Yoseph Ayele Kebede

UID: 114196729

Dr. Mitchell

ENPM701 Assignment 6

Servo Control and Encoder Count

Assignment #6

Assembly of Course Robotic Ground Vehicle

Question #1

1.2

```
import cv2
import os
import RPi.GPIO as GPIO
from picamera.array import PiRGBArray
from picamera import PiCamera
import time

# Initialize gripper states
closed = 2.5
half = 5
open_full = 7.5

def init():
    # initialize the Raspberry Pi camera
    camera = PiCamera()
    camera.resolution = (640, 480)
    camera.framerate = 25
    rawCapture = PiRGBArray(camera, size=(640,480))

    # allow the camera to warmup
    time.sleep(0.1)

    # Setup GPIO pin(s)
    GPIO.setmode(GPIO.BOARD)
    GPIO.setup(36, GPIO.OUT)

    GPIO.setup(31, GPIO.OUT) # IN1
    GPIO.setup(33, GPIO.OUT) # IN2
    GPIO.setup(35, GPIO.OUT) # IN3
```

```
    GPIO.setup(37, GPIO.OUT) # IN4

    # Set all pins low
    GPIO.output(31, False)
    GPIO.output(33, False)
    GPIO.output(35, False)
    GPIO.output(37, False)

    # Initialize pwm signal & move gripper to center position
    pwm = GPIO.PWM(36, 50)
    pwm.start(5.5)

    return pwm, camera, rawCapture

def take_img(camera, rawCapture, out, data, grip_state):

    for frame in camera.capture_continuous(rawCapture, format="bgr",
use_video_port=False):

        # grab the current frame
        img = frame.array

        img = cv2.flip(img,-1)

        cv2.putText(img, data, (20,30),cv2.FONT_HERSHEY_SIMPLEX,1,(0,0,0),2)

        if grip_state == half:
            cv2.putText(img, "Half-Opened",
(40,80),cv2.FONT_HERSHEY_SIMPLEX,1,(0,125,125),2)
        elif grip_state == open_full:
            cv2.putText(img, "Fully-Opened",
(40,80),cv2.FONT_HERSHEY_SIMPLEX,1,(0,0,255),2)
        elif grip_state == closed:
            cv2.putText(img, "Fully-Closed",
(40,80),cv2.FONT_HERSHEY_SIMPLEX,1,(255,0,0),2)

        # write frame into file
        out.write(img)

        return img

def slowly(cap,pwm,camera,rawCapture):

    # Initiate gripper in a closed state first
    pwm.ChangeDutyCycle(2.5)
```

```
grip_state = 2.5
cycle = 0
increment = 0.25
# Start incrementing gripper every 0.5 until full open
# then revert direction
start = time.time()
# define the codec and create VideoWriter object
fourcc = cv2.VideoWriter_fourcc(*'XVID')
# fourcc = cv2.VideoWriter_fourcc(*'MJPG')
out = cv2.VideoWriter('servo_action3.avi', fourcc, 3, (640, 480))

frm_cnt = 0
duration = 0

while True:

    if(grip_state <= open_full) and (grip_state >=2.5):

        if frm_cnt != 0:
            pwm.ChangeDutyCycle(grip_state)
            time.sleep(5)

        data = "Duty: " + str(grip_state) + "%"

        img = take_img(camera, rawCapture, out, data, grip_state)

        # Show resutls to the screen
        cv2.imshow("Servo motor slowly open/close", img)
        key = cv2.waitKey(1) & 0xFF

        print(data)

        # Break out of loop by pressing the q key
        # press the 'q' key to stop the video stream
        if (key == ord("q")):
            pwm.stop()
            GPIO.cleanup()
            break

        # clear the stream in preparation for the next frame
        rawCapture.truncate(0)

        if grip_state == open_full:
            increment = -increment
            cycle += 1
```

```
            elif (grip_state == closed) and cycle>0:
                increment = -increment
                cycle += 1

            if cycle > 1:
                pwm.ChangeDutyCycle(2.5)
                pwm.stop()
                GPIO.cleanup()
                break

            grip_state += increment

        frm_cnt += 1

    # Release video capture and video object
    cap.release()
    out.release()

def main():

    # Initialize pins and pwm
    pwm, camera, rawCapture = init()

    # Open video capture
    cap = cv2.VideoCapture(0)

    if (cap.isOpened() == False):
        print("Error reading video")

    # Slowly open and close gripper
    slowly(cap,pwm,camera,rawCapture)

    cv2.destroyAllWindows()

if __name__ == "__main__":

    main()
```

Video: https://youtu.be/-Yqtm0D6GXw

1.3

```
import numpy as np
import cv2
import imutils
```

```python
import RPi.GPIO as gpio
import time
import os
from picamera.array import PiRGBArray
from picamera import PiCamera

def distance():
    # Define pin allocations
    trig = 16
    echo = 18
    # Setup GPIO board & pins
    gpio.setmode(gpio.BOARD)
    gpio.setup(trig, gpio.OUT)
    gpio.setup(echo, gpio.IN)

    # Ensure output has no value
    gpio.output(trig, False)
    time.sleep(0.01)

    # Generate trigger pulse
    gpio.output(trig, True)
    time.sleep(0.00001)
    gpio.output(trig, False)

    # Generate echo time signal
    while gpio.input(echo) == 0:
        pulse_start = time.time()

    while gpio.input(echo) == 1:
        pulse_end = time.time()

    pulse_duration = pulse_end - pulse_start

    # Convert time to distance
    distance = pulse_duration * 17150
    distance = round(distance, 2)

    # Cleanup gpio pins & return distance estimate
    gpio.cleanup()
    return distance

def init():
    gpio.cleanup()
    gpio.setmode(gpio.BOARD)
```

```
    # Setup GPIO pin(s)
    gpio.setup(36, gpio.OUT) # Servo

    gpio.setup(31, gpio.OUT) # IN1
    gpio.setup(33, gpio.OUT) # IN2
    gpio.setup(35, gpio.OUT) # IN3
    gpio.setup(37, gpio.OUT) # IN4

def gameover():
    # Set all pins low
    gpio.output(31, False)
    gpio.output(33, False)
    gpio.output(35, False)
    gpio.output(37, False)

def forward(tf):
    #init()
    # Left wheels
    gpio.output(31, True)
    gpio.output(33, False)
    # Right wheels
    gpio.output(35, False)
    gpio.output(37, True)
    # Wait
    time.sleep(tf)

def reverse(tf):
    #init()
    # Left wheels
    gpio.output(31, False)
    gpio.output(33, True)
    # Right wheels
    gpio.output(35, True)
    gpio.output(37, False)
    # Wait
    time.sleep(tf)
    # Send all pins low & cleanup
#     gameover()
#     gpio.cleanup()

def pivotleft(tf):
    #init()
    # Left wheels
    gpio.output(31, False)
    gpio.output(33, True)
```

```
    # Right wheels
    gpio.output(35, False)
    gpio.output(37, True)
    # Wait
    time.sleep(tf)

    # Send all pins low & cleanup
#     gameover()
#     gpio.cleanup()

def pivotright(tf):
    #init()
    # Left wheels
    gpio.output(31, True)
    gpio.output(33, False)
    # Right wheels
    gpio.output(35, True)
    gpio.output(37, False)
    # Wait
    time.sleep(tf)
    # Send all pins low & cleanup
#     gameover()
#     gpio.cleanup()


def key_input(event):
    # Initialize board
    init()

    print("Key: ", event)
    key_press = event
    tf = 1

    if key_press.lower() == 'w':
        forward(tf)
    elif key_press.lower() == 's':
        reverse(tf)
    elif key_press.lower() == 'a':
        pivotleft(tf)
    elif key_press.lower() == 'd':
        pivotright(tf)
    elif key_press.lower() == 'p':
        gamestop()
    else:
        print("Invalid key pressed!!")
```

```
while True:
    time.sleep(1)
    print("Distance: ", distance(), " cm")
    key_press = input("Select driving mode: ")
    if key_press == 'p':
        break
    key_input(key_press)
```

1.4

```
import numpy as np
import cv2
import imutils
import RPi.GPIO as gpio
import time
import os
from picamera.array import PiRGBArray
from picamera import PiCamera

# Initialize gripper states
closed = 2.5
half = 5
open_full = 7.5

def distance():
    # Define pin allocations
    trig = 16
    echo = 18
    # Setup GPIO board & pins
    gpio.setmode(gpio.BOARD)
    gpio.setup(trig, gpio.OUT)
    gpio.setup(echo, gpio.IN)

    # Ensure output has no value
    gpio.output(trig, False)
    time.sleep(0.01)

    # Generate trigger pulse
    gpio.output(trig, True)
    time.sleep(0.00001)
    gpio.output(trig, False)

    # Generate echo time signal
```

```
    while gpio.input(echo) == 0:
        pulse_start = time.time()

    while gpio.input(echo) == 1:
        pulse_end = time.time()

    pulse_duration = pulse_end - pulse_start

    # Convert time to distance
    distance = pulse_duration * 17150
    distance = round(distance, 2)

    # Cleanup gpio pins & return distance estimate
    gpio.cleanup()
    return distance

def init():

    gpio.cleanup()
    gpio.setmode(gpio.BOARD)

    # Setup GPIO pin(s)
    gpio.setup(36, gpio.OUT) # Servo

    gpio.setup(31, gpio.OUT) # IN1
    gpio.setup(33, gpio.OUT) # IN2
    gpio.setup(35, gpio.OUT) # IN3
    gpio.setup(37, gpio.OUT) # IN4

    # Initialize pwm signal & move gripper to center position
    #pwm = gpio.PWM(36, 50)

    #return pwm

def take_img(camera, rawCapture, out, data, grip_state, dist):

    start = time.time()

    for frame in camera.capture_continuous(rawCapture, format="bgr",
use_video_port=False):

        # grab the current frame
        img = frame.array

        img = cv2.flip(img,-1)
```

```
        #for i in range(len(bbox)):
#                cv2.line(img,
tuple(bbox[i][0]),tuple(bbox[(i+1)%len(bbox)][0]), color=(0,0,255),thickness=4)

        dist = str(dist) + "cm"

        cv2.putText(img, data, (20,30),cv2.FONT_HERSHEY_SIMPLEX,1,(0,0,0),2)
        cv2.putText(img, dist, (500,30),cv2.FONT_HERSHEY_SIMPLEX,1,(0,0,0),2)

        if grip_state == half:
            cv2.putText(img, "Half-Opened",
(40,80),cv2.FONT_HERSHEY_SIMPLEX,1,(0,125,125),2)
        elif grip_state == open_full:
            cv2.putText(img, "Fully-Opened",
(40,80),cv2.FONT_HERSHEY_SIMPLEX,1,(0,0,255),2)
        elif grip_state == closed:
            cv2.putText(img, "Fully-Closed",
(40,80),cv2.FONT_HERSHEY_SIMPLEX,1,(255,0,0),2)

        # write frame into file
        out.write(img)

        # clear the stream in preparation for the next frame
        rawCapture.truncate(0)

        return img

def gameover():
    # Set all pins low
    gpio.output(31, False)
    gpio.output(33, False)
    gpio.output(35, False)
    gpio.output(37, False)

def forward(tf):
    init()
    # Left wheels
    gpio.output(31, True)
    gpio.output(33, False)
    # Right wheels
    gpio.output(35, False)
    gpio.output(37, True)
    # Wait
    time.sleep(tf)
    #
```

```
    # Send all pins low & cleanup
    gameover()
    #gpio.cleanup()

def reverse(tf):
    init()
    # Left wheels
    gpio.output(31, False)
    gpio.output(33, True)
    # Right wheels
    gpio.output(35, True)
    gpio.output(37, False)
    # Wait
    time.sleep(tf)
    # Send all pins low & cleanup
    gameover()
    #gpio.cleanup()

def pivotleft(tf):
    init()
    # Left wheels
    gpio.output(31, False)
    gpio.output(33, True)
    # Right wheels
    gpio.output(35, False)
    gpio.output(37, True)
    # Wait
    time.sleep(tf)

    # Send all pins low & cleanup
    gameover()
    #gpio.cleanup()

def pivotright(tf):
    init()
    # Left wheels
    gpio.output(31, True)
    gpio.output(33, False)
    # Right wheels
    gpio.output(35, True)
    gpio.output(37, False)
    # Wait
    time.sleep(tf)
    # Send all pins low & cleanup
    gameover()
```

```
    #gpio.cleanup()

def servo_cntrl(duty_cycle, pwm):

    pwm.stop()
    init()

    # Initialize pwm signal & move gripper to center position
    pwm = gpio.PWM(36, 50)

    pwm.start(duty_cycle)

    time.sleep(1)

    pwm.ChangeDutyCycle(duty_cycle)
    #time.sleep(2)

def key_input(event):
    # Initialize board
    #init()

    print("Key: ", event)
    key_press = event
    tf = 1

    if key_press.lower() == 'w':
        forward(tf)
    elif key_press.lower() == 's':
        reverse(tf)
    elif key_press.lower() == 'a':
        pivotleft(tf)
    elif key_press.lower() == 'd':
        pivotright(tf)
    elif key_press.lower() == 'p':
        gamestop()
    else:
        print("Invalid key pressed!!")

    return distance()

def main():

    # initialize the Raspberry Pi camera
    camera = PiCamera()
    camera.resolution = (640, 480)
```

```
    camera.framerate = 25
    rawCapture = PiRGBArray(camera, size=(640,480))

    # allow the camera to warmup
    time.sleep(0.1)

    gpio.cleanup()
    gpio.setmode(gpio.BOARD)

    # Setup GPIO pin(s)
    gpio.setup(36, gpio.OUT) # Servo

    # Initialize pwm signal & move gripper to center position
    pwm = gpio.PWM(36, 50)

    pwm.start(5)

    # Initialize variables
    start = time.time()

    # Initialize pins and pwm
    init()

    # Open video capture
    cap = cv2.VideoCapture(0)

    if (cap.isOpened() == False):
        print("Error reading video")

    # define the codec and create VideoWriter object
    fourcc = cv2.VideoWriter_fourcc(*'XVID')
    # fourcc = cv2.VideoWriter_fourcc(*'MJPG')
    out = cv2.VideoWriter('servo_action3.avi', fourcc, 3, (640, 480))

    frm_cnt = 0
    duty_cycle = 0
    data = ""
    grip_state = ""

    try:

        while True:
            time.sleep(1)
            dist = distance()
            print("Distance: ", dist, " cm")
```

```
            key_press = input("Select Driving Mode [w-forward, s-revert, a-
pivotLeft, d-pivotRight]: ")
            print("Drive Mode: " + key_press)

            if key_press == 'p':
                break
            key_input(key_press)
            dist = distance()
            img = take_img(camera, rawCapture, out, data, grip_state, dist)

            # Show resutls to the screen
            cv2.imshow("Distance", img)

            cv2.waitKey(0)
            cv2.destroyAllWindows()
            #key = cv2.waitKey(1) & 0xFF
            #time.sleep(3)
            check = input("Keep Driving? [y/n]: ")

            if check == 'n':
                while True:
                    grip_state = input("Servo duty cycle desired [2.5,7.5]: ")
                    data = "Duty Cycle: " + grip_state + "%"
                    print(data)
                    #duty_cycle = float(grip_state)


                    grip_state = float(grip_state)

                    servo_cntrl(grip_state, pwm)
                    time.sleep(1)
                    img = take_img(camera, rawCapture, out, data, grip_state,
dist)


                    # Show resutls to the screen
                    cv2.imshow("Servo motor status", img)
                    #time.sleep(3)
                    cv2.waitKey(0)
                    cv2.destroyAllWindows()
                    #cv2.waitKey(1) & 0xFF

                    result = input("Satisfied with grip [y/n]: ")

                    if result == 'y':
                        print("Satisified with grip")
```

```
                        break

                    print("Reselect duty cycle")

            # Break out of loop by pressing the q key
            # press the 'q' key to stop the video stream
            #if (key == ord("q")) or ( frm_cnt > 60):
            if (frm_cnt > 60):
                print("Terminating run as frm_cnt reached: " + str(frm_cnt))
                pwm.stop()
                gpio.cleanup()
                break
            frm_cnt +=1

    except KeyboardInterrupt:

        pwm.stop()
        gpio.cleanup()

        # Release video capture and video object
        cap.release()
        out.release()

        cv2.destroyAllWindows()

if __name__ == "__main__":

    main()
```

Video: https://youtu.be/Ul9XCR8DA-U

Question #2

Given

Gear Ratio: 1:120 = 1 wheel rev : 120 motor rev

Wheel radius: 65mm / 2 = 32.5mm = 0.0325 m

1 rev = 8 ticks

Required

a) How many **motor Revolutions** to move **1 meter** in straight line?
b) How many **encoder ticks** to move **2 meter** in straight line?

Solution

a) Calculating motor revolutions for 1 meter

Distance (s) = 1 meters

1 rev = 2 * pi * r = 2* 3.14 * 0.0325 m = 0.2041m => 1 rev = 0.2041m

⇨ 1 meter * $\frac{1\ wheel\ rev}{0.2041\ meter}$ * $\frac{120\ motor\ rev}{1\ wheel\ rev}$ = 587.95 motor rev ~= 588 motor rev

b) Calculating encoder ticks for 2 meters

As computed in part (a) above, 1 meters ~= 588 motor rev.

Encoder ticks when robot travels 2 meter straight will be

⇨ 2 meters * $\frac{588\ motor\ rev}{1\ meters}$ * $\frac{8\ encoder\ ticks}{1\ motor\ rev}$ = 9,408 encoder ticks

Question #3

Given

Robot Wheels = 2x

Gear Ratio: 1:53 = 1 wheel rev : 53 motor rev

Wheel radius: 14cm / 2 = 7cm = 0.07 m

Robot width: 30cm = 0.3m

Required

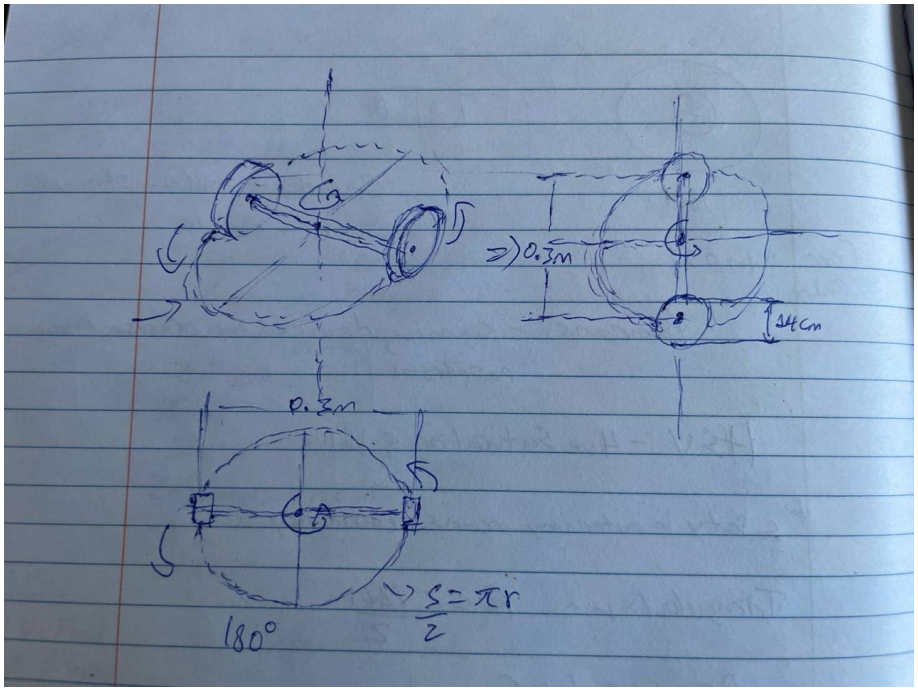
How many **motor Revolutions** of each motor are required for the robot to turn 180^0 in place?

Assumptions

- No wheel slip
- Identical motor hardware and performance for both motors

Solution

For the robot to turn 180 degrees with its center fixed at same point, the two motors need to rotate in the opposite direction from each other for a half circumference of the circular area between the two wheels. Therefore, the rotation needed per motor is computed below:



⇨ Distance traveled by each wheel = pi * r = 3.14 * (0.3/2) m = 0.471 m

⇨ Motor Rev / motor = 0.471m * $\frac{1\ robot\ wheel}{2 * 3.14 * 0.07\ \ m}$ * $\frac{53\ motor\ rev}{1\ robot\ wheel}$ = 56.79 motor rev ~ 57 motor revs