Collect&Drop: A Technique for Multi-Tag Interaction with Real World Objects and Information

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Abstract. The advancement of Ubicomp technologies leverages mobile interaction with physical objects and facilitates ubiquitous access to information and services. This provides new opportunities for mobile interaction with the real world, but also creates new challenges regarding the complexity of mobile applications, their interaction design and usability. In order to take advantage of this potential beyond simple interaction with single objects and tags, this paper investigates mobile interaction with multiple objects, tags and associated information. It introduces Collect&Drop as a generic technique for Multi-Tag Interaction that supports the collection, storage and management of information from the real world as well as its usage with different services. This paper describes the concept, architecture and interaction design of Collect&Drop and presents a user study that evaluates its features.

1 Introduction

Ever since 26th June 1974, when a pack of chewing gum was the first commercial product labeled with a barcode [1], everyday objects have been tagged for automated identification and access to associated information. Since then, the advancement of Ubicomp [2] technologies has increased the possibilities for mobile interaction with objects, information and services from the real world. NFC, RFID, visual markers or GPS make it possible to tag "*people, places and things*" [3], make them machine-recognizable and associate them with additional information. That way, physical objects can act as bridges into the digital domain, as they advertise ubiquitous information and services, facilitate their discovery and support the interaction with them. Complementary, mobile devices provide increasing technical capabilities for discovering, capturing and using information and services from the real world.

Physical Mobile Interaction (PMI) [4] takes advantage of these developments and uses mobile devices for physical interaction with tagged objects in order to facilitate the interaction with associated information and services. Due to its increased directness and simplicity, physical interaction can make mobile interaction more intuitive and convenient. Real world objects can serve as physical interfaces that complement mobile interfaces and adopt some of their features. Mobile applications are less confined to the constrained input/output facilities of mobile devices. Instead, users can interact with information and services by touching or pointing at physical objects, respectively by touching NFC-tags or by taking pictures of visual markers with their mobile devices.

Mobile interaction with physical objects is adopted by a growing number of applications for service discovery and invocation, ticketing, mobile payment, advertisement, information services or games: Visual markers are used as two-dimensional barcodes to identify consumer products or to tag objects with encoded URLs (e.g. Semapedia [5]). Mobile interaction with places is the foundation for location based applications and games like geo-tagging [6] or geo-caching [7]. NFC and RFID [8] are rapidly establishing as technologies for mobile ticketing (e.g. Octopus card [9]) or payment (e.g. iMode Felica [10]) as they reduce them to simply swiping a smart card or a mobile phone over a reader.

The further advancement of systems enabling or using PMI provides new opportunities for mobile interaction with a growing number of tagged physical objects and an increasing amount of information that is available from them. The impact of this development has been antedated by Mark Weiser: "*When almost every object either contains a computer or can have a tab [inch-scale machines that approximate active Post-It notes] attached to it, obtaining information will be trivial.*" [2].

However, most *Physical Mobile Applications (PMA)* – mobile applications using PMI - make only little use of this growing potential. They are often restricted to the interaction with single tags to facilitate the first step in an interaction workflow which is then continued on the mobile device, suffering from its usability constraints. Further interaction with physical objects is usually neglected. In most cases, the information from a tag is coupled with a specific service and cannot be combined with other information or reused with different applications. Similarly, mobile services are often confined to specific tasks, are not interoperable and don't exchange information.

In order to take better advantage of the increasing opportunities for mobile interaction with objects and information from the real world beyond *Single-Tag Interaction (STI)*, Physical Mobile Applications have to be able to interact with multiple objects and tags, combine their information and (re)use it with different applications and services. This paper investigates *Multi-Tag Interaction (MTI)* - PMI with multiple tags that are targeted at the same interaction process. It presents Collect&Drop as a generic technique for MTI that facilitates the collection, management and usage of information and services acquired from the real world in order to improve their combination, reuse and interoperability.

The next section provides an overview of related work about enabling technologies and interaction techniques for mobile interaction with physical objects as well as different applications using Multi-Tag Interaction. Section 3 presents the concept and interaction design of Collect&Drop as a technique for MTI in more detail. Section 4 describes the design and features of its mobile and physical interfaces while section 5 explains the architecture of Collect&Drop. Section 6 presents an evaluation of Collect&Drop, its interaction design and its features. Section 7 concludes the paper.

2 Related Work

Physical Mobile Interaction relies on various enabling technologies to implement the tagging of objects with information as well as its acquisition with mobile devices: In 1999, Want et al. [11] presented one of the first systems for tagging objects like books, documents or business cards with RFID-tags. By touching an object with an RFID-reader, users could open a corresponding virtual representation, e.g. a website, with further information on an attached tablet-PC.

Cooltown [3] augments people, places and things with infrared beacons to transmit URLs that point to the web presence of an object. Mobile devices can use these URLs to get more information about objects from a web page or send them to web-enabled appliances for further usage.

The recognition of two-dimensional visual markers with mobile phone cameras has become one of the most established technologies for PMI: Rohs and Gfeller developed the Visual Codes system [12] that implements a lightweight visual code recognition algorithm that is adapted to the technical constraints of mobile phones (e.g. low resolution and image quality, limited processing power).

Another visual marker system is CyberCode [13] that has been used for direct-manipulation techniques in physical environments. One example is InfoStick [14] that implements a physical drag-and-drop operation. It uses CyberCodes to identify objects and pick up digital information from them with a wand-like camera device. That way, digital information can be moved between different physical objects and devices (e.g. monitors, printers, projectors) that are also identified by CyberCodes.

Välkkynen and Tuomisto [15] use a laser pointer attached to a PDA to implement the *PointMe* interaction technique which has light sensors in the physical object react to the laser beam. An advantage of using a laser pointer for interaction is the observable feedback that users get when pointing into the direction of an object.

Different techniques have been built on top of these and other technologies in order to make the interaction with them more familiar and intuitive: In [16] Rukzio et al. compare the interaction techniques *Touching* (using NFC) *Pointing* (using a laser-pointer) and *Scanning* (using Bluetooth) that are used for the selection and usage of smart-home appliances in different contexts of location and activity (e.g. sitting, lying or standing). The choice for an interaction technique was dependent on the location of the user, his motivation and his activity.

Several applications already show how to use the interaction with multiple objects and tags as input for mobile applications: Pac-Lan [17] implements an outdoor version of Pac-Man where RFID-tags in the real world replace the pills in the game. Players have to touch them in order to update their position. Players are also tagged with RFID-tags in order to identify them.

The mobile interaction technique Point&Shoot [18] relies on a coordinate system implemented with a grid of visual codes in order to determine the absolute position of objects on a large display.

The SmartTouch [19] project developed a multi-tag application that lets elderly people choose from alternative meals for home-delivery by touching different NFC-tags on a menu-card. In addition, the delivery personnel mark their delivery route by touching NFC-tags at different locations.

In [20], Reilly et al. present a prototype that allows the selection of different regions on a map by touching attached RFID-tags. The prototype also supports different techniques for the selection of tags including path-select, multi-select or lasso-select.

3 Introducing the Concept of Collect&Drop

Collect&Drop is a generic technique for Multi-Tag Interaction (MTI) - Physical Mobile Interaction with multiple tags that are targeted at the same interaction process. Multi-Tag Interaction increases the scope of mobile interaction with the real world: While Single-Tag Interaction is by definition confined to the interaction with single tags on single objects, Multi-Tag Interaction implies the interaction with multiple tags on the same or on different objects for a collective purpose. In this context, Collect&Drop tries to take advantage of the diversity of real world information that is provided by the interaction with multiple objects and tags. For that purpose, it implements a generic mechanism for the collection, management and usage of information and services from the real world in order to improve their interoperability and to enable their (re)use and combination across different objects and applications.

3.1 A Use Case Scenario for Multi-Tag Interaction

In order to illustrate the concept of Collect&Drop, this section gives a short overview of a use case scenario that was chosen for its implementation with a mobile client prototype. This scenario demonstrates mobile interaction with three augmented posters for mobile ticketing and sightseeing. Each poster is associated with a specific Web Service and comprises multiple tags that provide parameters for its invocation. Users can interact with these tags and use their mobile devices to collect information about services and parameters (see Fig. 1). Collect&Drop supports the management of this information as well as its usage for the invocation of the Web Services.

Fig. 1. Collect&Drop enables mobile interaction with multiple objects and tags

The movie ticket-poster (Fig. 2a) allows the interaction with a Web Service for ordering movie tickets and provides four groups of parameters (movie, cinema, time, number of persons) for invoking it. These groups are arranged in a numbered order to guide users through the interaction workflow.

Similarly, the public transportation-poster (Fig. 2b) offers the possibility to buy tickets for a public transportation system and is associated with a corresponding Web Service. The poster comprises numbered groups of parameters to select a departure zone, a destination zone, the validity of the ticket and the number of passengers.

Finally, the city guide-poster (Fig. 2c) presents 10 popular sights in Munich, Germany. Users can select the sights they are interested in and send them to a Web Service to receive additional information about each object. The design of the poster highlights the beginning and the end of the interaction workflow, but does not number the different sights or suggest any order in which users should interact with them.

Fig. 2. Posters for mobile ticketing (a, b) and sightseeing (c). Each tag includes graphical symbols (d) to indicate and support the physical interaction with it by touching its NFC-tag, taking a picture of its visual marker or typing its numeric identifier into a form.

Each poster comprises multiple tags that contain or reference XML-encoded information that can be used to invoke the Web Service that is associated with the poster. Each tag is augmented with an NFC-tag, a visual marker and a numeric identifier which are indicated by different graphical symbols (see Fig. 2d). Users can interact with these tags and acquire their information by touching them with their NFC-enabled mobile device, taking a picture of the visual marker or typing the numeric identifier into a form.

3.2 Information Typing for Flexible Interaction

In order to allocate services, tags and parameters from the use case posters correctly and to enable their combination and usage across different objects, Collect&Drop builds upon the PERCI-framework [21] for PMI with Semantic Web Services and uses some of its technologies. The use case scenario for Collect&Drop reuses Web Services from the framework in order to guarantee the compatibility with these technologies. Opposite to the first mobile client for the PERCI-framework which implemented MTI in a rigid way (see [21]), Collect&Drop supports a much more flexible interaction with tags and information from physical objects.

The interaction design of Collect&Drop adopts the concept of *Abstract Parameter Types* from the PERCI-framework. Abstract Parameter Types are a generic typing-mechanism that adds semantic meaning to information from tags and marks it as a certain type with specific properties, e.g. as a cinema, movie or transportation zone. Collect&Drop uses this typing-mechanism with two kinds of information items that can be acquired from tags on physical objects:

- An *Action Item* describes a service or an application and provides information that is necessary for its execution. This information specifies a reference to the application/service (e.g. a URL), the interaction protocol (e.g. Web Service, Bluetooth …) and the types of parameters that are necessary for its invocation. For example, the cinema service needs information about a movie, cinema, time and the number of visitors. Fig. 3 shows a fragment of the XML-description of the Action Item for this service. The *params*-tag contains each of the necessary parameters with a label and its Abstract Parameter Type that is needed for finding matching parameters.
- A *Data Item* contains parameter information that can be used to execute applications or services. Data Items use the same Abstract Parameter Types to specify the type of their information for matching them with Action Items but also provide a specific parameter-value, e.g. the title of a certain movie.

Using the same typing-scheme for both Action and Data Items makes it possible to map applications/services and parameters to one another correctly. Information items can be independent from each other which again supports their combination and reuse - as long as their parameter types match. For example, a service from an Action Item can be invoked with any Data Item from any tag on any object, as long as their Abstract Parameter Types match. In the same way, Data Items that have been collected from one object can be reused with different Action Items to execute their services or applications. That way, Collect&Drop realizes mobile interaction with tags and information across different objects and improves the interoperability between information and services. Separating actions and parameters on the level of information items also makes it possible to combine Action Items and Data Items on the same tag (*Hybrid Tags*) and to map several of them to the same tag.

```
<actionItem protocol = "PERCIWebserviceAction">
  <label>Get movie ticket (Webservice)</label>
  <desc>This action invokes the Movie Ticketing Web Service with
     your data.</desc>
  <url>http://perci.medien.ifi.lmu.de:8080/axis/serviceDescription/
     extendedCinema/</url>
  <params>
    <param>
      <label>Movie Title</label>
      <abstype>http://perci.medien.ifi.lmu.de:8080/axis/domain/
         cinema/cinema.owl#MovieTitle</abstype>
    </param>

    ...

  </params>
</actionItem>
```

Fig. 3. XML-description of an Action Item including the parameters for its execution

3.3 Basic Interaction Design of Collect&Drop

Fig. 4 shows the interaction workflow of Collect&Drop which is divided into two phases: During the Collect-phase, mobile devices interact with tags (indicated by a black frame) on physical objects in arbitrary order to acquire their Data Items and/or Action Items (blue and red squares). Each tag can contain or reference one or more Action Items and/or Data Items, respectively service-URIs and parameters. The current Collect&Drop client supports the interaction techniques Touching (using NFC), Pointing (using the recognition of Visual Code markers) and Direct Input (typing of numeric identifiers) for mobile interaction with tags on physical objects, respectively the use case posters.

Collect&Drop stores and manages acquired Data Items and Action Items in *Collections* on the mobile device. Collections are data containers that facilitate the organization of information items and support the execution of applications and services specified by Action Items. Collect&Drop creates a new Collection for each Action Item that is acquired from a tag and adds Data Items according to their Abstract Parameter Types. This mechanism implements the matching between Action Items that require parameters of a certain type for their execution and available Data Items that provide these parameters. That way, an application that needs a certain type of information (e.g. a location) for its invocation, can use any Data Item as long as it matches the requested type. Whenever a new Data Item is collected, Collect&Drop automatically checks whether its Abstract Parameter Type matches the Abstract Parameter Type of all parameters that are required by any Action Item and adds matching Data Items to its collection. The system informs the user as soon as sufficient Data Items for the invocation of an action are available. Collections store information items beyond their immediate usage which provides the foundation for their combination and (re)use with different applications or services.

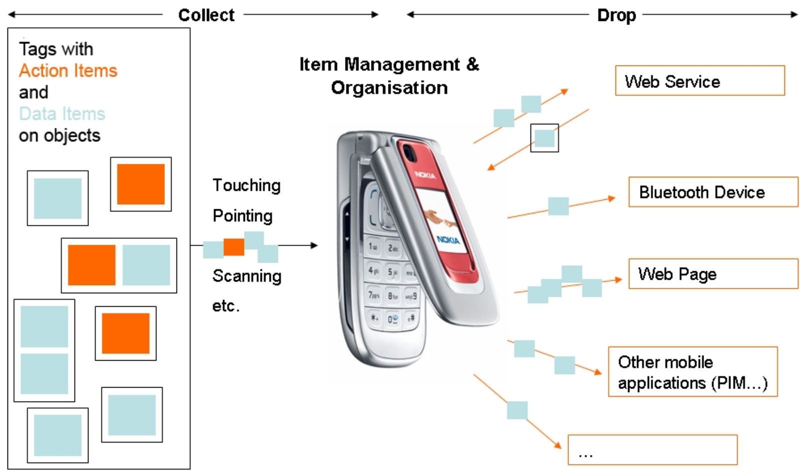

Fig. 4. The interaction workflow of Collect&Drop: collection, management and usage of information items

During the Drop-phase, Collect&Drop again relies on different technologies to execute applications or services from Action Items, respectively to "drop" Data Items from a collection to its Action Item. The name "Collect&Drop" tries to imply a certain mental model that when interacting with tags on a physical object, users can collect Data Items from different tags and then drop them to a tag with an Action Item in order to invoke its application/service. Technically, Collect&Drop does not really drop Data Items to a tag but rather picks up its Action Item to initiate the invocation of its application or service with collected Data Items. That way, a Web Service can be invoked via GPRS or UMTS, Data Items can be transferred to other devices via Bluetooth or NFC, a web page can be opened or information can be written to PIM-applications on the mobile device.

Applications and services can return a Data Item as the result of their invocation (see the return arrow from the Web Service action in Fig. 4). This item is again collected and stored by Collect&Drop and can be used with other applications. For example, the movie ticketing service returns a movie ticket-Data Item which can be used to order a transportation ticket to the cinema, using the location information from the ticket-Data Item.

4 Mobile and Physical Interfaces for Collect&Drop

The interface of Collect&Drop comprises both the Collection-interface on the mobile device as well as the physical interface that users interact with in the real world (e.g. the use case posters). The last section introduced Collections as data containers that manage information items acquired from tags on physical objects and support the execution of Action Items. For that purpose, the interface of the mobile Collect&Drop-client comprises four main elements:

- **Collection List:** The Collection List presents the different Collections to the user. Fig. 5a shows an example with three Collections for different services. When the user starts the application for the first time, an empty Collection List is displayed that briefly explains how to use the different interaction techniques. As users interact with physical objects and their tags, different Collections for acquired information items are automatically added to the list to facilitate the interaction with them. Whenever information has been collected from a tag, Collect&Drop provides feedback through vibration and a visual pop-up.
- **Item List:** This interface shows all information items in a Collection when it is opened from the Collection List. All information items in a Collection are separated into Action and Data Items. As Fig. 5b shows, there is only one Action Item in a Collection which lists all parameters, respectively Data Items that are available or missing for its execution. A traffic light visualization informs users about the individual states of all information items. Data Items are always yellow. Action Items are marked as red as long as there are parameters missing for their execution. As soon as suitable Data Items have been collected, they are added to the Collection. When enough Data Items - either stored or collected - are available for executing the action, it is marked as green (see Fig. 5c). The purpose of this visualization is to provide a better overview of collected information items and the status of actions that can be executed with them.

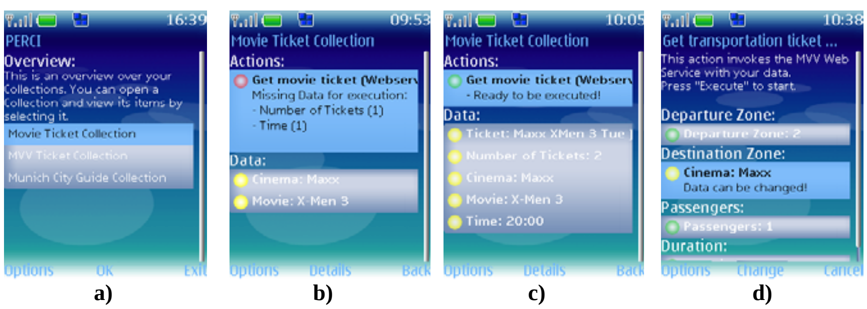

Fig. 5. Screenshots of a Collection List (a), two Item Lists (b, c) and an Action Execution Screen (d)

- **Action Execution Screen:** This interface asks users to confirm the execution of an action and presents an overview of the Data Items that have been selected for that purpose (see Fig. 5d). In case there are multiple Data Items with the same Abstract Parameter Type that can be used for the execution of the action, the item is highlighted with a yellow traffic light and the user can select from the alternatives.
- **Action Specific Screens:** After pressing the "Execute" command on the Action Execution Screen, the user interface control is handed over to the respective action component. Thus, it can present individual screens and control commands to the user, e.g. to indicate the transmission of data via GPRS or Bluetooth, to ask users to touch another NFC-device for data exchange or to execute additional steps in the interaction with a Web Service.

In order to fully realize MTI, the mobile Collect&Drop-client is complemented with physical interfaces that provide the input for the interaction with services and application. The separation of Data Items and Action Items, their association through the Abstract Parameter Types as well as the concept of Collections to manage information items on the mobile device persistently makes the interaction design of Collect&Drop very flexible. The design of the use case posters relies on this flexibility to implement different features for the interaction with multiple tags and physical objects.

The movie ticket-poster uses Hybrid Tags that combine Action Items and Data Items on the same physical tag. Apart from its specific parameter-information, each tag on this poster contains the same Action Item that provides information for invoking the movie ticketing service. This Data Item is implicitly collected whenever the user interacts with any tag on the poster. The idea behind Hybrid Tags is to make the interaction process less complex for the users as they don't have to collect a separate tag that is dedicated to the Action Item for the service. Since all tags are the same, the users can interact with them in arbitrary order. In addition, the Data Items of the cinema tags on this poster also provide location information. The Web Service that is associated with the public transportation-poster can use these Data Items as input to provide tickets for getting to the cinema.

Contrary to the movie ticket-poster, the public transportation-poster does not use Hybrid Tags but separates Data Items and Action Items by putting them onto different tags. A tag that is thus dedicated to a single Action Item is called *Drop Tag*. Opposite to Hybrid Tags which provide Action Items implicitly, users have to collect the Drop Tag explicitly in order to invoke the ticketing service. The added complexity of interacting with a dedicated Drop Tag might be useful for applications or services that rely on explicitly triggering an action by collecting its tag, providing some kind of closure for this process. Dedicated Drop Tags also make it easier to use the same Data Item on a physical object with different services. That way, the movie ticket-poster could easily be extended with Drop Tags for additional services to get further information about its movies or to buy merchandising for them.

In addition to the dedicated Drop Tag, the public transportation-poster also features a so called *Quick Drop*-tag that includes all Action Items and Data Items for requesting a standard ticket (1 person, 1 day, start zone defined by poster location), except the Data Item that specifies the destination of the journey. This tag implements a shortcut that only requires its users to drop a single Data Item from the poster or other objects to complete the request to the Web Service. The missing Data Item can be taken from Collections on the mobile device. That way, a user who has interacted with the movie ticket-poster and has collected a Data Item for a movie or a ticket, can use the location information from this Data Item with the Quick Drop-tag to easily get a transportation ticket to the location of the cinema for which he bought a ticket.

The city guide-poster also features a dedicated Drop Tag in order to provide some kind of closure with which users can finish their interaction with the poster. All other tags provide Data Items about sights and Data Items about their location that can be used with the Public Transportation Poster.

The three use case posters offer a wide range of different features for MTI: The movie ticket-poster features implicit interaction with Hybrid Tags while the public transportation-poster and the city guide-poster implement explicit interaction with dedicated Drop Tags. Data Items from the movie ticket-poster and the city guide-poster can be reused with the Drop Tag and the Quick Drop-tag from the public transportation-poster thus realizing cross-object interaction.

5 Collect&Drop Architecture

The concept of Collect&Drop brings out three main requirements for its system architecture regarding the interaction with physical objects, data management as well as the execution of different actions (see Fig. 4). Collect&Drop is a client-side mechanism that was implemented as a J2ME-midlet on the Nokia 6131 NFC mobile phone. It handles the interaction with physical objects and uses their information to invoke associated Web Services that are part of the PERCI framework (see [21] for details). The architecture of the mobile Collect&Drop application (see Fig. 6) comprises the following components:

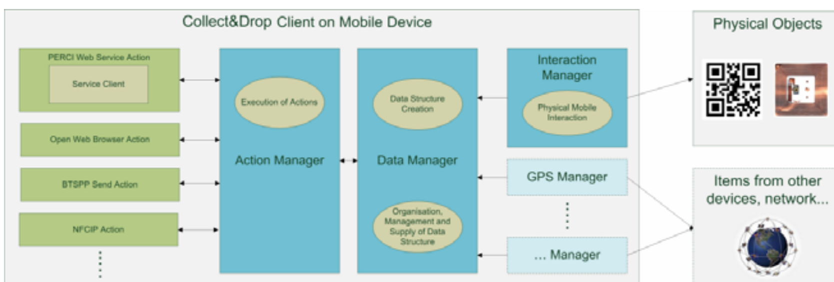

Fig. 6. The architecture of Collect&Drop including its components for PMI, data storage, management and the execution of actions

The *Interaction Manager* supports different PMI technologies and techniques through specialized sub-components and is responsible for receiving information through interaction with physical objects or other devices. The current implementation of the mobile Collect&Drop-client supports interaction through reading NFC-tags, taking pictures of visual markers and decoding them as well as the input of numeric identifiers. The Interaction Manager forwards information from tags to the *Data Manager* for further processing. When tags - especially visual markers - do not have enough capacity to store one or several information items directly, they only provide an identifier or a reference to this information, e.g. a URL. In that case, the Interaction Manager has to resolve this reference and download information items from a server.

The Data Manager provides different functionalities to parse and check information items, create new Collections and integrate new data with existing ones. The Data Manager must provide interfaces for other components to request or to delete data. It informs other components about the arrival of new data and the change or deletion of items and Collections. Other components can request data e.g. in order to present items and Collections to the user, to check whether new Data Items are available for an action or to use new items for action specific functionalities.

The *Action Manager* is responsible for mapping suitable Data Items to Action Items, checking whether Action Items are executable and finally organizing their final execution. This component has to manage the different Data and Action Items (which can be requested from the Data Manager) and check whether there are enough suitable Data Items for the execution of an Action Item. Actions can be executed automatically or manually from the user interface.

For every type of action there is an *Action Component* that describes the logic for executing a specific action. The Collect&Drop prototype currently supports the following actions, but can easily be extended with new ones:

- The *PERCI Web Service Action* component connects the Collect&Drop-client with Web Services from the PERCI-framework and handles their invocation.
- The *Open Web Browser Action* component uses the mobile device's standard web browser to open a website. The request is generated from an Action Item, providing the URL, and several Data Items, providing the request parameters. The resulting HTTP-GET request is processed by the server which generates and returns a web page according to the provided parameters.
- The *BTSPP Send Action* uses the Bluetooth Serial Port Profile (SPP) to send data to another Bluetooth device. Similar to the Open Web Browser Action, the Bluetooth address is taken from an Action Item and the data is assembled from Data Items.
- The *NFCIP action* is intended to send data to other devices via NFC. However, in this case no target address is specified. The generated data is sent to an NFC device which has to be touched after an NFCIP Action Item has been executed.

6 User Study and Evaluation

In order to evaluate Collect&Drop and its approach to Multi-Tag Interaction, a user study was designed and conducted with a working prototype and the use case posters. This section summarizes the design, setup and results of this study.

6.1 Scenario Design

For the evaluation of Collect&Drop, the subjects of the study had to carry out five different tasks for which they had to use the mobile Collect&Drop-client in order to interact with the use case posters.

- The first two tasks asked the subjects to interact with the movie and transportation posters separately. Apart from the overall interaction design and usability, these tasks tested whether the layout of the posters or the numbering of their options influenced the order in which the subjects collected them. In addition, the tasks tested whether users preferred interacting with dedicated Drop Tags (on the transportation poster) or with Hybrid Tags (on the movie poster).
- The third task evaluated cross-poster interaction as the subjects had to drop the movie ticket-Data Item they had received from the movie ticketing service to the Quick Drop-tag of the transportation poster.

- For the fourth scenario, the subjects had to drop the same movie ticket-Data Item to an NFC-tag that simulated a tag-reader at the entrance of a cinema. This task tested whether the subjects understood how to use a Data Item which they had received from a Web Service with other objects and applications.
- For the last task, the subjects had to collect tags for different sights from the sightseeing poster. Upon executing the action associated with the poster, Collect&Drop opened the web browser of the mobile phone and presented a web page with descriptions of these sights that was returned from a server. This task tested whether subjects got along with a different kind of action and a poster that allows the selection of an arbitrary amount of items.

6.2 Setup and Demography of the User Study

At the beginning of the study, each subject was shortly introduced to the Collect&Drop concept and the 5 tasks. The study was conducted with a panel of 15 subjects. Five of them were female, ten were male. The average age of the subjects was 25.5 years. 13 subjects were students: Nine of them had a background in computer sciences; four were studying other subjects like economics, geography, physics or statistics. The remaining two subjects worked as research associates that were not involved with the PERCI-project. All of the subjects owned a mobile phone and have done so for an average of about 6 years. The average skills with mobile phones were rated with 3.9 on a scale from 1 (not experienced at all) to 5 (very experienced). General technical skills were rated with an average of 4.1.

6.3 Results and Discussion

This section summarizes the results of the user study and the evaluation of Collect&Drop. Average values were calculated from Likert-scale ratings ranging from 1 (“do not agree at all”) to 5 (“fully agree”).

6.3.1 Collect&Drop Concept

The concept of Collect&Drop was accepted by the subjects, as 13 of 15 would use it if it was available. The subjects considered it to be very practical, easy, quick and time-saving. The comprehension of the Collect&Drop concept was rated with an average of 4.7. Several users stated that the whole application and the concept become clearer after the first usage. They said that it was a bit confusing at first and that they felt unconfident with the handling of the interaction and the application. But after they had seen how it worked, it became easier, clearer and more intuitive.

The design and the navigation of the Collection List and the Individual Item List were rated with an average of 4.1. Most subjects did not spend much time on the Individual Item Lists. During the interaction, the posters got more attention than the application. However, after every interaction with a tag, most of the subjects had a brief look at the list to check whether the collected Items had been added. The traffic light visualization did not get much attention and was not commented. The idea of managing information items in Collections was rated with an average of 4.5.

6.3.2 Comparison of Invisible Drop and Explicit Drop

A narrow majority of eight subjects was aware of the difference between posters with Hybrid Tags (movie poster) and a dedicated Drop Tag (transportation poster). A comparison between the two approaches shows that Hybrid Tags consistently got better results regarding simplicity, speed, intuitiveness and comprehensibility. Fig. 7 summarizes the results (rating from 1=worst to 5=best):

- **Simplicity:** Both systems are rated as easy to use, with Hybrid Tags scoring an average rating of 4.7 compared to 4.2 for the explicit Drop Tag.
- **Speed:** As expected, the results regarding the speed of both approaches show the biggest difference between them. The interaction experience without a dedicated Drop Tag is rated with 4.9, the one with a Drop Tag only with 3.4. This can be referred to the time that is needed to interact with the additional Drop Tag on the transportation poster.
- **Intuitiveness:** The explicit Drop Tag got an average rating of 3.7 and the Hybrid Tag 4.5 regarding intuitiveness of use. The results confirm that a Drop Tag does not make the system more intuitive, as assumed in the first place
- **Comprehensibility:** In terms of comprehensibility, the Drop Tag achieved a 4.1, the Hybrid Tags a 4.7. As Hybrid Tags always contain Action Items, their Collections always show information about their actions and missing parameters. One user stated that it was a very good idea to give such kind of feedback.

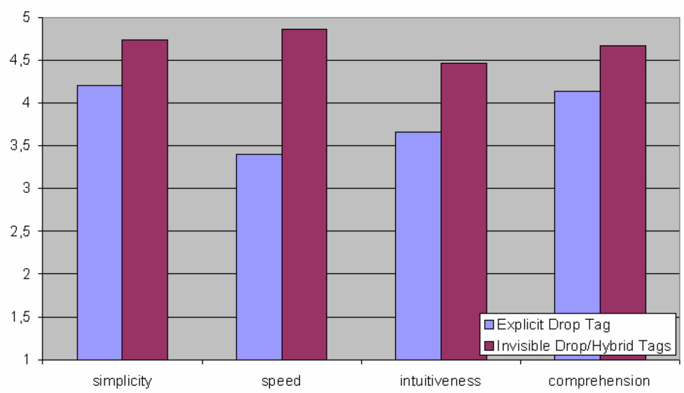

Fig. 7. Comparing Drop Tag and Hybrid Tags regarding simplicity, speed, intuitiveness and comprehension

When a Hybrid Tag has been collected, the usual pop-up showed the reception of two or more new information items. At the beginning, this information confused some users, as a single interaction resulted in the collection of two or more information items. However, after showing the Individual Item List, the concept became clearer or did not bother anymore.

6.3.3 Cross-Object Interaction and Quick Drop

Similar to the comparison of Hybrid Tags and Drop Tags, the subjects were asked to evaluate the concepts of Cross-Object Interaction between the posters and Quick Drop regarding speed, simplicity, intuitiveness and comprehension, again on a scale from 1 (worst) to 5 (best).

Cross-Object Interaction was rated as very quick with an average of 4.8, which can be explained with the fact that Data Items are already available on the phone and did not have to be collected again. The simplicity of Cross-Object Interaction was rated with an average of 4.2. Several users noted that it might get confusing if too many Data Items with suitable parameters were already on the phone. The average ratings for comprehension (3.9) and intuitiveness (3.3) were a bit lower. The posters were regarded as independent use cases and are more related to their individual services. Interoperability between posters seemed to be quite strange and unnatural at first. However, many subjects stated that the concept of Cross-Object Interaction became much clearer, more comprehensible and even quicker after the first try.

The results from the evaluation of Cross-Object-Interaction were similar to the results of the Quick Drop evaluation. This is not a surprise, since Quick Drop incorporates the idea of Cross-Poster-Interaction. The usefulness of Quick Drop was rated with 4.2. Problems appeared at the beginning of the Quick Drop scenario. Several subjects did not know how to start and asked if they were supposed to touch the Quick Drop tag first or do anything else. Another problem was that it was not clear to the subjects what would happen if more suitable Data Items were on the phone. If there are too many suitable Data Items for an Action Item to choose from, the users fear confusion and the loss of overview. Quick Drop still got a good rating for its simplicity (4.6). It might be an unnatural and unfamiliar process at first, but if somebody knows how to use it, it will be quite easy and practical. This was confirmed by many subjects, who said that after one try the functionality becomes much clearer and easier. The last category, speed, does not reveal any surprising results. As expected, the Quick Drop scored a high rating of 4.7 regarding the speed of interaction.

6.3.4 Poster Numbering

Four of the 15 subjects did not follow the numbering provided by the posters. In all cases, this phenomenon happened with the transportation poster during the first scenario. When asked about their preferences, all subjects advocated posters with numbering and a given order of interaction. They considered these as much easier and more intuitive as they are led through the process and no option can be forgotten. The provided orientation also prevents mistakes and is particularly helpful for beginners. Some subjects also stated explicitly that it was indeed a useful idea to provide a numbering, but it was also very practical that the order could be burst and an individual order of interaction could be applied.

6.3.5 Data Items as Output and Input

Receiving a ticket as the result of invoking a service and validating the movie ticket at the simulated tag reader caused no problems and was well understood (average 4.6). Subjects noted that it was a very good idea to have an electronic ticket on the phone as it avoids queuing at the cinema and is thus considered to be time-saving, very easy and intuitive.

7 Conclusion

This paper investigated the opportunities and challenges for mobile interaction with multiple physical objects, tags and information as it presented and explored the concept of Collect&Drop as a generic technique for Multi-Tag Interaction.

The evaluation of Collect&Drop provided interesting results about its own interaction design as well as MTI in general: One the one hand, the study showed that users basically understood and accepted the concept of Collect&Drop as well as its different features which confirms its approach to MTI. Users intuitively understood the rather abstract collection of information items on and between different objects and quickly learned how to use features that were unfamiliar to them at first. On the other hand there is still room for improving the interaction design and usability of Collect&Drop as some users still did not know how to start the interaction with the poster or had problems with the interaction workflow.

Probably the most interesting result of the study is that users quickly learn to use Multi-Tag Interaction, despite its increased complexity compared to Single-Tag Interaction. At different occasions during the study it could be observed that users did not understand the concept of MTI or the features of Collect&Drop at once. Nevertheless, users quickly learned how to use them and then even embraced them. In this context, the comparison between interaction with Hybrid Tags and a dedicated Drop Tag showed that MTI has to retain the simplicity of PMI, despite its added complexity.

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