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ORIGINAL ARTICLE

Identifying and structuring service functions of mobile applications in Google's Android Market

Yongyoon Suh[1] · **Yongtae Park**[2]

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Abstract Recently, mobile applications are considered one of the most opportune issues in mobile industry since the explosive growth of mobile applications has generated the myriad of service functions. In response, it is needed to extract useful information on dominant service functions and structural relationship among the service functions. However, there have been few methods for encapsulating information on major service functions and their relationships. Thus, this study aims at identifying dominant service functions and their structural relationships of mobile applications in Google's Android Market using frequent pattern (FP)-tree algorithm which retrieves and summarizes frequently used items according to association rules. In this study, the FP-tree algorithm is used for extracting information on service functions in terms of three factors: frequency, association, and hierarchical structure. Using the information of service function tree, the developers refer the systematic and mash-up combinations of service functions to design new mobile applications.

Keywords Service functions · Mobile applications · FP-tree algorithm · Mobile applications development · Android Market

✉ Yongtae Park
parkyt1@snu.ac.kr

Yongyoon Suh
ysuh@pknu.ac.kr

[1] Department of Safety Engineering, Pukyong National University, 45 Yongso-ro, Nam-gu, Busan, Republic of Korea

[2] Department of Industrial Engineering, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 08826, Republic of Korea

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1 Introduction

The mobile industry has held the attention of the research community over the past decade. It is now undergoing a tremendous transformation facilitated by advances in mobile computing. The mobile industry that can use mobile technology is one of the fastest developing industries in terms of the degree and nature of technology dynamism (Cai 2011; Yun et al. 2016; Suh and Lee 2017). The mobile industry is expanding the other industries such as vehicle industry and health industry by converging mobile IT. Technology innovations in hardware and software related to telecommunications have strengthened the capabilities of mobile products and services (Yu 2011; Giachetti and Marchi 2017).

In this situation, a newly major source, mobile applications delivering new service functions, has burst onto the mobile industry scene (Suh et al. 2012). The mobile service industry has rapidly emerged with the arrival of mobile services using the smartphone and its application platform, such as the iPhone and iOS (Holzer and Ondrus 2011; Wang et al. 2016). In fact, mobile applications have proliferated since the launch of new electronic markets, mobile applications markets. For example, in electronic markets in mobile applications, there are more than three million applications in Apple's "App Store" and more than two million applications in Google's "Play". The explosive growth of mobile applications is taking place in the booming space of various service fields such as communications, education, health care, and entertainment (Kim et al. 2014). The application economy contributes the job creation and increase of service production and electronic market size. The Google's Android Market passed 50 billion app downloads and featured over 1 million apps available and Apple reached 75 billion app downloads and features 1.2 million apps in the iTunes Store. By 2017, over 268 billion of mobile applications will be downloaded and 77 billion dollars in revenue is predicted (Gartner 2014). Also, it is reported that the market size of mobile applications is projected to 188.9 billion dollars (Statista 2017).

Thus, mobile applications are currently having an increased impact on the continuance of ongoing economic growth (Ghose and Han 2014). It is especially true that mobile applications and their electronic markets are emerging as one of the primary sources intervening in the value chain of converging mobile service industries (Feijoo et al. 2008). With the substantial growth in the number of mobile applications, a variety of service functions have been also generated in various service fields (Laudon and Traver 2010; Corley et al. 2013). The numerous service functions in mobile applications are being highlighted as an opportune issue for increasing the added value and availability of services in the now-converging mobile industries. The service functions in mobile applications are defined as a function of the useful activities provided by a service through mobile applications installed in smartphones. For example, if we need path finding services in the city, the service function in mobile applications is to provide navigation, map, and GPS. The various types of service functions offer ample commercial opportunities using advance mobile technology (Hsu and Lin 2015). The mobile application services include useful information for disruptive technology of smartphone such as GPS, voice recognition technology, and data communications technology. Using this technology, many users or developers have tried to extend mobile business sectors based on mobile applications for a variety of service functions such as applications for banking services, tourism reservation services, and path finding services (Noh and Lee 2016). Further, the new types of service functions are recently developed for realistic media service market such as virtual reality (VR) and augmented reality (AR). Put together, the service functions in mobile applications are emerging as viable potential sources of business and technology knowledge (Reuver et al. 2009; Gretzel et al. 2015). As more converging industries experience this, more service functions for mobile applications will be generated. Thus, service functions should be recognized as a critical resource in the current service economy, particularly in converging mobile service industries.

Although service functions of mobile applications are being highlighted in practice, there remains a lack of interest of this in academia yet. Previous research has mainly been in the form of qualitative studies of the relevance and importance of mobile applications (Nagi and Gunasekaran 2007; West and Mace 2010). These types of studies focus more on investigations of the potential usefulness of mobile applications rather than on the identification of the service functions of mobile applications. In these qualitative approaches, the speculation over the value of service functions in mobile applications is rife with descriptive arguments. Instead, service functions per se recently find more important issues in practice because mobile applications have provided service functions related to a multitude of other service industries. In this vein, several pioneering approaches to analyzing mobile applications have been proposed using network analysis and data-mining techniques (Kim and Lee 2012; Kim et al. 2014). However, there are few methods which capture information about the major service functions in mobile applications and their relationships. Previous studies focusing on the mobile applications themselves have major limitations in their ability to analyze the specific service functions in mobile applications. Therefore, a technical method is required to identify the structure of the service functions implemented in mobile applications.

For this, this study aims to identify the structure of service functions in mobile applications using the frequent pattern-tree (FP-tree) algorithm. Prior to the outset of the application of the research methodology, the following research questions should be stated to examine the need for identifying the structure of the service functions in mobile applications:

- Which service functions are frequently and dominantly used?
- Which service functions are provided together and related to each other?

The first question is to identify the service trends, as frequently used service functions tend to set a general trend (Lin 2009; Hu and Yeh 2014). Among numerous specific service functions of many mobile applications, some of them are frequently used as essential and basic service functions while others are used mainly as specific service functions. In fact, most mobile applications have frequently improved or added specific service functions based on previously developed mobile applications. Thus, frequently used service functions are critical in an effort to realize the trends or characteristics of mobile applications. The second question attempts to take into account the degree of the functional combination of services. Because mobile applications are used as an integrated platform for implementing a variety of service functions, the relationships between service functions are important when seeking to understanding the structure of the set of service functions (Suh et al. 2012; Kim et al. 2014). This representation of the current structure of the service functions will enable service developers to add new service functions and to extend related service functions as service platforms.

To address the questions above, amongst others, FP-tree algorithm is used in this study because our research focuses specifically on three interesting factors of the FP-tree algorithm: frequencies and associations, as based on its hierarchical structure. In other words, using the FP-tree algorithm, the relationships between the service functions are hierarchically structured according to association rules in the order of frequency. In terms of these characteristics, the proposed analysis is composed of two analysis modules: frequency-based analysis and association-based analysis. These analysis modules are used to answer the two questions above. First, regarding the frequency-based analysis, the service functions are identified as either dominant or auxiliary service functions in terms of their frequency. Second, for the association-based analysis, the relationships between the service functions are constructed in terms of association paths. By counting the numbers of converging and diverging association paths, the degrees of the relationships between each service function can be measured.

These FP-tree algorithm-based analysis modules will contribute to the analysis of the trends pertaining to (1) the frequently used service functions, (2) the relationships between service functions, and to our gaining of (3) a holistic view of the hierarchical structure of these service functions. The results of the two modules are used to propose newly analytic forms for finding frequently used service functions and identifying the relationships among these service functions.

2 Emergence of mobile applications and markets

The market of mobile applications is emerging in electronic markets as a new mainstream through the smartphone innovation. Since the mobile applications through smartphones was firstly introduced and developed by Apple Corporation, it brings a huge impact on both manufacturing and service industries. The consumers select the smartphones by considering how many mobile applications are delivered by each application markets such as Android and Apple application stores. In this respect, mobile applications have been started to have interest in both areas of academia and practice during this decade (Deng et al. 2010; Turban et al. 2004). As various service functions have been being delivered through numerous mobile applications, the importance of the mobile application per se is increasing. In fact, numerous mobile applications are being launched in electronic markets such as Google's Android Market "Play" and Apple's Market "App Store". Here, many categories of applications are introduced and each category means a service area such as social networking, entertainment, business and finance, games, travel, and utilities. At present, it is difficult to find people who do not use the mobile applications in their own life. The mobile applications become the inevitable source in new "smart" economy.

In this respect, a new mainstream of mobile applications has arisen in technology and business fields for electronic markets. First, the service functions in mobile applications include the technical and business information (Wang et al. 2016). The recent mobile technology in smartphone and telecommunications is derived from the application information such as gyroscope sensor or fingerprint scanning (Giachetti and Marchi 2017). Also, we can identify the telecommunication specification such as radio antenna, Bluetooth, and near field communication (NFC). Nowadays, the payment technology such as magnetic secure transmission in *Samsung Pay* is also explored in service functions. The advanced mobile information technology is integrated in smartphones and its service functions are implemented through the mobile applications. Recently, we can take a look at many mobile services in mobile application markets since the mobile applications are developed very fast and the lifecycle is very short as well. The opportunities to use these service functions are obtained for convenience and enjoy of our real life.

The development process of mobile applications is significantly different from the traditional process of product development. Conventionally, a product is developed with well-structured product information, from the ideation stage to the production ramp-up stage (Ulrich and Eppinger 2003). Information pertaining to materials, processes, functions, and designs is documented and summarized in detail. In particular, the product function and specifications are designed and refined using various methodologies. Through this design process, the product function is suitably developed over a long period of time, from idea discovery to the market. We can also find this product function and related specifications by examining patents or user manuals.

In contrast, the distinctive characteristics related to the development of mobile applications as compared to product development can be described as follows (Laudon and Traver 2010; Danado et al. 2010):

- User-generated services: users are able easily to implement the service functions in mobile applications by themselves using open-source or open-language programming.
- Gadget services: the cost of development is low and the development time is fast; thus, various service functions can be casually developed.

These are major differences from the characteristics of the product development process. Due to the rapid development and low cost in the mobile applications market, numerous developers have frequently and iteratively devised service functions in mobile applications. Mobile application services are incrementally improved with the addition of various service functions based on two characteristics above.

First, the service functions in mobile applications are more commonly user-generated using open sources and platforms (Laudon and Traver 2010). Users devise service functions and directly develop their required services. Numerous users as producers have frequently developed mobile services, and the number of mobile applications is rapidly increasing. Second, the service functions in mobile applications are similar to those of gadgets, which are akin to small machines and devices which do something useful. Mobile applications are usually used for solving specific problems, like a gadget. The service functions of mobile applications are not complicated; rather, they are simple and specific to various service areas, such as location services, call services, documentation services, and others, and are implemented using open source resources and coding techniques (Suh et al. 2012; Kim and Lee 2012). The difficulty in analyzing the service functions is that mobile services can readily be created without well-structured service information. From two characteristics, the problems can be summarized as two points: the large number of service functions and inferior structure of service information.

Unfortunately, it is difficult to understand the service functions such as technical functions or business contents in current mobile applications. Despite the interest in value of mobile applications, the structure of service function in mobile applications in terms of their main functions and characteristics is not commonly studied. Thus, it becomes inevitably necessary to monitor their current state of service functions so as to manage the mobile application markets because mobile applications become critical among a multitude of stakeholders such as manufacturers, service developers, and users.

3 Proposed approach

3.1 FP-tree algorithm

As a basic step to explore a trend, it is important to identify the frequency. Any items such as technology, product, and business is increasing when they are more powerful, successful, influential, or noticeable than other things. In addition, this trend makes relationships with other things to develop new or different things. Thus, the frequency and relationship is a basic measure for identifying the trends and uncovering new patterns. Amongst others, to identify frequency and relationships based on co-occurrence, the association rule mining (ARM) is a representative analysis technique due to the intrinsic characteristics of frequency and co-occurrence relationships. In the perspective of association rules, a variety of efficient algorithms for discovering frequent itemsets have been developed thus far. Above all, the *Apriori* algorithm is used to find frequent itemsets from market-basket datasets based on association rules, by adopting the generation-and-test paradigm, which generates all possible candidates (Agrawal and Srikant 1994). In this respect, the ARM is used to uncover the unknown relationships through the probability of relationships based on frequency of co-occurrence (Wu and Huang 2011). However, for long itemsets, the *Apriori* approach is associated with a lack of scalability due to the exponential increase in the algorithm's complexity (Shen et al. 1999; Tsay and Chiang 2005). Also, general ARM techniques could hardly represent the whole structure of relationships and it is difficult to prioritize the items in order of the frequency of an individual item because the ARM more focuses on the co-occurrence (Suchacka and Chodak 2016).

However, the FP-tree algorithm, which mines frequent itemsets through divide-and-conquer approach without the generation of candidates (Gopalan and Sucahyo 2004; Han et al. 2004), is introduced to prioritize the items in order of the frequency and effectively represent the structure of relationships through tree visualization. The FP-tree algorithm is a compact representation of the data which serves to arrange the keywords in the order of frequency without generating candidate patterns and scanning the database repeatedly (Han et al. 2004). It was recently found that the FP-tree algorithm is relevant to analyses of big data due to the speed of calculation. This algorithm encodes data sets using a compact data structure and extracts frequent itemsets directly from this structure. The pattern growth approach adopts a divide-and-conquer algorithm to produce frequent itemsets (Tan et al. 2006). Although the FP-tree algorithm still has the limitation of incremental mining to insert new data (Kotsiantis and Kanellopoulos 2006) and a memory problem on generating conditional FP-trees (Narvekar and Syed 2015), it is known that the efficiency of calculation outperforms the traditional *Apriori* algorithm of ARM. Conventionally, studies of the FP-tree algorithm have focused on efficiency and on the run time of the algorithm. However, recently practical areas have become a concern in relation to this FP-tree algorithm when used to identify frequent patterns or items in the areas of operations management or supply chain (Lin 2009). The application areas are extended due to simple algorithm and understandable presentation. Further, using the depth and width of structured tree, we can obtain insight for convergence and divergence patterns of items.

In this paper, the process of the FP-tree algorithm is simply described as follows (Tan et al. 2006; Suh et al. 2017) and as described in Fig. 1 [for more information, see the study of Han et al. (2004)]. The data input structure by transforming transaction representation into binary representation is modified to easily adapt coding structure based on previous study (Gopalan and Sucahyo 2004; Suh and Lee 2017).

- Step 1: Frequent items are sorted in a descending order. For example, for the data set shown in Fig. 1, *a*, *b*, *c* is the most frequent item, followed by *d*, and *e*.

ID	Items
1	[a, b]
2	[b, c, d]
3	[a, b, c, d]
4	[a, c, e]

ID	a	b	c	d	e
1	1	1	0	0	0
2	0	1	1	1	0
3	1	1	1	1	0
4	1	0	1	0	0
	3	3	3	2	1

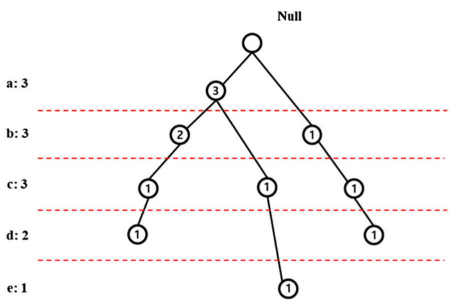

Fig. 1 Example of the FP-tree algorithm (modified from Suh and Lee 2017)

- Step 2: After reading the first ID, [*a*, *b*], the nodes labelled as *a* and *b* are drawn and a path is then created from null → *a* → *b* to encode the first ID. In this state, every node along the path has a frequency count of 1.
- Step 3: After reading the second ID, [*b*, *c*, *d*], a new set of nodes is made for items *b*, *c*, and *d*. The path is then formed from null → *b* → *c* → *d*. In this state, every node along the path has a frequency count of 1. However, for *b*, the paths are disjointed because the IDs do not share a common prefix.
- Step 4: The third ID, [*a*, *b*, *c, d*], has a common prefix of both *a* and *b*, with the first ID. The path for the third ID, null → *a* → *b* → *c* → *d*, overlaps with the path for the first ID, null → *a* → *b*. Owing to the shared path, the frequency of node *a* and *b* is increased to two, while the frequency for the new nodes, *c* and *d*, are equal to one.
- Step 5 and further steps: This process continues until all IDs have been formed onto one of the paths given in the FP-tree.

The code and number in the left side of FP-tree means the frequent item and its frequency of all IDs. On the other hand, the number in circle shows a frequency of each different path. In particular, this is noted that the context of *b* which has the 2 in a left node of a *b* layer can be different from the context of *b* which has the 1 in a right node of a *b* layer because there is no item *a*. Like this, we can deploy the items and understand the specific context according to frequency and associations.

3.2 Analytic procedure

The proposed approach is devoted to two issues: the construction of a database for service functions in mobile applications and the use of the FP-tree algorithm. First, as for the database, the service function is collected from the web documents in an application service store as shown in Fig. 2, such as Google's "Play" or Apple's "App Store." The pre-processing of these web documents is a very important task in the construction of the main database. Second, as pointed out before, the FP-tree algorithm is applied for analyzing frequent patterns of service functions based on the association rule and the divide-and-conquer structure.

In more detail, the FP-tree algorithm approach is proposed as shown in Fig. 3. First, the mobile service descriptions contained in web documents from the website of the Google's Android Market (known as Google Play, at play.google.com/store) were crawled. The reason why we select the Google's Android Market is to collect various applications data developed by many types of developers. In Apple's App Store, there is a high risk to collect similar applications because Apple has Apple's own voice recognition platform, *Siri*, which provides common set of functions. Also, availability to crawl data from the website automatically is one of the reasons we choose the Google's Android Market. Here, the mobile applications for voice (or speech) recognition services searched at December of 2014 were collected. The voice recognition has been recently proliferating through the smartphone. Previously, the voice recognition focused on more validating the accuracy of technology by distinguishing the difference of speech rather than providing various services. In fact, Google's speech API and Apple's Siri are basically installed in smartphones to

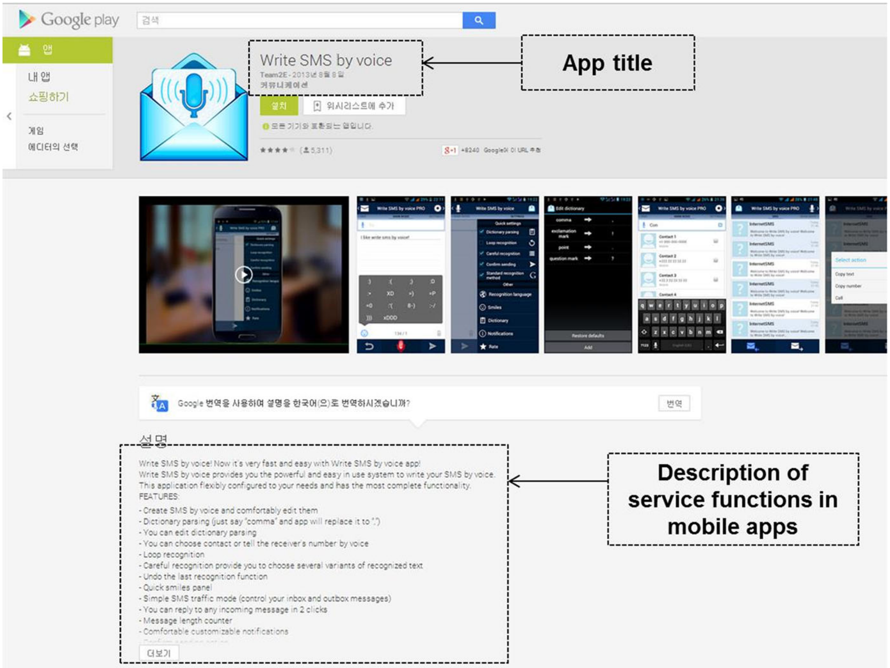

Fig. 2 Description of service functions in mobile applications (Google Play)

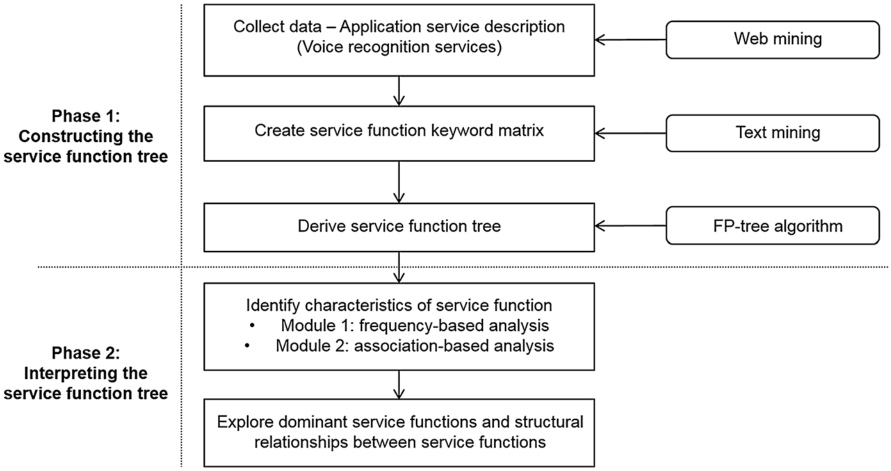

Fig. 3 Procedure for constructing service function tree

provide many voice recognition services such as intelligent personal assistance and internet search. Thus, it is more important for a service area of voice recognition to explore service functions in applications market as one of potential business market. In total, the contents of web documents of 124 mobile applications for voice recognition services were gathered. Second, keyword sets were extracted from the web documents using a text-mining algorithm. To construct the keyword vector matrix (as shown in Fig. 1), the keyword sets should be then transformed into keyword vectors. Third, based on the keyword vector matrix, the FP-tree algorithm is employed to construct the service function tree. To conduct the FP-tree algorithm, we implement the *R* program through the algorithm in Sect. 3.2. The main output extracted from the FP-tree algorithm is the paths of co-occurrence keyword sets and their keywords. By integrating and combining the paths, we visualize the service tree. From the service function tree, frequent patterns of service functions in mobile applications can be identified. Using the result of the FP-tree algorithm, two analytic modules are conducted: a frequency-based analysis and an association-based analysis. The dominant service functions and their relationships are useful for exploring the trends of service functions and selecting the design strategies.

3.3 FP-tree algorithm-based analysis modules

In this study, the application of the FP-tree algorithm for the proposed approach has two useful characteristics, as it provides both frequency and association rules based on a hierarchical structure. First, for the frequency rules, the frequent patterns of service functions in mobile applications can be extracted and hierarchically structured in the order of frequency. As some of the service functions are frequently used, this function can be considered as dominant among all mobile services. Thus, using the frequency-based analysis module, the current trends of service functions are monitored and key functions are identified. Second, for the association rules, the relationships between the service functions and the degrees of the relationships can be measured as a result of the divide-and-conquer algorithm. The types of service functions for mobile applications designs can be identified based on convergence and divergence paths. Also, the tree which is widely used as a metaphor for hierarchical relationships helps users and developers to understand the entire landscape structure by clarifying the relationships (Yoon 2010). The patterns of service function relationships are visually represented with converging or diverging points of service functions. By identifying patterns of combination based on relationships, the design of mobile services is supported by differentiating service functions through modular and customized design strategy. The design of API and mash-up functions is considered in the beginning of design process as well. Table 1 condenses the purposes and outputs of FP-tree algorithm analysis modules.

4 Structure of service functions in mobile applications

4.1 Phase 1: constructing the service function tree

The results of the service function tree with the aforementioned voice recognition applications are shown in Fig. 4. The frequency and structural association provides important information which can be used to understand current patterns of service functions in mobile applications. At a glance, in the service function tree, we can

Table 1 FP-tree algorithm-based analysis

Analysis modules	Purpose	Outputs
Frequency-based analysis	Which service functions are frequently provided?	Dominant and auxiliary service functions Frequent pattern of service functions
Association-based analysis	How many service functions are related?	Convergence and divergence paths Types of service functions Relationships between service functions Design support for mobile services

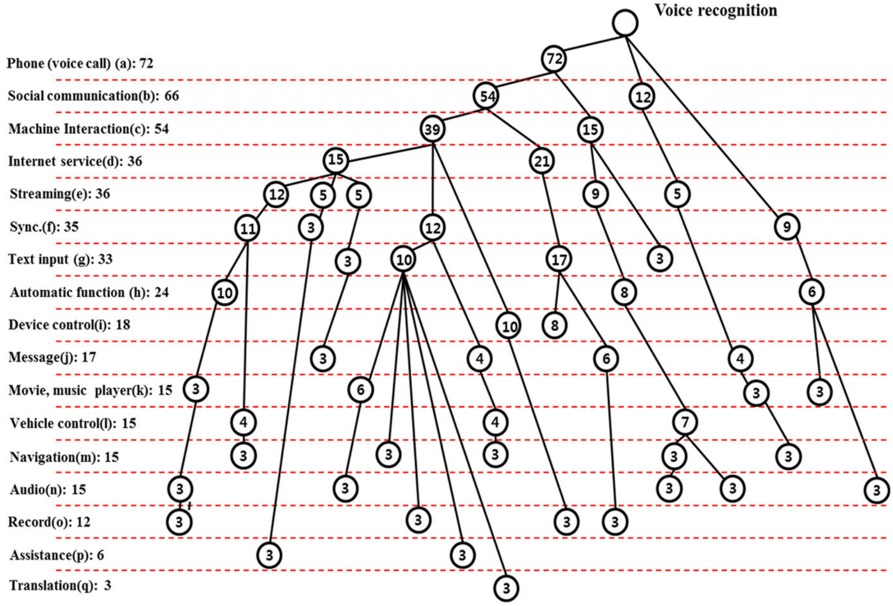

Fig. 4 Frequency-based service function tree

identify which service functions are combined with each other to develop and provide mobile applications. To derive main service functions for the voice recognition applications, we cut off the service functions which have the frequency below three because the number of keywords which have the frequency below three is substantially increased. These keywords might be minor functions and technologies and it is difficult to give valuable insights for understanding the main service functions due to the complexity. As a result, the 17 main service functions extracted from the FP-tree algorithm analysis include *Phone* (72), Social c*ommunications* (66), *Machine Interaction* (54), and *Internet Service* (36). In detail, voice recognition services provide service functions consisting of *contents service functions* and *support service functions*.

First, the contents service functions of *Phone*, *Message*, *Movie and music player*, and *Audio* are those which contain digital information. Some mobile applications provide service functions that can control content based on phone or music player functions through the recognition of voices instead of requiring the use of a touchscreen or button interface. These contents service functions can be used to call other people or to enjoy music or video services.

Second, the support service functions provide technical features that facilitate the better use of mobile phones or services by recognizing voices. For example, service functions such as *Machine interaction*, *Streaming*, and *Synchronization* are used to connect with other devices or to stream content across other devices or services. Also, the keyword *Vehicle* refers to service functions which are controlled in a vehicle, such as navigation or parking support systems. As both contents services and support service functions are combined, mobile applications deliver the service functions of voice recognition as a whole.

4.2 Phase 2: interpreting the service function tree

4.2.1 Module 1: frequency-based analysis

The frequency-based analysis aims to count how many service functions are usually used in mobile applications. The FP-tree algorithm enumerates service functions in the order of frequency from the top to the bottom of service function trees, as shown in Fig. 4.

Based on the frequency, this process illuminates which service functions are frequently used in mobile applications as a form of hierarchical structure. At a glance, we note that there are several major paths of service functions according to different contexts and situations. For example, the same keyword *Internet Service* has two parent nodes: {*Social communication*} related with a node of 21 frequencies and {*Social communication, Machine interaction*} related with a node of 15 frequencies; that is, on the one hand, the first keyword *Internet service* indicates a non-interaction-based internet service while on the other hand, the second keyword *Internet service* indicates an interaction-based internet service. The frequency of a non-interaction-based internet service is 21, but that of an interaction-based internet service is 15. In this way, the advantage of the FP-tree algorithm is that it takes into account a variety of uses and applications with respect to different contexts.

The service functions are classified into *dominant service functions* and *auxiliary service functions* from results of frequency-based analysis. First, the dominant service functions as frequently used functions are found. If service functions are usually used in mobile applications, those service functions are accepted as general functions. Some of the dominant service functions in the order of frequency are listed in Table 2. The service function of *Phone* (*voice call*) based on voice recognition is identified as the most dominant service function, followed by *Social Communication, Machine interaction, Internet service, Text input,* (interaction-based) *Service, Streaming*, and *Synchronization*. These dominant service functions

Table 2 Frequency-based analysis: dominant service functions

Pattern of dominant service functions	Frequency	Dominant service functions
{Phone (voice call)}	72	Phone-based
{Phone} → {Social communication}	54	Social communication-based
{Phone, Social communication} → {Machine interaction}	39	Machine interaction-based
{Phone, Social communication} → {Internet service}	21	Internet service-based
{Phone, Social communication, Internet service} → {Text input}	17	Text input-based
{Phone, Social communication, Machine interaction} → {Internet service}	15	Interactive internet service-based
{Phone, Social communication, Machine interaction, Internet service} → {Streaming}	12	Streaming interaction
{Phone, Social communication, Machine interaction} → {Synchronization}	12	Synchronization-based

are considered as basic contents service functions for implementing various service functions in recent voice-recognition-based mobile applications.

In contrast, the second part of the frequency-based analysis serves to explore auxiliary service functions. These service functions usually have detailed content service functions which differentiate the characteristics of mobile applications. Most voice recognition services have main purposes, such as phone, communication, synchronization or transformation from voice to text, but with auxiliary service functions, we can find what types of service functions are delivered in various service fields. In Table 3, several sets of service functions represent examples of auxiliary service functions. These are audio-based entertainment services, navigation services, support services, and translation services, for instance. From the patterns of the auxiliary service functions, the service fields related to entertainment, automobile, communication, and business utilities are explored as well. These auxiliary services are used to provide detailed service functions based on the set of dominant service functions. These patterns of service functions are used to find new service opportunities and to monitor the trends of mobile applications based on frequently used service functions.

Based on the linkage between dominant and auxiliary service functions, we can find the major patterns of service functions, as shown in Fig. 5. The dominant service function is developed as a basic service function and the auxiliary service function is added for matching with specific purposes. Among others, one of the most frequent patterns of the service functions in voice recognition applications is identified by a pattern which resembles combination of a dominant service function: {*Phone*, *Social Communication*, *Machine Interaction*, *Internet Service*, *Streaming*, *Synchronization*} and auxiliary service functions: [{*Automatic function*, *Movie and music Player*, *Audio*, *Record*}, {*Vehicle Control*, *Navigation*}]. This pattern can be

Table 3 Frequency-based analysis: auxiliary service functions

Pattern of auxiliary service functions	Frequency	Service field	Auxiliary service functions
{Movie and music player, Audio, Record}	3	Entertainment	Audio-based entertainment
{Message, Vehicle control} → {Navigation}	4	Automobile	Text-based navigation
{Streaming} → {Synchronization, Assistance}	5	Business utility	Streaming information support services such as schedule, e-mail, and notes
{Streaming} → {Text input, Message}	5	Communication	Streaming service for transformation from voice to text message
{Message, Vehicle control} → {Navigation}	4	Automobile	Voice to message input navigation
{Navigation, Audio}	3	Automobile	Audio navigation
{Message} → {Movie and music player, Navigation}	4	Automobile, entertainment	Movie and music services by message inputs in vehicle
{Translation}	3	Language utility	Interpreting and translation

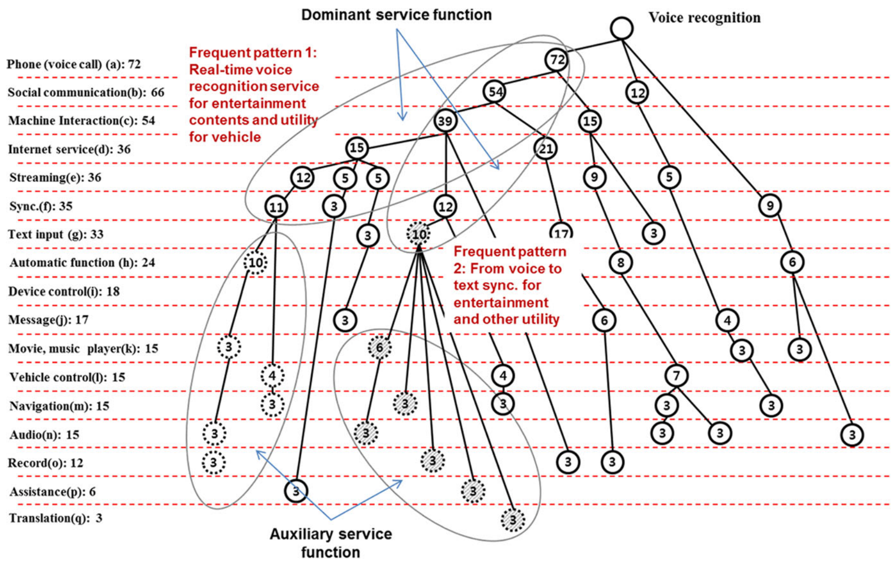

Fig. 5 Major frequent patterns of service functions

interpreted as "real-time voice recognition services for entertainment content and utility for vehicles" because the auxiliary services are related to entertainment and vehicle. Similarly, other frequent patterns can be shown as a pattern which is "data synchronization from voice to text for entertainment and utilities," that is, combination between the dominant service function: {*Phone*, *Social Communication*, *Machine Interaction*, *Synchronization*, *Text Input*} and auxiliary service functions: [{*Movie and Music Player*, *Vehicle Control*}, {*Navigation*}, {*Record*}, {*Assistance*}, {*Translation*}]. The identification of the frequent patterns provides useful insight to assist in the understanding of the recent trends of service functions in mobile applications.

4.2.2 Module 2: association-based analysis

The purpose of the association-based analysis is to identify how many service functions are related to each other. Due to the divide-and-conquer method of the FP-tree algorithm, the degree of the relationships can be measured using the number of association paths. The paths can be considered in two directions: from top to bottom and vice versa. The direction from top to bottom indicates a divergent association path, whereas that from bottom to top represents a convergent association path.

Thus, the degree of divergent and convergent relationships can be measured based on directions. On the one hand, for the direction from top to bottom, the number of divergent association paths can be counted with respect to all related links. To measure the related links, it should be noted that the association paths use different methods despite the fact that the same service function is related. For example, *Internet Service* linked with *Machine Interaction* (known as an interaction-based service) has a single keyword, *Streaming*, but the association path includes three methods with respect to *Streaming*. Also, *Synchronization*, which is sequentially related to *Internet Service* and *Streaming*, has two paths connecting to *Automatic* and *Vehicle*. In this way, the interaction-based *Internet Service* has four associations in all: {*Streaming*, *Synchronization*, *Automatic function*, *Movie and Music Player*, *Audio*, *Record*}, {*Streaming*, *Synchronization*, *Vehicle Control*, *Navigation*}, {*Streaming*, *Synchronization*, *Assistance*}, and {*Streaming*, *Text Input*, *Message*}, with four association paths. In the same way, it is found that *Service* linked with *Communication* has as many as two divergent association paths. In sum, there are six divergent association paths for *Service*. The number of divergent paths for each service function is represented in each node in Fig. 6.

On the other hand, from bottom to top, the number of convergent association paths can be taken into account. Similarly, the keyword *Internet Service* has two nodes, linked to *Machine Interaction* and *Social Communication*. It is known that there are two convergent association paths for *Internet Service* from bottom to top. This is identical to the number of nodes for each service function keyword. The number of convergence paths is indicated with the titles of service functions as shown in Fig. 6. Thus, the number of convergence and divergence paths for all service functions can be measured as shown in Table 4.

Based on the convergence and divergence ratio, three types of service functions are derived, as described in Table 5. Using the metaphor for tree, the types are referred to as *root*, *leaf*, and *branch* with the characteristics. These types can also be used to create modular designs of service functions in mobile applications.

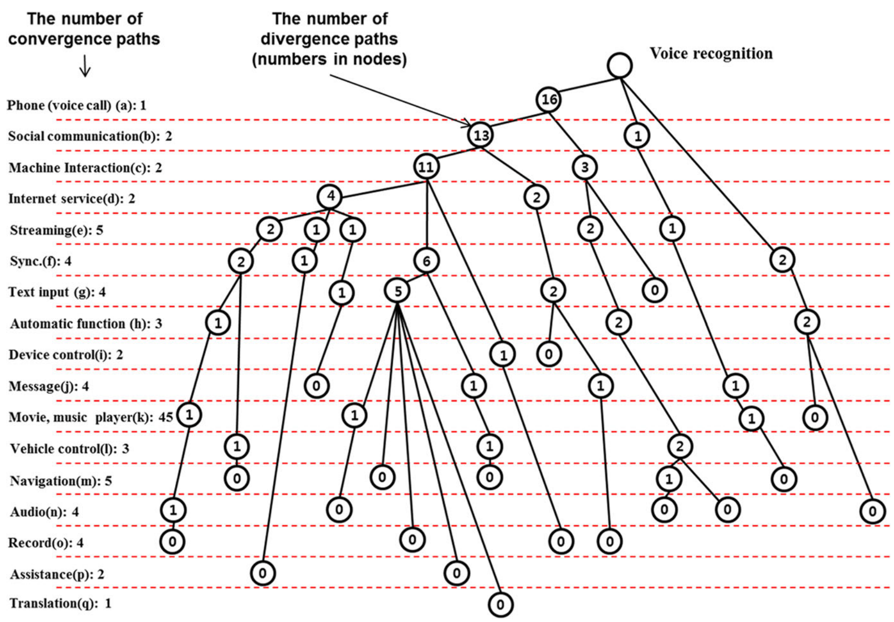

Fig. 6 Association-based service function tree

Table 4 Association-based analysis

	Path of divergence (a)	Path of convergence (b)	Ratio (a/b)	Types
Phone	16	1	16	Root
Social Communication	14	2	7	Root
Machine interaction	14	2	7	Root
Internet service	6	2	3	Branch
Streaming	7	5	1.4	Branch
Synchronization	11	4	2.75	Branch
Text input	8	4	2	Branch
Automatic function	5	3	1.67	Branch
Device control	1	2	0.5	Leaf
Message	3	4	0.75	Leaf
Movie and music player	3	4	0.75	Leaf
Vehicle control	4	3	1.33	Branch
Navigation	1	5	0.2	Leaf
Audio	1	4	0.25	Leaf
Record	0	4	0	Leaf
Assistance	0	2	0	Leaf
Translation	0	1	0	Leaf

Table 5 Types and characteristics of service functions

Types	Service functions	Characteristics	Design support for mobile services
Root service function	Phone, Machine Interaction, Social Communication	Service functions related to most service functions	Basic service functions that should be developed by service modules
		Mostly patterns of dominant contents service functions	Uses for API development strategies
Branch service function	Synchronization, Text input, Internet service, Automatic function, Streaming, Vehicle control	Service functions that are distinct functions, including entertainment and content services	Platform that provides specific service functions that can customize mobile services based on the APIs
		Mostly patterns of auxiliary contents service functions	A variety of service function are developed through a mash-up strategy
Leaf service function	Message, Movie and music player, Device control, Translation, Assistance, Audio, Record, Navigation	Service functions that are a means of implementing contents services	Design service functions related to operational technology for implementing the mobile services
		Mostly support service functions	

First, the root service function (which has a ratio more than 4) is a fundamental service that is related to most of the service functions. Root service functions are mostly included in the pattern of dominant service functions. Developers should consider these functions as basic service functions and provide them as service modules by combining root functions. The *Phone*, *Social Communication*, and *Machine Interaction* functions are included as root service functions for voice recognition services and are designed as a type of a service module. Specifically, for the API, it is important to provide a module that consists of basic application service functions. Here, an API refers to an independent service function in mobile applications, such as map, payment, or web document functions. Google provides users and developers with many APIs so that service functions can be used easily. Thus, an API module developed by root service functions can allow users and developers easily to understand the basic service functions and develop more advanced services.

Second, in contrast to root service functions, the leaf service function (which has a ratio of less than one) includes detailed service functions that make significant differences among mobile services such as *Audio*, *Record*, and *Navigation*. These leaf service functions can also be derived from the pattern of auxiliary service functions. During the development of mobile applications, these leaf service functions are versatile sources for customizing basic service functions. This finding provides useful information for those who create *mash-ups* of mobile services. To adapt these to specific purposes, many APIs are combined and new mobile service functions are incrementally developed.

Finally, the branch service function pertains to platform services for implementing contents service of root and leaf. The branch service functions (which have a ratio between 1 and 4), such as *Internet Service, Synchronization*, *Streaming*, and *Automatic function* are used as support service functions for implementing the root and leaf service function. Because most root and leaf service functions tend to be content service functions, support service technology is required to operate the content services. Thus, the branch service function is not a service function itself but is rather a technological support function that operates or implements services.

5 Managerial and practical implications

The illustration of design of service functions based on API and mash-up is portrayed in Fig. 7. From root service functions and branch service functions, the API is developed. Using *Phone, Social communication, Machine interaction, Vehicle control*, and *Streaming*, we can design the "Real-time interaction services for a vehicle". This is used as a software component which interacts with other service functions. Based on this API, the leaf service functions are combined to develop 'mash-up' applications. The mash-up is an emerging concept in design of mobile services by recombining the API and contents. Many location-based services are developed through this mash-up strategy by integrate the API of Google map and other contents such as tour or shopping information. Also, the platform such as smartphones or tablets plays a critical role in delivering the mash-up services. Here, we show the case of several customized service functions based on API such as "Interaction-based streaming" and platform such as "vehicles" by combining the contents of *Message*, *Movie and music player*, *Device control*, and *Navigation*. Similarly, more service functions can be implemented in mobile applications

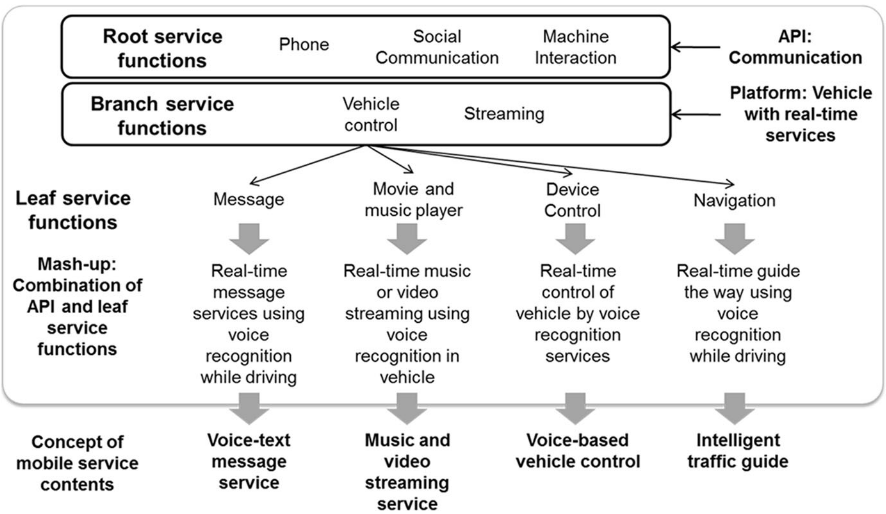

Fig. 7 Design of service functions in mobile applications: a case of mobile applications for vehicle

depending on the degree of mash-up; that is, how many leaf services combine with APIs and platforms.

Through concept development, the new mobile applications can be derived based on the service functions and the real situation for applying these service contents is described by proposing the use cases of each service as shown in Table 6. A first example is the voice message services for sending text message from voice recognition. In a vehicle, a driver can easily and safely use this voice-based text message service function by connecting a smartphone with the vehicle auxiliary. A second opportunity is to listen to the music and watch the movies with hands-free. A list of music can be selected and skipped by recognizing the voice command. A third case is a support function of controlling the car through voice recognition. It is related to the unmanned car nowadays, but this mobile application is only to handle the support functions such as turning on the indicator, wiper, and air conditioner. As a platform, the mobile applications can include core service functions for future vehicles. Lastly, the intelligent traffic guide for drivers can be developed to forecast the traffic or recommend the shortcut to the destination. The traffic information is downloaded in real-time and the optimal path toward destination can be derived. Although some of these mobile applications are already launched in application markets, we can more systematically design the new mobile applications through mash-up, dividing three parts: API, platform, and leaf service functions. In future, by analyzing more service functions in mobile applications, we expect that new opportunities will be continuously created in application markets and service developers can obtain new thinking of design of mobile applications through current research methodology.

For suggesting more practical implications, in addition to detailed service functions, we propose the general models such as API and platform by combining the leaf service functions. In other words, this approach can be defined as the bottom-up design from leaf to root. As shown in Fig. 8, *Streaming* and

Table 6 Opportunities for new mobile applications

Concept	Function	Advantage	Use case
Voice message service	Sending text message from voice recognition	Quick messenger communication	With USB connection between smartphone and vehicle, users send text message easily by voice recognition
Music and video streaming	Selecting and streaming music and video	Easy control of music and video players	Select or skip a music and video by voice recognition through a smartphone
Voice-based vehicle control services	Control the vehicle function through voice recognition	Support to driving	Turn on the indicator or the windscreen wiper Control the air conditioner or the heater
Intelligent traffic guide	Forecast the traffic or recommend shortcut	Support to driving	Suggest streaming-based shortcut Input destination through smartphone and interacting with navigation

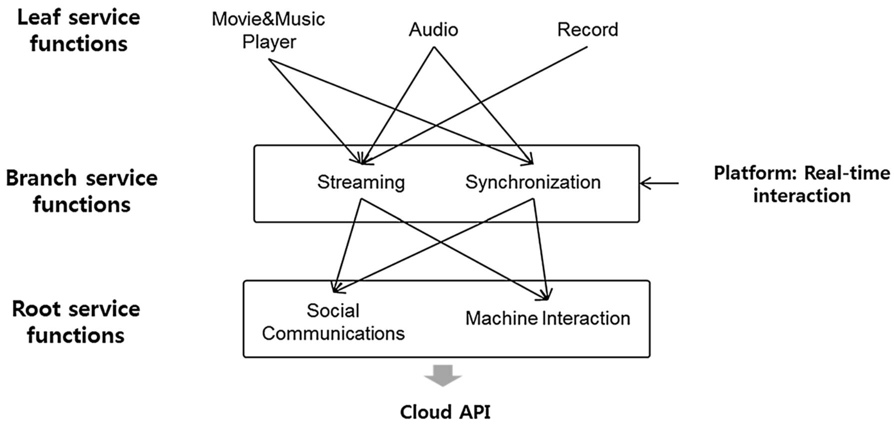

Fig. 8 Design of service platform and API by service functions in mobile applications

Synchronization of branch service functions are mainly related with the *Movie and music player*, *Audio*, and *Record* of leaf service functions. These two branch service functions could be defined as "Real-time interaction" platform and the related root service functions, *Social Communications* and *Machine Interaction*, provide the "Cloud API" function. Through this bottom-up procedure, more general models of service functions are designed for mobile applications developers who try to launch the new mobile applications.

6 Discussion

In general, this study is started from identifying the service functions in electronic markets such as Google's Play and Apple's App Store. To enhance market power of mobile devices and applications based on the install base of PC users, the Microsoft recently launched the application market as well with the OS of Windows 10. The Windows 10 enables users to install and apply applications in both PC and mobile devices. Thus, Google and Apple should prepare the advanced strategy for providing applications with PC users. Although there are millions of mobile applications in mobile markets and the economy of mobile markets is increasing, however, the attempt to analyze these mobile applications has not been conducted. In this respect, this is an initial study to analyze the service functions in mobile applications delivered by electronic markets, focusing on the voice and speech recognition services. The voice recognition is widely applied in various service categories such as in-car systems (Greengard 2015), health care services (Portet et al. 2013), telephony services (Schuster 2010), educations, and services for the disabled (Kumar and Sachan 2014). These previous studies have usually focused on the case studies to persuade the importance of voice recognition and the system architecture to implement voice recognition services. As voice recognition is increasingly used, the term of voice user interface beyond graphic user interface is coined and this situation reflect the increasing importance of voice recognition in various areas. However, there is a lack of sufficient studies in the level of service functions in the perspective of markets. To address this lack, we discuss the link between our research outputs and various service areas. Based on the service functions in mobile applications delivered by smart devices such as smartphones and tablet computers, our research outputs could extend to health care services, educations, and service for the disabled. The automobile, communications, and entertainment services have been already designed as shown in Table 6, but more opportunities should be considered in the other service areas because all most people have used the smartphones.

For this, what we firstly discuss is to find needs for users in other service areas. Second, based on the current service functions, we figure out the service functions which are usefully applied to satisfying the user needs. For example, in healthcare services, the aged need to use healthcare services easily and the voice recognition service are useful for them to be provide services. The service functions such as phone, machine interaction, and text inputs are made to support the telemedicine services. Also, in educations, voice recognition services help the children develop the speech and learn the interaction by using smartphones.

Further, while voice recognition services are applied to other service areas, the new service functions can be developed. As pointed out above, the current research results are mostly included in the service fields: automobile, entertainment, and communications. However, if the use of smartphones in healthcare services is proliferating, the new service functions such as checking temperature, pulse, and blood pressure are embedded in future smartphones and mobile applications. Thus, the service function tree will be deepened and expanded according to the scope of service fields. The research necessities on service functions in mobile applications are continuously discussed for increasing electronic markets of mobile applications.

7 Conclusions and future research

Interest in the value of mobile service has been continuously highlighted over the past decade. As mobile technology becomes more powerful and promotes the development of many derivatives, mobile applications are emerging as one of the major factors in the electronic markets as a new value chain of the mobile industry.

This paper makes three contributions to the end-users and application developers involved in mobile service industries. First, this is a recent study that aims to find frequently used service functions in numerous mobile applications. Using this type of frequency-based analysis, a FP-tree algorithm can be helpful for understanding both dominant and auxiliary service functions. Also, from these functions, end-users and application developers can examine the set of service functions and the trends of mobile application services. Frequency patterns of service functions enable users and developers to understand service trends and find the most frequently used service functions from top downloaded mobile applications. Second, according to the association-based analysis, the aforementioned relationships between service functions can be identified through convergence and divergence paths. In terms of the convergence-divergence ratio, three types of service functions, the root service function, the leaf service function, and the branch service function, are extracted. Each type provides useful information for the strategic development of mobile application services in accordance with API development, mash-ups, and operational service technology. Third, in practices, this systematic guideline to design mobile applications can be of high interest for developers who try to figure out new service functions in mobile applications. Even though this study focus on the voice and speech recognition services, many developers use our approach to other cases beyond this voice recognition. In other words, this study provides a research foundation as a starting point to analyze the service functions in electronic markets.

However, there is still a need for future research to overcome the limitations of this research. First, regarding the data, more data sets should be used. This research used 124 mobile applications, and 17 main service functions were extracted for only voice recognition service industries. If mobile applications are collected from more service industries, more significant service functions can be extracted. Also, if the mobile applications are gathered in order of publishing date, the dynamic analysis can be conducted to identify the change of service functions in mobile applications. More advanced techniques to distinguish the context of keywords such as fuzzy set theory and ontology would be used for improving research outputs. Second, because service functions in mobile applications are developed depending on the features of smartphones, an integrated approach to product-service systems which consists of smartphones and mobile application services could be a fruitful research area as well. The patent analysis of smartphones is applied to extract the new and advanced features. Thus, the new mobile applications that deliver new service functions are prepared in advance matching with new smartphone functions. Third, this study more focuses on the frequently used service functions provided from mobile applications, but user context should be considered to find valuable service functions and service needs. Service functions and design strategies are normally built around changes in user contexts and user groups. Thus, we will study the research on finding useful or synergetic service functions by evaluating the service functions derived from this current research in the perspective of user context. The user experience studies of smartphone uses can be helpful for identifying needs of new service functions in mobile applications. Finally, the visualization of FP-tree should be implemented for future study to represent effective results.

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