# Certificate

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Roll No : 20BAC10038  Exam No :

Institution ......V.I.T. Bhopal..........

This is certified to be the bonafide work of the student in the ......Autonomous Robotics...... Laboratory during the academic year 2022/ 2023

No. of practicals certified .......................... out of ........................ in the subject of ........................

.............................

Teacher In-charge

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Examiner's Signature  Principal

Date : ..........................  Institution Rubber Stamp

(N.B : The candidate is expected to retain his/her journal till he/she passes in the subject.)

# INDEX

# Title: Kinematic Modelling of 2 wheel Chassis [2 fixed wheel & 1 castor wheel]

**Aim:** This experiment aims to mathematically compute the kinematic modelling of a 2 wheel chassis comprising of 2 fixed wheels and 1 castor wheel.

**Components Required:** A chassis with 2 fixed wheels, mini track/table for the movement of chassis, stop watch, motor driver

**Theory:**

The kinematic model of a 2 wheel chassis describes the motion of the vehicle in terms of its position, velocity and acceleration. As far as our experiment is concerned, we shall model the robot as rigid body, operating on a horizontal plane. The total dimensionality of our robot is three, two for position in the plane and one for orientation which is along the vertical axis and orthogonal to the plane. In order to specify the position and motion, the obligation is to establish a relationship between the global and local frame of the robot. Motion mapping along axis of the global frame would be done after this. Here is the fundamental relation:

$$\dot{\xi}_{R} = R(\theta).\dot{\xi}_{I} \quad , \text{Here, } R(\theta) = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}_{(3\times3)}$$

[Rotation matrix]

Additional information: $\dot{\xi}_{I} = \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix}$ → Change in x direction; → Change in y direction; → Change in the angle of frame.

## Observation

| SL. No. | d(m) | l(cm) | α(rad) | β | v | t |
|---|---|---|---|---|---|---|
| 0 | 1m | 6.25 | $-\pi/2, \pi/2$ | 0 | 0.263 | 3.8 |
| 1 | 1.5m | 6.25 | $-\pi/2, \pi/2$ | 0 | 0.261 | 5.7 |
| 2 | 2m | 6.25 | $-\pi/2, \pi/2$ | 0 | 0.265 | 7.54 |
| $\theta = 33°$ | | | | | | |
| 0 | 1m | 6.25 | $-\pi/2, \pi/2$ | 0 | 0.266 | 3.75 |
| 1 | 1.5m | 6.25 | $-\pi/2, \pi/2$ | 0 | 0.263 | 5.7 |
| 2 | 2m | 6.25 | $-\pi/2, \pi/2$ | 0 | 0.266 | 7.51 |

Now, here is the equation for the mapping motion.

$$\dot{\xi}_{IR} = \begin{bmatrix} (r_1\dot{\phi}_1 + r_2\dot{\phi}_2)/2 \\ 0 \\ (r_1\dot{\phi}_1 + r_2(-\dot{\phi}_2))/2l \end{bmatrix}_{(3\times3)}$$

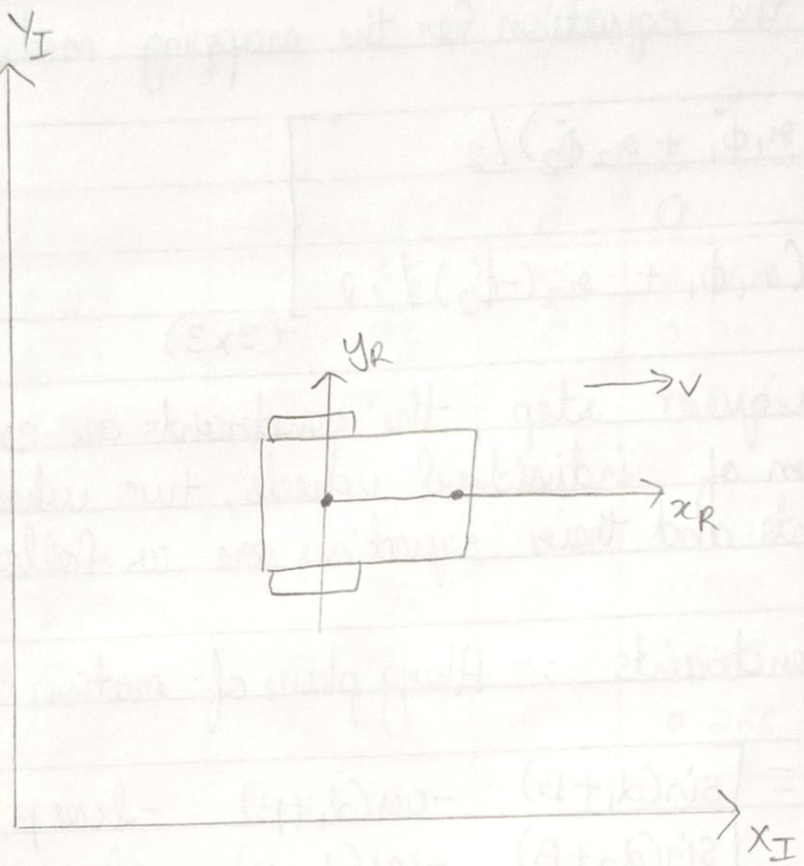
In the subsequent step, the constraints are expected to be applied over the motion of individual wheels, two wheels in our case. The constraints and their equations are as follows:

(i) Rolling constraints : Along plane of motion for wheel.

$$\begin{bmatrix} J_1 \\ \phantom{x} \end{bmatrix} \equiv \begin{bmatrix} \sin(\alpha_1+\beta) & -\cos(\alpha_1+\beta) & -l\cos\beta \\ \sin(\alpha_2+\beta) & -\cos(\alpha_2+\beta) & -l\cos\beta \end{bmatrix}_{(2\times3)} \dot{\xi}_{IR} = \begin{bmatrix} r_1\dot{\phi}_1 \\ r_2\dot{\phi}_2 \end{bmatrix}_{(2\times1)}$$

(ii) Sliding constraints: Perpendicular to the plane of the wheel.

$$\begin{bmatrix} C_1 \\ \phantom{x} \end{bmatrix} \equiv \begin{bmatrix} \cos(\alpha_1+\beta) & \sin(\alpha_1+\beta) & l\sin\beta_1 \\ \cos(\alpha_2+\beta) & \sin(\alpha_2+\beta) & l\sin\beta_2 \end{bmatrix}_{(2\times3)}$$




## Observations:

WHEEL 1: $\alpha_1 = \pi/2$ , $\beta = 0$ , $\dot{\phi}_1 = 1.31\ s^{-1}$
$l = 6.25\,cm$ , $r = 3.25\,cm$

WHEEL 2: $\alpha_2 = -\pi/2$ , $\beta = 0$ , $\dot{\phi}_2 = 1.31 s^{-1}$
$l = 6.25\,cm$ , $r = 3.25\,cm$

Calculations:

Data given / computed:

$\alpha_1 = \alpha_2 = \pm \pi/2$

$\beta = 0$

$2l = 12.5\,cm \Rightarrow l = 6.25\,cm$

$r = 3.25\,cm$

$N = 5$

$\dot\phi_1 = \dot\phi_2 = \frac{5}{3.8} = 1.31\,s^{-1}$

Case (i): Straight line linear motion.

$$J_1 = \begin{bmatrix} \sin(\pi/2) & -\cos(\pi/2+0) & -6.25\cos(0) \\ -\sin(\pi/2) & -\cos(-\pi/2+0) & -6.25\cos(0) \end{bmatrix}_{(2\times3)}$$

$$= \begin{bmatrix} 1 & 0 & -6.25 \\ -1 & 0 & -6.25 \end{bmatrix}_{(2\times3)}$$

$$C_1 = \begin{bmatrix} \cos(\pi/2+0) & \sin(\pi/2+0) & 6.25\cos(0) \\ \cos(-\pi/2+0) & \sin(-\pi/2+0) & 6.25\cos(0) \end{bmatrix}_{(2\times3)}$$

$$= \begin{bmatrix} 0 & 1 & 0 \\ 0 & -1 & 0 \end{bmatrix}_{(2\times3)}$$

$$J_2 = \begin{bmatrix} r_1\dot\phi_1 \\ r_2(-\dot\phi_2) \end{bmatrix}_{(2\times1)} = \begin{bmatrix} 3.25 \times 1.31 \\ -3.25 \times 1.31 \end{bmatrix}_{(2\times1)} = \begin{bmatrix} 4.2575 \\ -4.2575 \end{bmatrix}_{(2\times1)}$$

Now,

$$\dot\xi_R = \begin{bmatrix} (r\dot\phi_1 + r\dot\phi_2)/2 \\ 0 \\ (r\dot\phi_1 + r(-\dot\phi_2))/2l \end{bmatrix}_{(3\times1)} = \begin{bmatrix} 4.2575 \\ 0 \\ 0 \end{bmatrix}_{(3\times1)}$$

Error margin:

Error in angular speed ($\Delta\dot{\phi}$) =

$\Rightarrow$ Experimental angular velocity - calculated angular velocity

$\Rightarrow$ $1.31 - 1.50$

$= -0.19$

error = $\pm 12.6\%$

Putting this into the main matrix, we get:

$$\begin{bmatrix} \begin{bmatrix} 1 & 0 & -5.25 \\ -1 & 0 & -6.25 \end{bmatrix} \\ \begin{bmatrix} 0 & 1 & 0 \\ 0 & -1 & 0 \end{bmatrix} \end{bmatrix}_{(4\times3)} \begin{bmatrix} 4.2575 \\ 0 \\ 0 \end{bmatrix}_{(3\times1)} = \begin{bmatrix} \begin{bmatrix} 4.2575 \\ -4.2575 \end{bmatrix} \\ \begin{bmatrix} 0 \\ 0 \end{bmatrix} \end{bmatrix}_{(4\times1)}$$

Case(ii): When the motion is curvilinear, one wheel stopped $\dot{\phi}_2 = 0$ and $\theta = 33^\circ$

$$J_2 = \begin{bmatrix} r_1 \dot{\phi}_1 \\ r_2(-\dot{\phi}_2) \end{bmatrix}_{(2\times1)} = \begin{bmatrix} 4.2575 \\ 0 \end{bmatrix}_{(2\times1)}$$

$$\dot{\xi}_{R} = \begin{bmatrix} (r_1\dot{\phi}_1 + r_2\dot{\phi}_2)/2 \\ 0 \\ (r_1\dot{\phi}_1 + r_2(-\dot{\phi}_2))/2l \end{bmatrix}_{(3\times1)} = \begin{bmatrix} 2.1887 \\ 0 \\ 0.3406 \end{bmatrix}_{(3\times1)}$$

Now,

$$\begin{bmatrix} \begin{bmatrix} 1 & 0 & -6.25 \\ -1 & 0 & -6.25 \end{bmatrix} \\ \begin{bmatrix} 0 & 1 & 0 \\ 0 & -1 & 0 \end{bmatrix} \end{bmatrix}_{(4\times3)} \begin{bmatrix} 2.1887 \\ 0 \\ 0.3406 \end{bmatrix}_{(3\times1)} = \begin{bmatrix} \begin{bmatrix} 0.05995 \\ 4.3174 \end{bmatrix} \\ \begin{bmatrix} 0 \\ 0 \end{bmatrix} \end{bmatrix}_{(4\times1)}$$

**Results:** We have computed $\dot{\xi}_R$ for two different cases and also the main equation, we obtain the following:

**Conclusion:** The kinematic modelling for a 2 wheel chassis case has been carried out and verified succesfully.

# Title: Kinematic Modelling of 4 wheel Chassis [4 fixed wheel & 1 Caster wheel]

**Aim:** This experiment aims to mathematically compute the kinematic modelling of a 4 wheel chassis comprising of 4 fixed wheels and 1 castor wheel.

**Theory:**

The kinematic model of a 4 wheel chassis describes the motion of the vehicle in terms of its position, velocity and acceleration. As far as our experiment is concerned, the body is modelled as a rigid body in horizontal plane with three dimensions of motion. Here, two will be in the plane while another is a vertical axis orthogonal to the plane. Just like the experiment of the 2 wheel chassis, the position and motion will be given by the following relations:

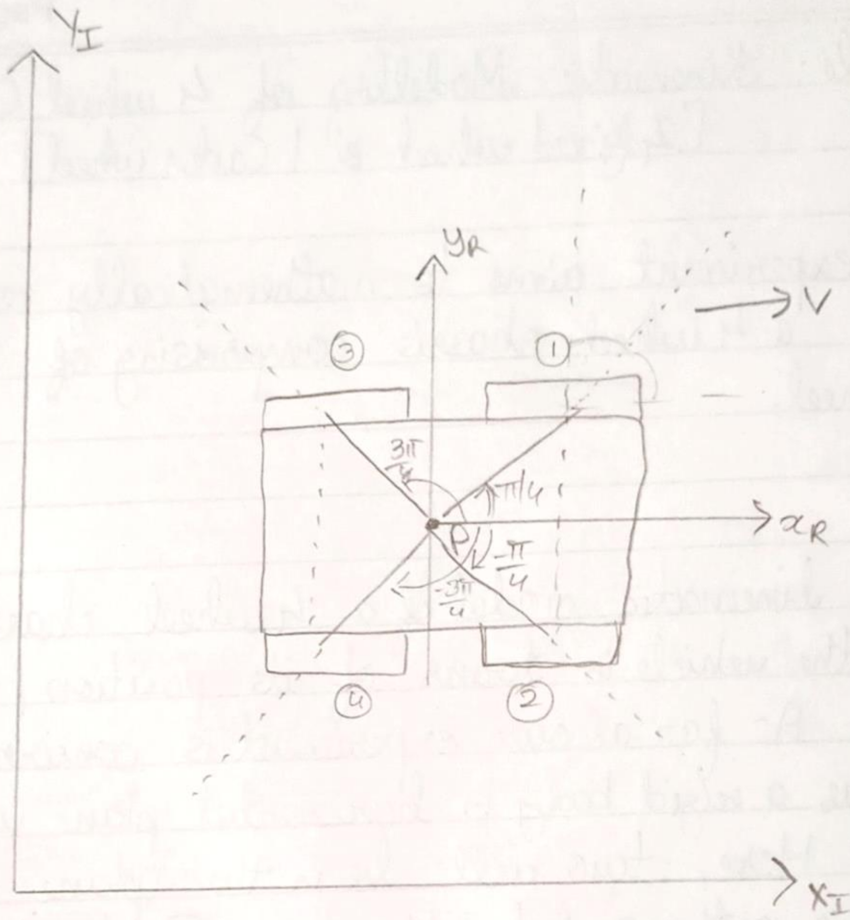
$$\dot{\xi}_R = R(\theta).\dot{\xi}_I \quad \text{Here, } R(\theta) = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}_{(3\times3)}$$

[Rotation matrix]

Additional information: $\dot{\xi}_I = \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix}$ $\begin{array}{l} \rightarrow \text{Change in } x \text{ direction} \\ \rightarrow \text{Change in } y \text{ direction} \\ \rightarrow \text{Change in the angle of frame} \end{array}$

Our equation fo the mapping motion is:

$$\dot{\xi}_R = \begin{bmatrix} (r_1\dot{\phi}_1 + r_2\dot{\phi}_2 + r_3\dot{\phi}_3 + r_4\dot{\phi}_4)/4 \\ 0 \\ (r_1\dot{\phi}_1/(l/\sqrt{2}) + r_2\dot{\phi}_2/(l/\sqrt{2}) + r_3\dot{\phi}_3(l/\sqrt{2})(-1) + r_4\dot{\phi}_4(l/\sqrt{2})(-1) \end{bmatrix}$$




OBSERVATIONS :

WHEEL 1 : $\alpha_1 = \pi/4$, $\beta = \frac{\pi}{2}$, $\dot{\phi}_1 = 1.31\ s^{-1}$
$l = 6.25\text{cm}$

WHEEL 2 : $\alpha_2 = 3\pi/4$, $\beta = \frac{-\pi}{2}$, $\dot{\phi}_2 = 1.31 s^{-1}$
$l = 6.25\text{cm}$

WHEEL 3 : $\alpha_3 = -\pi/4$, $\beta = \frac{-\pi}{2}$, $\dot{\phi}_3 = 1.31 s^{-1}$
$l = 6.25\text{ cm}$

WHEEL 4 : $\alpha_4 = -3\pi/4$, $\beta = \frac{\pi}{2}$, $\dot{\phi}_4 = 1.31 s^{-1}$
$l = 6.25\text{ cm}$

In the subsequent step, kinematic constraints for each wheel shall be applied and put into the following equation.

$$\begin{bmatrix} J_1 \\ C_1 \end{bmatrix}_{(2\times1)} R(\theta).\dot{\xi}_I = \begin{bmatrix} J_2\phi \\ 0 \end{bmatrix}_{(2\times1)}$$

We have the equations for the two constraints as follows:

(i) Rolling constraint: Along the plane of motion for the wheel.

$$J_1 = \begin{bmatrix} \sin(\alpha_1+\beta) & -\cos(\alpha_1+\beta) & -l\cos\beta \\ \sin(\alpha_2+\beta) & -\cos(\alpha_2+\beta) & -l\cos\beta \\ \sin(\alpha_3+\beta) & -\cos(\alpha_3+\beta) & -l\cos\beta \\ \sin(\alpha_4+\beta) & -\cos(\alpha_4+\beta) & -l\cos\beta \end{bmatrix}_{(4\times3)}$$

$$J_2 = \begin{bmatrix} r_1\dot{\phi}_1 \\ r_2\dot{\phi}_2 \\ r_3(-\dot{\phi}_3) \\ r_4(-\dot{\phi}_4) \end{bmatrix}_{(4\times1)}$$

(ii) Sliding constraint: Perpendicular to the plane of the wheel.

$$C_1 = \begin{bmatrix} \cos(\alpha_1+\beta_1) & \sin(\alpha_1+\beta_1) & -l\sin\beta \\ \cos(\alpha_2+\beta_2) & \sin(\alpha_2+\beta_2) & -l\sin\beta \\ \cos(\alpha_3+\beta_2) & \sin(\alpha_3+\beta_2) & -l\sin\beta \\ \cos(\alpha_4+\beta_1) & \sin(\alpha_4+\beta_1) & -l\sin\beta \end{bmatrix}$$

Components Required: A chassis with 4 fixed wheels, mini track / table for the movement of the chassis, stop watch, motor driver.

## Calculations :

Case : Straight line linear motion

Data given / computed :

$$\alpha_1 = \frac{\pi}{4},\ \alpha_2 = \frac{-\pi}{4},\ \alpha_3 = \frac{3\pi}{4},\ \alpha_4 = -\frac{3\pi}{4}$$

$$\beta = \frac{\pi}{2} \text{ and } \frac{-\pi}{2} \text{ (case to case basis).},\ l = 6.25\text{ cm}$$

Computing the value of $J_1$ and $C_1$ from the above data.

$$J_1 = \begin{bmatrix} \sin(\pi/4+\pi/2) & -\cos(\pi/4+\pi/2 & -6.25\cos(\pi/2) \\ \sin(\pi/4-\pi/2) & -\cos(\pi/4) & -6.25\cos(-\pi/2) \\ \sin(-3\pi/4) & -\cos(-3\pi/4) & -6.25\cos(-\pi/2) \\ \sin(-\pi/4) & -\cos(-\pi/4) & -6.25\cos(\pi/2) \end{bmatrix}$$

$$= \begin{bmatrix} 0.707 & 0.707 & 0 \\ 0.707 & -0.707 & 0 \\ -0.707 & 0.707 & 0 \\ -0.707 & -0.707 & 0 \end{bmatrix}$$

$$C_1 = \begin{bmatrix} \cos(3\pi/4) & \sin(3\pi/4) & -6.25\sin(\pi/2) \\ \cos(\pi/4) & \sin(\pi/4) & -6.25\sin(\pi/2) \\ \cos(-3\pi/4) & \sin(-3\pi/4) & -6.25\sin(-\pi/2) \\ \cos(-\pi/4) & \sin(-\pi/4) & -6.25\sin(\pi/2) \end{bmatrix}$$

$$= \begin{bmatrix} -0.707 & 0.707 & -6.25 \\ 0.707 & 0.707 & 6.25 \\ 0.707 & -0.707 & 6.25 \\ 0.707 & -0.707 & -6.25 \end{bmatrix}$$

Computing the value of $J_2$.

$$J_2 = \begin{bmatrix} r_1\dot{\phi}_1 \\ r_2\dot{\phi}_2 \\ r_3\dot{\phi}_3 \\ r_4\dot{\phi}_4 \end{bmatrix}_{(4\times1)} = \begin{bmatrix} 4.2575 \\ 4.2575 \\ -4.2575 \\ -4.2575 \end{bmatrix}_{(4\times1)}$$

$$\dot{\xi}_{R} = \begin{bmatrix} (r_1\dot{\phi}_1 + r_2\dot{\phi}_2 + r_3\dot{\phi}_3 + r_4\dot{\phi}_4)/4 \\ 0 \\ \sqrt{2}/4l\,(r_1\dot{\phi}_1 + r_2\dot{\phi}_2 + r_3(-\dot{\phi}_3) + r_4(-\dot{\phi}_4)) \end{bmatrix}_{(3\times1)} = \begin{bmatrix} 4.2575 \\ 0 \\ 0 \end{bmatrix}_{(3\times1)}$$

Putting all this in the main equation:

$$\begin{bmatrix} \begin{bmatrix} 0.707 & 0.707 & 0 \\ 0.707 & -0.707 & 0 \\ -0.707 & 0.707 & 0 \\ -0.707 & -0.707 & 0 \end{bmatrix} \\ \begin{bmatrix} -0.707 & 0.707 & -4.41 \\ 0.707 & 0.707 & 4.41 \\ 0.707 & -0.707 & 4.41 \\ 0.707 & -0.707 & -4.41 \end{bmatrix} \end{bmatrix}_{(8\times3)} \begin{bmatrix} 4.2575 \\ 0 \\ 0 \end{bmatrix}_{(3\times1)} = \begin{bmatrix} 3.0105 \\ 3.0105 \\ -3.0105 \\ -3.0105 \\ -3.0105 \\ 3.0105 \\ 3.0105 \\ 3.0105 \end{bmatrix}_{(8\times1)}$$

Results: The rolling and sliding constraint equation has been computed successfully.

Conclusion: The experiment for kinematic modelling of a 4 wheel chassis has been carried out successfully.

Title: Kinematic Modelling of a Swedish wheel

Aim: This experiment aims to mathematically compute the kinematic modelling of a swedish wheel.

Components Required: A chassis comprising of 2 swedish wheels, a motor driver, a track/table for the movement of the chassis.

Theory: Swedish wheel is a type of omnidirectional wheel that can be used in wheeled robotic applications. The kinematic modelling of a Swedish wheel involves analyzing their motion and determining their effect on the overall motion of the robot.
The pose of a Swedish wheel is expressed exactly as in a fixed standard wheel, with the additional term, $\gamma$ which actually represents the angle between the main wheel plane and the axis of rotation of the small circumferential rollers.
Just like the previous cases, the body is modelled as a rigid body in horizontal plane with three dimensions of motion. Two in the plane while another is a vertical axis orthogonal to the plane.
The position and motion of the rigid body can be established from the following equation:

$$\dot{\xi}_{R} = R(\theta).\dot{\xi}_{I} \qquad \text{where } R(\theta) = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}_{(3\times3)}$$

Additional information: $\dot{\xi}_{I} = \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix}$

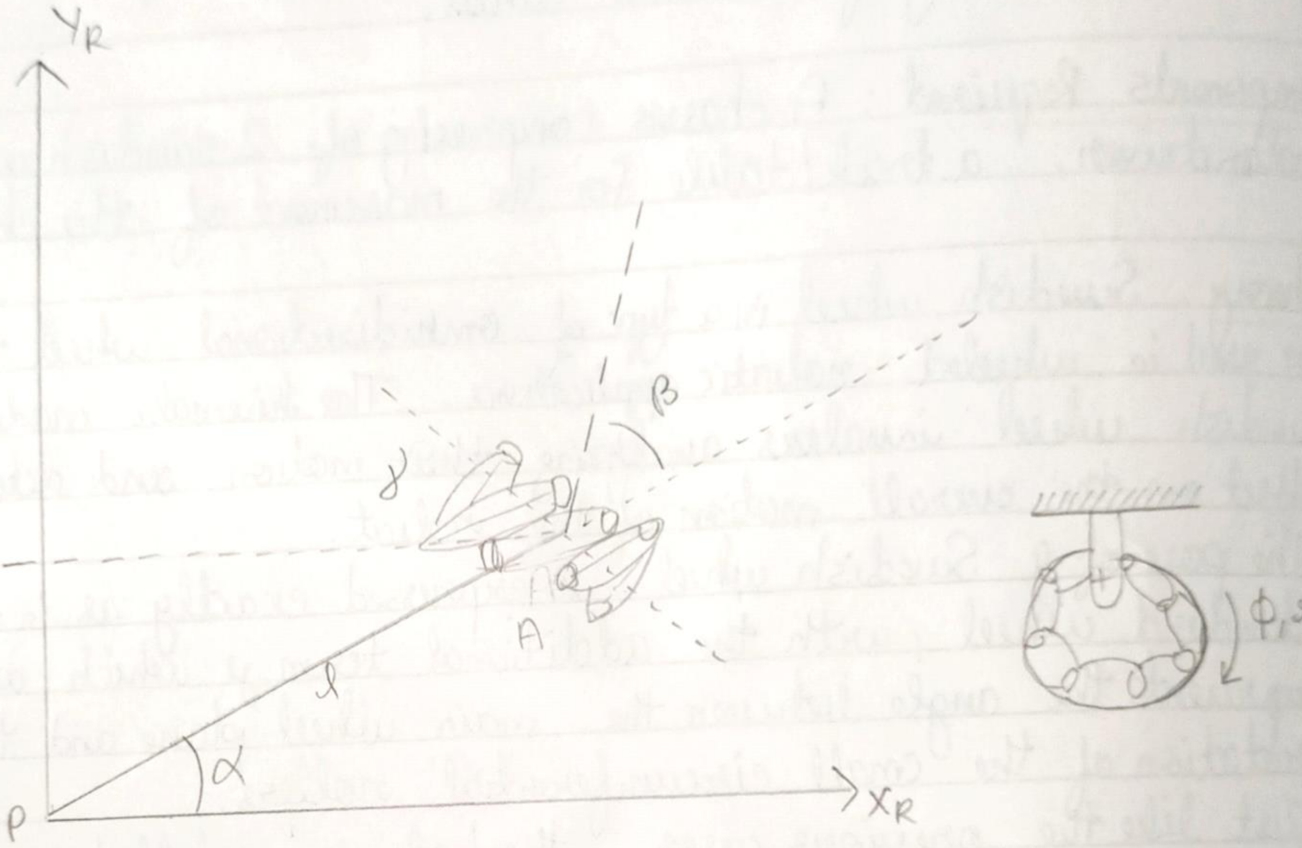



Fig. A Swedish wheel and its parameters.

Kinematic constraints for the robot shall be given by:

$$\begin{bmatrix} J_1 \\ C_1 \end{bmatrix} R(\theta).\dot{\xi}_{I} = \begin{bmatrix} J_2 \dot{\phi} \\ C_2 \dot{\phi} \end{bmatrix}_{(2\times1)} \quad (2\times1)$$

We shall define the respective rolling and sliding constraints as follows:

(i) Rolling constraints: Along the plane of motion for the wheel.

$$J_1 = \begin{bmatrix} \sin(\alpha_1+\beta_1+\gamma_1) & -\cos(\alpha_1+\beta_1+\gamma_1) & -l\cos(\beta+\gamma) \\ \sin(\alpha_2+\beta_2+\gamma_2) & -\cos(\alpha_2+\beta_2+\gamma_2) & -l\cos(\beta+\gamma_2) \end{bmatrix}_{(2\times3)}$$

$$J_2 = \begin{bmatrix} r_1 \dot{\phi}.\cos\gamma \\ r_2 \dot{\phi}_2 \cos\gamma \end{bmatrix}_{(2\times1)}$$

(ii) Sliding constraints: Perpendicular to the plane of the wheel.

$$C_1 = \begin{bmatrix} \cos(\alpha_1+\beta_1+\gamma_1) & \sin(\alpha_1+\beta_1+\gamma_1) & l\sin(\beta_1+\gamma_1) \\ \cos(\alpha_2+\beta_2+\gamma_2) & \sin(\alpha_2+\beta_2+\gamma_2) & l\sin(\beta_2+\gamma_2) \end{bmatrix}_{(2\times3)}$$

$$C_2 = \begin{bmatrix} r_1 \dot{\phi}_1 \sin\gamma + r_{sw}\dot{\phi}_{sw} \\ r_2 \dot{\phi}_2 \sin\gamma + r_{sw}\dot{\phi}_{sw} \end{bmatrix}_{(2\times1)}$$

observation

| S.L NO | d | l | $\alpha$ | $\beta$ | N | t(s) |
|---|---|---|---|---|---|---|
| $\theta = 0^\circ$ | | | | | | |
| 0 | 1m | 6.75 | $-\pi/2, \pi/2$ | 0 | 0.284 | 3.51 |
| 1 | 1.5m | 6.75 | $-\pi/2, \pi/2$ | 0 | 0.287 | 5.22 |
| 2 | 2m | 6.75 | $-\pi/2, \pi/2$ | 0 | 0.282 | 7.09 |
| $\theta = 33^\circ$ | | | | | | |
| 0 | 1m | 6.75 | $-\pi/2, \pi/2$ | 0 | 0.289 | 3.46 |
| 1 | 1.5m | 6.75 | $-\pi/2, \pi/2$ | 0 | 0.288 | 5.20 |
| 2 | 2m | 6.75 | $-\pi/2, \pi/2$ | 0 | 0.284 | 7.04 |

Calculations:

Computed / calculated data:

$\alpha_1 = \frac{\pi}{2}$ , $\alpha_2 = \frac{-\pi}{2}$

$\beta = 0$

$\gamma_1 = \frac{\pi}{4}$ , $\gamma_2 = \frac{-\pi}{4}$

$l = 6.25\,cm$

$r = 3.25\,cm$

Putting these into $J_1$ and $C_1$, we must get:

$$J_1 = \begin{bmatrix} \sin(\pi/2 + 0 + \pi/4) & -\cos(\pi/2 + 0 + \pi/4) & -l\cos(0+\pi/4) \\ \sin(-\pi/2 + 0 - \pi/4) & -\cos(-\pi/2 + 0 - \pi/4) & -l\cos(0-\pi/4) \end{bmatrix}_{(2\times3)}$$

$$J_1 = \begin{bmatrix} \sin(3\pi/4) & -\cos(3\pi/4) & -6.25\cos(\pi/4) \\ \sin(-3\pi/4) & -\cos(-3\pi/4) & -6.25\cos(\pi/4) \end{bmatrix} (2\times3)$$

$$J_1 = \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & -6.25/\sqrt{2} \\ -1/\sqrt{2} & 1/\sqrt{2} & -6.25/\sqrt{2} \end{bmatrix} (2\times3)$$

For $C_1$,

$$C_1 = \begin{bmatrix} \cos(\pi/2 + 0 + \pi/4) & \sin(\pi/2 + 0 + \pi/4) & l\sin(0+\pi/4) \\ \cos(-\pi/2 + 0 - \pi/4) & \sin(-\pi/2 + 0 + (-\pi/4)) & l\sin(0-\pi/4) \end{bmatrix} (2\times3)$$

$$C_1 = \begin{bmatrix} -1/\sqrt{2} & 1/\sqrt{2} & 6.25/\sqrt{2} \\ -1/\sqrt{2} & -1/\sqrt{2} & 6.25/\sqrt{2} \end{bmatrix} (2\times3)$$

The values of $J_2$ and $C_2$ are also computed as follows:

$$J_2 = \begin{bmatrix} r_1 \dot{\phi}_1 \cos(\pi/4) \\ r_2 \dot{\phi}_2 \cos(-\pi/4) \end{bmatrix}_{(2\times1)} = \begin{bmatrix} 3.0105 \\ 3.0105 \end{bmatrix}_{(2\times1)}$$

$$C_2 = \begin{bmatrix} r_1 \dot{\phi}_1 \sin(\pi/4) \\ r_2 \dot{\phi}_2 \sin(-\pi/4) \end{bmatrix}_{(2\times1)} = \begin{bmatrix} 3.0105 \\ -3.0105 \end{bmatrix}_{(2\times1)}$$

Plugging in all these values into the main matrix, we get:

$$\begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & -\frac{6.25}{\sqrt{2}} \\ 1/\sqrt{2} & 1/\sqrt{2} & -\frac{6.25}{\sqrt{2}} \\ -1/\sqrt{2} & \frac{1}{\sqrt{2}} & \frac{6.25}{\sqrt{2}} \\ -1/\sqrt{2} & \frac{1}{\sqrt{2}} & \frac{6.25}{\sqrt{2}} \end{bmatrix}_{(4\times3)} \dot{\xi}_R{}_{(3\times1)} = \begin{bmatrix} 3.0105 \\ 3.0105 \\ -3.0105 \\ -3.0105 \end{bmatrix}_{(4\times1)}$$

Results: The required rolling and sliding constraint equations have been derived successfully.

$$\begin{bmatrix} 3.0105 \\ 3.0105 \\ -3.0105 \\ -3.0105 \end{bmatrix}$$ shall be the final J/C matrix

Conclusion: The experiment has been carried out successfuly.

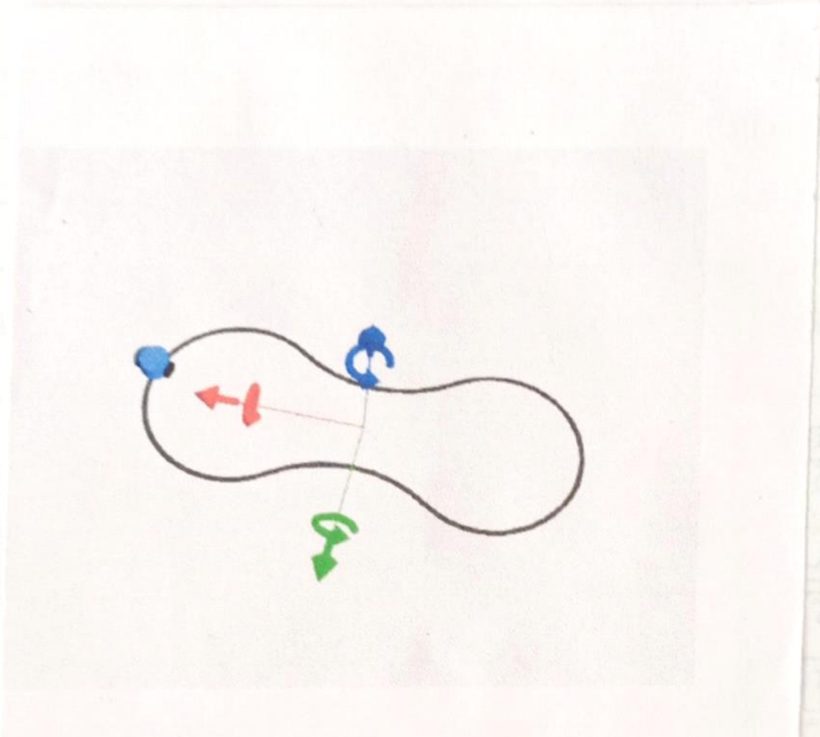


Fig. Simulation

# Title: Designing a line following robot with two fixed wheels

Aim: This experiment aims to design the simulation of a line follower bot which has two fixed wheels.

Components Required: Laptop/PC - Windows 10 or higher, WeBots software and relevant libraries pre installed, Python 3

Theory: A line follower bot is a robot that actually follows a line, typically a black line with the assistance of sensors such as IR Sensors. The movement's adjustment is also based on the line that is present. The working of a line follower bot involves a combination of mechanical, electrical and electronics engineering with a blend of coding.
Some of the key terminologies that are associated with a line follower bot are:

(i) Sensors

(ii) Motors

(iii) Control system

(iv) Programming

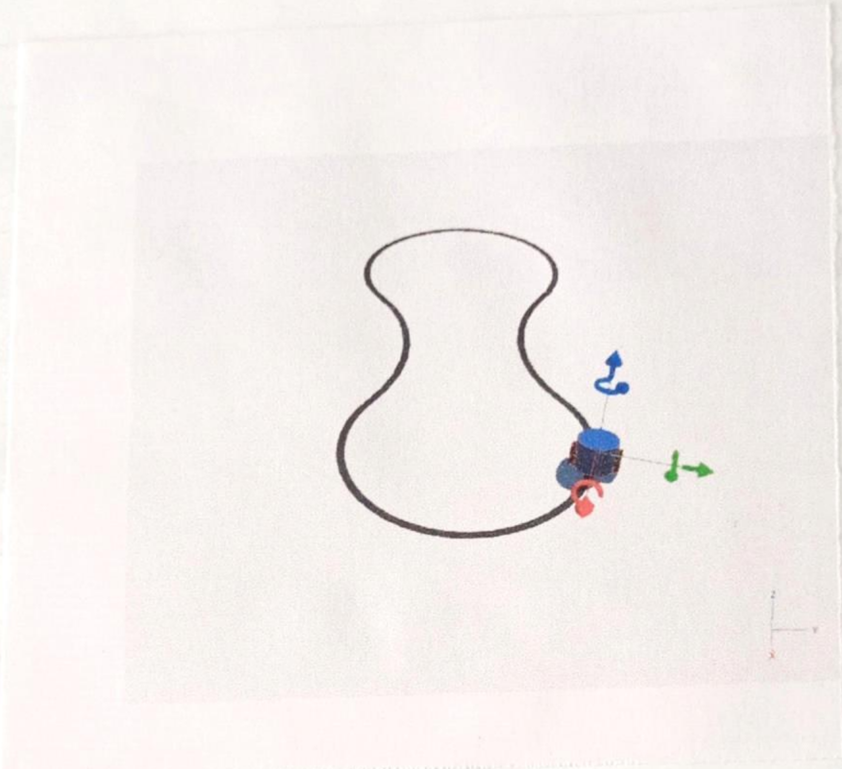


Fig. Simulation

Code:

```
from controller import Robot          # Importing library

def drive_robot (robot):
    timestep = 32
    max_speed = 6.28

    # Initializing Motors
    left_motor = robot.getDevice('motor_left')
    right_motor = robot.getDevice('motor_right')
    left_motor.setPosition(float('inf'))
    right_motor.setPosition(float('inf'))
    left_motor.setVelocity(0.0)
    right_motor.setVelocity(0.0)

    # Enable IR Sensors
    left_ir = robot.getDevice('ir_left')
    left_ir.enable(timestep)

    right_ir = robot.getDevice('ir_right')
    right_ir.enable(timestep)

    while robot.step(timestep) != -1:
        # read IR Sensors
        left_ir_value = left_ir.getValue()
        right_ir_value = right_ir.getValue()
```

```
print("left: {} right: {}".format(left_ir_value, right_ir_value))
left_speed = max_speed/2
right_speed = max_speed/2
# Conditions for tracing
if (left_ir_value > right_ir_value) and (300< left_ir_value
                                                   <400):

    print("Go left")
    left_speed = -max_speed

elif (right_ir_value > left_ir_value) and (300<
                                         left_ir_value <400):
    print("Go right")
    right_speed = -max_speed +0.5

left_motor.setVelocity(left_speed)
right_motor.setVelocity(right_speed)

if __name__ == "__main__"
    my_robot = Robot()
    drive_robot(my_robot)
```

Results: The robot was able to successfully trace the black line. Screenshot attached for reference.

Conclusion: The design based simulation has been carried out successfully.

Teacher's Signature ______

Date: 09/05/2023

Expt. No. 5 Page No. 16

# Title: Designing an obstacle avoidance robot with two fixed wheels.

**Aim:** This experiment aims to design the simulation of an obstacle avoidance bot with two fixed wheels on webots software.

**Components Required:** Laptop/PC with Windows 10 or higher, WeBots software with relevant libraries installed, Python3

**Theory:** An obstacle avoidance robot is a type of autonomous mobile robot that is designed to navigate a given environment while avoiding obstacles that may lie in its path. These robots typically use of combination of sensors and algorithms to detect and respond to obstacles, allowing them to navigate around them and continue on their path.

The most common sensor used for this application shall be the IR sensor or the HC-SR04 Ultrasonic sensor.

The environment is constructed on the WeBots software and visualisation is done using the same.

Teacher's Signature ____________

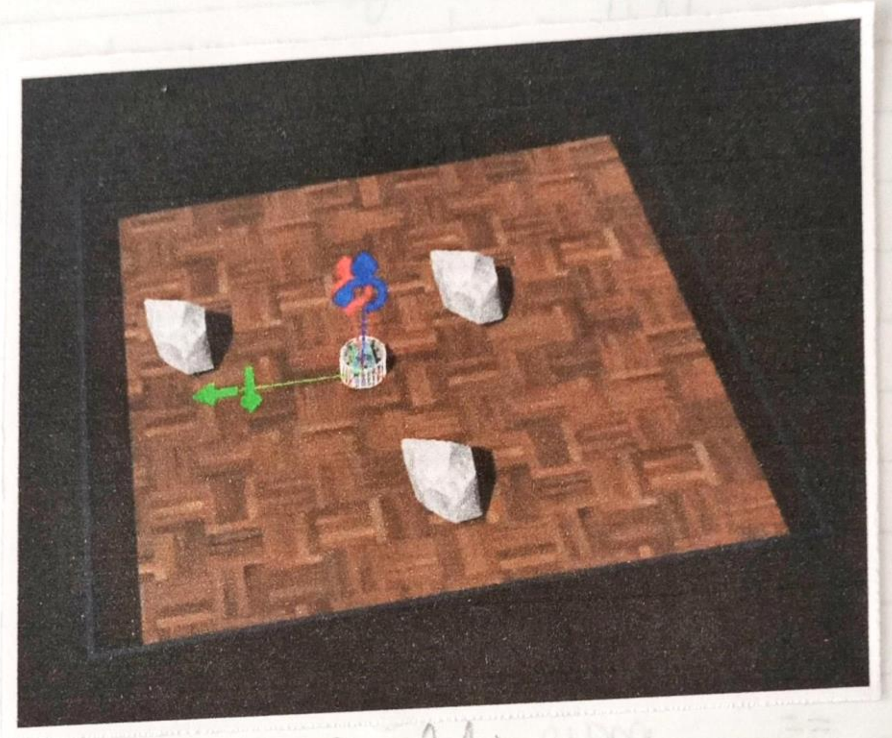


Fig. Simulation

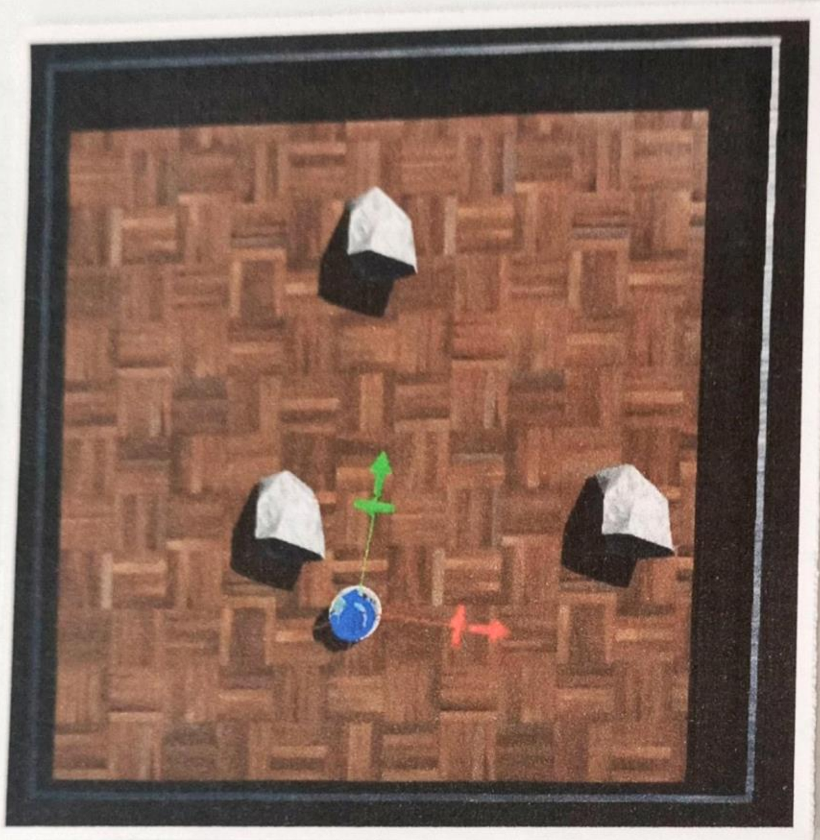


Fig. Simulation

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Code:

```
from controller import Robot        # Importing Library.

# Defining the constants.
TICK_TIME = 32
MAX_SPEED = 6.28
STOP_DISTANCE = 0.2

# Defining drive robot function.
def drive_robot(robot):
        # Initializing HC-SR04 sensor.
        us = robot.getDevice('us')
        us.enable(TICK_TIME)

        # Initializing the motors
        left_motor = robot.getDevice('motor_left')
        right_motor = robot.getDevice('motor_right')
        left_motor.setPosition(float('inf'))
        right_motor.setPosition(float('inf'))
        left_motor.setVelocity(0.0)
        right_motor.setVelocity(0.0)

        # Main loop for control of robot
        while robot.step(TICK_TIME) != -1:

            us_value = us.getValue()

            if us_value < STOP_DISTANCE:
                left_motor.setVelocity(-MAX_SPEED)
```

```
        right_motor.setVelocity(-MAX_SPEED)
    else:
        left_motor.setVelocity(MAX_SPEED)
        right_motor.setVelocity(MAX_SPEED)


#Main Program
if __name__ == "__main__":
    #Initialization
    my_robot = Robot()

    #Driver initialization
    drive_robot(my_robot)
```

Results: The designed robot is able to avoid obstacles successfully. The simulation performed on the WeBots software is able to explain the visualization of the same.

Conclusion: The experiment has been carried out successfully.