NFC-Based User Interfaces

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***Abstract*—Here, we discuss the potential of user interfaces built from NFC phones and NFC tags. We present these NFC-based user interfaces as components of interactive spaces, environments equipped with rich user interfaces and offering a large variety of services for users. Moreover, we specify an interaction model for NFC-based user interfaces and a graphical language for advertising NFC tags. In the model, interaction is decomposed into discovery, composition and usage stages and described using users, tokens, resources, and services. The language provides graphical elements for advertising a large set of different services and commands in a uniform manner. Attention, interaction, technology, and action elements are the most important ones and additional information can be given with context and instruction elements.**

I. INTRODUCTION

The amount of NFC phones is increasing at a fast pace. One hundred million NFC phones have been estimated to be shipped in 2012 [1]. Hence, applications utilizing NFC can reach large amounts of users and have potential for profitable business. Payment, ticketing, and information access are seen as promising application areas for NFC [2,3] – and these application areas have indeed attracted a large share of the development efforts. In addition, some games using NFC have been presented, like Angry Bird Magic [4] and Fruit Ninja [5]. Foursquare is an example of social applications utilizing NFC [6].

These examples illustrate how NFC can be applied in many different application areas. Generally, NFC technology can be used to replace manual typing, menu selections, and other user interface actions with acts of touching. Users can carry either devices equipped with NFC readers or NFC tags and, respectively, either NFC tags or NFC readers can be installed in the environment. In this article, we focus on NFC phones and NFC tags placed in the environment.

In the simplest case, the environment contains only individual NFC tags storing commands for phones. We foresee much richer environments in which large amounts of devices (like displays and white goods) and services are controlled by touching NFC tags with phones. NFC tags are attached both on the devices and onto physical objects related to services, devices, commands, and content.

We call these environments as *interactive spaces* to emphasize the active role of the user [7]. The environment does not have to be "smart" or "intelligent" and predict (based on sensor data) the services the user is about to need. Instead, the user has the initiative and controls the services she/he needs. Hence, the main challenge is to provide easy-to-use user interfaces for controlling services. First, we need to communicate clearly to the user the available services, how they can be controlled, and the devices the services use. Second, the actions for controlling the services need to be easy to perform.

NFC excels in tackling this challenge. When tags are advertised by graphical icons (i.e. each NFC tag is placed under an icon), a user can easily identify the tags present in her/his environment. The command performed when a tag is touched can be encoded in the icon as well. Then, a user can identify the available services and commands by scanning visually her/his local environment and just touch the icon presenting the desired service and command. As a result, the phone reads the command from the tag and executes it – either completely in the phone or by sending commands to servers and local resources like displays. Interactive spaces offer also other means for interaction like traditional GUIs and gestures, but in this article, we focus on NFC.

We have realized and tested over twenty prototypes containing NFC-based user interfaces. In this article, we formulate based on this experience an interaction model for NFC-based user interfaces. The earlier version of this model is presented in [7]. Our aim is to develop for application designers a tool that can be used to identify and present all components of an NFC-based user interface and to model the interaction. In addition of documenting user interfaces at design stage, this tool might be used to present recommended interaction patterns, for example.

Moreover, we present our work on advertising NFC tags with graphical icons. A more detailed description of this work can be found from [8]. Our latest version of the graphical language allows a large set of different services and commands to be advertised in a uniform manner.

In the next section, we present the related work that has inspired us in our work, including our earlier efforts. In the third section, we describe the interaction model and the graphical language in the fourth section. In the last section, we present discussion and consider future directions for developing NFC-based user interfaces.

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II. Related work

Our interaction model resembles the interaction models for smart spaces [9-12]. Although they are not as such suitable for interactive spaces, the similarities between smart and interactive spaces enable using these models as a basis when creating a model for interactive spaces. Our model was inspired by the work of Dahl [9] and Anokwa *et al.* [13]. Dahl proposes five different model elements: users, virtual zones, tokens, token containers, and computer devices. He also presents a set of icons to represent each model element, semantics for those elements, and examples of interaction.

Anokwa *et al.* propose an NFC interaction model based on three model elements: items, objects and actions. Items are NFC enabled devices, while objects are anything that an item can encapsulate. For example, an NFC enabled movie poster (item) could contain a movie ticket and a movie trailer video (objects). Finally, actions determine what users can do with objects (e.g., give a movie ticket to a friend). Objects can also perform actions by themselves. A mobile phone scans an item to get its list of objects and the actions that it can perform with them. The user selects the action to perform and the objects to retrieve. The phone executes the action and retrieves the objects selected by the user.

NFC-based user interfaces can be classified as tangible user interfaces [14, 15] as phones are used like physical objects rather than as traditional I/O devices. As Ullmer and Ishii [14] point out, tangible interfaces employ physical objects as both representations and controls and also couple these objects with digital representations. For example, an object equipped with an NFC tag can represent a video and touching the object with an NFC phone can, for example, start the video on a wall display.

Some examples of tangible user interfaces are Reactable* [16], URP and Sandscape [17]. Reactable* is a tabletop surface for composing music by placing and moving different objects on it. URP is a tool for urban planners to simulate shadows, light reflections, wind flows, and traffic congestion of an urban environment. Locations' effect on these factors can be studied by moving a building model on the table. Sandscape is an organic tangible interface for simulating landscapes. Users alter the landscape by manipulating sand with their hands.

The interaction model presented in this article is based on a set of application prototypes we have built during the last six years such as Touch&Control, Touch&Collect, Interactive Poster, Touch&Vote [7] and Touch&Learn [18]. With Touch&Control, a user can control multimedia players on displays by touching tags in the environment. Touch&Collect, on the other hand, uses NFC tags as file repositories. Users can pick files from tags and store them in the mobile phone and drop files from the phone to tags as well.

The Interactive Poster application is composed from several services. The application is integrated into a physical poster with NFC tags and icons advertising the tags. Visitors can watch content related to the poster on a nearby display and send comments to the poster's author. Touch&Vote permits voting for a certain subject by touching an NFC tag placed in the environment. Touch&Learn was developed for a kindergarten for three-to-five-year old children. This application supports children in their efforts to learn to read. NFC tags are placed in the environment behind nametags that are used in the kindergarten to label chairs, beds, coat racks, etc. When a children touches a nametag with a phone, the phone presents the name, as it is written and pronounced.

Advertising NFC tags (and the RFID tags used before NFC) has not been studied much. Arnall [19] has studied the visual link between information and physical things. Välkkynen *et al.* [20] have suggested some graphics for visualizing RFID tags. In a more recent work, Hang *et al.* [21] have performed usability studies on three different types of symbols. Explanatory symbols are used to explain to the user how NFC technology works. Adhesive symbols' task is to catch the attention of the user. Finally, action symbols are used to trigger actions. These symbols were inspired by familiar GUI elements. The studies concentrate on analyzing where and when these symbols should be used.

We have designed so far five versions of graphical icons for advertising RFID and NFC tags. The first four versions [22, 23, 7] are presented in Figure 1. In the first three versions, the icons were divided into general and special sections; the general section advertising a point to touch and the special section advertising the action.

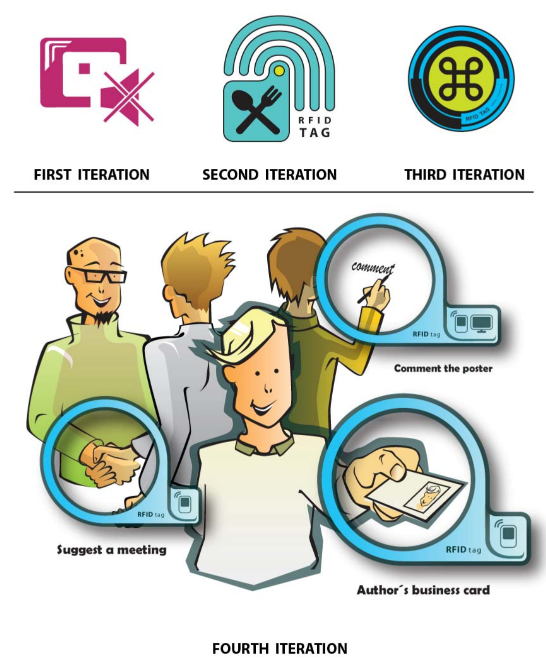

Figure 1. Four versions of advertising NFC and RFID tags.

In the first two versions the general section represented an RFID antenna, but in the third version more emphasis was put on having a common symbol attracting the attention to the special section in the middle. The special section contains a pictogram, and sometimes text, representing the action performed when the tag is touched. In the fourth version, individual icons were replaced with cartoons presenting characters that perform different actions. A blue circle surrounding each action indicates a point to touch; to perform that action. The fifth version is presented later in this article.

III. Interaction model

NFC-based interaction in interactive spaces differs from the classical interaction based on the WIMP (Windows, Icons, Menus, Pointer) style and from interaction in traditional smart spaces as well. User interfaces in interactive spaces are not restricted to conventional I/O devices but they are built from physical objects. Furthermore, the system does not perform automatically operations that it reasons to match the user's situation. Instead, the user makes decisions and interacts with services by handling physical objects, for example, by changing the position of an object.

We are developing a model for interaction in interactive spaces. The aim of this model is to facilitate identifying and presenting the components of user interfaces and modeling the interaction. Also other technologies can be utilized, but we focus here on NFC. We divide the interaction into three stages [24] and describe the interaction with four model elements.

The three interaction stages are *discovery*, *composition* and *application usage*. These stages can be illustrated with the Skål media player presented by Arnall [19]. Skål allows starting and controlling a video on a display by placing objects into a bowl close to the display; each object represents a different command for a multimedia player. Bowls are equipped with RFID readers and objects with RFID tags. The discovery stage is performed by scanning visually the space to find the objects to interact with. A user might detect two displays, two wooden bowls near the displays, and different toys distributed in the room. Since both bowls are physically connected to the displays, the user can infer (possibly with the help of some instructions) that placing an object in a bowl starts a video on the corresponding display. In the composition stage, the user composes the application he or she wants to use by selecting a toy and a bowl. The toy determines multimedia content and the bowl the display. The application is composed of these user interface components and the service, the multimedia player. The toy represents both a video file and a "play" command for the service. Placing the toy in the bowl starts the application usage stage. Other objects might be available during this stage for controlling the multimedia player, for example, one wooden block might pause the video, another continue playing it.

The model elements are the following (see Figure 2): A *user* is a person in an interactive space. A *token* is a physical object in the space. Users can control and observe the states of tokens (and relations between tokens). A *service* is a digital object consisting of a set of functionalities and policies controlling their usage. Users achieve their goals with these functionalities. A *resource* is a device in the physical space. Services use resources to realize their functionalities: to recognize the states of tokens, to change the states of tokens and other environment, and to present information to users. Resources can also offer input functionality to the users (e.g., a touch display) and resources can store information as well.

Resources are closely related to tokens. Users interact with tokens in the physical space and services interact with resources in the digital space. The mapping between tokens and resources determines how services experience the user-token interaction and how users experience the service-resource interaction. Resources can be considered as a bridge between the physical and digital worlds.

An object can be from the user perspective a token and from the service perspective a resource. For example, NFC phones are handled by users as a physical object (token) but also detect "near" relations between them and objects equipped with NFC tags and inform about this relation to services (resource). NFC tags are resources as well; they are capable of storing information, though they require phones or other NFC readers to communicate with services. When NFC readers are installed in the environment, a user handles tokens equipped with NFC tags.

Figure 2 presents interaction in which a user reads an NFC tag by touching an object with her/his phone (1), the phone sends the data read from the tag to the corresponding service (2) and the service performs the command related to that data (3), in this case, presents information on a wall display. The touched object is a token; the phone and the display are both tokens and resources.

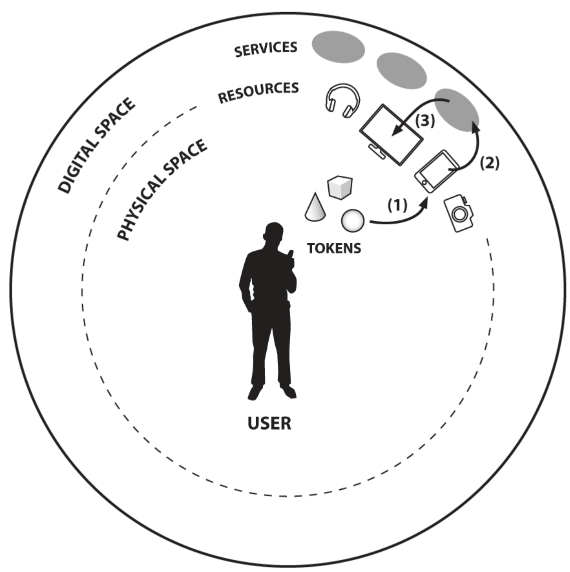

Figure 2. Elements of the interaction model.

The mapping between resources and tokens is not one-to-one. A resource can be integrated in a token and sense directly the state of the token, for example movements with an acceleration sensor. Or, a vision system resource can observe the movements of tokens inside its visual field. Such a vision system might track, for example, the positions of wooden blocks on a table. Moreover, an NFC tag installed on a wall can be an individual token, the tag itself as it is observed by a user, or together with some graphics attached to the tag. For example, a tag with a graphical command icon is a command token; a user can recognize the command and execute it by touching the icon (and the NFC tag) with an NFC phone.

On the other hand, a tag attached onto a coffee mug can be a part of the mug token. In this case, a user does not observe the tag as a separate object but understands that the mug can be touched at a certain point to interact with it. We have used NFC tags both as command tokens (together with graphical icons) and as parts of tokens (i.e. attached to physical objects).

Also resources presenting information (visual, auditory, etc.) to users can be either separate tokens (e.g., a wall display) or parts of tokens (e.g., a display on a mug). From the user perspective, the content of a display can be considered as environment state (i.e. the state of the corresponding token). From the service perspective, a display offers an API for presenting information to users. Generally, traditional I/O devices can be represented as tokens and as resources.

An application consists of one or more services and of the tokens and resources forming the user interface. Before using an application, a user has to discover the user interface components and compose the application. In the discovery stage, a user scans the environment and recognizes the tokens in the space. In the composition stage, the user decides the services to use and the tokens to be used by these services. These decisions can be made, for example, by touching tokens with a phone.

The choices the user can make depend on the service and the space. When an application is fixed, that is, a service has fixed tokens and resources for the space the user is in, the user just needs to start the application. Some other services can allow rich configuration possibilities. In a simple case, the user might be able to select the display to play content on, for example. The application is built from the service and the tokens selected by the user; the resources are determined by the token-resource mapping. As a result, the application is now ready for usage.

In the usage stage, the user communicates with the application by interacting with the tokens. Resources generate events based on changes in tokens' states. The services react to these events by triggering the corresponding functionalities, some of which can further trigger the resources to change the state of the space and present information to the users. These changes can, in turn, result in the user performing new actions and thus generating new events.

The mapping from tokens (and changes in their states) to service functionality can depend from the service and the situation, though some objects can also have a fixed meaning and always trigger the same functionality. Moreover, the mapping can be determined by service developers, service providers, the administrator of the interactive space, or even by the user. A more detailed definition of the mapping is currently under way.

IV. ADVERTISING NFC TAGS

We advertise NFC tags with service advertisements; graphical advertisements communicating information about interaction possibilities and offering the means for realizing the interaction [8]. These advertisements are placed on top of NFC tags and they consist of visual elements (i.e. icons). Service advertisements can utilize other modalities as well, and support other interaction technologies in addition to NFC, but we focus here on visual advertisements advertising and offering NFC-based interaction possibilities.

A service advertisement specifies the exact position to touch, an action (i.e. a command), a service, and all the other details a user needs to know when making a decision on whether to touch a tag or not. Figure 3 presents an example of a service advertisement.

The *attention element* draws a user's attention to the advertisement. This element is included into each advertisement. Hence, it enables users to quickly estimate the number and the locations of NFC tags by scanning the local environment visually. The *technology element* indicates the technology utilized in the interaction. Also other interaction technologies, like 2D barcodes and Bluetooth, can be used, but they are outside the scope of this article.

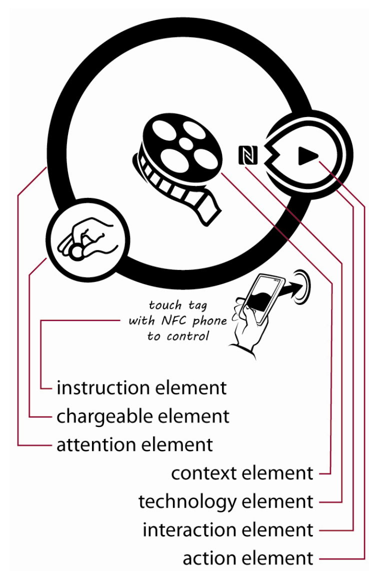

Figure 3. Elements of a service advertisement.

The *interaction element* advertises the exact point to touch; NFC tags are placed under these elements. The shape of the interaction element hints that an important part of the service advertisement is in the middle of the element, so the action element is placed inside the interaction element. A service advertisement can contain multiple interaction elements chained to each other. The advertisement in Figure 4 contains one element to vote "Yes" and another to vote "No". Users can vote by touching these elements, possibly presenting some credentials for the voting service.

The *action element* indicates the action the system performs when a user touches the interaction element. The related NFC tag stores the command to execute that action, or the data the system maps to the command. The well known icons can be used as action elements, for example, "Play", "Stop", "Save", and "Print". A tag for starting and stopping a service can be advertised with an "On/Off" icon, or with an icon representing the service itself.

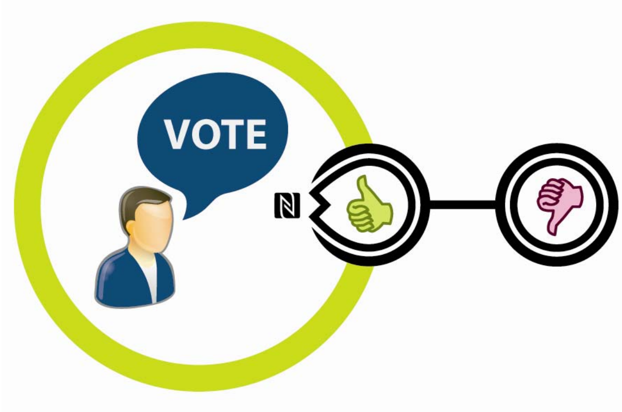

Figure 4. Advertisement for a voting service.

When these four elements, together with other available information, do not determine the service and the action accurately enough, the context and instruction elements can be used.

The *context element* can be used to present, for example, the service to be commanded. We do not specify a separate service element, because a service advertisement's core function is to determine an action (i.e. a command). The context element can also be used to advertise the device(s) belonging to the user interface. For example, digital content can be presented on a wall display or on the phone's display.

Context elements are placed inside the attention element. The silhouette of a person and the speech balloon in Figure 4 form a context element. Moreover, the chargeable element in Figure 3 is a context element illustrating how several context elements can be included in an advertisement. Other types of context elements can be specified as required by services.

The *instruction element* is used to explain how the interaction is to be performed. Instructions can be given as text, cartoon, etc. Separate instruction elements, together with attention elements, can give general instructions about services in a certain area. If a specific client application is needed for using the services, a service advertisement for downloading the client can be attached to the instructions. Alternatively, a user can be instructed to start the application to which an NFC user interface is offered. Other information can be included as well – rich general instructions can in fact allow simplifying the advertisements at tag locations.

A service advertisement does not have to contain all elements, however. When users become familiar with NFC and some details are known otherwise, less details suffice in service advertisements. The instructions might be common and verbose when NFC phones are introduced, but compressed and even left out from many advertisements when the technology becomes more common. The amount of information depends on the targeted environment and users as well.

For example, in home environments, the same users can use a service for long periods of time. In such cases, only the point to touch and minimal information about the service and the action need to be presented. As an example, Figure 5 presents a simplified service advertisement for a kitchen: touching the advertisement (and NFC tag) attached on an oven brings the remaining cooking time to a user's phone display. In this case, touching the advertisement might create a wireless connection between an Internet-enabled oven and the phone; resulting the timer on the phone to change in real-time as the oven updates the estimates of the remaining time.

Figure 5. An example of a simplified service advertisement.

V. Discussion

NFC has much larger potential in HCI than has been reported until now. The applications published so far are clearly just the tip of the iceberg. They use NFC for simple interaction (for example, to start an application). We envision NFC technology to be a key technology in building easy to use but functionally rich interactive spaces. NFC is applicable to a truly large set of applications as it can simplify many tasks a user has to perform, whether entering data, giving commands to an application, or creating links between resources in the environment.

In principle, NFC does not enable any new applications, as it is always possible to enter the data read from an NFC tag by other means as well. However, NFC can produce much better user experience than other input methods. NFC is also suitable for applications that require sequences of user input. The data to enter at each step can be stored in NFC tags. But NFC is not a replacement for keyboard or other input methods aimed at entering large amounts of text or at fast pace interaction with applications. Touching is a quite slow action, and hence best for individual inputs, not for long nor fast sequences.

NFC excels in interacting with the local environment. There are no other input methods with an equal combination of user control, easiness to use, robustness, and price. The limiting factor is that the tags need to be clearly advertised to the users, and reachable as well. NFC is most suitable for context-sensitive functionality: the input is related to the current location of the user. This is one strength of NFC: the set of possible inputs can be decomposed into subsets based on location.

A further advantage of NFC is that the user is always in control. The user selects services and the operations the services perform by touching icons in the environment. This is important also from the privacy point of view. For example, an interactive space does not need to contain sensors monitoring users, but users touch NFC icons when they want to interact with the environment. Moreover, NFC enables cheap personalized user interfaces, for example, by printing NFC icons on a poster and attaching NFC tags behind the icons. User interfaces with extra large icons can be built for visually impaired people, or user interfaces containing Braille icons for blind people.

However, the current mobile phone form factor is not optimal for NFC. In fact, the recent introduction of large touch displays has deteriorated the usability of NFC phones. Earlier clamshell models like Nokia 6131 NFC were easier to hold in hand and to hold in correct orientation when touching NFC tags. As the display sizes grow and the difference between phones and pads gets blurred, touching NFC tags with these devices becomes even more cumbersome.

One way to improve usability could be to design a separate device, an ”NFC mouse”, for touching tags. This device can be designed to be comfortable to hold when touching NFC tags at different orientations. This device can then communicate wirelessly with the much larger pad, mainly used for consuming content and using GUI applications. When we add earphones and a microphone to this set up, we get a mobile device for handling many operations on the fly: giving commands by touching tags in the environment and by speech, getting feedback by vibration and sound to the earphones, etc.

Although we focused on NFC phones, the work presented in this article can be applied to NFC mouse and other NFC devices as well. We presented a general interaction model for NFC-based user interfaces. We divide the interaction process into three stages (service discovery, application composition and application usage) and describe interaction with four model elements: tokens, resources, users, and services.

We base this model on the experience gained in building more than twenty NFC prototypes. Our next step will be to design the model in more detail. Our goal is that the model can be used to describe the tokens and resources available in interactive spaces and mapping between token handling (i.e. user interaction) and service operations. We will also study graphical representations for describing all the components (services, tokens, resources) of a user interface and the sequence of interaction and service operations. The model can facilitate creating applications from components distributed in the network and local environment, even dynamically based on users’ context and selections. Hence, it will be one central enabler for interactive spaces.

We will verify the model as well. This will be done by using it in designing the next prototypes. We will analyze the benefits of using the model and also compare the interaction described by the model to the interaction actually realized by the prototypes.

The graphical language will be developed in a similar manner: more details will be designed and the language will be verified by using it in applications. Feedback received from test users will guide the development. A further task will be to integrate the interaction model and the graphical language. The model and the graphical language are applicable to many other means of interaction. We have started the work with NFC and will include other technologies as we proceed in the development.

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