Vastara: Project Ara for Wearables

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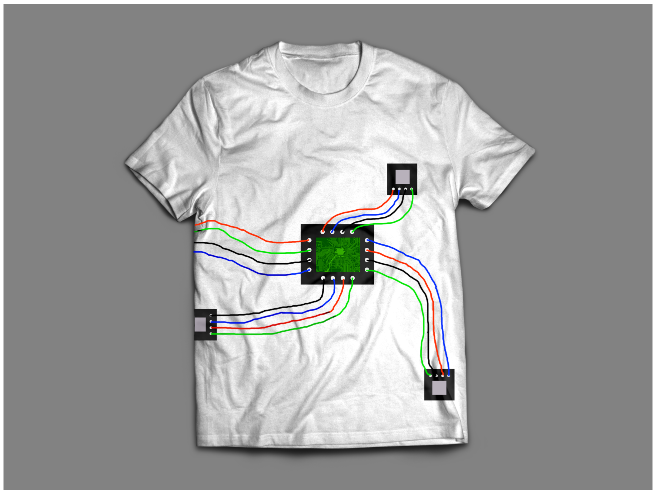

Figure 1. Overall design

Figure 2. Fabric 5-way bus connection

PROBLEM DEFINITION

Video description of the project linked here.

Most common consumer products like mobile phones and cars are unmodifiable by the end-user. These products tend to be self-contained and have a generic set of functionality; not everyone wants or needs to modify their devices.

However, enthusiasts may be inclined to customize their product to their needs; the closest we have to a custom-made consumer product, is the self-built desktop PC, which requires a technically knowledgeable end-user as well. In case of very personal devices like wearables (which are attached to the human body), the default functionality may not suit every person due to a wild variety of needs.

Hence we propose a modular wearable system, consisting of a set of cloth "patches", each with different components like sensors, communication modules, and output modules, which may be programmed step-by-step via IFTTT. They can be selectively connected together, clipped anywhere onto the user's clothes or body, depending on their needs.

ACM ISBN 978-1-4503-2138-9.
DOI: 10.1145/1235

EXISTING PRODUCTS AND LITERATURE

DIY Platforms

The Arduino [3] is one of the more famous prototyping platforms for DIY electronics; it provides an easy-to-use development board with I/O ports for connecting input and output devices like sensors and motors, and a clear, simplified programming environment. A variant of the Arduino, the Lilypad [6] is a sewable, snappable microcontroller board for wearables with the same development environment.

One level of abstraction above, are Phidgets [2]; they consist of a set of mini dev boards for each kind of component connectable via wire, which can be programmed via the Phidgets API. However, its adoption is not nearly as widespread as the Arduino's because of it being closed-source and its relatively high cost.

We are not targeting the DIY maker audience, since we do not want to restrict ourselves to just technical users who are willing to deal with wire and programming. The examples which follow, are the kind of application-specific kits (for us, wearables attached to clothing) we seek to emulate, possibly at the cost of reduced flexibility.

Application-specific Commercial Products

The littleBits [8] kit is composed of colour-coded, magnetic, input and output "blocks" which can be snapped together to implement logic. These are geared towards children for familiarizing them with circuits and to introduce them to the joy of making. All logic is tangible and non-programmable, that is, the logic is decided by setting switches on the blocks themselves, but however, are somewhat limited in functionality.

Another kit is the Lego Mindstorms [1] kit for building robots. It contains a central "brick", to which input/output bricks like colour and infrared sensors, and motors can be connected by a single cable, and programmed via a drag-and-drop interface.

Finally of course, we have Project Ara [5]; Google's now-dead ambitious modular smartphone project. It consisted of a skeleton with exposed ports, meant for different modules like a camera module, an e-ink display, or a speaker module, to be swapped out on the fly, to create a customizable smartphone. BLOCKS [4] is another similar product in beta, but for smartwatches.

In Literature

There have been a few notable explorations in modular wearables in literature, like MakerWear [7], i*CATch [10], and the TeeBoard [9], which eliminate the need for sewing for prototyping. However, they all have drawbacks and nitpicks which may prevent widespread commercial adoption.

The MakerWear is suitable for children, but too conspicuous for adults; not all adults may want to wear visible cloth patches on their clothes, something more discreet would be preferred. More importantly, the patches are essentially connected together and are not distributed throughout clothing, thus are restricted to a single body location.

The i*CATch is the closest to our idea, however, it is still not completely free-form like the Lilypad; it requires the modules to be plugged into pre-specified socket locations onto the i*CATch bus. The TeeBoard is too intrusive with respect to clothing (too much going on for emulating a breadboard on a t-shirt!) and only a special t-shirt can be used. It is good for prototyping, but not as a usable product.

The i*CATch and the TeeBoard still involve software for configuring the prototype, while the MakerWear eliminates the need for programming by making all configuration tangible.

USER RESEARCH PLAN

Our target audience consists of intermediate users of technology who are not averse to minor configuration of their devices; for example, someone who can set up an IFTTT recipe on their own. However due to the relative obscurity of wearables (apart from wrist-worn devices), we don't expect most consumers themselves would know what they would do with a modular wearable they could attach anywhere on their body, so just asking them so would be unhelpful.

Our stakeholders are also defined by our selected set of sensors and output modules, and the applications made possible by them. Hence, we have compiled a sample list of applications as follows (by no means exhaustive), to serve as benchmarks in our user research workshop for evaluating our system:

- Athletes
  - `if` heart-rate is HIGH `and` outside temperature is HIGH, `then` RGB turns red.
  - `if` heart-rate is LOW, `then` RGB LED turns blue.
- Generic adults
  - `if` blood alcohol content is HIGH, `then` phone connects to bluetooth speaker of car and screams "Don't drive!".
  - `if` back is bent at a HIGH angle for long, `then` turn ON haptic vibration motor to signal poor posture.

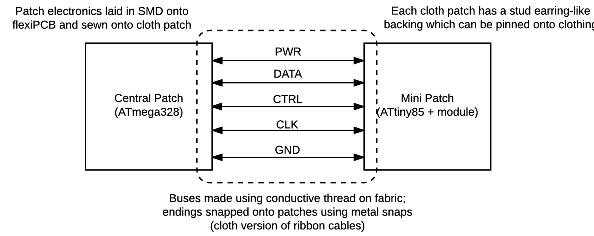

Figure 3. Cloth patch and bus connection overview

- Women
  - `if` push-button patch on waist is ON, `then` phone calls `and` sends location to emergency contact number.
- Young people
  - `if` IR sensor input is HIGH, `then` dot-matrix display increments by 1.
  - `if` push-button input is HIGH, `then` RGB LED flashes red. (laser tag!)

We plan on holding a small workshop for a group of college-aged people (the age group covers the spectrum of applications covered above) for validating our system for the set of sample applications. We will evaluate it on the basis of a few parameters, like how fast and easy was initial setup, did the patches hinder movement, does the system work correctly, ease of interaction, etc. We would then like to note what are the applications the test users themselves come up with for our system, and how easy do they find it to set it up, and whether they feel restricted by our system (it isn't modular enough to execute their idea).

We will then end with a pointed questionnaire to figure out which further component(s) would be of use for what purpose, for the responder.

GOAL

We would definitely like to get this down to a finished commercial product; we have thought about it to the extent that we want to get our PCBs fabricated and go SMD for good, for a potential Mother of all Demos. An exceptional (and probably too ambitious) outcome would be if we manage to make at least one other team's project construction obsolete, with minimal effort on the user's end. (this way we would know our system is powerful enough to easily implement even a reasonably complex application/idea)

IMPLEMENTATION OVERVIEW

Our work-in-progress GitHub repository for the software-side of the project is here.

Components

Our system will consist of a central patch (using a bare ATmega328 microcontroller, without the Arduino) with peripheral modules attached to it.

We plan on making modules ("mini patches") for the following set of sensors and output devices:

- Sensors
  - DHT11 temperature sensor
  - Light-dependent resistor
  - Heart-rate sensor
  - Flex sensor
  - Alcohol sensor
  - Push-buttons
- Output devices
  - Haptic vibration motor
  - Dot-matrix display
  - RGB LEDs

This assortment of components has been chosen keeping in mind a variety of communication protocols involved. Each module will have a common interface of PWR-GND-DATA-CTRL-CLK, regardless of what protocol the sensor internally uses, so that communication is consistent and abstracted out. It will be interfaced via an ATtiny45/85 uC present on each module.

For the sensors having 2 states (such as light or dark, hot or cold, bent or straight), there will be a physical switch present on its mini-patch to select the state the output patch (if any) should be active, hence making basic set-up of the system tangible, and not requiring IFTTT to program it.

The "mini patches" will be connected to the central patch via the interface wires embedded in the fabric "cable" itself with conductive thread, with metalic snaps at the end. All the patches would be attached to the clothing in the same way stud earrings are clipped onto the ear with plastic stoppers.

The final envisioned version of these patches would be in flexiPCB form, laid out in SMD as flat as possible to be as non-intrusive on the body as possible. These flexiPCBs would be sewn onto quick-dry material cloth (the kind of material used in sports jerseys).

Potential Body Locations

We are not targeting any body locations in particular, but rather, clothing to which our system of patches can be clipped onto.

CHALLENGES ANTICIPATED

Power Supply

Having a common PWR and GND line simplifies our lives a bit, but different devices run at different supply voltages as well, so we will have to have voltage regulators onboard "mini patches" in certain situations. There is also the practical matter of how many devices can a 3.7V LiPo battery power and for how long. More importantly, designing a dependable power supply which works independently of the number of patches connected will also be a challenge.

Safety

None of the components should shock the user at any point. We are also concerned about how our system will behave on contact with water, such as rain. We plan on covering all exposed electronics with heat shrink tubing and cling wrap, but further testing will have to be done to see what happens.

RESOURCES AND SKILLS NEEDED

- Embedded systems
  - Most of the electronics deals with so.
  - People: Aryan and Radhika
- PCB designing
  - Need to build a stable prototype at some point, with the components laid out as flat as possible.
  - People: Aryan and Radhika
- Power supply design
  - "Patches" are isolated pieces, distributed throughout the user's body, but are connected together; need to make sure they have a single, non-cumbersome power supply.
  - People: Aryan
- Sewing/stitching
  - Need to make electrical connections on the "patches" of cloth using conductive thread and sew PCBs onto cloth.
  - Need to learn; need access to a sewing machine.
- Software/library design
  - Need to create API for accessing many different modules on the "patches" consistently, with minimal change every time we add a new type of "patch" and IFTTT integration.
  - People: Kartik and Radhika
- Android programming
  - Will be integrating mobile phones into the system.
  - People: Kartik

TIMELINE

We have largely adhered to deadlines so far, hence do not feel the need to modify our timeline for now.

- September 18:
  - Basic isolated "patch" electronic modules prototyped individually on perfboard, functioning correctly.
- October 9:
  - Previously prototyped modules now sewed onto "patches", connectors made using conductive thread and cloth strips.
  - Modular power supply functional.

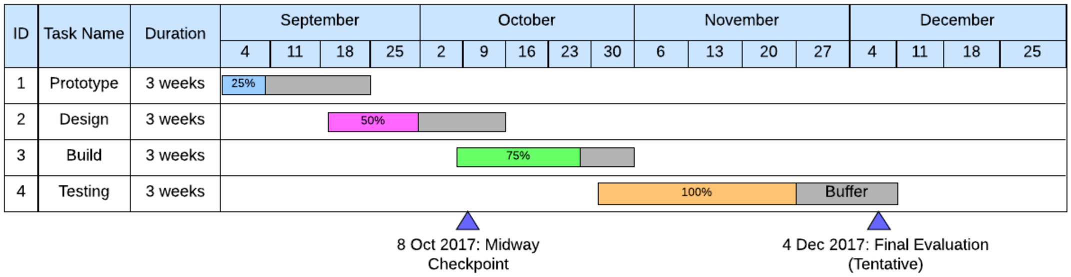

Figure 4. Tentative Gantt Chart for project timeline

  - High-level API created to access sensor/module functions.
- October 30:
  - IFTTT integration done.
  - More sensor/communication modules added.
  - PCB designed, and tested on homemade PCB using ferric chloride solution and copper clad.
- November 20:
  - Finished version with flexiPCB sewn onto cloth, drag-and-drop programming interface functional.
  - Testing on sample consumers.

If we receive favourable feedback for our project, we hope to perfect the design further and work further about how to fabricate it at, at least a small-to-medium production run.

TENTATIVE BUDGET

- Patch components: INR 1500
  - DHT11 temperature sensor
  - Light-dependent resistor
  - Heart-rate sensor
  - Flex sensor
  - Alcohol sensor
  - Push-buttons
  - Haptic vibration motor
  - Dot-matrix display
  - RGB LEDs
- Microcontroller chips: INR 1250 - INR 2000
  - ATmega328P: 150 x 3 = 450
  - ATtiny45/85: 80 x 10 = 800 or 300 x 5 = 1500
- Miscellaneous: INR 500
  - Wire
  - PCBs
  - Cloth
  - Earring backing

Total tentative budget: INR 4000

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