# Tangible Mashups: Exploiting Links between the Physical and Virtual World


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## ABSTRACT

The link between corresponding physical and virtual worlds has been the subject of research for many years now. The instantiation of this link was often a complex task that involved special purpose techniques to identify and search for the virtual information that belongs to a selected physical object. It is since the conception of physical tagging technologies such as RFID that physical objects can carry their own virtual information. In this paper we show a simple yet effective approach to extract the virtual information of physical objects and aggregate it in a sensible way for the user. We rely on Web 2.0 techniques to accomplish this. A useful side-effect of our approach is the fact that a set or *mashup* of physical objects leads to a mashup of their related information in the virtual world.



## Keywords

Mashups, RFID, Internet of Things, Ubiquitous computing, Visualization


## 1. INTRODUCTION

The *Internet of Things* (IoT) can be considered as an extension of the current Internet, in which everyday devices and physical objects are given the ability to connect to a data network [4]. Although this vision is not yet a reality, existing technologies can already easily identify physical objects. The most common approaches consider individual objects, while in real life combinations of objects or object collections often occur. For example, consider the use of a physical tool to alter the state of another physical object. In this paper we investigate how we can support the representations of physical object combinations or collections in the virtual space.

For identification of objects, Radio-Frequency Identification (RFID) is an established low-cost technology, replacing the traditional barcodes [12]. An RFID tag contains a unique code that can be read by a wireless reader. Warehouses already use these tags to make shipping more efficient. It is not unlikely that in the future many objects in our everyday environment will be equipped with an RFID tag. Although most RFID-enabled objects do not yet have any computing power or network access, it is an important first step towards bridging the physical and digital worlds. Any kind of (online) data can be linked to the unique ID provided by an RFID tag. This means objects can be identified and annotated with additional information.

An important problem for the realization of the IoT is the accessibility of the digital information that is embedded in the everyday objects around us. Our environment will contain many different kinds of information (e.g. geographical coordinates, dates, ISBN numbers, . . . ), and a way to extract this data and present it to the user in a sensible way is needed.

An interesting approach to this problem has been taken with Web 2.0 mashups. According to Wikipedia [13], a *web mashup* is a website or application that combines content from more than one source into an integrated experience. A well-known example is displaying pictures on a map according to the geographical location they were taken. This example combines two web services: a photo sharing service such as Flickr[1] and a map service such as Google Maps[2].

The work we present in this paper allows users to mashup data attached to different physical objects. These objects are identified by their RFID tags and can be annotated with snippets of information. This information can be seen as the virtual representation of the physical object. A user can visualize his or her environment by putting a number of objects together in the vicinity of an RFID reader. We argue that this is an intuitive technique, since creating a mashup of objects in the real world (putting them together) results in a mashup of their related information in the virtual world.

The remainder of this paper is structured as follows. First, we present the details of object annotation. We then discuss an example usage scenario that covers object annotation and the creation of a mashup. After presenting the main ideas

[1] `http://www.flickr.com/`
[2] `http://maps.google.com/`

and the current status of our work, relevant related work is discussed. Finally, we draw the conclusions and look into possibilities for future work.

## 2. OBJECT ANNOTATION

Our approach allows to annotate physical objects with a virtual counterpart for their physical presentation. As mentioned in the introduction, the physical objects are tagged with an RFID tag that contains the virtual information or identifies where the information can be found. We use a persistent URL (purl)[3] to identify the virtual information related with a tag. The current architecture of the World Wide Web is fit to rely on persistent URIs to identify data, but does not allow to infer properties of the data from the URI [5] (a consequence of the minimalist and orthogonal design of the URI scheme). However, the virtual information has a certain type that needs to be defined by a schema so it can be checked for well-formedness and even for completeness. For now a schema for the data to which the purl points is inferred by the purl domain name or on an ad-hoc basis. A more generic approach is required however.

We identify two classes of physical objects: *tool objects* and *data objects*. A physical object can be in one or even both of these classes depending of its perceived affordances. For example: a map can be considered as data (names of places) and as a tool (for way-finding). Each tagged object can contain metadata, independent of its class. Notice the similarity with different classes of web resources: a data object can be mapped on a web fragment, a metadata object can be mapped on a MIME type or even a Resource Description Framework (RDF) description contained in the web fragment[3] and a tool object can be mapped on a web service (described with WSDL). This is an example of an ideal mapping of physical objects onto web resources that is seldom possible in the real world.

We propose these mappings as a basis for an extensible web-based mashup framework for working with physical objects. Sect. 4 explains the architecture of this framework into detail. We have built an initial system to assess whether combinations or collections of annotated physical objects can be represented as mashups in the virtual space by making use of traditional web resources.

## 3. USAGE SCENARIO

We will explain how objects can be annotated and combined in a mashup by means of an example usage scenario.

Bob is browsing through the pictures from his vacation in Cyprus last summer. Unfortunately he can't remember where all the pictures were exactly taken. He decides to use the metadata associated with the pictures, such as the geographical coordinates of the position where it was taken. Each digital photo print contains an RFID tag, which links the picture with its virtual information. Bob holds the picture in front of the RFID reader, after which the system reads the tag and existing metadata associated with it. Bob can also add more information if he wants to (Fig. 1). He adds a link to the digital counterpart of the picture at Flickr, including its tags such as `culture` and `holidays`. Bob repeats this process for all his holiday pictures.

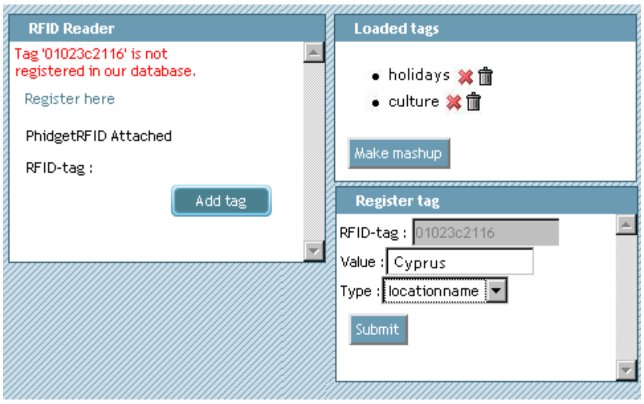


**Figure 1: Reading an RFID tag**

He then takes out a map (which is also RFID-enabled) and lays it out on a table, together with all the pictures, as seen in Fig. 2. The map functions as a tool object that refers to the Google Maps service.

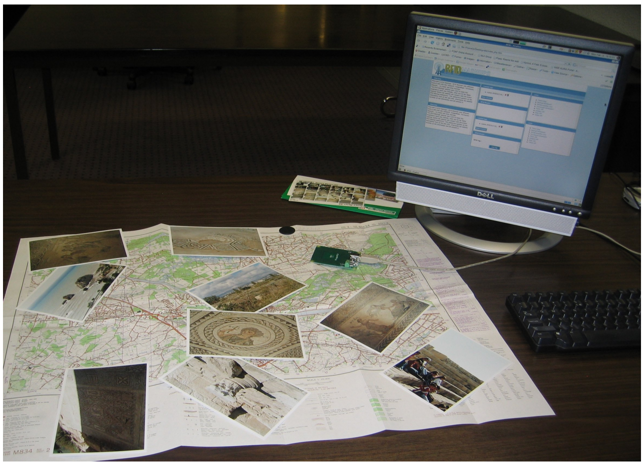

**Figure 2: Combining physical objects to make a mashup of their virtual information**

The system recognizes the tags and inspects the data objects and their corresponding schemas. Finally, the system decides that the geographical coordinates attached to the pictures can be used as an input to the Google Maps tool and combines them. The resulting mashup is shown in Fig. 3.

The next section gives an overview of the system architecture and the current status of our implementation.

## 4. CURRENT STATUS

We have built a first prototype to verify whether our approach was feasible. Fig. 4 gives an overview of the system architecture. An AJAX-enabled website allows a user to annotate objects and to create and visualize a mashup. We used an RFID reader from Phidgets, Inc.[4] and the tags that

[3] `http://www.purl.org`

[4] `http://www.phidgets.com/`


**Figure 3: The resulting mashup**

accompanied it. This website functions as a portal on the virtual space ("front-end") and allows the virtual counterparts of the physical objects to be queried or manipulated. The mashups of the combined virtual counterparts will be presented inside this same website.

A special purpose portal web service ("back-end") manages a database that relates the unique identifier of a tag (and thus physical object) with its virtual counterpart. The portal web service can also query different external web services (e.g. Google Maps, Flickr, ...) and return the aggregated results to website that is used as a portal on the virtual world. The portal and the portal web service exchange XML documents that adhere to a specific schema.

Our implementation is not yet complete though. A first shortcoming is the fact that the web services we use are predefined and will all be queried at once. Adding a new web service would require custom query code. Additionally, we do not yet support schema checking but use a few custom data types (e.g. `subject`, `locationGPS`, `URL`, ...).

To be able to use tool objects as we envisioned in the previous section, schema checking and automatic service invocation is required. We currently support a number of different web services such as Amazon for retrieving information about books, DVDs and CDs; Ebay which is used for searching related auctionable items; Flickr for retrieving images; Yahoo for collecting related media items and information (images, related tags, videos, news, ...) and Google Maps to place physical objects on a map according to a geographical location.

A final imperfection of the current prototype is the fact that the system cannot read multiple tags at once. At the time, we used an RFID reader from Phidgets, Inc. which has no support for *anti-collision*. The anti-collision feature enables a single reader to read more than one tag in its vicinity. The lack thereof makes the mashup process a bit inconvenient: objects cannot simply be put together within the range of

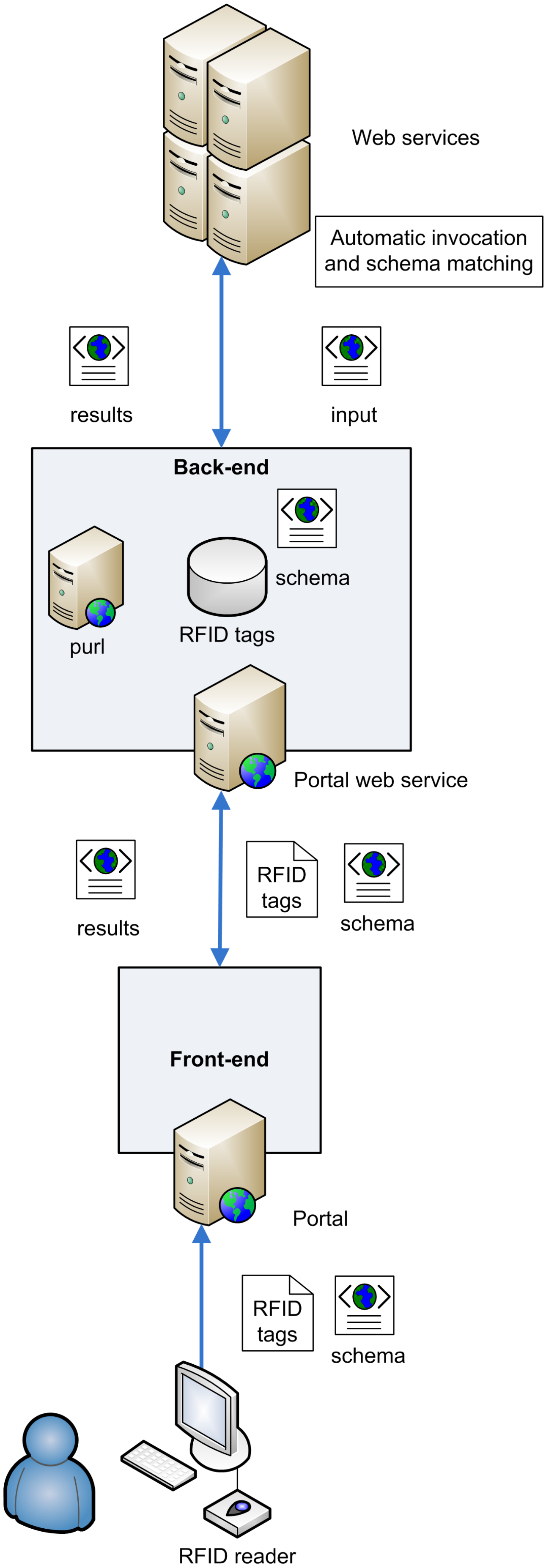


**Figure 4: An overview of the Tangible Mashup architecture**

the reader, they have to be scanned separately, one after the other. However, we recently acquired a portable reader from Socket Mobile, Inc.[5] which supports anti-collision. The system should require only minimal changes in order to switch to this reader.

# 5. RELATED WORK

One of the earliest approaches towards the IoT was the concept of *physical hyperlinks* [2, 6], which link physical objects with web resources.

U-Textures [7] are self-organizable universal panels that act as building blocks for smart environments. One of its applications is AwareShelf: a shelf-shaped structure which combines one u-Texture to extract information from RFID-enabled physical objects, and another one to visualize this information. Although this idea is similar to the approach presented here, the AwareShelf visualizes just one item at a time and only supports data objects.

The DataTiles system [9] consists of a flat-panel display with integrated RFID readers on which transparent tiles can be positioned. The display detects the RFID-enabled tiles and accordingly displays different information beneath it. The system distinguishes between a few different types of tiles, of which two can be compared to our notion of data and tool objects: application tiles and portal tiles. Application tiles are bound to specific applications or functions while portal tiles represent real-world things. As an example the authors describe a map tile that is placed next to a portal tile, after which the system shows the current location of the corresponding physical object on the map. Our work differs from DataTiles in two ways. First, our tool objects are real-world objects as well and can thus vary in appearance. The application tiles on the other hand are represented by the tile itself, and thus have a fixed physical representation. Secondly, the communication between tiles is less flexible: their corresponding Java interfaces have to be matched which requires extra code when new functionality is added.

SensorMap is a portal website to visualize and query real-time data (e.g. sensor data) on geo-centric web interfaces such as Google Maps [8]. Although the system is centered around the geographical location of data sources, there are some interesting similarities with the work we present in this paper. SensorMap uses metadata to describe additional information about a sensor (e.g. its name or location) and a markup language to describe the data interface of a sensor. This is similar to the concept of metadata and data type schemas for the information attached to physical objects. The fact that SensorMap is able to succesfully aggregate different sources accounts for the feasibility of this technique.

*Blogjects* go one step further than the Things we describe in this paper: they can disseminate a record of experiences to the web [1]. As an example the authors envision a scenario where flocks of vehicles constantly transmit information about their fuel consumption, allowing for a real-time visualization of fuel consumption and carbon monoxide exhaust on part of a freeway. Our system might also be useful for visualizing the data blogjects produce, although this would require support for real-time updates in the resulting mashup.

MediaBlocks [11] are small, tagged wooden blocks that serve as physical icons for the containment, transport and manipulation of online media. They share some properties with our physical objects. Most tangible interfaces integrate *representation* and *control*, while graphical interfaces make a fundamental distinction between input (*controls*) and output devices (*representations*) [10]. Both mediaBlocks and our physical objects interface with input and output devices. The physical objects in this paper serve as an input to the system while the output (the resulting mashup) will be displayed on the screen. Nevertheless, we feel our objects also have some advantages over the wooden blocks Ullmer et al. describe: a mediaBlock's physical shape does not embody a hint to its *virtual representation*. RFID-enabled physical objects reveal part of their virtual representation, exactly by their physical form. For example, a user might be able to predict that laying out a set of physical (printed) pictures on an unfolded map will visualize them according to their geographical location.

According to the taxonomy of tangible user interfaces (TUIs) proposed in [10], our system can be seen as a *mixed constructive/relational system*. Objects can be put together (*constructive*), thereby triggering an action by the system according to the relation of these objects to each other (*relational*).

# 6. CONCLUSIONS AND FUTURE WORK

This paper presented an early approach to visualize information embedded in physical objects in our environment. RFID tags are used to identify the objects, which allow them to be annotated with additional information. We distinguish between two classes of objects: data objects and tool objects. When tool objects and data objects are put together, the system tries to find a match between the information from the data objects and the inputs of the tool objects. It then visualizes the corresponding output of the tool objects. So in fact, by mashing up a set of physical objects (putting them together), a mashup of their virtual counterparts is created. An architecture for this technique was proposed, after which we discussed an example usage scenario. Finally, we gave an overview of the current status of the system, and presented a first working prototype.

We are exploring a few directions for future work. While discussing the status of our work, we explained that the current implementation is still incomplete. The first step is thus of course to complete the prototype with schema checking and automatic service invocation. The system should also be adapted to use an RFID reader that supports anti-collision. An important area for future work is providing multiple visualization methods. For one, a variety of data types, each with their own visualization requirements, need to be displayed. Secondly, users might have difficulties when interpreting large amounts of data. Data summaries or a zoomable user interface could offer a solution to this problem. The issue of privacy provides a final opportunity for future work. After all, a mashup could reveal sensitive information. It would be cumbersome if anyone could walk into an office and create a mashup of the environment.

[5] `http://www.socketmobile.com/`

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## 8. REFERENCES

[1] J. Bleecker. A manifesto for networked objects – cohabiting with pigeons, arphids and aibos in the internet of things. Feb. 2006.

[2] P. Couderc and M. Banâtre. Spreading the web. In M. Conti, S. Giordano, E. Gregori, and S. Olariu, editors, *PWC*, volume 2775 of *Lecture Notes in Computer Science*, pages 375–384. Springer, 2003.

[3] I. Davis. Grddl primer, 2006. [Online; accessed 12-February-2007].

[4] N. Gershenfeld, R. Krikorian, and D. Cohen. The internet of things. *Scientific American*, 291:76–81, Oct. 2004.

[5] I. Jacobs and N. Walsh. Architecture of the world wide web, volume one, 2004. [Online; accessed 12-February-2007].

[6] Kindberg et al. People, places, things: web presence for the real world. *Mob. Netw. Appl.*, 7(5):365–376, 2002.

[7] Kohtake et al. u-texture: Self-organizable universal panels for creating smart surroundings. In *UbiComp 2005: Ubiquitous Computing: 7th International Conference*, pages 19–36. Springer Berlin / Heidelberg, 2005.

[8] S. Nath, J. Liu, and F. Zhao. Challenges in building a portal for sensors world-wide. In *First Workshop on World-Sensor-Web: Mobile Device Centric Sensory Networks and Applications (WSW'2006)*, Boulder, Colorado, USA, Oct. 2006.

[9] J. Rekimoto, B. Ullmer, and H. Oba. Datatiles: a modular platform for mixed physical and graphical interactions. In *CHI '01: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 269–276, New York, NY, USA, 2001. ACM Press.

[10] B. Ullmer and H. Ishii. Emerging frameworks for tangible user interfaces. *IBM Systems Journal*, 39(3&4):915–, 2000.

[11] B. Ullmer, H. Ishii, and D. Glas. mediablocks: physical containers, transports, and controls for online media. In *SIGGRAPH '98: Proceedings of the 25th annual conference on Computer graphics and interactive techniques*, pages 379–386, New York, NY, USA, 1998. ACM Press.

[12] R. Want. An introduction to rfid technology. *IEEE Pervasive Computing*, 5(1):25, 2006.

[13] Wikipedia. Mashup — wikipedia, the free encyclopedia, 2007. [Online; accessed 29-January-2007].