RingIoT: A Smart Ring Controlling Things in Physical Spaces

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Abstract

The increasing number of devices in the IoT landscape makes it difficult for users to remember control options and relationships among different devices. Users often find it tricky and non-intuitive to interact with devices. This paper presents *RingIoT*, a finger-worn device, which attempts to simplify 'users-device' interaction by empowering users with a simple pointing gesture to select IoT devices. It has a display, touch and sensing capabilities which facilitate to define dynamic relationships among things based on their potentials and user specific needs. RingIoT interprets different finger gestures to communicate control commands. This paper explores interactions between RingIoT and devices, and their implementation details. In order to evaluate our ring, we created an IoT ecosystem with few IoT devices and validated our system with a small scale user study.

Author Keywords

Internet of Things; Smart-Home; Wearable Computing; Smart-ring; Spatial Interaction.

ACM Classification Keywords

H.5.2 [User Interfaces and Presentation]: Input Devices and Strategies

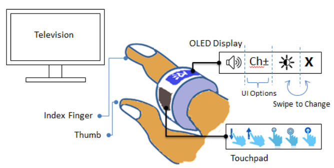


Figure 1: User selects TV using RingIoT. Basic control UIs of TV are rendered on the ring's display.

Introduction

Since the emergence of IoT, our everyday environments (i.e. homes and workplaces) are getting populated with an ever increasing number of smart things, and this growing trend is bringing us a step closer to Ubiquitous Computing. In our everyday life, we interact with different smart objects for our task-specific needs. But, it is difficult for users to remember control options and relationships among different things, especially for UI-less entities. Moreover, users often find it tricky to select IoT devices instantly to interact with them. There is a need for developing more convenient user interfaces.

In order to address this problem, industry leaders like Samsung[1], Philips[2], Apple[3], WeMo[4] allows users to control smart appliances using their respective companion applications installed on their smartphones. In this technique, users have to browse a 1D or 2D list presented on the screen to select their intended devices. However, this method has naming and scaling issues while the number of controlled devices increases in the IoT environment. To overcome these problems, past researches suggested to use phones [1][2] or wand [3] to directly point at the target devices in physical world. In their approaches, users have to keep their hands busy to hold the phone or the wand while performing the operation.

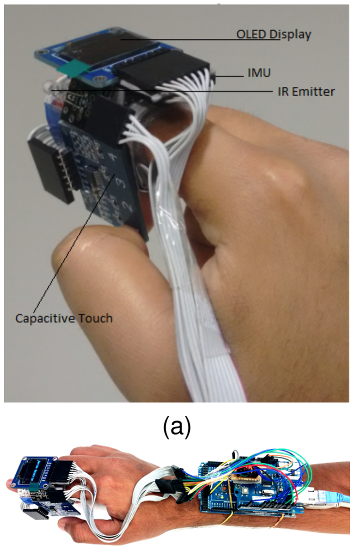
In this paper, we propose RingIoT, a finger-worn embedded ring to provide spatial interaction with IoT devices. It consists of four major hardware components - infrared (IR) transmitter, small OLED display, IMU sensor, and a capacitive touch. User wears this ring in the index finger of their dominant hand, and select the target equipped with the infrared receiver by pointing ring's infrared emitter. Once a target is selected, a user interface (UI) related to the selected device is rendered on the ring's display, and user performs appropriate finger gestures corresponding to a UI control option to provide the control command to the object (see Fig.1). RingIoT allows users to select a single device or multiple devices at a time, and they can dynamically define meaningful relationships (like composite, collaborative, and augmentation) among selected devices based on the task-specific needs like controlling multiple ceiling lights simultaneously, or connecting speakers with a television.

[1]SmartThings, http://www.samsung.com/uk/smartthings/
[2]Philips Hue, http://www2.meethue.com/en-in/
[3]Apple HomeKit, https://developer.apple.com/homekit/
[4]WeMo Light Switch, http://www.wemothat.com/

Related Work

There exists substantial body of work covering how people can interact with multiple IoT devices in a smart environment. Researchers have developed numerous techniques to let users specify which thing(s) they want to use. Usually, people prefer pointing towards an object when two devices are distant from each other. This pointing technique is enabled by many technologies, such as infrared [3][4], laser [1], projection [5][6], IMU sensing [2] and computer vision [7][8][9]. The advantage of pointing is that the mobile device can display information about the target as soon as it is aligned with it. In [1], Patel S. N. et al. mounted a laser on a handheld device for identifying and interacting with objects in the physical world. Swindells C. et al. [4] developed gesturePen using infrared and wireless communication techniques to select and interact with the target devices. The XWand system [3] uses a wireless wand with buttons and sensors to control multiple electrical devices in a complex environment.

PICOntrol [5] employs an off-the-shelf pico-projector as a handheld control device for users to directly control various physical objects in the environment through visible light. In



(a)

(b)

Figure 2: (a) The RingIoT prototype; (b) Detailed connection of the ring with Arduino board.

this solution, the targeted devices need to be augmented with photo-sensors. SuperVision [6] can control both objects in the user's field of view and also outside it (i.e. behind a wall) using the projection interface. Unlike PICOntrol [5], SuperVision does not need a tagged environment.

MagicPhone [2] supports the convenient direct selection of appliances by natural pointing. It uses phone's built-in accelerometer and magnetometer to understand the pointing orientation. In [7] and [8], researchers used Microsoft Kinect to enable interaction for the control of appliances in smart environments. Snap-To-It [9] allows users to interact with any device simply by taking a picture of it.

In some prior works, head mounted display has been used for selection and interaction with physical devices. Zhang B. et al. [10] augmented a Google Glass with an infrared (IR) emitter to select targets equipped with IR receivers. In [11], researchers presented an idea to control devices directly by eye-gaze. In [12] and [13], researchers used augmented reality (AR) to control smart-objects. The proxemic-aware spatial relationships [14] and drawable user interface [15] are other approaches to configure smart-devices.

In summary, researchers have looked into several possible techniques to control IoT devices, but in majority of the approaches, users have to either carry a phone or a tablet or wear a head mounted display. This is quite intrusive to users for continuous everyday usage. Our technique takes advantage of ring form-factor. Earlier research explored few interactive ring prototypes like NotiRing [16], TRing [17], but not directly from the perspective of controlling IoT devices. There are commercially available ring devices like Ring Zero[5], Titanium Falcon[6], Fin[7] which support interaction with smart devices. To control devices using these rings, either users have to remember a particular gesture corresponding to a device or pair the device beforehand. Thus instant selection is not possible and users can not dynamically define relationships among devices.

[5]http://ringzero.logbar.jp/
[6]http://titaniumfalcon.com/
[7]http://drop-kicker.com/2014/03/the-fin-ring/

RingIoT

RingIoT consists of an infrared (IR) emitter (OSRAM SFH 4545), capacitive touch, small OLED display, and an IMU sensor. The current ring prototype is built with off-the-shelf components using an Arduino Mega ADK board with Ethernet connectivity as shown in Fig.2(a) & (b). The dimension of the current prototype is 5cm $\times$ 4cm $\times$ 5cm (length $\times$ width $\times$ height).

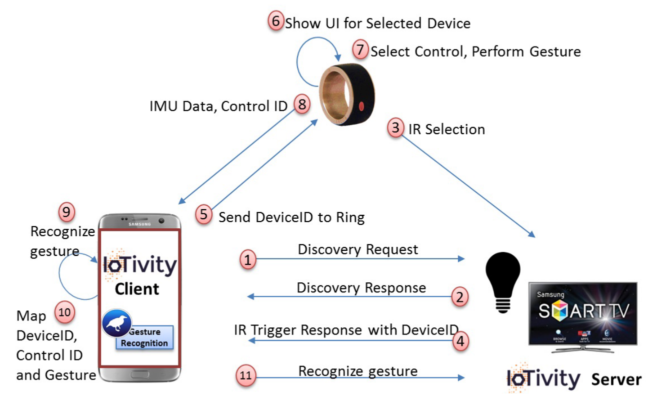


Figure 3: Interaction Model : RingIoT and IoT Devices

Each target device is equipped with an infrared receiver (Vishay TSOP38238) and connected to Arduino Mega ADK board with Ethernet Shield. Infrared pointing technique is used to select smart objects with the ring. IoTivity[8]

[8]https://www.iotivity.org/

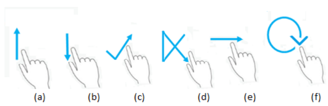


Figure 4: Finger-gestures: (a)Up (b)Down (c)OK (d)Cancel (e)Forward and (f)Circle.

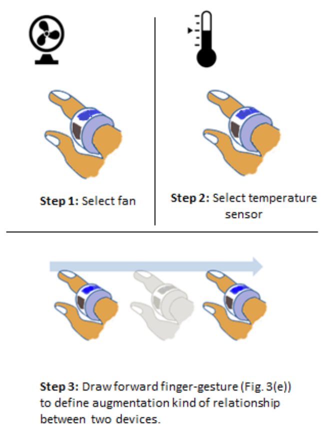


Figure 5: RingIoT allows user to define device augmentation type relationship among smart things.

framework is used for bidirectional communication between the ring and target devices. Fig.3 presents the interaction model for the ring and controlled devices.

Interaction Model

In order to interact with different devices RingIoT supports a set of six gestures shown in Fig. 4. The first four gestures (namely up, down, OK and cancel) are Control Gestures which can be used to control different devices whereas the last two gestures (i.e Forward and Circle) are Relationship Geatures which are used for defining relationships among things. The interaction model consists of two stages - (1) Target Device(s) Selection (2) Interaction scenarios.

Target Device(s) Selection

A user first sees the surrounding physical space to locate target devices. Then user points the ring to a device and provides a long press on ring's touchpad to send out infrared signal continuously from the IR emitter. Once a target comes into ring's line-of-sight, it offers immediate visual feedback via blinking the on-board LED, and user confirms his desire to connect to it by tapping on the ring's touchpad. In order to select multiple devices, user has to repeat IR pointing. The selection of a device is easy if there is only one target in the view range. However, a user must accurately perform pointing in an environment with multiple targets. Ring collects the device IDs of selected targets via IoTivity communication channel.

Interaction Scenarios

RingIoT enables users to configure, and personalize interfaces to IoT devices using two possible interaction scenarios (a) single device and (b) multiple devices.

Single Device Once user confirms the selection of a device, ring gets a unique device ID from the target which is sent to a 'UI server' hosted in a phone. UI server provides device specific user interface which are rendered on the ring's display. User can vertically scroll to navigate through all UI options, and perform required finger gestures (see Fig.4) corresponding to a particular UI option. If ring is connected to a TV, it displays basic UI such as volume, channel, etc. Fig.1 shows single device interaction with a TV using RingIoT where volume option is selected. To increase volume, a user holds the touchpad by the thumb (i.e. beginning of gesture), draws up gesture (see Fig.4(a)), and releases the thumb (i.e. end of gesture). It also supports removal of current target from the ring. If a user wants to stop interaction with a TV, he performs cancel gesture (see Fig.4(d)) corresponding to 'cancel UI option'.

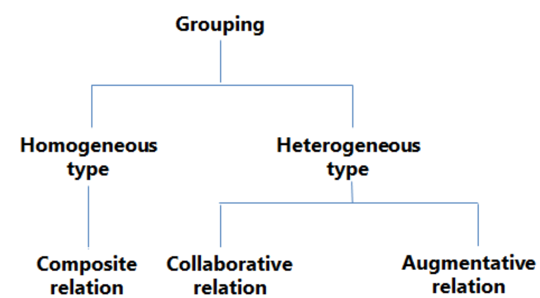


Figure 6: Hierarchy of grouping relationship among devices.

Multiple Devices This scenario can involve homogeneous or heterogeneous devices. User selects multiple devices and defines a relationship between them. A user may define a *composite*, *collaborative*, or an *augmentative* relationship using finger gestures. There are two finger

Table 1: Evaluation of different classifiers for Gesture recognition.

Different Classifier	Classification Accuracy (F1 score)						**Mean F1 score**
	Up	Down	Ok	Cancel	Forward	Circle	
SVM	0.857	0.812	0.791	0.803	0.967	0.764	**0.832**
Naive Bayes	0.884	0.829	0.811	0.827	0.965	0.819	**0.856**
Bagging	0.865	0.874	0.872	0.886	0.981	0.832	**0.885**

gestures (a) circle: for composite and collaborative relationship; (b) forward: for augmentative relationship. The ring sends all device IDs with the intended relationship to the ‘UI server’ to obtain suitable user interface. The composite relationship allows a user to control homogeneous devices. For example, a user can control all ceiling lights in a room using the ring. The collaborative relation allows user to interact with heterogeneous devices using a common interface. If a user selects a TV and two speakers, then joint actions such as turning them on/off and adjusting volume can be performed. Augmentative relation allows a user to augment one heterogeneous device over the other. If a user defines an augmentative relation on a fan and temperature sensor, then the fan adjusts its speed based on temperature sensor reading (see Fig.5). In an augmentative scenario, there must be some dependency between devices where the output of one device acts as input for the other device. User can break relationship using the same procedure as in single device scenario.

Finger Gesture Recognition Framework

We collected 3 axes (x, y and z-axis) accelerometer and 3 axes gyroscope sensor data at 50Hz sampling rate from six participants (4 Male + 2 Female) using GY-521 MPU6050 IMU sensor. Each participant repeats each gestures 20 times, and our dataset contains 720 samples (i.e. 20×6 $\times$ 6 gestures). We calculate 4 time-domain features from a 500 msec sliding window (with 50% overlap): mean, standard deviation, max, min. Then we extract 6 frequency domain features: lower 4 power bands of FFT, kurtosis, and skewness. We perform same calculation for all six axes. Therefore, each feature vector is of 60D (i.e. 6 axes $\times$ 10 features from each axis). We compared gesture recognition accuracy using Weka[9] implemented SVM, Naive Bayes, and Bagging classifiers running on Samsung Galaxy $S6$ Android phone. Table 1 represents the summary of F_1 score for different classifiers. In our dataset, Bagging outperforms other classifiers. When user performs a finger gesture, ring transfers its IMU sensor data to the phone and the phone sends the gesture recognition output to ring using IoTivity communication stack.

Experimental Evaluation

To demonstrate our concept, we implemented two scenarios where users can control a TV and two bulbs at a distance (see Fig.7 & 8). Fig.7 represents the single device scenario where a user is controlling a TV using our ring. For quick prototyping, we didn’t play around with inherent TV sensors using relevant SDK. Therefore, we used an Arduino Mega ADK board with IR transmitter and receiver, as an interface for the TV. The Arduino interface acts as a communication intermediary between ring and TV. Fig.8 represents the multiple devices scenario where a user is

[9] http://www.cs.waikato.ac.nz/ml/weka/

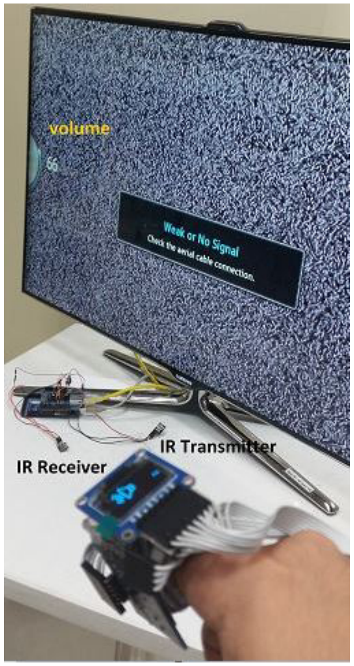


Figure 7: Single Device Scenario

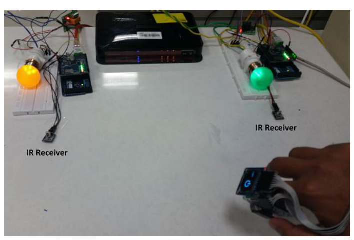


Figure 8: Multiple Device Scenario

controlling two homogeneous devices by defining composite relationship among them.

We invited 8 participants (3M + 5F), who are IoTivity stack developers in Samsung. These developers were new to gesture based control of smart-devices. We initially described the RingIoT set-up to them, then asked them to perform certain tasks like turning on/off TV, changing volume/channel of TV, turning on/off bulbs. All participants were able to successfully complete the list of tasks and commented positively about the RingIoT prototype. One user remarked that *“I don’t have to find different remotes for different devices anymore"*. Another participant pointed that *“after selecting the devices using IR pointing, there is no need to maintain directionality to control them like traditional remotes"*. All of participants were specifically happy to see IoTivity running in an end to end set-up. The idea of selecting multiple devices and control them simultaneously was liked by most of the participating users. In this small experiment, the users did not face any problem regarding IR pointing as devices were separated enough from each other, while they raised a concern about scenarios where devices are densely located.

The feedback of participating users was collected in form of responses to the questionnaires mentioned in NASA-TLX form. The parameters of evaluation in NASA TLX are Mental Demand(MD), Temporal Demand(TD), Physical Demand(PD), Performance(P), Effort(E) and Frustration(F). The responses in NASA-TLX are taken on a 20 point Likert scale (1 = very low/perfect , 20 = very high/failure). Fig.9 represents the list of statements, mean responses, and standard deviations. In 20 point scale, users rated all questions below 10 which is really impressive. Moreover, three statements got below 5 rating which are Mental Demand (mean: 4.34, sd: 1.12), Temporal Demand (mean: 3.84, sd: 0.86), Frustration (mean: 4.74, sd: 1.33). The participants rated Physical Demand (mean: 7.35, sd: 1.82), Effort (mean: 6.64, sd: 0.52), and Performance (mean: 7.88, sd: 1.05) little higher, because of the bulkiness of current ring prototype.

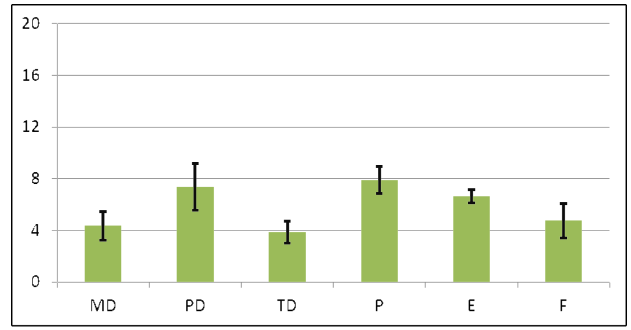


Figure 9: NASA-TLX Evaluation

Conclusion

We presented RingIoT, a wearable finger-ring that enables instant interaction with IoT devices in smart-environments. This paper mainly focuses on the implementation details and possible interactions among smart objects. The results of our user study in terms of six questionnaires are overall positive. The participants are little concern regarding physical demand and effort as the current prototype appears bulky, but the physical size can be significantly reduced by custom fabrication involving PCB design and 3D printing. RingIoT does not provide remote target access (i.e. control dining-room’s lights from living-room) since we use IR communication for target acquisition. Users may face difficulties to select a device in dense environments with IR pointing and it needs further exploration.

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