

# Memory Stones: An Intuitive Copy-and-Paste Method between Multi-touch Computers

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## Abstract

This paper proposes a novel direct manipulation technique for executing copy-and-paste operations between multi-touch devices. Under our interface concept, dubbed “Memory Stones,” a user can “pick up” a data object displayed on one device screen, “carry” it to another device screen, and “put down” the object on that device using only his or her fingers. During this copy-and-paste operation, the user is invited to pantomime the act of carrying a tangible object (the “stone”) and to keep his or her fingertip positions unchanged. The system identifies the source and target devices by matching the shape of the polygon formed by the fingertips when touching the respective screens. We have developed a prototype system for small-to-large-sized multi-touch computers including smartphones, tablets, notebooks, and desktop PCs, and have carried out a preliminary evaluation of its feasibility.

## Author Keywords

Graphical user interfaces (GUI); copy-and-paste; multi-touch; multiple computers.

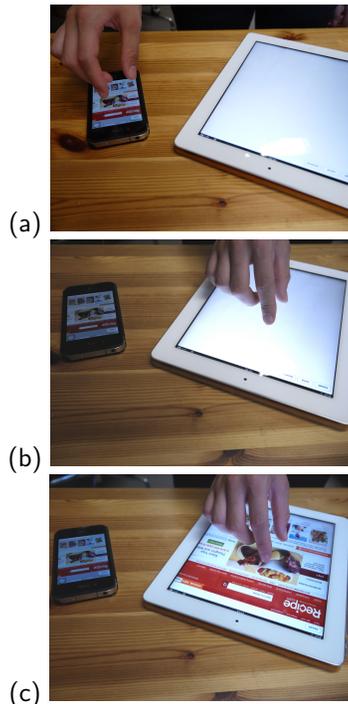
## ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation (e.g. HCI)]: Interaction styles (e.g., commands, menus, forms, direct manipulation).



**Figure 1:** Copy-and-paste examples (a) from notebook PC to tablet PC, (b) from smart-phone to tablet PC, and (c) from tablet PC to printer.

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CHI 2013 Extended Abstracts, April 27-May 2, 2013, Paris, France.  
ACM 978-1-4503-1952-2/13/04.



**Figure 2:** Proposed copy-and-paste method between two computing devices. A user picks up an information object (a) from one device by fingers, (b) brings it to another device, and (c) puts it on that device.

## General Terms

Human Factors

## Introduction

As computing devices become ubiquitous commodities in everyday life, the number of users who own multiple devices is sharply increasing, and it is no longer exceptional for a user to operate more than one computing device at the same time. Given this use scenario, there is an increasing need for an easy and intuitive user interface method for operations among multiple computing environments, such as copy-and-paste between two devices [2]. For example, when a user finds a dinner recipe on a Web page using a desktop or notebook PC, but wants to follow the recipe in the kitchen while using a tablet PC, he or she has to find some way to copy-and-paste the URL of the Web page from one device to another. Similar needs arise frequently in everyday use: when a user wants to present pictures or documents to his or her friend or colleague; when a user wants to use a nearby printer to make a hard copy of a document on his or her mobile device; or when a user wants to present a document on his or her notebook or tablet PC using a projection device in a meeting room. Already, such scenarios are common in daily life and are likely to be more common in the near future. Although there are ways to transfer documents between two different computers, such as using a device-to-device network connection or a portable memory device, most such methods involve cumbersome or complicated procedures and are not comfortable for average users. In this paper, we propose a new method we call “Memory Stones.” This method involves direct manipulation of multi-touch devices using finger gestures, metaphorically allowing the user to “pick up” data from one computing device, “carry” it to a nearby device, and “put down” the data on that device.

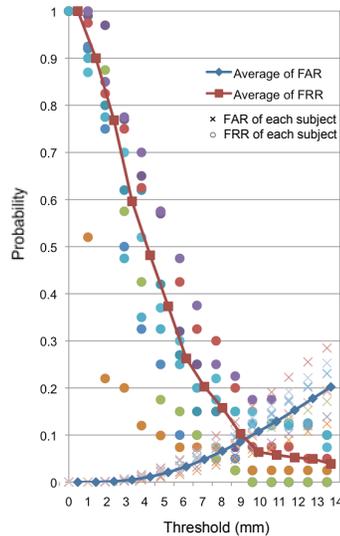
## Related Work

Several studies have proposed methods for achieving easy pairing between two computers before conventional data transfer through a computer network takes place. For example, Shake Well Before Use [1] uses accelerometers, and it connects two devices when they are shaken together by a user. AirPrint<sup>1</sup> detects printers within the same network and list them in a selection menu.

A number of user-interface methods have also been proposed for achieving seamless copy-and-paste between two devices using implicit pairing functions. In Pick-and-Drop [2], a user can “pick up” an information object, such as an icon visible on a computer display, using a pen device, and “drop” it on another computer display. This system uses an identifiable pen device to pair the two computers within a local area network. In Toss-It [4], information transfer is achieved when a user makes a throwing gesture with the source device towards the target device. A background process identifies and spatially locates all computers within the shared physical space, and calculates a landing spot for the virtual object thrown by the user. The computer nearest to the landing spot will receive the virtual object.

Our proposed Memory Stones technique also aims to provide both information transfer and implicit pairing in a single, seamless operation. In order to develop a practical user-interface method, we have restricted our technique to commonplace hardware devices or sensors that are available in consumer computing products. Therefore, we have avoided methods that require precise position sensors [4], and identifiable pen devices [2]. Because we also intended to support larger computing devices such as

<sup>1</sup><http://www.apple.com/iphone/features/airprint.html>



**Figure 3:** Matching threshold for the mean squared error of the distance between fingers and the average FAR and FRR among participants.

desktop PCs, notebooks, and large-sized tablets, acceleration-based methods [4] [1] were also avoided.

## Memory Stones

In the real world, we can transfer objects such as printed documents by picking them up from one desktop and putting them down on another desktop. If the object we pick up is solid, such as a stone, the form of our fingertips is unchanged over the course of picking up, carrying, and putting down the object. Our proposed user-interface method, termed “Memory Stones,” applies these common actions to the copy-and-paste operation between two devices equipped with multi-touch input. Using our method, a user can copy-and-paste an information object using the same actions he or she would apply to a physical object like the aforementioned stone: “picking up” the information object from one device screen, “carrying” it to another device screen, and “putting down” the object on that screen. Figure 2 illustrates this sequence of actions by a user who copies a Web page from a smartphone and pastes it to a tablet PC. The user first picks up the Web page by touching the screen with three fingers (Fig. 2(a)). Next, she moves her hand to the target computer keeping her fingertip positions unchanged, as if she were carrying a solid object (Fig. 2(b)). Finally, she touches the target computer display with the same fingers and fingertip positions, at which point the Web page is copied to that computer (Fig. 2(c)). Using this method, she can copy-and-paste intangible information as if she were moving a tangible object. We have added visual feedback in the form of a virtual stone (a “Memory Stone”) to both the source display and target display as an indication that the copy-and-paste action was accepted and completed. This visual feedback also reinforces the metaphor of carrying something tangible from one device to another. Our Memory Stone method utilizes off-the-shelf

multi-touch devices such as touch-panel displays and trackpads. By comparing the shape of the two polygons formed when a user’s fingertips touch the displays of two different devices, the system can identify and pair the source and destination devices to which the copy-and-paste action should be applied. As multi-touch input becomes popular on a wide range of computing devices including smartphones, tablets, notebooks, and desktop PCs, we expect that our proposed method will be widely implementable without requiring additional input devices or sensors. Moreover, as multiple fingertip positions help to identify a given user [3], we think it will be feasible to identify the devices by a user’s fingertip position pattern.

## Implementation

To test the feasibility of our “Memory Stones” method, we implemented a prototype system in Objective-C for use on iOS 5 and Mac OS X 10.7 operating systems. These platforms use a single programming framework to support multi-touch input on a wide range of devices, including smartphones (iPhones), tablets (iPads), notebooks (MacBooks), and desktop PCs (Macs and iMacs).

### System Overview

The prototype system functions as a simplified Web browser for computing devices running iOS and OS X operating systems. When a user touches the multi-touch display or the trackpad of the device with multiple fingers, the URL of the Web page is copied to the system. The URL is pasted to the target device when the user touches the multi-touch display or trackpad of the target with the same fingertip pattern, after which the pasted URL is loaded into the simplified Web browser running on the target. To indicate to the user that his or her copy-and-paste operation was successful, the system

displays the image of a stone on the screens of both the source and target devices. When a user touches with multiple fingers on the source device, a stone scaled to fit within the polygon formed by his or her fingers appears on the screen, and disappears when the user lifts his or her fingers from the display. The same stone appears when the user touches the destination device with near-identical fingertip positions to indicate successful completion of the copy-and-paste operation. In the current prototype, the user must copy-and-paste using more than two fingers in order to avoid conflict with commonly adopted multi-touch operations using two fingers, including pinching (zooming), rotating, sliding (scrolling), and tapping.

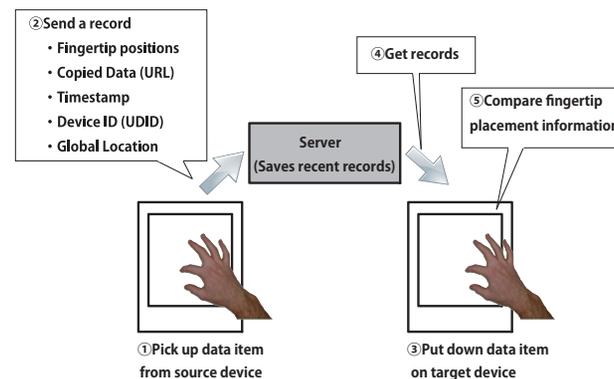


Figure 4: System configuration and operation.

#### Operation

Figure 4 shows the series of operations between devices when a user performs a copy-and-paste action. When a user touches a source computer to pick up an information object (e.g., a Web page), the client application pushes the following data to a prepared server: the timestamp,

the global position of the computer, the URL of the data object (Web page), the UDID (unique device ID supported by both iOS and OS X) and the fingertip positions. The server preserves this data <sup>2</sup>.

When the user touches the destination device to drop the information object, the client application on that device fetches recent records <sup>3</sup> from the server. From the received recent records, those that are physically farthest from the destination device (based on global positioning) are removed. After excluding unqualified records, the program uses a polygonal congruence condition to try to find a record with a matching fingertip shape. Specifically, if the square summation of the difference between the lengths of corresponding sides is less than a given threshold, then the two fingertip shapes are considered a match. If a match is found, the client application fetches the URL from the matched record and loads it into the browser, thereby completing the copy-and-paste procedure.

#### Threshold for Identification

Once the fingertip position data are acquired at the source and destination computers, the system matches the polygon formed by the fingertips as follows. First, it calculates the distances between each pair of fingers, and sorts them by length. Second, it calculates the mean squared error between each distances pair of the same order. If the polygons formed by the fingertips are exactly congruent, the mean squared error should be zero. Finally, in the third step, the system determines that the fingertip positions are identical if the mean squared error is less than a given threshold.

<sup>2</sup>5 records are maintained in the current implementation.

<sup>3</sup>Records within 5 s in the current implementation.

To determine an appropriate threshold, we assigned nine participants (eight undergraduate and one graduate female students) copy-and-paste tasks to be performed 40 times each (a total of 360 times) between two tablet PCs (iPad) and obtained the fingertip position data. By using this data, we calculated the False Acceptance Rate (FAR) and False Rejection Rate (FRR) to obtain several threshold candidates. FAR is the probability that the system incorrectly matches the fingertip position pattern to a non-matching pattern in the server, while FRR is the probability that the system fails to detect a match between the fingertip position pattern and a matching pattern in the server.

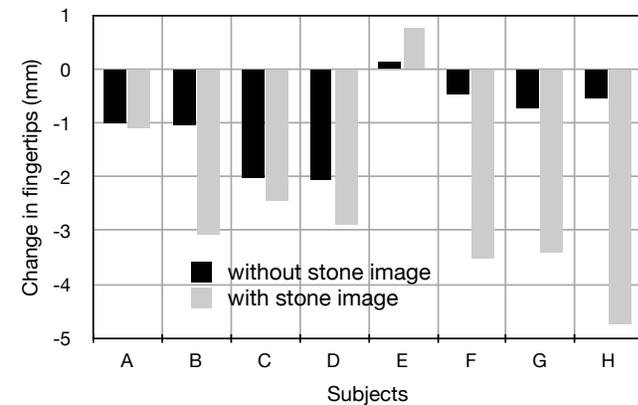
Figure 3 shows the average of FAR and FRR for over all the participants. The horizontal axis shows the threshold (mm) for the mean squared error comparison. If threshold is very low, the matching is so accurate that even a correct user's finger pattern is possibly rejected and FRR is increased. On the other hand, if the threshold is very high, the matching is inaccurate that a wrong user's finger pattern is eventually accepted and FAR is increased. We determined the threshold to be approximately 9 mm such that FAR and FRR are equal; the Equal Error Rate (EER), which the error rate at this point, is less than 10.0% in the worst case. In addition, we can expect an improvement in FRR when a user masters the gesture operation. In that case, the system could provide a strict threshold option for skilled users to allow a more secure operation.

### Evaluation Experiments

Using our prototype of Memory Stones, we carried out an evaluation of its feasibility.

### Method

We asked eight participants (four undergraduates and four graduate female students) to participate in our experiment. All the participants were familiar with smartphones, tablet PCs, and notebook PCs with trackpads, and all had experience using multi-touch devices. We assigned each participant four copy-and-paste tasks between two smartphones (iPhones). In the first two tasks, a stone image was shown when they touched the display, and in the last two tasks, no stone image was shown. We recorded all fingertip position data from their copy-and-paste actions. We also asked for each participant's personal evaluation of the system, and for comments on the usefulness of the stone image shown on the display for the tasks they performed.



**Figure 5:** Per user average change in perimeter of polygons formed by fingers between “pick up” and “put down” actions.

### Results

All the participants positively evaluated our method as intuitive and easy to use. As described in the previous section, the participants tried to copy-and-paste 32 times. We asked each participant the following question: “Of the two methods of interaction, one with the stone image and one without, which method gives you a feeling of greater realism, as if you were transferring an information object with your hand?” All of the participants responded that the method using the stone image gave them a stronger feeling of handling information with their fingers.

Figure 5 provides a comparison of the change in the total length of the sides of the polygon formed by the fingertip. In cases where the total length of the polygon decreased between the copy action and the paste action (i.e., the user closed her fingers while “carrying” the object to its destination), the bar extends in the negative direction. Each bar indicates the average polygon size increase for each participant, A to H, as they perform with and without the stone image. As all the results except E show negative values, we conclude that a majority of participants moved their fingers inward between the copy and paste actions. The graph also shows that their fingers moved inward even more when a stone image was presented on the screen. This result implies that people tend to grasp or clutch more deliberately when a tangible object metaphor is used.

In future adjustments of the threshold for determination of polygonal congruence, we will need to consider that human fingers tend to close inward during copy-and-paste actions, and that this tendency is exaggerated when using the image of a stone.

### Conclusion

We proposed a novel user-interface method, Memory Stones, for executing copy-and-paste operations between nearby devices equipped with multi-touch inputs. We implemented a prototype of Memory Stones that runs on smartphones, tablets, notebooks, and desktop PCs, and carried out a preliminary evaluation. In a future work, we plan to enhance the scalability of our system so that the system can be used by larger numbers of users and eventually become a worldwide service.

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