# SmartFinger: Connecting Devices, Objects and People seamlessly

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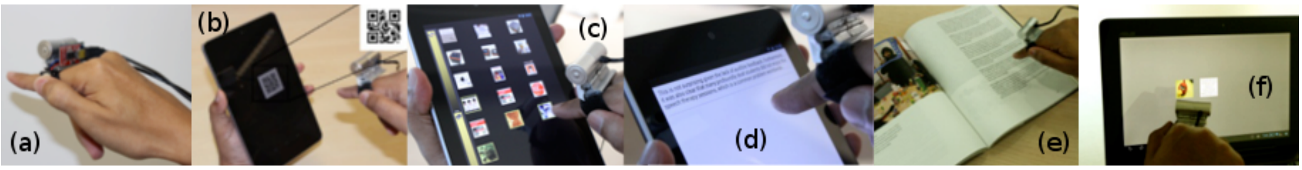


**Figure 1. SmartFinger; (a) current prototype (b) connecting to a digital device (c) copying digital media (d) extracting a part of digital document (e) extracting contents from a physical document (f) pasting selectively**

## ABSTRACT

In this paper, we demonstrate a method to create a seamless information media 'channel' between the physical and digital worlds. Our prototype, SmartFinger, aims to achieve this goal with a finger-worn camera, which continuously captures images for the extraction of information from our surroundings. With this metaphorical channel, we have created a software architecture which allows users to capture and interact with various entities in our surroundings. The interaction design space of SmartFinger is discussed in terms of smart-connection, smart-sharing and smart-extraction of information. We believe this work will create numerous possibilities for future explorations.

### Author Keywords

Finger augmentation, Media sharing, Smart copy-paste, Device identification, Intuitive Interface.

### ACM Classification Keywords

H5.2. [**User Interfaces**]; Interaction styles, Input devices and strategies, Graphical user interfaces (GUI), Screen design.

## INTRODUCTION

With advancements in technology and the impact of consumerism in our society, we now find ourselves surrounded by a myriad of devices. Personal computers, smart phones, and tablets are examples of digital devices that have become fragments of our daily life. Although they provide us with a rich set of interactions with the digital domain, they disconnect us from our physical surroundings. We believe that connecting the digital world with our physical surroundings in a prevailing manner could yield significant benefits.

There have been attempts to design systems for either extracting information from the physical surrounding (Ryokai, 2004; Ryokai, 2005), or data transfer between digital devices (Rekimoto, 1997). Most of these systems require special instrumentation of the environment, devices or both. This limits the natural interactions due to the imposed constraints. Therefore, we focus on exploring methodologies to create a 'seamless channel' that links personal digital devices and physical objects without special instrumentation of the environment or the device.

One of the key characteristics shared by both digital devices and physical objects is their physical appearance such as colors, dimensions, textures, etc. This motivated us to use visual information to connect devices, objects and people. Our goal was to make this interaction seamless by developing a technology that feels like a natural extension of the body and behavior. For example, a person might be able to point at a device and make a virtual connection to it, point at an object to extract/copy relevant information, point at another person to share digital contents, etc. To this end, we develop a finger-worn interface and explore the interaction design of it.

## RELATED WORK

Related work can be categorized into systems that extract data from the physical world (Gormish,2011; Liao,2009; Liao,2010; Liu,2010; RyoKai, 2004; Ryokai, 2005; Yang,2012) and systems that transfer media between digital devices (Hinckley, 2004; Ikeda, 2003; Mistry, 2011; Rekimoto, 1997). The use of extensive hardware components is present in some of these works, utilizing sensors such as IR nodes (Rekimoto, 1998; Zigelbaum, 2008), wireless RFID tags (Want, 1999), stylus-like touch accessories (Hinckley, 2004; Rekimoto, 1997; Song, 2011), and ultrasonic transducers (*JAJA* (HEX3, 2012)). Another feature of related works was the use of location data for device pairing. For example, *Bump* (Bump, 2013)


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and *Swÿp* (Linder, 2013) uses network location and account information (Google, Facebook etc.) to pair digital devices. However, these methods may have reliability issues in situations where four or more users are at the same location. There are related works that are designed to work with futuristic scenarios where physical objects are being created with an attached digital body (Zigelbaum, 2008). Undoubtedly, in a ubiquitous computing (UbiComp) environment, devices have become digital containers for keeping digital media closer to us. Hence, the necessity of linking them seamlessly remains a significant challenge. Extracting information from the physical world (take a photo, scanning a book, etc.) is a common task (Thakur, 2011); and intuitive methods for extracting data from physical objects remains an important challenge that should not be ignored.

## BACKGROUND SURVEY

We conducted a survey with 14 participants (8 male 6 female; aged 18–35 years) with various backgrounds. The objective of this survey was to identify characteristics about (i) the usage of digital devices, (ii) methods that are used for sharing digital media, likelihood of usage, levels of satisfaction and problems associated with these methods, (iii) methods that are used for extracting information from physical world, likelihood of usage, captured data types, and problems associated with these methods. Our findings are summarized below.

### Usage of digital devices

Participants were asked about the type of digital devices they use on a daily basis. The responses shown in Figure 2 indicate that all the participants use a Smartphone, and Notebook Computers, Digital Cameras and Tablets are the other common devices. About 80% of the participants (11 out of 14) indicated that they use more than 3 digital devices. One of the participants uses as many as 9 different devices. This suggests that a method to link these devices is likely to be important and useful.

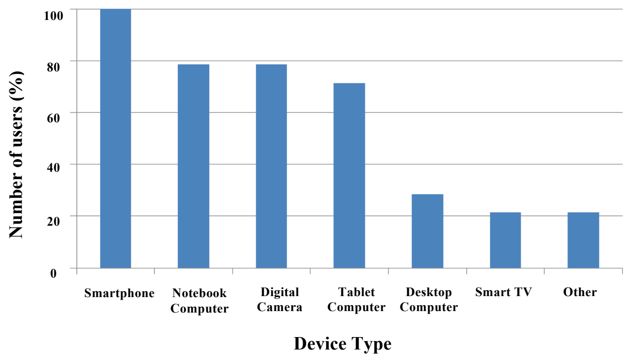


**Figure 2. Number of users for different digital devices.**

### Sharing Digital Media

Participants were asked to list the types of hardware and software solutions they use for sharing digital media between devices. Figure 3 summaries the likelihood of usage and level of satisfaction for different hardware and software solutions. It is interesting to note that all the participants use at least 4 solutions (USB, Dropbox, Google Drive and Email attachment) more than 70% of the time. This implies that there is no universal solution to transfer media between devices. In fact, some participants mentioned that different solutions work better for different scenarios.

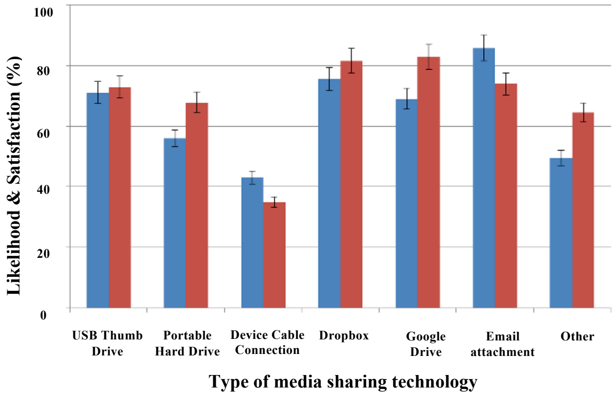


**Figure 3. Digital media sharing technologies ( Likelihood of usage and Satisfaction)**

Also, the level of satisfaction is more than 60% for most of the existing techniques, except for cross cable connection. It is clear that a solution like Google Drive with very established infrastructure has been able to achieve about 82% satisfaction level. The qualitative comments of 11 participants indicated that even though they are satisfied with the cloud services such as Google Drive, the process of transferring media to the drive was tedious (e.g. using a USB cable to get images from the Digital Camera).

### Extraction of information from physical world

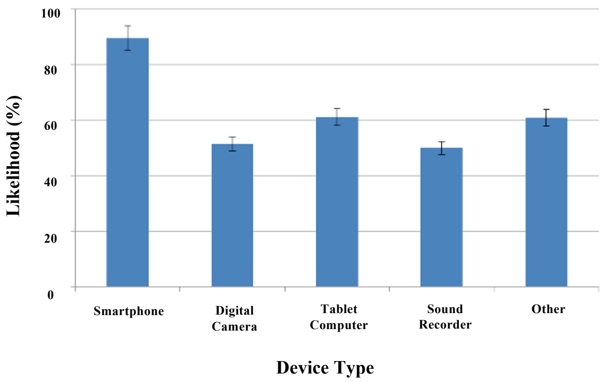


**Figure 4. Likelihood of usage for information extraction from physical world.**

We asked participants the type of digital device they used for capture information from the physical world (such as taking a photo, recording audio, scanning book etc.) and the likelihood of usage. Figure 4 summaries their responses. Smartphones, Digital Cameras, Tablet and Sound Recorders are commonly used tools with Smartphones being the most likely to be used. In addition, most participants mentioned that they would have to use additional tools or manual methods to extract information from the captured data; for example, extracting a URL from a photo had to be done manually. This observation supports the need of having a seamless channel to extract relevant information from the physical surroundings.

## INTERACTION DESIGN SPACE

SmartFinger aims to create a 'seamless channel' between our physical surroundings and the digital world, facilitating the information extraction, sharing, switching between physical and digital worlds. With the metaphorical concept of an information-channel, SmartFinger supports a cohesive information stream between physical and digital objects. The finger-worn camera device that leverages the pointing gesture (Nanayakkara, 2012; Chatterjee, 2006) suggests a convenient and intuitive interface. We envision SmartFinger to be embedded into a wearable ring (Figure 5.1) that makes it an always-available device.

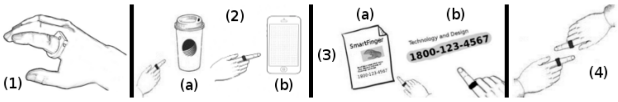


**Figure 5. (1) Envisioned form-factor of SmartFinger; (2) Smart connection to (a) physical objects and (b) digital objects based on visual features; (3) Smart-extraction (a) entire image and subsequent segmentation (b) selective extraction with pointing gesture; (4) Smart-Sharing between SmartFingers;**

This finger-worn form factor allows users to switch between physical and digital worlds easily. The interaction design space enabled by SmartFinger can be divided into three categories: Smart-Connection, Smart-Extraction, and Smart-Sharing.

### Smart-Connection

SmartFinger captures the visual features associated with objects, uniquely recognizes and establish a connection with them. These visual features could be visual data that an entity owns from its origin (e.g. human face), visual data attached to an entity (e.g. personalized sticker – Figure 5.2.a) and visual data that an entity has acquired over time (e.g. scratches on the surface). Digital objects that do not have a unique appearance (e.g. smartphone), could generate a unique visual feature on the screen in real-time so that the SmartFinger could identify them (Figure 5.2.b). For example, with the current technology, a unique QR code would appear on the screen when a user with the SmartFinger touches the screen.

Once SmartFinger recognizes a digital or physical device, it creates a continuous flow of information between the recognized object/device and SmartFinger. The information is shared between entities through a virtual connection via the cloud. When a user wants to paste data to a digital device, a preview of the available data (semantically extracted data from previous interactions) is displayed on the screen for selective pasting.

### Smart-Extraction

Data copied/extracted by SmartFinger can consist of valuable information such as textual data, pictures, human presence, colours/textures from objects etc. Each of these pieces of data may have significant information embedded.

For instance, an image might contain text, pictures, colours, geographical data, animal presence, URLs, etc. SmartFinger could semantically analyse this data and allow users to select only the information that they need (Figure 5.3.a). Alternatively, with the finger-worn form factor, users could point at the information they are interested in (e.g. phone number in an advertisement) and 'extract' that information (Figure 5.3.b).

### Smart-Sharing

SmartFinger allows users to share data between each other without having to use an additional device. Each SmartFinger device would be considered an 'information container', carrying information itself, or be a pointer to the information source. This would allow users to perform a device-to-device tapping gesture between them to establish a virtual connection (Figure 5.4). This eliminates the necessity of having an intermediate device to exchange data. Based on the gestures a user performs, digital information can be shared selectively.

## SMARTFINGER PROTOTYPE

The overall system architecture of the SmartFinger prototype is comprised of (a) a standard webcam and a push button switch attached to the index finger using Velcro (Figure 1.a); (b) a backend server implemented on a computer running Windows 7 (64bit); (c) a tablet running Android OS 4.0. Each SmartFinger has its own unique ID and the camera provides a continuous image stream of the object/scene to the server. The server's responsibilities lie within (i) managing the data cloud and the device data, (ii) capturing the button events to operate the camera, (iii) communicating with Google Cloud Messaging (GCM) service, and (iv) segmenting and extracting information from the image stream.

In the current SmartFinger prototype, a long press on the tablet screen generates a unique Quick Response (QR) code on the screen (Figure 1.b). This QR code is seen by SmartFinger and sent to the server to identify the device. Therefore, this could be reapalced by other patterns or the appearance of the device as discussed in the Smart-Connection section.

Digital images and documents can be copied as a single file by touching them with SmartFinger (Figure 1.c). In addition, a portion of the text in a digital document could be copied by dragging SmartFinger along the text (Figure 1.d). Physical documents can be copied by pointing SmartFinger at it and performing a single click (Figure 1.e).To paste data to a second device, a user performs a long press on the device screen. The user will then see a preview of the available data and select the one to be pasted (Figure 1.f).

## DISCUSSION

Our current system has a few limitations which we intend to address in the future. The system, being in a very early prototype stage, is bulky and requires wired connections to the processing system for robust recognition. Learning from related work such as *MagicFinger* (Yang, 2012), we believe that our system can be miniaturized to a great extent. We intend to shrink the size of the SmartFinger system, possibly down to a ring form factor, or even a fingernail size, which would allow the user to wear the device in a more ubiquitous but subtle manner.

Observations from the survey portray the requirement of a digital channel between the physical and digital spaces. As such, with these improvements, we believe that SmartFinger can ubiquitously integrate into the daily wearables of a user while providing a seamless information channel between the physical and digital worlds. This creates a vast area for potential application domains such as activity logging, context aware interfaces, interfaces to get just-in-time information, etc.

The proposed SmartFinger system discussed in this paper focuses on finger worn devices. However, a myriad of devices such as Google Glass (Google, 2013), and Memoto Life Logging camera (Memoto, 2013), etc. are becoming popular wearable devices with integrated cameras as well. These are other platforms that can be utilized as visual channels to the system that can be worn on different parts of the body. As such, we propose to develop a platform that cohesively enables the Smart-Recognition, Smart-Connection and Smart-Extraction design spaces as one of our main visions for the future. This would enable such camera-integrated devices to become ubiquitous and unobtrusive channels that transfer information and media into the digital space from the physical surroundings. These devices could be the 'informative eyes' of the physical world to our digital devices.

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