Modeling and Simulation of MEMS based 3D Vibrating Gyroscope for Mobile Robotic Applications

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Overview

- **A biomimetic vibrating 3D MEMS Gyroscope was modeled and simulated using COMSOL Multiphysics 4.1. The simulated results show that the displacement due to Coriolis effect, used for restoring the body back to its initial position, was greater when compared to that of the electrostatic force. These results let us to conclude that this gyroscope would provide valuable orientation information for robotic applications.**

Contents

Gyroscope

- Angular rate sensors or angular velocity sensors
- Senses rotational motion
- Detects changes in orientation
- Used for guidance and control.

Types of Gyroscope

- **Spinning Gyroscope**
- **Optical Gyroscope**
- **Vibrational Gyroscope**

Vibrating Gyroscope

- Use vibrating mechanical elements to sense rotation, which contains no rotating parts
- Coriolis Effect – Newton's third law

Principle

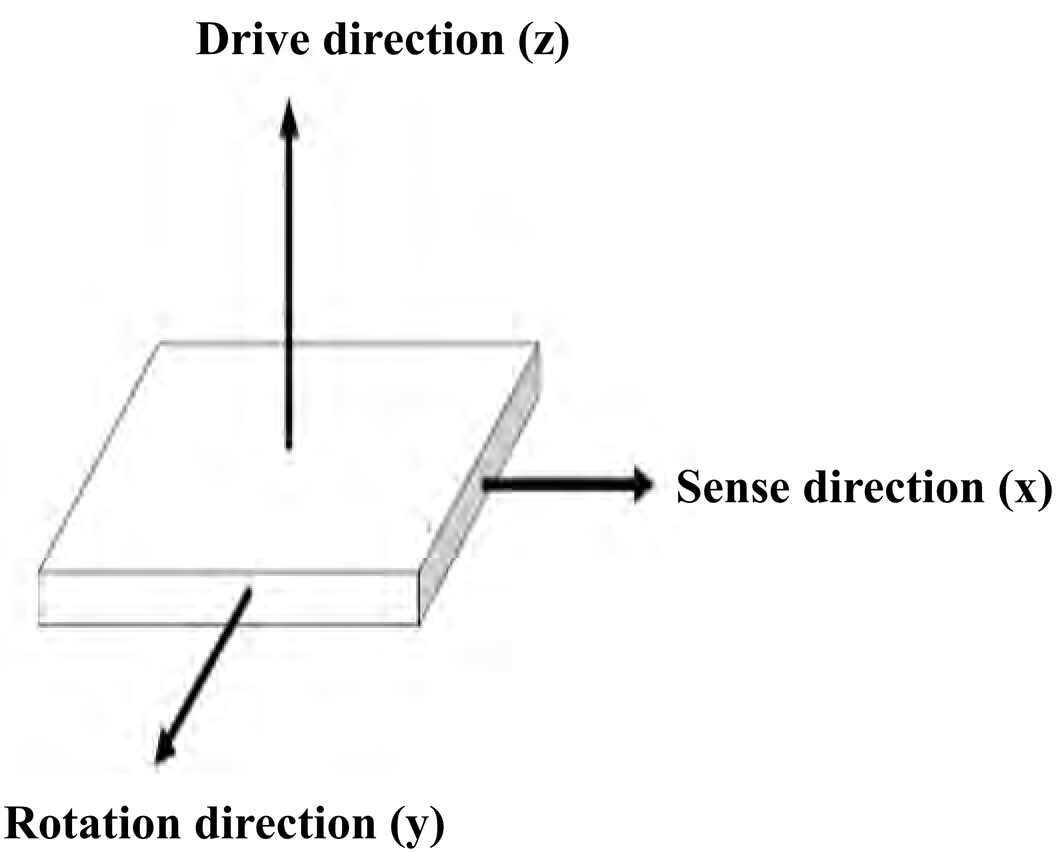


Fig.1 Basic principle of gyroscope

- Device rotating along rotational (y) axis
- Drive force applied in (z) axis
- Coriolis force induced in sense direction (x), perpendicular to drive and rotational direction

Coriolis Force

- **Force exerted on a body when it moves in a rotating reference frame**

$$F_c = -\,2m\,(\omega \times \upsilon)$$

- **Acts perpendicular to rotation axis and velocity of body in rotating frame**
- **Proportional to rotation rate**

How it works?

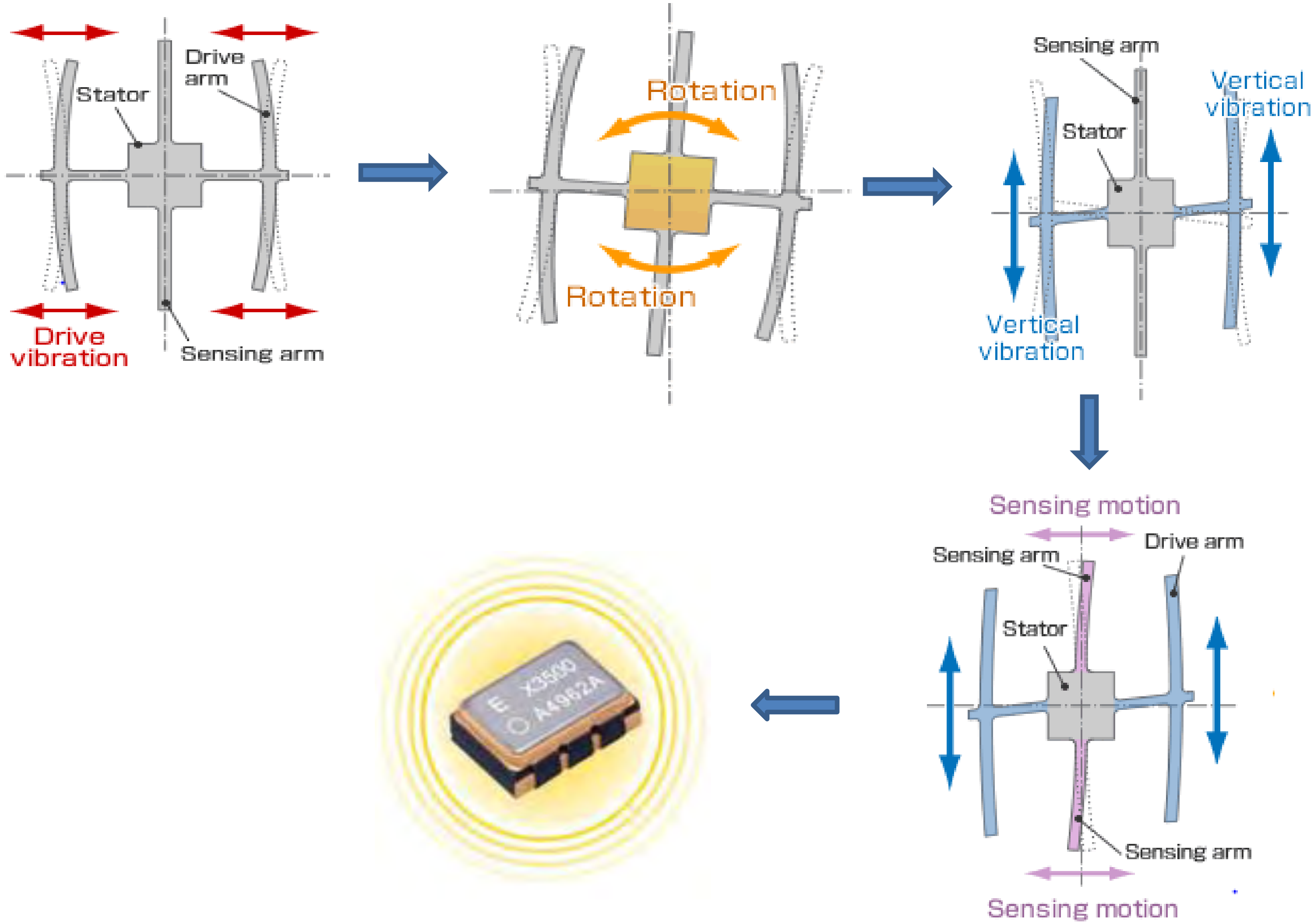


Fig.2 Illustration of a vibrating gyroscope

Why MEMS Vibrating Gyroscope?

- **Small**
- **Lightweight**
- **Inexpensive**
- **Higher resolution**

Robot Balance Control

Moving forward, demand for vibration gyros is expected to grow in areas such as vehicle driver safety and support systems, and in robot motion control.

- **Closed-loop control system**
  - **To maintain prescribed vibration**
  - **For reorientation**

- **Senses vibration produced by external factors, and transmits vibration data as electrical signals to a CPU**

Biomimetic approach

- **Flies-(*Drosophila, Calliphora vicina)*-halteres**
- **Halteres-**
  - **Evolutionary modified hind wings which beat antiphase to the wings**
  - **Serve a sensory function during flight**
  - **Sensitive to Coriolis force during rotational movements**
- **Campaniform sensilla**

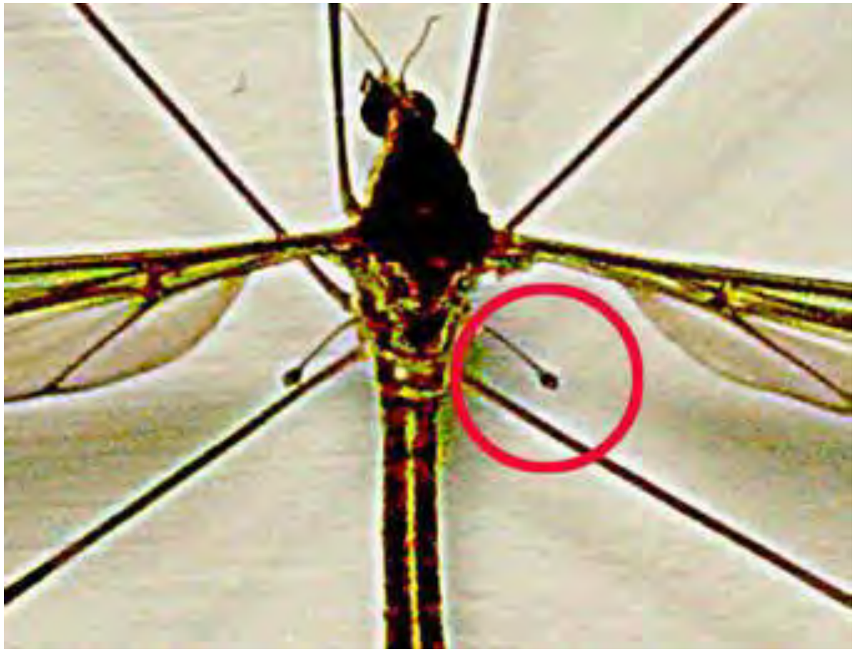


Fig.3 Haltere of an insect

Structural Design

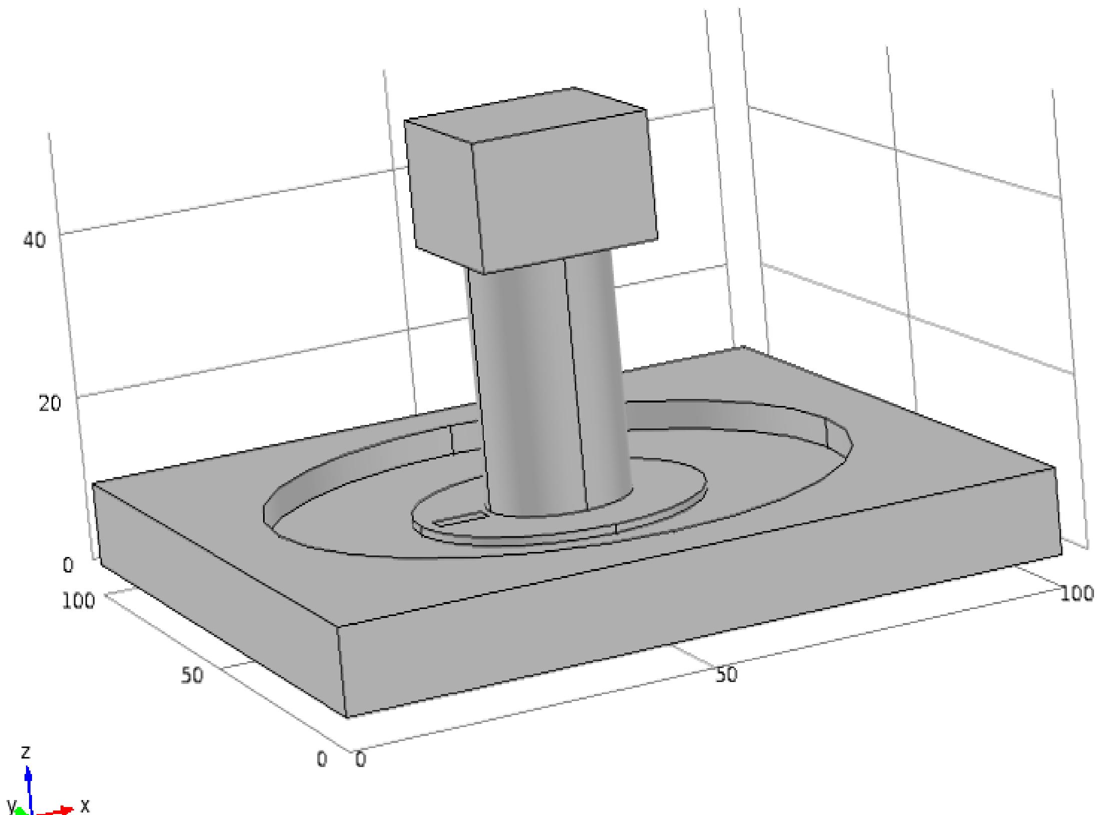


Fig.4 Adopted 3D model

Simulation Results

Displacement due to Electrostatic and Coriolis Forces

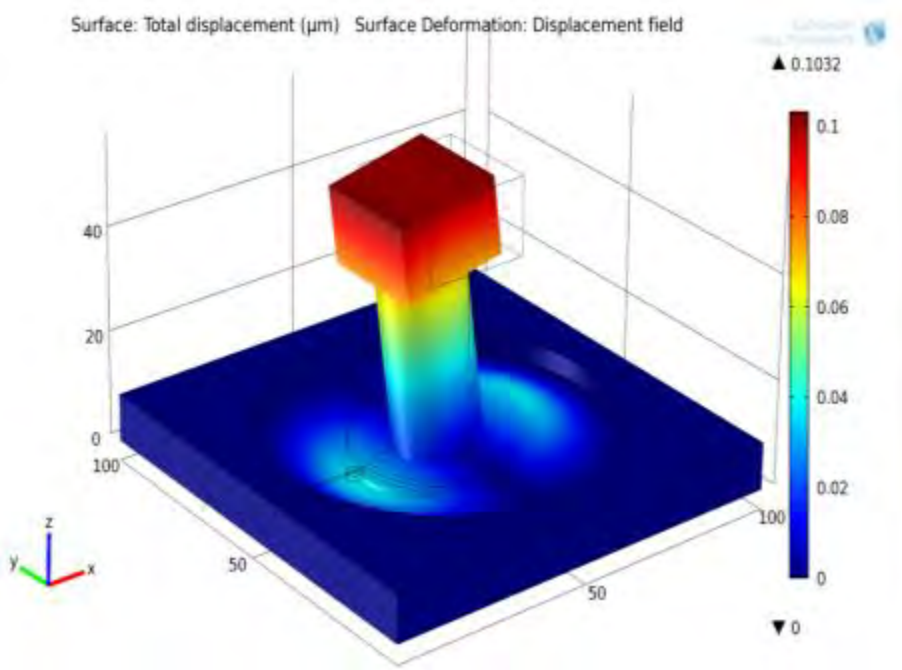


Fig.5(a) Displacement field due to Electrostatic force

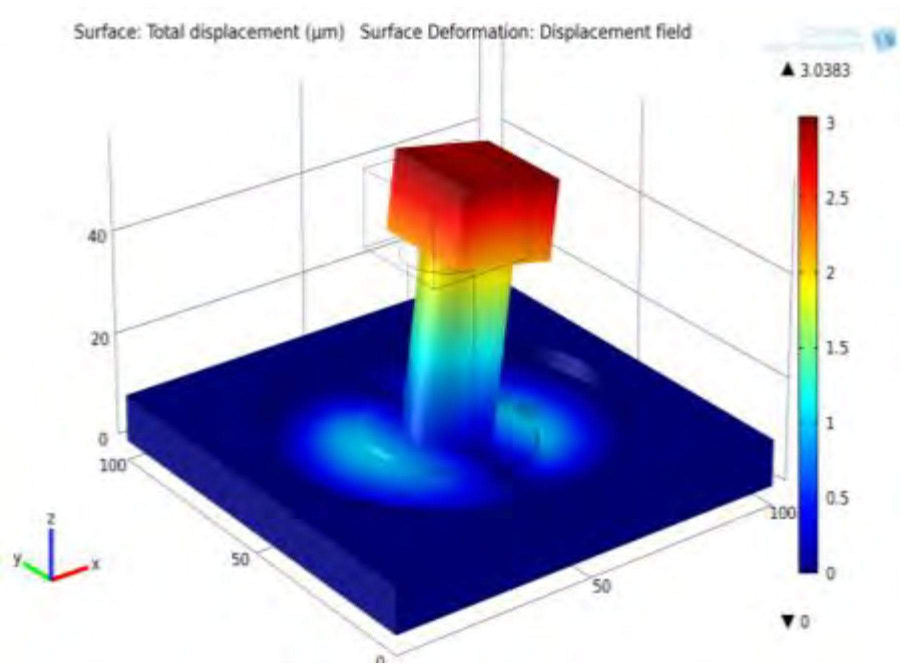
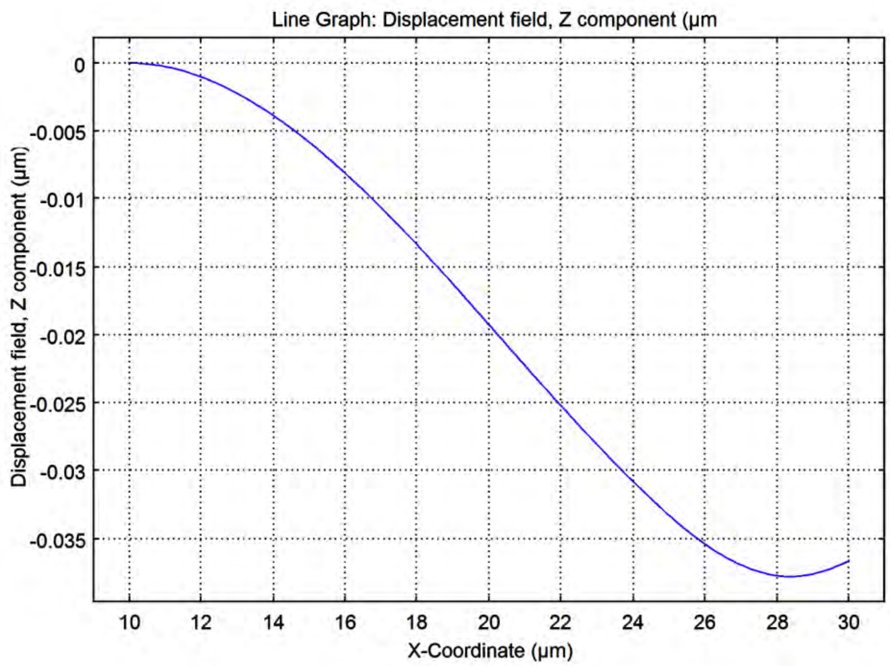


Fig.5(b) Displacement field due to Coriolis Force

Z axis displacement field in the thinner membrane



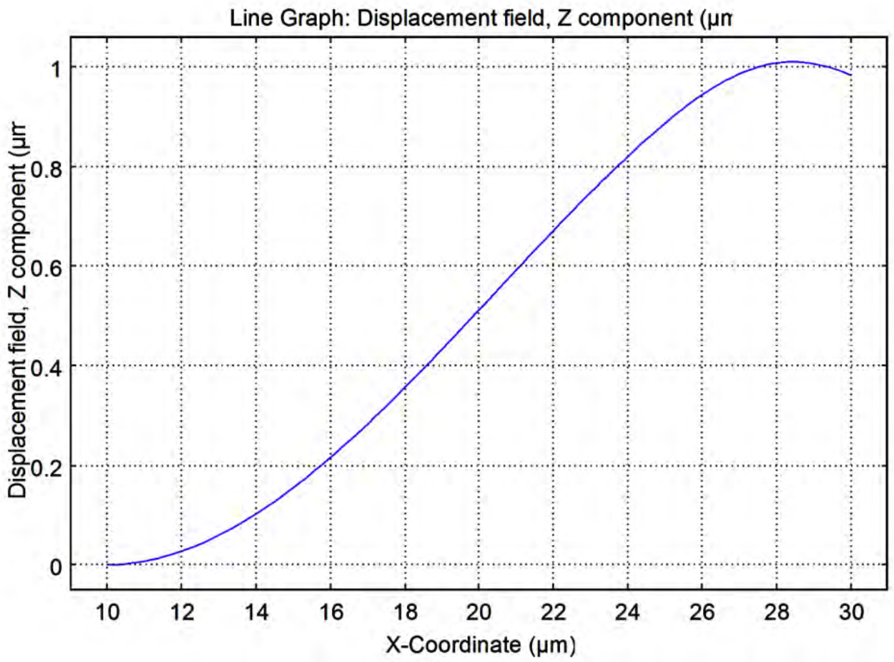


Fig.6 (a) Graphical representation of displacement field due to Electrostatic Force

Fig.6(b) Graphical representation of displacement field due to Coriolis Force

Sensing Methodologies

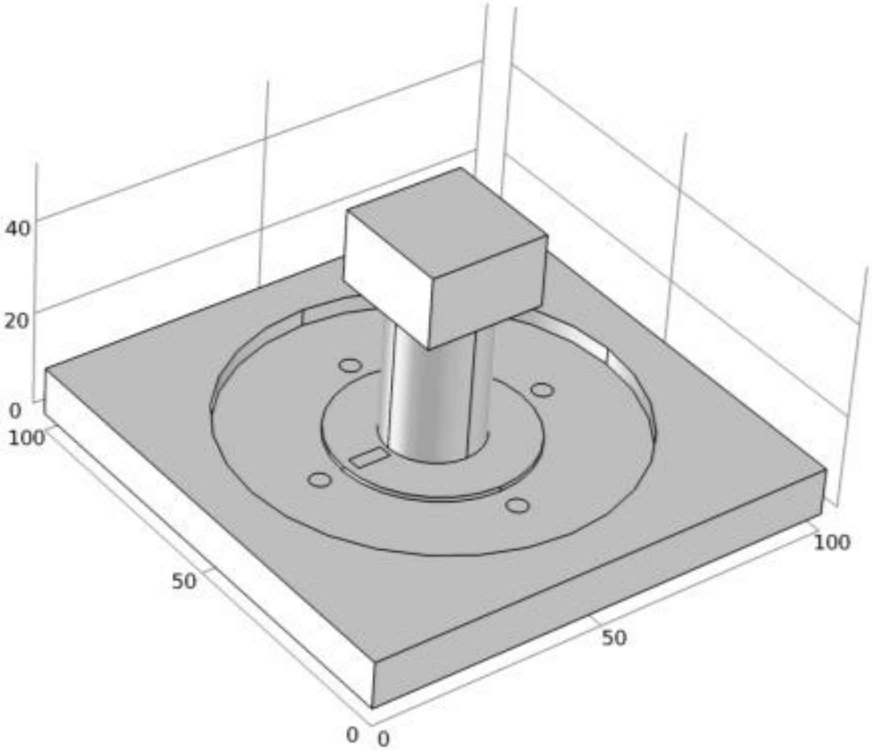


Fig.7(a) Piezoelectric Sensing

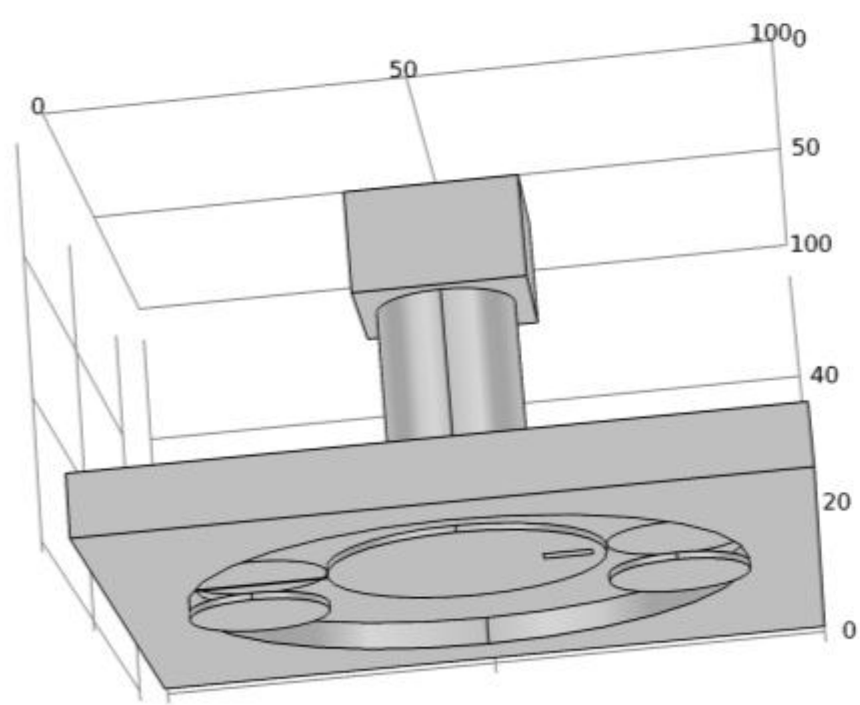


Fig.7(b) Capacitive Sensing

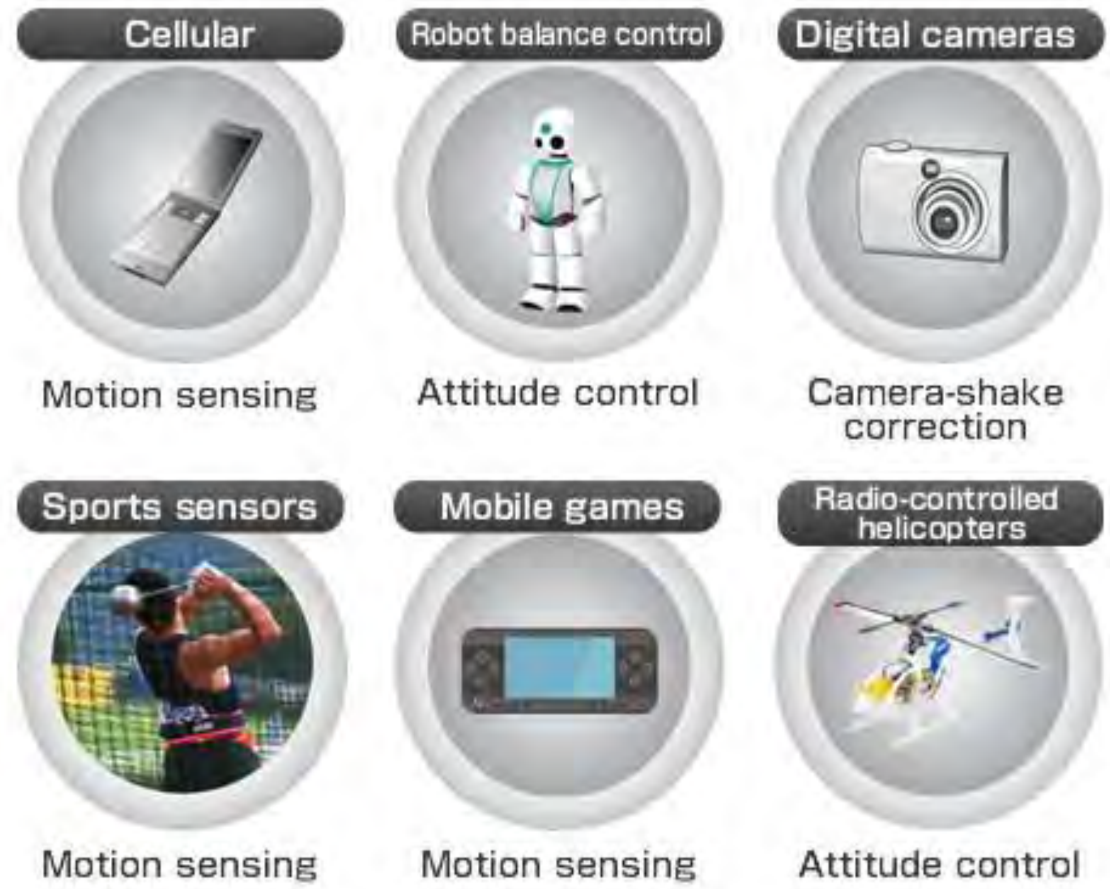
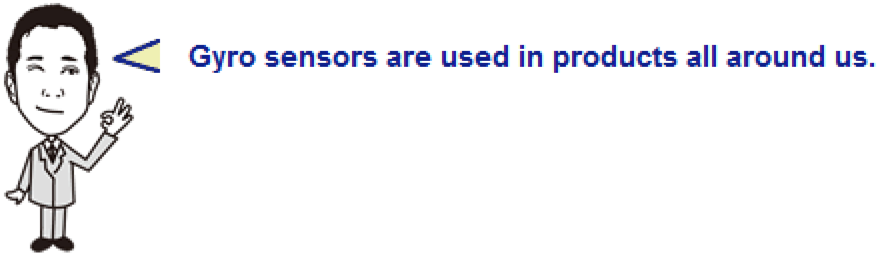


Fig.8 Applications



Conclusion

- **Displacement due to Coriolis effect, used for restoring the body back to its initial position, was greater when compared to that of the electrostatic force.**

- **Provides valuable orientation information for robotics applications.**

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