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Project: **Skipy**

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Index

Abstract

The robot, named **Skipy**, is a social robot designed to **manage microwave queues in a university setting** by providing numbered tickets and offering a lottery-based "skip the line" privilege

Skipy is a modular robot, composed of five main independent units that communicate via the I2C system: **Communication, Actuator 1, Actuator 2, Localization (Movement), and Power Supply**

This report details the design and development of Skipy, a modular robot with a **lottery-based priority system**.

The **Communication Module** focuses on user interaction through movement, light, and sound, establishing meaningful engagement.

The **Actuator 1 Module** is responsible for **printing and deploying numbered receipts or "lucky" tickets** via a custom-made linear deployment system, housed within a UFO-shaped shell.

The **Actuator 2 Module**, inspired by lottery machines and space aesthetics, uses **airflow for ball propulsion and recirculation** within a transparent spherical chamber, integrating color recognition and electromechanical actuation for selective ball display.

The **Movement and Localization Module** provides **omnidirectional navigation** and basic obstacle detection, serving as a compact, autonomous platform.

The **Power Supply Module** ensures the robot's **long-term autonomy** through efficient energy management and autonomous recharging at a custom-designed charging station.

Disclaimer

To have a better knowledge on the functions of each module the single reports should be read.

Phase 1: Discover

The initial phase focused on team organization, project management, and extensive research.
Project management utilized **GANTT charts** and collaborative tools like WhatsApp, Google Drive, OneDrive, and Figma to streamline workflows and communication.
Research began by **brainstorming common problems in the university campus**, identifying microwave congestion during peak lunch hours as a significant issue.
Early **theatrical exercises explored non-verbal communication** for human-robot interaction, emphasizing the importance of intuitive communication.

Teams created first create some **cardboard prototypes** to visualize their module concepts:

- **Actuator 1:** Ideas included a basketball canister for trash, a system to distinguish objects, and a carnivorous plant
- **Communication:** Concepts included a basketball-themed head with LEDs and antennas, a dog-mouth-inspired waste robot, a "hungry" screen-displaying robot, and a microwave-oven-inspired exchange system with mechanical elements.
- **Actuator 2 :** Explored mechanical movement with magnet-embedded balls, Archimedean screw, and retractable actuator, shifting to air-based propulsion.
- **Movement/Localization:** Explored omnidirectional robots with three or four wheels in square, triangular, or polygonal shapes, considering stability, maneuverability, and mechanical complexity.
- **Power Supply:** Ideas included simplifying battery design for compactness, modular multi-adaptive sub-batteries, automatic exchange battery systems, and dual battery systems with a charging station.

Phase 2: Define

This phase focused on establishing precise objectives and a design framework for Skipy, aligning conceptual ideas with functional and aesthetic requirements.

The **overall concept envisioned Skipy as a social robot** in the shape of an alien, roaming in its spaceship, designed to manage microwave queues by assigning numbered tickets and offering a "lucky ball" lottery system.

A **narrative backstory** was developed where the alien (Skipy) lands on Earth to find an astronaut who once touched it kindly, believing the microwaves to be similar to stars from its home planet, and seeks recognition through user interaction and a lottery system.

Key Functionalities for each module were defined:

- **Communication Module:** Establishes meaningful interactions, initiates greeting sequences, and seeks user touch via head/arm movements and sound cues. It communicates with other modules and manages internal states for user interaction.
- **Actuator 1 Module:** Responsible for **printing numbered or special tickets** (lucky star) and **linearly delivering** them to the user. It incorporates mechanisms for holding, cutting, and extending/retracting the ticket.
- **Actuator 2 Module (Lottery Module):** Features a **closed-loop system for ball agitation via air propulsion** within a transparent sphere, colour recognition using sensors, and **selective ejection of balls** through a vertical tube.
- **Movement and Localization Module:** Enables the robot to **patrol autonomously, stop for user interaction, and navigate to a charging station** when the battery is low. It requires omnidirectional movement and basic obstacle detection.
- **Power Supply Module:** Ensures the robot's power needs are met. It incorporates a **rechargeable LiFePO4 battery** and defines a **charging station with pogo pins** as the primary charging method, with **cable charging as a backup**.

Electronics were specified for each module, and overall power requirements were calculated, leading to the selection of a **12V 8Ah LiFePO4 battery**. Arduino UNO boards were identified as the main microcontrollers for Communication, Actuator 1, Actuator 2, and Localization (initially ATmega328P).

Structural and shape concepts were developed to integrate the modules cohesively. The robot was envisioned with an **alien head (Communication)**, a **spaceship component (Actuator 1)**, a **sphere (Actuator 2)**, and a **base (Localization)**.

The **Movement module's base was designed as a dodecagonal (polygonal) shape** for stability and sensor placement, approximating a circular form. The **charging station was conceptualized with a rocky, extraterrestrial aesthetic** to "guide" the robot for alignment

Phase 3: Develop

This phase focused on translating defined concepts into working prototypes and refining designs through iterative testing.

Electronics Development

Communication

An **audio amplifier (XH-230)** was added to address low speaker volume. **180-degree servo motors replaced 360-degree ones** for controlled arm movement. A **custom capacitive touch sensor** was built for the alien's head.

Actuator 1

A significant challenge was the **thermal printer**; initial attempts resulted in a short circuit. A replacement printer with an **automatic cutter** was acquired, eliminating the need for separate servo motors for cutting. Communication with the printer shifted from TTL to **RS232, requiring a MAX3232 converter**. **Photoresistor and hall effect end stops** were integrated for ticket detection and arm position feedback.

Actuator 2

The initial air-based propulsion system with a PC fan failed to provide sufficient upward airflow. A **cone-shaped cover** was designed to redirect airflow. Later, a **Bearing Brushless 12V Fan** was integrated *inside* the transparent sphere for better ball agitation, and the process was **split into two phases**: visual agitation/recognition within the sphere and selective upward propulsion of a detected ball via a separate fan in a 3D-printed chamber.

Movement/Localization

Bench tests validated DC motors, omnidirectional wheels, and ultrasonic sensors. A **camera module was incorporated for QR code detection** to enable autonomous docking with the charging station, a feature not initially planned.

Power Supply

Custom pogo pins were designed and built to be "quite big" to tolerate less precise alignment, avoiding internal springs and using cable lug terminals for robust connections. A **hidden direct plug-in charging port** was added for alternative charging. An **ON/OFF button** was placed on the bottom base for maintenance. An additional LM2596 was added to the charging station to provide the correct 14V for the battery from a 19V input.

Coding Development

A **state machine approach** was adopted across modules for managing robot behavior. States for Communication included `IDLE`, `GREET_PERSON`, `SEEK_INTERACTION`, `AWAIT_BALL`, `CELEBRATE`, `CALL_NEXT90`.

I2C (Inter-Integrated Circuit) communication protocol was implemented for inter-module communication using the `Wire.h` library, with a custom message protocol for addressing and commands.

Actuator 1 developed custom helper functions for the thermal printer to print large horizontal numbers and bitmaps (e.g., Skipy logo, lucky star) by sending byte-by-byte commands.

Actuator 2 implemented probabilistic red-ball rejection (20% chance) and a guaranteed win mechanism (every 80 activations) to balance user engagement with reward control.

Power Supply tested battery voltage monitoring, but determined continuous monitoring wasn't critical due to long battery life. It also implemented a **"Cloud Thunder Effect" lighting system** using `Adafruit_NeoPixel` for aesthetic purposes on the base.

Localization with the help of Power Supply explored various methods for finding the charging station: Bluetooth, Wi-Fi, ESP-NOW (all relying on RSSI, which was found to be inaccurate for precise distance indoors), IR Transmitter/Receiver (limited by line-of-sight), ultimately deciding on a **Raspberry Pi vision-based method using visual markers (AprilTags or QR codes)** for high precision in cluttered environments.

Structural and Shape Development

Communication

Addressed arm movement by using **parabolic elements** to maintain visual continuity. The head mechanism was redesigned to **slide along the body on a rod** to eliminate gaps. Speaker was secured with magnets. Body sections connected with a **bayonet locking system and interlocking joints**. Shape evolved from geometric to **rounder, softer forms for a more alien and approachable appearance**.

Actuator 1

Printer scaffold was designed to be **adjustable for precise placement** and hinged for easy maintenance. The ticket delivery system shifted from friction-based to a **gear-and-rack-like system using the corrugated tube's teeth**. A **rail system** was added inside the UFO for axial rotation stability. The grabber unit was redesigned for a **larger ticket gap** and a more appealing aesthetic, with a hidden spring. The UFO shape evolved to a **polygonal, flat-bottomed structure** for stable mounting.

Actuator 2

Initial mechanical designs (rotating base plate, magnet on wire, Archimedean screw) were discarded for air propulsion. 3D-printed support structures and metal tubes were used to cover the fan and funnel airflow. Balls were changed from ping pong to **expanded polystyrene spheres** for better responsiveness to airflow.

Movement/Localization

The chassis was constructed from **dodecagonal wooden plates** and vertical rods. An **initially planned lower platform was removed** due to interference with wheel clearance, and components were relocated to the main base. The robot's aesthetic progressed from a white fabric cover to a **fluffy, cloud-like appearance with embedded LEDs simulating a storm cloud**.

Power Supply

The charging station's shape was inspired by **rocky formations and extraterrestrial architecture**, with a multi-layered, semi-circular layout to guide the robot. The final construction method was **vacuum forming** using natural materials as molds to create lightweight, durable plastic shells.

Phase 4: Deliver

The final phase ensured Skipy was a functional, integrated, and presentable robot.

Final Robot Description

Skipy is an **autonomous social robot** that manages microwave queues, offers a "skip the line" lottery, interacts playfully with users, and autonomously recharges at a custom station.

Strategy

The overall strategy focused on **long-term autonomy through energy management** and encouraging social interaction. The **Raspberry Pi vision-based method with QR codes** for precise docking via pogo pins was the chosen strategy for autonomous charging. The design of Actuator 1 aimed to **limit the number of motors for energy efficiency** and ease of wiring.

Mechanics and Updated BOM

Movement Module: Features **two dodecagonal wooden platforms** connected by vertical columns, housing **three DC motors with 58mm omnidirectional wheels** in a triangular layout. **DRV8871 motor drivers** control the motors. Five **HC-SR04 ultrasonic sensors** are used for obstacle detection. A **camera module** is integrated for QR code detection.

Actuator 1 Module: Includes a **thermal printer with an automatic cutter**. The ticket delivery system uses a **corrugated tube** as a rack moved by a DC motor, guided by rails, with magnetic endstops for position feedback. A **spring-powered grabber** with a wider gap was designed.

Actuator 2 Module: Employs a **closed-loop system for ping-pong ball movement via air propulsion** using multiple fans. A **color sensor (TCS3200)** identifies balls, and servo-controlled gates selectively eject them into a Y-shaped tube. The system separates ball agitation (RS-550 motor) from ejection (four 12V brushless DC fans).

Power Supply Module: Uses **custom-built "big" pogo pins** for charging, with magnetic alignment for precise docking. It also has a **hidden direct plug-in charging port**. An **ON/OFF button** is located on the bottom base for maintenance.

Electronics

Battery: A **12V 8Ah LiFePO4 battery with an integrated BMS** is the primary power source.

Connectors: XT60 connectors are used for power supply to the robot, and an **XT90 female pin** is used for charging cables.

Voltage Regulation: LM2596 DC-DC Buck Converters step down the 12V battery voltage to 5V for various components and convert 19V input from the transformer to 14V for battery charging.

Microcontrollers: Arduino Uno boards are central for Actuator 1, Actuator 2, and Communication. The **ATmega328P** serves as the core of the Movement module. A **Raspberry Pi** is used for the vision-based localization system.

Motor Drivers: L298N Motor Driver Modules are used for Actuator 1 and Actuator 2. **DRV8871 H-bridge drivers** control the Movement module's motors.

Sensors: TCS3200 Color Sensor (Actuator 2). **HC-SR04 Ultrasonic Distance Sensors** (Communication, Movement)

Capacitive Sensor (Communication)

Photoresistor and **Hall Effect Endstops** (Actuator 1).

Audio/Visual: MP3-TF-16P Module and **Speaker** with an optional **XH-A230 Audio Amplifier** (Communication)

WS2812B RGB LED Strip (Communication, Power Supply)

Informatics

The **Raspberry Pi vision-based method using AprilTags or QR codes** on the charging station enables precise autonomous docking.

I2C (Inter-Integrated Circuit) serial communication protocol is used for communication between Arduino boards (Actuator 1, Actuator 2, Communication, Localization), where Actuator 1 acts as the **I2C master**.

The code utilizes a **state-driven architecture** and **non-blocking programming** for responsiveness.

Actuator 2 incorporates **probabilistic red-ball rejection and guaranteed win mechanisms** for lottery control.

A **"Cloud Thunder Effect" lighting system** is implemented for aesthetic purposes on the robot's base.

Conclusion

The project provided valuable experience in **interdisciplinary collaboration**, balancing ambition with **time management**, and the importance of **continuous communication**. Challenges included logistical issues in material procurement, voltage instability and overheating in the power supply design, and achieving reliable robot mobility and docking. The iterative design process and adaptability of the teams were crucial in overcoming these obstacles, leading to a functional, aesthetically coherent, and structurally robust robot.

Photos