



Design of a Low-Cost Monkey Deterrent System

GOEE4002

Abstract

An academic assignment on the research and development of a monkey deterrent system for the protection of crop fields in Zimbabwe

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Scope

This paper will concern the research and development of a low-cost monkey deterrent system to be used in the protection of crops for the Chomzangari Women's Cooperative in Zimbabwe. It shall focus on these main areas of concern:

- Monkey behaviour and adaptability
- Deterrents and monitoring
- Instrumentation
- Design and Simulation
- Power supply
- Construction
- Cost
- Conclusion

Monkey behaviour and adaptability

The vervet monkey will be the focus of the system as it is one of the more populous monkey species in the area. 'Densities vary between 9 and 104 individuals/km²' (Isbell and Jaffe 2013).

These are small and agile monkeys between 0.5 – 1 meter including the tail and can weigh between 3.5 – 8 Kg (<https://www.awf.org/wildlife-conservation/vervet-monkey>). They are omnivorous and survive on seeds, insects and fruit. This will suggest the vervet to be a main pest for the crop fields.

As they are agile and adaptable, the system will need to be able to change states of deterrent, use multiple types of sensors for detection and be sustainable.

Deterrents and monitoring

It would be cruel and dangerous to employ any system that would bring harm to the monkeys such as electric fences and physical deterrents. It would be best to use harmless deterrents such as barriers, sound and lights which will cause them to flee to surrounding areas.

Output devices

A sound-based deterrent can be reliable as it doesn't have to be targeted in some way can be an ambient sound that effects a certain area. Effective sounds may include leopards or eagle calls as a main predator to the vervet monkey (<https://www.britannica.com/animal/vervet>). Simulated leopard calls will be around 130 Hz (Sunkuist, 2002) and eagles shall be between 2000 – 6000 Hz. A mixture of these frequencies shall be tested and analysed for effectiveness.

Lighting can also be used as a visual deterrent in conjunction with the sound-based deterrent. An LED style strobe light will be deployed when a monkey is within proximity to the sensors.

Input devices

Monitoring the monkeys to activate the deterrents will be achieved through input devices such as PIR sensors and sound detection systems. These input devices shall be linked to the output devices in an autonomous setup to be self-activating and remove the need for human intervention unless in the case of maintenance or repair.

The deterrent device will need to be rotatable to allow for a wide area to be covered and not on one focal point as the monkeys may come from any direction. This will need to be a slow rotation as to not activate the PIR with fast movements.

The design will need to be robust, strong and weather resistant to withstand physical damage and from the changing weather. It will also need to be powered without the use of an electrical grid.

Instrumentation

With consideration of the design criteria, the design will use the following components:

Input devices		
System materials and components	Description	Function
Ultrasonic distance sensor (HC-SR04)	Sound based detection device	Uses sound to calculate the distance from itself and an object, will be used to detect monkey movement
Parallax PIR hub	Light based detection device	Uses light to detect movement in certain range, will be used to detect monkey movement
Output devices		
System materials and components	Description	Function
Neopixel ring 12 (WS2812)	LED ring	Used to emit light to deter monkeys in a set frequency and colour
PUI 100dB piezo buzzer	Sound emitting device	Used to emit sound to deter monkeys in a set frequency
Geared DC motor (4.5V)	Electric DC motor	A motor used to rotate the system to cover a 360 degree area
Communication		
System materials and components	Description	Function
Arduino Uno R3	5v micro controller	Act as the system brain to control I/O modules
Electronic components	Connecting devices	Multiple electronic components to help connect all devices together such as resistors, transistors and diodes
Power		
System materials and components	Description	Function
Solar Cell	Converts solar energy into electrical energy	Used as a primary electrical source for the system in place of an electric grid
Rechargeable battery unit	Stores electrical energy	Used as a backup and storage devices for electrical energy generated by the solar cell
Structure		
System materials and components	Description	Function
Fixed tripod system	Metal structure made of durable material	Used to mount the system at high level and provide a stable base for all devices
System enclosure	Durable container	Used to house the system and components to protect against damage and mount the solar cell on top

The main control unit will be the Arduino Uno R3 which will be used to receive data from input devices and operate output devices as deterrents to monkeys.

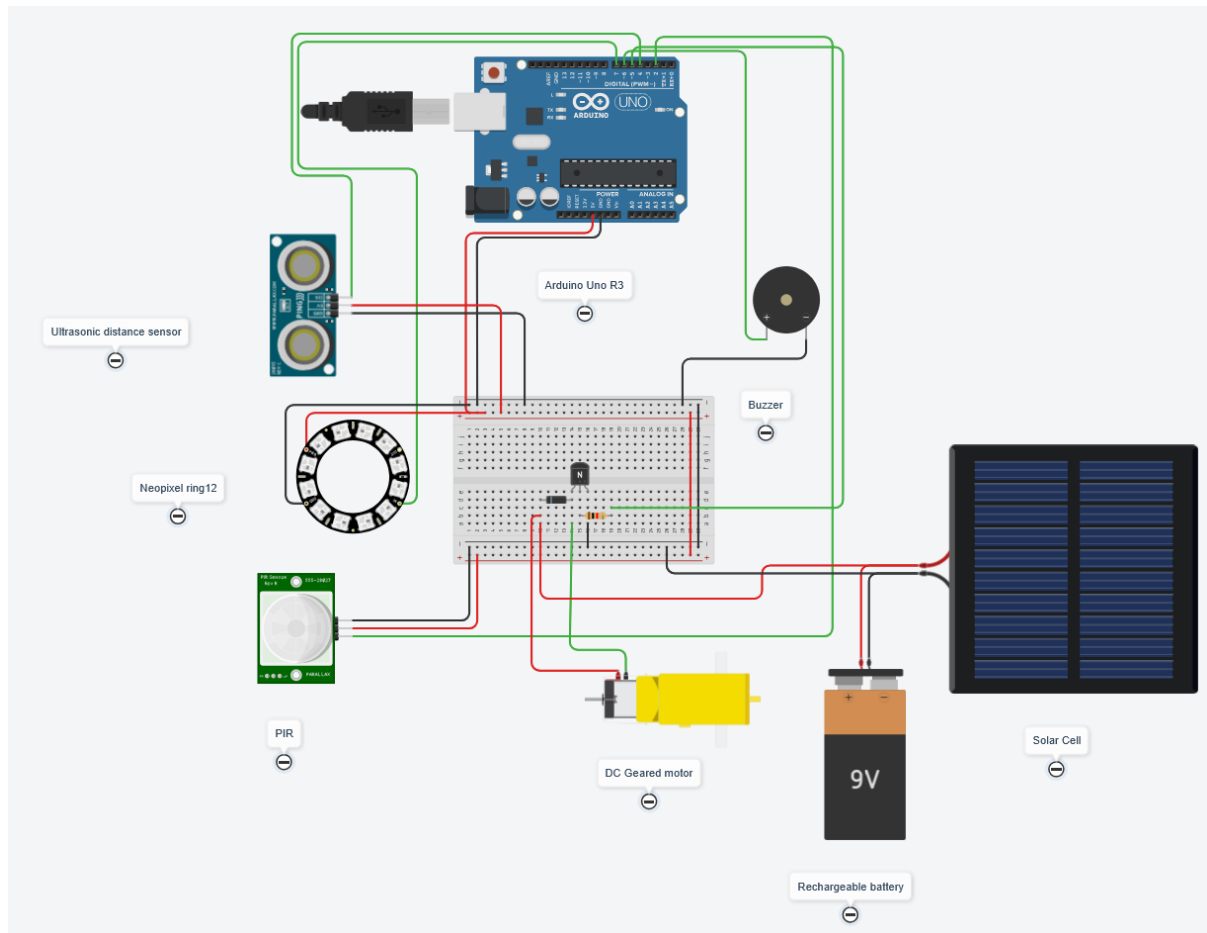
The output devices will use both sound and light as a deterrent that can be configured over time to adapt to monkey reactions, such as changing the colour/frequency of the Neopixel LED's or changing buzzer frequency to find the most effective combination. The geared DC motor shall be mounted at the base of the system to slowly rotate the system to cover a 360-degree area without compromising the input device functions.

The input devices shall work in together to prevent nuisance triggering of the system such as slow-moving leaves and changes in light levels due to weather.

The solar cell and rechargeable battery will be used as the main power source to the system. The solar cell shall provide the primary supply with the battery storing excess electrical charge to use at a time of low sunlight.

Design and Simulation

Using simulation software, the design of the system will be:



Due to the limitations of the software, the 9v battery has been used as a placeholder for the rechargeable battery.

Code for the system

```

12 Adafruit_NeoPixel strip(NUM_LEDS, LED_PIN, NEO_GRB + NEO_KHZ800);
13
14 int distanceThreshold = 20;
15
16 void setup() {
17   pinMode(PIR_PIN, INPUT);
18   pinMode(TRIG_PIN, OUTPUT);
19   pinMode(ECHO_PIN, INPUT);
20   pinMode(MOTOR_PIN, OUTPUT);
21   pinMode(BUZZER_PIN, OUTPUT);
22
23   strip.begin();
24   strip.show();
25
26   Serial.begin(9600);
27 }
28
29 // 📡 Ultrasonic
30 long readDistance() {
31   digitalWrite(TRIG_PIN, LOW);
32   delayMicroseconds(2);
33
34   digitalWrite(TRIG_PIN, HIGH);
35   delayMicroseconds(10);
36   digitalWrite(TRIG_PIN, LOW);
37
38   long duration = pulseIn(ECHO_PIN, HIGH);
39   return duration * 0.034 / 2;
40 }
41
42 // 🚦 Motion check
43 bool motionDetected() {
44   return (digitalRead(PIR_PIN) == HIGH && readDistance() < distanceThreshold);
45 }
46
47 // 🌟 Turn NeoPixel ON
48 void pixelsOn() {
49   for (int i = 0; i < NUM_LEDS; i++) {
50     strip.setPixelColor(i, strip.Color(255, 255, 255));
51   }
52   strip.show();
53 }
54
55 // 🌟 Turn NeoPixel OFF
56 void pixelsOff() {
57   strip.clear();
58   strip.show();
59 }
60
61 void loop() {
62
63   // 🟢 STEP 1: Motor runs slowly
64   analogWrite(MOTOR_PIN, 100);
65
66   // Wait for motion
67   if (motionDetected()) {
68
69     // 🛑 Stop motor
70     analogWrite(MOTOR_PIN, 0);
71
72     int freq = 5; // start at 5 Hz (strobe)
73     int buzzerFreq = 130; // start at 130 Hz
74     unsigned long lastIncrease = millis();
75
76     while (motionDetected()) {
77
78       // ⏰ Increase frequency every 1 second
79       if (millis() - lastIncrease >= 1000) {
80         freq *= 2;
81         buzzerFreq *= 2;
82
83         lastIncrease = millis();
84
85         Serial.print("Strobe Hz: ");
86         Serial.print(freq);
87         Serial.print(" | Buzzer Hz: ");
88         Serial.println(buzzerFreq);
89       }
90
91       // ⏱ Strobe timing
92       int delayTime = 1000 / (freq * 2); // half period
93
94       // ON
95       pixelsOn();
96       tone(BUZZER_PIN, buzzerFreq);
97       delay(delayTime);
98
99       // OFF
100      pixelsOff();
101      noTone(BUZZER_PIN);
102      delay(delayTime);
103    }
104  }

```

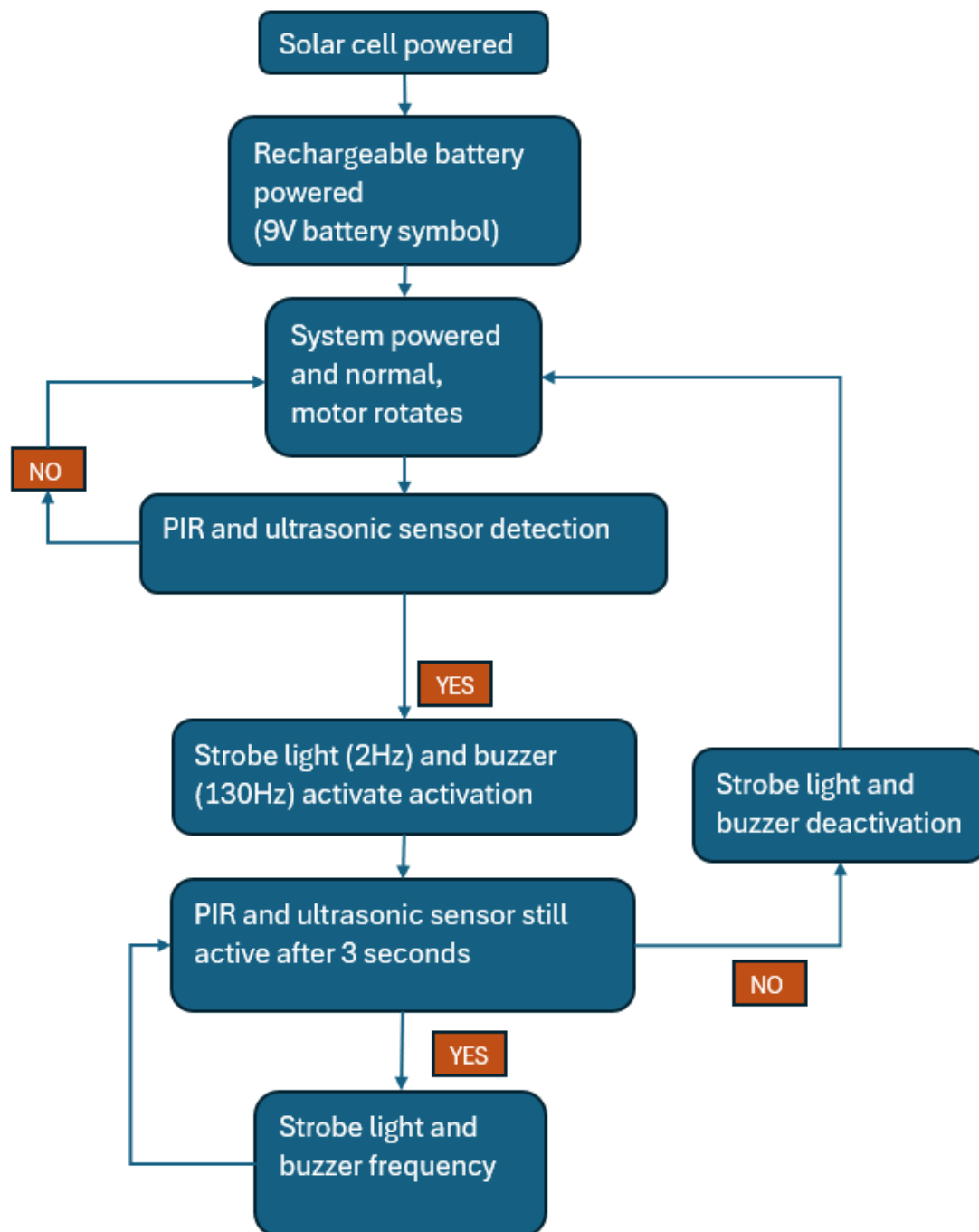
Simulation

While testing the system, the following outcomes were found.

1. In a normal situation where all input devices were healthy, the motor would continue to rotate and slowly turn the system input devices in a 360-degree motion.
2. The system would not change if only 1 input device detected movement as planned.
3. Once both input devices were triggered, the motor would stop rotating keeping the motion in view of the input devices. If no movement was shown after stopping, the motor would then continue to rotate the system.
4. If movement is still present, the buzzer (130Hz) and LED (2Hz) will operate as a deterrent. If movement persists after 3 second, the frequency of each deterrent will double. This will continue until the input devices deactivate, or the deterrents reach their maximum output frequency.
5. Once the input devices deactivate, the motor will resume operation causing the system to rotate

The system will be able to adapt to monkey behaviour by generating multiple different auditory frequencies and light frequencies. The system is rotatable so monkeys can be detected in a 360 degree area of view. The microprocessor and I/O devices can be configured over time to generate other visual and auditory effects in the event of monkeys becoming desensitised to the programmed responses. This will make the system sustainable over a long period of time.

System block diagram



Power supply

The solar cell and battery backup need to be sufficiently sized, so the system operates during the day when the vervet monkeys are most active and likely to hunt for food.

The battery will need sufficient power to operate independently of the solar cell on days of low sunlight. The solar cell will need to output enough power to charge the battery and operate the system components as to not rely on battery power.

Below is a table showing component specifications and calculations for power consumption.

Voltage consumption			Battery power supply			
Item	Voltage (volts)		Item	Amps per hour needed (Ah)	Amps per hour supplied (Ah)	Supply duration without recharge (hours)
Arduino Uno R3	12		RS PRO 12 V NiMH Rechargeable Battery Pack 10, 2 Ah	0.3601	10	27.77006387
HC-SR04	5					
Parallax PIR hub	5					
Geared DC Motor	12					
Neopixel ring 24 (WS2812B)	5					
PUI 100dB piezo buzzer	5					
Maximum	12					
Amperage consumption			Solar cell supply			
Item	Amperage (amps)		Item	Power needed per hour (watts)	Power supplied per hour (Watts)	Power diverted to battery backup (Watts)
Arduino Uno R3	0.02		Seeit 50 W Monocrystalline Photovoltaic Solar Panel	9.3105	50	40.6895
HC-SR04	0.15					
Parallax PIR hub	0.0001					
Geared DC Motor	0.19					
Neopixel ring 12 (WS2812)	1.2					
PUI 100dB piezo buzzer	0.008					
Total	0.3601					
Power consumption						
Item	Power (Watts)					
Arduino Uno R3	0.24					
HC-SR04	0.75					
Parallax PIR hub	0.0005					
Geared DC Motor	2.28					
Neopixel ring 12 (WS2812)	6					
PUI 100dB piezo buzzer	0.04					
Total	9.3105					

Power consumption calculations

$$Power = voltage \times current$$

All values for calculation have been taken from manufacturer datasheets and specifications. Each component has been calculated using maximum values taken from datasheets to give a safety margin and to account for maintenance and inefficiency factors such as unfavourable weather conditions, vibration etc.

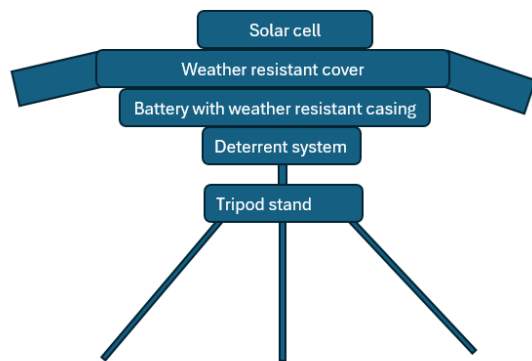
The solar cell will be able to charge the battery and operate the system will in optimal light conditions and the battery is optimally sized to allow for over a day of supply if the solar cell doesn't supply power.

All components have been assumed to be on at all times whereas they will only be on partially and at less than maximum power consumption as another safety margin to total power consumption.

Construction

The system will need to be tall enough to look over the nearby crops and be strong enough to withstand harsh and varied weathers as it will be placed outside in agricultural environments. The system will need to construct in a way to protect vulnerable system components and be light enough to be portable.

System construction



The solar cell (<https://uk.rs-online.com/web/p/solar-panels/2651103>) shall be placed on top to allow for optimal direct sunlight. All other components shall be below a corrugated metal sheet that will be support from below using strengthen struts.

The battery (<https://docs.rs-online.com/ea02/A700000012203464.pdf>) shall be housed in a weather resistant container (https://ukfixingsdirect.com/products/masterplug-wbx-ms-weatherproof-electric-box-for-outdoors-345-x-220-x-126-5-mm-grey?variant=41020014428243&gad_source=4&gad_campaignid=21998218075&gclid=Cj0KCQjwyr3OBhD0ARIsALlo-OqAcxmnZ7zn5Dt7HD1gUu1gInVrDvibO_skyvBB35YNGN1ZWhn9XuoaAraVEALw_wcB) below the canopy to protect against harsh weather conditions.

The deterrent system will also be housed within a similar weather resistant container to protect the vulnerable electrical components inside. This container will need to be modified to allow it to rotate around the tripod structure using the geared motor (<https://uk.rs-online.com/web/p/dc-motors/4130616>) and have a mesh window to allow the I/O components to interact outside the enclosure.

The whole system shall be supported by a galvanised tripod system (https://ilsirrigation.co.uk/shop/drip-irrigation-sprinklers/tripods/tripod/?gad_source=1&gad_campaignid=22691057489&gclid=Cj0KCQjwyr3OBhD0ARIsALlo-Om4D0he4A2yZUA3P2gb7vDzyGUy1ESe3a0ZsDv6egkCI9SdNbKffrgaAgfEEALw_wcB) that can be anchored into the ground to give a strong base to the system and protect against physical damage.

Cost

The cost of the system should be within a range to be more cost effective than the current method of using manual labour to deter the monkeys. The budget for the system shall be less than £500. Below is a spreadsheet for the current cost of the system.

Input devices	
System materials and components	Cost (£)
Ultrasonic distance sensor (HC-SR04)	3
Parallax PIR hub	15
Output devices	
System materials and components	
Neopixel ring 24 (WS2812B)	20
PUI 100dB piezo buzzer	
Geared DC motor (12V)	15
Communication	
System materials and components	4
Arduino Uno R3	25
Electronic components/wires	5
Power	
System materials and components	
Solar Cell	165
Rechargeable battery	140
Structure	
System materials and components	
Fixed tripod system	60
System enclosure	20
Battery enclosure	20
Total cost	492

The system costs lower than the budget set and will save more money over time with minimal maintenance and labour costs for original method for monkey deterrents.

Conclusion

This system will be used to provide a long-term monkey deterrent that can be adaptable, strong and cost effective. Through long term review and adjustment, the deterrent system can be fine tuned to deter the local population of monkeys and be upgraded, if necessary, in the event it is not working as effectively in simulation conditions.

References

Isbell, L.A. and Jaffe, K.E. 2013. Chlorocebus pygerythrus Vervet Monkey. In: T.M. Butynski, J. Kingdon and J. Kalina (eds), The Mammals of Africa. Volume II: Primates, pp. 277-283. Bloomsbury Publishing, London.

Sunquist, M., Sunquist, F.: Wild Cats of the World. University of Chicago Press, Chicago (2002) ISBN 0-226-77999-8

Component data sheets

DC motor

<https://uk.rs-online.com/web/p/dc-motors/4130616>

Arduino uno r3

<https://docs.arduino.cc/hardware/uno-rev3/#tech-specs>

PIR

<https://www.mouser.com/datasheet/2/321/PIRSensor-V1.2-27724.pdf?srltid=AfmBOoqxrfhWDlqdfJbUY7ul6KlIBM691tgsZPIhdMtlS6aHSFuJv11->

Echo ultrasonic detector

<https://cdn.sparkfun.com/datasheets/Sensors/Proximity/HCSR04.pdf>

Neopixel 24 LED

[https://www.handsontec.com/dataspecs/module/WS2812%20Neopixel%20Ringx24.p](https://www.handsontec.com/dataspecs/module/WS2812%20Neopixel%20Ringx24.pdf)
[df](https://www.handsontec.com/dataspecs/module/WS2812%20Neopixel%20Ringx24.pdf)

Buzzer

<https://uk.rs-online.com/web/p/piezo-buzzers/0276726>

Solar cell with connecting components

<https://uk.rs-online.com/web/p/solar-panels/2651103>

Rechargeable battery

<https://docs.rs-online.com/ea02/A700000012203464.pdf>

Weather resistant container

https://ukfixingsdirect.com/products/masterplug-wbx-ms-weatherproof-electric-box-for-outdoors-345-x-220-x-126-5-mm-grey?variant=41020014428243&gad_source=4&gad_campaignid=21998218075&gclid=Cj0KCQjwyr3OBhD0ARIsALlo-OkAcxmnZ7zn5Dt7HD1gUu1gInVrDvibO_skyvBB35YNGN1ZWhn9XuoaAraVEALw_wcB

Galvanised tripod

https://ilsirrigation.co.uk/shop/drip-irrigation-sprinklers/tripods/tripod/?gad_source=1&gad_campaignid=22691057489&gclid=Cj0KCQjwyr3OBhD0ARIsALlo-Om4D0he4A2yZUA3P2gb7vDzyGUy1ESe3a0ZsDv6egkCI9SdNbKffrgaAgfEEALw_wcB