The Design of Tools for Sketching Sensor-Based Interaction

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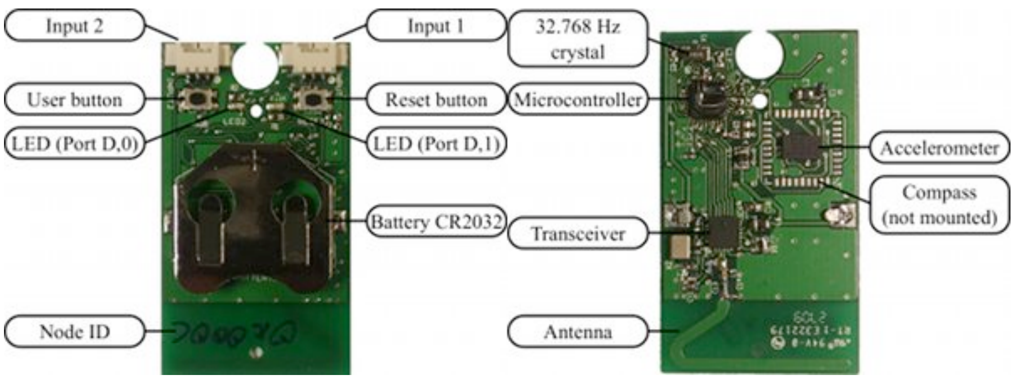

Figure 1. DUL Radio sensorboard (front and back). Size: 25 x 43 x 6 mm (1 x 1.7 x 0.2 inches).

ABSTRACT

In this paper we briefly motivate, present, and give an initial evaluation of *DUL Radio*, a small wireless toolkit for sketching sensor-based interaction. In the motivation, we state the purpose of this specific platform, which aims to balance ease-of-use (learning, setup, initialization), size, speed, flexibility and cost, aimed at wearable and ultra-mobile prototyping where fast reaction is needed (e.g. in controlling sound), and we mention general issues facing this category of embodied interaction design tools. We briefly present the platform, both regarding hardware and software. In the evaluation, we present our experiences with the platform both in design projects and in teaching. We conclude that DUL Radio was the preferred platform for sketching sensor-based interaction compared to other solutions, and that it does seem to be a relatively easy-to-use tool, but that there are many ways to improve it. Target users include designers, students, artists etc. with minimal programming and hardware skills, but this paper addresses the issues with designing the tools, which includes some technical considerations.

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Author Keywords

sensor-based interaction, wearable computing, audio, tangible interaction design, wireless, pervasive computing.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design, Experimentation, Human Factors, Theory.

INTRODUCTION

One of the main obstacles in tangible and embedded interaction design is the complexity of tools and competences required for sketching and casual prototyping. Whether for educational[8], designerly[4], or artistic[6] purposes, various other projects have addressed this challenge, and a range of tools and platforms have emerged[5]. *DUL Radio* (Fig. 1) is a concrete attempt to develop a platform for sensor-based interaction design that is both (a) easy to use and (b) has a specific feature set not typically present in a single, unified system.

Ease of use applies to the point of view of the prospective interaction designer (whether formally trained or not): no steep learning curve, easy initialization and set-up, requiring no or minimal programming skills or hardware experience. Thereby, we aim to accommodate users who are not (yet) technically skilled, typically designers, students, and artists.

The feature set of any platform represents trade-offs as a result of different developer traditions, standards, needs, end-product perspectives, and even pedagogy and ethics. But in general, the development environments tend to favor either ease of use or low-level hardware control.

DUL Radio seeks to balance size, speed, flexibility, and cost optimized for wearable and ultra-mobile prototyping scenarios where fast reaction is needed (e.g. in controlling sound and triggering events). It aims to be efficient and flexible while still favoring ease of use.

DUL RADIO VS. OTHER PLATFORMS

DUL Radio is a research prototype platform and is not commercially available presently. However, both the hardware and software (including source and specifications) are shared with interested parties.[1]

While custom-made, it is essentially a set of components that is comparable to other common components you can buy in well-equipped electronic retailers. The differentiation of DUL Radio is therefore not in the technical properties. Differentiation lies in the optimized performance with regard to sketching sensor-based interaction.

The platform consists of (a) a sensorboard (custom-made hardware design as well as software, i.e. firmware and bootloader), (b) a USB-stick-transceiver, and (c) an optional custom-made desktop application for easy configuration. It comes configured out-of-the-box, ready for serial communication via the host. The host can be any device, e.g. a laptop or mobile phone, with a 2.5 GHz ISM band transceiver, e.g connected through a USB-stick.

DUL Radio can both be used with platforms like Arduino[6] and it can exist as a standalone toolkit. It is possible to interface with DUL Radio through any programming language/environment capable of running a process on the host that can open a serial connection (e.g. PHP, Java, Processing, MAX/MSP, C, C++).

DUL Radio can be tweaked so that it is possible to move in the range from minimum power consumption to maximum polling frequencies. Below is an illustration of the range (Figure 2):

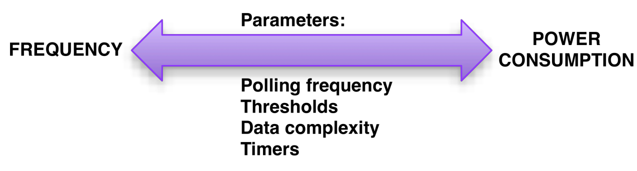

Figure 2: Trade-offs. Optimize frequency or power use.

[1] http://www.digitalurbanliving.dk/dul-radio

When the polling frequency is high (left), the microprocessor almost never sleeps and as much data as possible is being sent, thus power consumption is high. When the polling frequency is low, power consumption is optimized (right) because the processor sleeps almost constantly, the analog-digital converters are deactivated, thresholds for waking the processor are high etc. Through the configuration application it is possible to tweak where in the above range DUL Radio should be in relation to a specific project or purpose.

Reducing complexity in sketching is another purpose of DUL Radio as illustrated below (Figure 3):

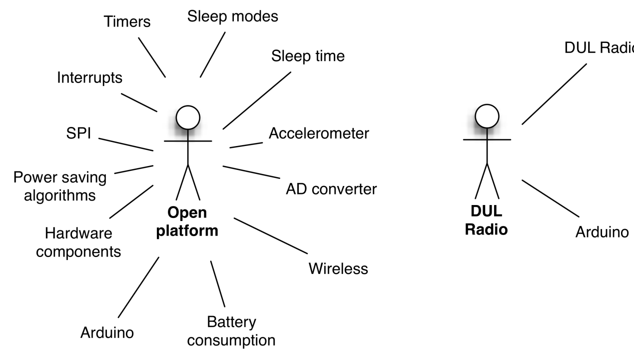

Figure 3: Complexity. DUL Radio vs. open platforms.

Also here, our approach is based on trade-offs. As opposed to what we call an "open platform" approach (e.g. Arduino), DUL Radio has been built with a deliberate goal to hide both hardware and software complexity under the hood, so to speak, but without limiting too many relevant features, while still leaving open the option of setting free the access to hidden complexities at some later stage.

What sets it apart from any compatible wireless Arduino board, seen so far at least, is a combination of features:

- The transceiver is integrated on the board.
- The board has sensor-sockets mounted on it.
- A 3D accelerometer is mounted on the board.
- Power access is mounted on the board.
- The atomization feature which can have a variety of configurations.

The sensorboard is equipped with the following:

- Two 10 bits ADC's
- Slot for a CR2032 3V lithium cell battery
- Microcontroller (mega168PA[2] from Atmel)
- Transceiver (nRF24L01+[7] Nordic Semiconductor)
- Accelerometer (ADXL345[1] from Analog Devices)

See [3] for detailed specifications and a comparison with other systems.

PERFORMANCE

We have conducted testing with the current hardware configuration and software and the findings so far are:

- DUL Radio can run up to 5 days with full load on the ADC's (considerably longer with only use of the accelerometer), with a 3V cell battery
- Indoor range of 10-15 meters
- Outdoor range 45-70 meters

It is possible to put an external antenna on the DUL Radio, but it is not possible to do so without soldering. Therefore it is not facilitated in the current hardware configuration. We are now working on the version two of the software. This next version will make it possible to increase battery time considerably.

Software

For the sake of usability and ease of use, we have created a configuration application (available online). It is possible to set all parameters that relate to the DUL Radio, and the main features are:

- Set which USB stick a sensor board should send data to.
- Disable and enable ADCs and the accelerometer.
- Set output data format.
- Set thresholds for when ADCs and the accelerometer should be activated or inactivated (go to sleep).
- Set the sample rates for both the ADCs and the accelerometer.

By moving the cursor over the parameter values is it possible to see what every parameter precisely does. With this interface the designer is able to configure the DUL Radio to whatever fits the specific purpose. This interface still needs usability improvements.

Interfacing with interaction designers

Interaction designers and others can use the configuration application to setup DUL Radio, but they can also use DUL Radio in any environment that facilitates serial communication. Because DUL Radio uses serial communication, it is possible to write custom programs that use the data from the sensorboards. Furthermore, is it possible to use programs like MAX/MSP, so a designer can set up a system very easily and without any programming skills. With DUL Radio, the designer does not have to think much of all the complexity hidden in wireless sensing, and that way the designer can focus on the important tasks in the design process.

INITIAL EVALUATION

During 2011 we have had the opportunity to use the DUL Radio in various settings, including with four classes of interaction design and audio design where the students were introduced to the platform as part of a comprehensive curriculum. A total of more than 80 students were using DUL Radio. The following are some initial experiences, from student projects, and from using the platform in teaching, including the results of a small survey.

Example Student project

To briefly show the kind of projects the students have made and explored, here is an example: In spring 2011, a student project was conceived where the students wanted to track the gestures of a guitarist with the objective to extend the control of sonic manipulations with other means than the traditional standard foot or stomp-pedals.

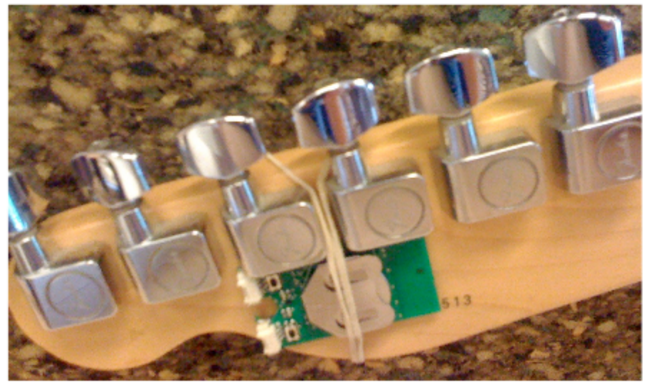

Figure 4: The hardware approach was really basic. A DUL Radio transmitter simply strapped to the stock head of a guitar with a couple of rubber-bands.

The focus of the project was on the sonic element, the resulting output of the guitarist's interaction with the 3D accelerometer (Figure 4). A software system was devised containing several elements, most notably the sonic effects palette. But in relation to the accelerometer software calibration, scaling and mapping algorithms where programmed.

A number of footswitches operated with an Arduino board allows for direct access to a number of parameters that control the accelerometer. As mentioned, the main objective in this project was to extend multi-parameter control over a palette of sonic effects. So the main effort in this project was certainly put there.

So what should be emphasized here is that the student had another focus than putting together the sensor-based interaction, but still managed to add that element quite easily. What we see is a different hardware sketching approach than if he had opted for an Arduino-based interaction solution. The students using the DUL Radio are design students with limited hardware knowledge. Whereas Arduino requires substantially better competences in software and hardware engineering.

Teaching Sensor-Based Interaction Design

From the early stages of developing DUL Radio, it has been a main objective to make it well suited to be used in project-based design courses at universities and design schools. We now have a fair amount of experience with teaching the use of the platform, and we have an evaluation based on questionnaries from 29 bachelor students from the

Aspect	DR	N	OP
Understanding of concept	22	2	5
Usability	24	0	5
Feature sets	0	0	29
Ease of installation vs. Arduino	14	6	9
Prototype realization vs. Arduino	18	9	2
Stimulation of creativity	13	7	9
Quickly from idea to prototype	24	0	5
	115	24	64

Table 1: Survey results from design students (n=29) comparing DUL Radio (DR) to open platforms (OP), e.g. Arduino, or no preference (N). Shade indicates preference.

interaction design course taught at 3rd or 4th semester at the Digital Design study program (Table 1). In another part of the survey, the students were asked to evaluate their own abilities in programming and/or hardware experience. All marking their abilities as none or almost none.

As shown in the table, the students generally found it easier to understand the (simpler) concept of the DUL Radio (wireless, shake the monkey (the accelerometer), and the music plays), than the more complex and versatile Arduino-platform.

Given that sensors are prepared for fitting in the sockets on the board, and that it has the onboard accelerometer, the students found it generally easier to rapidly prototype when constrained to using predefined features that where equally accessible on both platforms.

Obviously, when working without constrains, the Arduino platform's wealth of features is incomparably rich opposed to DUL Radio. We emphasize that this is not a critique of the Arduino, only an exploration into a specific situation which suggests that in the case of sketching sensor-based interaction in the scenarios encountered during this course, the DUL Radio seemed to be preferred.

Overall, as with any platform in an early stage, there were trivial problems that overshadowed the use. But the feedback and actual use clearly indicates that the students that had an interaction design goal which was accommodated by DUL Radio, did choose that platform over Arduino (which they were also introduced to), and that they generally appreciated the trade-offs between ease-of-use and configurability.

The students indicated that Arduino's strength is that its open architecture provides endless possible uses, but also that this complexity was its largest drawback. So it seems clear that the two platforms are indeed perceived as different kinds of tools for sketching sensor-based interaction, and that DUL Radio does provide a relevant, balanced feature set for certain types of exploratory work.

CONCLUSIONS & FUTURE WORK

In conclusion, the DUL Radio platform for sketching sensor-based interaction balances ease-of-use and many design parameters to create a tool for interaction designers to sketch embodied interaction easily compared to more complex platforms while still allowing for a high level of configuration. While it is now in a stable condition (Version 1), there are many improvements that could make it much better, e.g. optimized power consumption, a better bootloader, interrupt-based software, and better usability. We will also conduct a more detailed evaluation in teaching settings, including, hopefully, at other institutions than our own.

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