A Taxonomy for Mobile Location-Based Services Functions Identification

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Abstract. Location-based services (LBS) are widely used. We address the problem of identifying functions of a mobile LBS for functional requirements. We found some taxonomies for LBS useful for identifying functions; in them some characteristics are too general for finding specific functions; there are not enough dimensions in these taxonomies, and some dimensions have not enough characteristics. We found papers classifying LBS into groups and for each group they present typical functions, but do not present the dimensions for identifying all functions for an app. Our objective is to reduce these gaps. We applied Nickerson's method to find a taxonomy for function identification. We found 3 new dimensions, and 11 new characteristics for existing dimensions. We organized several LBS groups by saying for each group which dimensions to consider and which characteristics for these dimensions to consider; this provides a new systematic way for identifying functions for an app in a group.

Keywords: Location-Based Services, Function Identification, Taxonomy Definition, Requirements Engineering, Mobile Applications.

1 Introduction

Today, mobile LBS are widely used. A LBS is defined by the International Open Geographic Consortium ([1]): "A wireless-IP service that uses geographic information to serve a mobile user. Any application service that exploits the position of a mobile terminal".

In this paper we consider the problem of identifying the functions of a mobile LBS app; to have such functions is useful for the functional requirements phase, and for the app description in an app store. A function has a purpose and involves one or more steps consisting of: an event or a user input happening, the processing of the event or input, possibly showing an output or a notification.

General classification of functions for mobile apps are scarce (e.g. [2]) and not appropriate because they do not consider the specific needs of the LBS domain (e.g., specific location-based tasks that cannot be inferred easily from general function types need to be identified), and operations for information management are too general for identifying the needs of LBS apps. (E.g., having CRUD operations and

notifications is not enough because as we will see the types of content and information to consider may vary a lot and need to be related to the domain of LBS.)

In the literature we have found some taxonomies for the field of LBS apps that can be used for identifying some typical functions for LBS app development (see [3, 4, 5, 6, 7, 8]). They cover the following characteristics:

- Location-based tasks and location-based calculation functions (see [5,6,7]).
- Location of geographic objects, traveling conditions, and location of events - [3,7].
- Characteristics about object information [3,6] (e.g.: restaurants, shopping, places, events).
- Pull services characteristic – see [4,7,8].
- Push services characteristic - see [4, 7].

The last two items are too general characteristics, and their names do not help much with the identification of specific functions. For instance, consider *view driver information* of Uber app and *view standings table* of Waze app; *service provider information* and *application information* are more specific characteristics than *pull services* that can be used for identifying both functions.

However, functions of actual LBS apps indicate that the listed characteristics in the literature are not enough. For instance, the following functions belonging to actual existing LBS apps are not covered by the listed characteristics:

- In Foursquare app: *see my tastes*, *see all places I visited*; these are examples of *user information* functions.
- In Swarm app: *send group messages*, *send direct messages*; these are examples of *communication* functions.
- In Waze app *show ads*, and in Uber app *pay by credit card*; these are examples of commercial operations.
- In Swarm app *look your friend's check-ins*, and in Target app *find item location inside a store*; these are examples of location information associated with other kinds of entities not presented in the 2nd item of the characteristics of the literature.

In addition, there are some papers that classify LBS into groups (see [9, 10, 11, 8, 12, 13]), and for each group they present only some typical functions. These papers do not say what to do when we need to identify the functions of a LBS app that do not belong to a group; in addition, they do not present the necessary dimensions for identifying all functions and not only the typical ones.

The objectives of this paper are: Find new dimensions of LBS apps, improve existing dimensions by introducing lacking characteristics, and decompose too general characteristics into more specific ones for easing function identification.

In this paper we applied the well-known Nickerson's method (see [14]) to find a taxonomy that serves for identifying functions for functional requirements of LBS and for achieving the objectives.

Nickerson's method is shortly described in Sec 2. A set of LBS groups we have found in the literature is presented in Sec 3; such groups are important for choosing a sample of LBS apps to examine during the definition of our taxonomy. Sec 4 shows how we specialized the Nickerson's method in our study. The obtained taxonomy after following the specialized method is shown in Sec 4. The found taxonomy has 8

dimensions, and each dimension has between 4 and 7 mutually exclusive characteristics. Given a LBS app belonging to a LBS group, Sec 5 tells which dimensions to consider and which characteristics for these dimensions may be used or must be used. Our contributions are summarized at the beginning of Sec 7.

2 Methodology

In this paper we used the Nickerson's method for systematic taxonomy development ([14]). Nickerson defines a taxonomy as a set of dimensions, where each dimension consists of mutually exclusive and collectively exhaustive characteristics; therefore, each object under consideration has exactly one characteristic for each dimension.

Nickerson says that a useful taxonomy is *concise* (i.e. with a limited number of dimensions and a limited number of characteristics on each dimension), *robust* (i.e. it should contain enough dimensions and characteristics for clearly differentiating between the objects of interest), *comprehensive* (i.e.: 1) classify all known objects within the domain under consideration; 2) should include all dimensions of objects of interest), *extendible* (i.e. allow for inclusion of additional dimensions and new characteristics within a dimension when new types of objects appear), *explanatory* (i.e. provide useful explanations of the nature of the objects under study).

Nickerson recommends defining a *meta-characteristic:* it is the most comprehensive characteristic that serves as a basis for the choice of characteristics of the taxonomy. Each characteristic should be a logical consequence of the meta-characteristic.

Nickerson's method is iterative, and it is important to choose objective and subjective ending conditions for determining when to terminate. On each iteration the researcher can use either an *empirical to conceptual* approach (i.e. identify a subset of the objects to classify, identify common characteristics of these objects, group characteristics into dimensions to create or revise the taxonomy) or a *conceptual to empirical* approach (i.e. conceptualize new dimensions without examining actual objects, propose characteristics for these dimensions, examine objects for these dimensions and characteristics, and make corrections to the taxonomy if necessary).

In the literature we have found that functions can also be classified by defining Unified Modeling Language (UML) profiles (see [15]). We consider that the Nickerson's method is better when we need a systematic well-thought procedure for finding a taxonomy, and this is the case for LBS; this is because a UML profile is a way to describe a taxonomy, not a procedure for finding one.

3 Classes of Location-Based Services

We have found papers that classify LBS into groups of apps in [9, 10, 11, 8, 12, 13]. In Table 1 the first column contains names for groups of LBS found in the literature. We use a 'X' for indicating that an author includes a group. After the 'X' we can put a group name, only if this group is more general than the group in the first column. For instance, *safety of life* group includes and is not equal to *emergency apps*.

Table 1. Groups of LBS found in the literature

Type of LBS	Giaglis et al [9]	Steiniger et al [10]	Werner [11]	Elazab et al [8]	Bauer et al [13]	Steinfield [12]
Emergency	X	X	X, safety of life	X		X, safety & medical
Navigation	X	X	X	X	X	X
Information	X	X	X		X	X
Advertising	X		X, retail, and commerce	X	X, transaction services	
Billing	X	X			X, transaction services	X, transactions, and billing
Tracking	X	X, tracking & management		X	X	X
Mobile work force management		X, tracking & management	X, management services	X		X, mobile office
Augmented reality		X				
Social networking (SN)			X, SN & joint activities	X	X, communication services	
Entertainment			X gaming		X	X
Traffic management				X		

4 A proposed Taxonomy for Location-based Services Functions Identification

4.1 Application of the Nickerson's Method in our Study

Objects to Classify. We say that a function of an application is atomic if neither includes another function of the application (by considering behavior inclusion) nor generalizes another function of the application (inheriting its behavior).

The problem with non-atomic functions is that they resist the attempts for defining taxonomies because they may respect more than one characteristic of the same dimension; Nickerson's method requires every function to have only one characteristic per dimension. E.g., if we have a *communication* dimension with characteristics *to one* (to communicate with one person) and *to many* (to communicate with many persons); a non-atomic function (of Swarm app) that considers both characteristics is *Send direct or group messages*. If we have a dimension *entity content* with characteristics including *acquaintance* and *service provider*, then a non-atomic function (of Uber app) that considers both characteristics is *deliver package*.

The purpose of this paper is defining a taxonomy that given a LBS serves as a guide for the systematic identification of a list of atomic functions (for this app) by people without much experience in the LBS domain or by people with experience in LBS domain that want to speed up this task. These functions will be described during functional requirements phase.

The objects to classify are lists of atomic functions of different mobile LBS. The taxonomy will be obtained by sampling LBS and by classifying the list of all or some atomic functions of these apps.

LBS Sampling. For sampling LBS we consider the different groups of LBS found with the exception of *entertainment* (this is a complex field we do not want to concentrate on.), *augmented reality*, and *traffic management* (these apps are usually not mobile.). In addition, we added to this list the LBS group *service provision* (these are LBS apps allowing people to offer their services); this group is new to our knowledge (examples of apps in this group are: Uber, and Airtasker).

For each of these groups of LBS we choose at least one app. For finding actual and popular LBS apps some blogs were used; in addition, some apps were taken from the literature about LBS because they present interesting functions to classify.

Meta-characteristics. For finding the characteristics of our study, we either generalize the type of information managed by a function or specify the purpose of the task performed by the function; therefore, the meta-characteristics of this study are information type and task purpose.

Approach Employed and Ending Conditions. Due to our lack of expertise in the field of LBS, we adopted only the empirical to conceptual approach.

We considered the following objective ending conditions:

- The functions of a representative sample of LBS apps have been examined.
- At least one function is classified under every characteristic of every dimension.
- No new dimensions or characteristics were added in the last iteration.
- No dimensions or characteristics were merged or split in the last iteration

We considered the following subjective ending conditions that were defined in Sec 2: robust, extendible, concise, and explanatory.

To meet the first objective ending condition Table 2 shows for each group of LBS the apps considered in our study; in addition, we indicate if either all or some of the atomic functions listed by the app were classified.

Table 2. Apps considered for each LBS group.

LBS services group	**LBS app**
Information services	Dark sky (all), Foursquare (all), infotainment service in [9] (some)
Advertising services	Target (all), Gas buddy (all), advertisement service in [9] (some)
Navigation services	Waze (all), navigation service in [9] (some)
Billing services	Smart logistic app in [11] (some)
Tracking services	Kidsguard pro (all), Find my device (all)
Service provision	Air tasker (all), Uber (all)
Emergency services	Disaster alert (all), EchoSOS (all), emergency service in [5] (some)
Work force management	allGeo (all)
Communication services	Swarm (all), Social service in [5] (some),

	communication service in [4] (some)
Other	Map my fitness (all), smart conference room app in [6] (some)

4.2 Definition of the Taxonomy

After applying Nickerson's method as explained in subsection 4.1, we found the following dimensions with their characteristics:

- **(D1) User Information**
  - *Areas of life*: For example: financial, health, banking, professional, educational, genetic, religious.
  - *Account*: application account information about the user.
  - *Event*: an event generated by the user.
  - *Plan*: an action, task or activity planed by the user.
  - *Historic*: chronological list of events, tasks, activities of the user.
  - *Preferences*: user preferences.
  - *Non emotional set*: set of items associated to the user without an emotional meaning (e.g.: like, prefer, hate, etc.) and not belonging to areas of life.
  - *Statistics*: statistics about the user and not about areas of life.
  - *Not user information*.
- **(D2) Entity Content**
  - *Acquaintance*
  - *Service provider*
  - *Geographic object: e.g.: a place, a route, a region.*
  - *Physical object*
  - *Application*
  - *Virtual object*: a virtual object that is not an application.
  - *Not entity content*
- **(D3) Location Related Content**. For relationships between entities and locations.
  - *Person*
  - *Geographic object*
  - *Physical object*
  - *Virtual object*
  - *Not location related content*
- **(D4) Location-Based Calculation**
  - *Shortest route*
  - *Alternative routes*
  - *Route estimators*: e.g., distance, estimated time to traverse the route.
  - *Nearest (entities)*
  - *Entities around*: e.g., entities of the same type nearby the user, a region in a map nearby the user.

- *Movement estimators*: e.g., speed, acceleration.
- *Statistics*: e.g., distribution of a set of objects in different regions.
- *Not location related calculation*

- **(D5) Location-Based Task**. It is not a calculation, but it can involve a calculation plus something else.
  - *Locate*: detect the location of an entity in space, e.g., in a map, using coordinates.
  - *Send to person*: route the nearest vehicle to the location of a person.
  - *Guide me*: considers the actual position of a person, and gives this person instructions for going in the direction of a desired fixed destination.
  - *Meet moving person*: periodically route a person to meet a moving person.
  - *Check presence in space*: check if an entity is present in a space.
  - *Track*: follow the trail of an entity to find it or note its course.
  - *Location-based notification*: receive a notification of a location-based event. E.g.: geofence violation notification, proximity triggered advertisement, speed limit violation alert.
  - *Not location-based task*
- **(D6) Software Task**. Application or system task.
  - *Configure*: to set up the software in such a way that is ready for operation for a particular purpose.
  - *Get state*: get information about the software state.
  - *Perform command*: e.g.: add a phone number and message to lock screen, erase the device, put a password on your device and lock it.
  - *Event notification:* e.g.: notify it is time for a planned cab ride.
  - *Get monitoring output*: e.g.: get current traffic conditions.
  - *Not software task*
- **(D7) Commercial Task**
  - *Payment*
  - *Bill*
  - *Reservation*
  - *Notification*: e.g.: notify when an order is ready, show add.
  - *Not commercial task*
- **(D8) Communication Task**. The act of the user communicating with people; the act of another person communicating with the user.
  - *To me*: the act of another person communicating with the user. E.g., an invitation (e.g.: to join a group, to join an event, to join an activity, to be a friend), a message to the user.
  - *To many – evaluation*: evaluating several aspects of something and being objective, or rating something.
  - *To many – tip*: opinion on what you should do in a particular situation; a piece of special or secret information.

- *To many – share*: to share your thoughts, feelings, ideas, or something that someone else has put on a web site. E.g., sharing an event, content sharing.
- *To many – information*: facts or details about something (definition of information in Oxford Learners dictionary).
- *To many – message*: e.g., email, chat.
- *To one*: the user communicating with one person. E.g., rejecting/accepting an invitation, sending a message to a person.
- *Not a communication task.*

Each dimension *X* has a characteristic *not X* to be used for functions that defeat the purpose of the *X's* name. In our taxonomy *not X* is mutually exclusive with the other characteristics of *X*. For each dimension *X*, the characteristic *not X* is present to obey the rule saying that each function to examine must have one characteristic for every dimension. For instance, *invite to join a group* is not a *commercial task*; if we do not put the characteristic *not commercial task*, this function will not have a characteristic under the dimension *commercial task*.

In our study we carried out 7 empirical to conceptual iterations. During the last one we examined Air Tasker and Map my fitness apps; we found no new characteristics.

4.3 Application of the Taxonomy to Yik Yak LBS

Yik Yak is a LBS used to anonymously connect with everyone within 5 miles (i.e.: your herd). Visible messages to your herd are called *yaks*. You can express if you like or dislike a yak. Yaks may have comments. A yak has a *score* (i.e.: number of likes – number of dislikes); yaks with a score lower than -5 are not allowed. A yak is *top* if it belongs to the set of top ranked yaks. Yaks can be reported using different criteria. A yak can be local or nationwide. Non top yaks expire in 24 hours. You can share yaks that you like and report the ones that are abusive. Each user has an icon assigned randomly that can be reseted. Cuss Buster hides some inappropriate language from view in yaks and comments. You can have blocked people. You can delete all the data in your account. You can have notifications if you like. You get points (called yakarma) for yakking, commenting, and receiving likes on yaks and comments.

Considering this description and our taxonomy we identify and classify atomic functions for Yik Yak.

- *User information*: *Account*: create account, delete your account. *Historic*: see my yaks, see my comments. *Statistics*: update yakarma.
- *Entity content*: *virtual object*: get comments associated with a yak, see nationwide hot yaks (ranked by votes), see nationwide top yaks, report a yak, remove yaks with vote score of -5, remove expired yaks.
- *Location related content*: *virtual object*: remove yaks with vote score of -5, share a yak, remove expired yaks.
- *Location based calculation*: *entities around*: get new yaks 5 miles around you, get hot yaks 5 miles around you (i.e.: ranked by votes), see local top yaks, see your position and the radius of your herd on a map.

- *Location based task*: *Locate*: detect your location. *Location based notifications*: see your notifications.
- *Software task*: *Configure*: block user, unblock all the blocked users, reset comment icon, turn Cuss Buster on/off, turn notifications on/off. *Perform command*: log out.
- *Communication task*: *to many – evaluate*: upvote yak, downvote yak. *To many - share*: comment yak, create yak. *To one*: share your yakarma, share a yak.

5 Use of the Taxonomy

When a LBS does not belong to any LBS group, we can use our taxonomy for identifying the characteristics (that will guide the identification of functions) and identify (if necessary) the functions associated to them. Some characteristics have a generic function name, and when used it is necessary to specialize this function name.

When the LBS to be developed belongs to a known group of LBS, it is not necessary to check the complete taxonomy for identifying the functions; this is because less work can be done by reusing the knowledge about that domain; in other words, we would like to say about a LBS group: which characteristics are mandatory, which ones are optional (i.e.: they are used in some apps of the group, but not in all of them), which dimensions have characteristics that do not start with the word 'not', and which dimensions we do not need to worry about; therefore, we consider useful to have this kind of information about characteristics and dimension for groups of LBS.

We performed a study for compiling this kind of information for the types of LBS of Table 2. (We exclude *billing services* due to space reasons.)

For each group of LBS we present the characteristics derived from: 1) all functions of the apps in that group considered in Table 2, and 2) all functions of that group mentioned in papers about classifications of LBS into groups (we considered the papers cited in this work).

We use the following rules for expressing domain information associated with a group of LBS: 1) We express that a characteristic is mandatory by putting an '*' after the characteristic name. 2) We express that a dimension must have a characteristic that does not start with 'not' by putting an '*' at the start of a cell; a cell refers to a dimension for a LBS group. 3) When two characteristics are mutually exclusive, this is expressed by separating the characteristics by using the word ‘XOR’.

The results of the study can be seen in tables 3 and 4.

Table 3. Characteristics for navigation, information, advertising services and tracking groups.

	Navigation	**Information**	**Advertising services**	**tracking**
user information	Preferences, plan, account	Historic, non-emotional set, preferences	preferences, areas of life, statistics, historic, account	historic
Entity content	geographic object*, Application	*, acquaintance, virtual object, application	*, physical object, virtual object	(Acquaintance XOR physical object)* Virtual object

Location related content	Geographic object*, person	Object: geographic, virtual	*, Object: virtual, physical	(person XOR physical object)*
Communication	To many: share, information.	To many: evaluation, tip, information.	*, To one, to many: information.	
Commercial task	notification	Notification, reservation	Notification*, reservation	
Software task	configure*, event notification, get monitoring output	Configure	configure	Get state, command, configure
Location based calculation	shortest route*, alternative routes*, route estimators, movement estimators	Entities around* nearest*	entities around	Movement estimators, nearest
Location based task	Locate*, guide me*, entities around	Locate*, location-based notification*	Locate*, location-based notification*	Locate*, track*, notification

For instance, for *information* group the *entity content* dimension must have a characteristic that does not start with 'not', for *navigation* group the *shortest route* characteristic in *location-based calculation* dimension is mandatory, and for *tracking* group the characteristics *person* and *physical object* are mutually exclusive (in *location related content* dimension).

Table 4. Characteristics for communication services, safety of life, work force management and service provision groups.

	Communication services	**Safety of life**	**Work force management**	**Service provision**
user information	non-emotional set, historic, statistics, plan	Areas of life	Event, plan	account
Entity content	Acquaintance*, geographic object	service provider, geographic object*	Virtual object	Service provider*, virtual object, geographic object
Location related content	Person*, geographic object	*, Object: virtual, geographic		Object: virtual, Geographic
Communication	*, to many: message share, information. To one, to me	*, To one, to many: information	To one*, to me*	to one*, to many*: information, evaluation
Commercial task				Payment*
Software task	configure	Command	configure	Configure
Location based calculation	Entities around, statistics	Entities around		Nearest, entities around, shortest route, route estimators

Location based task	Meet moving person, location-based notification	Locate*, location-based notification*, send to me, track	Locate*, track	Track

Tables 3 and 4 show that:

- The following dimensions have characteristics in all groups: *user information*, *entity content*, *location-based task*, *software task.*
- The following dimensions have characteristics in all but one group: *location related content*, *communication*, *location-based calculation*.
- The characteristic *configure* of software task appears in all but one group.
- In the *user information* dimension, there are no mandatory characteristics.
- *Commercial task* has characteristics neither for work force management nor for tracking; it has characteristics in service provision and advertising services.

6 Related Work

We consider as related work papers defining taxonomies in the field of LBS that can be used for identifying some functions for LBS development. We have found three kinds of such related papers: a) papers presenting some of our characteristics (perhaps with another name) or some refinements of our characteristics, b) papers presenting coarse grained characteristics that can be mapped onto some dimensions or characteristics in our study, c) papers satisfying both a) and b).

Table 5. Comparison of characteristics of this work with the papers in the literature

Dimension	**This work**	**Berger et al [3]**	**Gratsias et al [5]**	**Dombroviak et al [6]**	**Mohammadi et al [7]**
Location based calculation 7	Entities around	Search for objects in proximity	What is around	Proximity awareness	
	nearest		Nearest		
	Shortest route, Alternative routes	Routing*	Routing*		Navigating*
Location based task 7	Guide me		Guide me		Mobile resource allocation*
	Send to person		Find me		
	Meet moving person		Get together		
	locate	Localization of person, object, and places		Absolute location	Positioning, Locating, searching
	Check presence in space			Space awareness*	
	track				Tracking
	Location based notification*			Transition awareness	
				Event awareness*	

Software task 5	Get state			Object awareness*	
	Event notification			Event awareness*	
Entity content 6	Geographic object*	Restaurants, sightseeing, shopping. Traveling conditions			Identify characteristics of a place, check events occurring at a place
	Physical object			Object awareness*	
	Virtual object*	Available entertainment possibilities, current events, night life.			
Location related content 4	Geographic object				Identify search properties of a place
	Physical object			Object Awareness*	

Table 5 shows the characteristics found in papers of type a) and c). Column 1 is for the dimensions of our work. For each dimension and paper, we have a set of characteristics. In a dimension cell we put the number of characteristics in our paper for this dimension; if this number is bigger than the number of characteristics for the dimension for every paper not of us, then this means that there are characteristics of us for the dimension not found in the related work.

Characteristics in the same row are either similar or more general; we put the character '*' in the 2nd case. For instance, *routing* is more general than *shortest route* or *alternative routes*; *space awareness* is more general than *check presence in space*. Some characteristics are used in more than one dimension. E.g., *object awareness* is used in 3 dimensions, and is more general than *physical object* and *get state.*

Now, we look at papers of type b). There are some papers that consider a characteristic for information (i.e.: *pull services* in [4, 7], and *reactive services* in [8]); these characteristics of information are refined in our work with the dimensions: *user information*, *entity content*, and *location related content*. There are some papers that consider the characteristic *push services* ([4, 7]); this characteristic is refined in our work with the characteristics: *location-based notification* (in *location-based* task), *event notification* (in *software task*), and *notification* (in commercial task).

The characteristics of *commercial task* dimension can be found in papers considering taxonomies in the field of mobile commercial applications (see [16, 17]); these taxonomies contain more characteristics than the ones we found for LBS; for instance, we have not found *banking*, *brokerage*, and *pre-pay*.

Application areas that are related to communication services are: mobile 2.0 apps, web 2.0 applications, and social web applications. We have found characteristics in the following papers about these areas: [18, 19, 20]. Characteristics of these papers not found by us in LBS and LBS papers we examined are the following: commenting (content), voting, send a gift (to a friend or contact). The other characteristics we

found in these papers are generalized by characteristics of us. For instance, *invitation* (to join a group, to participate in an event, to an activity), *friend request*, *social posting* (i.e.: data flow to a single user in a community pool) are generalized by our characteristic *to me*; for example, characteristics *accept* (invitation), *reject* (invitation), and *direct message* are generalized by our characteristic *to one*.

7 Conclusion

Comparing our results with existing taxonomies in the literature, we found 3 new dimensions (with 19 characteristics in them): *user information*, *commercial task*, and *communication task*. In addition, for existing dimensions in the literature we found 11 new characteristics. We found:

- Dimensions for which scarce characteristics were provided in the found related work: *software task* (we added *configure*, *perform command*, and *get monitoring output*) and *location related content* (we added *person* and *physical object*).
- Dimensions for which several characteristics were provided in the related work found, but we discovered some new characteristics: *location-based calculation* (we added *route estimators*, *movement estimators*, and *statistics*), *entity content* (we added *acquaintance*, *service provider*, and *application*).

Some characteristics in the literature were divided by us into smaller characteristics/dimensions for facilitating the identification of functions of a LBS. For instance, the *pull services* characteristic was decomposed into *user information*, *entity content*, and *location related content* dimensions. The *push services* characteristic was decomposed into *location-based notification*, *event notification*, and *commercial task notification* characteristics (in different dimensions).

In addition, for facilitating systematic function identification for a LBS group app, for 8 of the most common LBS groups we say which dimensions to consider, and for each of these dimensions we say which characteristics are mandatory and which have been used by some apps of the group but not all of them.

For the related domains commercial applications, mobile 2.0 apps, and social web applications we found a set of characteristics (in our taxonomy) that are valid for LBS; we also mentioned some functions of these domains that were not encompassed by our characteristics; we admit that we do not know if some of them are used now or will be used in the future; the reason is that we did not find them in the sample of LBS apps we considered and in the found papers about taxonomies for function identification in the field of LBS.

With this paper the practice of finding functions for a LBS using a taxonomy changed in the sense that we found new dimensions and characteristics to consider. Moreover, the practice of finding functions for a LBS group app changed in the sense that we consider which dimensions of our taxonomy are used by the group, and for each of these dimensions we say which characteristics can be used by the group; the purpose is having a systematic way for identifying non typical functions of a LBS group in addition to the mandatory ones.

8 References

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