



Robotics

Mobile Robots Navigation

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Dead reckoning

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Dead reckoning also known as deduced reckoning estimates current position as original position plus integration of all moves since then.

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odometry

Doppler shift method

inertial navigation



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odometry

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Doppler shift method

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inertial navigation

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Triangulation - angles

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odometry

Doppler shift method

inertial navigation

Triangulation - angles

Triangulation - distances

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Odometry relies on measurement of wheel rotation (two or more wheels) or wheel rotation and heading angle. Problem is the accumulation of errors.

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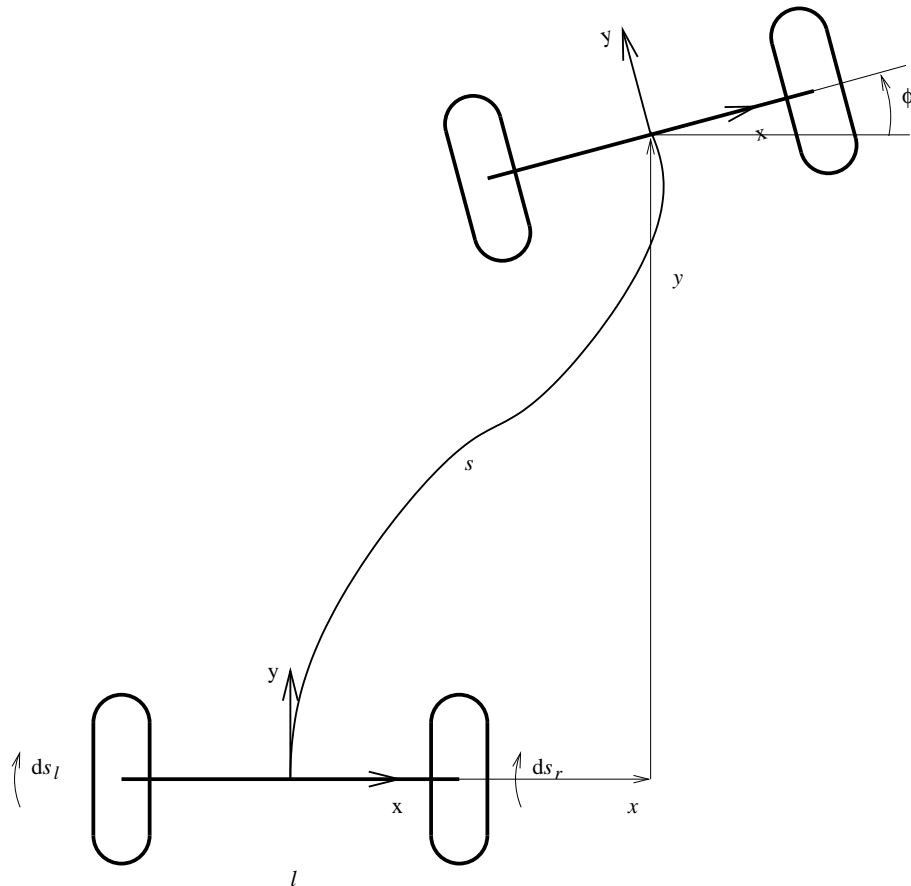
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$$d\phi = 2 \frac{ds_l - ds_r}{l}$$

$$dx = \cos \phi ds$$

$$dy = \sin \phi ds$$

$$x = \int_0^s \cos \phi ds$$

$$y = \int_0^s \sin \phi ds$$

$$v_l = \frac{ds_l}{dt}$$

$$v_r = \frac{ds_r}{dt}$$

$$d\phi = \frac{ds_l - ds_r}{l}$$

$$v = \frac{v_l + v_r}{2}$$

$$dx = v \cos \phi dt$$

$$dy = v \sin \phi dt$$

$$x = \int_0^t v \cos \phi dt$$

$$y = \int_0^t v \sin \phi dt$$

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Inertial navigation relies on the integration of the longitudinal and angular acceleration measurement and its integration.

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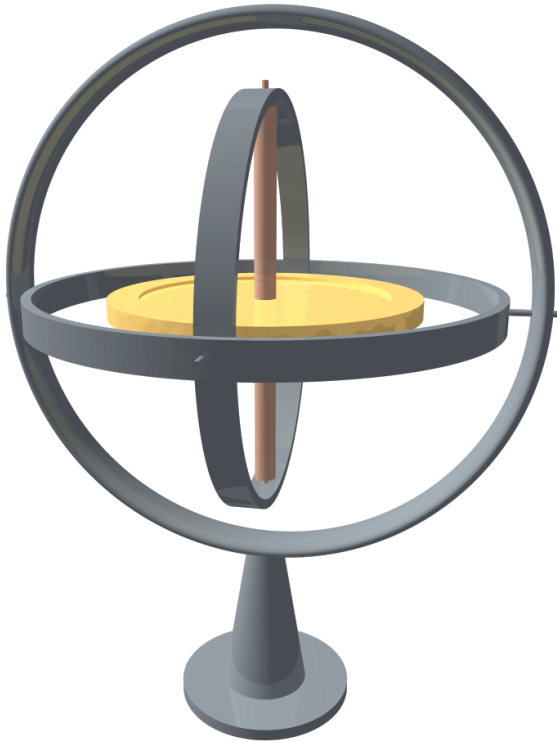
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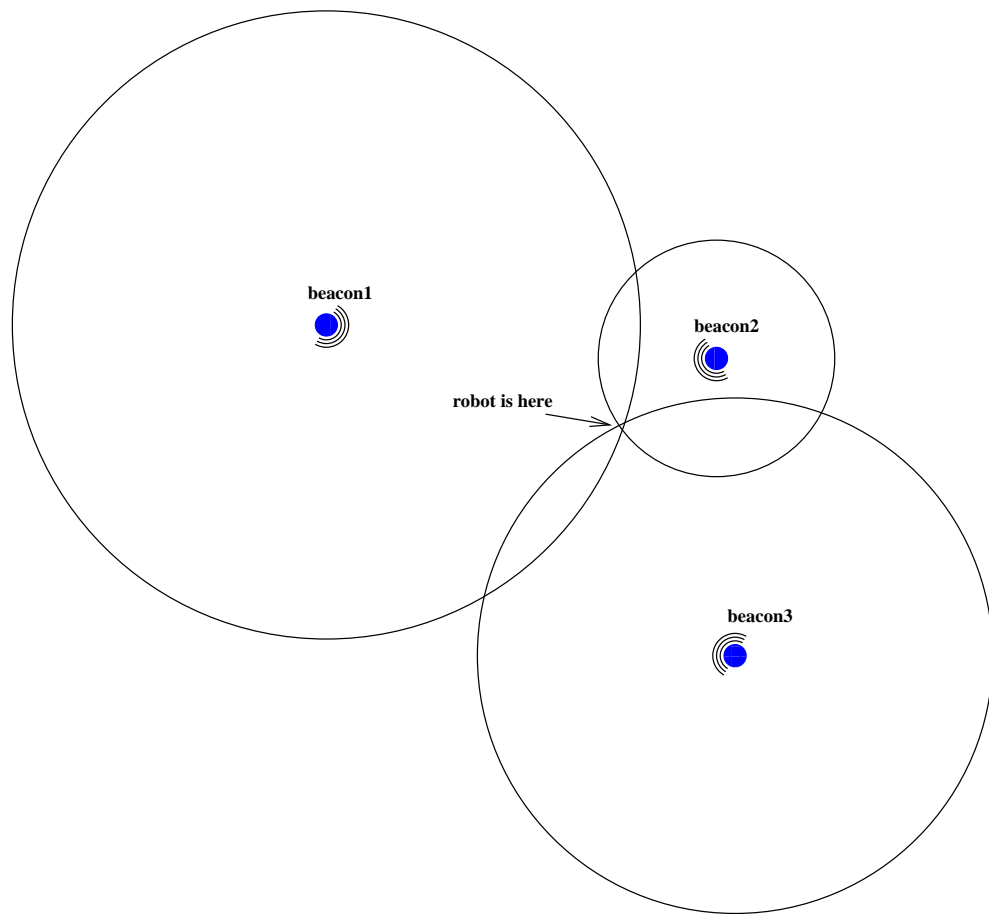
Mechanical gyroscope in Cardan Joint

Mechanical gyroscope in operation

Accelerometers:

Physical principle	Long.	Ang.	Measured variable
Mechanical gyro in Cardan suspension	No	Yes	2-D orientation
Mechanical gyro in spring suspension	No	Yes	angular acceleration
Fiber optics gyro	No	Yes	acceleration
Mechanical accelerometer	Yes	Yes	acceleration
Solid state accelerometer	Yes	Yes	acceleration

Position Estimation – Known Distances



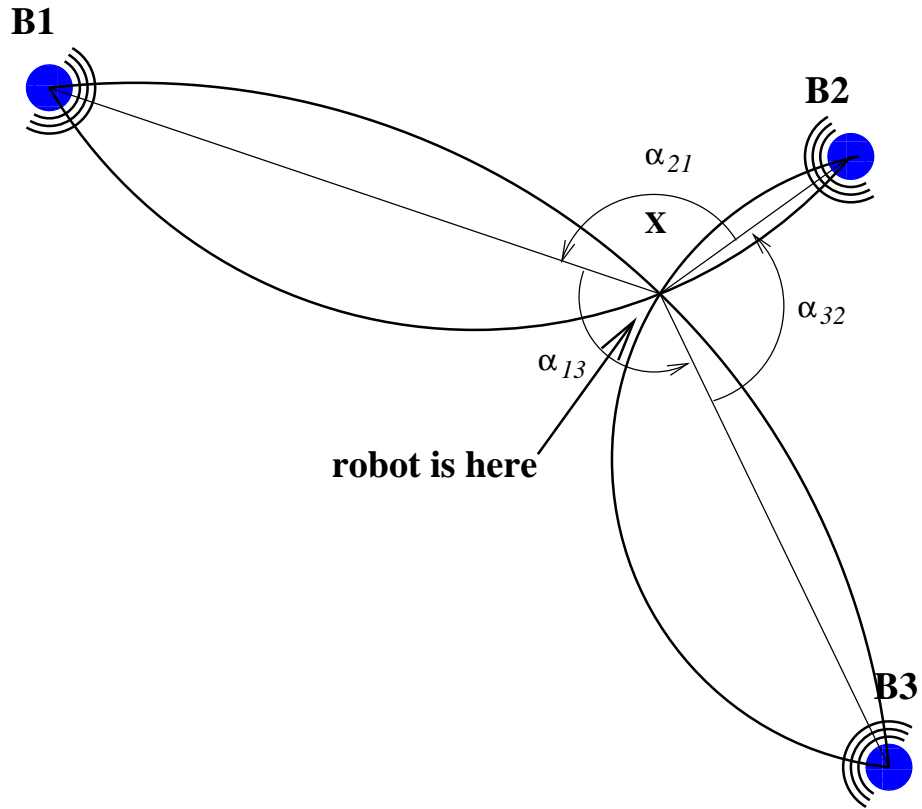
$$(x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 = c^2(t - t_1)^2$$

$$(x - x_2)^2 + (y - y_2)^2 + (z - z_2)^2 = c^2(t - t_2)^2$$

$$(x - x_3)^2 + (y - y_3)^2 + (z - z_3)^2 = c^2(t - t_3)^2$$

$$(x - x_4)^2 + (y - y_4)^2 + (z - z_4)^2 = c^2(t - t_4)^2$$

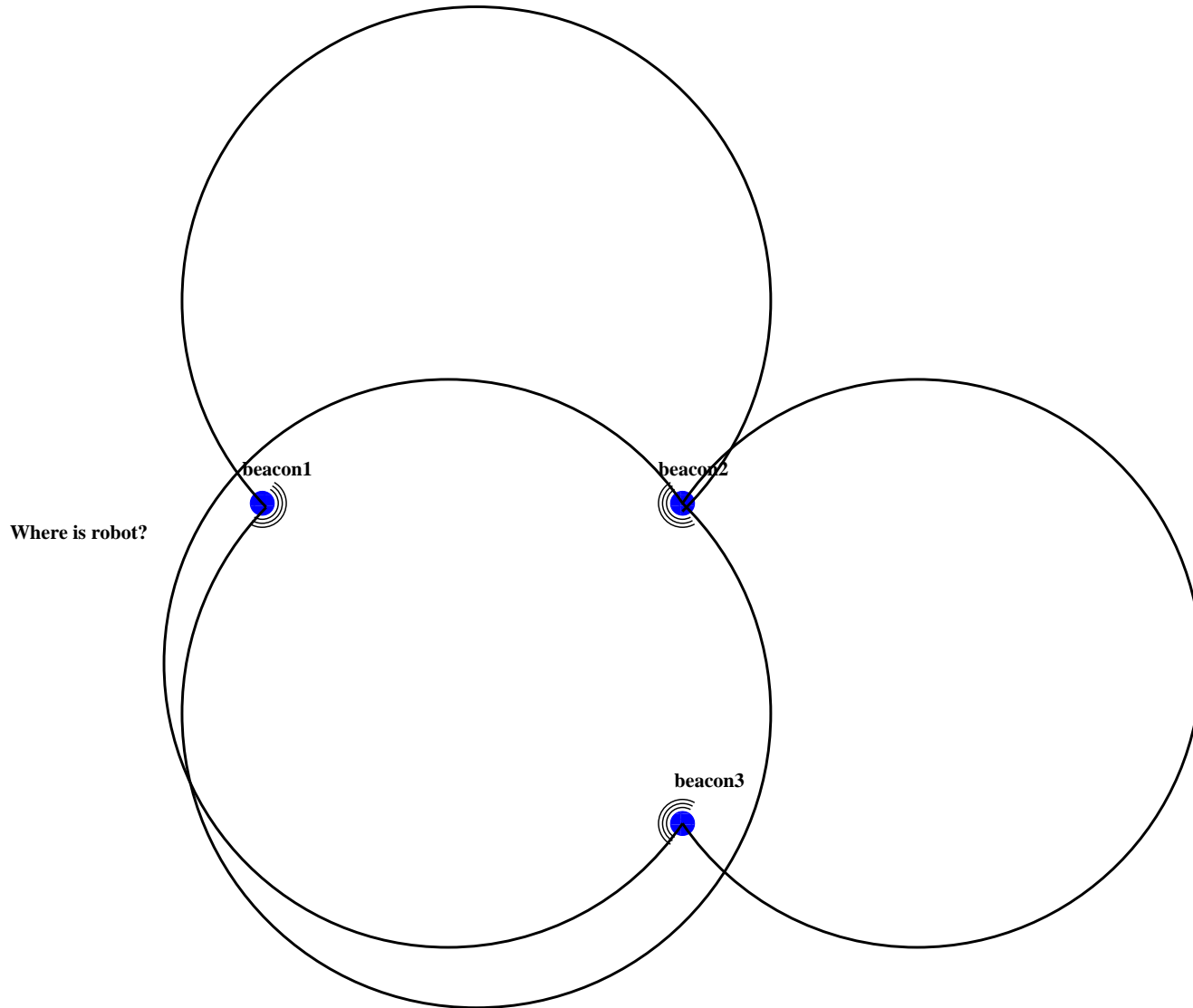
Position Estimation – Known Angles



$$\|XB_1\|^2 + \|XB_2\|^2 - 2 \cos \alpha_{12} \|XB_1\| \|XB_2\| = \|B_1B_2\|^2$$

$$(x - x_1)^2 + (y - y_1)^2 + (x - x_2)^2 + (y - y_2)^2 - \cos \alpha_{12} \sqrt{((x - x_1)^2 + (y - y_1)^2)((x - x_2)^2 + (y - y_2)^2)} = (x_1 - x_2)^2 + (y_1 - y_2)^2$$

Position Estimation – Known Angles





Tactile sensors

Proximity sensors

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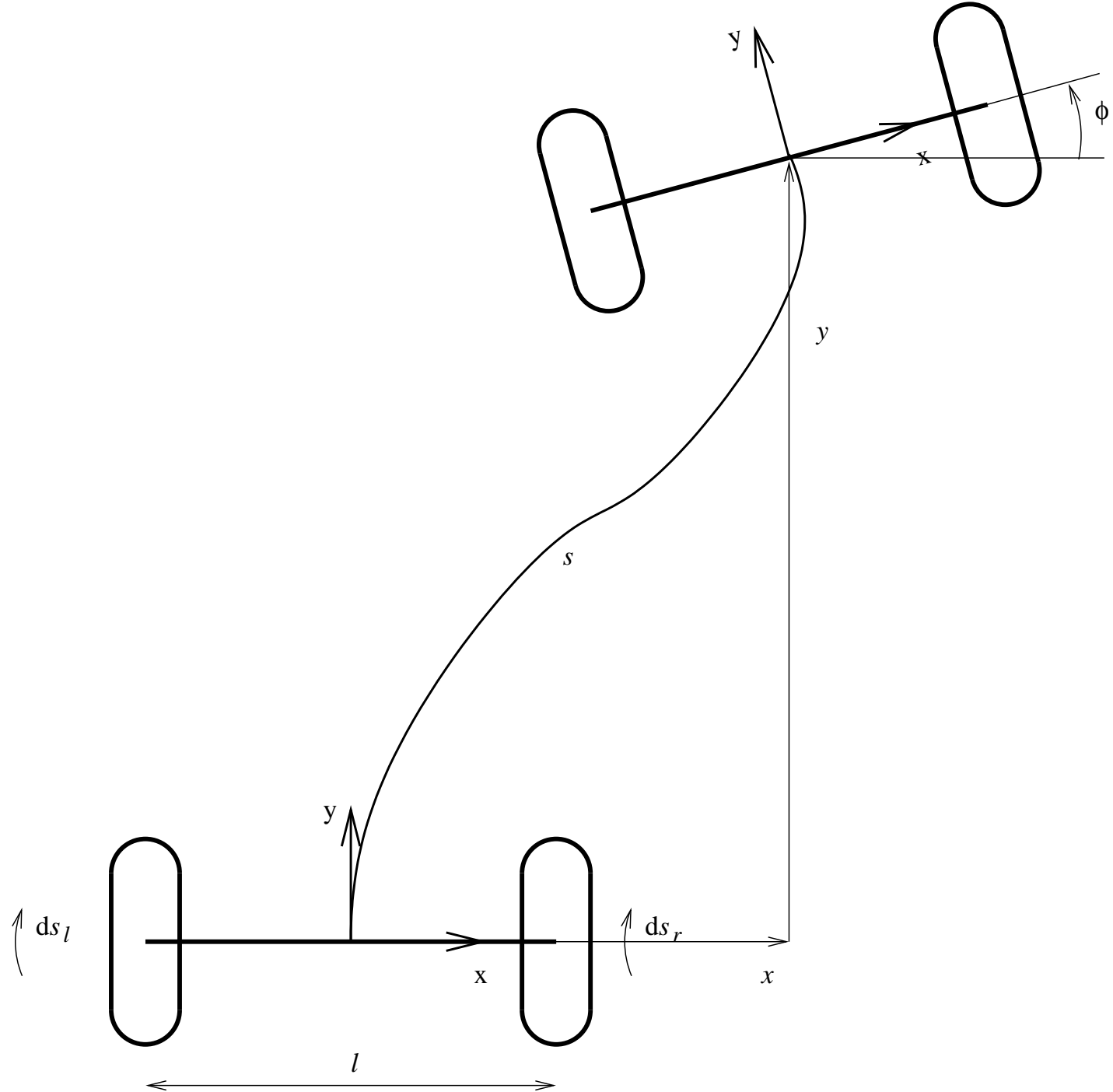
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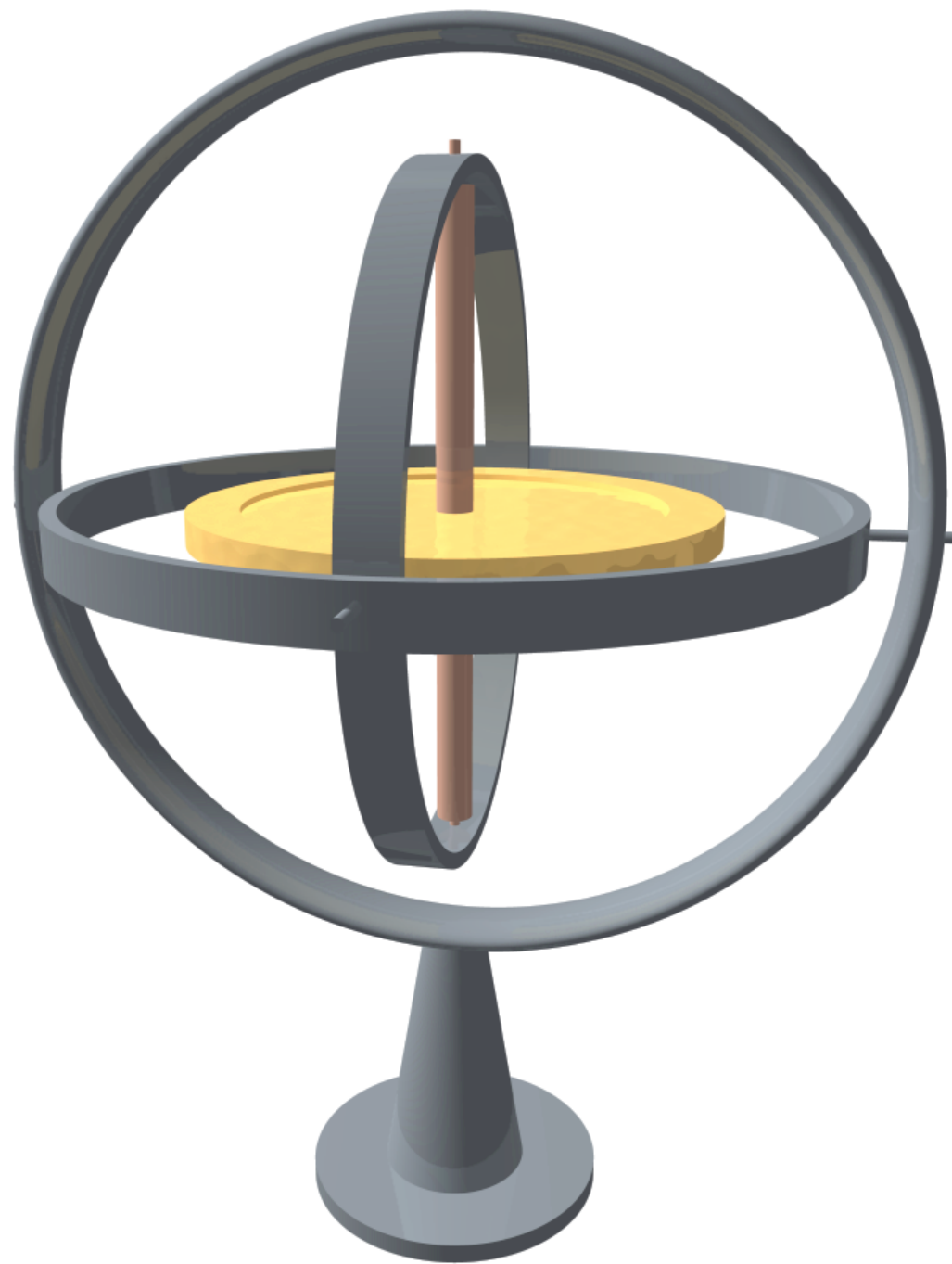
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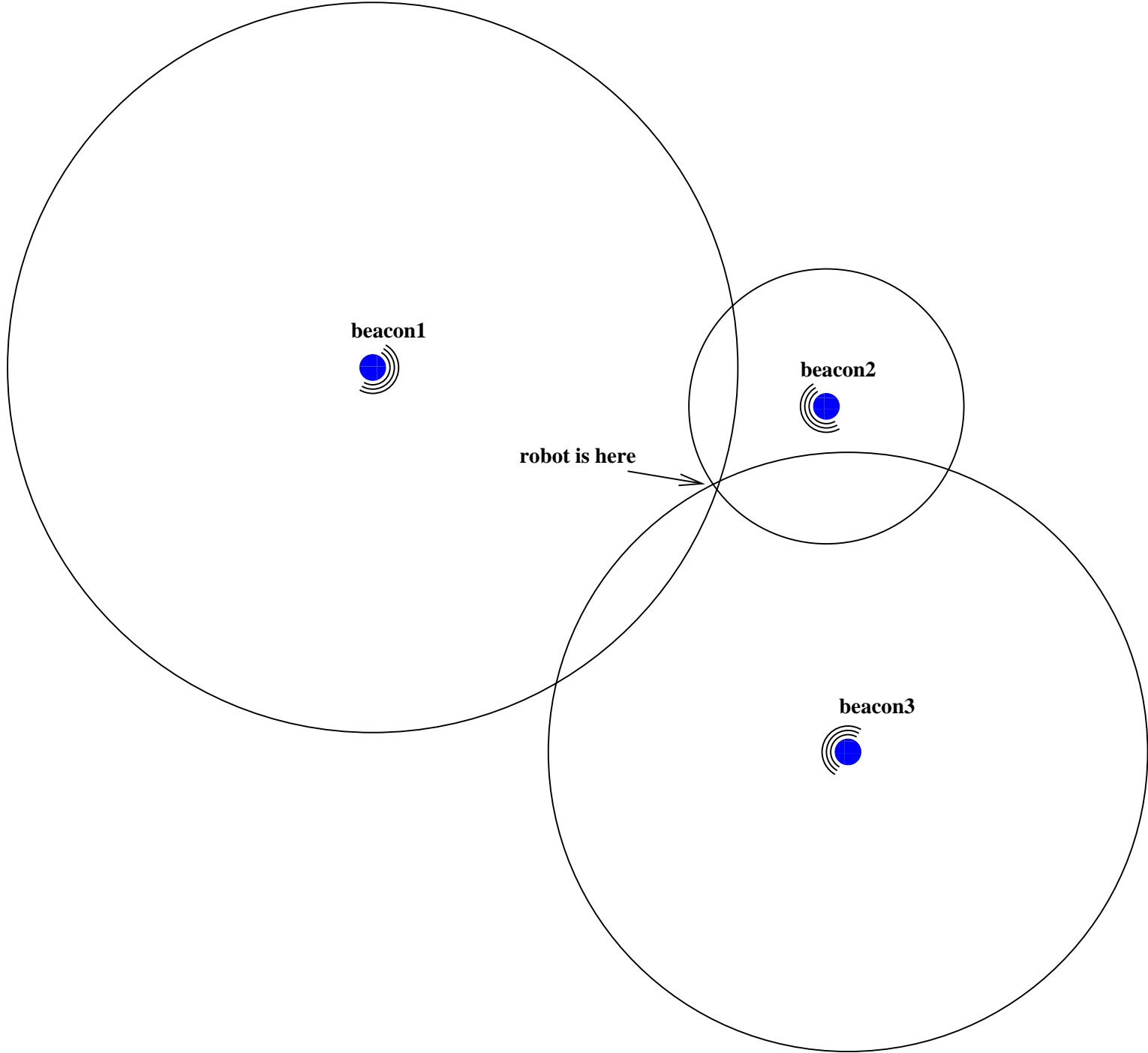
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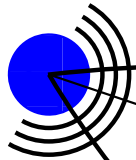
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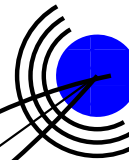




B1



B2



α_{21}

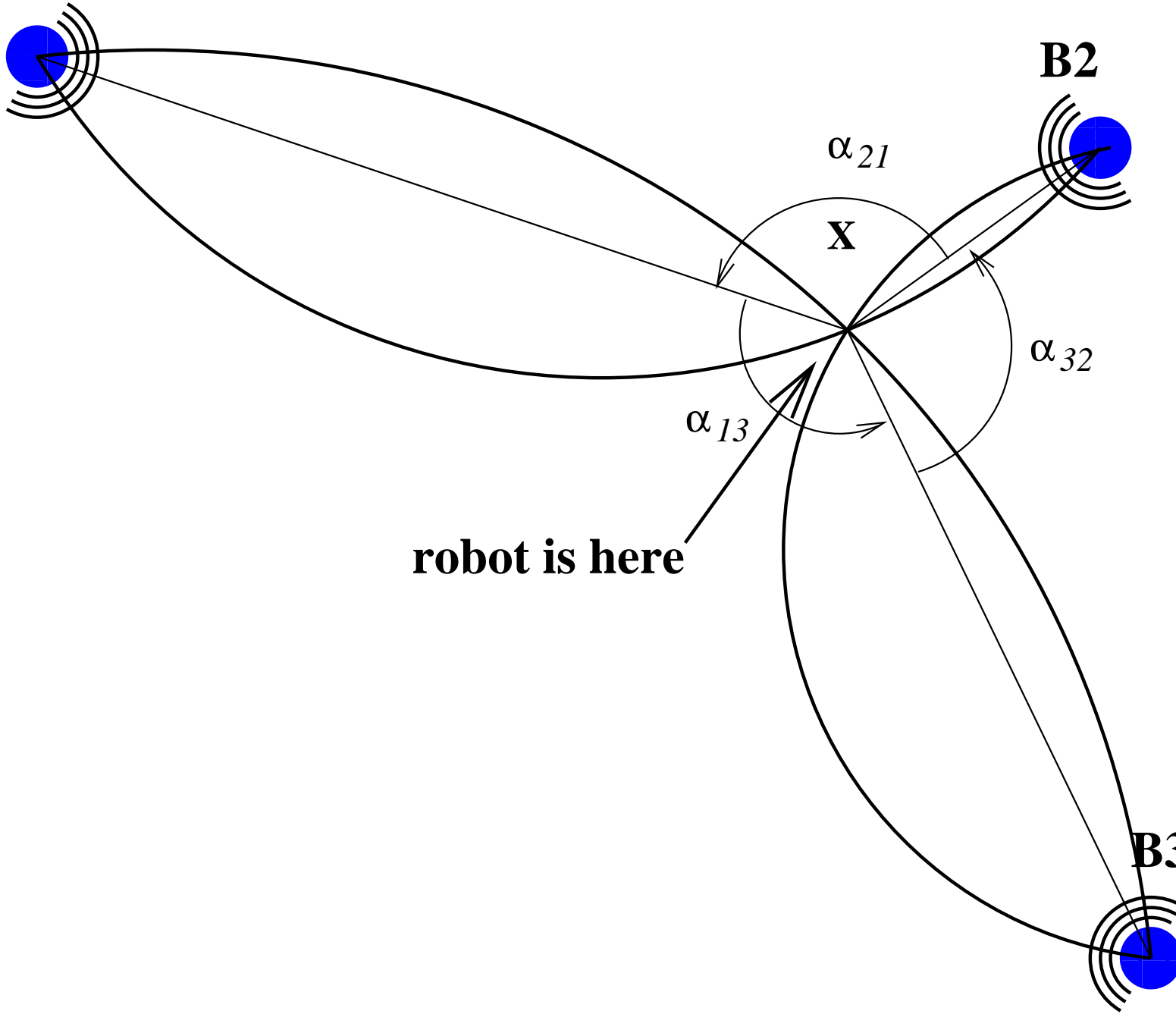
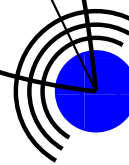
X

α_{32}

α_{13}

robot is here

B3



Where is robot?

