# CHIMPS – Cognitive Humanoid Intelligent Monkey for Public Sanitation

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## 1. Abstract

CHIMPS is a wheeled ground robot (approx. 40 cm size) inspired by primate mobility designed to detect, pick up, and return trash to a collection point. This document contains the system design, mechanical and electrical calculations, component selection, BOM, and integration plan for a basic prototype using camera + ultrasonic sensors for perception and a Raspberry Pi + Arduino control stack.

## 2. Design Choices and Assumptions

**Summary of chosen configuration:**

- Robot size (approx): 40 cm

- Mobility: wheeled (ground robot)

- Arms: 2 arms, 3 DOF per arm (total servos estimated: 8)

- Perception: Camera + Ultrasonic sensors (3 units)

- Control: Raspberry Pi + Arduino (basic, reliable stack)

- Target runtime: ~3.0 hours (design battery capacity: 12297 mAh at 11.1V nominal)

## 3. Mechanical Calculations

3.1 Torque and Arm Sizing

- Assumed max trash mass: 300 g

- Arm reach (r): 15 cm (0.15 m)

- Load force F = m \* g = 0.300 \* 9.81 = 2.943 N

- Required torque (static) τ = F \* r = 2.943 \* 0.15 = 0.441 N·m

- Design torque with safety factor 2.0 → τ\_design = 0.883 N·m

- Typical servo torque (MG996R class) ≈ 0.98 N·m. This meets the design torque with a small safety margin.

Recommendation: Use MG996R/MG995 high-torque analog servos or a similar digital servo rated ≥ 10 kg·cm (≥ 0.98 N·m). If you anticipate heavier loads, use stronger digital servos (~15–20 kg·cm) or add gearing at the joint.

3.2 Wheel & Drive Sizing

- Wheel radius r\_w = 0.04 m (approx 8 cm diameter wheels)

- Desired speed v = 0.5 m/s → angular speed ω = v/r = 12.50 rad/s → rpm ≈ 119.4

- To accelerate robot (mass 3.0 kg) to 0.5 m/s in 2 s, acceleration a ≈ 0.25 m/s².

- Force required F = m\*a = 0.75 N → per wheel ≈ 0.38 N → torque per drive wheel ≈ 0.015 N·m.

Recommendation: Use geared DC motors with nominal torque ≥ 1.5–2 N·m or high-reduction gearboxes to ensure reliable movement across mildly rough terrain. Consider using larger diameter wheels or suspension if terrain is rough.

## 4. Electrical & Power Calculations

4.1 Power Budget Estimate (average)

- Raspberry Pi 4 average power: 5.0 W

- Arduino: 1.0 W

- Camera: 1.0 W

- Servos: 8 units × 2.0 W (avg) = 16.0 W

- Drive motors: estimated average 12.0 W total

→ Total estimated average power draw = 35.0 W

4.2 Battery Sizing

- Energy required (for 3.0 h) = 35.0 W × 3.0 h = 105.0 Wh

- Using nominal battery voltage 11.1 V → required capacity = 9.459 Ah → design capacity with 30% headroom = 12297 mAh

## 5. Component Selection & BOM

Below is a recommended Bill of Materials with rough cost estimates (USD). Prices are indicative; source locally for exact pricing.

| S/N | Component | Qty | Unit Price (USD) | Total (USD) |
| --- | --- | --- | --- | --- |
| 1 | Raspberry Pi 4 Model B (4GB) | 1 | $55.00 | $55.00 |
| 2 | Arduino Mega 2560 | 1 | $18.00 | $18.00 |
| 3 | DC Geared Motor (12V) with encoders | 2 | $25.00 | $50.00 |
| 4 | Motor driver (L298N or similar) | 1 | $8.00 | $8.00 |
| 5 | MG996R High Torque Servo | 8 | $6.00 | $48.00 |
| 6 | Camera module (Raspberry Pi Camera or USB cam) | 1 | $12.00 | $12.00 |
| 7 | Ultrasonic sensor HC-SR04 | 3 | $3.00 | $9.00 |
| 8 | Battery Pack (11.1V ~ 12297 mAh) | 1 | $45.00 | $45.00 |
| 9 | Wheels (pair) - 8cm dia | 2 | $6.00 | $12.00 |
| 10 | Chassis materials (PLA/Aluminum/fasteners) | 1 | $40.00 | $40.00 |
| 11 | Power distribution board / voltage regulator (5V, 6V) | 1 | $12.00 | $12.00 |
| 12 | Misc (wires, screws, connectors) | 1 | $15.00 | $15.00 |
| 13 | Optional: IMU (MPU-6050) for improved stability | 1 | $6.00 | $6.00 |
|  | Estimated Total |  |  | $330.00 |

## 6. Software & Control

Suggested software stack:

- Raspberry Pi 4: runs main perception and high-level planning (Python, OpenCV, TensorFlow Lite)

- Arduino Mega: low-level motor & servo control (PWM), sensor polling and failsafe

- ROS2 (optional) for modular nodes and message passing; or a lightweight custom MQTT/serial protocol for simplicity.

High-level flow: Camera capture → inference (trash detection) → target selection → path planning/obstacle avoidance (ultrasonics) → motion commands to motors & arm servos.

## 7. Integration & Testing Plan

1. Mechanical assembly: build chassis, mount wheels, servos, and arms.

2. Electrical wiring: install battery, motor drivers, distribution board, and set up BEC for servos.

3. Software: start with simple motor control tests, then integrate camera and run object detection on Pi.

4. Closed-loop tests: combine perception and motion, evaluate pickup success rate, iterate on gripper geometry and control parameters.

5. Field tests: run across typical campus terrain; measure runtime, success rate, and logs. Record meeting videos and test sessions for evaluation.

## 8. Risk Assessment and Mitigation

- Overcurrent on servos/motors: use fuses and current-limited battery or ESC, and a proper BMS.

- Stability on rough terrain: use larger wheels, low center of gravity, and possibly add passive suspension.

- Vision failures in low light: add low-cost LED ring illumination or switch to depth camera later.

- Lab technician assistance: log any external help as per course rules (they can assist but not do your work).

## 9. Appendix: Key Calculations (summary)

- Load force F = m\*g = 0.3 \* 9.81 = 2.943 N

- Static torque τ = F\*r = 2.943 \* 0.15 = 0.441 N·m

- Design torque (SF=2.0) = 0.883 N·m

- Wheel rpm for 0.5 m/s = 119.4 rpm

- Estimated average power draw = 35.0 W

- Energy required for 3.0 h = 105.0 Wh → battery design 12297 mAh at 11.1 V nominal