e-Yantra Robotics Competition

eYRC-BB#2403

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Think and Answer

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Instructions:

- Maximum **30 marks** will be awarded
- There are no negative marks
- Write your answer in given space only. Suggested n**umber of lines** will be taken seriously at the time of evaluation
- **Unnecessary explanation** will lead to less marks even if answer is correct
- Use the same **font and font size** for writing your answer

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Q1:

Explain angular velocity. How is it important while making Balance Bot?

(3+3 lines: 2 + 2 marks)

Answer:

Angular velocity is the angular speed, at which an object is rotating, in the direction of its rotation. It can expressed mathematically as the **rate of change of angular displacement** or $\omega = \frac{d\theta}{dt}$, where θ is the central angle which changes during the course of rotation.

The **gyroscope sensor** we use, gives the **output in terms of angular velocity**, when the Bot tilts forward and backward. Integrating this over discrete time, we can **obtain the pitch angle** of the Balance Bot to compensate the rotation offset and keep the Bot upright using suitable techniques.

Q2:

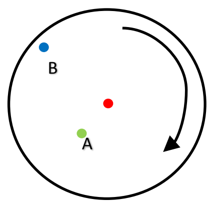

Figure 1

A disk with a diameter of 100 cm (Figure 1) is rotating with speed of 1 revolution per 2 seconds. Point A and point B are located at 10 cm and 45 cm away from the center respectively. What will be the linear and angular velocity of point A and point B? Give your answer in both meter/second and radian/second.

(1+1 marks)

Answer:

Point A

Linear Velocity: **0.3142 meter/second**

Angular Velocity: **3.1416 radian/second**

Point B

Linear Velocity: **1.4137 meter/second**

Angular Velocity: **3.1416 radian/second**

Q3:

Consider an object falling under gravitational force. What will be the instantaneous velocity of the object after 5 seconds from the start of fall? Show steps for calculation and then state the answer.

(1+1 marks)

Answer:

Time (t) = 5 s

Initial Velocity (u) = 0 m/s

Acceleration (a) = g = 9.8 m/s^2

$$Final\ Velocity\ (v) = u + \ at$$

Substituting,

v = 0 + 9.8 m/s^2 x 5 s

v = 49 m/s

Hence, final instantaneous velocity (v) = 49 m/s

Q4:

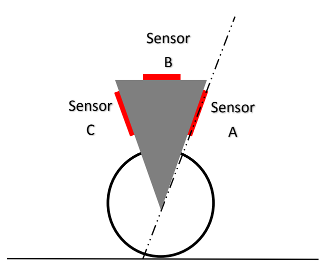

Figure 2

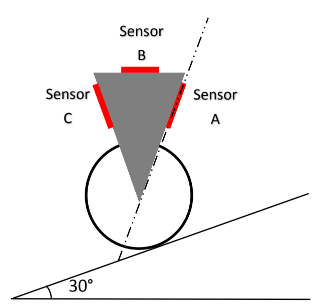

Figure 3

A self-balancing system is shown in Figure 2 and Figure 3. Sensor-A shows 80° angle, when the system is balanced on a plane surface as shown in Figure 2. What will be the value of Sensor-A, if the same system is placed on a 30° inclined surface as shown in Figure 3 in balanced state?

(1 line: 2 marks)

Answer:

Value of Sensor-A in the balanced state = **80°**

Q5:

Explain gyroscope in brief (No marks for definition)

(5 lines: 3 marks)

Answer:

A gyroscope is a device used to measure the angular velocity in the X, Y, and Z directions, using which we can calculate its orientation. In mechanical systems, it consists of a rotor mounted on a series of concentric rings with different axes of rotation. In the L3G4200D, a micro mass is placed at the center of a vibrating element (MEMS), where rotations lead to Coriolis force. A change in the direction of vibration causes changes in the capacitance between the various arms. Thus, the angular velocity can be measured.

Q6:

Compare accelerometer and gyroscope for measuring an angle.

(Up to 5 valid points of comparison: 5 marks)

Answer:

Accelerometer	Gyroscope
Accelerometer measures the acceleration due to gravity when static, using which, we can compute the orientation angle.	Gyroscope measures the angular velocity around a particular axis which needs to be integrated over discrete time to find the angle.
Using two axis: $$\theta = arctan(\frac{-X_g}{Z_g})$$ Using three axes: $$\theta = arctan(\frac{X_g}{\sqrt{Y_g^2 + Z_g^2}})$$	Pitch angle can be calculated by just measuring the angular velocity around Y-axis alone. $$\theta = (Angular\ Velocity) * (Delta) + \theta_p$$ Where, $$Delta = Current\ Time - Last\ Time$$ $$\theta_p = Previous\ Pitch\ Angle$$
Since it measures the accelerations, it also measures the vibrations, which may gave us false readings for the angle.	Since it measures angular velocity alone, it is unsusceptible to vibrations caused.
Angle measurement has a slow response time.	Angle measurement has a faster response time.
Precise calculation of average angle over a period of time. Hence, it is suitable for static angle calculation.	Increase in calculation (integration) error over longer periods or drift. It is suitable only for instantaneous in-motion angle calculations.

Q7:

Other than Accelerometer and Gyroscope which sensor can be used to measure the angle in balance bot? Justify your answer.

(5 Lines: 1 + 1 marks)

Answer:

A **gravity rotation sensor** (rotary potentiometer) can be used for angle measurements by interfacing the knob, at the bottom of the upright body of the robot, so that the knob rotates with the forward and backward motion of the body. This generates an analog voltage corresponding to angle of rotation of the robot. Since the robot has less than 180^{o} of rotation at all times, this is feasible and by implementing feedback, the voltage can be maintained with its in balanced (quiescent) value.

Q8:

Why do we require complementary filters to calculate angle using accelerometer and gyroscope? Give one example/application where complementary filter is not required.

(10+2 lines: 4+1 marks)

Answer:

An **accelerometer** measures all forces/accelerations on the object including the forces that drive the system (motor). So, in motion, it is affected by acute noise (vibrations) which may give us false angle computations even when there is no rotation (*High frequency noise*). It also has a slow response time.

Whereas, in a **gyroscope**, measurement is not susceptible to external forces, but it has tendency to drift, not returning to zero when the system comes back to original position, which has a cumulative effect, and thus, is accurate for short term measurements (*Low frequency noise*). It has a faster response time.

A **complimentary filter** is used to remove both of these noises. A low pass filter and a high pass filter is combined to fuse the pitch angles calculated by the accelerometer and gyroscope readings as follows:

$$angle = \alpha * (angle + gyro\_rate * dt) + (1 - \alpha) * (accel\_angle)$$

If an application tends to be oriented towards one sensor, such as accident detection for airbag deployment or free fall detection (sudden accelerations), then the complimentary filter is not required.

Q9:

Other than complementary filter for angle measurement using accelerometer and gyroscope, which technique can be used to calculate tilt angle in balancing a robot?

(2 lines: 1 mark)

Answer:

Tilt angle in can also be calculated using the **Kalman Filter**, which implements an algorithm to estimate an accurate angle using a dataset of noisy angle calculations, but requires more processing time.

Q10:

Explain the term “free fall detection” (Refer ADXL345 data sheet).

(5 lines: 3 marks)

Answer:

The accelerometer measures the accelerations in terms of g. When the accelerometer is static, either one of the axes will read a value of 1g in the direction of gravity. When all the axes read 0g, there is a good chance that the object is under free fall. In ADXL345, the *FREE_FALL* bit in the interrupt is set when acceleration on all axes is less than the value of *THRESH_FF* register for a time more than *TIME_FF* register. *THRESH_FF* holds the minimum threshold value, whereas *TIME_FF* holds minimum time for free fall detection to be triggered.

Q11:

Which sensor among accelerometer and gyroscope can be used to measure vibration of a surface?

(1 line: 1 mark)

Answer:

Accelerometer is well adapted to measure the vibration of a surface as it measures accelerations.