ISE 589 Spring 2023

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HW1

Problem 1.

We can use the formula for circumference of a circle to solve for the radius of the tracking wheel:

$$C = 2\pi r \quad (1)$$

where C is the circumference and r is the radius.

We know that the encoder generates 360 pulses per revolution, which means that each pulse corresponds to 1/360th of a revolution. Therefore, the number of revolutions of the tracking wheel can be calculated as:

number of revolutions = 18,000 pulses / 360 pulses per revolution = 50 revolutions

The distance travelled by 1 revolution =C = (5 m) / (50 rev)= 0.1 m

The distance traveled by the tracking wheel in one revolution is equal to the circumference of the circle, which is given by (1). We can rearrange this equation to solve for the radius:

$$r = C / (2\pi)$$

Now we can substitute the values we have:

$$r = (0.1 \text{ m}) / (2\pi) = 0.0159155 \text{ m}$$

Therefore, the radius of the tracking wheel is approximately 16 mm.

Problem 2.

a) The resolution of an 8-bit absolute encoder is 2^8, or 256 discrete positions. To achieve a resolution of 1 mm, we need to determine the distance that corresponds to one position of the encoder.

Let's assume that the robot has wheels with radius r. The distance traveled by the robot for one wheel revolution is equal to the circumference of the wheel, which is given by (1).

If the encoder has 256 discrete positions per revolution, then the distance that corresponds to one position of the encoder is:

distance per position = C / 256

To achieve a resolution of 1 mm, we want the distance per position to be 1 mm, so we can set up an equation:

$$1 \text{ mm} = C / 256$$

Solving for the radius of the wheel, we get:

$$C = 2\pi r$$

$$1 \text{ mm} = 2\pi r / 256$$

$$r = (1 \text{ mm}) \times 256 / (2\pi) = 40.74 \text{ mm}$$

Therefore, the robot would need wheels with a radius of approximately 40.74 mm to achieve a resolution of exactly 1 mm with an 8-bit absolute encoder.

b) The resolution of an absolute encoder depends on the number of bits used to encode the position. The number of positions that can be encoded by an n-bit encoder is 2^n. To achieve a resolution of 1 mm or higher for a wheel with a circumference of 10 cm, we need to determine the number of bits required to encode the position of the wheel.

The distance traveled by the wheel for one encoder count is equal to the circumference of the wheel divided by the number of encoder counts:

$$\text{distance per count} = C / 2^n$$

For a resolution of 1 mm or higher, we want the distance per count to be 1 mm or less, so we can set up an equation:

$$1 \text{ mm} \leq C / 2^n$$

Solving for the minimum number of encoder counts, we get:

$$2^n \geq C / 1 \text{ mm}$$

$$2^n \geq 100 / 1 \text{ mm}$$

$$2^n \geq 100$$

To encode 100 positions, we need a minimum of 7 bits, since 2^7 = 128. Therefore, to achieve a resolution of 1 mm or higher for a wheel with a circumference of 10 cm, the absolute encoder needs at least 7 bits.

c) Accumulated errors: "Dead reckoning" relies on the robot's wheel odometry to estimate its position, which means that any errors in the measurement of wheel rotation or the estimation of the wheel's size can accumulate over time and result in significant position errors. Additionally, any slip or skid of the wheels, or changes in the surface traction, can lead to further errors. Therefore, the position estimation will become increasingly inaccurate over time, and the robot's actual position may differ significantly from its estimated position.

Environmental changes: The robot's environment can change unpredictably, and these changes can cause significant errors in the estimated position. For example, if an object is moved in the room, the robot may not be able to detect the change and may continue to navigate based on its previous estimate, resulting in collisions or incorrect positioning. Similarly, changes in lighting conditions, reflections, or sensor interference can cause the robot's sensors to provide inaccurate readings, which can lead to incorrect position estimation. Therefore, "dead reckoning" is not a reliable approach for long-term position tracking and may need to be supplemented with other localization methods such as GPS or visual odometry.

Problem 3.

a)

Number	Binary code	Gray code
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101
10	1010	1111

b) When moving from number 7 to 8, the binary code changes by 3 bits, and the gray code changes by only 1 bit.

For binary code, there are 3 bits that change: the LSB changes from 1 to 0, the second bit changes from 1 to 0, and the third bit changes from 1 to 0.

For gray code, only 1 bit changes: the third bit changes from 0 to 1.

Assuming that for each bit change there is a chance for the encoder to misread, the total number of all possible results read by the encoder in binary code and gray code respectively when moving from number 7 to 8 can be calculated as follows:

For binary code: Since there are 3 bits that can change, there are 2^3 = 8 possible results that the encoder can read.

For gray code: Since only 1 bit can change, there are only 2 possible results that the encoder can read.

Therefore, when moving from number 7 to 8, the encoder reading can result in up to 8 possible values in binary code and up to 2 possible values in gray code, assuming a chance for the encoder to misread for each bit change.

c) In the example given in (b), when moving from number 7 to 8, the binary code changes by 3 bits, which means that there are 8 possible values that the encoder can read, assuming a chance for the encoder to misread for each bit change. This can lead to errors in the encoder reading and affect the accuracy of the position measurement.

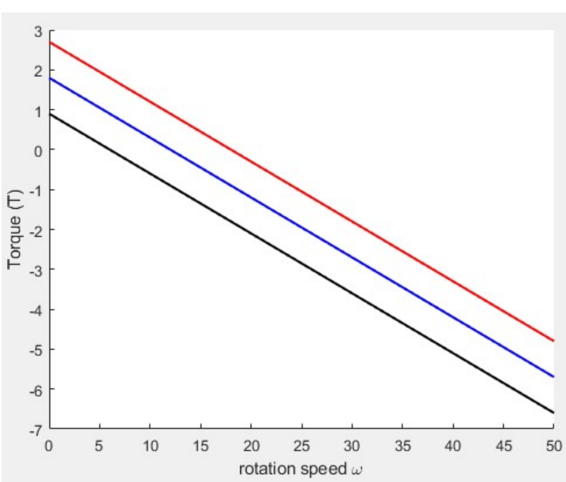
On the other hand, the gray code scheme changes by only 1 bit when moving from number 7 to 8, which means that there are only 2 possible values that the encoder can read, assuming a chance for the encoder to misread for the bit change. This reduces the likelihood of errors in the encoder reading and makes the gray code scheme more robust than binary code.

Furthermore, in gray code, only one bit changes between one segment and the next, which means that the transitions are more gradual and less prone to sudden changes or noise. This reduces the chance of errors in the encoder reading caused by noise or sudden changes in the signal.

Therefore, the gray code scheme is more robust than binary code in terms of accuracy and noise resistance, which makes it a preferred choice for position measurement applications where accuracy and reliability are critical.

Problem 4.

a) To determine the best motor for the conveyor belt system, we need to compare the torque output of each motor to the required torque of at least 2 Nm. Based on the given motor specifications, the best motor for the system would be Motor 2, which has a Torque Constant of 1.5 Nm/A, the highest value among all four motors.



b) The Torque Constant (Ke) measures the motor's efficiency and power output and affects its speed and acceleration. It is a critical parameter in motor control systems, used to determine the appropriate amount of current needed to produce a desired amount of torque. Higher values of Ke imply a more powerful motor but can also result in higher manufacturing costs.

c) The Back-EMF Constant (Kb) is a measure of the voltage generated by a motor when it is rotating. It impacts the system by providing information about the motor's speed and its ability to generate torque, which can be used to control the motor's performance and efficiency. Higher values of Kb result in higher motor speeds and better overall motor efficiency.

d) The terminal resistance (R) of a motor affects the amount of current that can flow through it and, in turn, impacts the motor's performance and efficiency. A higher value of R will result in less current flowing through the motor, which reduces its power output and torque. Additionally, a higher value of Rt can cause the motor to heat up more quickly, which can result in reduced lifespan and efficiency. Therefore, it is important to choose an appropriate value for R to ensure optimal performance and efficiency of the motor.

e) Based on the given specifications, Motor 3 has the highest Motor Constant value of 1.5 V-s/rad, making it the motor that can provide the maximum angular velocity.

It's important to note that the actual angular velocity of the motor will also depend on the applied voltage and the load on the motor. However, all other factors being equal, Motor 3 has the highest Motor Constant and can, therefore, provide the highest angular velocity among the given motors.

f) Increasing voltage in an electrical system can result in higher current flow, motor speed, and power output. However, exceeding the motor's rated voltage can lead to damage and reduced lifespan. It is crucial to supply voltage within the motor's rated voltage range for optimal performance and longevity.