Research Statement

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My research lines in the technical side of ubiquitous computing and human computer interaction. I adopt a human-centered perspective to build a pervasive interface to bridge the digital and physical worlds and enable a natural and efficient interaction experience. My efforts to build such a pervasive interface has led to 10 publications at top-venues including SIGCHI and IMWUT with two paper awards. My previous work falls into three categories (Figure 1): **Sensing Tags**, **Finger Wearables,** and **Interconnection Techniques**. I believe the three parts need to be jointly designed for a seamless integration of the two worlds.

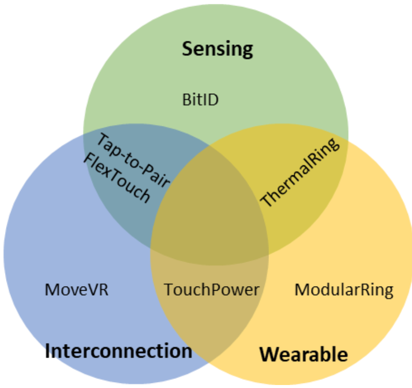

Figure 1: Taxonomy of my previous works.

1. Augmenting everyday objects with sensing tags

Interactive everyday objects are “technologies that weave themselves into the fabric of everyday life”[3], which can create an immersive interaction experience. However, users can still distinguish such computing enhanced objects, since they are usually expensive and require extra maintenances (e.g. charging). Users are also reluctant to replace existing objects for aesthetic or sentimental reasons. To overcome such limitations, I invent passive wireless sensing tags that can be easily deployed on existing everyday objects. The sensor’s many hardware (e.g. power source, RF oscillator) and computation (e.g. signal digitalization) are offloaded to one remote device. The cost, size, and power consumption of the sensors are then minimized. The small and thin form factor and the passive nature make them suitable for ubiquitous deployment on existing infrastructure and objects.

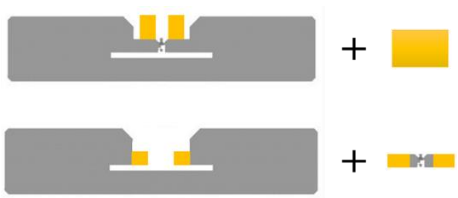

Figure 2: BitID tags enabled by shorting the IC (top) and separating the IC with the antenna (bottom)

In **BitID** [4], I modify commercial-off-the-shelf (COTS) low-cost and passive UHF RFID tags to behave as sensors. By attaching shorting stubs to exposed antenna around the chip (Figure 2), the tag’s readability is modulated by the connection status of the shorting stubs. Users can easily make BitID sensors using only copper tape and scissors. When properly deployed, a BitID sensor can detect the binary states of an object. We deploy BitID sensors various objects (Figure 3) to show its high scalability. The codes for the BitID sensing system is open sourced on GitHub. The RFID reader used in BitID is not widely available yet. So, I look into opportunities to leverage more accessible computers to power and compute for the resource-constrained tags, such as smart phones [2] and smart rings [8].

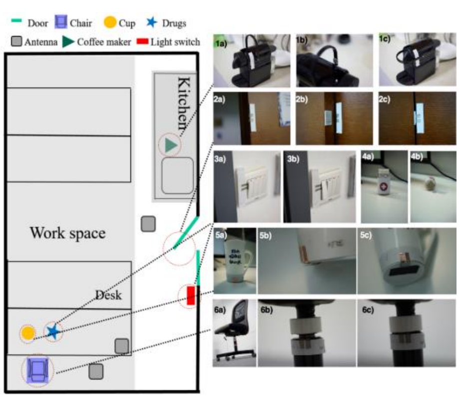

Figure 3: BitID deployed on six objects in an office room.

2. Enriching interactivity of finger wearables

Wearable devices are close and readily available to users, which enables a spontaneous and consistent interaction experiences. Finger wearables can support a richer set of input gestures thanks to the dexterity of fingers. Also, they are usually the closet on-body devices to the interacting object, which makes them ideal candidates for resource sharing. However, finger wearables are challenging to design due to size constrains. The small size further limits the available computing, I/O, and power resources, which can impact interaction experience.

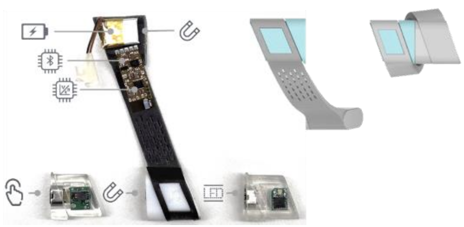

Figure 4：ModularRing adopts a modular design for smart rings.

To overcome such resource constrains, I explored modular design for a smart ring (Figure 4). Instead of integrating various I/O functions into one piece of hardware, **ModularRing** [1] uses switchable I/O modules for interaction. The novel wearing design allows the I/O module to be separated from the wireless MCU and battery. Users can then switch the I/O module based on needs, and combine multiple rings with different I/O modules to create advanced interfaces. For example, a ring with a microphone module and a ring with a speaker module can work together as an audio interface. ModularRing won Finalist of 2018 Global Innovation Competition and led to three patents.

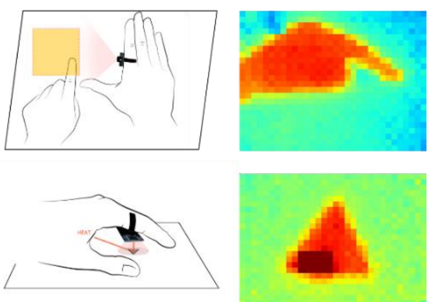

Figure 5: Thermal imaging of a hand and a passive tag.

In **ThermalRing** [8], I proposed a novel I/O module-a low-power low-resolution thermal camera for gesture and tag inputs. ThermalRing analyzes the heat silhouette of the hand to recognize drawing gestures on flat surfaces (Figure 5). I also proposed ThermalTag, passive tags that can be easily made using materials with high heat reflectivity (e.g. copper tape). When covered by hand, ThermalTag reflects the heat radiated from the hand and thus can be imaged. This demonstrates how the on-body wearables can work together with off-body tags for more interaction possibilities.

3. Distributing resources by establishing interconnections among devices

Currently, most interaction interfaces are designed for powerful and independent computing devices, which adopts a device-centered design approach. A human-centered pervasive interface, however, requires seamless interconnection among devices for resource redistribution. By allocating energy, computation, and interaction resources based on needs, the design of the interfaces can be more flexible and thus truly be woven into the fabric of everyday life.

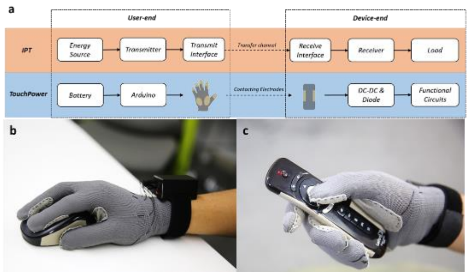

Figure 6: Components of IPT systems (a). TouchPower used with a mouse (b) and a remote control (c).

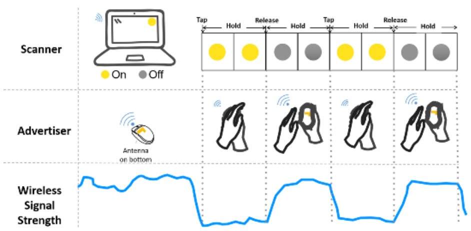

Figure 7: Tap-to-Pair associates two wireless devices by synchronous tapping.

Power interconnection between few on-body wearables and many off-body objects can significantly reduce user maintenance efforts. I invented the concept of **Interaction-based Power Transfer (IPT)** [7], which transfers on-body energy to off-body devices leveraging the contact and closeness between user and object during interaction. IPT is especially suitable for devices that only need to be powered during interaction (e.g. mouse, remote controller). The concept was validated with a glove-based IPT prototype **TouchPower** (Figure 6), which transfers DC power through contacts of electrodes on the glove and objects. With careful design of the transfer interface, energy can be distributed without affecting the original interaction.

It is challenging to establish interconnection between resource-constrained IoT devices. **Tap-to-Pair** [6] provides a spontaneous device association experience based on temporal correlation of two signals. Users can tap the initiating device to induce periodic wireless signal strength changes, which is then correlated with the blinking patterns of target devices for association (Figure 7). In a follow up work [5], I proposed a 2D design space and design guidelines for blinking patterns by applying Bayesian models of user tapping behaviors. Such optimization enables the technique to support robust selection among more targets.

Future Research Directions

My previous work focus on building sensing and interactive systems for pervasive interaction. In the future, I plan to continue the effort and improve the existing work. Aside from that, I will also start formularizing the general theory and design guidelines for such an interface. I'm also eager to collaborate with colleagues with various backgrounds to apply my skills in HCI, electronics, and computer science to new application domains, including but not limited to smart building, smart city, education, etc. Specifically, I plan to

1. Develop new wireless sensors and sensing algorithms

I plan to build customized backscatter wireless sensing platforms that can leverage resources from wearable devices, robots, and drones. At the same time, I will look into non-contact wireless sensing techniques to take advantage of ubiquitous wireless signals. I am especially interested in multimodal sensing, which combines sensing data from multiple sources with ambient wireless signals for event detection and prediction.

2. Design and implement resource redistribution mechanisms

The pervasive interface should have a mesh-topology instead of the existing star-topology. Different resources should flow freely among digital devices and follow the user for a truly pervasive interaction experience. I plan to design mechanisms to request and transfer resources with a finer gratuity (e.g. UI elements transfer across multiple devices).

3. Human-AI symbiosis theory and applications in HCI

Figure 8: Human-AI collaborative interaction

My previous research focus on pure explicit interactions, for which users fully express their intention by completing gestures. A pure implicit interaction predicts and auto-completes the task without any deliberate expressions from users. I'm utterly curious about the sweet spot between the two extremes (Figure 8), where it is optimal (in terms of naturalness, efficiency, etc.) for users and practical (in terms of expense, lag, etc.) for AI to collaborate on interaction tasks. I plan to adopt a bottom-up approach to search for this sweet spot.

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