

# A User-App Interaction Reference Model for Mobility Requirements Analysis

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**Abstract**—Contemporary mobile applications (apps) value mobility as a key characteristic that allows users to access services or features ubiquitously. In order to achieve decent mobility, apps shall provide features that are suitable to use under a wide range of contexts. In this paper, we analyze the situational contexts, towards which the mobile apps shall comply with in terms of mobility. By analyzing the contexts and the ways of interaction between users and apps, we propose and illustrate a mobile requirements analysis process model to identify the conflicts between users’ ideal ways of interaction and the way the feature is designed to provide. The identified conflicts help to elicit requirements for the enhancement of the apps’ mobility.

**Keywords**—Mobility; Mobile application; Requirements; Context; Situational Context; Interaction;

## I. INTRODUCTION

The emergence of iOS and Android OS has been changing the mobile industry and people’s daily lives, and been providing new trends in the academic research [1]. Changes in distribution process and mobile software market mechanism lead to better customer accessibility towards mobile apps and inevitable competition [2]. The ranking mechanism also intensifies the competition, demanding mobile apps satisfying users’ diversified demands, which shall be reached in varying situations, compared to desktop software. It thus requires companies to take into account the capability of the mobile applications to provide satisfactory user experience regardless the changing environment [3].

Mobility is one of the most significant and unique features for mobile apps, referring to the ability to access services ubiquitously through wireless networks and various mobile devices [4][5]. The vision of mobility is to be able to work “anytime, anywhere” [6]. However, with limited support of systems towards mobility, the capability of being comfortably used at “anytime, anywhere” of mobile apps is seldom achieved. Thus, achieving mobility shall result in the enhanced competitiveness of mobile apps in terms of user satisfaction.

Contexts, which refers to the information that characterizes the situation of an entity, has a great impact on usability and user experience of mobile apps [7]–[10]. Mobility, as a key aspect of usability of mobile apps, is also affected largely by their context [11], which also influences the way, by which a user interacts with an mobile app [12]. By specifying the ways, in which user and app interact, we analyze their relation towards different contexts. The elicited mobility requirements shall thus reflect suitable interaction ways between users and apps in different contexts.

Many studies analyze the phenomena of use situations concerning mobile commerce [4][13] and other types of mobile apps [14]. But studies on mobility requirements analysis are very limited. A goal-oriented framework for modeling and analyzing requirements for varying contexts was proposed based on the goal model to reason variants [15]. But it fails to address how to identify the varying contexts and derive

requirements regarding the way of interaction. Several other studies [16][17] address challenges and methods of requirements analysis for mobile systems and pervasive services, but lack a concrete proposal on taking varying contexts into account for requirements analysis.

In this study, we focus on the analysis of context of use of mobile apps and the possible ways of interaction between users and an app, and further study the way of analyzing mobility requirements. The paper tries to tackle the following questions.

- RQ1 *What are the contexts that affect the interaction between user and mobile apps?*
- RQ2 *What are the ways in which a user interacts with mobile apps, and what are their relations with different contexts?*
- RQ3 *How to take into account contexts and ways of interaction when analyzing apps mobility requirements?*

The purpose of this research is to enhance the mobility of mobile apps by taking into account the varying contexts in requirement analysis. To answer RQ1, we summarize the definition of mobility and main perspectives of mobile app contexts by reviewing the literature on the concept of mobility and context in Section 2. We also tackle RQ2 by analyzing the relation between the way users interact with mobile apps and different contexts via user-app interaction reference model in Section 3 and 4. In Section 5, we propose our approach to analyzing mobility requirements with a case study for further illustrating and discussing in Section 6, which altogether answers RQ3. Section 7 concludes with implications for future research.

## II. MOBILE APPS AND THEIR MOBILITY REQUIREMENTS

Mobile devices and applications has enabled new freedom and flexibility on the way people communicate, work, and entertain by providing services beyond the constraints of fixed locations and devices. Compared to the old style of using manufacturer provided mobile software, contemporary mobile apps have lower distribution costs and can be more easily accessed by customers via the change in distribution process and mobile software market mechanism [2]. The mechanism stimulates the development of mobile application markets and results in fierce competition with even software on personal computers challenged. Prior to the investigation of the circumstances, under which users would prefer to mobile applications rather than desktop software, the unique mobility characteristics of mobile applications differentiated from those of desktop software shall be understood.

### A. Mobility

Mobility was understood as the human’s independency from geographic constraints or the ability and/or quality to ensure the given entity can move or be moved [18]. Mobility primarily facilitates a mobile device to operate properly when

its location changes. This provides a generic view of how mobility is supposed to be acquired by users when they use mobile apps, and forms a general goal in mobile app development. According to [5], the key feature of mobile technology is the capability of using services on the move, with wireless network and various devices, which provides the literal meaning of mobility. Other similar terms, such as nomadicity, which indicates a system’s capability of providing services to the nomad as he moves from place to place in a transparent and convenient form [6], also reflexes the concept of mobility.

Consequently, mobility is an attribute of both human beings and the computational devices they interact [11]. The mobility of mobile devices refers to the ability to access services ubiquitously, or “anytime, anywhere” through wireless networks and various mobile devices [4][6] and for mobile apps as well. As a critical feature of mobile apps usability, mobility has considerable impact on the interaction between users and mobile devices and apps [19]. Thus, compared to mobility of human beings, mobile app mobility is seen as the usefulness and ease of use provided by the app towards user satisfaction in “anytime, anywhere”.

There are three types of mobility in terms of modality [20], i.e., travelling, visiting and wondering. The mobility towards the usability of mobile apps is hence seen in these three perspectives as well, that is, to provide services when users are traveling, visiting, and wondering. Similar categorization is also given by [21], which describes the motion of mobile app users into none motion, constant motion and varying motion. Besides the categorization of mobility regarding spatial movement, time and context changes also contribute to the mobility attribute provided by mobile apps [18]. In this study, we see all the factors that influence the mobility of the mobile app from outside the app itself as its context.

From the context of use perspective, mobility implies that the app shall provide context-aware features and/or services. Following the definition of the concept of context, i.e., the information that can be used to characterize the situation of an entity [7][8], where an entity can be a place, person, physical or computational object, we define context-aware features as the use of context to provide task-relevant information and/or features, which a user feels easy to use. The situation can be characterized in perspectives, such as location, surrounding changing objects, and people, and can define where you are, who you are with, and what resources are nearby [22][23]. These perspectives can be further refined into users, tasks, equipment (i.e., hardware, software and materials), location, physical environment, temporal context, social environment, technical and information context, etc. and have been intensively addressed and adapted in surveys and research on the context in mobile computing and the impact on the overall design of the product [8][10][17][24]–[28] .

**B. Mobility Requirements Analysis**

We consider mobility as an intrinsic attribute of mobile applications. It refers to the capability of providing receptive and pleasant services acquired by users in spite of the changes in environments. Such an attribute can be refined into different types of requirements contributing to users’ satisfaction. The requirements include functional requirements complementing the main features of an application and supporting users to

fulfill their goals, interface requirements facilitating the interaction between users and the application, as well as constraints on the application.

In addition to analyzing the core features of an application, mobility requirements analysis shall emphasize ease of use in the dynamic environment of use, and focus on analyzing the diversity of context of use and ways of interaction between users and the app. Accordingly, we adapt the generic requirements syntax of Mavin et al.’s EARS model [29] for mobility requirements, emphasizing the context and the interaction with users, as shown below.

In **<situational contexts>**,**<optional preconditions>**  
**<optional trigger>** the **<mobile app name>** shall **<app response>** in **<ways of interaction>**.

The syntax marked in grey is what was specified in the EARS model [29]. It can be further specialized into different types of requirements following temporal logic defined between the precondition, the trigger, the app response, etc. [29]. In addition, the components marked in black are situational contexts and ways of interaction, which highlights the mobility attributes a mobile app shall reflect and the requirements analysis shall take into account. The situational context encompasses a wide range of elements, such as the location and surroundings, the social context, the user’s movement, the temporal context, etc. Combining value of these elements forms a variety of scenarios of using a mobile app. Changes of the scenarios continuously reframe a user’s interaction with a mobile app. Obviously not all scenarios are desired and friendly. The requirements analyst shall be aware of the suitable ways of interaction is adopted towards typical scenarios, which secures users’ satisfaction and receptiveness largely.

**III. A USER-APP INTERACTION REFERENCE MODEL**

Interaction between a user and a mobile app occurs after the user opens the app and before he or she closes it [30]. We call it a user-app interaction. According to the definition of context given by [7][8], the context of a user-app interaction is referred to as the information to characterize the situation of the two entities, i.e., the user and the app. The context is further depicted in Figure 1.

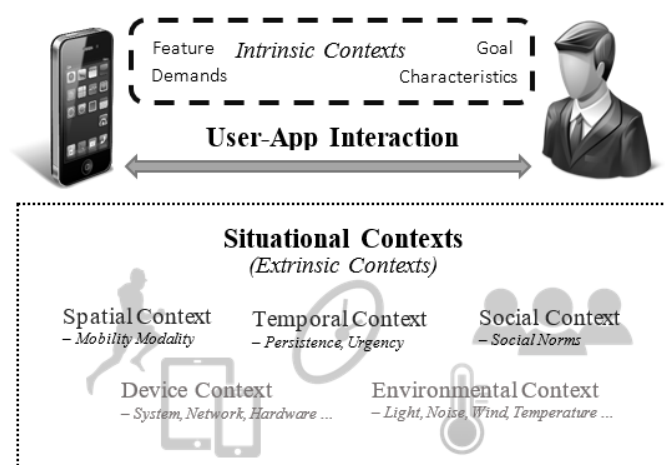


Figure 1. User-App Interaction Reference Model.

The context shall ideally contain all possible situations that affect the user-app interaction. Similar to the contexts categories described in previous studies [17][22]–[24], the ideal context shall contain multiple perspectives including user profile, operating system, hardware system and network, physical context, temporal context, task context, and social context. As shown in Figure 1, we divide the wide range of context into intrinsic and extrinsic ones. The intrinsic context refers to the inner attributes of entities that influence, or occasionally determine the occurrence of a user-app interaction. For example, the features provided by mobile apps and demands for operating them intrinsically determine their usefulness when users' goals and their characteristics determine whether to use. The extrinsic context refers to the external factors that influence a user's decision of his or her engagement in a user-app interaction. The extrinsic contexts, defined also as situational contexts, include device context, environmental context, spatial context, temporal context and social context. The device context (e.g. system, network, hardware, etc.) and the environmental context (e.g. light, noise, wind, temperature, etc.) have been often studied in requirements engineering for self-adaptive software systems [31]. However, the other extrinsic contexts, such as spatial, temporal, and social contexts are rarely discussed in requirements analysis process. Hereby, we focus on these situational contexts to investigate their relations with the mobility attribute of a mobile app.

#### A. Intrinsic Contexts

Many researchers have addressed and verified that a user's demographic properties, such as age, gender, education, income, etc. are relevant factors affecting a user's attitudes and preference to the use of an app [17][28][32]–[34]. Besides the demographic properties, individual users with various interests and attitudes toward the mobile value form other important perspectives influencing a user's engagement in an app activity. Users' adoption to mobile services has been analyzed from the perspectives of a user's characteristics, major value, attitude, and major interests. [28]. Concerning a user-app interaction, the user's goals refer to the objectives of the user at the critical moment when the interaction occurs. For an instance, the goal of a student working on an exam is to pass the exam. It is not only related to mobile applications but also has a wider range than the term described in goal-oriented requirements engineering [35]. Thus the characteristics and goals of the user form the intrinsic and determinant context to the initiation of a user-app interaction [36].

On the other hand, a user-app interaction occurs when a user determines to perform a task associated with a mobile app with a particular purpose, i.e., fulfilling a user's goal. The features of a mobile app contain capabilities that enables users to fulfill their goals by accomplishing the tasks. The user is prone to intrinsically start an interaction with the app when the provided features comply with his or her intention to achieve his or her goal. The demands are defined as the workload that a user is obliged to engage in order to accomplish the task as the demands, which contain six subscales, i.e., mental demand, physical demand, temporal demand, frustration, effort and performance [37]. They define the subjective experience of users on using the app and are affected by the intrinsic contexts of a user-app interaction as well.

#### B. Situational Context Model

The situational context refers to the extrinsic properties of the user and the app that impact the initiation of a user-app interaction. As mentioned above, we only focus on the temporal, spatial and social perspectives to discuss the situational context in this study.

1) *Temporal Context*: Temporality, as one of the dimensions of the mobility concept originally [18], has been influenced by the mobile technology inherently in terms of human interaction. The multiple perspectives of temporality, such as structural and interpretive, monochronicity and polychronicity and so on have been studied previously [18][38]. Compared to the previous frameworks, we argue that the temporality in terms of a user-app interaction is determined by the user's sense of time and the persistence of the app to accomplish one operation session, and define temporal context in this paper as the sense of external time pressure of the user caused by the confliction or the accordance of user's goal and app's demands. Thus, two values of intensive and allocative are used to describe temporal context. Intensive refers to the situation when the user is in urgent need of achieving his or her goal and has limited spare time of interacting with the app (e.g. the user is busy in working on assignments with approaching deadline). Allocative, on the other hand, indicates that the user has no urgent goal to achieve and is temporally available (e.g. the user is staying at home idle).

2) *Spatial Context*: The spatial perspective of mobility indicates the geographic movement of the user when engaged in the interaction with the mobile app [18]. In this study, the spatial context refers to the current movement of the user further indicating the physical availability for the app usage. we adopt the mobile modality types given by [20] categorizing the spatial context, including visiting, traveling and wandering. Visiting context indicate that the user is in a physically stationary status(e.g. sitting in a meeting). Traveling context refers to the situation when the user is in a transportation tool (e.g. a car or train). Wandering, on the other hand, refers to the situation when the user is physically moving from place to place (e.g. walking or running). However, the categorization given by [20] did not specify the difference between driving a transportation tool or sitting in one in terms of traveling perspective. In addition, exercise related scenarios of walking or running is not taken into account either. In this study, these distinctions shall be reflected by the combination with other contexts.

3) *Social Context*: The social context is interpreted by [8][10][17][24]–[28][39] as the influence of other persons' presence and the interpersonal interaction between the user and others. In this study, we interpret the social context of a user-app interaction as the social norms that constrain user from or encourage user into the interaction [40], which contains similar meaning towards the functional place concept in [39]. We define the scale of social context from constraining to encouraging the use of apps based on the social norms. For example, a conference presentation is socially constraining when idleness at home is socially encouraging.

According to the three perspectives of situational context mentioned above, values are assigned to each perspective, combining which leads to a unique context scenario description (shown in Table I).

Ideally, based on the given situational context model, the situational context of user can be described by the combination

TABLE I. VALUES OF SITUATIONAL CONTEXT PERSPECTIVES.

Perspective	Value
Temporal	Intensive, Allocative
Spatial	Visiting, Traveling, Wondering
Social	Constraining, Encouraging

of the three perspectives. The 12 situational contexts include *Intensive-Visiting-Constraining (IVC)*, *Allocative-Visiting-Constraining (AVC)*, *Intensive-Visiting-Encourage (IVE)*, *Allocative-Visiting-Encourage (AVE)*, *Intensive-Traveling-Constraining (ITC)*, *Allocative-Traveling-Constraining (ATC)*, *Intensive-Traveling-Encouraging (ITE)*, *Allocative-Traveling-Encouraging (ATE)*, *Intensive-Wondering-Constraining (IWC)*, *Allocative-Wondering-Constraining (AWC)*, *Intensive-Wondering-Encouraging (IWE)*, and *Allocative-Wondering-Encouraging (AWE)*. For each combination of values from different perspectives, we provide a typical situational context scenario, shown in Table II.

TABLE II. TYPICAL SCENARIOS FOR EACH SITUATIONAL CONTEXT.

Situational Context	Typical Scenario
IVC	In a conference giving presentation
AVC	In a lecture listening
IVE	In a cafe working on assignments with close deadline
AVE	At home idle
ITC	In a car driving with time limit
ATC	In a car driving and sight seeing
ITE	In a train when it is about to arrive at the destination
ATE	In a train idle
IWC	Running in a race
AWC	Wondering in a cocktail party as a host
IWE	Running to catch a bus
AWE	Walking in a park relaxing

In practice, the scenarios that used for describing situational contexts might vary based on the collective understanding of the contexts from the team. For example, the scenario “In a conference giving presentation” and “in a contract signing meeting negotiating” can both be used describing the situational context of IVC.

#### IV. WAYS OF USER-APP INTERACTIONS

The concept of mobility is not only just a matter of people traveling, but also the interaction people perform, that is, the way in which they interact with each other [18]. The mobility is thus reflected in the way in which users interact with the apps. It occurs when an app sends out a notification to the user who responds it and ends when the user finishes using the app and closes it. However, users in different situational contexts, who have different goals and characteristics, will expect to interact with different features of the app differently but comfortably. In order to find the match between the designed and expected ways of interaction, we adapt the dimensions of interaction modality [41][42] discussing the situational characteristics of mobile apps including their obtrusiveness and persistence.

An obtrusive interaction imposes obligation to notice or react [18], which indicates that the interaction is evoked by notifying the user to start it without the user’s internal motivation to do so. For example, an obtrusive interaction is initiated when the user stops original reading activity and responds to the new message notification from WeChat. On the contrary, an unobtrusive interaction is initiated with the user’s internal motivation. For example, the user encounters an unfamiliar term while reading and decides to look it up in Eudic without receiving notification. On the other hand, the

persistence dimension specifies the duration of an interaction, which is largely depending on the time length a user spends on completing an interaction task. An ephemeral interaction requires a short time to achieve user’s goal (e.g. replying a message, looking up a word). A persistent interaction oppositely takes a long period to accomplish (e.g. playing Subway Surfers, listening to Spotify).

With the two dimensions combined, a user-app interaction can thus be described as *obtrusive-persistent (OP)*, *unobtrusive-persistent (UP)*, *obtrusive-ephemeral (OE)*, or *unobtrusive-ephemeral (UE)*. By analyzing the relation between different types of user-app interactions and the way they fit in the process of the way of the user’s original activity, we conclude four ways of interaction, including *intermittent*, *interrupting*, *accompanying*, and *ignoring*.

An intermittent way of interaction refers to the interlaced engagement in both the user’s original task and the user’s interaction towards the mobile app, with the whole process of several short interactions, which are neither consistent nor interfering the proceeding of the original task. For example, when watching TV, the user starts the interaction with WeChat. Within the whole process, the user inconsistently responds messages but his or her task of watching TV remains proceeding. An intermittent way of interaction often consists of a number of ephemeral interactions, which are also mostly obtrusive.

An interrupting way of interaction requires the user to convert full concentration on the interaction and cease the original activity. For example, to start playing Subway Surfers, the user has to stop the original task, such as reading books or watching TV. It can be interpreted as the original task is interrupted by this user-app interaction. An interrupting way of interaction is mostly persistent.

An accompanying way of interaction refers to the paralleling engagement in both user’s original task and the user-app interaction tasks. Comparing to the interrupting or the intermittent way of interaction, the accompanying one will not attract the user’s full attention, as the user does not stop the continuous progress of the original task. For example, when running on a treadmill, the user starts watching films from Netflix. The activity of running is, instead of interrupted, paralleling with the user-app interaction. The interaction can be ephemeral or persistent, depending on the amount of engagement an app requires from the user.

An ignoring way of interaction indicates that the interaction with the mobile app is ignored by the user in order to maintain the proceeding of his or her original task. For example, when taking an examination at school, the user will ignore any types of interaction with the mobile apps.

The relation between different types of user-app interactions and the according ways of interaction is summarized in Figure 2. In Figure 2, the narrow arrows underneath represent the user’s original task, and the thick ones represent the user-app interactions. Lighter gray arrows are the interactions ignored and not executed. In addition, the length of the arrows indicates the timeline of proceeding with the task or interaction.

By analyzing the different ways of user-app interactions, we are enabled to analyze the expected way of interactions towards each mobile app feature. And towards mobility, expected ways of interaction shall comply with the previously

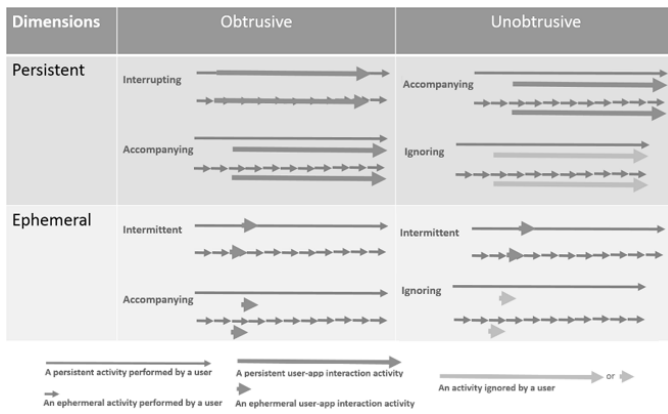


Figure 2. Ways of User-App Interactions

defined situational contexts. Combining this analysis, we shall be able to detect how an app feature is expected to perform in different situational contexts. For requirements analysts, each feature and the refined requirements could be analyzed and mapped into the situational contexts assigned with expected ways of user-app interactions. For example, Table III shows the expected ideal ways of interaction towards given situational context .

TABLE III. IDEAL WAY OF INTERACTION FOR EACH SITUATIONAL CONTEXT.

S.C.	Typical Scenario	Ideal Ways
IVC	In a conference giving presentation	Accompanying
AVC	In a lecture listening	Intermittent
IVE	In a caf working on assignments with close deadline	Intermittent, Accompanying
AVE	At home idle	Interrupting, Intermittent, Accompanying
ITC	In a car driving with time limit	Accompanying
ATC	In a car driving and sight seeing	Accompanying, Intermittent
ITE	In a train when it is about to arrive at the destination	Accompanying, Intermittent
ATE	In a train idle	Interrupting, Intermittent, Accompanying
IWC	Running in a race	Accompanying
AWC	Wondering in a cocktail party as a host	Intermittent
IWE	Running to catch a bus	Accompanying
AWE	Walking in a park relaxing	Accompanying, Intermittent

Table III indicates that in a specific situational context one mobile app feature shall enable users to interact comfortably in the ideal ways of interaction. Taking the situational context scenario of IVC as an example, the ideal way is the accompanying way of interaction. Thus, a mobile app feature which offers such a way of interaction is more likely to be used in this circumstance. For example, the slide presentation feature of Prezi can provide accompanying way of interaction in the IVC context scenario of “In a conference giving presentation”. The typical scenario of situational contexts can be also different. For example, IVC context can also be represented in the scenario of “In a university exam with time limit” or “In a chess competition with time limit for each move”. When a certain feature fails to initiate the ideal ways of interaction, it shall be adjusted at requirement specification level towards the ideal ways. Therefore, a process of identifying such features and specifying the according strategy of mobility enhancing adjustment is required.

V. MOBILITY REQUIREMENTS ANALYSIS PROCESS

The mobility requirements analysis process contains a sequence of pre-defined steps, by following which requirements analysts can specify existing user requirements towards enhanced mobility. The aim of mobility requirements analysis is to provide specified requirements that enable users to use the given features in a satisfied way in the possible situational contexts. As defined previously, a user’s satisfaction for a specific feature is achieved by using this feature in different situational contexts via ideal ways of interactions. Thus the proposed mobility requirements analysis process is to refine existing app features by taking into account the given situational contexts and the according ways of interactions. The process of mobility requirements analysis is described as Figure 3.

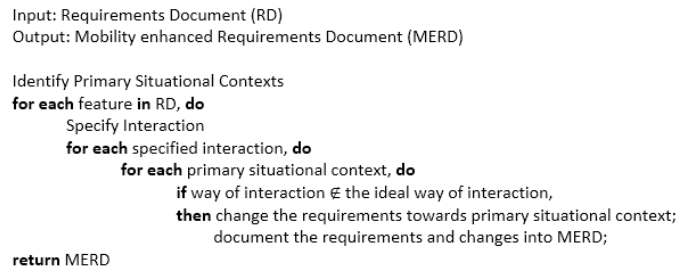


Figure 3. Mobility Requirements Analysis Process.

The analysis process consists of four key steps, as explained below.

Step 1. Identify the Primary Situational Contexts

Mobile apps are meant to satisfy users’ needs in all possible situational contexts in an ideal way. However, mobile apps have distinct visions and features, and cannot comply with every situational context to meet users’ needs. It thus requires the requirements analysts to identify the primary situational contexts by prioritization. The outcome of this activity is a list of prioritized situational contexts, or a number of primary situational contexts.

Step 2. Specify the Expected Way of Interaction for Each Feature

For each feature of the mobile app, requirements analysts shall be able to specify an expected way of interaction, which is expected by users. It means that users will use this feature most comfortably via that way of interaction. The outcome of this activity is a list of features together with expected ways of interaction respectively.

Step 3. Compare the Previous Two Outcomes and Identify the Conflicts

By comparing the outcomes of the previous steps with Table III, we can find the features, of which the expected way of interaction, conflicts with the ideal ones of the primary situational contexts. These conflicts shall be adjusted in the next step to enhance the app’s mobility attribute.

Step 4. Adjust Conflicting Feature towards Mobility Requirements

We diminish the conflicts by changing the requirements related to the feature or adding new ones.

VI. CASE STUDY

By following the steps of mobility requirements analysis process, we are able to identify the features of a mobile app that may contain conflicts against the ideal ways of

interaction in specified primary situational contexts, and also to analyze and adjust the according features towards eliminating the conflicts, hence enhancing their mobility. In this section, we apply our proposed approach to analyzing three mobile apps, WeChat[43], Gmail[44], and AlienBlue[45]. WeChat is a messaging and calling app. It allows users to communicate with friends for free text (SMS/MMS), voice & video calls, moments, photo sharing, and games. Gmail (IOS) is the official mobile app for iPhone and iPad. It supports real-time notifications of new mails, multiple accounts, and mail search across the entire inbox. AlienBlue is the official app for Reddit, an online bulletin system. It enables users to browse threads from Reddit, post new threads and reply on others' threads with other features, such as liking or disliking, subscribing, image uploading, and so on.

The three mobile apps share the essential feature of user communication but contain differences in details. For example, WeChat enables users to receive, send, and share multimedia messages instantly. Gmail contains no voice messaging feature and takes longer time on individual operation session, such as browsing and replying emails. On the other hand, the communication between users on AlienBlue is fulfilled by posting, reading and replying threads in Reddit. Thus, in the study, we focus on the communication feature of the three apps to analyze their mobility attributes and requirements.

*Step 1. Identify the Primary Situational Context*

Firstly, the primary situational contexts shall be identified amongst the previously defined 12 situational contexts, as well as the scope of the analysis. Instead of prioritizing the 12 situational contexts precisely, for these cases, we categorize situational contexts into three prioritization level, including, *primary*, *secondary* and *ignorable*. Primary situational contexts indicates that most users tend to use this feature in these situational contexts. Secondary contexts are those situational contexts in which the user has the equal possibility of using the app or not. And ignorable contexts are those in which users nearly never use the feature. In terms of the "user communication" feature of the three cases, the according categorization of situational context is shown as Table IV.

TABLE IV. PRIMARY SITUATIONAL CONTEXTS.

	WeChat	Gmail	AlienBlue
Primary	AVE, ATE, AWE	AVE, ATE	AVE, ATE
Secondary	AVC, IVE, ITE, AWC	ITE, AWE	AWE
Ignorable	IVC, ITC, ATC, IWC, IWE	IVC, AVC, IVE, ITC, ATC, AWC, IWC, IWE	IVC, AVC, IVE, ITC, ATC, ITE, IWC, AWC, IWE,

Taking WeChat as an example, it enables users instant communication. Thus, the actions of reading and replying messages is to a large extent encouraged in the situation without social constraints (e.g. driving for safety reason) or time limit towards other objectives (e.g. deadlines). The social encouraging and time allocative contexts are also the primary contexts for the other two apps. But different from them, instant communication feature of WeChat is also encouraged in 'wondering' contexts. Besides, even with certain social constraints and time limits, users tend to use WeChat more than the other two, which is why more secondary situational contexts are identified for WeChat.

*Step 2. Specify the Expected Ways of Interaction*

The expected way of interaction for the feature shall be determined by the way in which most of the users use

the feature, which can be identified and analyzed by using different requirements elicitation techniques, or asserted by requirements analysts based on the use pattern of other similar products. For example, the expected way of interaction for WeChat communication is *intermittent*, as users only allocate short time for instant communication without original activity fully interrupted. Comparatively, Gmail and AlienBlue require more concentration and time from users for reading and replying emails, which results in an *interrupting* way of interaction.

*Step 3. Compare the Previous Two Outcomes and Identify the Conflicts*

Comparing the pre-defined ideal ways of interaction for the primary situational contexts and the expected way of interaction for the feature, we find no conflicts for all apps in their primary situational contexts (shown in Table V). When no conflicts are found for all primary situational contexts, we can indicate that this existing feature provides adequate mobility support.

TABLE V. COMPARISON OF IDEAL AND EXPECTED WAYS OF INTERACTION

Primary	Ideal	WeChat	Gmail	AlienBlue
AVE	Interrupting, Intermittent, Accompanying	Intermittent	Interrupting	Interrupting
ATE	Interrupting, Intermittent, Accompanying	Intermittent	Interrupting	Interrupting
AWE	Intermittent, Accompanying	Intermittent	<b>Interrupting</b>	<b>Interrupting</b>

However, conflicts are found in the secondary context of AWE for Gmail and AlienBlue. Compared with the primary contexts, we find that users in "wondering" context are more likely to start interaction with WeChat rather than Gmail and AlienBlue based on their expected ways of interaction. Thus, to enhance the mobility of them, conflicts for this secondary situational context shall be addressed with additional mobility requirements as in practise the secondary situational contexts might be also of high priorities.

*Step 4. Adjust Conflicting Feature towards Mobility Requirements*

Once the conflicts were detected, the according feature or function shall be adjusted in order to improve the overall mobility of the app. According to the conflicting situational context (i.e., AWE), the mobility requirement to adjust is as follows.

*In a situational context of "Allocative-Wandering-Encouraging", the Gmail/AlienBlue app shall provide user text-based communication functionality in the intermittent way of interaction.*

The mobility requirements provide the goal for requirements analysts indicating which specific situational contexts and by which ways of interaction the target feature shall be adjusted. The adjustment can be applied by adding or editing the existing requirements related to this function. Taking AlienBlue as an example, part of functions related to text-based communication in thread discussion is summarized in Table VI.

When adjusting the functions, we shall take into account the conflicting situational context. The perspective that plays a critical part of the conflict is firstly focused. For example, concerning the specific situational context of "Allocative-

TABLE VI. ALIENBLUE'S FUNCTIONS

App Name	Functions
AlienBlue	AFR1.The app allows the user to view through the whole thread; AFR2.The app allows the user to reply on a specific comment; AFR3.The app allows the user to send replies with images and emojis; AFR4.The app allows the user to like or dislike other comments; AFR5.The app allows the user to receive comments notifications;

Wandering-Encouraging”, social encouraging and time allocative contexts do not hinder user’s interaction with the thread receiving and replying feature of AlienBlue. Thus, within the range of this very feature, we change the existing function with more specified function variations. As follows, based on the given functions, we provide examples on how to change the existing function or add new functions that comply with the “Wandering” situational context.

Taken as examples, AFR1 and 2 are two of the essential function of the AlienBlue app, which must not be removed. However, as a persistent and non-obtrusive functions, based on Figure 2, these functions are prone to be ignored in most situational contexts, especially for the “Wandering” context. One way to change them is to shorten the operating session.

Thus, the AFR1 and AFR2 can be changed into:

AFR1.1 *The app shall allow the user to view exclusively his or her own comments and the ones he or she comments on with unrelated comments folded;*

AFR1.2 *The app shall allow the user to view unrelated comments by unfolding them;*

AFR1.3 *The app shall allow the user to quickly control the display of the thread interface by hand gestures;*

AFR1.4 *The app shall allow the user to view comments concerning him or her on the lock screen;*

AFR2.1 *The app shall allow the user to reply with predefined quick responses;*

AFR2.2 *The app shall allow the user to save unfinished comments automatically and to continue composing;*

AFR2.3 *The app shall allow the user to respond to the received comments on the lock screen;*

Compared to the original requirements, the specified requirements largely reduced the browsing time by directly enabling the user to focus on the relevant comments. Meanwhile, the specified requirements also enhance the obtrusiveness of the notification, which allows the user to better respond to the notification. In this way, based on the existing functions, these functions are adjusted in order to eliminate the conflicts between ideal way of interaction in a certain primary situational context and the expected way of interaction of this feature. By repetitively doing so with all the features of the mobile app, the mobility of the target mobile app is supported as users are enabled to interaction with the features in the expected way of interaction.

In this case study, we adopt existing mobile apps as examples to demonstrate how the mobility requirements analysis process can be applied. It is easy to identify the features that require mobility enhancement and the corresponding change proposal for well-known apps. In practise, it is hard to predict and fully specify all situational contexts and assure that the target app attract users to use in their expected way. The proposed approach and process provides a way of analyzing situational contexts, in which the app is put to use and eliciting requirements that enhance its mobility. This study contributes

in filling the gap in the studies on applying the understanding of context into mobile app requirements analysis. Furthermore, the user-app interaction reference model and the situational context analysis provides an extensible framework of studying the context of a user-app interaction where more perspectives can be added to enrich the scenario set of situational contexts. This approach also enables developers to choose the suitable set of context scenarios and prioritization, as well the ideal ways of interactions, based on the vision and scope of their target mobile apps.

## VII. CONCLUSION

In this paper, we explore the concept of mobility as the characteristic of mobile apps, which satisfies users’ need to use them under changing contexts. By analyzing the perspectives of mobility, we define situational contexts as the key extrinsic factors that influence users’ satisfaction in user-app interactions. Compared to the other context factors, such as device context and environmental context, the situational contexts are more tangible towards the understanding of how users and apps interact, and also the factors shall be taken into account when mobile development team aims to enhance the mobility of their mobile products.

Furthermore, based on the specification of typical situational context scenarios, we further analyze connection between these situational contexts and the ideal ways of user-app interactions. Hence, seeking the conflicts between ideal ways of interaction and the current ones is the method to detect the key mobility-lacking features of a mobile app. On the basis of the analysis, we propose the mobility requirements analysis process, which helps to adjust features and the according requirements towards the ideal ways of interaction. Accordingly, the overall mobility of the mobile app improves.

The future work of this study will focus on the other extrinsic contexts and their influences on user-app interactions, which shall be utilized as the replenishment for the existing reference model. The user characteristics and goals, as well as their connection towards the mobile application feature and demands, shall also be reviewed and analyzed in the mobile app domain. In addition, the connection between the improvement of mobility and user satisfaction to mobile apps shall be also studied as the validation of our mobility requirements analysis method in our future studies.

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