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An Introduction to Continuous Interaction

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Abstract. Users are currently expected to benefit from the concurrent use of different computing devices and applications: Personal computers for an easier content production, mobile devices for increased mobility and context-awareness, wearable devices for more transparent health-related data acquisitions, etc. However, the simultaneous use of different devices and applications could be perceived as disruptive or unproductive, due to the need of additional settings, lack of integration, etc. As a first step to overcome this problem, in this paper we introduce the notion of Continuous Interaction (CoIn) systems. These systems intend to promote the simultaneous use of multiple devices and applications to complete tasks in a more effective, flexible and easy way. To achieve that goal, a set of human-centred design principles have been figured out to enable users to seamlessly share tasks across multiple devices, independently of the software applications supporting their completion. The case study of a Mobile Forensic Workspace (MFW) will be presented to highlight the benefits that CoIn systems could bring to the Ambient Intelligence (AmI) and Ubiquitous Computing research fields.

Keywords. Human-Centred Design, Workflow Modelling, Ambient Intelligence, Ubiquitous Systems, Usability

1. Introduction

Nowadays, it is increasingly common to make use of several computing devices to carry out our daily tasks in different situations or environments: while moving, at home, at the office, etc. In this manner, smartphones, tablets, personal computers and other devices coexist to offer a rich computing environment in which we spend much of our leisure and professional time.

Ideally, end users are expected take advantage of the characteristics of each specific device and application: Personal computers for an easier content production, mobile de-

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vices for increased mobility and context-awareness, wearable devices for more transparent health-related data acquisitions, etc. Nonetheless, these devices, and their underlying platforms (operating systems, middleware, frameworks, etc.), have not been designed to work together in an integrated manner. In consequence, for instance, most of us have to rely on external Cloud-based tools (like Dropbox, Box, iCloud, OneDrive, etc.) or remote services to synchronize our information between our own devices. As an example, Figure 1 depicts, as a UML state diagram, an increasingly usual workflow when composing an e-mail, which can be considered as an straightforward and common task.

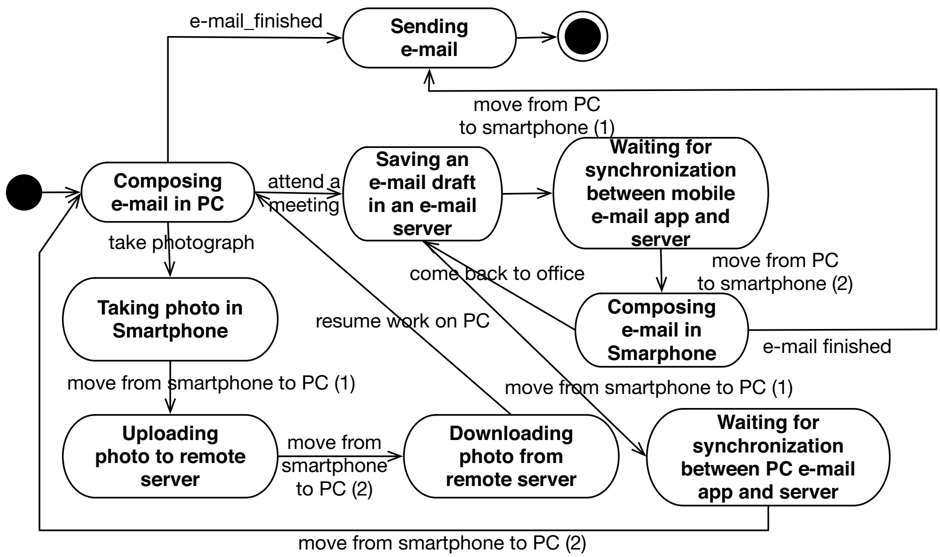

Figure 1. Increasingly common workflow when composing an e-mail, depicted as a UML state diagram.

These types of workflows, even in simple cases (like the one depicted in Figure 1), can be very disruptive, slow (i.e., we have to wait for the upload and download of information from remote services), resource consuming and even difficult to carry out for many users. A possible solution could be to shift the focus from sharing information between devices and applications, to actually share the tasks to be completed between multiple devices and applications. In consequence, the software should be designed to allow the user to interact in a continuous way with multiple devices at the same time, taking advantage of their distinctive capabilities to more easily complete a certain task through several applications and underlying platforms.

As a first effort to achieve that goal, in this paper, we present the notion of Continuous Interaction (CoIn) systems through the description of their human-centred design principles. The idea is to highlight their objectives and key end-user features. Moreover, the design principles could be taken as a basis to have a clearer notion on which features should be incorporated into a software system to allow multiple devices to be concurrently used to more easily carry out certain tasks. In fact, the design principles could aid into producing designs for a wide range of computing systems, such as ubiquitous, AmI, etc.

The case study of a Mobile Forensic Workspace (MFW) [1][2] is used to illustrate the problem, and the benefits that CoIn systems could bring to software usability and productivity.

The remaining of this paper is structured as follows. In Section 2, the case study of the MFW is presented. Section 3 describes the human-centred design principles that a CoIn system should meet. In Section 4, the MFW case study is revisited, with the intention of highlighting the benefits that the adoption of those principles could bring to this kind of collaborative, AmI systems. Some related work is summarized in Section 5, including a description of some recent technologies that could allow to implement CoIn systems. Finally, the conclusions and some lines of future work are presented in Section 6.

2. Case Study: A Mobile Forensic Workspace (MFW)

This section presents the case study of a Mobile Forensic Workspace (MFW). The idea is to make explicit how the use of multiple devices can decrease usability (even when using different instances of a single application), if a software system has not been designed to achieve that goal. As it will be described, the usability decrease may also impact in other quality properties like security or reliability.

Firstly, a summary of the objectives and overall characteristics of the MFW are presented. After that, we highlight the usability difficulties that the users have found while using the MFW on multiple devices.

2.1. Introduction to MFW

A Mobile Forensic Workspace (MFW) has been proposed to facilitate collaboration, data collection and sharing in scenarios with multiple victims. In these scenarios, official agencies, like regional police forces or Interpol (Interpol DVI forms, available online at: `http://www.interpol.int/es/INTERPOL-expertise/Forensics/DVI-Pages/Forms`), apply protocols of action intended to support victim identification in natural disasters, accidents, terrorist attacks, mass murders, etc. These protocols try to deal with how victim data is collected and how professionals (e.g., members of police forces, forensic experts, etc.) have to cooperate to complete their tasks.

MFW is considered as an AmI system, since it poses the following features:

- **Sensitive:** It is able to automatically detect nearby professionals collecting data, and the location of each victim (and his/her associated personal effects) whose associated data was previously collected into the workspace.
- **Responsive:** The detection of nearby professionals is notified to the users, and makes it possible to communicate with them through the workspace in order to coordinate the data collection activities.
- **Adaptive:** It is adaptable to the needs of many official agencies, since it can be configured to support the collection of many different types of data (location, photographs, descriptive texts, dental characteristics, radiographs, body sketches, etc.), depending on the applied official protocol of action.
- **Transparent:** The collected information is automatically and transparently disseminated among nearby professionals, even if they are applying heterogenous protocols of action involving the the collection of different data.

- **Ubiquitous:** MFW has been designed to be used in mobile platforms. Additionally, the automatized location of victims and personal effects (after their registration into the workspace) is meant to be achieved through small location "tags" that are integrated into the physical location of the disaster.
- **Intelligent:** It detects data conflicts, tries to automatically solve them and, in case it is not possible, it tries to communicate the involved professionals to manually solve the conflict.

AmI systems may contribute to enhance disaster management [3], and emergency services in general [4]. In consequence, AmI systems may be appropriate for official agencies intending to use ICTs to improve the coordination and cooperation between the professionals that have to collect data in forensic scenarios with multiple victims.

2.2. Observed Usability Problems when Using Multiple Devices at the Same Time

In scenarios with multiple victims, many of the in-situ tasks involve both collecting information and accomplishing physical works (e.g., body recoveries, security increases, aiding to alive victims, etc.).

In the current approach to the MFW, professionals are intended to use a unique personal device at the same time, which, in this case, can be a tablet, an smartphone or a personal computer. However, the professionals do different works depending on the needs, which, in many cases, should involve a device change (to increase mobility, allow an easier content production, etc.). By design (i.e., to increase security), in MFW, each device must have a digital certificate that authorizes a specific user to incorporate and share information. In consequence, to change from one device to another, the user has to install his/her personal digital certificate in the new device, re-enter some individual access credentials and make the appropriate interactions to continue with the information collection just at the same point in which it was interrupted. Additionally, the professional should uninstall the digital certificate and log-out from the previous device, in order to avoid security issues. An example of this device change workflow has been depicted in Figure 2 through a state diagram.

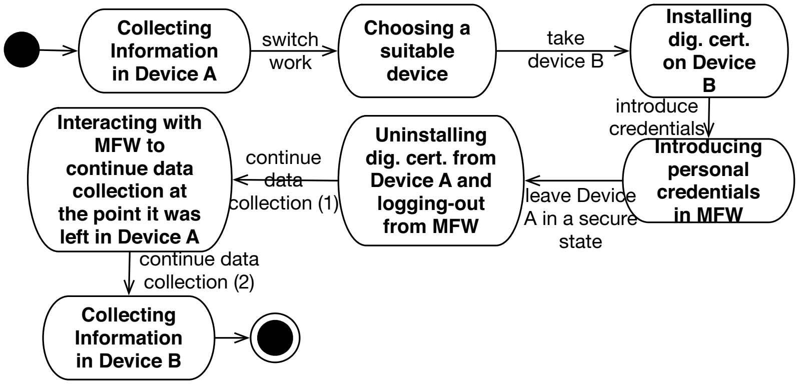

Figure 2. The current workflow for changing from one device to another in MFW, depicted as a UML state diagram.

Due to this potentially complex and disruptive workflow, users trend to avoid device changes. To do that, we have observed the following behaviors:

- Either they stop using the MFW while carrying out different works, and then they return back to use it to introduce the information that they have collected, commonly, by manual means,
- or they exchange their personal device with another professional for a while, thus making the authoring mechanisms completely useless.

Consequently, in MFW the use of multiple devices by a professional, not only decreases usability, but also negatively impacts on the security of the workspace and the reliability of the collected information (i.e., the authoring may not be clear, a user may change the information collected by another user, etc.).

3. Continous Interaction (CoIn)

In this section we introduce the notion of a Continuous Interaction (CoIn) system, which is a software system designed according to, at least, the following four design principles, which will be detailed in the following subsections:

1. The task is the element to share, not the data.
2. Seamless completion of tasks by several users using multiple devices and different applications.
3. The applications should explicitly recommend device and application changes to the user.
4. Continuous interaction.

These principles intend to leverage the *tasks* to become the central point of any user interaction, in order to facilitate multi-device and multi-application interactions, while increasing usability. As a matter of clarification, the conceptualization (i.e., the metamodel) of a *task* is depicted in Figure 3 as a UML class diagram. That conceptualization has been extracted from the AMENITIES conceptual model for collaborative systems [5].

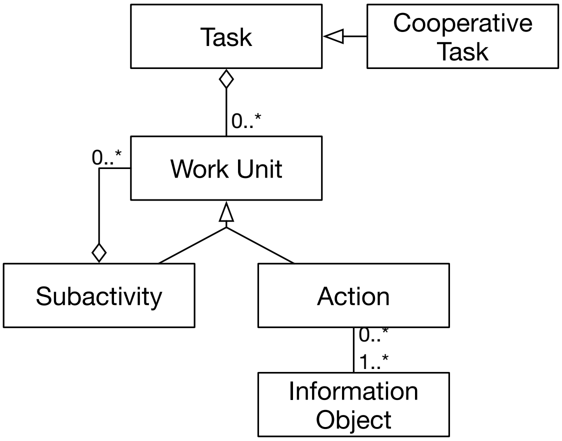

Figure 3. Metamodel of a *Task*, extracted from the AMENITIES conceptual model [5] and depicted as a UML class diagram.

3.1. The task is the element to share, not the data

Most current software systems allow an easy data sharing through different mechanisms: cloud-based storage services, shared databases, etc. These mechanisms enable the interoperability between different applications and devices.

However, sharing data is not enough to facilitate an user to seamlessly interact with multiple devices and applications to complete a specific task. In fact, the data that the user manages does not contain enough information to easily continue interactions between different devices and applications. To do that, the tasks themselves should be shared, including (but not limited to) the following information:

- The data that the user is managing.
- The application context, that is, the specific point in which an application is being executed by the user at a given moment (i.e., the user is composing an e-mail, taking a photograph, etc. within a specific application) to complete the task.
- The user context, that is, at least, the location of use, the collection of nearby people, hosts and accessible devices, as well as to changes to such things along time [6].
- The task context, that is, the workunits, actions and subactivities that the user is carrying out at a certain time.

In this way, CoIn systems could enable users to more seamlessly switch devices and applications to complete tasks.

3.2. Seamless completion of tasks by several users using multiple devices and different applications.

Nowadays, user cooperation is increasingly common in software systems to be able to complete complex tasks in a more productive manner.

Task sharing mechanisms should leverage cooperation by not only providing the data to be shared, but also contextual information about the other users, their application contexts and their tasks' context (i.e, the work units, sub-activities and actions that they are carrying out). In consequence, there could be more natural software mechanisms for end users to cooperate and use the joint benefits of heterogenous devices to complete their tasks.

Moreover, using multiple devices and applications should be as less disruptive, fast and easy as possible. In fact, users should not need to carry out configuration steps to switch between different devices and applications to complete a specific task.

In order to carry out that goal, software systems could make use of several mechanisms to allow a more seamless transition between devices and applications:

- Software systems could use context-awareness mechanisms to proactively detect when a user will switch from one device or application to others, and to transfer the tasks that are being carried out to them. In this manner, the software could anticipate to the user, who will find the other device or application completely ready to continue his/her tasks.
- Tasks could be represented using the *file* metaphor. Currently, users make a very active use of this metaphor to organize their daily tasks. In this way, representing tasks as files could be helpful for end users in order to better understand task sharing, task transition between devices and applications, etc.

3.3. The applications should explicitly recommend device and application changes to the user

The benefits of moving between devices and applications may not be directly obvious for many users. Indeed, the user may not know which are the benefits of using different devices and applications to carry out a task. Therefore, the applications should provide recommendations to move from one device or application to others, depending on the data to be managed and the user, application and task contexts.

To achieve that goal, applications and devices could explicitly announce their characteristics to others within their context. Intelligent systems could decide when it is more appropriate to complete a certain task in each specific device or application, and recommend it so to the end user. The recommendation should be presented together with an explanation about why the device change is allowed, and what are going to be the benefits for the end user. In this way, the user is provided with enough information to understand why it should be appropriate to continue his/her tasks in other devices (e.g., increased mobility, improved computing power, availability of sensors, etc.).

3.4. Continuous Interaction

Software systems should be designed to always allow the user to carry out an uninterrupted flow of interactions to complete a task. In consequence, their design should have a focus on improving reliability as much as possible, thus increasing the perceived fault tolerance, availability and recoverability [7].

Therefore, the design should take into account mechanisms focusing on avoiding the disruption of the user interaction upon network interruptions, unavailability of users or computing resources (battery, memory, etc.), etc.

4. Revisiting the MFW

The MFW is currently being re-designed to make more explicit the tasks that need to be carried out by professionals (according to the Interpol DVI Forms), while supporting an improved cooperation and facilitating multi-device interactions. To achieve that goal, the different CoIn design principles are currently being applied as follows:

1. *The task is the element to share, not the data:* Instead of focusing on collecting forensic data, the MFW will focus on the completion of forensic tasks. Those tasks will be the object that will be shared among professionals, rather than the data. Professionals will be able to share tasks, partially complete them, reassign them to others, etc. In this manner, we expect professionals to have a clearer mindset about what tasks they need to do, and the activities (involving data collection) that will need to be done in order to complete them.
2. *Seamless completion of tasks by several users using multiple devices and different applications:* In order to overcome the issues presented in Section 2, a task model has already been designed to transparently synchronize tasks between multiple devices and applications (i.e., it will be necessary for other applications to adopt that task model in order to enable interoperability with MFW). The required cooperation to complete a forensic task will implicitly involve sharing

the collected data and the application, user and task contexts (see Section 3 for more information about these contexts). However, synchronization and context-awareness mechanisms have been designed to make those processes transparent to end users.

3. *The applications should explicitly recommend device and application changes to the user:* A rule-based subsystem will recommend the user when and why it will be necessary to change from one device to another. Currently, we are working on defining rules depending on the user location, user movements (moving around fast, being sit down, etc.) and available resources on each device.
4. *Continuous interaction:* Different mechanisms will be used to avoid disruptions while interacting with the MFW. For instance, we have been researching on methods to improve availability in ad-hoc networks [13], and middleware technologies to manage offline and online modes [14].

By adopting previous design principles, we expect that the workflow for changing from one device to another in MFW will become as simple as it is depicted in Figure 4, in contrast with the current workflow, which was depicted in Figure 2.

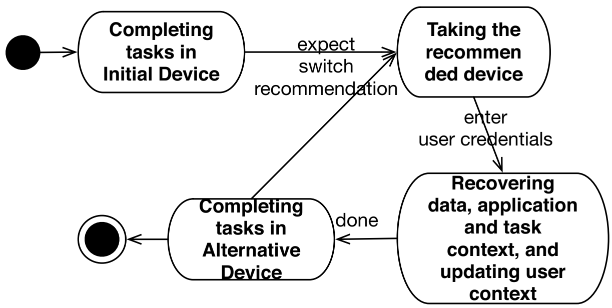

Figure 4. The expected workflow for changing from one device to another in MFW, depicted as a UML state diagram.

5. Related Work

In is common on research works related to ubiquitous, AmI and context-aware systems to make an explicit or implicit mention to the need of concurrently using multiple devices within the user environment [8] [6] [9]. For instance, the “Tangible Bits” paradigm [10] intends to translate reality into digital environments (or the other way round), potentially involving the use of many devices to complete even simple tasks. Adaptive graphical user interfaces have also been explored to increase usability and user satisfaction in scenarios with varying contexts in which several devices could coexist [11]. Moreover, in [12] it is mentioned the increasing parallelism of human thought (partially contributed by the new computing paradigms), which we think it will involve the concurrent use of multiple devices and applications.

The contribution presented herein intends to complement previous works by tackling with how the users will be able to manage multi-device, multi-application interactions without decreasing usability.

AMENITIES [5] has been taken as the conceptual model to figure out how to solve the usability problems that have been highlighted along this paper. That model has allowed us to understand that it might be necessary to leverage the concept of task even further than applications, files or other software abstractions.

For example, the notion of adaptive user interface is more focused on adapting specific applications to context variations. In contrast, in this work we aim at moving task execution to the most appropriate devices, depending on the user context, and even between multiple applications (i.e., understanding that the use of multiple applications might even be necessary, depending on the device).

In terms of technologies, several recent industrial contributions could enable the implementation of CoIn systems, taking into account the presented design principles.

Continuity (`https://www.apple.com/ios/whats-new/continuity/`) is a technology introduced by Apple in iOS 8 and OSX 10.10. It allows to transfer the state of a specific application to multiple Apple devices owned by the same user. The application can have different implementations depending on the device (iPhone, iPad or Mac computers), but they must be explicitly marked (through the appropriate software development mechanisms) to be the "same one" (i.e., the different implementations should have the same application name, same objectives, mostly the same functionalities and have to be developed by the same developers).

Continuity makes use of BlueTooth and Cloud-based synchronization services to offer its end user functionalities. In that sense, the improvement of the reliability and ubiquity of those technologies could improve the feasibility of implementing CoIn systems.

6. Conclusions and Future Work

This paper has introduced the notion of Continuous Interaction (CoIn) systems. These systems are aimed at facilitating user interactions with multiple devices and applications in order to complete a task. The idea is to benefit from the different characteristics that those devices and applications may offer to the end user: an improved content production, a better mobility, an easier content consumption, etc.

CoIn systems should be designed according to five design principles:

1. The task is the element to share, not the data.
2. Seamless completion of tasks by several users using multiple devices and different applications.
3. The applications should explicitly recommend device and application changes to the user.
4. Continuous interaction.

The Mobile Forensic Workspace (MFW) has been used as a case study to highlight the difficulties that end users may encounter while interacting with multiple devices within the context of an AmI system. The CoIn design principles are currently being applied to design a newer version of the MFW intended to overcome those difficulties.

As for future work, we plan to implement a new prototype of the MFW according to the new CoIn design, and evaluate its usability and perceived reliability. We also plan to propose a Platform-Independent Model (PIM) for CoIn systems, to make it more explicit their characteristics, inherent concepts and relationships between them. Finally, we will review the CoIn design principles according to the feedback obtained from end users and external researchers.

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