SMART DEVICES

Enseignant : Grisolia

Project Description

The Smart Device course explores various technological fields with the objective of designing innovative connected devices. Throughout this program, we worked on the design and development of a gas sensor intended to measure air quality. This project covered all stages, from hands-on activities at the AIME microelectronics laboratory to the creation of a technical datasheet. We also designed an electronic shield and implemented a wireless communication system to transmit the collected data.
This experience allowed us to grasp the complexity of a multidisciplinary engineering project, combining knowledge in chemistry, electronics, microfabrication, and programming.

Achievements and Learnings

1. Gas Sensor Design
During an intensive week, we had the opportunity to be trained at the AIME laboratory (Atelier Inter-universitaire de Micro-nano Électronique) at INSA Toulouse. The primary objective was to design a sensor based on nanoparticles capable of detecting gases such as ammonia or ethanol, which are key indicators of air quality.
This development process involved advanced techniques in a controlled environment (cleanrooms), and we carried out several key steps:

- **Synthesis of WO_3 nanoparticles:** This stage involved fabricating the sensitive material used in the sensor, providing insights into the importance of the physico-chemical properties of nanoparticles in gas detection.
- **Development of the microelectronic chip:** This work enhanced my understanding of integrated circuits and their role in smart sensors.
- **Deposition of the sensitive layer:** We applied nanoparticles onto the chip using deposition techniques, which demonstrated the precision required for such operations.
- **Electrical characterization:** Conducted in a controlled atmosphere, this step was crucial for analyzing the sensor's performance and establishing danger thresholds.
  These activities not only honed my technical skills but also taught me the importance of collaborative work in a laboratory, experimental rigor, and effective time management in a short-deadline project.

2. Performance Characterization
After fabricating the sensor, we proceeded with its characterization by collecting precise measurements under different atmospheric conditions. These data enabled us to understand the sensor's behavior, particularly its sensitivity and stability at varying gas concentrations.

This process highlighted the importance of data analysis in improving a technological system. It was also critical for defining the sensor's specifications, which would later be included in the technical datasheet.

3. Integration on a Development Board

The next step was to integrate the sensor into a functional system using an Arduino development board. Although our own sensor was not finalized for this phase, we utilized a commercially available sensor for validation.

We designed a PCB (Printed Circuit Board) using the KiCad tool to adapt our sensor to the board. This stage enhanced my skills in electronic design and familiarized me with CAD tools for PCB creation. However, delays in the project prevented the production of the PCB, teaching me the importance of proactively managing unforeseen issues.

4. Wireless Data Communication

A major objective of the project was to develop a system to wirelessly transmit sensor data. We chose the MQTT protocol, a widely used solution in IoT applications.

We equipped our development board with a LoRa antenna, a technology ideal for long-range, low-power communication. Thanks to the LoRa infrastructure already installed on the INSA campus, we successfully tested this system.

For data management, we utilized the Chirpstack server provided by INSA's DGEI as the MQTT broker. This part of the project deepened my understanding of IoT network challenges, particularly in terms of data reliability and security.

5. Application Development for Data Visualization

To exploit the data published by the sensor, we developed two complementary solutions:

- **MIT App Inventor:** This tool allowed us to quickly create an Android application that displayed air quality status through a real-time graph. We also experimented with activating an LED via LoRa, giving me insight into hardware-software interactions.
- **Node-RED:** Using this visual programming tool, we designed a simple web interface capable of displaying data received from the sensor.
  These approaches taught me the basics of user interface development and the importance of simplicity and ergonomics in presenting technical data.

Personal Analysis and Reflection

This project provided a valuable opportunity to deepen my technical skills while helping me better envision my professional future, particularly through the focus on wireless communication and application development, which aligns directly with my aspirations in software development and connected systems integration. Working with the MQTT protocol and implementing LoRa technology enhanced my understanding of data exchange mechanisms in IoT, while strengthening my knowledge in network configuration and server management. These experiences allowed me to build a solid understanding of technical and organizational challenges, providing a strong foundation that I can further develop in future projects related to connected technologies.

Skill Matrix: Introduction to Sensors

Service Oriented Architecture	Expected	Estimated
Understand basic notions of sensors, data acquisition: physics, electronics and metrology point of view	4	2
Be able to manufacture a nano-particles sensor using micro-electronics tools: chemical synthesis, assembly, testing	4	2
Be able to design the datasheet of the sensor manufactured	3	3

Skill Matrix: Micro Controllers

Service Oriented Architecture	Expected	Estimated
Be able to design a shield to accommodate the gas sensor	3	2
Be abe to design the sofware to use the gas sensor and its HMI	4	4
Be able to combine all of the above mentioned components into a smart device	3	3
Understand microcontroller architecture and how to use them	3	3
Be able to design data acquisition system (sensor, conditioner, microcontroller) with respect to the application	3	2
Be able to design the electronic circuit of a sensor's signal conditioner (design + simulation)	3	2