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Printed Electronics and the “Internet of Things” - Design Issues and a Rapid Prototyping Platform

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Zusammenfassung

In this article we introduce „fingies“ - a rapid prototyping framework for „Internet of Things“ (IoT) applications based on the Arduino Yún connected to hybrid sensors and actors. The hybrid sensors and actors are composed of silk-screen printed electronic circuits combined with conventional electronic parts, Surface Mounted Device (SMD) sensors and actors. We discuss design paradigms and their relevance for physical Interfaces of „Internet of Things“ (IoT) applications with a focus on printed electronics.

1 Introduction and related works

1.1 „form follows function“ in the digital age

The phrase „form follows function“ has been an architecture and design paradigm for more than 100 years. It was coined by the American architect Louis Sullivan, in his article „The Tall Office Building Artistically Considered“ (Sullivan 1896). Form is related to the physical form or appearance of an object and function refers to the usefulness or ease of use. It is a strategy that has its roots in the industrial age. Often it is also used with a reference to the „Bauhaus“ design where form was supposed to reflect the function of an object or architecture - leaving away unnecessary decoration.

Today Designers face the task to develop physical objects with embedded electronic functionalities communicating with the ubiquitous digital sphere. To do this in a way in which users understand the digital functionalities it seems essential that form is also reflecting these digital functions. The affordances of these objects combining physical and immaterial digital properties need to be identified and taken into account. It seems obvious that this design paradigm can especially be applied to Tangible User Interfaces (TUI´s). TUI´s are expected to link digital bits with physical objects and allowing people to interact with that digital information by grasping and manipulating physical objects. (Ishii et al. 1997) The importance of smart materials and their properties for the tangibility of these interfaces becomes evident (Ishii et al. 2012). Today design approaches (e.g. „User Centered Design“, „Design Thinking“) integrate the „user“ perspective by defining Personas and Scenarios, building prototypes and by evaluating and improving these prototypes in an iterative design cycle. Bill Buxton summarizes this approach by „Getting the right design, and then getting the design right“ (Buxton 2007). Visions for the future individualization of production predict that users will download digital blueprints of their „objects“ and use their personal 3D printers to produce their individualized products (Schmidt et al. 2011).

1.2 Copy Left or how the WWW triggered new design strategies

Starting in the early nineties of the last century interaction and navigation concepts as well as visualization strategies for complex and fast growing data structures that evolved with the tremendous growth of the Internet showed the usefulness but also the limitations of traditional design approaches. Visual „form“ was mainly related to the visual design of 2-dimensional screen based interfaces. Traditional well-established design strategies were useful in many aspects. But new qualities were introduced - especially the concept of hyperlinks and flexible layouts was very different from the design paradigms of static layouts based mainly on paper media. Navigating complex hyperlinked structures and interacting with animated multimedia content created new challenges for designers. From our perspective one factor that contributed to the enormous growth and success of the WWW in the early times was the possibility that every webpage could technically be copied and easily modified. This fueled the rapid growth of the WWW driven by web developers and designers. This „design principle“ also contributed to the open source scene and is a blue print for establishing new frameworks until today. Frameworks like Arduino, Processing or more recently Intel Gallileo/Edison, Microsofts IoT platform or even programs like Xcode - they all rely on the principle of communities sharing experiences and providing code examples. Today also physical interfaces to the „Internet of Everything“ have to deal with these complex requirements.

1.3 Design meets Electronics

Parallel to the development of the WWW - hardware development platforms featuring small mini „computers“ evolved. Early examples like Conrads C-Control (ranging back to the 1990´s) and others were outperformed by the success of the Arduino platform that was developed more than 10 years later but came along with an easy to use software development framework. Today the term „physical computing“ is commonly associated with building interactive physical objects by the use of prototyping platforms that combine Hardware and Software and that can sense and respond to the analog world (e.g.Arduino, Raspberry Pi). Design issues often do not play a dominant role in „Physical Computing“ examples because the development of prototypes with these prototyping platforms is focused on demonstrating functionalities. Currently many designs incorporate the circuit board with the processor and breadboard layouts as a visible component. From our perspective design issues have to be taken into account when we want to evaluate usability or user experiences.

1.4 The Internet of Things (IoT) and printed electronics

The Internet of Things (IoT) or Internet of Everything can be seen as a combination of hardware components and the WWW. It is a network of physical objects with embedded electronic functionalities communicating with each other via the Internet. Typical IoT applications offer services based on the exchange of sensor data between different objects, places people, etc. From our perspective the IoT is the next consequent and important step in the continuous development of the WWW from static and multimedia web-pages in the 1990´s, Web 2.0 services and social networks, location based services and last but not least the pervasiveness of smart-phones in the last couple of years. Mark Weisers vision of the vanishing computer is about to come true with this development (Weiser 1991). Printed electronics offer very specific potentials for IoT applications. Conventional print design and the design of printed functionalities can be combined. Examples range from the individual production of highly customizable thin film touch-displays (Olberding 2014) to mass printed applications combining traditional print media with printed functionalities (Geelhaar et al. 2013). The printing of the electronic circuits can easily be realized with silkscreen or inkjet printers. Inkjet printers make this technology available at a reasonable price (Kawahara, Y., Hodges, S., Cook, B.S., Zhang, C., and Abowd, G.D. 2013) Some recent projects like „Printoo“ (http://www.printoo.pt) or the „Paperduino“ (http://paperduino.eu) suggest paper based Arduino compatible platforms or even tools for printing combined with pick and place functionalities (http://visionbot.net and https://www.botfactory.co) These projects also demonstrate the interest of the Maker scene in the area of printed electronics.

2 “fingies”

„fingies“ is the name of an integrated framework that connects the world of printed electronics to the Internet. It provides an easy-to-use prototyping tool for quickly experimenting with „Internet of Everything“ applications and offers the possibility to develop hybrid sensor/actor systems with both printed and conventional electronics (Geelhaar 2014).

Image 1: “fingies” hardware components

The “fingies” framework technically consists of the following components:

1. A central electronic hardware component allowing wifi connections
2. An „operating system“ for the Arduino Yún
3. Different hybrid sensor/actor cards with printed circuits
4. A server software providing sensor data
5. An online administration tool
6. A Web based simulator for Webkit Browsers on smartphones, laptops or desktops

The Arduino platform is used worldwide not only by experts but by a large number of people from the Maker scene. They build a vast variety of interactive objects and realize very individual projects. The Arduino developer scene for open source applications is huge and vivid. Lots of sample applications are published online and can be used and modified. The huge global acceptance and availability makes the Arduino platform a perfect fit for our platform Hardware add-ons (so-called “shields”) are common in the Arduino world. We developed a hardware shield allowing the connection of sensor and actor cards via super-magnets allowing physical and electronic contact between the sensor/actor cards and the Arduino Yún. Furthermore we developed a software for the Arduino Yún that allows automatic identification of these sensor/actor cards. The software can be installed and updated easily via the Internet or via standard SD cards.

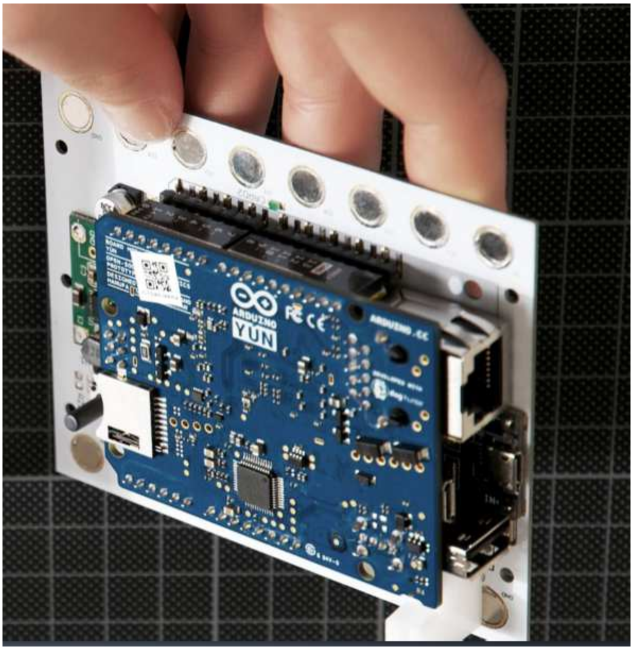

Image 2: Hardware Shield and Arduino Yún

We developed a set of screen printed circuits on flexible, postcard sized paper cards attached with different conventional SMD sensors (e.g. temperature, light, bend, etc.) and actors (e.g. LED, loudspeaker, vibration motors). The sensor/actor cards are physically and electronically connected to an Arduino Yún via eight magnetic contacts and the Arduino shield developed by us. The SMD sensors on the cards enable the Arduino Yún to record and process these sensor values (e.g. temperature or humidity). With the actor cards active parts like LED´s, loudspeakers or vibration motors can be controlled. The connection to our server is realized via Wifi connection of the Arduino Yún.

The printed electronics sensor/actor cards are hybrid systems. They consist of printed circuits and conventional electronic compounds such as sensors for light, temperature, acceleration, touch, microphone sensors and actors such as led, loudspeakers, vibration motors. Overall the current system supports 27 different sensors and actors. The extension to an almost unlimited set of sensor and actor cards is technically relatively easy to implement. and is planned as one of the next development steps. Conventional electronic parts can then be applied with conductive glue or low melting

The node.js / websocket server not only allows communication between the different sensor/actor cards attached to the “fingies” hardware but also to and between smart phones and computers. Sensor values can be “subscribed” by other „fingies“ boxes or Web and App Applications on smart phones and computers. We use standard Web-Technologies to enable platform independent access.

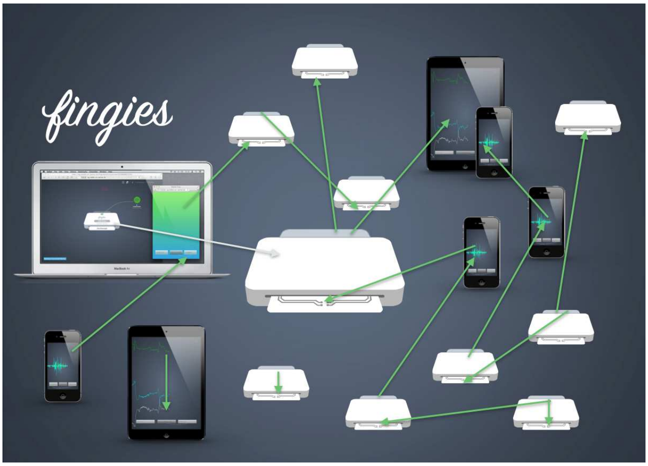

Image 3:Configuration Interface

Software and Hardware developers can use „fingies“ as a rapid prototyping tool to connect their own printed sensors or actors to Web Based Application. Software developers can prototype smartphone and computer applications that make use of sensor data acquired from the sensors by subscribing to a specific sensor via our server. This opens a wide field of different digital services like the management of medical sensor data or the documentation of parameters like temperature in logistics. Hardware developers of printed sensors and actors can use „fingies“ to control their actors via Smartphones and Computers or to provide sensor values to cloud based applications

3 Conclusion

We developed a hardware and software framework for experimenting and prototyping Internet of Things / Everything applications. We connect the world of printed electronics with the Arduino platform. The technical functions of the first „fingies" version were demonstrated at TEI 2014 in Munich (http://www.tei-conf.org/14/studios.php) and a second revised version at the Media Architecture Biennale 2014 in Aarhus. The framework was also evaluated in several student projects during the last two semesters.

One of the first problems that we encountered in all workshops was establishing network connections with an existing WiFi. This issue is related to the Arduino Yún. Our solution for this problem is to use an UMTS WiFi Router or to set up a network connection with a personal smart-phone hotspot. Also working with many Arduino Yún´s at the same time in the same room sometimes caused problems with WiFi settings. It makes sense to identify the MAC-Address of each Arduino Yún before turning on all of them at the same time. We mainly used pre-manufactured circuit boards. The circuits were silk-screen printed on paper with silver ink. Workshop participants were then soldering SMD sensors and actors on the cards. This worked well. Currently we also evaluate inkjet printed silver inks on special photographic paper and other carrier materials. We will publish these results as soon as they are available.

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