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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 a context-aware knowledge model for smart service systems that 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 context-aware knowledge model for 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. To demonstrate the approach, a case study about a chatbot as a smart service for customer support is presented.

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 that enables 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). Therefore, to smart services,

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the service context plays a key role that influences the service behaviors. From another perspective, smart services are considered as suitable knowledge provided to consumers and smart objects based on their circumstances. 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).

Therefore, the paper presents an approach based on a context-aware knowledge model for smart service systems. This approach aims at organizing the domain and context-aware knowledge of smart service systems into knowledge components based on the three levels of services: Services, Service system and Network of service systems (Le Dinh and Pham Thi 2012). The context-aware knowledge model for 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 for deploying smart services.

The rest of the paper is organized as follows. Section 2 provides the background of contexts, service systems, and smart service systems. Section 3 proposes a context-aware knowledge model for smart service systems. Section 4 illustrates our proposed approach with a specific case of smart services for a software support center. Section 5 provides some conclusions and future research work.

2 Background

2.1 Context-Aware Systems

Context. "Context" is defined as "the situation within which something exists or happens, and that can help explain it" in Cambridge dictionary. In the computing 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 such as computing context, physical context, time context, and user context (Chen and Kotz 2000). In the context of smart services, 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.

Context-Aware Systems. A system is context-aware if it uses context to provide relevant information and/or services to the user, where 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.

2.2 Services, Service System and Network of Service Systems

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 and Vargo 2008). Services include all economic activities in which individuals, organizations and technologies work together, apply specialized competences and capabilities to co-create business value.

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 have been used to generate information and automate business operations to create more value for customers.

Network of Service Systems. Besides, 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 (Lusch et al. 2008; Le Dinh and Léonard 2009).

2.3 Smart Service and Smart Service Systems

Smart Services. Services delivered to or through intelligent products that feature awareness and connectivity are called "smart services" (Lim and 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).

Smart Service Systems (SSS). 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). Furthermore, 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 means people have easy access to information about a particular service system, as well as others that interact with it. Intelligent means recommendation algorithms that work to provide stakeholders 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 and Maglio 2018).

Indeed, the field of smart service systems is still an emerging field that covers different research topics (Lim and Maglio 2018). One of the most important topics is how to "design of smart service systems" which addresses knowledge for the design of these systems, including design model, approach, and process. For this reason, this paper addresses this challenge and presents a context-aware knowledge model for designing and building a smart service system in the following sections.

3 CAK Model for Smart Service Systems

3.1 Research Design

3.1.1 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 (CAK) model, called CAK model, which can be used to design and build context-aware smart service systems. Indeed, a smart service system (SSS) must be capable of learning, dynamic adaptation, and decision-making. Therefore, a SSS 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 study.

3.1.2 Definition of a Context

After reviewing the relevant thematic and methodological literature (Le Dinh et al. 2014), the paper considers a context is all the formation 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).*

3.1.3 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 and 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. 2015) at different levels of services (Table 1).

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

Table 1. Knowledge components of the CAK model.

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

cocreation. 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.

3.2 Context-Aware Knowledge Model

3.2.1 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 co-produce common results (Le Dinh and 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 (John-son 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 and Pham Thi 2012). **Know-with** is the relational knowledge that concerns with the knowledge in 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 and Pham Thi 2012).

In the CAK model, know-who is represented by *Entity*; meanwhile, know-with is represented by *Contract*. Table 2 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 smart software support service. The Adobe Photoshop had been chosen to develop the service based on its popularity and available resources. A service is required and begun when

Table 2. 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)

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 Adobe partners are the service provider. This service disposes of some different resources such as the software itself, documentations, 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 provider.

3.2.2 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 in 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 will take 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 3 presents the concepts of the CAK model at the Service system level.

Table 3. 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

Regarding our example, in order to use the Image processing tool, the user needs to access the Adobe Photo link and sign in. The tool is available for 24/7. In relation to the help center and the 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.

3.2.3 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 and 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 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 4 presents the concepts of the CAK model at the Service level.

Table 4. 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

Some concepts related to the service operation in our example can be 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, Edited, 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. To conform to the contract, some rules are required to help users getting a high-quality image and good experience during the image processing.

3.2.4 Elements of the CAK Model and Their Interrelationships

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

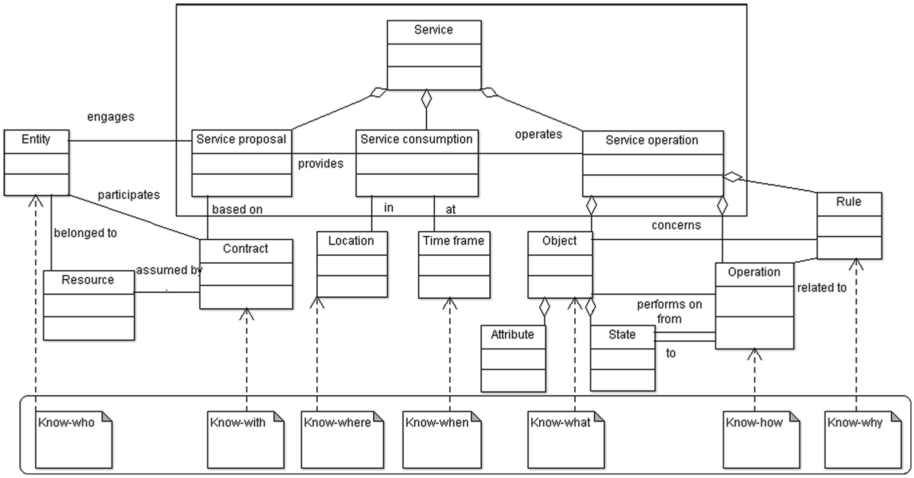

Fig. 1. Elements of the CAK model and their interrelationships

Firstly, a service consists of service proposals, service consumption and service operations. Economic entities (know-who) can engage in a service such as service provider 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 a service consumption. A service operation can be performed 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) are taken into account. The scope of a rule covers a subset of relative objects, and the influence of a rule may lead to fail points of certain operations.

4 Chatbot as a Smart Service for Customer Support

To illustrate and evaluate the approach, a smart service for customer support based on the CAK model, called *Adobot*, is proposed as part of the applicability check. The paper continues to use the Adobe Photoshop software to demonstrate the implementation of the approach. This case study has selected the specific knowledge components of the CAK model that fit to its application domain and requirements for the time being.

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.

Concerning the service operation, Adobot aims at building a chatbot-based interactive question-answering (QA) to provide the technical support with the focus on what – and how- questions. Concerning the service consumption, the context information related to know-where and know-when are used to refine the responses by increasing the accuracy and quality when answering the users' queries. Concerning the service proposal, the chatbot can be used as a new resource to provide customized services in order to increase the customer satisfaction. Moreover, the interaction between users and the service system can help to build a knowledge base that can co-create more value for customer support services. Finally, to demonstrate the implementability of the approach, an ontology-based model is used for implementing the context-aware knowledge model, and the RASA framework[1] is used for building the Adobot at the Service system and Service levels.

4.1 Adobot at the Network of Service Systems Level

Customers are always eager to get accurate and timely supports from companies when they encounter problems on products, especially complex products such as software products. Therefore, most software companies heavily invest in customer support services such as building websites showing product information, even assigning employees to answer online. 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 customer care staff as well as meet customer expectations and increase customer satisfaction.

4.2 Adobot at the Service System Level

At the Service system level, the implementation of the CAK model in this case is based on a combination of ontologies for the representation of contextual knowledge and advanced chatbot technologies. In particular, to validate and experiment this chatbot in practice, the knowledge model is built from the questions and answers related to Adobe Photoshop software. The abundant data obtained by the Photoshop's forum facilitates the construction of a contextual knowledge base that reflects the operations in Photoshop (Dulceanuy et al. 2018). In this knowledge base, the *know-what* component represents the definition of objects that users want to ask about, such as "What is the recoding tool in CS6?" or "What is the back ground layer?". Thus, the *know-how* component represents 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 doesn't work?". The *know-when* component represents the time frame and version (as its enhanced concept, such as CS5, CS6); meanwhile, the *know-where* component describes the context for location and environment (e.g. Window, Mac OS, Ubuntu, etc.).

To construct the knowledge base, the questions related to Photoshop are manually analyzed and then classified into 557 what- and 1,334 how-questions, in which the content explaining about a definition of objects is classified into *know-what* component; and the content guiding the operations is classified into *know-how* component.

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[1] https://rasa.com/.

4.3 Adobot at the Service Level

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

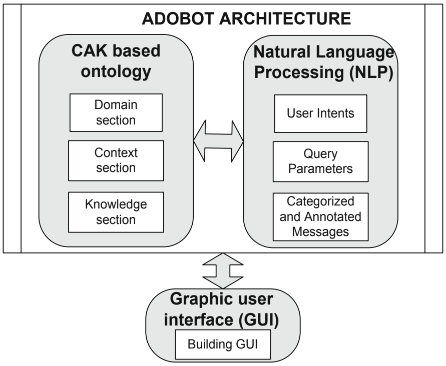

Fig. 2. Architecture of adobot

The CAK based ontology includes three sections: i) *Domain section* represents the knowledge related to the service proposal such as the Photoshop product of the Adobe company; ii) *Context section* represents the knowledge related to the service consumption, which can be 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.

Concretely, for each user’s message, the Adobot performs 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. A process view of Adobot presented in the Fig. 2 demonstrates how Adobot components combine with each other to deal with user messages. Firstly, the NLP component based on Rasa NLU 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 Adobot cannot fully extract the required information, the system responds to the user by asking additional information via the GUI component. Otherwise, it sends via APIs all the context information to the Ontology component to query and give feedback.

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 by 3,000 questions collected from the Photoshop’s forum. The user intent classification is performed by supervised embedding (Wu et al. 2018) while query parameter extraction (including context information) is performed by ner_spacy[2] (Luong et al. 2020).

[2] https://spacy.io/usage/training#ner.

5 Conclusion

This paper proposes an approach for context-aware knowledge model for smart service systems based on the knowledge components. We believe that the proposed knowledge model can capture all the information and knowledge related to smart services and their environment to provide the right information in the right circumstances for a right person. The proposed model is being tested and experimented in a chatbot application as a smart service for a customer support center.

Compared with the similar approach, such as the 5W1H context (Kim and Son 2012), our proposed approach disposes 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 purpose of any service; ii) It shows the relationship between contexts thanks to its related concepts in the knowledge model that allows to further exploitation and better understanding of user contexts; iii) By keeping context information in a knowledge repository, it helps to further analysis for better service quality and improving user satisfaction.

Concerning the implications of our work in practice, the proposed knowledge model can be extended and adapted for different types of 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 efficiency smart services. Concerning the implications for research, this approach needs to be validated and experimented on a broader scale. Moreover, our future researches aim at enhancing the approach for complicated and more elaborate smart services, as well as at integrating the knowledge model with current artificial intelligence techniques such as deep learning and reinforcement learning.

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