COMP5047 Assignment (Phase 2)

TANAKA CHITETE, SIDDEK LIANG, FENGYI YANG, and YAQI ZHOU

1 ACTIVITIES

1.1 Completed Activities

1.1.1 Acquiring parts

Acquiring the necessary parts was a pivotal initial step. Essential components were procured from Core Electronics, ensuring the availability of critical hardware. Additionally, an appropriate bin to serve as the physical container was sourced from Kmart.

1.1.2 Assembling scale

The assembly process involved meticulous execution. Following DFRobot's comprehensive tutorial [3], we methodically attached the exposed load cell wires to the HX711 ADC converter. Subsequently, The scale's base and top were affixed to the load cell, using screws for precision. Calibration was conducted using an AirPods case, an object of known weight, ensuring accurate weight measurements.

1.1.3 Writing embedded processing code

The authorship of embedded processing code formed the core of this phase. Notable function implementations include:

- `onWrite()` — Responds to user requests with real-time waste insights
- `calibrateScale()` — Ensures precise scale calibration using a known object
- `setupBluetooth()` — Configures bluetooth connectivity using the BLE C++ library
- `loop()` — Continuously reads scale weight, logs data, prints it to the serial monitor, and notifies users via LightBlue
- `calculateTotal()` — computes comprehensive daily, weekly, and monthly waste insights

1.1.4 Configuring version control

Effective version control is paramount to any collaborative project. The university's GitHub platform was leveraged to establish a dedicated assignment repository. Subsequently, project code was routinely committed, ensuring a streamlined development process while maintaining code integrity.

1.1.5 Troubleshooting

Troubleshooting proved indispensable to resolve critical issues. Key troubleshooting activities included:

- *Wire adjustments* — Addressing connection issues, the wire was more securely placed into the ADC converter, optimizing the electrical connection.
- *Latency reduction* — Latency issues in communication between the FireBeetle and both the serial interface and Bluetooth were mitigated through code refactoring.

Authors' address: Tanaka Chitete; Siddek Liang; Fengyi Yang; Yaqi Zhou.

- *Scale calibration enhancement* — To address inconsistent weight readings, we conducted a thorough scale calibration. We saved the calibration value as a macro, enhancing measurement accuracy and reliability.

1.2 Subsequent Activities

1.2.1 Designing Node-RED interface

Whilst LightBlue has proved to be an invaluable tool in prototyping Terra, it's usability will be prohibitive to many prospective users. Its command-centric user interface necessitates familiarity with prescribed commands, rather than encouraging exploration. As such, development on a graphical user interface using Node-RED is planned.

1.2.2 Writing embedded processing code

Future coding efforts aim to augment Terra's embedding processing functionality. Subsequent work includes enabling user-configurable waste level notification thresholds. They would allow users to customize when they receive alerts based on capacity limits, such as 500g or 750g, personalising the solution.

1.2.3 Troubleshooting

A specific challenge lies in fixing bugs. During the demo it was discovered that the user can reset logged readings, whilst there is waste in the bin, falsely logging it as empty. This bug will need to be fixed, and a systematic examination will be conducted to discover any and all further bugs.

2 CHANGES

(1) It was identified that the original problem space had no clear link to the UN goals. The revised problem space is in *Section 3.1: Problem Space*.
(2) It was identified that the solution cannot be context-aware due to manual connection via LightBlue. The revised characteristic relations are in *Section 3.2.1: Relation to Characteristics of Pervasive Computing*.
(3) It was identified that revisions to both the problem space and characteristic relations suggest that the user scenario also be revised. The revised user scenario is in *Section 3.2.2: User Scenario*.
(4) It was identified that implementing a battery would require the purchase of a voltage regulator. The revised conceptual diagram and associated details are in *Section 4: Design and Technical Concept*.
(5) It was identified that the microcontroller operates at 3.3V, while the display module has an operating voltage of 5V. The associated revisions is also in *Section 4*.
(6) Numerous tasks outlined in the original project plan were either completed earlier than projected or are no longer applicable. The revised project plan is in *Section 5: Project Plan*.

3 PROJECT THEME AND SCOPE

3.1 Problem Space

Terra, a Bluetooth-enabled weight-sensing bin, aims to address *Sustainability Goal 12: Ensure sustainable consumption and production patterns*. It represents a solution to the excessive levels of food waste exhibited by Australian households, emphasising the need for sustainable consumption and production patterns.

Food wastage is a substantial issue in wider society. Each person discards an average of 120 kilograms of food annually [2]. The urgency to reduce per-capita food waste and loss by 2030, as pleaded by the UN, remains a significant global challenge. Notably, high-income countries, including Australia, contribute disproportionately to this problem, with a material footprint per capita ten times that of low-income countries [2].

In contemporary societies, wasteful practices have become ingrained, evident in everyday rituals such as brewing coffee, which results in the disposal of coffee grounds. Terra seeks to transform such wasteful habits by providing insights into resource utilization. For example, used coffee grounds can serve multiple purposes, from organic fertilizers to pest repellents, aligning with sustainable consumption and waste reduction goals.

Pervasive computing solutions, like Terra, offer a broader perspective on addressing wastage. These solutions, with their embedded nature, seamlessly integrate into households. In this context, Terra's role as a waste-tracking bin aligns with the broader pervasive computing paradigm, promoting sustainable consumption and production patterns while reducing household wastage.

3.2 Proposed Solution

3.2.1 Relation to Characteristics of Pervasive Computing

Embedded. Beneath the unassuming exterior of a waste bin, a microcontroller and network-enabled scale, are both discretely embedded within the bin itself. This embedded design ensures that Terra blends into the user's daily routine without disrupting the aesthetics of their living space.

Anticipatory. Upon the user's connection to the device through the LightBlue smartphone app, Terra promptly compiles and sends comprehensive waste insights for the past day. This anticipatory feature empowers users with real-time information, enabling them to make informed decisions about their consumption patterns and waste management.

Personalized. Users will have the flexibility to customize the bin's operation by adjusting the maximum capacity threshold. This customization feature will allow users to define when they receive notifications to empty the bin, aligning with their specific needs and preferences. Terra's adaptability to individual user requirements will contribute to a more personalized and user-friendly experience.

Adaptive. When the bin reaches its predefined maximum capacity, the user receives a notification, reminding them to empty it. This adaptive behavior ensures that users are promptly alerted when it's time to take action, reducing the risk of overflows and waste spillage. Terra's adaptive notifications contribute to efficient and effective waste management within the household.

3.2.2 User Scenario

Charlie, a busy programmer, is facing the daily challenge of managing his household waste efficiently. Over time, Charlie noticed an increase in his living expenses, primarily due to the growing amount of waste generated during his hectic workdays. Intrigued by the prospect of reducing wastage and saving money, he decided to adopt Terra as a solution to his problem.

His typical day begins with making a cup of coffee in the morning, followed by a day filled with work-related tasks. After work, he often orders takeout meals and enjoys some drinks. Each of these activities generates waste, from coffee grounds to takeaway containers and drink cans. Charlie places all of these items into Terra.

LightBlue plays a vital role in Charlie's waste management routine. When he connects to the device via the app, he can immediately request insights about his daily waste production. These insights help Charlie become aware of, and reduce, his environmental footprint.

Additionally, Terra's adaptability ensures that Charlie is never caught off guard by an overflowing bin. When the bin reaches its predetermined maximum capacity, Terra sends Charlie a notification, prompting him to empty it. This adaptive behavior prevents wastage accumulations and maintains a healthy living space.

As the week progresses, Terra tracks Charlie's waste and offers valuable suggestions for reducing waste and saving resources. It recommends repurposing coffee grounds as organic fertilizers, reusing takeaway containers for storage, and recycling drink cans. These recommendations align with Charlie's commitment to sustainability and provide him with actionable steps to minimize wastage further.

Here, Terra demonstrates its practicality and effectiveness in promoting sustainable consumption and waste reduction. Charlie's experience with Terra showcases how pervasive computing solutions can empower individuals to make informed decisions, reduce waste, and contribute to a more sustainable future.

4 DESIGN AND TECHNICAL CONCEPT

4.1 Conceptual Diagram

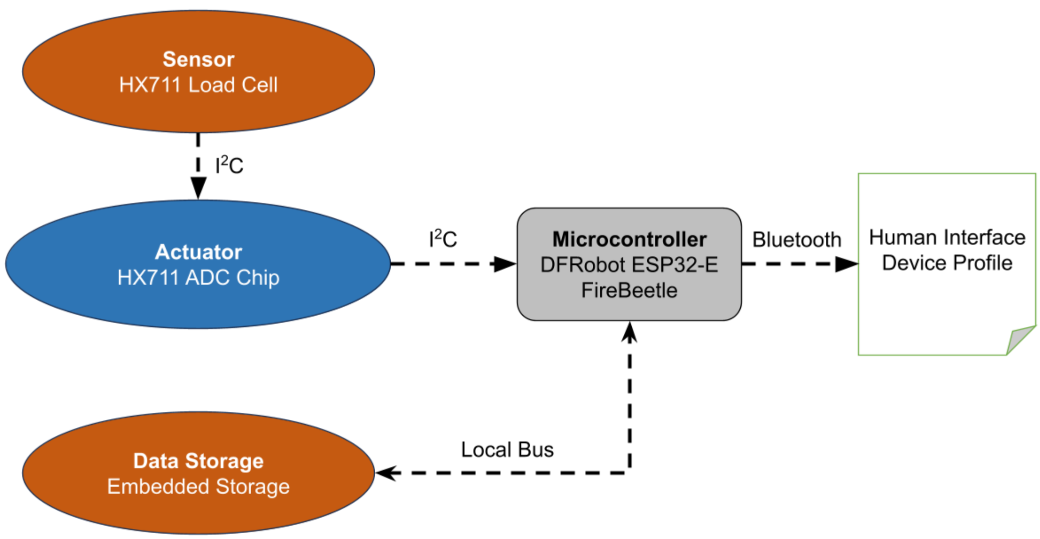

Fig. 1. Revised Conceptual Diagram

4.2 Details

4.2.1 HX711 Load Cell

The HX711-compatible load cell plays a pivotal role in Terra's functionality. It is responsible for accurately sensing the weight of waste within the rubbish bin. This load cell communicates with the HX711 Analog-to-Digital Converter (ADC) chip using the I^2C protocol. The load cell provides raw weight data to the HX711 Convertor Chip, ensuring precise weight measurements.

4.2.2 HX711 ADC Chip

The HX711 ADC chip acts as an intermediary between the load cell and the FireBeetle. It receives raw weight data from the HX711-compatible load cell via I^2C communication. Once the raw weight data is received, the HX711 ADC chip processes and manipulates it, converting it into a format that is understandable to the ESP32 FireBeetle. This chip ensures accurate and reliable weight data conversion.

4.2.3 Embedded Storage

Embedded storage refers to the internal storage capacity integrated into the FireBeetle. This built-in storage serves as a repository for various types of data, including sensor readings and user-defined settings. Data is stored securely within the ESP32 FireBeetle, allowing for efficient data access and retrieval as required. This feature ensures that essential data is readily available for analysis and user interactions.

4.2.4 DFRobot ESP32 FireBeetle

The FireBeetle serves as the central processing unit of the smart rubbish bin system, playing a pivotal role in data processing and communication. The FireBeetle receives the converted weight data from the HX711 ADC chip and handles its further processing. Equipped with Bluetooth capabilities, it facilitates seamless communication with phones and tablets using LightBlue. The FireBeetle utilizes Bluetooth connectivity to establish a connection with Human Interface Device (HID) profiles, enabling user interactions and data exchange.

4.2.5 HID Profile

The HID profile is a Bluetooth profile tailored for smart devices. In Terra's context, the HID profile serves as a critical bridge for communication between the FireBeetle and external devices. Through the HID profile, users can interact with the smart rubbish bin, issuing instructions and receiving data via Bluetooth connectivity. This profile facilitates a user-friendly and intuitive interface, enhancing Terra's usability and ensuring effective user-device interaction.

5 PROJECT PLAN

Weekly Gantt chart

Smart Bin
project name

Tanaka Chitete, Siddek Liang, Fengyi Yang, Yaqi Zhou
owner

31/07/2023
start date

05/11/2023
end date

Project Description

The project is to make a smart trash can. By measuring the amount of waste thrown away, people are reminded to reduce waste.

Remarks

Weekly monitoring shall be done to check if the objectives are being achievedImprovement on the action plans shall be enhance along the way.

Task ID	Task Name	Start Week	End Week	Resouces	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14
1	Phase 1-Create plan	1	7		1	1	1	1	1	1	1							
1.1	discuss the project theme and scope	3	6				1	1	1	1								
1.2	Develop a design and technical concept	3	6				1	1	1	1								
1.3	Synthesize the requirements and planned activities	3	6				1	1	1	1								
1.4	Write a report	6	7							1	1							
2	Phase 2-Assemble devices and write programs to complete activities	7	11								1	1	1	1	1			
2.1	Set the sensor	7	8								1	1						
2.2	Set the actuators	7	8								1	1						
2.3	Set embedded Processing	7	9								1	1	1					
2.4	Set data Storage	7	9								1	1	1					
2.5	Write the user interface	8	9									1	1					
2.6	Connect with Bluetooth	8	9									1	1					
2.7	Completion display module	8	10									1	1	1				
2.8	Complete reset button	8	9									1	1					
2.9	Write a report	10	11											1	1			
3	Phase3-Perform evaluations and sum up	11	13															
3.1	Complete the unfinished parts of Phase2	11	13															
3.2	Perform evaluations to make corrections	11	13															
3.3	Write a report and create a video	13	14															

Fig. 2. project plan 2

6 EVALUATION PLAN

6.1 Technical Evaluation

6.1.1 Accuracy

The scale's accuracy had been evaluated by comparing its weight measurements to known weights using controlled experiments. As previously mentioned, the calibration object is the charging AirPods Pro (2nd generation) charging case, which has a specified weight of 50.8g [1]. The reading retrieved from Terra was 51g. The percentage error is 0.39%, which is more than acceptable for the scale's application.

6.1.2 Physicality

The dimensions, weight, and materials of Terra will be determined. The overall dimensions after assembly are 120 x 100 x 30 mm. Considering the smart scale fully embeds itself inside the bin, this is perfectly acceptable.

6.2 Usability Evaluation

6.2.1 Ethical Considerations

Ethical considerations will be paramount throughout the evaluation process. The University of Sydney Participant Information Sheet (PIS) and Participant Consent Form (PCF) documents will be obtained and tailored for our project as required. Thus, ethical approval will be obtained as per university policies and national ethical guidelines [4].

6.2.2 Participant Recruitment

Participants will be recruited to ensure a representative sample of users, considering demographics, backgrounds, and interests. The aim is to have at least 4 participants, including a diverse range of users [4].

6.2.3 Participant Introduction

Participants will be welcomed and informed that the evaluation is focused on the system, not the participant. Transparency about data recording and the ability to opt out at any time will be maintained [4].

6.2.4 Process Demonstration

Participants will be provided with a clear explanation of Terra and its functionalities.

6.2.5 Closing Questionnaire

Participants will be asked introductory questions to collect additional data and they will also be invited to ask questions in order to address any initial queries or concerns [4].

6.2.6 Task Prescription

Users will be informed about both the abstract task, and the concrete tasks. The abstract task:

The user can take control over wastage in their household.

The concrete tasks:

- *Determine the amount of waste in the bin at the moment.*
- *Determine the amount of recorded over the past 24 hours.*
- *Determine the amount of recorded over the past week.*
- *Determine the amount of recorded over the month.*
- *Change the maximum capacity threshold.*
- *Reset the bin.*

6.2.7 Task Supervision

Users will walk through the tasks while being observed and recorded. Issues and positive aspects will be noted, and support will be provided when necessary [4].

6.2.8 Closing Questionnaire

After task completion, participants will be given a closing questionnaire to gather additional insights, and any final questions or concerns will be addressed [4].

6.2.9 Participant Debrief

Participants will be thanked, reminded of the usefulness of their results, and details will be confirmed [4].

6.2.10 Report Preparation

Evaluation results will be summarized in a table, with columns for users and rows for tasks. Cells will indicate completion status (easily completed, completed with difficulty or help, could not complete), and main issues and possible solutions will be identified [4].

7 JOURNAL

7.1 Tanaka Chitete

Week	Activities
1	Collected DFRobot ESP32-E microcontroller and Kitronik Inventor's Kit; Installed required software; Got started with Arduino development
2	Brainstormed project ideas—came up with smart-bin concept; Experimented with console output—configured and used `Serial.printf()` and related functions to produce console output; Documented and shared code with group
3	Conducted research on project hardware components—sensors and actuators; Experimented with LED-circuit-building and PWM—assembled a circuit with an LED to implement PWM to control the brightness; Documented and shared circuit structure and code with group
4	Conducted further research on project hardware components—sensors and actuators; Experimented with photo-transistor-circuit-building—assembled a circuit with an LED and photo-transistor to implement light-sensing to control ambient lighting; Documented and shared circuit structure and code with group
5	Conducted research on project software components—interfaces and communication; Experimented with Bluetooth and WiFi communication—modified the previous circuit to communicate photo-transistor readings via Bluetooth and WiFi; Documented and shared circuit structure and code with group; Translated tasks to report sections; Sourced report template
6	Finalised project hardware and software components; Purchased all parts; Experimented with motor and transistor—assembled a circuit with a fan, motor and transistor to implement PWM to control brightness and motor RPM; Documented and shared circuit structure and code with group; Wrote sections 1.1, 1.2, 1.3, and 3.1; Co-wrote sections 1.4, 2.2, 2.3, and 3.2 of Phase 1 report; Performed final edit of Phase 1 report
7	Experimented with MQTT and Node-RED to broadcast and receive messages between FireBeetle and Node-RED; Experimented with MQTT and Node-RED to control LED brightness; Acquired weight sensor kit from Core Electronics, and a bin from Kmart
8	Brainstormed technical evaluation; Brainstormed usability evaluation; Acquired battery and display module from Core Electronics
Mid-semester Break	Assembled scale; Wrote embedded processing code; Configured version control; Troubleshot hardware and software; Documented and shared circuit structure and code with group
9	Translated assignment specification tasks to report sections; Sourced report template; Wrote sections 1.1, 1.2, 2, 3.1, and 3.2; Co-wrote sections 4.1, 4.2, 6.1, and 6.2 of Phase 2 report; Performed final edit of Phase 2 report

7.2 Siddek Liang

Week	Activities
1	FRobot ESP32 FireBeetle has not been collected, installed the essetial kits and previewed the arduino development
2	Familiar with microcontrollers, trying to use the series communication
3	Follow the user handbook of FRobot ESP32 FireBeetle, assembled the circuit and use code sample to implement PWM control of the led brightness. Collaborate with team members to modified the code.
4	Follow the code and circuit diagram on user handbook of FRobot ESP32 FireBeetle, rearranged the code control the led brightness by analog of photo transistor.
5	Worked on Bluetooth and Wifi on FRobot ESP32 FireBeetle. Tranfering the signal read from photo transistor to mobilephone via http. Guided team members to learn about the WIFI module.
6	Assemble the circuit for PWM to control the motor RPM. Conduct the lab learning(transistor, PWM control). Researched on 4-digit 7-segments and added the interface to the project. Wrote section 2.1 and 2.2; Proof-read all sections, editing content where necessary
7	Atending the lab and used NodeRED/MQTT and a microcontroller to control the luminance of an LED using pulse width modulation (PWM). And discussed ideas and contributed to ideation to improve the user interface of the project.
8	Join the meeting(Lab) for discussing Evaluating Systems, specifically evaluation plan, abstract tasks and concrete Tasks and contributed to the ideation.
Mid-semester Break	Implemented partial interface on node-red, try some features from dashboard
9	Completed the Revised Conceptual Diagram added descriptions and confirmed with Tutor. Stated the changes from the initial plan and wrote the changes. Wrote the technic aspect of evaluation plan.

7.3 Fengyi Yang

Week	Activities
1	Install all software and drivers required for tutorial.
2	Get the kits and write simple code to check if the ESP32 FireBeetle can be written on the computer.
3	Brainstorm and decide on the theme of smart rubbish bin.
4	Based on the Canvas code and handbook, use a photo transistor to sense the surrounding brightness and adjust the brightness of the LED light through PWM.
5	Use the Bluetooth module and Wi-Fi module of the FireBeetle to send the current brightness of the environment to the mobile phone.
6	Drive the motor by using transistor. And control the speed of motor by PWM. Wrote section 1.4
7	Use Node Red and MQTT to control PWM to adjust brightness, and use the scroll interface. Participate in project discussions and make some suggestions for project functions.
8	Discuss evolution in the tutorial, including technical assessment and usability assessment.
Mid-semester Break	Self-study about fire beetle kit and Node Red.
9	Receive feedback from the tutor on phase1 and summarize and improve it. Assign the task of phase2. Responsible for phase2 6.2 and 8.3

7.4 Yaqi Zhou

Week	Activities
1	Install the necessary accessories and understand arduino development
2	Learned how to use the FRobot ESP32 FireBeetle, learned how to use VS Code for arduino development
3	Discussion topic and learn IoT
4	Follow the user handbook of FRobot ESP32 FireBeetle, control the led brightness
5	learned to use Bluetooth and WiFi on FRobot ESP32 FireBeetle.
6	Learned to use PWM control the motor speed. Wrote sections 3.2 and 3.3
7	Use NodeRED and MQTT and microcontroller to control the brightness of an LED.Discuss the project.
8	Discuss the evaluation plan, including abstract tasks and concrete tasks.
Mid-semester Break	Learned some NodeRED knowledge.
9	Receive feedback from the tutor on phase1 and improve the gantt chart. Assign the task of phase2. Responsible for phase2 5 and 8.4

REFERENCES

[1] Apple (Australia). 2022. *Airpods Pro (2nd generation) - technical specifications.* Retrieved October 13, 2023 from https://www.apple.com/au/airpods-pro/specs/

[2] United Nations. 2023. *Ensure sustainable consumption and production patterns.* Retrieved September 8, 2023 from https://sdgs.un.org/goals/goal12

[3] DF Robot. [n. d.]. *HX711 Weight Sensor Kit Arduino.* Retrieved September 1, 2023 from https://wiki.dfrobot.com/HX711_Weight_Sensor_Kit_SKU_KIT0176

[4] Anusha Withana. [n. d.]. Lecture 8: Evaluating Pervasive Systems.