Linoc: A Prototyping Platform for Capacitive and Passive Electrical Field Sensing

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Abstract: In this paper the Linoc prototyping toolkit is presented. It is a sensor toolkit that focuses on fast prototyping of sensor systems, especially on capacitive ones. The toolkit is built around two capacitive and two Electric Potential Sensing (EPS) groups providing unobtrusive proximity detection in the field of Human Computer Interface (HCI). The toolkits focus lies on its usability and connectivity in order to be adapted in future research and novel use cases. A common obstacle in the beginning of a project is the time required to familiarize with present tools and systems, before the actual project can be attended to. Another obstacle while tackling new tasks is the actual physical connection of sensors to the processing unit. This situation can be even worse due to dependencies on previous work, most of the times not fully documented and missing knowledge even if the the original designer is involved. Good toolkits can help to overcome this problem by providing a layer of abstraction and allowing to work on a higher level. If the toolkit however requires too much time to familiarize or behaves too restrictive, its goal has been missed and no benefits are generated. To assess the quality of the Linoc prototyping toolkit, it was evaluated in terms of three different aspects: demonstration, usage and technical performance. The usage study found good reception, a fast learning curve and an interest to use the toolkit in the future. Technical benchmarks for the capacitive sensors show a detectable range equal to its predecessors and several operational prototypes prove that the toolkit can actually be used in projects.

1 INTRODUCTION

When it comes to prototyping with any kind of sensors, the most common ones can be connected via intra-board bus protocols such as Inter-Integrated Circuit (I^2C), Serial Peripheral Interface (SPI), Universal Asynchronous Receiver-Transmitter (UART) or JTAG-programmers. This often requires programming skills and knowledge of embedded systems in order to work with the sensor data. Many sensor suppliers attempt to reduce the amount of programming needed, by supplying libraries or other interfaces to open source platforms like Arduino or Raspberry Pi.

However these platforms or libraries often lack advanced features and prevent programmers to access many in-depth parameters or functions, making them unsuited for more complex projects.

Rapid prototyping has made its way into research and design processes and accelerates the adoption of new techniques and concepts. The Linoc rapid prototyping toolkit is designed to provide an easy to use platform to be used in future projects for easy data acquisition. With this in mind the requirements for the firmware of the Linoc prototyping toolkit are on one hand the ease of usage and on the other hand the possibility for further refinement for advanced use cases. The board has two measurement groups each for capacitive sensing and for passive EPS. Both measurement principles are primarily used to detect activity, proximity and movement, each method performing differently depending on the ambient conditions. It is assumed that the Linoc board in most cases will be used mainly as a sensor whereas signal processing as well as higher level interactions are done on a separate computer. For this the setup and configuration procedure needs to stay as simple as possible. If then for example a demonstration was successful and the next step is to eliminate the need for a separate computer, the firmware design needs to allow modular extensions to be integrated. Only at this point knowledge of C programming and embedded systems is required. The aim of the Linoc prototyping toolkit is to provide easy interfaces for data collection, setup of sensor networks and configuration of the board, while preserv-

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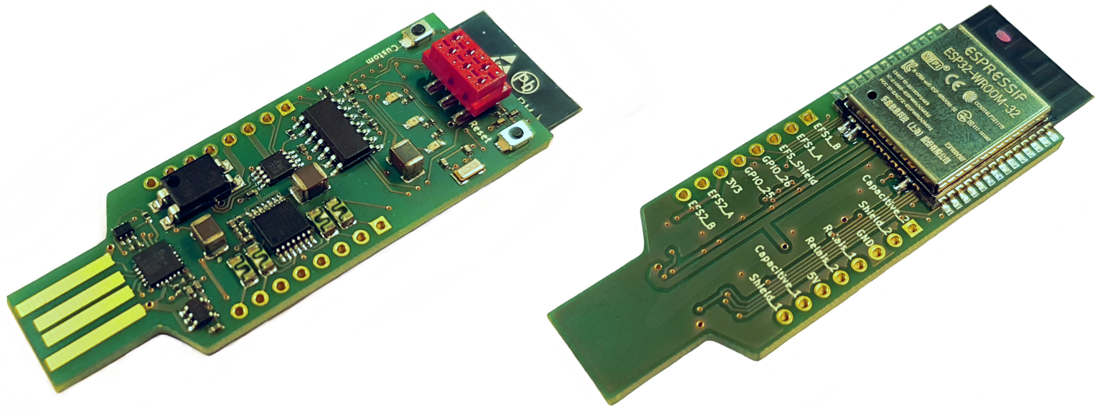

Figure 1: Front and back of the Linoc prototyping toolkit.

ing the possibility to easily customize the source code to satisfy advanced use cases. To obtain larger sensor arrays, multiple Linoc boards can be connected to form a sensor network. One device will then take the role of the master to aggregate sensor data of multiple slaves before posting them to the server or host computer via USB or a wireless technique. This paper begins with an overview of the role of toolkits in the modern design process, presents related work in the field of HCI and proximity sensing alongside the actual hardware design of the Linoc toolkit. The Linoc hardware is detailed in section 4 followed by the firmware design and its components, alongside information about challenges, limitations and design choices during the implementation process. In the final chapter the toolkit is evaluated and an example project is presented, demonstrating the toolkit's fast prototyping capabilities. This is accompanied with a use case study to determine its usability.

2 RELATED WORK

There are a couple of toolkits in the HCI area available. In this section, we will summarize them and compare them with the Linoc rapid prototyping toolkit.

Hamblen *et al.* (Hamblen and van Bekkum,) describe the process of building a prototyping toolkit for future student works. They provide a cloud based compiler to their students to eliminate setup time and provide documentation in form of a wiki. The cloud based compiler is an attractive way to eliminate platform dependencies and can be hosted cheaply on even weaker computing platforms like single board computers.

WatchConnect (Houben and Marquardt,) is a toolkit to develop cross-platform applications to explore interactions between the smartwatch and a second screen. The sensor data as well as the smartwatch's screen are used to extend classic input methods.

The Proximity Toolkit (Marquardt et al.,) provides an open-source hardware setup, interfaces to access higher-level proximity representation and a tool for visualization to use in proximity aware applications. It is designed to be hardware oblivious, so that different sensor techniques can be used. It focuses on the interaction with digital devices and provides developers with information about "orientation, distance, motion, identity and location information between entities", which are the dimensions for proximity in ubiquitous computing defined by Greenberg *et al*. The authors state that their motivation is to address the initial problem to acquire proximity sensor data for developers. Even if sensing hardware is available, effort is still required to translate sensor information into proximity, as calibration and noise can have a big impact. Their setup differs from the Linoc prototyping toolkit context as this toolkit is designed to require no counterpart in sensors or devices to work. Furthermore Linoc aims to be unobtrusive whereas the proximity toolkit focuses on intended interactions.

Midas (Savage et al.,) is a toolkit to design flexible capacitive touch sensors to apply to other objects in order to enrich interaction possibilities. While their focus lies on touch interactions it might be interesting to use their toolkit for electrode design. The evaluation was done in a way that the participants received a task to complete. They received feedback that videos can convey certain instructions better than images and addressed this by adding animations.

The CapToolkit (Wimmer et al.,) is the second generation of capacitive toolkits by Wimmer *et al*. A stated goal is to make implicit interaction concepts easier to develop. It supports up to eight loading mode sensors, as shown in Figure 2 with a sampling frequency between 25Hz and 100Hz.

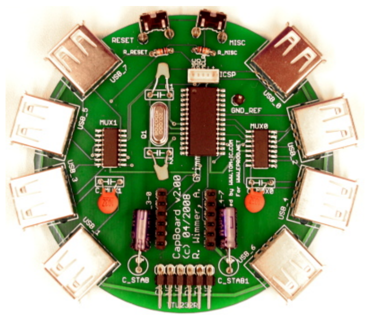

Figure 2: Captoolkit by Wimmer *et al* (Wimmer et al.,).

Sensor reconfiguration is possible at run-time using a custom protocol via USB connection. User Datagram Protocol (UDP) and Transmission Control Protocol (TCP) interfaces can be used by the connected host computer. The Linoc prototyping toolkit provides this functionality directly by the sensor board, which is made possible by recent microcontroller development. Thus these interfaces can still be used with battery powered sensors without physical connection to a computer. With a 10cm x 10cm electrode the CapToolkit is able to detect a human body at a distance up to 1m and hand movements up to 50cm. The spatial resolution is given at 1cm at 25cm distance, but was not reproduced in experiments by Puppedahl *et al.* (Grosse-Puppendahl et al., a).

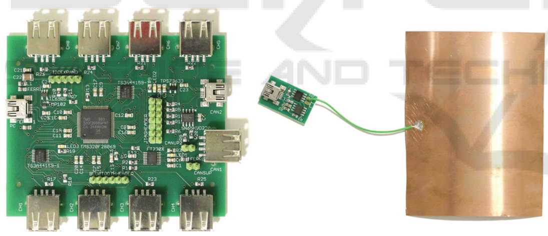

Figure 3: OpenCapSense by Puppedahl *et al.* (Grosse-Puppendahl et al., b).

The OpenCapSense (shown in Figure 3) board is inspired by the CapToolkit and addresses three shortcomings: confinement to loading mode capacitive measurement, slow sample frequency and no options to connect multiple sensor boards. The last aspect is overcome by providing two Controller Area Network (CAN bus) real time bus interfaces to synchronize data. The board features eight Universal Serial Bus (USB) ports for external capacitive sensors and a framework for data exchange. It supports different sensor types, and has been used with the three different capacitive measuring modes, as well as EPS sensors (Grosse-Puppendahl,). It operates at frequencies up to 250Hz with eight and up to 1kHz with one sensor attached. (Grosse-Puppendahl et al., a).

The OpenCapSense board is in a way the direct predecessor of the Linoc prototyping toolkit and has been used in various research projects (Braun,) in the HCI area. It was originally designed by Tobias Große-Puppendahl. It is thus closest related in application purpose, albeit having a different sensor concept. Linoc also focuses even more on usability than OpenCapSense and was designed with a more modern processor and more possibilities to connect the sensor to a computer.

3 DESIGN GOALS

Before describing the actual hardware and software, we will briefly discuss the design goals of the Linoc prototyping toolkit. Linoc was built to be fitting for a wide variety of use cases. That is why it should meet the following requirements.

1. High connectivity
2. Easy to use
3. Support for multiple programming languages
4. Realization of advanced use cases possible
5. Chaining of multiple boards

Design goal 1 was the main reason to create Linoc. While many available toolkits have multiple interfaces, most of the time additional hardware is needed if more than a USB connection is required. This leads to more effort required while building an actual prototype both for hardware and software development.

An easy to use user experience as stated in design goal 2 is very important if the toolkit is to be used in an academic environment. This will enable students and teachers alike to use Linoc seamlessly in every kind of project. It also reduces the amount of time that users need, both experienced and inexperienced ones, to get their hands on the first data.

While most toolkits require a certain programming language to use them, Linoc was designed so that it can be programmed in several languages. In times where new programming languages are created apparently on a daily basis, it is another time consuming hassle to be bound to a certain language that the user might not prefer. With the freedom to choose the language as stated in goal 3, the user is empowered to use the language he is most capable of and that is most fitting for his current project.

Having a toolkit that is easy to use should not limit the number of use cases you can use it for. In many cases, easy usability restricts versatility. To prevent

Linoc from being a prototyping toolkit only for beginners, we included design goal 4.

Another important aspect learned while using other toolkits was, that no matter how many sensors can be attached to a board, there is always a use case where you need more. While some toolkits like OpenCapSense have a CAN-bus interface to combine multiple boards, it is still a task that takes up several hours to connect and reprogram them. That is why we added design goal 5. In this way, the user is able to acquire higher dimensional data by adding more sensors.

After explaining why we choose these design goals, we will now focus on how we implemented them in hardware and software.

4 HARDWARE

4.1 Microcontroller

The microcontroller used on the Linoc board has to fulfil several requirements; The choice of the microncontroller is a critical step because most of these requirements have to be covered by the controller itself. To be precise, the controller affects the design goals 1, 3 and 4. The ESP32 from Espressif fulfills all of these requirements. It features Wi-Fi, Bluetooth and Ethernet connectivity as high level protocols. For intra-board communication, the user can choose between several low level protocols such as UART, I^2C, Inter-IC Sound (I^2C), CAN bus and SPI to name only the most common ones. This makes the ESP32 a good processor for our needs of high connectivity. The ESP32 has enough memory to support a Real-Time Operating System (RTOS). This allows for complex use cases as we planed in goal 4.

Since the ESP32 is the direct successor of the ESP8266, which was (and still is) very popular in the maker-scene and for Internet of Things (IoT) products, there are a couple of toolchains for different programming languages available.

Table 1: Programming languages and toolchains available for the ESP32.

Toolchain	Language	Editor
ESP-IDF	C/C++ with FreeRTOS	Eclipse IDE
Mongoose OS	C & JavaScript	Browser page
MicroPython	Python	-
PlatformIO	C/C++	Atom editor, Eclipse IDE, Visual Studio Code, ...
Arduino	C++	Arduino IDE

Table 1 lists a selection of possible languages and editors for the ESP32. Note that this not only is in favor of our design goal 3, but also goal 2. This is because the ESP32 is, amongst others, also Arduino compatible. Arduino is a commonly used language by beginners when it comes to embedded programming.

4.2 Capacitive Measurements

The Linoc prototyping toolkit features two capacitive loading mode sensors. The sensors were added directly onto the board, so that in contrast to other prototyping toolkits, there is no need to add more external hardware.

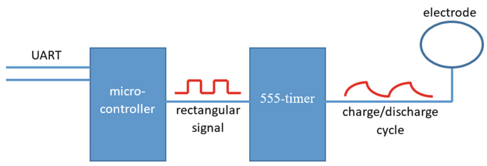

Figure 4: Model of the capacitive sensor.

The capacitive group's main component is the 555 timer which generates the charging cycles on the electrode, as shown in Figure 4, with a constant charging current. Since the current is constant, the charging process is influenced by the environment. When a conductive objects approaches the electrode, the resulting capacity between electrode and object increases. Hence, the time needed to charge this capacitor with the same amount of current increases. A pulse counter module in the microcontroller then counts the number of cycles per second, which is the final measurement parameter. The microcontroller is also able to dis- and re-enables the 555 timers so that it is possible to prevent cross talk when multiple sensors are active at the same time.

Linoc also features a shield for both capacitive sensors to support coaxial cable or to minimize environmental influences on selected parts of the electrode. The shield is realized by a simple voltage follower, implemented with an opamp, of the capacitive feed line.

4.3 Electric Potential Sensing

Besides the two capacitive sensors, Linoc features two electric potential sensors. Electric potential sensing is another form of capacitive sensing. The main differences between a capacitive loading mode sensor and an electric potential sensor are the detection range, the mode of operation and the energy consumption. Electric potential sensing can detect moving conductive objects in a distance of up to two meters(von Wilmsdorff et al., 2018), while the range of capacitive sensing is limited to about 35cm (see 6.2). A loading mode sensor measures the capacity of a virtual capacitor that is created between electrode and user, whereas an electric potential sensor measures the induced current that a user can transmit through the same virtual capacitor between electrode and himself. This also implies that the electric potential sensor of the Linoc toolkit is only able to detect movements, while the loading mode sensor is capable of sensing non-moving objects. The last difference is the energy consumption which is lower for electric potential sensors, but since the microcontroller draws far more power than all sensors combined and because the Linoc toolkit is designed to be used with a USB connection or a USB powerbank, this is not a crucial point of the toolkit discussion.

4.4 Board Layout

Since one of the main goals in mind while designing the Linoc prototyping toolkit is fast data acquisition, the board features numerous connection types. The Linoc prototyping toolkit can sent data over various protocols, as well as raw binary data, as shown in Table 2.

Table 2: Outputs and their correlating connectors.

Protocoll	Connector
Wi-Fi (b/g/n)	2.4GHz antenna
Bluetooth	2.4GHz antenna
USB	front board connector
I^2S	left and right pinouts
UART	micromatch connector
Binary data over GPIO	left and right pinouts
Binary data over relais	left and right pinouts

Figure 5 clarifies the location of all connectors. The prototyping board also has three free programmable Light-Emitting Diodes (LEDs) as well as a free programmable button. The second button of the board is hard wired to reset the microcontroller.

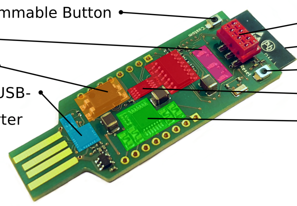

Figure 5: Hardware layout of Linoc.

A mosfet relais was added to board (see Figure 5) to cover more use cases (see design goal 4) without the need of further soldering. The relais enables the user to directly connect LEDs, piezo buzzers or other hardware that requires more voltage and higher currents to the board (up to 30V and 1A).

The micromatch connector was added for several reasons. Since the board should be capable of creating sensor chains, which was discussed in goal 5, a ribbon cable is a suitable solution. This is because, again, no further soldering is required when crimping new connectors to a ribbon cable. Ribbon cables can be configured with any number of connectors which can be spaced at any distance.

Another important feature of the toolkit is the built in USB to UART converter. The converter is required to flash the microcontroller. By integrating it onto the board an external programmer, common to many toolkits, is not required here. Note that the connection over UART/USB does not support live debugging as JTAG adapters do.

5 SOFTWARE

Central interface to the Linoc toolkit is a console over the UART bus of the microprocessor, which is connected to the USB interface. Without programming or flashing, the configuration of sensor groups, sampling frequency and sensor array configuration can be changed as well as wireless connections established and system diagnostics be printed. A help command lists available options. This is usually sufficient to use the toolkit in own projects and fulfills use case 2, because no further programming is required.

The software implementation is done with the ESP-IDF and FreeRTOS in the programming language C. This allows advanced users to access low-level functionality of the microcontroller in order to modify the software to their needs as aimed for in design goal 4. Multiple sensors can be connected to a sensor array (design goal 5) and communicate via I^2C with each other. After initiating the setup from the master device (the one connected to the users computer), the order on the array is established by pressing a button on the slave devices in the respective order. This allows for various physical setups.

The sensor data is transferred to the host computer via UART, or transmitted via Wi-Fi, either by posting to a given TCP server or by hosting a TCP server on the toolkit to which other entities can connect to (design goal 1). This data can then be further processed by the user with her preferred tools or programming languages (design goal 3).

6 EVALUATION

To generate a meaningful and comparable evaluation, we choose to cover multiple categories identified in the meta study by Ledo *et al.* (Ledo et al.,), in which evaluation strategies and common pitfalls were identified by analyzing 68 published toolkits. Thus we chose to evaluate in terms of usability, performance and demonstration.

6.1 User Evaluation

To evaluate usage, a set of tasks was devised for the participants to explore the functionality of the toolkit. The instructions besides setup, were vaguely formulated, to determine if the Linoc interfaces are designed intuitively and the information provided through the console sufficient. The advanced tasks were only given as concepts to provide some freedom for the participants to explore the toolkit. Following the set of tasks a Likert scale questionnaire was answered by the participants. The questionnaire is attached in Appendix 6.3. The study was carried out with eleven participants. More information about the participants and what operating systems they used is listed in Table 3. Most participants needed some time to familiarize with the toolkit and the way the commands work, but became more fluent over time. The majority of participants needed about 20 to 30 minutes to complete the survey.

Table 3: Participant information.

Age	24 - 39, Average: 30
Gender	Female: 4, Male: 7
Occupation	School: 2, Study: 6, Work: 3
OS used	Windows: 5, Mac: 2, Linux: 4

The results of the questionnaire are presented in Table 4. The usage of the toolkit and even the complex task of setting a sensor array was reported as intuitive. Even participants reporting not experienced in programming or computer systems mostly did not feel overwhelmed by the system and a participant feeling overwhelmed in the beginning was able to finish the given tasks with some assistance.

Eight out of the eleven participants reported receiving assistance during the study. Nearly all participants were able to complete all the given tasks successfully. In most cases the assistance was limited to occasional clarifications, only two minor technical difficulties arose during the evaluation which resulted in receiving more assistance than just clarifications.

As the results of the evaluation in Table 4 show, the overall feedback is very positive. This is not only shown by the high marks but also by the low standard deviation, which indicates that the opinion of all participants are nearly the same. Application ideas for future projects as stated from the users in ”Free questions” section of the questionnaire centered around general activity and proximity detection and integration to cloud computing.

Table 4: Results from the questionnaire, ranging from 1 (strongly agree) to 5 (strongly disagree).

Question	Mean	Median	STD
Experienced User?	1,91	1	1,6
Similar systems already used?	3,09	3	1,51
Tasks successful?	1,45	1	0,69
Feeling overwhelmed?	4,18	5	1,25
Usage intuitive?	1,82	1	1,25
Functionality sufficient?	1,09	1	0,42
Sensor array intuitive?	1,82	2	0,98

6.2 Performance

To assess the performance of the loading mode sensors, the Linoc prototyping toolkit was mounted in an automatic test stand. The test stand consists of a metal box to shield from external influences and a conductive platform that is moved by a stepper motor. It can be lifted up to 35cm over the sensor.

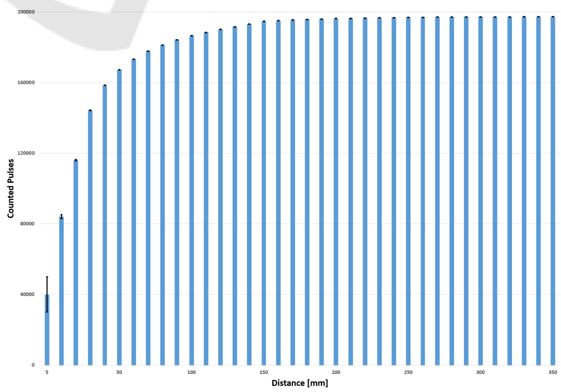

Figure 6: Data of a test run in the automated test stand including the standard deviation.

All sensor values are recorded for several minutes, then the platform is moved upwards 1cm. For this test, the pulses of the 555 timer (see 4.2) were counted for 0,5 seconds, which corresponds to a sensor sam-

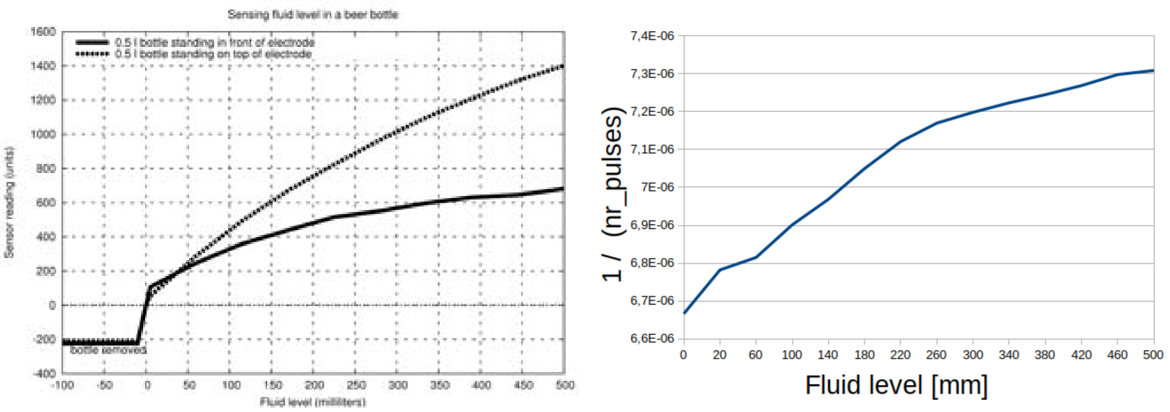

Figure 7: Comparison of the fluid level metering in (Wimmer et al.,) ("sensor reading (units)" is plotted over "Fluid Level [mm]") and a reproduction using the same electrode and beer bottle on the right.

pling rate of 2 Hz. This means that over 200 samples were collected for every position of the movable test platform.

It is possible to distinguish between two different distances of the test platform as long as the measured values don't overlap. A graphical representation with error bars was arranged, as illustrated in Figure 6, to visualize which distances were distinguished successfully and thereby concluding the maximal range of the system. To derive if a distance is distinguishable from the previous, following metric is used:

$$\bar{m}_i - \bar{m}_{(i-1)} - \sigma_i - \sigma_{i-1} > 0$$

Meaning that if the mean value of a distance $\bar{m}_i$ minus its standard deviation σ_i is still bigger than the mean value of the previous measured distance $\bar{m}_{(i-1)}$, including its standard deviation σ_{i-1}, all sensor values of these two distances can be clearly assigned.

In our tests, the maximal testable range of 35cm of the automated test stand was detectable with the Linoc toolkit, matching the performance of the OpenCapSense, as shown in Figure 6. Note that this test stand is shielded from environmental noise so that the detectable range can be lower in noisy environments. The big standard deviation, seen at a distance of 5mm in Figure 6, is the result of a settling time of the sensor. This is why the first values of the loading mode sensor can be observed as more noisy than values recorded later on.

Another impact factor of the sensor range are custom firmwares. A software which generates strong fluctuations in the energy demand of the processor will also destabilize the sensors power supply. Very CPU intensive tasks followed by a CPU idle time can induce such a behaviour. To prevent this issue, Linoc was equipped with large decoupling capacitors.

6.3 Demonstration: A Ten Minute Built of a Fluid Level Metering

CapToolkit (Wimmer et al.,) demonstrated a fluid level metering for a beer bottle with a 10cm x 10cm electrode. This demonstration was repeated for comparison. Care was taken to buy the same beer brand (*Augustiner Lagerbier Hell*). To ensure consitent results and to exclude the tester, he had to stay at a constant distance and allowing the signal to tune in after pouring out 4cl beer at a time. A calibration curve similar to the one presented in (Wimmer et al.,) was measured and is shown in Figure 7.

Note that the unit on the y-axis differs from the usual unit throughout this paper. This is due to the fact, that Wimmer *et al.* measure the time of the capacitive charging cycles and not the frequency. The relationship is $t = 1/f$ and the absolute value determined by the sampling length.

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APPENDIX

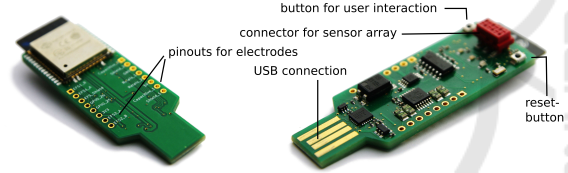
Questionaire

Evaluation of the Prototyping Platform for Capacitive and Electrical Field Sensing

TECHNISCHE UNIVERSITÄT DARMSTADT

1 Introduction

The Linoc toolkit is built for activity detection through electric field measurement and has two measurement techniques: capacitive and passive electric field sensing.
Its benefits are easy reconfiguration of sensor groups and connectivity without knowledge of embedded systems.



2 Setup

The Linoc sensor is connected to the computer via USB. The electrodes are connected to the pin-outs at the side of the board. Labels are on the bottom side of the chip.

2.1 Connection Setup

To communicate with the sensor a couple of steps are necessary.
Windows:
In the device-manager it can be checked if the Linoc is detected correctly. If this is not the case, the right device driver has to be installed from *www.ftdichip.com*. The connection is then made with the program Putty (*putty.org*).
After the installation, start Putty with the option *serial*, the com-port from the device-manager, a baud rate *115200* and without hard- and software control flows. Messages should now appear in the terminal.
Linux:
Start a terminal *(Ctrl+Alt+t)*. The current user has to belong to the group *dialout*
This can be checked with following command:
groups | grep 'dialout'
If the output is empty the user has to be added to the group using following command:
sudo usermod -aG dialout $USER
A reboot is necessary to apply the changes.
Linux & MacOS Communication happens easiest via Putty.
(if *Putty* is not available it can be installed with *'sudo apt install putty'*. Alternatives are screen, minicom, or other programs supporting serial connection). Putty is started with the option *serial*, the port (like */dev/ttyUSB0*) and a baudrate of *115200*
Messages should now appear in the terminal.

☐ setup was completed successfully ☐ setup was not necessary
☐ messages from sensor are displayed ☐ setup was not possible

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Evaluation of the Prototyping Platform for Capacitive and Passive Electrical Field Sensing

2.2 Visualization (optional)

A graphical visualization helps understanding sensor values. A multitude of programs can be used for this. As example the Arduino IDE is mentioned here (*https://www.arduino.cc/en/Main/Software*). The respective port has to be selected in the menu 'Tools'. Afterwards the'Serial Plotter' can be started from the same menu.
The 'Serial Monitor' can be used to change the configuration.

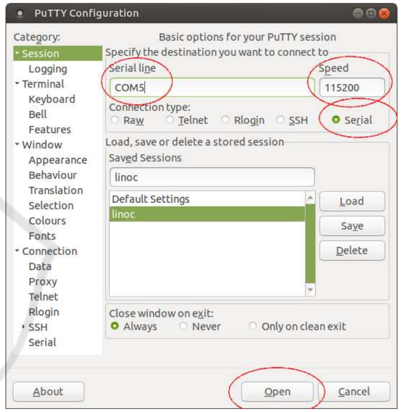

Abbildung 1: Putty window. relevant settings marked with circles

2

Evaluation of the Prototyping Platform for Capacitive and Passive Electrical Field Sensing

3 Configuration

3.1 Console

The configuration of the Linoc toolkit happens over a console. The console can be reached through pressing the button on the board, on the side with the connectors notch.
Typing *help* displays an overview of available commands.
☐ Console is displayed ☐ Commands are executed

3.2 Changing the Sensor Configuration

With the commands *capacitive_switch*, *eps_switch* and *frequency_set*, the sensor configuration can be changed. With *exit* the sensor returns to displaying values. *sensor_info* displays the current setup.

Please configure the sensor to the configurations described in the sections below and check if the values change if you move your hand towards the measuring electrode. For the configuration it might be necessary to change the placement of the electrodes on the chip.

3.2.1 Task 1: Configuration #1

Active sensors: Capacitive 1 & 2
Sampling frequency: 2 Hz
☐ Two value pairs are printed per second

3.2.2 Task 2: Configuration #2

Active sensors: EPS 1
Sampling frequency: 50 Hz
☐ Values appear noticeably faster

3.3 Task 3: Connect to Wi-Fi

Connect to the provided Wi-Fi hotspot and start a TCP server on the sensor.
Stop the connection again afterwards.
☐ connection established successfully. ☐ values can be queried from another device

4 Sensor Array

Multiple Linoc sensors can be connected to a sensor array (Daisy Chain).
The command to initiate is *'daisy_chain init'*.
Follow the instructions provided in the console from now on.
The connected devices takes the role of the master and queries sensor values of the other sensors.

4.1 Task 4: Sensor Array Setup

Connect 3 sensors with the provided cable to a sensor array

4.2 Task 5: Configuration

Follow the instructions in the console to setup all sensors.
☐ Number of sensors detected correctly ☐ Sensor values of all sensors are printed correctly

4.3 Break up the Sensor Array

Stop the sensor array. This is done with the command 'daisy_chain break'.
Check if the sensor can be used as before.
☐ Sensor array stopped ☐ Sensor can be used as before

3

Evaluation of the Prototyping Platform for Capacitive and Passive Electrical Field Sensing

5 Evaluation

Please answer following questions briefly:
Age: __ Years
Gender: ☐ F ☐ M ☐ n.b. ☐ n.A.
What is your current occupation: ☐ school ☐ study ☐ apprenticeship ☐ work ☐ something else

Which operating system are you using? ☐ Windows ☐ Mac ☐ Linux ☐ n.A.
Did you receive help with the tasks?: ☐ Yes ☐ No

Are you experienced in programming and/or computer systems?	strongly agree	agree	neutral	disagree	strongly disagree
Have you worked with similar toolkits?	strongly agree	agree	neutral	disagree	strongly disagree
Did you manage to fulfill the tasks with the information provided?	strongly agree	agree	neutral	disagree	strongly disagree
Did you at any time had the feeling to be overburdened?	strongly agree	agree	neutral	disagree	strongly disagree
Was the handling of the Linoc toolkit intuitive?	strongly agree	agree	neutral	disagree	strongly disagree
Do you think the functionality is sufficient?	strongly agree	agree	neutral	disagree	strongly disagree
Was the setup of the sensor array intuitive?	strongly agree	agree	neutral	disagree	strongly disagree

5.1 Free questions

What did you like about the system?

What did you dislike?

Could you imagine using the toolkit in a project?

Which applications can you imagine?

Which aspects should be improved?

What would facilitate the handling?

Further comments:

4