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IMPLEMENTATION OF A HAND HYGIENE SYSTEM WITH INTEGRATED TEMPERATURE SENSORS

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RESUMO

Este trabalho foi desenvolvido na empresa Ophardt Hygiene AG, em Niederbipp, na Suíça. O objetivo do trabalho foi a realização eletrônica de um sistemade desinfecção de mãos capaz de realizar medições de temperatura. Esse sistema é composto de vários sensores de radiação infra-vermelha integrados em um dispositivo de desinfecção de mãos. Esse sistema coleta e processa dados de vários dispositios sensoriais para identificar possíveis infecções. Um demonstrador parcial foi submetido a testes em campo por três meses durante o estágio.

ABSTRACT

This work was done at the company Ophardt Hygiene AG, in Niederbipp, Swizerland. The goals of the internship were the electronical realization of a temperature-sensing and hand hygiene system. This system is composed of multiple infra-red sensors integrated in a hands desinfection dispenser. The system collects and processes data from the sensors to identify probable infections. A partial demonstrator was developed and submitted to three months of field testing during the work.

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1 INTRODUCTION

The context of the internship is the object of this chapter. Here, the company is presented, as well as theand the project are presented. In the framework of the project, the tasks and goals of the internship are described. They are divided in impedance-based bacteria detection and demonstrator realization.

1.1 THE COMPANY

The company where the internship took place was Ophardt Hygiene AG. Ophardt produces hygiene solutions and dispensing systems for health care, industry and public washrooms.

Ophardt is a German multinational company implemented in Germany, Canada, Ireland, the Philippines, Belgium, Armenia and the United States. The vision of Ophardt is to provide universal access to life-saving hygiene solutions (1). With this vision in mind, the company has a strong Research and Development department. It constantly develops new hygiene solutions. One of the projects in development by the R and D team at Ophardt is *GeDeSens*. This was the project in which the internship tasks are performed.

1.2 THE *GEDESENS* PROJECT

The prevention of nosocomial infections in hospitals plays a central role in patient safety, especially in invasive medicine. The development of antibiotic resistant pathogens is a factor that has increased the risk of nosocomial infections in recent years. Campaigns such as the World Health Oranization's "Save Lives: Clean Your Hands" have increased awareness to the importance of hand hygiene and led to increased hand hygiene compliance (2). However, nosocomial infections still cause costs of several millions of euros per year. Besides, they cause death of up to fifteen thousand patients per year in Germany alone.

The *GeDeSens* project acts in this point: the aim of the project is to develop a multi-component sensory device for early detection of nosocomial infections. The sensory device is capable of identifying and classifying bacteria. *GeDeSens* takes advantage of the fact that in general these types of dispenser are already largely accessible in hospitals. Even with a detection rate of only 20% of infections, this will already save several hundred lives and up to a quarter of a bilion euros a year to the German healthcare system.

1.2.1 Demonstrator Realization

During the internship, a demonstrator of the *GeDeSens* project was developed. It consists of an Ophardt dispenser adapted and integrated with the technologies in table 1.1. The system collects the hand's temperature of the user. These elements are connected to a microcontroller and to a Raspberry Pi. The microcontroller commands the infra-red sensors and the Rapberry Pi records the information collected.

Component	**Function**
Infra-red sensors	Measure the temperature of user's hands
Screen	User feedback
Microcontroller	Controls the sensors, the screeen and the pump
Raspberry Pi	Records and analyzes sensor data and images

Table 1.1: Components integrated in the demonstrator and their respective functions.

2 MATERIALS AND METHODS

The matherials and methods used during the internship are presented in the following chapter.

2.1 DEMONSTRATOR REALIZATION

The realization of a *GeDeSens* demonstrator consists on the mechanical and electronical integration of the components detailed in this section. They include, as discussed in 1.2.1, a microcontroller connected to sensors,ca Raspberry Pi computer and user-interface elements. This was done in cooperation with Timo Mooren. He was a student at the Hochschule Rhein-Waal, in Kleve, Germany, and an intern at Ophardt at the time this work was developed. He was responsible for the mechanical integration of the components inside a dispensor. This work explores, thus, mainly the electronical integration and software development.

2.1.1 PRAESIDIO Dispenser

The PRAESIDIO dispenser is an Ophardt disinfectant dispenser. It includes a capacitive hand detector for touchless operation. It is also easily interfaceable with the microcontroller through the microcontroller's GPIO (General Purpose Input and Output) pins. For the development of the *GeDeSens* demonstrator, the dispenser was adapted. Its body was expanded to fit the sensory devices that compose the demonstrator system, and holes were drilled in the hands disinfection area to fit the temperature sensors.

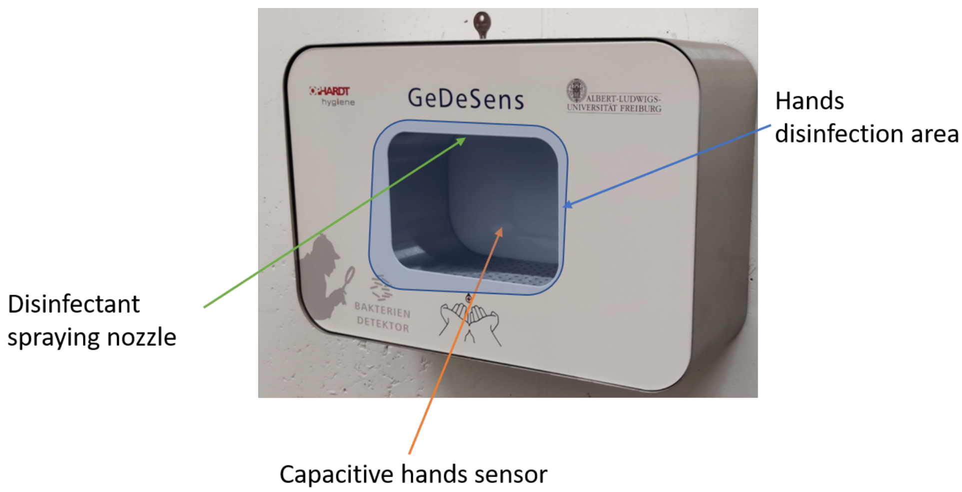


Figure 2.1: A wall mounted PRAESIDIO dispenser. The capacitive hands sensor, hands disinfection area and disinfectant-spraying nozzle are highlighted in the dispenser.

Figure 2.1 shows a PRAESIDIO dispenser. The capacitive hands sensor is located in the back side of the disinfection area of the dispenser. The nozzle that sprays disinfectant when hands are detected is on the top of the hands disinfection area.

2.1.2 Microcontroller

The microcontroller used for this project was the STM32 Nucleo F303K8. The microcontroller choice was received as a legacy from the previous versions of the demonstrator. This microcontroller has 64 kbit of flash memory, I2C communication capability, PWM output in selected pins and hardware interuption options on all pins(3). Those functionalities were explored in the electronical realization of the system. It is also compatible with software tools such as the Arduino IDE and the cross-platform PlatformIO extesion. Both were used for the development of the controller firmware. Furthermore, it's compatible the Arduino libraries `Arduino.h`, `Adafruit_NeoPixel`, `LiquidCrystal_I2C.h`, `MLX90614.h` and `Wire.h` (4), which were used throughout the firmware development for interface with the other components.

2.1.3 Infra-Red Sensors

The IR sensors integrated in the demonstrator were the MLX90614-DCC. They include a thermopile for IR sensing, a low-noise signal amplifier and a communication module for microcontroller interfacing. They are integrated in a DFRobot SEN0206 module and are able to measure temperatures between $-70°$ C and 382° C with a precision of $0.5°$ C (5). Their angle of view of view is 35°. They are interfaced with the microcontroller using the library `MLX90614.h`. These sensors were chosen by students of Télécom Physique Strasbourg as part of a first-year Engineering Project[1]. In paralell with the work of this internship, other sensors and various experimental setups were validated by Timo Mooren.

2.1.3.1 I2C communication protocol

The IR sensors use I2C (inter-integrated circuit) as the communication protocol with the microcontroller. I2C is a synchronous communication protocol that uses two pins. They are named SDA and SCL. SCL is the synchronous clock pin, which sets the communication rate. The SDA pin is used to transmit or receive 8-bit data. A pair I2C pins in the microcontroller can be used to communicate with multiple devices, since each device has a unique address.

2.1.4 Screen

The screen used in the temperature measuring system was the Elecrow SF101. It is a touch-screen dispaly commonly used in RaspberryPi projects. Its size is 10.1 inches and its resolution is 1920x1080 pixels. This screen uses an HDMI port for video connection and a USB connection for touch information.

[1] Projet Ingénieur TI-Santé 1A promo 2023: Development of a body-temperature detection system. Group: Eddy TORRES, Anna REITMANN, Mathilde BOGAERT and Valentin TARDIEUX

2.1.5 Data Mining and Analysis

The data collection and analysis module was written in Python and integrated in a Raspberry Pi 4. The Raspberry Pi is a small, low-cost computer that runs the Raspian operational system and includes two HDMI ports, four USB ports and 24 GPIO pins. The microcontroller is connected to it via USB. It uses the serial communication to send the temperature information collected with the IR sensors to the Raspberry Pi, which records it on aa text file with a timestamp. The microscope is also connected via USB to the Raspberry Pi, and the data recording program saves an image collected from the microscope every time the dispenser is activated.

3 MOTIVATIONS AND CHALLENGES

The motivation for this work is to forward the development of an infection-detecting hand hygiene dispenser in the framework of the *GeDeSens* project. The *GeDeSens* project proposes the aggregation of data from different sensing systems inside a dispensor as a way to detect nosocomial infections in their early stages. The development of the *GeDeSens* project involves, among many other points, sensor development and system integration, each of these steps having their particularities and challenges.

The main challenge faced when working on system integration was the necessity to work on an existing dispenser, learn about its working particularities and interface it with the microcontroller. The sensor choice was limited by price, minimum accepted precision and minimum accepted accuracy. A series of mechanical adaptations was made to the dispenser, including the addition of a box in its back to increase the space for the components.

4 RESULTS AND DISCUSSION

The results of the internship are presented in this chapter. Section 4.1 shows the steps for the realization of a functional system capable of measuring the temperature of the hands of a hand-hygiene dispenser user. The system includes the componets detailed in 1.2.1.

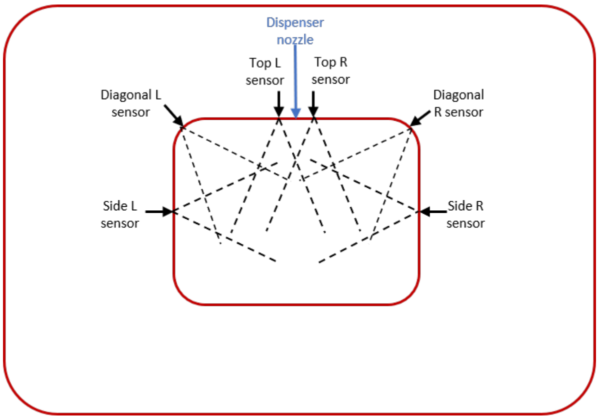
4.1 REALIZATION

The realization of the system shown in figure 4.1 was done in cooperation with Timo Mooren and divided in mechanical and electronical integration of the different sensors and components. The mechanical integration consists on the placement of the components inside the dispenser in a way that optimized the teperature measurements and protects the electrical components from contact with fluids. It is further discussed in Timo Mooren's work (6). The electrical integration is the electrical connection of the components was the scope of this internship, as well as the development of the software used in the system. It is discussed in more details in the following sections.

4.1.1 Electronical integration

The electronical core of the demonstrator consists of the elements described in 2.1. The Raspberry Pi is connected via USB to both the microcontroller and the screen. The communication between the microcontroller and the IR sensors is made via the inter-circuit comunication (I2C) dedicated pins. These connections are shown in 4.2. Figure 4.3 shows the schematic of the electronic board that connects the microcontroller to the IR sensors, LED strip and pump, as well as to the hands sensor of the dispenser. In the schematic, it can be seen that the pins D4 and D5, which are I2C-dedicated, are connected to the IR sensors and to the LCD screen, that use this type of communication. The D11 pin is used to read the hands

(a)



(b)

Figure 4.1: (a) A picture of the partial demonstrator. (b) A diagram showing the sensor positions and angles of view.

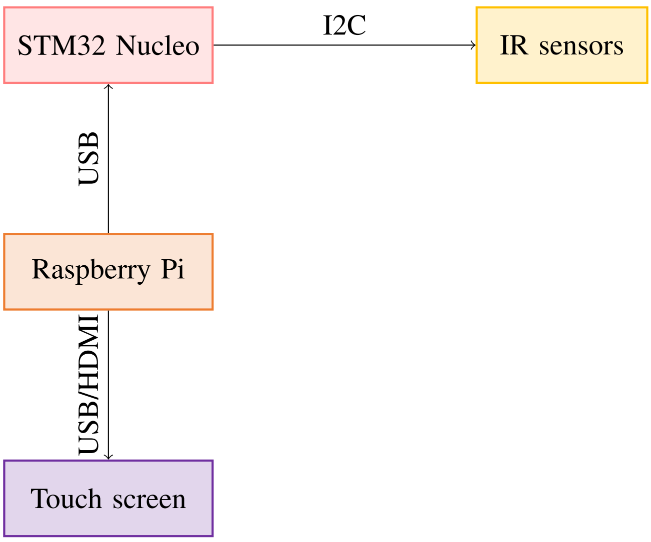


Figure 4.2: Schematic of the electronical realization of the demonstrator. The connections between elements are shown in this image, as well as the way these connections were made. The Raspberry Pi is connected via USB to the microcontroller. The microcontroller's pins are connected to the sensors, and the communication with them is made via I2C.

sensor of the dispensor. The LED strip's input uses the analogic pin A6. The pump is controlled using the PWM pin D9 and the digital pins D6 and D7. Adittionally, the motor driver is connected to the pump and to the exteral power supply that powers the pump.

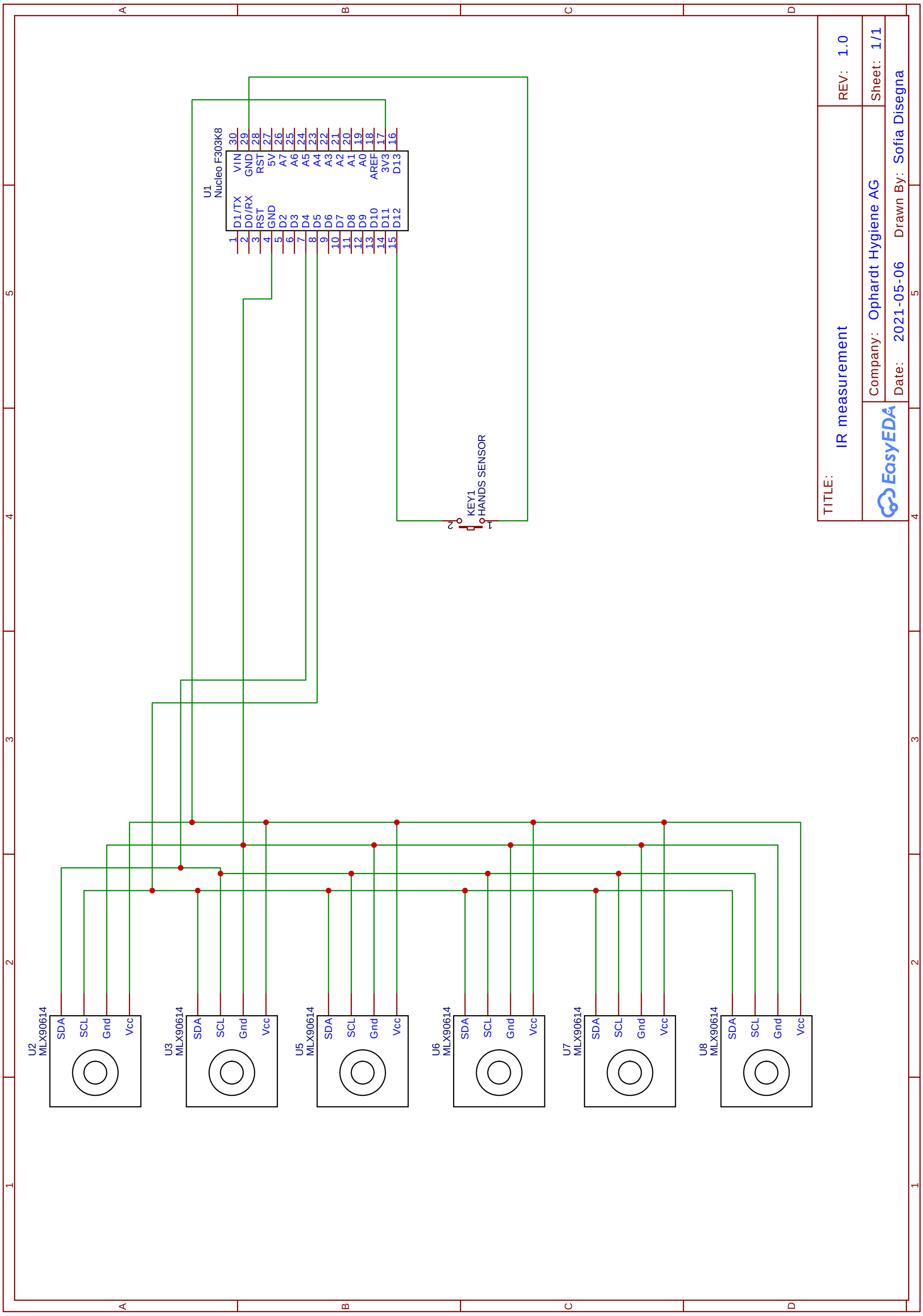


Figure 4.3: Schematic of the electronic board.

4.1.2 Data collection

The data collection program was written in Python 3.7. Figure 4.4 shows a flowchart of the data collection program. Once the program is started by the user, it reads serial input from the microcontroller and from the microscope. The microcontroller signals the detection of hands by the dispenser, triggering the reading and saving of temperature information. The microcontroller also signals the end of the pump process, which means that the overspray was pumped by the pump into the microscope. When the signal of the end of the pump process is sent by the microcontroller, the program records a picture from the microscope.

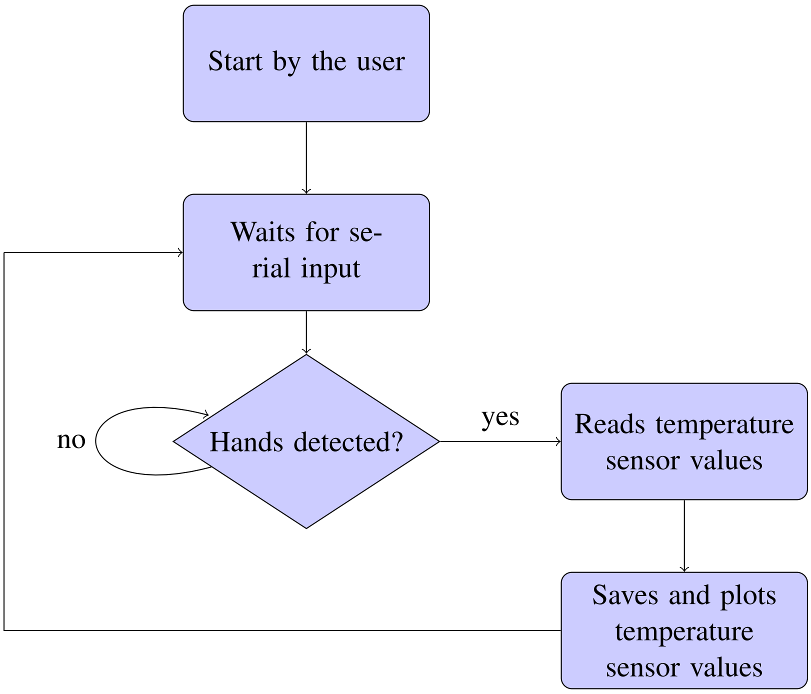


Figure 4.4: Flowchart of the data collection program.

4.2 FIELD TESTS OF THE SYSTEM

With this system, it was possible to collect hands temperature data from multiple people across multiple days in a test field at the BIOSS lab of the Albrecht-Ludwigs-Universität Freiburg, in Freiburg im Breisgau (Germany). It was used for two months by more than 20 persons, recording almost 900 hand hygiene events. Figure 4.5 shows a histogram of the temperature colected using the partial demonstrator. A deeper analysis of this data is the scope of Timo Mooren's work (6).

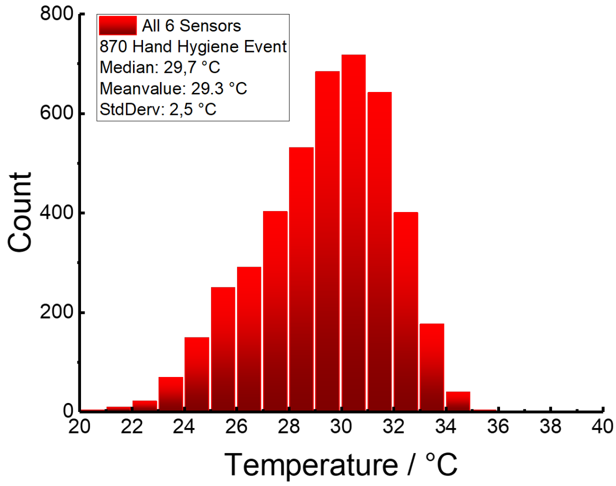


Figure 4.5: A histogram of the hands temperatures values collected using the partial demonstrator developed during the internship.

5 CONCLUSION

In conclusion, the work of this internship involved sensor development and system integration. This work was a part of the development of *GeDeSens*, an infection-detecting system. It helped advance the project and point out future improvement paths.

A hand temperature measuring system was developed during the internship. It consisted of different sensors and a system to collect and analyse their data. The development of the demonstrator involved microcontroller programming, electronical design and high-level programming in a Raspberry Pi. The integration of all components in a dispenser developed by Ophardt was done in cooperation with Timo Mooren. .

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