Robot Design and Competition
EN-2532
Assignment 5

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1 Introduction

In this assignment, we are going to choose the necessary motors for the mobile robot. The mobile robot has to achieve many subtasks during the competition. The motors we choose must be capable of handling all those subtasks without failing. Therefore, we need a good understanding of the requirements of each task. So, in the document below, we have calculated each variable for each subtask individually. Finally, we have selected the necessary motors which can handle every task during the competition.

2 Governing

In this section, the general movement during the main task will be considered.

2.1 Assumptions and requirements

To calculate the parameters for the motor, we need many measurements and known values. For example, mass and position of the center of gravity. Since we haven't built the robot yet, reasonable assumptions must be made with rough calculations. Also, the designers' requirements for the robot should be considered when choosing the actuators. Top speed, top acceleration, and stall torque are some examples of designer requirements.

1. **Assumptions**

   I. **The mass**
   We have roughly calculated the total mass of the robot by summing up the values given on the internet. The rough value was $1.5kg$. But many components which we haven't decided can be a part. Therefore, we are assuming the maximum mass will be $2kg$.

2. **Requirements**

   I. **The top speed**
   To move between two distant points in the given dimensions in task v1.1, at least $30cms^{-1}$ linear speed is required.

   II. **Top acceleration/deceleration**
   The top speed must be achieved within a second. Hence, the top acceleration/deceleration must be $30cms^{-2}$.

2.2 Calculations

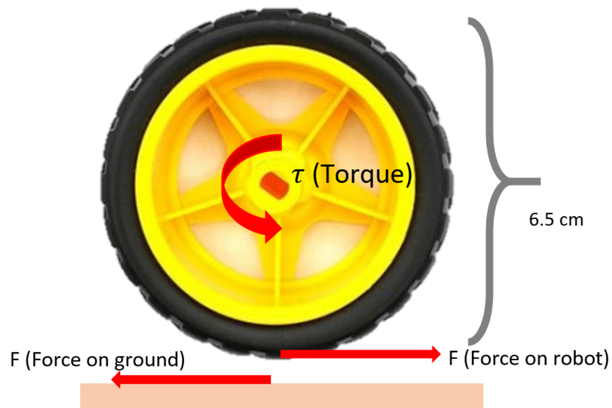

Figure 1: Force diagram

Derive equations,

$$\tau = F\frac{d}{2}(Nm)$$
$$\tau = 5.1020 \times Fd(kgcm)$$
$$RPM = \frac{v}{\pi d} \times 60$$
$$F = m \times a$$

Calculate the forces,

$$F_{max} = 2 \times 0.3 = 0.6N$$

$$\tau_{max} = 0.6 \times 3.25 \times 10^{-2}$$
$$\tau_{max} = 0.0195Nm = 0.198kgcm$$
$$RPM_{max} = \frac{30}{\pi \times 6.5} \times 60 = 88.147$$

Calculate power Requirements,

$$P = \tau \times \omega$$
$$P = 0.0195 \times \frac{2\pi \times 88.147}{60} = 0.1799Watts$$

3 Maze solving

For positioning, we are going to use static sensors directed to all four directions (left, right, front, back) respect to robot. No use of motors in this task.

Reason for that can be explained by referring to mechanism and motor characteristics.

If we had an approach where we use only one distance sensor and turning it to required directions

1. Rotation takes time
   The rotation profile of the sensor will contain a time period of accelerating and decelerating as well. So if robot would need to sense left after right, it must rotate 180 degrees, so will result in a **considerable delay to the process**.

2. Sensing data should be also mapped with direction data
   When the robot senses the distance, orientation (direction) of the sensor right at that

time should also be provided to the algorithm to do the calculations. For this purpose we must use an encoder (or Servo Motor). **This method comes with the price of "algorithmic complexity"**.

3. Additional pin requirements
   For motor control (speed, direction of rotation) and encoding, multiple pins will be required than affordable (with our pin budget).
   (If we use a Servo Motor, cannot neglect the vibrations!!!)

4. Power requirements are high
   Considering **this motor will be active in the whole maze solving part**, this will cause draining the battery unnecessarily.

5. Gear mechanism is needed
   Both **brushed dc and BLDC motors rotates too fast that the stopping point will be uncontrollable**. So using a gear mechanism is necessary to control the rotation of sensor-holder. (Sensor-holder will have a momentum when it's rotating)
   If the sensor rotate multiple revolutions, wires will get twisted around axel !!!

With all these problems we have to face with motor-controlled-sensor, **we are very much convinced that using static sensors covering all direction will do the job in an easy, faster and much simpler way**.(We covered all 3 motor types and their problems regarding using them in this task.)

4 Line Following Sub Task

In this task we need motors to drive the wheels of the robot to follow a line at a speed of around $3cm^{-s}$. The speed of the robot should not be very high as otherwise it will be difficult to take the turns / follow the curved lines smoothly. When selecting motors for this task we need to consider parameters such as force, weight, mass, torque, acceleration, and velocity. To move the robot forward the force is given by torque. Here the frictional force is ignored. Therefore, this task can be achieved by using Governing motors. **For this task there is no need of using motors for the operation of the sensors**.

5 Ball Shooting

Assume that we want to shoot the ball in a way such that, the ball stops after reaching the start line of goal post. That means the ball need to travel at least 0.9m to stop. The reason for ball to stop is the friction by the surface and we don't know what the **friction coefficient** μ is.

Let's assume that in the worst case, only 20% of the kinetic energy from the rod transfers to the ball and only 20% from that value remains after reaching the goal post due to the friction on ball. Other kind of energy transformations are neglected.

Take mass of the rod $M = 100g$, length of the rod $L = 10cm$, Let's say we want to reach the goal with a speed of $0.4ms^{-1}$.

$$E_{start} \times \frac{20}{100} = E_{end}$$

$$\frac{1}{2}mu^2 \times \frac{20}{100} = \frac{1}{2}mv^2$$

$$u = \sqrt{5} \times v = 0.4 \times \sqrt{5} = 0.8944ms^{-1}$$

Now we will find the rotational kinetic energy of the rod.

$$E_\omega \times \frac{20}{100} = E_{ball}$$

$$\frac{1}{2}I\omega^2 \times \frac{20}{100} = \frac{1}{2}mu^2$$

$$\frac{1}{3} \times ML^2\frac{\omega^2}{5} = mu^2$$

$$\frac{1}{3} \times 0.1 \times 0.1^2 \times \frac{\omega^2}{5} = 2.7 \times 10^{-3} \times 0.8944^2$$

$$\omega = 5.6919rad.s^{-1}$$

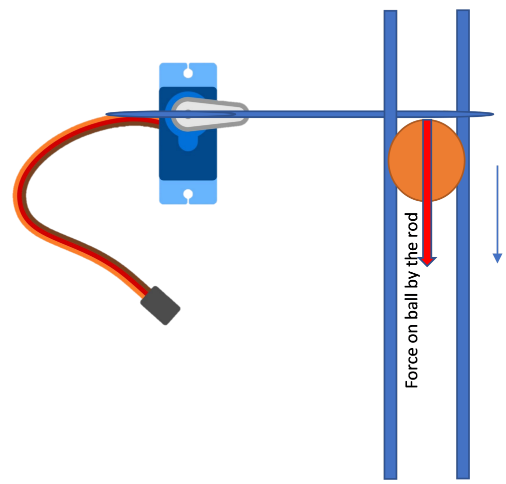

Figure 2: Back Panel IO Ports

Now the angular velocity of the SG90 servo motor with loaded conditions is $2\pi rads^{-1}$. Therefore, the **SG90 is a good choice for this task**.

6 The Bridge

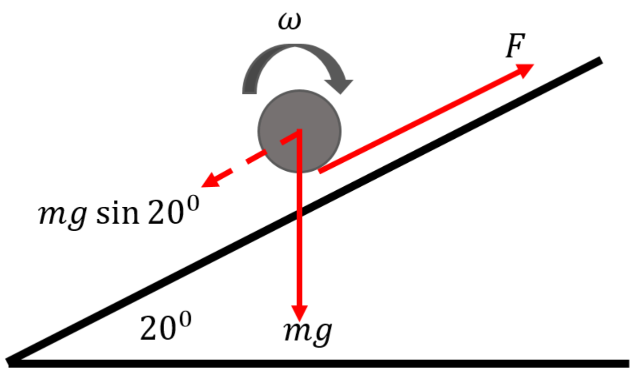

Figure 3: Bridge

6.1 Assumptions and requirements

1. **Requirements**
   When the robot goes through the inclined surface, we need a minimum speed of $5cms^{-1}$.

6.2 Calculations

Now, in this scenario, the robot must move along the inclined path,

$$F > mg\sin 20 = 2 \times 9.8 \times 0.342$$

$$\tau > F\frac{d}{2} = 6.703 \times 3.25 \times 10^-2$$

$$\tau > 0.2178Nm = 2.222kgcm$$

Calculating the minimum RPM,

$$RPM = \frac{5}{\pi \times 6.5} \times 60 = 14.69$$

$$\omega = 2\pi \times \frac{14.69}{60} = 1.5384rads^{-1}$$

Calculate the power requirement,

$$P = \tau \times \omega$$

$$P > 0.2178 \times 1.5384 = 0.3350Watts$$

7 Final Specification of the motor

Now suitable motors must be selected according to the above calculations. Mainly, we have 4 types of motors (BDC, BLDC, STEPPER, SERVO).

7.1 Governing

For the general movement, the requirements are,

$$RPM_{max} = 88.147$$

$$\tau_{min} = 2.222kgcm = 0.2178Nm$$

$$P_{min} = 0.3350W$$

For the general movement, the requirements are those. Hence, the servo motor is eliminated due to its limited angle, BLDC is eliminated due to high power and high RPM, the stepper motor is eliminated due to high vibration and mass. These are two motors that match our criteria.

Figure 4: Standard plastic gear motor

- Rated Voltage : 3 6V
- Operating Speed (6V): 200+/- 10% RPM
- Stall Torque (6V) : 1.1kg.cm
- Torque : 0.15Nm 0.60Nm

Figure 5: ZGA25RP model

- Rated Voltage : 12V
- Operating Speed (12V): 200 RPM
- Stall Torque (12V) : 3.5kg.cm
- Torque : 3 Kg.cm

Between these two motors, ZGA25RP model is selected due to its good performance. The other one was eliminated because its stall torque is in the margin of our requirement.