

Design of a Low-Cost Monkey Deterrent System

HNC Electrical & Electronic Engineering – Level 4

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Chomzangari Women's Cooperative, Zimbabwe

The Problem

Context

The Chomzangari Women's Cooperative in Zimbabwe faces persistent crop damage from monkeys.

This directly impacts income and food security for rural communities.

Monkeys are highly intelligent and quickly adapt to traditional deterrents, making the problem difficult to manage.

Key Challenges

- High monkey intelligence
- Rapid habituation to deterrents
- Remote rural location
- No reliable electricity supply
- Limited budget for maintenance



Project Objectives

1 Mathematical Model

Develop a second-order dynamic model of the actuator mechanism

2 PID Controller

Design a suitable PID closed-loop control system

3 MATLAB Simulation

Simulate and analyse system performance in MATLAB

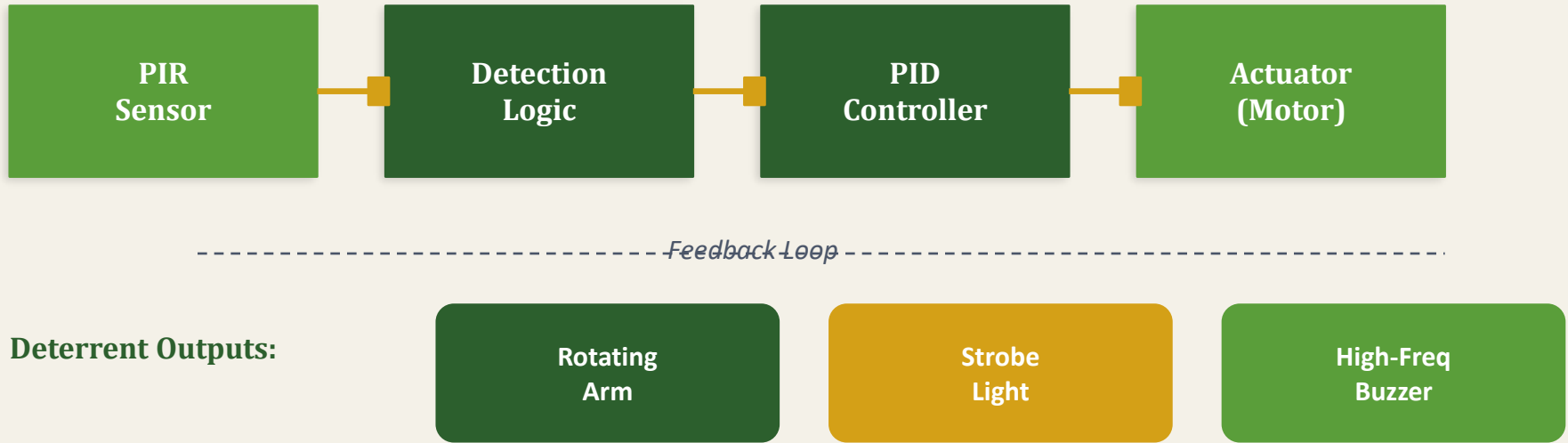
4 Performance Metrics

Evaluate rise time, settling time, overshoot & steady-state error

5 Solar Power Supply

Design a simple solar supply for off-grid rural operation

Integrated System Architecture



Night/Day logic + AND gate prevent unnecessary activation and conserve solar power.

PID Controller Design

Why PID?

- Simple and reliable – well-suited to low-cost systems
- Low computational requirements
- Eliminates steady-state error via integral term
- Reduces oscillation via derivative damping
- Derivative filter ($N=50$) handles outdoor sensor noise

Tuned Parameters

K_p	60	Proportional Gain – fast response
K_i	40	Integral Gain – eliminates steady-state error
K_d	10	Derivative Gain – reduces overshoot
N	50	Derivative Filter – rejects sensor noise
m	2 kg	Actuator mass
b	5 Ns/m	Damping coefficient
k	20 N/m	Stiffness

Simulation & Results

Rise Time

Fast

Rapid physical movement on detection

Steady-State Error

Zero

Integral term fully eliminates error

Overshoot

Controlled

Stable settling without oscillation

System Output

Actuator achieves rapid rise and reaches target displacement with controlled overshoot. Confirms PID gains strike the right balance between speed and stability.

Error Signal

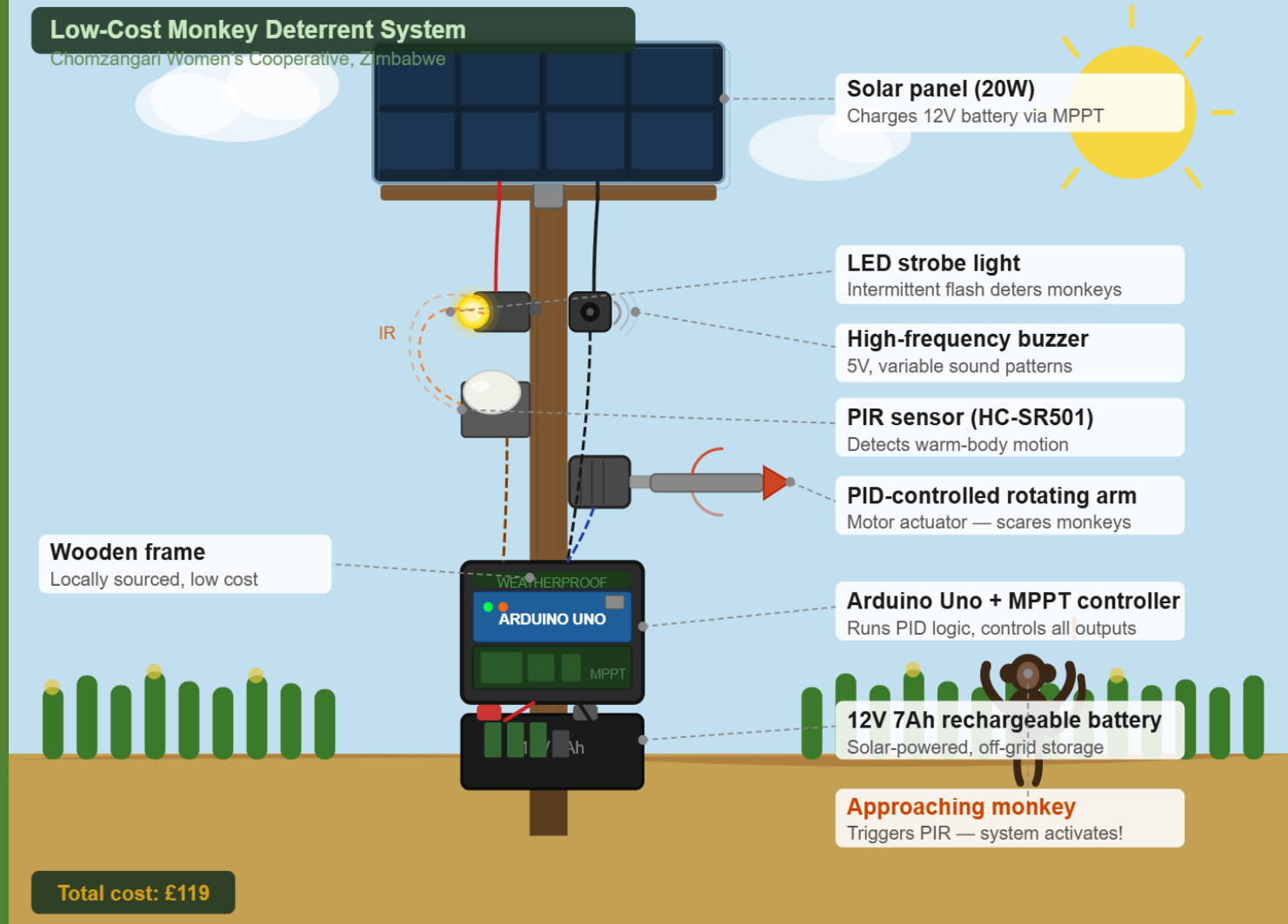
Error smoothly converges to zero. The integral term successfully eliminates steady-state error, ensuring full deterrent activation every time.

Control Effort

Initial spike overcomes inertia, then stabilises. Concentrates energy use at start—ideal for solar-powered operation where battery conservation matters.

Low-Cost Monkey Deterrent System

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Power Supply & Cost Analysis

Solar Power Design

- 20W Solar Panel
- 12V 7Ah Rechargeable Battery
- Solar Charge Controller
- Zimbabwe's high solar irradiance makes this ideal
- Motor: 2A for 10s per activation
- All other components: < 0.25A combined
- Clean, renewable & low maintenance

Component Cost Breakdown

Solar Panel (20W)	£20
Battery 12V 7Ah	£15
Arduino Uno	£20
Motor (Actuator)	£15
Solar Charge Controller	£12
USB Power Bank	£10
Frame (Wood)	£10
Wiring & Misc	£10
PIR Sensor	£2
Buzzer + LED	£5
TOTAL	£119

Sustainability, Strengths & Limitations

Strengths

- Fast response to detected activity
- Solar powered – environmentally friendly
- Low-cost, locally repairable
- Reduces manual labour demands
- Multi-modal outputs resist habituation
- Night/Day logic conserves power

Limitations

- Mechanical wear in outdoor conditions
- Sensor sensitivity may degrade over time
- No adaptive or learning-based detection
- Fixed PID gains may need re-tuning

Future Improvements

- Adaptive PID tuning for optimal performance
- Camera-based or AI-enhanced detection
- Randomised sound frequency patterns
- Remote monitoring via IoT module

Conclusion

- Successfully modelled a second-order actuator using a mass–spring–damper system
- PID controller ($K_p=60$, $K_i=40$, $K_d=10$) achieves fast, stable activation with zero steady-state error
- MATLAB simulation confirms effective balance between responsiveness and energy efficiency
- 5-second validation delay and Night/Day logic reduce false triggers and conserve solar power
- Multi-modal deterrents (motion, strobe, buzzer) reduce risk of monkey habituation
- Total system cost of £119 makes this highly accessible for rural agricultural communities
- Provides a foundation for future enhancements such as adaptive control and AI-based sensing