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The Solar Panel Powered IoT Based Lawn Mower Robot

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ABSTRACT :

The fully automated solar lawn cutter is a solar-powered robotic vehicle that can cut grass without human intervention and avoid obstructions. The main goal of this research study is to create a mower that is both environmentally friendly and cost-effective. In this study, an ESP32 camera and a mobile phone are utilized, with the camera capturing and sending video of the pathway's current course and the mobile phone acting as a receiver to manage the robot. The system's vehicle movement and grass cutter motors are powered by 12V batteries. Everyone also use a solar panel to charge the battery, eliminating the need to charge it outside. The grass cutter and vehicle motors are connected to an 8051-family microprocessor, which regulates the operation of all motors. It also connects to an ultrasonic sensor for object detection. In the absence of an obstacle, the microcontroller directs the vehicle's motors onward. When an obstruction is detected, the ultrasonic sensor monitors it, and the microprocessor stops the grass cutter motor to avoid damaging the object/human/animal, whatever it is. If the robot clears the item, the microcontroller spins it and moves the grass cutter ahead again.

Introduction :

The growth of Internet of Things (IoT) devices has driven innovation in a variety of fields, including lawn care. This study describes the creation of a fully automated, solar-powered lawn mower robot intended to simplify lawn maintenance activities and enhance environmental sustainability. The fundamental goal of this project is to develop a low-cost, environmentally friendly method for cutting grass autonomously without human involvement.

The suggested system uses an ESP32 camera to record real-time video of the lawn, delivering visual information about the path and potential impediments. A mobile phone serves as a remote control, receiving camera feed and sending commands to the robot. To ensure independent functioning, the device is outfitted with 12V batteries that are replenished by a solar panel, removing the need for additional power sources.

An 8051-family CPU is used to control the lawn cutter and vehicle motors. In addition, an ultrasonic sensor is used to detect obstructions in the robot's path. The lawn mower robot uses these technologies to navigate its surroundings, avoid collisions, and cut grass efficiently, providing a practical and ecologically responsible lawn care option.

Literature Review :

This literature study covers cutting-edge technologies and approaches for powered by solar IoT-based lawn mower robots. The review seeks to identify current advancements, difficulties, and future prospects in this subject.

Powered by sunlight Lawnmower Robots: Solar-powered lawn mower robots use solar panels to capture solar energy and convert it to electricity. These robots are often outfitted with autonomous navigation systems, allowing them to navigate lawns and trim grass without human involvement. The utilization of solar electricity makes these robots more environmentally friendly and less reliant on traditional energy sources.

IoT-based lawn mower robots have sensors and connectivity modules that allow them to collect and transfer data to a central server or user interface. These robots may be remotely controlled and monitored, as well as designed to function autonomously using predetermined settings. The incorporation of IoT technology enables real-time monitoring and control of robots, increasing their efficiency and performance.

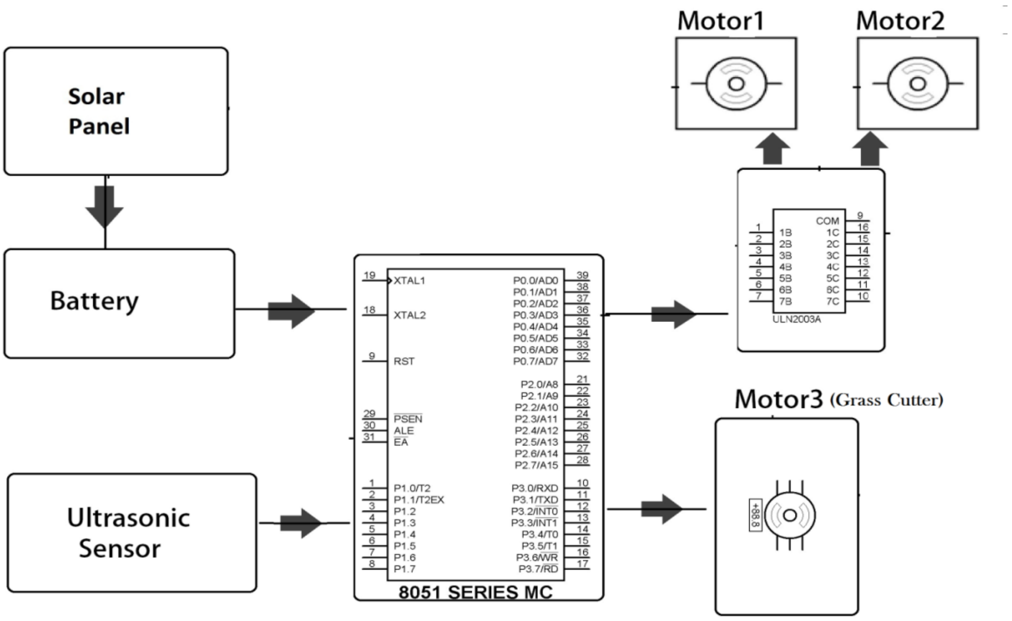
Hardware specifications include an Arduino and a 3 watt IN-3P solar panel.

Motor Driver IC. DC motors.
BLDC Motor.
Ultrasonic Sensor.
Battery: 6 volts
Solar Charger Controller, 10A
Robotic body.
Wheels
Motor mounts
Supportive frame.
Screws and bolts.

Controller circuitry
Bearings
Bluetooth module for Arduino.

Software Specifications:
Arduino IDE
MC Programming Language: Embedded C.

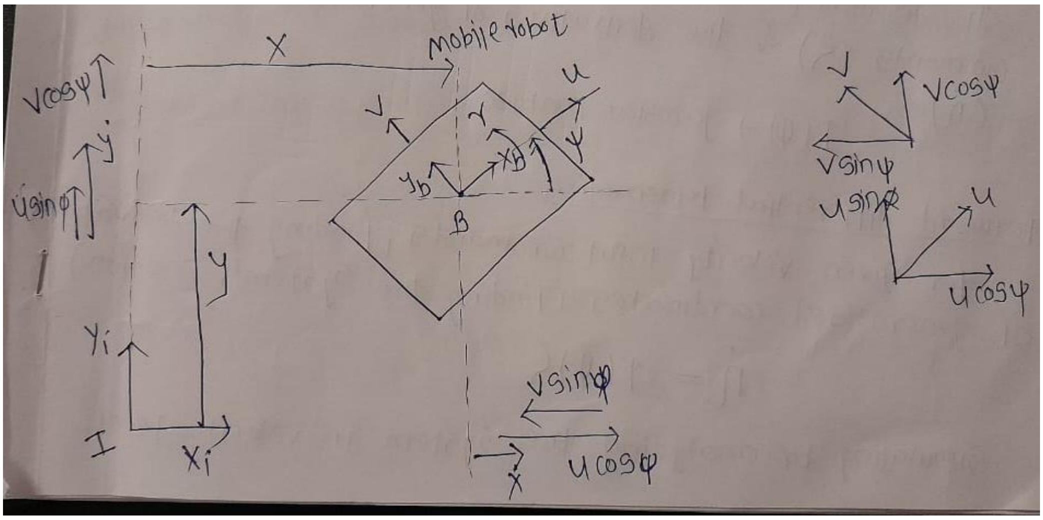
Block Diagram of Solar Panel Powered Iot Based Lawn Mower Robot



CALCULATION AND CODE

The solar grass cutter robot delivers following benefits.

- It can cut grass with ease using high powered motor.
- Variable head to define the grass cutting height.
- Heavy Duty body, wheels, and drive motors to navigate offroad.
- Autonomous motion with obstacle avoidance using ultrasonic.
- Motorized drive using DC motors.
- Solar powered machine for self-charging



Mobile robot kinematics

X: forward displacement of the mobile robot w.r.t
Y: Lateral displacement of the mobile robot w.r.t
ϒ: Angular displacement of the mobile robot w.r.t
U: forward velocity of the mobile robot w.r.t
V: Lateral velocity of the mobile robot w.r.t
R: Angular velocity of the mobile robot w.r.t

$$\begin{bmatrix}\dot{x}\\ \dot{y}\\ \dot{\psi}\end{bmatrix} = \begin{bmatrix} u\cos\psi - v\sin\psi \\ u\sin\psi + v\cos\psi \\ r \end{bmatrix} \quad \cdots\cdots (1)$$

$$\begin{bmatrix}\dot{x}\\ \dot{y}\\ \dot{\psi}\end{bmatrix} = \begin{bmatrix} \cos\psi & -\sin\psi & 0 \\ \sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u \\ v \\ r \end{bmatrix}$$

$$\dot{\eta} = J(\psi)\zeta$$

It describes the relationship between the velocity inpu commands (ζ) & the derivatives of generalised ~~for~~ coordi ($\dot{\eta}$).

$J(\psi) \rightarrow$ Jacobian matrix

Forward Differential Kinematics – For given velocity input coordinates, finding the derivatives of generalized coordinates (finding the system's motion.)

$$\dot{\eta} = J(\psi)\zeta$$

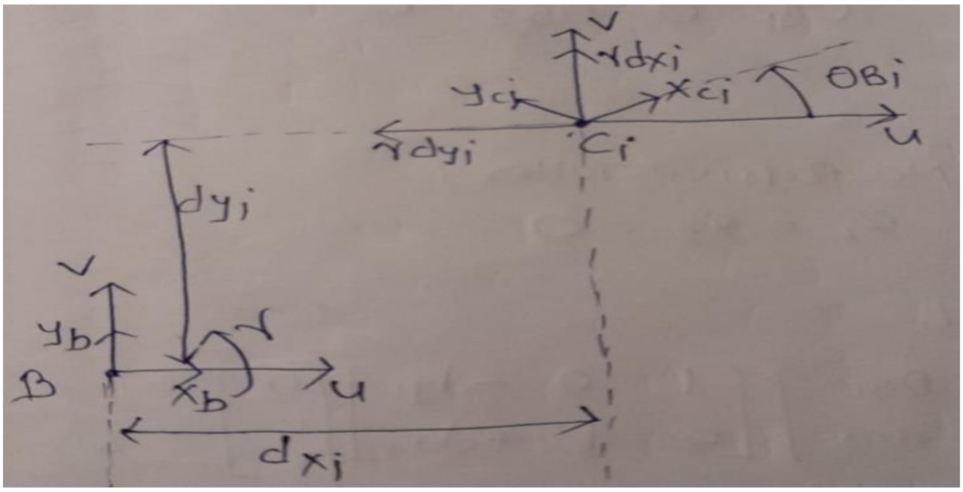
Simulation or analyzing the system in velocity level.

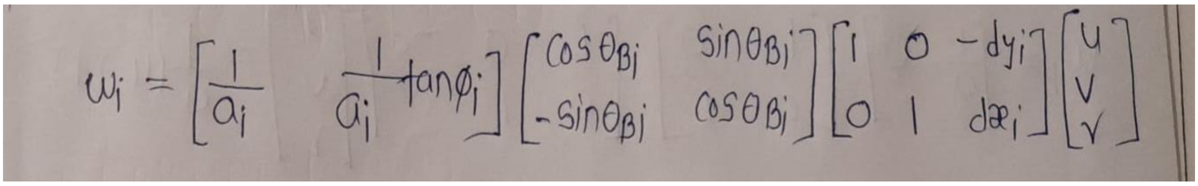
Inverse Differential Kinematics – for the desired (given) derivatives of generalized coordinates (or given position trajectory), finding the corresponding velocity input commands.

$$\zeta = J^{-1}(\psi)\dot{\eta}$$

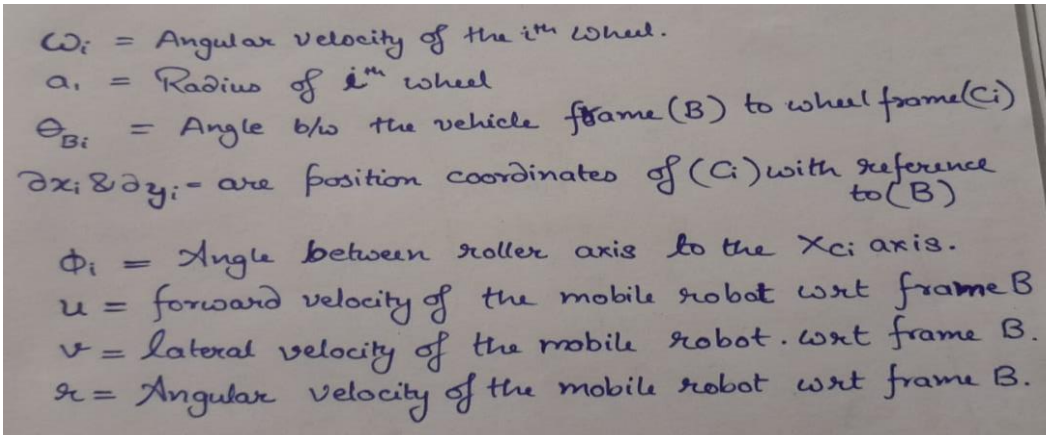
Controlling the system in velocity level.

Generalised wheel kinematic model –





$$\omega_i = \begin{bmatrix}\frac{1}{a_i} & \frac{1}{a_i}\tan\phi_i\end{bmatrix}\begin{bmatrix}\cos\theta_{Bj} & \sin\theta_{Bj}\\ -\sin\theta_{Bj} & \cos\theta_{Bj}\end{bmatrix}\begin{bmatrix}1 & 0 & -dy_i\\ 0 & 1 & dx_i\end{bmatrix}\begin{bmatrix}u\\ v\\ r\end{bmatrix}$$



ω_i = Angular velocity of the i^{th} wheel.

a_i = Radius of i^{th} wheel

θ_{Bi} = Angle b/w the vehicle frame (B) to wheel frame (Ci)

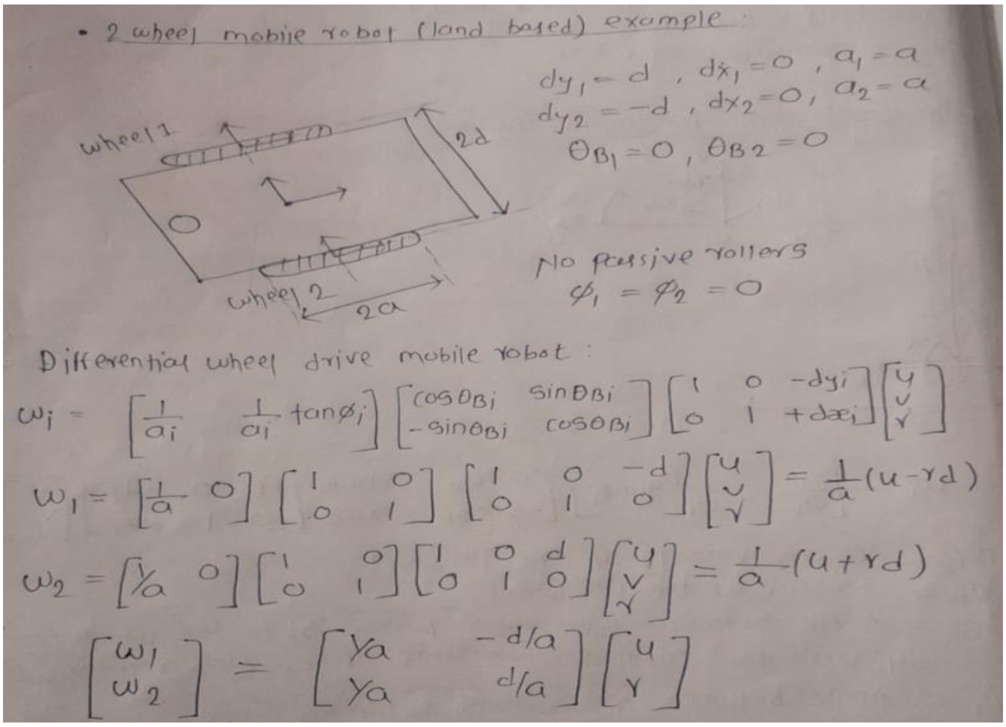
∂x_i & ∂y_i - are position coordinates of (Ci) with reference to (B)

Φ_i = Angle between roller axis to the X_{ci} axis.

u = forward velocity of the mobile robot wrt frame B

v = lateral velocity of the mobile robot. wrt frame B.

r = Angular velocity of the mobile robot wrt frame B.



- 2 wheel mobile robot (land based) example :

$dy_1 = d$, $dx_1 = 0$, $a_1 = a$

$dy_2 = -d$, $dx_2 = 0$, $a_2 = a$

$\theta_{B1} = 0$, $\theta_{B2} = 0$

No passive rollers

$\phi_1 = \phi_2 = 0$

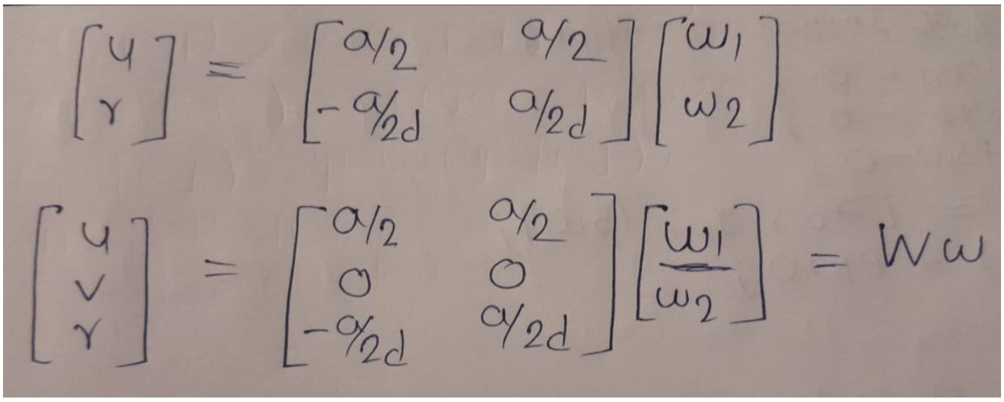
Differential wheel drive mobile robot :

$$\omega_i = \begin{bmatrix}\frac{1}{a_i} & \frac{1}{a_i}\tan\phi_i\end{bmatrix}\begin{bmatrix}\cos\theta_{Bi} & \sin\theta_{Bi}\\ -\sin\theta_{Bi} & \cos\theta_{Bi}\end{bmatrix}\begin{bmatrix}1 & 0 & -dy_i\\ 0 & 1 & +dx_i\end{bmatrix}\begin{bmatrix}u\\ v\\ r\end{bmatrix}$$

$$\omega_1 = \begin{bmatrix}\frac{1}{a} & 0\end{bmatrix}\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & -d\\ 0 & 1 & 0\end{bmatrix}\begin{bmatrix}u\\ v\\ r\end{bmatrix} = \frac{1}{a}(u - rd)$$

$$\omega_2 = \begin{bmatrix}1/a & 0\end{bmatrix}\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & d\\ 0 & 1 & 0\end{bmatrix}\begin{bmatrix}u\\ v\\ r\end{bmatrix} = \frac{1}{a}(u + rd)$$

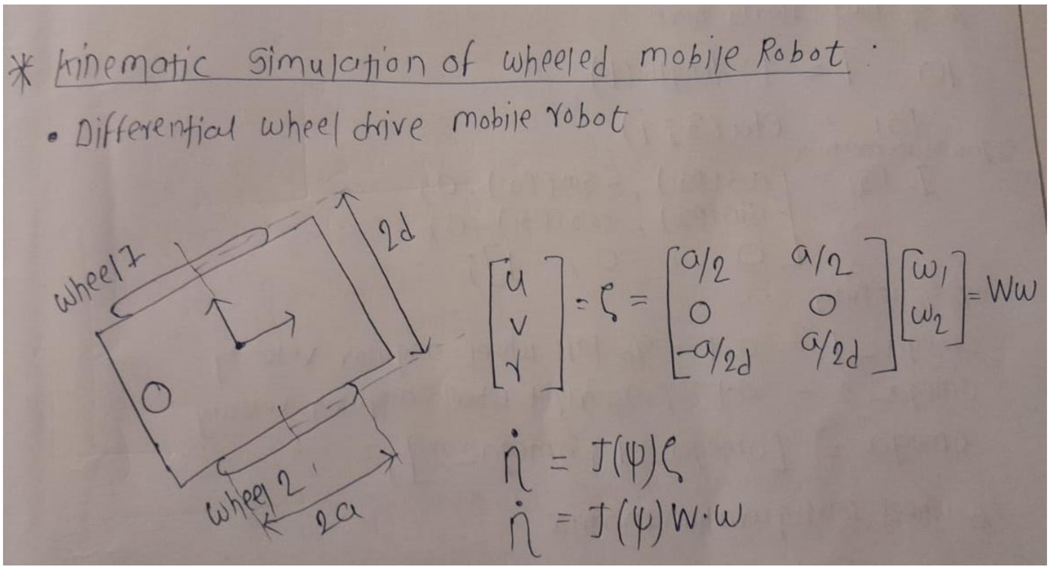
$$\begin{bmatrix}\omega_1\\ \omega_2\end{bmatrix} = \begin{bmatrix}1/a & -d/a\\ 1/a & d/a\end{bmatrix}\begin{bmatrix}u\\ r\end{bmatrix}$$



$$\begin{bmatrix}u\\ r\end{bmatrix} = \begin{bmatrix}a/2 & a/2\\ -a/2d & a/2d\end{bmatrix}\begin{bmatrix}\omega_1\\ \omega_2\end{bmatrix}$$

$$\begin{bmatrix}u\\ v\\ r\end{bmatrix} = \begin{bmatrix}a/2 & a/2\\ 0 & 0\\ -a/2d & a/2d\end{bmatrix}\begin{bmatrix}\omega_1\\ \omega_2\end{bmatrix} = W\omega$$

Kinematic Simulation of wheeled mobile robot –



* Kinematic Simulation of wheeled mobile Robot :

- Differential wheel drive mobile robot

$$\begin{bmatrix} u \\ v \\ r \end{bmatrix} = \zeta = \begin{bmatrix} a/2 & a/2 \\ 0 & 0 \\ -a/2d & a/2d \end{bmatrix} \begin{bmatrix} \omega_1 \\ \omega_2 \end{bmatrix} = W\omega$$

$$\dot{\eta} = J(\psi)\zeta$$

$$\dot{\eta} = J(\psi)W \cdot \omega$$

MATLAB SIMULATION ROBOT KINEMATICS

#1. MATLAB Code for Land-Based Mobile Robot Kinematics

```
%% Kinematic simulation of a land-based mobile robot
clear all; clc; close all;
%% Simulation parameters
dt = 0.1;  % Step size
ts = 10;  % Simulation time
t = 0:dt:ts;  % Time span
%% Vehicle (mobile robot) parameters
a = 0.055;  % Radius of the wheel (fixed)
d = 0.125;  % Distance between wheel frame to vehicle frame (along y-axis)
%% Initial conditions
x0 = 0;
y0 = 0;
psi0 = pi/2;
eta0 = [x0, y0, psi0];
eta(:, 1) = eta0;
%% Loop starts here
for i = 1:length(t)
    psi = eta(3, i);
    %% Jacobian matrix
    J_psi = [cos(psi), -sin(psi), 0; sin(psi), cos(psi), 0; 0, 0, 1];
    %% Inputs
    omega_1 = 5;  % Left wheel angular velocity
    omega_2 = 10;  % Right wheel angular velocity
    omega = [omega_1; omega_2];

    %% Wheel configuration matrix
    W = [(a/2), (a/2); 0, 0; (-a/2*d), (a/2*d)];
    %% Velocity input commands
    zeta(:, i) = W * omega;
    %% Time derivation of generalized coordinates
    eta_dot(:, i) = J_psi * zeta(:, i);
    %% Position propagation using Euler method
    eta(:, i+1) = eta(:, i) + dt * eta_dot(:, i);
end
%% Plotting
figure;
plot(t, eta(1, 1:i), 'r-');
hold on;
plot(t, eta(2, 1:i), 'b--');
plot(t, eta(3, 1:i), 'm--');
legend('x,[m]', 'y,[m]', '\psi,[rad]');
set(gca, 'fontsize', 24);
xlabel('t, [s]');
ylabel('\eta, [units]');
%% Animation (mobile robot motion animation)
```

```
l = 0.35;  % Length of the mobile robot
w = 2*d;  % Width of the mobile robot
%% Mobile robot coordinates
mr_co = [(-l/2), (l/2), (l/2), (-l/2), (-l/2); (-w/2), (-w/2), (w/2), (w/2), (-w/2)];
figure;
for i = 1:length(t)
   % Animation starts here
   psi = eta(3, i);
   R_psi = [cos(psi), -sin(psi); sin(psi), cos(psi)];  % Rotation matrix
   V_pos = R_psi * mr_co;
   fill(V_pos(1,:) + eta(1, i), V_pos(2,:) + eta(2, i), 'g');
   hold on; grid on;
   axis([-1 3 -1 3]);
   axis square;
   plot(eta(1, 1:i), eta(2, 1:i), 'b-');
   legend('MR', 'path');
   set(gca, 'fontsize', 24);
   xlabel('X, [m]');
   ylabel('y,[m]');
   pause(0.1);
   hold off;
end
```

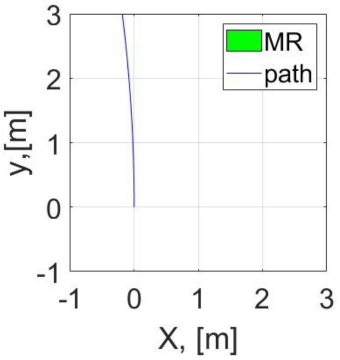
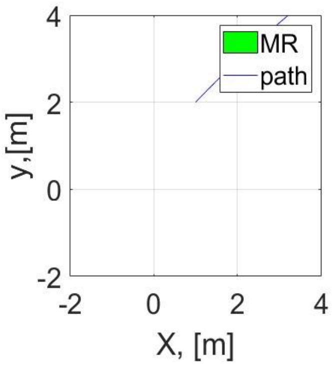


Fig1

#2. Here's the modified MATLAB code with adjusted parameters to simulate a different robot configuration and motion:

```
%% Kinematic simulation of a land-based mobile robot
clear all; clc; close all;
%% Simulation parameters
dt = 0.05;  % Step size
ts = 20;  % Simulation time
t = 0:dt:ts;  % Time span
%% Vehicle (mobile robot) parameters
a = 0.06;  % Radius of the wheel (fixed)
d = 0.15;  % Distance between wheel frame to vehicle frame (along y-axis)
%% Initial conditions
x0 = 1;
y0 = 2;
psi0 = pi/4;
eta0 = [x0, y0, psi0];
eta(:, 1) = eta0;
%% Loop starts here
for i = 1:length(t)
   psi = eta(3, i);
   %% Jacobian matrix
   J_psi = [cos(psi), -sin(psi), 0; sin(psi), cos(psi), 0; 0, 0, 1];
   %% Inputs
   omega_1 = 8;  % Left wheel angular velocity
   omega_2 = 5;  % Right wheel angular velocity
   omega = [omega_1; omega_2];
   %% Wheel configuration matrix
   W = [(a/2), (a/2); 0, 0; (-a/2*d), (a/2*d)];
   %% Velocity input commands
   zeta(:, i) = W * omega;
   %% Time derivation of generalized coordinates
   eta_dot(:, i) = J_psi * zeta(:, i);
   %% Position propagation using Euler method
```

```
    eta(:, i+1) = eta(:, i) + dt * eta_dot(:, i);
end
%% Plotting
figure;
plot(t, eta(1, 1:i), 'r-');
hold on;
plot(t, eta(2, 1:i), 'b--');
plot(t, eta(3, 1:i), 'm--');
legend('x,[m]', 'y,[m]', '\psi,[rad]');
set(gca, 'fontsize', 24);
xlabel('t, [s]');
ylabel('\eta, [units]');
%% Animation (mobile robot motion animation)
l = 0.35;  % Length of the mobile robot
w = 2*d;  % Width of the mobile robot
%% Mobile robot coordinates
mr_co = [(-l/2), (l/2), (l/2), (-l/2), (-l/2); (-w/2), (-w/2), (w/2), (w/2), (-w/2)];
figure;
for i = 1:length(t)
    % Animation starts here
    psi = eta(3, i);
    R_psi = [cos(psi), -sin(psi); sin(psi), cos(psi)];  % Rotation matrix
    V_pos = R_psi * mr_co;
    fill(V_pos(1,:) + eta(1, i), V_pos(2,:) + eta(2, i), 'g');
    hold on; grid on;
    axis([-2 4 -2 4]);
    axis square;
    plot(eta(1, 1:i), eta(2, 1:i), 'b-');
    legend('MR', 'path');
    set(gca, 'fontsize', 24);
    xlabel('X, [m]');
    ylabel('y,[m]');
    pause(0.1);
    hold off;
end
```



4. Results and Discussion

Hardware and Software Implementation

The requested lawn mower robot was successfully built with the supplied components. The ESP32 camera recorded real-time footage of the lawn, allowing the cell phone to track the robot's location and surroundings. The solar panel supplied 12V batteries, which provided enough energy for the vehicle and grass cutter engines. The 8051-family CPU effectively operated the motors and communicated with the ultrasonic sensor to detect obstacles.

Experimental Evaluation

The robot's performance was assessed in a variety of lawn situations, including those with obstacles, uneven terrain, and fluctuating grass height. The ultrasonic sensor correctly identified impediments, and the CPU successfully managed the robot's movements to avoid collisions. The solar panel effectively charged the batteries, allowing for continuous operation during daylight hours.

Performance Analysis

The lawn mower robot displayed efficient grass cutting abilities, maintaining a steady cutting height and creating a clean finish. The autonomous navigation system enabled the robot to cover the full grass area without human involvement. The solar-powered architecture greatly reduced the need for external power sources, making it a more ecologically responsible option.

Challenges and Limitations.

While the lawn mower robot operated admirably in most instances, several difficulties were discovered. Low sunshine, complicated terrain, and dense flora all had an impact on the robot's performance. Furthermore, the battery capacity may limit the robot's operating time on overcast days or during long mowing sessions.

Conclusion

The created solar-powered IoT-based lawn mower robot marks a big step forward in autonomous lawn care technology. The technology seamlessly integrates solar energy, IoT, and robotics to offer a convenient and environmentally responsible lawn maintenance solution. Future research could concentrate on improving the robot's performance in demanding environments, boosting battery capacity, and investigating sophisticated navigation algorithms. By solving these issues, the lawn mower robot can be developed to better match the changing needs of homeowners and contribute to sustainable lawn care methods.

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