# Interaction Study of Shuriken: User Grouping and Data Transfer Based on Inter-device Relative Positioning

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**Abstract.** We present Shuriken, a method for user grouping and data transfer for smart devices that are in close proximity. Users point their devices towards each other to link them into a group (point to link). The relative positions are estimated between the grouped devices (link to group) with Bluetooth low energy received signal strength indication and the digital compass readings. The relative positions are then used for identifying the recipients for data transfer by swiping towards the physical direction (swipe to send). In this paper, we studied the possible operations to enable: point to link, link to group and swipe to send and compared Shuriken to existing techniques for user grouping and data transfer. We envision practical uses of Shuriken in collaborative shopping in a café, data transfer in business meetings and localisation of smart devices.

## 1 Introduction

The affordance of smart mobile devices has made it an essential method of group communication. Messaging applications, such as WhatsApp, Line and WeChat, provide group-messaging services through an Internet connection that is designed for remote users. These applications extend their messaging services to allow transferring other forms of data. However, in order to preserve the affordance of the application, there is generally no strong distinction between transferring data and transferring messages. Due to the practicalities of using these applications, users often use these methods to transfer data even when they are in close proximity.

In close proximity, users can communication verbally while their smart devices are used to transfer data that cannot be easily described in words (e.g., images, shopping catalogues). In a scenario where a group of friends are browsing shopping catalogues in close proximity, the users have many more options to share their catalogues with a group other than through messaging services.

Infrared was a method of data transfer between devices. In order to identify your target, the users to physically point the phones together throughout the course of data transfer. However, the iPhone 3 did not ship with inherit infrared transceivers that may have caused the phase out using infrared for data transfer in smart devices. Infrared requires the user of the sending device to consistent point towards the receiving device. This method of


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identification is simple and intuitive, however, this physically limits the possibilities for user grouping and is inconvenient especially when the data transfer rate is slow.

Bluetooth technology has experienced a significant growth in the last 20 years. Prior to Bluetooth v2.0, the device designated as "master" searches for "slave" device and a relationship is established only when both devices have entered the same PIN. After Bluetooth v2.1, many other methods of pairing, such as passkey entry (instead of a PIN) and out of band pairing methods emerged. A popular method for out of band pairing is NFC however, the physical constraints NFC also limits the capabilities of user grouping.

Similar to Bluetooth, WIFI direct allows data transfer in the absence of an Internet connection. AirDrop (developed by Apple Inc.) incorporates Bluetooth Low Energy (BLE, Bluetooth v4.0) to discover devices and WIFI direct to send the data.[1] AirDrop provides an ad hoc data transfer mechanism for users in close proximity. However, the interactions of using AirDrop do not differ from typical messaging services where users select recipients of data transfer through a list of usernames.

We present Shuriken, an intuitive method to create a group of devices in an ad hoc network and to identify recipients for data transfer. Users point their devices together to create a linkage between devices and linked devices are placed in the same group. The locations of the devices within a group are used to identify recipient of data (based upon methods of passing tangible media). Shuriken is built upon the BLE framework to create an ad hoc network and uses the BLE RSSI and digital compass readings to estimate the relative positions of the devices.

In this paper, we studied the operations for Shuriken to enable: point to link, link to group and swipe to send. In addition, the usage of Shuriken was compared to existing methods to group and transfer data between devices.

## 2 Related Work

Although Airdrop provides a simple medium to transfer data, the uses of usernames may be unintuitive for data transfer. In this section, we describe methods presented in the literature focusing on intuitive pairing solutions and intention based grouping.

### 2.1 Intuitive Pairing Solution

Intuitive pairing solution focuses on identifying recipients for data transfer in a simple yet secure manner.

Memory stones [1] describe a method where users imagine that they pick up a stone and place it to the device to be sent to. The central server records the touch positions during pick up and send it to the device that received the same touch positions. This method was designed for copy and pasting between devices in a network. For example, data can be copied from smart phones to tablets or from smart phones to printers. Memory stones provides an interesting and intuitive method to identify recipients of data. However, touch positions will be required in both the sending and receiving device, deeming Memory stones ineffective for multiple users.

[1] http://ipad.about.com/od/iPad_Guide/ss/What-Is-Airdrop-How-Does-It-Work.htm.

Bump [2] describes a method that requires two devices to be physically "bumped" together to share contact information. The time and positions are estimated and used to determine if two users are intending to share information. Specifically, to establish a connection, a "bump valid" signal from both devices must be received in the central server at approximately the same time from approximately the same location (e.g., from the same wireless network or within a predetermined distance estimated by RSSI). Bump provides a method to intuitively initiate and accept a connection for data transfer. However, Bump uses location to confirm connections that will be inaccurate when multiple users are in close proximity.

### 2.2 Intention Based Grouping

Intention based grouping systems extends intuitive pairing solutions to allow multiple devices to connect.

Point and Connect [3] describes a method where users physically point towards the recipient of the data. This system only uses ultrasound (i.e., speakers and microphone) therefore the system functions even in the absence of a central server. Ultrasound is used to determine the change in the relative positions of the devices while the user points their phone towards the target recipient of the data (causes a displacement towards the recipient). Point and Connect provides an intuitive method to group devices and to identify the recipients for data.

Airlink [4] uses in-air gestures to direct data transfer from sender to recipient. The Doppler-shifted reflections of ultrasound are measured to estimate the relative positions of the devices. Furthermore, the relative positions are used identify the sender and recipient of data.

## 3 Design Guidelines

Shuriken must be a pure software-based solution that does not require additional hardware and must not require any additional infrastructure support or modifications of the original operating system of the device. The implementation and the details of the operations that were studied were described in the subsections "point to link", "link to group" and "swipe to send".

### 3.1 Point to Link

Users link their devices by pointing them towards each other and a unique identifier and the digital compass reading are advertised using the BLE framework. Also Shuriken processes the incoming advertisements along with the received signal strength indication (RSSI). If the RSSI is within the "near" range (similar to the iBeacon protocol [5] ) and the digital compass readings are approximately opposite, the users are required to confirm the linkage of the devices. We studied the accuracy of pointing a device towards another device with the three methods of confirming the link: (a) button, (b) timer (2 s) and (c) shaking (Fig. 1).

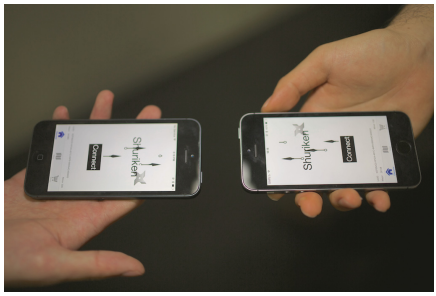


**Fig. 1.** An example showing the mechanism to point the devices together with the "button" method to confirm the device link.

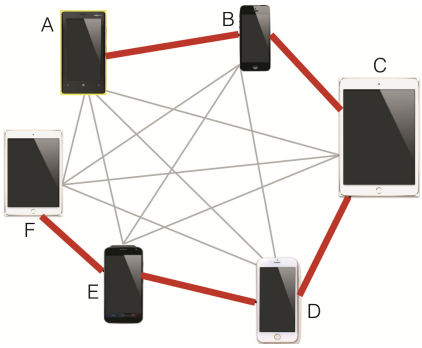


**Fig. 2.** The group created by Shuriken (bold edges represents BLE connections that were created between linked devices where relative positions are known. Non-bolded edges represent inferred connection between devices).

### 3.2 Link to Group

The confirmation of the linking acts as an acknowledgement to accept data transfer, estimates the relative positions and initiates a BLE connection between the linked devices. The devices also stop sending and processing incoming advertisements.

The relative positions between devices in a group that were not physically linked (e.g., device A and D in Fig. 2) are inferred through the linked devices (e.g., device A- > B- > C- > D). If the devices being were already in a group, information of all grouped devices will be sent and propagated to all devices. The information of the devices was displayed in a real-time map of devices.

### 3.3 Swipe to Send

The devices in a group can send information by swiping towards the physical direction of the intended recipient. As mentioned in Sect. 3.2, the data (which includes relative position information) is transferred using a multi-hop approach. The two methods of initiating swipe to send includes using: (a) two-finger-swipe and (b) hold-and-swipe.


**Fig. 3.** (a) and (c) indicates the two possible operations to complete swipe to send, (b) shows an example of the guide presented after swipe to send has been initiated (where the arrow represents the direction of the swipe and the two semi-circles represent directions of the possible recipients).

## 4 User Study Design

An application was developed to evaluate the operations of Shuriken in a series of quantitative experiments. Furthermore, a qualitative study was conducted to compare Shuriken to no data transfer (i.e., physically showing the device) and using AirDrop in a collaborative shopping exercise. The following list summarises the user studies conducted:

*Quantitative test*

- Point to link operation accuracy (button, timer and shake)
- Swiping to send operation accuracy (2-finger-swipe, hold-and-swipe)

*Qualitative tests for the collaborative shopping*

- No data transfer
- AirDrop
- Shuriken

### 4.1 Subjects

Five participants (3 male, 2 female, age 24.6 ± 1.67) were assigned to perform the quantitative tests for operations. All the participants were familiar with the operations of the iPhone. To ensure that the users are novel to Shuriken, another three participants (2 male, 1 female, age 25.66 ± 0.577) were recruited to performing the qualitative tests for collaborative shopping.

### 4.2 Apparatus

An application of Shuriken was developed for devices running iOS 8.0. The devices used in the user study included: iPhone 5 (screen size: 4 in), iPhone 6 (screen size 4.7 in), iPhone 6 plus (screen size 5.5 in) and iPad mini 1 (screen size 7.9 in).

### 4.3 Quantitative Study

The quantitative study included testing the accuracy of point to link with three confirmation methods (button, timer and shaking) and swipe to send direction accuracy (two-finger-swiping, hold-and-swipe).

Three targets were securely fastened onto a stands that resulted in the targets being about 70 cm above the ground. The targets were pointing at the absolute north directions at 0, 90 and 270 degrees (Fig. 4).

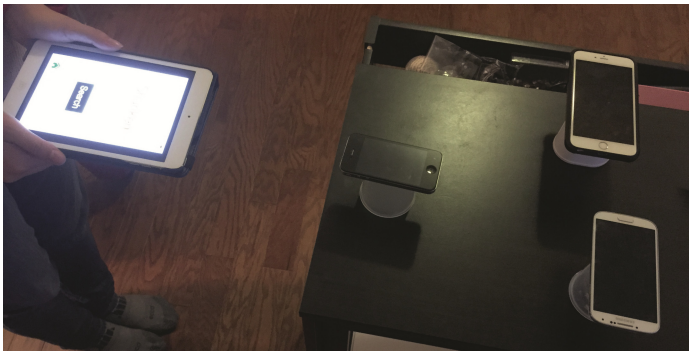

**Fig. 4.** Quantitative study experiment setup

The participants were provided with an iPhone 6, an iPhone 5 s and an iPad Mini 1 and were instructed to hold the device about 30 cm away from the target. The following operations towards the targets were performed: (1) point and press a button, (2) two-finger-swipe, (3) point for 2 s, (4) hold-and-swipe and (5) point and shake. To ensure that the participants have to separately aim for each operation, they were asked to randomly move the device between operations. The steps were repeated ten times for each target and then repeated for each device.

The directional error is defined as the difference between the intended direction with the opposite of the actual direction (pointing directional error is shown in Fig. 5).

The directional error for swipe to send is calculated by finding the difference between the opposite of the actual target direction and the swipe direction with respect to the direction of the device.

The data was explored with descriptive statistics where the mean for every participant per device was calculated (i.e., mean for all trails for all targets). The differences between the point to link operations (button, timer and shake) was explored with repeated measures ANOVA with a within subject factor of device type (iPhone 6, iPad Mini 1 and iPhone 5 s). In addition, the difference between the swipe to send operations (2-finger-swipe and hold-and-swipe) was explored with the same repeated measures ANOVA. If significant differences were found, post hoc t-tests with Bonferroni corrections were preformed to find differences between the specific devices and operations.

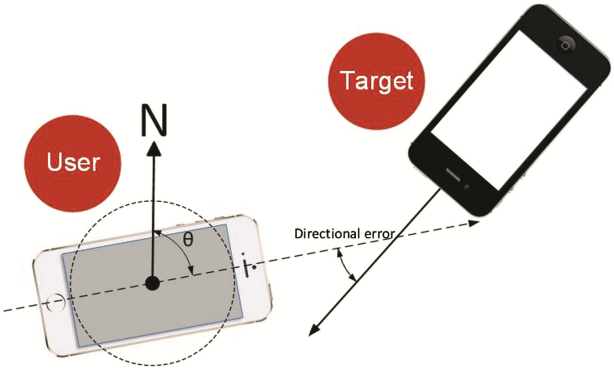


**Fig. 5.** The calculation of the directional error for point to link operations, that is, the difference in the estimated direction of the users' device compared to the actual device of the target.

### 4.4 Qualitative Study

The user satisfaction study was conducted to compare using Shuriken to existing techniques. The participants were engaged in a collaborative shopping exercise where the group was asked to purchase an outfit for a randomly chosen participant. The three participants were provided with a choice of using an iPhone 6, an iPad Mini 1 or an iPhone 6 preinstalled with Shuriken. The moderator provided brief instructions on how to use Shuriken and then the participants were asked to shop for an outfit with three grouping method: (1) without data transfer, (2) with AirDrop and (3) with Shuriken, for each participant in the group.

After the exercise, participants completed a questionnaire that discusses the perceived workload (based on NASA-TLX [6]) and satisfaction of each grouping method. Statements such as "the method requires a lot of physical effort" were asked and the participants provided a rating based on a 5-point Likert scale (2 = strongly agree -2 = strongly disagree). In addition, general comments and the overall preferences were recorded.

## 5 Results

In this section the qualitative and quantitative results are described separately.

### 5.1 Quantitative Results

The directional errors for the point to link operations are shown for each device in Fig. 6.

Repeated measures ANOVA suggest that the directional error in the point to link operations was not significant differences between the confirmation method ($F(2, 8) = 1.477$, $p = 0.284$). However, significant differences were found between the devices types ($F(2, 8) = 7.349$, $p = 0.015$). In addition, no significant interactions were found between the operations and the device type ($F(4, 16) = 2.386$, $p = 0.096$). Post hoc

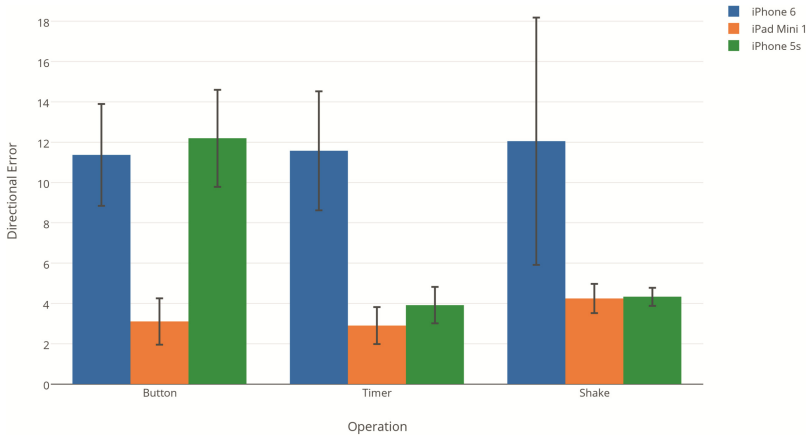


**Fig. 6.** Directional error in the point to link operations (Figure created by plot.ly)

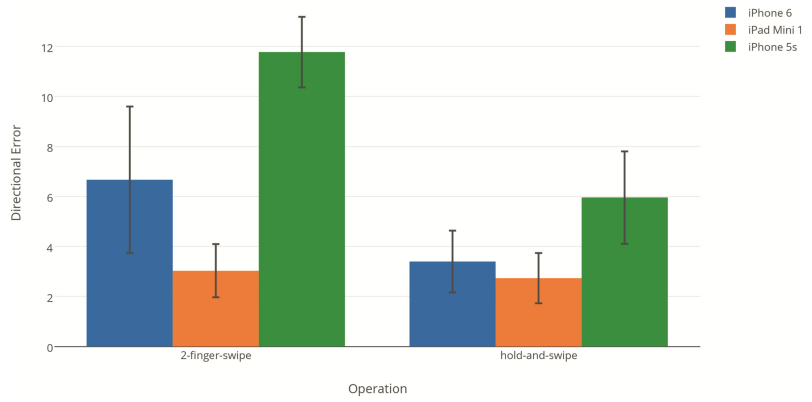


**Fig. 7.** Directional error in the swipe to send operations

t-tests showed that directional error was significantly different between the iPad Mini 1 and the iPhone 5 s ($p = 0.045$). Although no significant differences were found between the point to link operations, the results suggest that on average, the timer method was the most accurate ($6.116 \pm 0.834$ degrees) followed by shaking ($6.966 \pm 2.396$ degrees) then button ($8.863 \pm 1.278$ degrees).

The directional error for the 2-finger-swipe and hold-and-swipe are shown in Fig. 7.

Repeated measures ANOVA showed that the directional error in the 2-finger-swipe and hold-and-swipe for swipe to send are significantly different ($F(1, 4) = 12.592$, $p = 0.024$) and significant differences were found in the directional error between the device types ($F(2, 8) = 43.170$, $p < 0.001$). In addition, significant swipe to send operation X device type interactions were found ($F(2, 8) = 8.134$, $p = 0.012$). Post hoc t-tests showed that the directional error of 2-finger-swipe and hold-and-swipe was significantly different ($p = 0.024$). Also, significant differences in the directional error were found between the devices (iPhone 6 vs iPhone 5 s: $p = 0.018$;

iPad Mini 1 vs iPhone 5 s: $p < 0.001$). The average directional error of the hold-and-swipe (4.026 ± 0.505 degrees) was found to be significantly smaller than the 2-finger-swipe (7.183 ± 0.487 degrees). The results obtained in quantitative study were incorporated into Shuriken prior to the qualitative study.

### 5.2 Qualitative Results

A collaborative shopping exercise was conducted to qualitatively test Shuriken. The results of the post-exercise questionnaire for each grouping method are shown in Table 1.

**Table 1.** Mean and standard deviation of the qualitative study

| | No data transfer | AirDrop | Shuriken |
|---|---|---|---|
| Task easy | 1.33 ± 0.57 | -2.00 ± 0.00 | 1.33 ± 0.33 |
| Task fast paced | 2.00 ± 0.00 | -2.00 ± 0.00 | 2.00 ± 0.00 |
| Task demanding | -2.00 ± 0.00 | 1.66 ± 0.33 | -2.00 ± 0.00 |
| Task annoying | 0.00 ± 1.00 | 2.00 ± 0.00 | -1.66 ± 0.33 |
| Small learning curve | 2.00 ± 0.00 | 0.00 ± 0.00 | 2.00 ± 0.00 |
| Task successful | 2.00 ± 0.00 | 2.00 ± 0.00 | 2.00 ± 0.00 |
| Task fun | 1.33 ± 0.66 | -2.00 ± 0.00 | 2.00 ± 0.00 |

The general comments made by the users were mainly comparing between no data transfer and Shuriken. The participants suggest that physically sharing the device is a natural method of collaborative shopping. However, as the distance between users and number of users increase, techniques with data transfer will become applicable. The participants felt that AirDrop was inappropriate for user grouping and data transfer in the context of collaborative shopping, as it does not support group interactions. Shuriken was positively received as a novel, smart and fun method for collaborative shopping.

## 6 Discussion

The user study indicated that the participants positively received Shuriken to create a group for collaborative shopping. Besides collaborative shopping, Shuriken could be used for business meetings, conferences and banquets. Also, Shuriken can be employed with mobile gaming, digital signage and gesture input.

The quantitative study suggested that the timer operation provided the least directional error for point to link. The timer operation allows user to carefully align their devices prior to linking the device however, the lack of manual input may cause erroneous relative position estimates. Also, the hold-and-swipe operation was found to have the least directional error. Hold-and-swipe allows the users to operate Shuriken with one

hand (which is the preferred method according to Hoober [7]) however, the hold-and-swipe operation overrides the basic operations such as initiating copy and pasting.

The results of the qualitative study showed that the participants felt Shuriken was applicable for collaborative shopping. Table 1. Showed that Shuriken was similarly rated compared to collaborative shopping with no data transfer. However, the participants felt that Shuriken was more fun to use.

## 7 Conclusion and Future Work

In this paper we present Shuriken, a method for user grouping and data transferring based on inter-device relative positioning. Users intuitively link their devices by point their devices together. Linking the devices creates an ad hoc network using the BLE framework. Devices in the group can send data by swiping towards the physical direction of the intended recipient. Shuriken was developed on top of a shopping application for iOS enable collaborative shopping and a user study was conducted to test its feasibility. The users showed positive reviews of Shuriken felt that it improved collaborative shopping experience.

In the scenario where the users are grouped in a line, swipe to send will be insufficient to distinguish between the devices.

To mitigate these effects, the energy of the swipe can be inferred from the distance travelled during the swipe. Currently, when swipe to send has been initiated a guide with the possible recipients is shown (Fig. 3). This guide can be extended to include information about the energy of the swipe (left of Fig. 8).

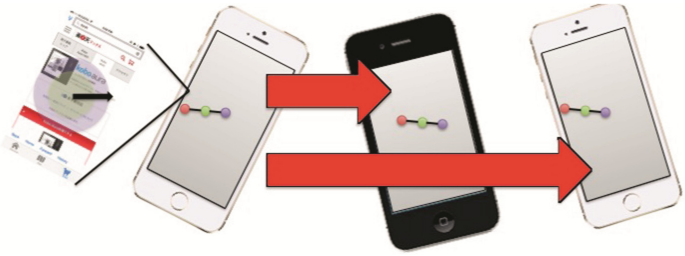

**Fig. 8.** Swipe to send is insufficient to distinguish between devices that were grouped in a line

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