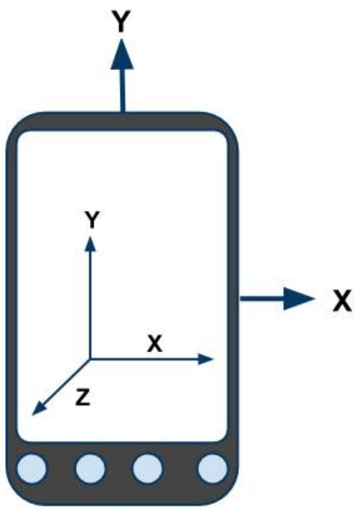
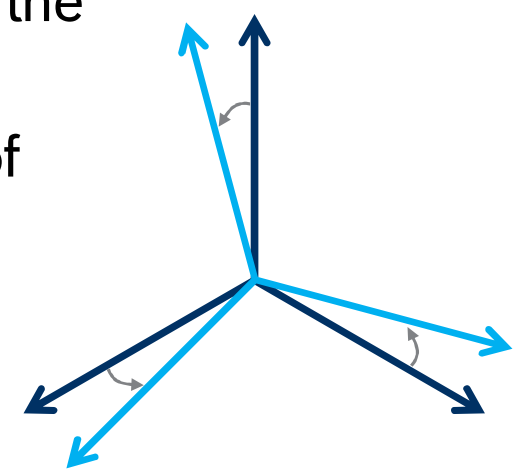
Tilt Compensation

- The horizontal component of the Earth's magnetic field is used to compute the magnetic heading.
- Pitch and Roll are the tilt angles along X and Y axis.
- These tilt angles influence the magnetic field along XY axis.
- When the device is not horizontal, ,i.e. tilt angles are non zero, the heading calculation will be incorrect.
- We need to ensure that tilt angles are compensated before orientation calculation.
- The tilt angles must be compensated before orientation calculation by rotating the XY plane with the help of accelerometer.



Orientation description

- Orientation of an object describes how it is placed in the 3D space.
- Typically the orientation is given relative to a frame of reference specified by a coordinate system.
- At least three independent values as parts of a 3-dimensional vector are needed to describe the orientation, All the points of the body change their position during a rotation except for those lying on the rotation axis.
- BSX provides Euler angles, Directional Cosine Matrix(DCM) and quaternion to measure the orientation of the device .

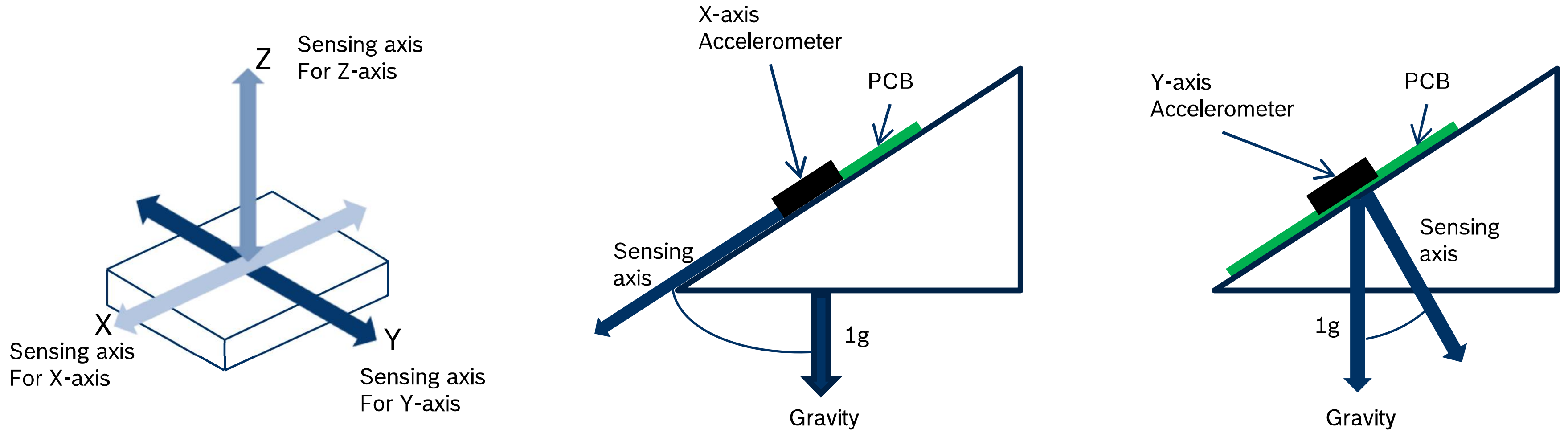


Euler Angles

- Three reference frames that could rotate one around the other by starting with a fixed reference frame and performing three rotations

- These are the three angles knows as Roll, Pitch and Heading (yaw)

- Roll and pitch are calculated with the assistance from accelerometer after dynamic suppression and heading using the magnetic field strength from magnetometer

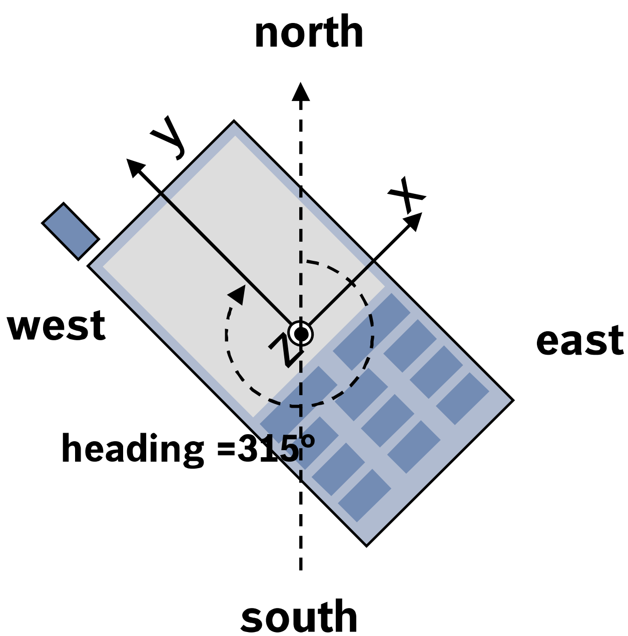


BOSCH

BSXlite - Sensor Fusion Software

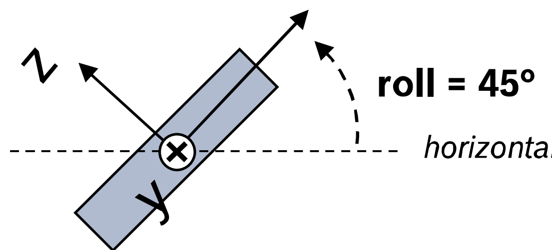
3D Inclinometer Yaw is the angle between the magnetic north direction and the y-axis, around the z-axis. Heading ranges from 0° to 359° (0=North, 90=West, 180=South, 270=East).

This output is required only for Windows 8.There is no change in 3D Inclinometer Yaw when there is change in Roll & Pitch



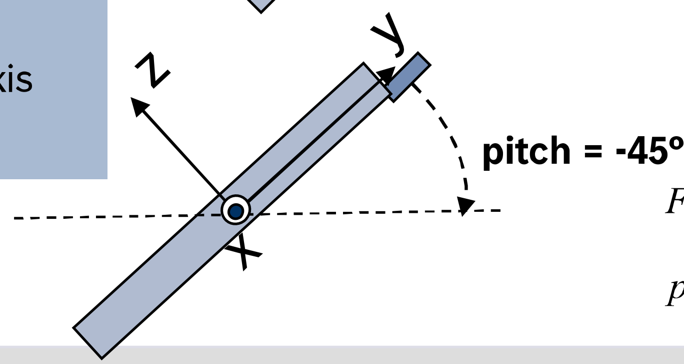
Heading is the angle between the magnetic north direction and the y-axis, around the z-axis. Heading ranges from 0° to 359° (0=North, 90=East, 180=South, 270=West).

$$heading = \arctan(-\frac{Hxc}{Hyc})$$



Roll is defined as the rotation around Y axis (-90 to 90), with increasing values when the x-axis moves toward the z-axis.

$$roll = \arctan(\frac{a_x}{\sqrt{a_y^2 + a_z^2}})$$



Pitch is defined as the rotation around X axis (-180 to 180), with increasing values when the z-axis moves toward the y-axis for Android.

For Windows

$$pitch = \arctan(-\frac{a_y}{a_z})$$

For Android

$$pitch = \arctan(\frac{a_y}{a_z})$$

Quaternion

- Any rotation in three-dimensions can be represented as an axis vector and an angle of rotation.
- 4D vector representing object orientation in space and avoids the problem of gimble lock (refer to http://en.wikipedia.org/wiki/Gimbal_lock).
- Also known as orientation quaternions or attitude quaternions.

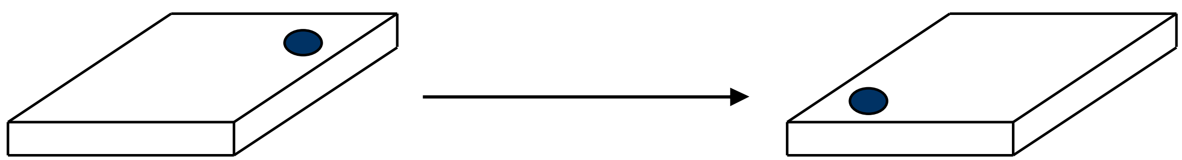
$$\vec{q} = (w, x, y, z)$$
$$\vec{v} = (x, y, z)$$
$$\vec{q} = (s, \vec{v})$$

$$w = cos(\alpha/2)$$
$$x = u_1 \cdot sin(\alpha/2) \rightarrow s = cos(\alpha/2)$$
$$y = u_2 \cdot sin(\alpha/2) \rightarrow \vec{v} = sin(\alpha/2) \cdot \vec{u}$$
$$z = u_3 \cdot sin(\alpha/2)$$
$$\vec{u} \ldots rotation\ axis$$
$$\alpha \ldots rotation\ angle$$

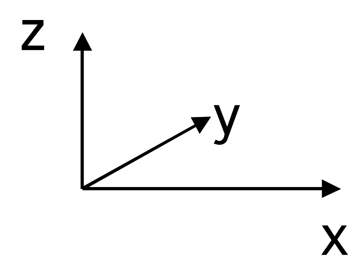
BOSCH

Describing rotation with quaternion

Device orientation



Reference orientation



- ➔ Rotation axis → z-axis → $\vec{u}$= (0, 0, 1)
- ➔ Rotation angle → alpha = 180°

$$w = \cos(180°/2) = 0$$

$$x = 0 \cdot \sin(180°/2) = 0$$

$$y = 0 \cdot \sin(180°/2) = 0$$

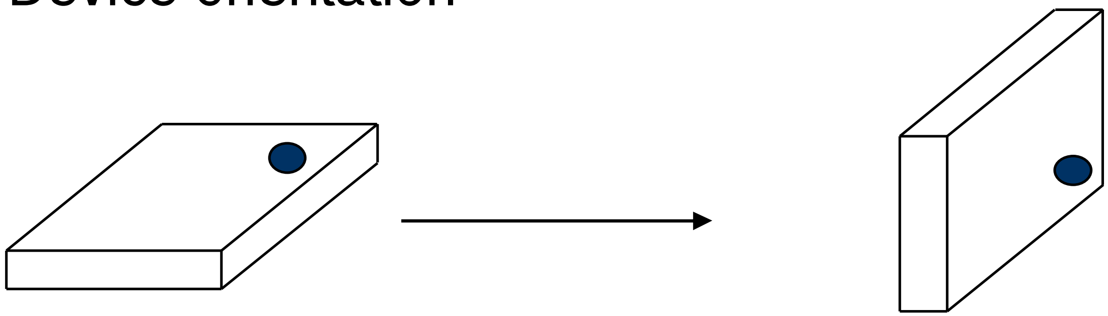
$$z = 1 \cdot \sin(180°/2) = 1$$

$\vec{q}$ = (w, x, y, z) = (0, 0, 0, 1)

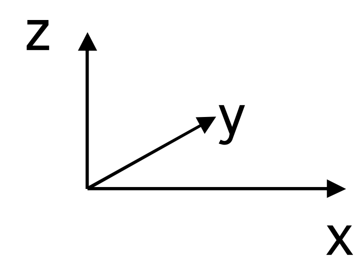
Example 1

Describing rotation with quaternion

Device orientation



Reference orientation



- ➔ Rotation axis → y-axis → $\vec{u}$= (0, 1, 0)
- ➔ Rotation angle → alpha = 90°

$$w = \cos(90°/2) = \frac{\sqrt{2}}{2} = 0.701$$

$$x = 0 \cdot \sin(90°/2) = 0$$

$$y = 1 \cdot \sin(90°/2) = \frac{\sqrt{2}}{2} = 0.701$$

$$z = 0 \cdot \sin(90°/2) = 0$$

$\vec{q}$ = (w, x, y, z) = (0.701, 0, 0.701, 0)

Example 2

BOSCH