# TAXONOMY DEVELOPMENT IN INFORMATION SYSTEMS: DEVELOPING A TAXONOMY OF MOBILE APPLICATIONS

Nickerson, Robert C., San Francisco State University, College of Business, San Francisco, CA 94132, USA, RNick@sfsu.edu

Muntermann, Jan, Goethe-University Frankfurt, Grüneburgplatz 1, 60323 Frankfurt, Germany, muntermann@wiwi.uni-frankfurt.de

Varshney, Upkar, Georgia State University, 35 Broad Street, Atlanta 30302-4015, Georgia, USA, uvarshney@gsu.edu

Isaac, Henri, Université Paris Dauphine, DRM UMR n° 7088 CNRS, 75775 Paris Cedex 16, France, henri.isaac@dauphine.fr

## Abstract

*The complexity of the information systems field often lends itself to classification schemes, or taxonomies, which provide ways to understand the similarities and differences among objects under study. Developing a taxonomy, however, is a complex process that is often done in an ad hoc way. This research-in-progress paper uses the design science paradigm to develop a systematic method for taxonomy development in information systems. The method we propose uses an indicator or operational level model that combines both empirical to deductive and deductive to empirical approaches. We evaluate this method by using it to develop a taxonomy of mobile applications, which we have chosen because of their ever-increasing number and variety. The resulting taxonomy contains seven dimensions with fifteen characteristics. We demonstrate the usefulness of this taxonomy by analyzing a range of current and proposed mobile applications. From the results of this analysis we identify combinations of characteristics where applications are missing and thus are candidates for new and potentially useful applications.*

*Keywords: Taxonomy, Taxonomy Development, Mobile Application, M-Commerce, Mobile Business.*

## 1 INTRODUCTION

A fundamental problem in many disciplines is classifying objects of interest into taxonomies. Biology has studied this problem extensively and developed a number of classification schemes that order the complexity in the living world and provide a foundation for biological research. In the management science and information systems fields, the importance of taxonomies is well recognized. Several taxonomies exist in various domains, including manufacturing services (e.g., Miller and Roth 1994) and decision support systems (e.g., Alter 1977). These taxonomies provide fundamental research foundations in the form of a common domain language in which problems and their solutions can be defined and explored.

Although the process of developing a taxonomy has been studied in a number of disciplines (e.g., Sokal and Sneath 1963 and Eldredge and Cracraft 1980 in biology; Bailey 1994 in the social sciences), little has been written about this process in the field of information systems. A well-conceived method for developing taxonomies in information systems would serve as a basis for developing new taxonomies that could bring order to complex areas and potentially lead to new research directions. The purpose of this research-in-progress paper is to present such a method and to demonstrate its applicability by developing an exemplary taxonomy.

We apply our taxonomy-development method to mobile applications. We have chosen this domain because of its increasing complexity with many mobile applications existing today and new applications appearing regularly. Users, researchers, and developers need to be able to determine where a new mobile application fits with existing applications in order to determine if it is something entirely new and unique, a significant variation of an existing application, or just a retread of what we already have. A taxonomy of mobile applications would provide a basis for making this determination and could point out voids where new applications might be developed.

This paper is organized as follows. First, we discuss our research approach (section 2). Then we review the literature related to taxonomy development (section 3) before presenting our method for developing taxonomies in information systems (section 4). Next we review existing mobile application taxonomies (section 5) and demonstrate the use of our taxonomy development method to develop a new taxonomy of mobile applications (section 6), which we present in detail (section 7). Finally we show how our mobile application taxonomy can be used to analyze current and future applications (section 8) before summarizing our results and providing suggestions for future research (section 9).

# 2 RESEARCH APPROACH

This paper is based on the design science research paradigm that aims to address new knowledge about artificial (i.e., man made) objects that are designed to meet certain goals and provide utility to their users (Simon 1969). March and Smith (1995) present four kinds of contributions (artifacts) and two characteristic processes (research activities) that characterize design science research in IS.

The four central research outputs are *constructs*, *models*, *methods*, and *instantiations*. As a most fundamental artifact type, constructs define a conceptual vocabulary that provides the basis for representations of problem domains or for the construction of models. Models describe the relationship among developed constructs, that is, they describe how things are. Methods describe a set of defined steps to provide a solution to a given task. Finally, instantiations are implementations that operationalize other artifacts. As system architectures or system designs, they demonstrate the feasibility and applicability of the models and methods developed.

The two processes that characterize design science research are *artifact building* and *artifact evaluation*. Since utility is of vital importance, design science research aims at developing novel artifacts and suitable evaluations that assess the artifact's appropriateness to contribute to the problem's solution (Nunamaker et al. 1991).

We present a method that provides guidance for researchers developing a taxonomy for a specific domain. This method is an artifact that serves as a basis for future design science research, the purpose of which is to develop new taxonomies. Such new taxonomies are artifacts (models) in themselves.

We use the two processes of design science in our research. First we build an artifact (method) for developing new taxonomies. The process of taxonomy development is a complex task because the explanatory power of a taxonomy that constitutes its usefulness to users depends on a well-defined set of dimensions. The method we present guides users on how to define these dimensions.

Second we evaluate the artifact (method) we have built by using it to develop a taxonomy that describes and classifies existing or future objects in a specific domain in a sensible way. The domain we have chosen is that of mobile applications, an important research area in IS (March et al. 2000).

The result of the second step is an artifact (the taxonomy) that is subject to evaluation. Therefore, we evaluate the taxonomy by assessing its efficiency to classify objects in the problem domain of interest (i.e., existing and proposed future mobile applications). Evaluation results then provide evidence if it is necessary to redefine the underlying dimensions of the taxonomy.

# 3 TAXONOMY DEVELOPMENT

Suitable taxonomies play an important role in research and management because the classification of objects helps researchers and practitioners understand and analyze complex domains. The reduction of complexity and the identification of similarities and differences among objects are major advantages provided by taxonomies (Bailey 1994). Furthermore, taxonomies enable researchers to study the relationships among objects and, therefore, to hypothesize about these relationships. As a vocabulary of a domain and as a set of defined constructs, taxonomies can add to the IS knowledge base and therefore lay the basis for future research approaches (Hevner et al. 2004; March and Smith 1995).

Developing a taxonomy is a complex process. Biology, with its well-known taxonomy of living organisms, provides some guidance. The traditional Linnaean taxonomy, commonly found in biology textbooks, classifies organisms based on a predefined hierarchy of categories from kingdom to species. Determining where a new organism falls in the taxonomy involves identifying into which classification the organism fits at each level of the hierarchy. Biological taxonomy development also includes phenetics and cladistics. *Phenetics*, also called numerical taxonomy, involves classifying organisms solely on the basis of their similarity. Characteristics are identified and organisms with similar characteristics are clustered using statistical methods to distinguish them from other organisms (Sokal and Sneath 1963). *Cladistics*, on the other hand, looks at the evolutionary relationships among organisms, not just their common features (Eldredge and Cracraft 1980). Thus two organisms may be closely related in a cladistic taxonomy because they have a common ancestor even though they do not share certain characteristics, thus putting them in different groups in a phenetic analysis.

Bailey (1994) provides a thorough review of taxonomy development in the social sciences. Bailey makes a distinction between a typology and a taxonomy, saying that the former is derived conceptually or deductively and the later is derived empirically. In the conceptual typology approach, the researcher may propose a typology of categories or *types* based on a theoretical ideal or model. In the process the researcher could define an *ideal type*, which Bailey (citing Weber 1949) explains is the "extreme" or "nirvana" of types. The ideal type is used to examine empirical cases in terms of how much they deviate from the ideal. Alternatively, the researcher could define a *constructed type*, which, as Bailey (citing McKinney 1966) explains, is not the ideal but based on reference to empirical cases. The constructed type is used to examine "exceptions" to the type. The ideal type can be compared to the highest value in a set of data (assuming highest is best) whereas the constructed type can be compared to the mean of the data (Bailey 1994, 23).

In the conceptual taxonomy approach the proposed classification is not based on empirical data, although such data could be brought in toward the end of the process. The empirical approach, on the other hand, starts with data and derives the classification from this data using cluster analysis or other statistical methods (Bailey 1994, 34). The goal is to find similarities among the data and to classify similar objects into the same category. Each category in the resulting taxonomy is called a *taxon* (plural *taxa*). Using the concepts from biology, this approach is phenetic.

Bailey (1984) describes the approaches just examined as different levels – conceptual and empirical – of a two-level model. Although researchers can approach classification through either level, he suggests that a common and often more useful approach is to use a three-level model that includes conceptual, empirical, and *indicator* or *operational levels*. In this method the researcher has two choices. One is to start with the deductive approach and then to examine empirical cases (deductive to empirical) to see how they fit with the conceptualization. The other choice is to start with empirical data clusters and then to deductively conceptualize the nature of each cluster (empirical to deductive).

# 4 AN APPROACH TO TAXONOMY DEVELOPMENT IN INFORMATION SYSTEMS

We now present our approach to taxonomy development for objects in the information systems field. Following the design science paradigm, we are building an artifact that is a method.

We choose to use the term taxonomy for our classification because it is more common and recognizable than the term typology, although we recognize that the later may be more correct in some situations. We define a taxonomy T as a set of n dimensions $D_i$ (i=1, … , n) each consisting of $k_i$

($k_i \geq 2$) mutually exclusive and collectively exhaustive characteristics $C_{ij}$ (j=1, … , $k_i$) such that each object under consideration has one and only one $C_{ij}$ for each $D_i$. The goal is to develop a taxonomy with a set of dimension each consisting of a set of characteristics that sufficiently describes the objects in a specific domain of the information systems field.

Our purpose is to develop a useful taxonomy, but not necessarily a best or optimal one, as the later may be a moving target that could change over time as information systems evolve. A review of the literature found little help identifying metrics for evaluating taxonomies. Indeed, Bailey (1994, p. 2) makes this clear when he repeatedly asks which of his example classifications is "best" without giving guidance for finding the answer other than saying that "a classification is no better than the dimensions or variables on which it is based." Thus we are left on our own to define a useful taxonomy. We proposed that a useful taxonomy has the following desirable attributes:

- It should be concise. It should contain a limited number of dimensions or a limited number of characteristics in each dimension, because an extensive classification scheme with many dimensions and many characteristics would be difficult to comprehend and difficult to apply.
- It should be sufficiently inclusive. It should contain enough dimensions and characteristics to be of interest. For example, a taxonomy with only one dimension and two characteristics within that dimension would not be very interesting. This attribute can conflict with the conciseness attribute.
- It should be comprehensive. It should provide for classification of all current objects within the domain under consideration.
- It should be extendible. It should allow for additional dimensions and new characteristics within a dimension when new types of objects appear.

Our approach to developing a taxonomy is phenetic, looking at the characteristics of the objects being examined. We do not look at the evolutionary development of the objects, and thus our approach is not cladistic. Our approach uses Bailey's three-level indictor model in which we combine both the empirical to deductive approach and the deductive to empirical approach.

Before starting to develop a taxonomy, the researcher must decide on the most comprehensive or *meta-characteristic* that will serve as a basis for the classification. The choice of the meta-characteristic should be based on the purpose of the taxonomy. For example, assume that the researcher is trying to classify computer platforms (hardware and operating system) into a taxonomy. If the researcher's purpose is to distinguish platforms based on processing power, then the meta-characteristic is the hardware and software characteristics, such as CPU power, memory, and operating system efficiency, that impact measures of power such as speed and capacity. On the other hand if the researcher's purpose is to distinguish among computer platforms based on how users use them, then the meta-characteristic is the capability of the platform to interact with users, such as the number of simultaneous users and user interface. The choice of the meta-characteristic must be done carefully as it impacts critically the resulting taxonomy. Further investigation of the selection process is needed.

We see meta-characteristics appearing research that develops taxonomies for various purposes, although they are not identified as such. For example, Nickerson (1997) develops a taxonomy of collaborative applications based on the meta-characteristic of communication among group members. Williams, Chatterjee, and Rossi (2008) choose two meta-characteristics – design and objectives – in developing their taxonomy of digital services. Leem, Suh, and Kim (2004) develop a classification scheme for mobile business models based starting with the meta-characteristic of "business players."

We find Bailey's (1984) three-level indicator model to be most appealing for the development of taxonomies in the information systems field. It does not take a single approach but relies on both deduction and empiricism. We do not propose that our approach is the best or only taxonomy development method in the information systems field, only that that it follows from the taxonomy development literature and is practical.

Figure 1 shows the approach that we propose based on Bailey's model. The researcher begins by examining a subset of objects that he/she wishes to classify. These objects are likely to be the ones with which the researcher is most familiar or that are most easily accessible, possibly through a review of the literature. Next the researcher identifies general characteristics of these objects. In what ways are objects similar? What distinguishes objects from each other? Identification of these characteristics leads to the first effort at a taxonomy. The characteristics are grouped into dimensions that form the initial taxonomy. Each dimension contains characteristics that are mutually exclusive and collectively exhaustive. For example, dimension $D_1$ may group characteristics $C_{11}$, $C_{12}$, and $C_{13}$ and dimension $D_2$ may group characteristics $C_{21}$ and $C_{22}$. All objects have one and only one of the characteristics $C_{1j}$ in dimension $D_1$ and one and only of the characteristics $C_{2j}$ in dimension $D_2$. Some dimensions may be dichotomous (e.g., $D_2$) and some may not be (e.g., $D_1$). This process is based on the (limited) empirical data that has been gathered about objects and the deductive conceptualization of the researcher. Thus, up to this point the process follows Bailey's empirical to deductive approach.

Now the researcher reviews the first taxonomy to look for additional conceptualizations that might not have been identified or even present in the original empirical data. In the process new characteristics may be deduced that fit into existing dimensions or new dimensions may be conceptualized each with their own set of characteristics. It may even be the case that some dimension or characteristics are combined so that fewer dimension and/or characteristics result. The researcher examines empirical cases using the new characteristics and dimensions to determine their usefulness in classifying objects. Out of this step comes a revised taxonomy. This process follows Bailey's deductive to empirical approach. The researcher then repeats the empirical to deductive and deductive to empirical approaches, as appropriate, until the researcher is sufficiently satisfied that the taxonomy has the attributes of conciseness, sufficient inclusiveness, comprehensiveness, and extendibility. Such closure is subjective and difficult to define; further investigation is needed to clarify it.

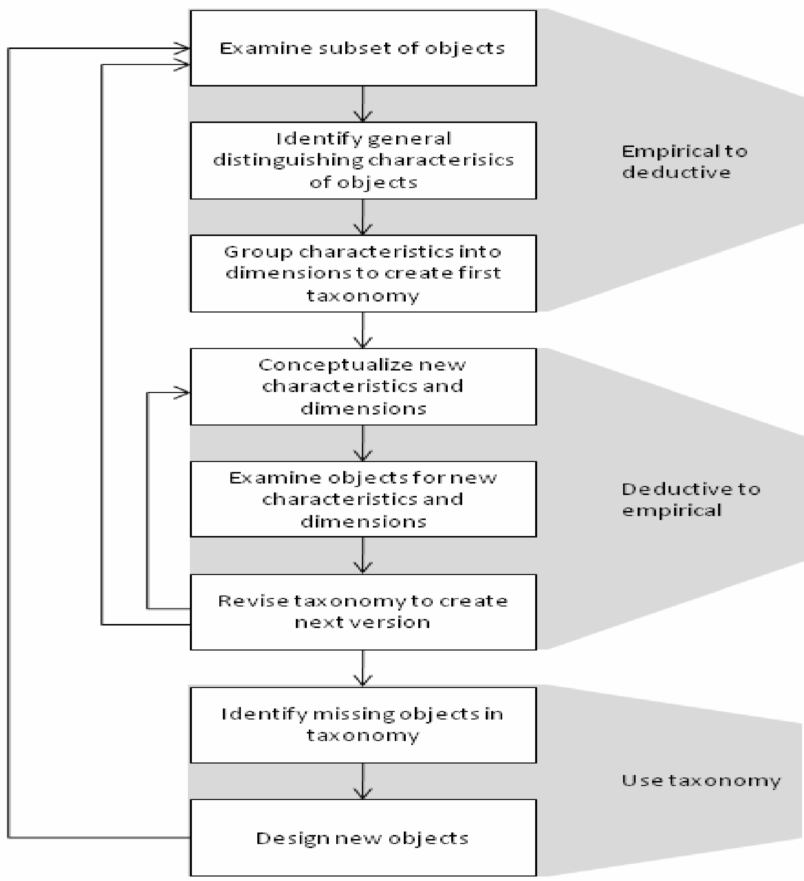


*Figure 1. The taxonomy development method*

Figure 1 also shows how the taxonomy could be used after it is completed. One use could be to identify missing objects in the taxonomy. For example, there may be no objects that have certain characteristics, such as $C_{12}$ in dimension $D_1$ and $C_{21}$ in dimension $D_2$. There are several reasons for such a situation. The characteristic or combination of characteristics might be undesirable for the objects under consideration or it might be difficult or infeasible to create an object with the characteristic(s). Alternatively, no one may have thought of creating an object with the specific characteristic(s). In this situation, researchers or practitioners may try to create objects with the missing characteristics, thus expanding the set of objects in the domain. If this process continues long enough new objects may start to appear that do not fit in the taxonomy resulting in the need to start the taxonomy development process over again from the beginning.

# 5 MOBILE APPLICATION TAXONOMIES

Before using our method to develop a taxonomy of mobile applications we review the literature on the subject. Unfortunately, in mobile commerce and mobile business there exist little research on taxonomies. Only a few taxonomies have been proposed (e.g. Lehmann and Lehner 2002, Okazaki 2005), and there is a lack of a general taxonomy of mobile applications.

Kemper and Wolf (2002) propose a taxonomy based on a three-dimensional classification scheme. The chosen dimensions are degree of innovation, speed of development, and risk, and a set of characteristics focused on mobile application development. The taxonomy is narrowed down to the development process and does not feature the specific characteristics of mobile applications.

Leem et al. (2004) develop a hierarchical classification scheme based on mobile business models. In a first step, they partition into the two dimensions of B2C and B2B/B2E business models. They subdivide each of these dimensions into further dimensions. Their approach enables practitioners and researchers to classify mobile applications from a business model perspective. Thus it can support managerial decision-making and be a basis for mobile business model research. Their approach, however, focuses on a specific perspective and does present general mobile application classifications.

A basic two-dimensional classification scheme of mobile services is suggested by Nysveen and Thorbjørnsen (2005). They group services by type of interactivity and process characteristics. Both dimensions feature binary categories (person- vs. machine-interactive and goal-directed vs. experimental) only. The resulting fourfold scheme provides limited descriptive power. Williams, Chatterjee, and Rossi (2008) also discuss a taxonomy of digital services, but not just mobile services.

Heinonen and Pura (2006) developed a classification scheme for mobile services from a customer-centric perspective that is based on the four dimensions of type of consumption, context, social setting and relationship. Identifying industry specific classification as a limitation of their taxonomy, they suggest further research towards a more general taxonomy of mobile applications.

Dombroviak and Ramnath (2007) present a taxonomy that focuses on applications they call "mobile, pervasive," which they characterize as "an application integrated with its physical environment and/or aware of its location." Their taxonomy consists of six general dimension – transitionality, time constraints, goal, collaboration, lifetime, and centricity – and seven location and location-related awareness dimensions – absolute location, space, proximity, transition, event, object, and operational.

Finally, Dobson (2004) does not classify applications per se, but instead provides a detailed classification of location in pervasive computing. He gives seventeen types of answers to the question of where someone or something is, ranging from absolute position to unknown, and organizes these answers into hierarchical taxonomy of location.

# 6 DEVELOPMENT OF A TAXONOMY OF MOBILE APPLICATIONS

With this background we now apply the approach described previously to develop a taxonomy of mobile applications. Again, using the design science paradigm we are validating the artifact (method) built previously by using it to develop another artifact, specifically a model.

We define a mobile application as a use of a mobile technology by an end-user for a particular purpose, e.g., purchase a ring tone, check a weather forecast, transfer funds at a bank, make an airline reservation. Mobile applications are provided by mobile services that have the infrastructure necessary to deliver the application. A mobile service, however, may provide several different applications under the umbrella of one service. For example, a mobile service may provide information about popular music and sell MP3 music files. For this paper we view these as two different applications – one, an informational application, and the other, a transactional application – both provided by one service.

We are interested in the use of applications, not in their hardware/software characteristics such as type of mobile device used or speed of network connection. We want to be able to use our taxonomy to identify how users use applications currently or may use applications in the future. Specifically, the purpose of our taxonomy is to distinguish among mobile applications based on how the user interacts with the application. Such a taxonomy will be able to help us identify whether new applications are truly unique from the user's perspective and where applications do not exist in the taxonomy suggesting opportunities for new applications. Thus the meta-characteristic for our taxonomy development process is the interaction between the user and the application.We start by listing a number generic mobile applications derived from the literature (Varshney and Vetter 2002, Varshney 2007). We note that this list is not exhaustive.

- Mobile communications
- Mobile messaging
- Mobile navigation
- Mobile TV
- Purchasing location-based contents
- Mobile inventory management for a company
- Product location and tracking for individuals
- Mobile auctions & financial services
- Mobile games – individual
- Mobile games – group
- Mobile advertisement user – specific
- Mobile advertising – location-specific
- Mobile entertainment services (contents-on-demand, live events)
- Mobile personal services (mobile dating)
- Mobile distance education – offline
- Mobile distance education – online
- Mobile product recommendation
- Mobile telemedicine and patient monitoring
- Mobile ticketing
- Mobile communities
- Mobile emergency/safety management
- Mobile habitat/environmental monitoring
- Mobile social networking

We begin by noting certain user interaction characteristics of these applications. With some applications users interact synchronously (in real time) with information flowing from the application to the user and with the user engaging in financial transactions. An example of this type of application is purchasing location-based contents such as weather information. With other applications users interact asynchronously (not in real time), they only report information to the application, and they do not engage in a financial transaction. An example is mobile inventory management. We continue by finding other applications with these characteristics. Once we gain confidence that we have identified some distinguishing characteristics, we group these characteristics into dimensions as follows:

- Temporal dimension: synchronous and asynchronous characteristics
- Communication dimension: informational and reporting characteristics
- Transaction dimension: transactional and non-transactional characteristics

At this point we have our first taxonomy, which we have derived using an empirical to deductive approach. Reviewing the taxonomy we deduce that the communication dimension may also have a bi-directional characteristic in which information flows from the application to the user and from the user to the application. We find that some applications (e.g., mobile auctions) have this communication characteristic. We call this characteristic interactional and add it to the communication dimension:

- Communication dimension: informational, reporting, and interactional characteristics

We have modified our taxonomy using a deductive to empirical approach. We continue in this way to develop newer versions of the taxonomy, going either from empirical cases to deduction or deduction to empirical cases. For example, we speculate that some applications can interact with anyone, that is, they are public, and some applications can only be used by individuals who have certain privileges such as those who work for a company, that is, they are private. We identify instances of these types of application. For example, purchasing location-based contents is a public application and mobile inventory management is a private application. Thus we add another dimension to the taxonomy:

- Public dimension: public and private characteristics

This new dimension creates the next version of our taxonomy. We continue in this way until we are satisfied that we have identified dimensions with characteristics for a taxonomy with the attributes of conciseness, sufficient inclusiveness, comprehensiveness, and extendibility. Deciding when to end the taxonomy development process is highly subjective.

Rather than continuing with a detailed description of the development process we present in the next section our final taxonomy of mobile applications that we derived by following this iterative process.

# 7 A PROPOSED TAXONOMY OF MOBILE APPLICATIONS

Our taxonomy of mobile applications is based on the meta-characteristic of the interaction between the user and the application. It consists of seven dimensions, some of which have already been described. We summarize all the dimensions and their characteristics here. For another discussion of these dimensions see Nickerson, Varshney, Muntermann, and Isaac (2007).

Temporal dimension. The user can interact with some mobile applications in real time, meaning that the application services the user's request almost immediately, whereas the interaction between the user and the application may be deferred in other applications. The temporal dimension identifies when the user and the application interact. It has the following characteristics:

- Synchronous: user and application interact in real time
- Asynchronous: user and application interact in non-real time

Communication dimension. Information may flow uni-directionally between the user and the application or bi-directionally. The communication dimension relates to which way information flows as the user interacts with the application. Its characteristics are as follows:

- Informational: information flows only from the mobile application to the user; uni-directional information flow to the user; information push from the application to the user
- Reporting: information flows only from the user to the mobile application; uni-directional flow from the user; information pull by the application from the user
- Interactional: information flows in both directions between the user and the mobile application; bi-directional flow between user and application; information push and pull

Transaction dimension: Some mobile applications all users to purchase goods or services, normally through a financial transaction, while others do not. The transaction dimension captures this characteristic of the user interaction. This dimension has the following characteristics:

- Transactional: user can purchase goods or services through the application
- Non-transactional: user cannot purchase goods and services through the application

Public dimension: Mobile applications may be available to the general public, or their use may be limited to members of specific groups, such as certain employees of a business. The public dimension relates to whether the application is generally available. Its characteristics are the following:

- Public: application can be used by any user; may be limited to a group but any user may self-select to be part of the group that uses the application
- Private: application can only be used by a pre-selected (by a third party) group of users

Multiplicity (or participation) dimension: Although mobile applications can be used by many users simultaneously, users are often not aware of this characteristic and view their use of the application as singular. With some applications, such as multiple user mobile games, the user knows that he or she is part of a multiple-user community using the application. The multiplicity dimension captures this concept of individual or multiple user interaction with the following characteristics:
- Individual: one user; user experiences the application as if he/she were the sole user
- Group: multiple users; users view use of the application as part of a group

Location dimension: Some mobile applications provided customized information or functionality based on the user's location, whereas other applications do not depend on where the user is located. The location dimension deals with whether the location of the user is used to modify the interaction of the application with the user. It has the following characteristics:
- Location-based: mobile application uses the user's location
- Non-location-based: mobile application does not use the user's location; the mobile application may know the user's location but it does not use this knowledge to modify the user interaction

Identity dimension: Like the location dimension, some mobile applications adjust their information or functionality based on an awareness of who the user is, whereas other applications do not depend on the user's identity. The identity dimension relates to whether the identity of the user is used to modify the way the application interacts with the user application based on the user's identity. This dimension has the following characteristics:
- Identity-based: mobile application uses the user's identity
- Non-identity-based: mobile application does not use the user's identity; the mobile application may know the user's identity but it does not use this knowledge to modify the user interaction

# 8 USE OF MOBILE APPLICATION TAXONOMY

The final steps in our taxonomy development process are to use the taxonomy to analyze objects of interest. Table 1 lists the generic mobile applications identified earlier (not an exhaustive list) and the characteristics of each application using the dimensions we have identified in our taxonomy. The decisions to identify characteristics for an application in this table are based on our understanding of each application. It is possible that variations of the applications may exist or become available in the future with different characteristics. Such variations can be easily added along with new applications.

We observe several things from this table:
1. There are a large number of generic mobile applications and some applications exist in more than one variation to suit different requirements.
2. The use of seven dimensions and fifteen characteristics appears to be sufficient to describe an application. These dimensions and characteristics also are helpful in differentiating among or classifying diverse applications.
3. There are an approximately equal number of synchronous and asynchronous applications in this lest. In the future, new applications could emerge that will be "preferred" to run in synchronous mode, but if network infrastructure is experiencing high traffic load, these applications could adjust to run in asynchronous mode.
4. Only two applications in this list are reporting. Although the current needs of the user for reporting may be met via PC or laptop, it is expected that such requirements will move to handheld devices as many other applications have moved in the past. Thus more research could be done in designing mobile applications that have the reporting characteristic. Many of the reporting applications may be followed by user actions supported by one or more other mobile applications.
5. There is a good balance of transactional and non-transactional applications in this list.

| Applications | Temporal | | Communication | | | Transaction | | Public | | Multiplicity | | Location | | Identity | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | AS | INF | RP | INT | T | NT | PU | PR | I | G | LB | NLB | I | NI |
| Mobile communications | X | | | | X | | X | | X | X | | | X | X | |
| Mobile messaging | | X | X | | | | X | | X | X | | | X | X | |
| Mobile navigation | X | | X | | | | X | X | | X | | X | | | X |
| Mobile TV | X | | X | | | | X | X | | X | | | X | | X |
| Purchasing location-based contents | X | | X | | | X | | X | | X | | X | | X | |
| Mobile inventory management for a company | | X | | X | | | X | | X | X | | X | | X | |
| Product location and tracking for individuals | | X | X | | | | X | X | | X | | X | | | X |
| Mobile auctions and financial services | | X | | | X | X | | X | | | X | | X | X | |
| Mobile games-individual | X | | | | X | X | | X | | X | | | X | X | |
| Mobile games-group | X | | | | X | X | | X | | | X | | X | X | |
| Mobile advertisement-user specific | | X | X | | | | X | X | | X | | | X | X | |
| Mobile advertisement-location-specific | | X | X | | | | X | X | | X | | X | | | X |
| Mobile entertainment services | X | | X | | | X | | X | | X | | X | | | X |
| Mobile personal services | | X | | | X | X | | X | | X | | | X | | X |
| Mobile distance education-offline | | X | | | X | | X | X | | X | | | X | X | |
| Mobile distance education-online | X | | | | X | | X | X | | X | | | X | X | |
| Mobile product recommendation systems | | X | X | | | | X | X | | X | | | X | | X |
| Mobile Telemedicine and patient monitoring | X | | | | X | | X | X | | X | | | X | X | |
| Mobile ticketing | | X | | | X | X | | X | | X | | | X | | X |
| Mobile communities | | X | | | X | | X | X | | | X | | X | | X |
| Mobile emergency/safety management | X | | | | X | | X | X | | | X | X | | | X |
| Mobile habitat/ environmental monitoring | X | | | X | | | X | X | | | X | X | | | X |
| Mobile social networking | | X | | | X | | X | | X | | X | | X | X | |

*Table 1. Characteristics of selected generic mobile applications*

6. There are only four private applications in this list, although several applications can be modified to limit them to private users, including mobile distance education. The overwhelming number of public applications could be because most mobile applications are B2C at this time. As more mobile B2B or B2E applications are developed, there are likely to an increase in applications with the private characteristic.
7. There are six group applications in this list. There may be an opportunity, however, for more new mobile group applications. It should be noted that most of the wireless infrastructure is not designed to support group-oriented applications due to resource and bandwidth limitations and the difficulty in supporting group mobility. Also, the resource and networking requirements may grow non-linearly with an increase in the group size. These factors may hinder the design and development of group-oriented mobile applications.
8. There is a good balance of location and non-location based applications in this list. In practice, the range of location capability varies among wireless networks, from no location management to

some location management in some places to highly accurate location management. With increased use of location technologies such as GPS, RFID, and sensor networks, there will be more infrastructure support for location-based applications.

9. There are fewer non-identity based, or anonymous, applications than identity based applications in this list. More work should be done in designing non-identity based applications. More specifically, some people might be more comfortable conducting transactions and interactions for services/contents if their identity is not known or kept secret.

These observations are based only on the listed applications, which is not exhaustive. As more applications are analyzed using the taxonomy, additional observations may be made. Also work can be done in studying the demographics of the users of these applications and designing applications to suit different age groups with varying requirements. Most of the mobile applications are designed for working adults, but there are opportunities to design new applications for young adults, older adults, and geriatric populations. For example, an application could be developed to fill a void identified in the taxonomy that is a reporting, non-transactional, private, group application for older adults. This application would allow users to report wellness and interesting tidbits from their daily life to a group of geriatric friends who may not be able to meet face-to-face often.

# 9 SUMMARY AND CONCLUSION

This paper describes a method of taxonomy development that can be used in the information systems field. The method, developed by following the design science paradigm and based on the taxonomy development literature, uses an indictor model that combines both empirical to deductive and deductive to empirical approaches. The process is iterative and terminates when the researcher is satisfied that the taxonomy has the attributes of conciseness, sufficient inclusiveness, comprehensiveness, and extendibility.

We evaluate the method by developing a taxonomy of mobile applications with seven dimensions – temporal, communication, transaction, public, multiplicity, location, and identity – and fifteen characteristics. We show that the dimensions and characteristics in this taxonomy are useful by analyzing some current and proposed mobile applications. Using this taxonomy, we identify that there are fewer applications among those considered that have the characteristics of reporting, private, group, and non-identity based, and we suggest that new applications can be designed.

The application of our method to the development of a mobile application taxonomy demonstrates that the method can be a useful approach to taxonomy development. We note, however, that one test of a method is not sufficient to show its ultimate usefulness and that further tests are needed. Our analysis of mobile applications using the mobile application taxonomy shows that the taxonomy resulting from our method is a useful tool for analyzing current and future mobile applications.

Further research in this area can follow several paths. One is to continue to explore the effectiveness of the proposed taxonomy development method by applying it to other domains, possibly resulting in improvements in the method. The second path is to refine the mobile application taxonomy by adding, deleting, changing, or combining dimensions, and to continue to test the taxonomy's efficacy by categorizing more mobile applications. A final research path is to use the results of the analysis in Table 1 or similar tables derived by applying the taxonomy to identify voids that could lead to the design and development of potentially more suitable mobile applications or the redesign of existing applications to better support user needs. The work can be extended in the future by elaborating more on user needs and the current context. We continue to explore all these avenues of research.

# 10 REFERENCES

Alter, S. (1977). A Taxonomy of Decision Support Systems. Sloan Management Review, 19(1), 39-56.

Bailey, K. D. (1994). Typologies and Taxonomies - An Introduction to Classification Techniques. Sage, Thousand Oaks, California.
Bailey, K. D. (1984). A Three-Level Measurement Model. Quality and Quantity, 18, 225-245.
Dobson, S. (2004). A taxonomy for thinking about location in pervasive computing. Technical report TCD-CS-2004-05. Department of Computer Science, Trinity College Dublin.
Dombroviak, K. M. and Ramnath, R. (2007). A Taxonomy of Mobile and Pervasive Applications. Proceedings of the 2007 ACM symposium on Applied computing, 1609-1615.
Eldredge, N. and Cracraft, J. (1980). Phylogenetic Patterns and the Evolutionary Process. Columbia University Press, New York.
Heinonen, K. and Pura, M. (2006). Developing a Conceptual Framework for Mobile Services. Proceedings of the Helsinki Mobility Roundtable 2006.
Hevner, A. R., March, S. T. and Park, J. (2004). Design Science in Information Systems Research. MIS Quarterly, 28(1), 75-105.
Kemper, H. and Wolf, E. (2002). Iterative Process Models for Mobile Application Systems: A Framework. Proceedings of the 23rd International Conference on Information Systems, 401-413.
Leem, C. S., Suh, H. S., and Kim, D. S. (2004). A Classification of Mobile Business Models and its Applications. Industrial Management & Data Systems, 104(1), 78-87.
Lehmann, H. and Lehner, F. (2002). Making Sense of Mobile Applications - A Critical Note to Recent Approaches to their Taxonomy and Classification. Proceedings of the 15th Bled eCommerce Conference, 493-507.
March, S. T. and Smith, G. F. (1995). Design and Natural Science Research on Information Technology. Decision Support Systems, 15(4), 251-266.
March, S., Hevner, A., and Ram, S. (2000). Research Commentary: An Agenda for Information Technology Research in Heterogeneous and Distributed Environments. Information Systems Research, 11(4), 327-341.
McKinney, J. C. (1966). Constructive Typology and Social Theory. Appleton-Centur-Crofts, New York.
Miller, J. G., and Roth, A. V. (1994). A Taxonomy of Manufacturing Strategies. Management Science, 40(3), 285-304.
Nickerson, R. C. (1997). A Taxonomy of Collaborative Applications. Proceedings of the AIS 1997 Americas Conference on Information Systems, 560-562.
Nickerson, R. C., Varshney, U., Muntermann, J., and Isaac, H. (2007). Towards a Taxonomy of Mobile Applications. Proceedings of the Thirteenth Americas Conference on Information Systems.
Nunamaker, J. F., Chen, M., and Purdin, T. D. M. (1991). Systems Development in Information Systems Research. Journal of Management Information Systems, 7(3), 89-106.
Nysveen, H., Pedersen, P. E. and Thorbjørnsen, H. (2005). Intentions to Use Mobile Services: Antecedents and Cross-Service Comparisons. Journal of the Academy of Marketing Science, 33(3), 330-346.
Okazaki, S. (2005). New Perspectives on M-Commerce Research. Journal of Electronic Commerce Research, 6(3), 160-164.
Simon, H.A. (1969). The Sciences of the Artificial. The MIT Press, Cambridge, Massachusetts.
Sokal, R. R. and P. H. A. Sneath (1963). Principles of Numerical Taxonomy. W. H. Freeman and Company, San Francisco.
Varshney, U., Vetter, R. (2002). Mobile Commerce: Framework, Applications and Networking Support. ACM/Springer Journal on Mobile Networks and Applications (MONET), 7(3), 185-198
Varshney, U. (2007). Pervasive Healthcare and Wireless Patient Monitoring. ACM/Springer Journal on Mobile Networks and Applications (MONET), 12(2-3), 113-127
Weber, M. (1949). The Methodology of the Social Sciences. Translated by E. A. Shils and H. A. Finch. Free Press, Glencoe, Illinois.
Williams, K., Chatterjee, S., and Rossi, M. (2008). Design of Emerging Digital Services: A Taxonomy. European Journal of Information Systems, 17, 505-517.