system can help to refine a knowledge base that can co-create more value for customer support services.

Finally, to demonstrate the proposed approach, which is an implementable solution, an ontology-based model is used for implementing the context-aware knowledge model, and the RASA framework (<https://rasa.com/>), an open-source conversational AI platform, is used for building the chatbots at the Service system and Service levels.

The following section presents the design of the chatbots at different levels of services as well as their implementation.

5.1. Chatbot design at the network of service systems level

Customers are always eager to get accurate and timely supports from companies when they encounter problems with products, especially complex products such as software products or smartphones. Therefore, most companies heavily invest in customer support services such as building websites showing product information, even assigning employees to answer online. It is also vital for e-commerce companies to improve such types of services to entice their customers into their sites. One of the effective solutions is to build chatbots for customer technical support as a key resource (Skianis, 2017). Consequently, companies can save training and operating costs for the customer care staff as well as meet customer expectations and increase customer satisfaction.

5.2. Chatbot design at the service system and service levels

At the Service system level, the implementation of the CAK model is required to support the combination of advanced chatbot technologies and the representation of context and contextual knowledge. In particular, to validate and experiment with these chatbots in practice, a knowledge model is built from the questions (context) and answers (contextual knowledge components) related to Adobe Photoshop software and Smartphone sites. The abundant data obtained by these sources facilitates the construction of a contextual knowledge base that reflects the operations in Photoshop for Adobot (Dulceanuy et al., 2018; Le Dinh et al., 2020) and in smartphone shops for Smabot (Truc et al., 2020).

In these knowledge bases, the *know-what* component represents the definition of objects that users want to ask about: (i) In the Adobot case: 'What is the recoding tool in CS6?' or 'What is the background layer?', and (ii) In the smartphone shops case: 'What is the price of iPhone 11?', 'Is the iPhone 11 waterproof?' or 'Can I unlock Samsung Galaxy A01 with fingerprint?'. These questions correspond to the context of what that associates to a *know-what* component, which is the answer of the questions.

Meanwhile, the *know-how* component represents the answer to the questions that users ask about operations, such as 'How to paint 3D images?' or 'Yesterday, I opened my Photoshop to use the paint 3D image, but it did not work' or 'How can I replace the battery of iPhone 8?'. These questions correspond to the context of how.

The *know-when* component represents the timeframe and version (as its enhanced concept, such as CS5, CS6), the *know-where* component describes the location (e.g. shops, stores, etc.) and environment (e.g. Window, Mac OS, Ubuntu, etc.). Table 6 presents some knowledge components in Adobot and Smabot cases at the Service level.

Table 6. Knowledge components of chatbots at the Service level.

Concept	Knowledge component	Examples
Object	Know-what	<ul style="list-style-type: none"> • Smabot: smartphones like iPhone 11, Samsung Galaxy A32, etc. • Adobot: Adobe Acrobat, images, documents
Attribute		<ul style="list-style-type: none"> • Smabot: attributes of smartphones such as price, battery, screen, camera, keyboard, etc. • Adobot: image attributes such as background color, layer
State		<ul style="list-style-type: none"> • Smabot: Smartphone devices: Brand new, Sold, Repaired, In Stock, Out Stock • Adobot: Image in editing process: original, editing, finished states
Operation	Know-how	<ul style="list-style-type: none"> • Smabot: make the keyboard bigger in Samsung A32; replace the battery of an iPhone 8 • Adobot: change the background color; install Photoshop

To construct the knowledge bases, all the questions are collected from websites then manually analyzed and classified into what – and how-questions, in which the content explaining a definition of a software product / smartphone, or a property and value / state of a product / smartphone is classified into *know-what* component; and the content guiding the operations is classified into *know-how* component.

5.3. Chatbot implementation

The ontology-based contextual knowledge as presented above plays an important role in the architecture of the chatbots, which includes the CAK based ontology, the NLP (Natural Language Processing) and GUI (Graphical User Interface) components. Figure 2 presents the overall architecture of Adobot.

Concretely, for each user’s message, the chatbots perform the user message analysis, including user intent classification, and then query parameter extraction. Based on this information, the system interacts with the ontology to respond to the user. The architecture of the chatbots presented in Figure 2 also demonstrates how the chatbots’ components combine with each other to deal with user messages. Firstly, the *NLP component*, which is based on the open-source Rasa NLU for creating a conversational agent (Bocklisch et al., 2017), receives a user message. Then, the user intent and the context information are identified and stored. This information is processed to decide which next action is called. If the chatbots cannot fully extract the required information, the system responds to the user by asking for additional information via the GUI component. Otherwise, it sends via APIs all the context information to the Ontology component to query and give feedback.

The *CAK based ontology* presented in Figure 3 includes three sub-models: (i) *Domain section* represents the knowledge related to the service proposal such as the Photoshop product of the Adobe company or smartphone; (ii) *Context section* represents the knowledge related to the service consumption, which can be a shop location, a version, an environment, or an agent, etc. There are two context types such as ‘Context-When’ related to the time, version (CS6, CS5) and ‘Context-Where’ related to location, environment (Window, Mac OS, Ubuntu, etc.); and (iii) *Knowledge section* represents the knowledge related to the service operation such as know-what and know-how.

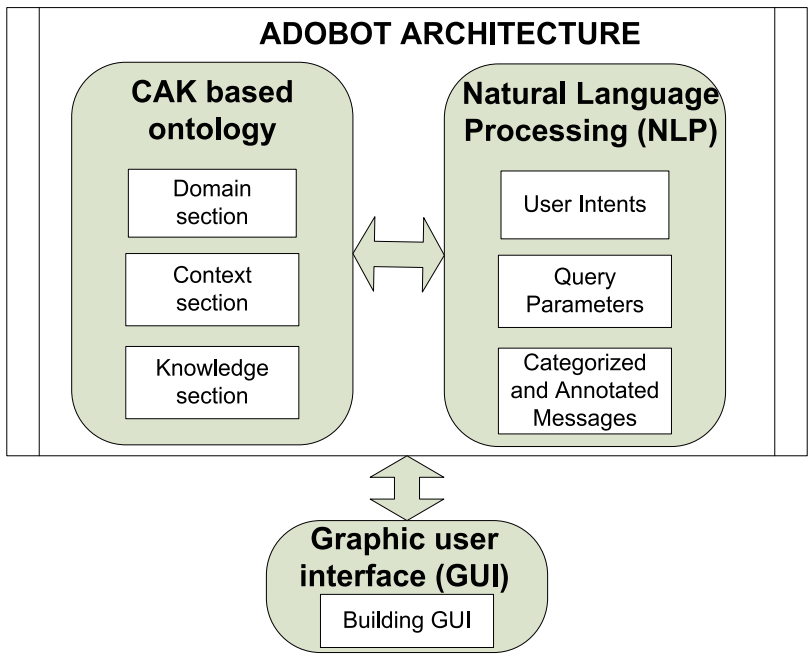


Figure 2. Architecture of Adobot.

Concerning the knowledge bases, models for user intent classification and query parameter extraction are learned from the categorized and annotated messages, called the training corpus. The training corpus is formed from 3000 questions collected from the Photoshop’s forum (<https://forums.adobe.com/community/photoshop>) in the case of Adobot and 2600 questions collected from smartphone e-commerce sites (such as thegioididong.com, FPT.com.vn, and cellphones.com.vn) in the case of Smabot. The user

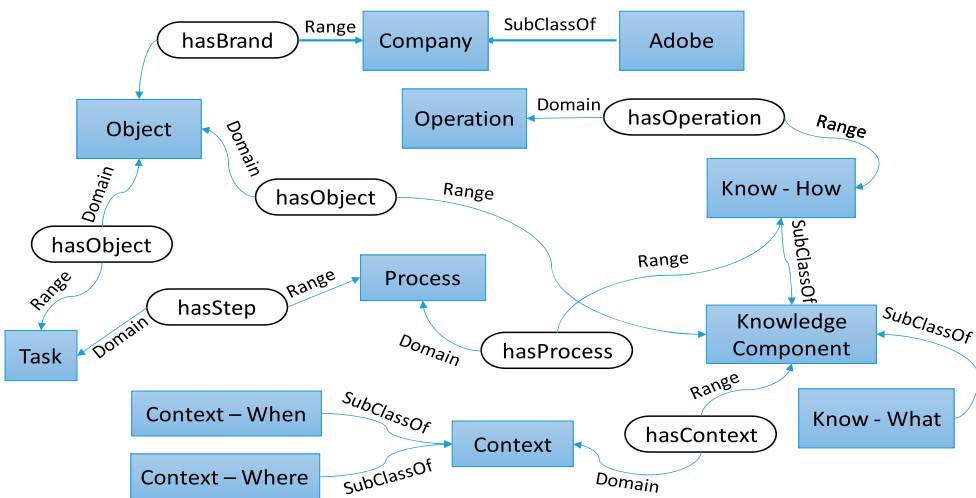


Figure 3. Snapshot of ontology representing the knowledge-based model in Adobot.

intent classification is performed by a supervised embedding algorithm (Wu et al., 2018) while query parameter extraction (including context information) is performed by *NER_spacy* (³<https://spacy.io/usage/training#ner>), an open-source library for named entity recognition.

6. Evaluation

According to Peffers et al. (2012), there are different evaluation methods for design science research evaluation such as Logical argument, Expert evaluation, Technical experiment, Subject-based Experiment, Action research, Prototype, Case study and Illustrative scenario. In order to evaluate our proposed artefact – the CAK model, we use Logical argument, Case study and Technical experiment evaluation methods. Using Logical argument method, we compare our approach with other relevant approaches at the conceptual level. Using the Case study method, we have implemented the CAK model in two chatbots Adobot and Smabot as presented in Section 5 and measured the user satisfaction level of the chatbots. Obviously, analyzing user messages and understanding user intention play an important role in the effectiveness of chatbots, therefore we also conduct an experiment to evaluate the machine learning algorithms used in chatbots.

6.1. Logical argument

A logical argument is an argument with the validity of the proposed constructs (Peffers et al., 2012). As mentioned above, most of the context-aware systems and approaches found in the literature are related to pervasive computing or ubiquitous computing applications. Context data come from various sources and have different context representation, and most of the approaches have context knowledge management. Table 7 presents the comparison of the CAK approach and other context-aware approaches based on different knowledge components. In general, most of the approaches deal with the know-what (service), know-who (user), know-where (location) and know-when (time). This observation confirms the affirmation of Abowd et al. (1999) regarding the primary context that the questions of who, what, when, and where are often used to identify the contextual information.

In general, our approach is similar to the goal-based approach, which is based on the 5W1H context model, in which each context data is tagged or classified in one of the categories such as what, who, why, when, where and how. However, the goal-based approach has focused on the context of industrial services, whereas our approach focuses on business services. In addition, apart from context knowledge, our approach also allows developing the business service knowledge over the three levels of a service organization (network, service system and service). Moreover, the CAK approach proposes know-with, a new knowledge component that represents the business relationship between the stakeholders in a service value creation network to promote value co-creation.

Indeed, a context category associates with a suitable knowledge component at each level, which helps in reasoning and providing the relevant information or services against the context data captured. For example, in our Adobot case study, a question from users such as 'How to paint 3D images?' corresponds to 'How' contextual information. That contextual information associates with a 'How' knowledge component

Table 7. Comparison of the CAK approach and context-aware approaches.

Approach	Know-What	Know-How	Know-Why	Know-Where	Know-When	Know-Who	Know-With
CAK	*	*	*	*	*	*	*
User-based	*			*	*	*	
Sensor data based	*			*	*	*	
User situation based	*			*	*	*	
Goal-based	*	*	*	*	*	*	
Location-based	*			*		*	
User location based	*			*	*	*	

stored in the knowledge base – which is the answer of the question provided to users. Compared with the goal-based approach (Kim et al., 2012), our proposed approach proposes the following advantages: (i) It can cover various context environments; therefore, it can be used to determine the unified context that describes context-aware information without dependence on the purpose of any service; (ii) It shows the relationship between contexts thanks to its related concepts in the knowledge model that allows further exploitation and a better understanding of user contexts; (iii) Keeping context information in a knowledge repository helps to conduct further analysis for improving service quality and user satisfaction.

6.2. Case study

The case study evaluation method aims at applying the artifact to a real-world situation (Peffer et al., 2012). In our case, two chatbots Adobot and Smabot have been developed applying the CAK model. To evaluate the effectiveness in using the model in real-world situation, our study has selected two measures to evaluate a chatbot, which are User service quality on dialogue and User satisfaction (Morgan et al., 2018; Shawar & Atwell, 2007).

User service quality on dialogue. For Adobot, we conduct the experiment on 11 users, including 4 new users (who have never used Photoshop), 4 occasional users (who have used Photoshop less than a year), and 3 experienced users (who have used Photoshop more than a year). For Smabot, we experiment on 17 regular users, who are all required a basic knowledge about smartphones. The purpose of the survey is to get comprehensive reviews of the approach through the diversity of participants, how they can understand the responses of the chatbots and how relevant the answers can fit to the context of users. In both cases, we guide them on how to use chatbots and clarify the types of questions that chatbots can support. After the survey, we collected the feedback from all 28 participants at three levels of the dialogue quality: (i) *Reasonable*: the answer is suitable for the question, and users can understand it; (ii) *Weird but understandable*: It is not very good but users can understand the answer; and (iii) *Nonsensical reply*: users think that the answer is not relevant to the question.

Figure 4 (a) shows the results of the survey on the dialogue quality from 28 users. It shows that more than 96% of users can understand the answers, in which 64% of them found the answers totally matched their expectation. Only 4% provide negative feedbacks that the answers are not relevant to their questions.

User satisfaction. We give five criteria to evaluate users' satisfaction, and the survey is rated on a scale of 1–5. This study specifically measures the form of using the chatbot, the

relevance of the answers (e.g. how users find the right answer when using the chatbot), the ease of use (i.e. whether the chatbots are easy to use), the chatbot interface, and finally the satisfaction level after using the chatbot.

Figure 4(b) presents the results of a small-scale experiment indicating that the chatbots using the context-aware knowledge base basically satisfies the user needs. We also found that the satisfaction depends on some other factors such as the nature of language used in chatbots, the interface, and the response scenario (i.e. sequence of answers). However, in general users are happy with the service as most of them rank this service above average, at levels 4 and 5 (68%), some of them rate as average (25%), and only a few give below average (7%).

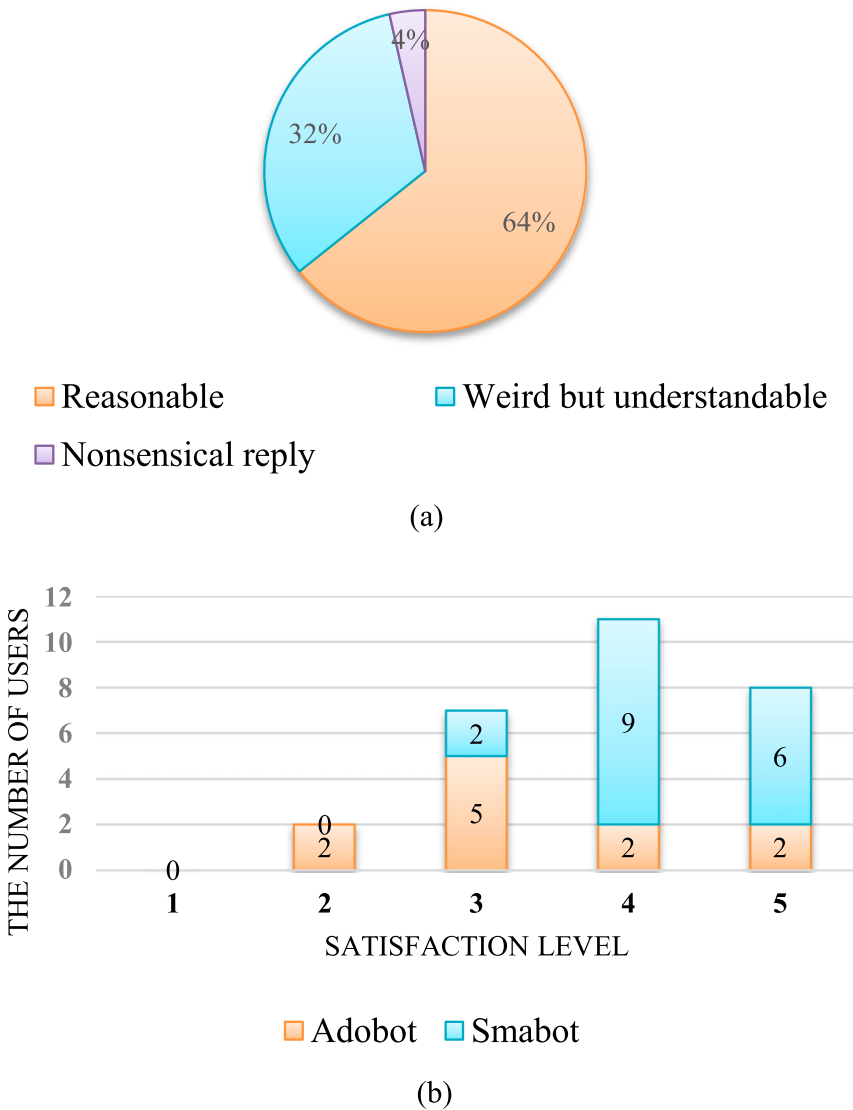


Figure 4. Charts of user’s assessment of the dialogue quality and of user satisfaction. (a) The dialogue quality from 28 users (b) The satisfaction from 28 users.

Table 8. Measurement of user message understanding of the algorithms used.

Chatbot	Algorithm	Precision	Recall	F1-Score
Adobot	Supervised Embedding	96.35%	94.5%	94.6%
	Ner_spacy	84.31%	87.77%	86.01%
Smabot	Supervised Embedding	95.6%	94.6%	93.9%
	Ner_spacy	77.9%	76.7%	76.1%

6.3. Technical experiment

The case study evaluation method aims at carrying out the performance evaluation of an algorithm implementation using real-world data designed to evaluate the technical performance (Peffer et al., 2012). In this study, the experiment evaluates the algorithms used for intent classification and parameter extraction of the user messages in the chatbots.

For the intent classification (ask_what, ask_how), we use 1,411 messages for training and 196 messages for testing. For the query parameter extraction (Object, Operation, Context), we use 1,437 messages for training and 195 messages for testing. All of them are collected from the Photoshop forum for our ontology construction.

The efficiency of the supervised embedding (for intent classification) and NER_spacy (for parameter extraction) is achieved through the F1-score measure. Specifically, the F1-score is a combination of two measures, precision and recall, as follows:

$$Precision = \frac{TP_i}{TP_i + FP_i}; Recall = \frac{TP_i}{TP_i + FN_i}; F1_score = 2 \cdot \frac{Precision \cdot Recall}{Precision + Recall}$$

where TP_i is the number of the items correctly predicted class i ; FP_i is the number of the items incorrectly predicted class i ; and FN_i is the number of items of class i mistakenly predicted other classes. The experimental F1-score results are shown in Table 8. The result shows that for the intent classification, Adobot and Smatbot achieve an F1-score of 94.6% and 93.9% with Supervised Embedding, respectively. Ner_spacy gives the F1-score of the query parameter extraction of 86.01% in Adobot and 76.1% in Smabot. These results show that Adobot and Smabot are quite competitive with some recently published chatbots such as Nigam et al. (2019) with F1-score of 77.63% for intent classification and 82.24% for query parameter extraction; Nguyen and Shcherbakov (2021) with F1-score of 86.3% for intent classification and 81.5% for query parameter extraction; Morgan et al. (2018) with F1-score of 98% for intent classification; and Ruf et al. (2020) with F1-score of 87% for query parameter extraction.

7. Conclusion

This paper proposes a knowledge model for context-aware smart service systems based on the knowledge components, called the CAK (Context-Aware Knowledge) model. The CAK model can capture all the information and knowledge related to context-aware smart services and their environment to provide the right information in the right circumstances to the right person. The proposed model is being tested and experimented with the chatbot applications as context-aware smart services for customer support centers. The CAK model can also integrate all the information and knowledge related to smart services, knowledge components and context awareness that can play a key role for any framework, infrastructure, or applications for deploying context-aware smart services.

Concerning the implications of our work in practice, the proposed knowledge model can be extended and adapted for different types of context-aware smart services, especially knowledge-intensive services so that knowledge about services can be linked and used based on corresponding user-centric contexts in order to implement effectively and efficiently context-aware smart services. Concerning the implications for research, this approach needs to be validated and experimented on a broader scale. Moreover, our future research aims at enhancing the approach for more complicated and elaborated context-aware smart services, as well as at integrating the knowledge model with current artificial intelligence techniques such as deep learning and reinforcement learning to create new contextual knowledge based on existing knowledge bases.

Concerning the future work direction, it is foreseen that the new concepts related to the context representation should be extended to support the context recognizing and knowledge reasoning, especially in the context of business services relative to real time big data analytics (Dam et al., 2021). Furthermore, rapid advances in information and communication technology, especially artificial intelligence, big data, and the Internet of Things, allow designing novel information systems that are able to enable the new configuration of smart service systems and their business ecosystems (Beverungen et al., 2017). Consequently, we intend to study novel information systems, which can interoperate on different levels of service systems as well as different smart service systems. This research direction is emerging as multidisciplinary research, which enhances our previous frameworks related to the interoperability of information systems (Le Dinh & Nguyen-Ngoc, 2010), the design of a value creation network (Le Dinh & Leonard, 2009), and the information system upon information systems (Le Dinh, 2004).

Note

1. dictionary.cambridge.org.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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