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# CASE STUDY REPORT

## BEAM ROBOTICS

## XCSHA3

## INTRODUCTION TO MACHINE LEARNING

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# INTRODUCTION

BEAM Robotics (Biology, Electronics, Aesthetics, and Mechanics) is a branch of robotics that focuses on building simple, efficient robots without the use of microcontrollers or complex programming. These robots mimic biological behaviors such as phototaxis (movement towards light), obstacle avoidance, or energy-seeking. BEAM robots are often solar-powered and rely on analog circuits to generate adaptive responses to environmental stimuli.
This case study highlights the development and analysis of a Straight-Line BEAM Robot and an Obstacle Avoidance BEAM Robot, examining their working principles, applications, and limitations.

# HISTORICAL BACKGROUND

- Late 1980s–1990s: Concept developed by Mark W. Tilden at the University of Waterloo and later at Los Alamos National Laboratory.
- 1992: BEAM robots gained global attention when A.K. Dewdney introduced "photovores" in Scientific American
- 1990s–2000s: Growth through hobbyist communities and companies like Solarbotics, which released BEAM kits and circuits (e.g., Miller Solar Engine).

The philosophy parallels Rodney Brooks' subsumption architecture, proving that simple rules and behaviors can generate complex lifelike activity.

# KEY PRINCIPLES OF BEAM ROBOTICS

1. Direct Sensor-Actuator Coupling – minimal processing between sensors and motors.
2. Nv Neurons – RC-based timing circuits mimicking biological neurons.
3. Energy-Centric Design – solar harvesting and burst energy release for motion.
4. Form Follows Function – structure and circuitry together define behavior.

# PROBLEM STATEMENT

Most educational and hobbyist robots are built using microcontrollers, sensors, and programming. While this approach enables complex functionality, it also makes such robots costly and difficult for beginners to build and understand. As a result, many students and enthusiasts face barriers when trying to learn the basics of robotics.

To address this challenge, there is a need for a simple and low-cost robotic system that can perform basic intelligent behaviors such as straight-line movement and obstacle avoidance without relying on microcontrollers or programming. Such a system would make robotics more accessible, affordable, and beginner-friendly.

# INTRODUCTION TO BEAM ROBOTICS

BEAM robotics, short for Biology, Electronics, Aesthetics, and Mechanics, represents a minimalist school of thought in autonomous robotics. Unlike traditional robots that depend on microcontrollers and sophisticated programming, BEAM robots use simple analog circuits, solar energy, and direct sensor-to-motor connections.

## Common BEAM models include:

- Photovores – robots that move toward light
- Symets – solar-powered movers
- Walkers – robots with insect-like gaits.

is philosophy emphasizes rugged design, low energy consumption, and lifelike motion emerging from circuitry rather than software.

# THIS CASE STUDY EXPLORES TWO TYPES OF BEAM ROBOT

1. Straight line robot
2. obstacle avoidance robot

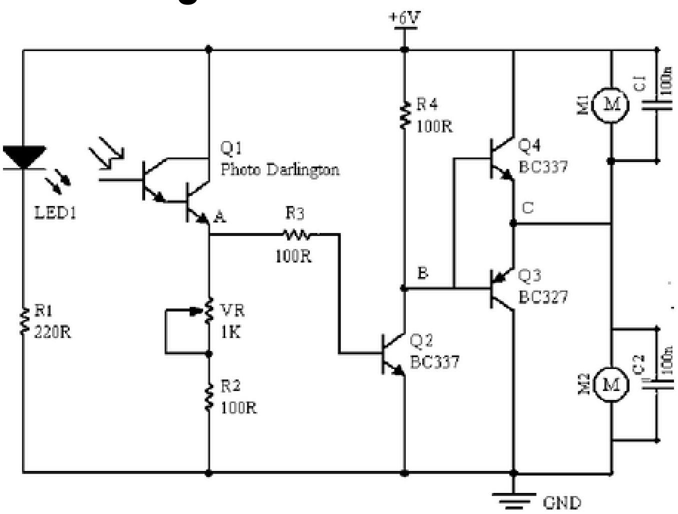
# (1) STRAIGHT LINE BEAM ROBOT

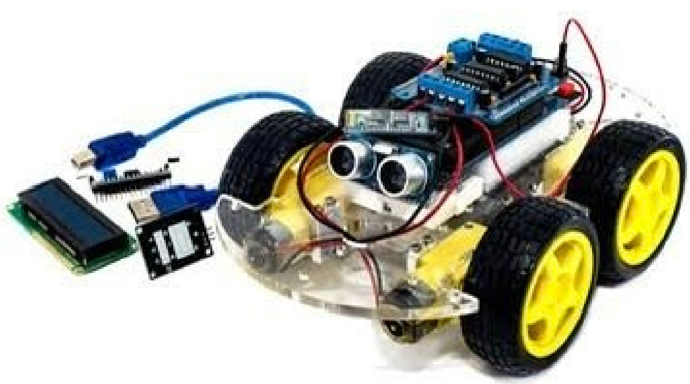
A straight-line BEAM robot is a simple type of BEAM (Biology, Electronics, Aesthetics, Mechanics) robot that moves forward in a straight path without using any microcontroller, programming, or sensors.

### Characteristics of a Straight-Line BEAM Robot:

1. No Programming – Works only on analog electronics and mechanics.
2. Low Cost & Simple – Uses minimal components, often powered by solar energy.
3. Movement Mechanism – Generally two identical motors/wheels or a vibration motor setup to ensure straight-line motion.
4. Educational Value – Helps beginners understand robotics without diving into coding or complex circuitry.

### Circut Diagram

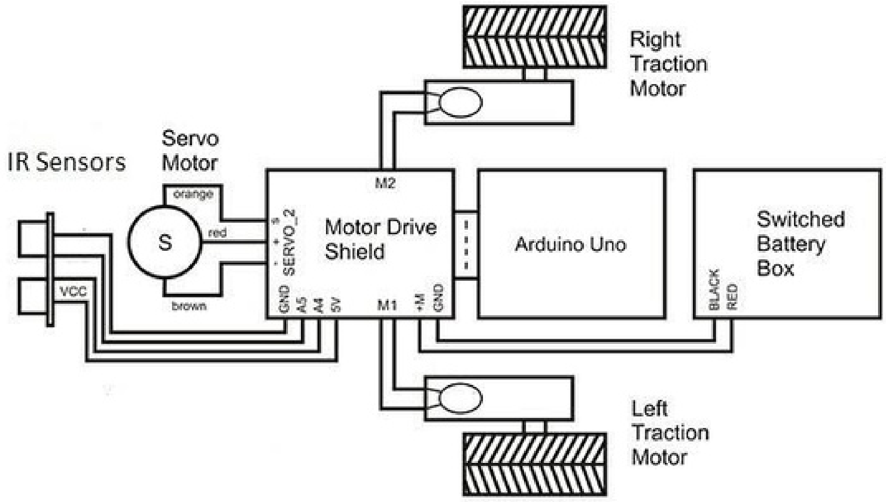


### Working principle

A line follower robot works on the principle of light reflection and detection using sensors. It is designed to follow a specific path, usually a black line on a white surface, by using infrared (IR) sensors placed underneath the robot. These sensors detect the difference in reflectivity, as black absorbs IR light while white reflects it. The sensor signals are sent to a control unit, such as a microcontroller or a simple logic circuit, which processes the information and decides how the motors should move. When both sensors detect the line, the robot moves straight; if one sensor goes off the line, the controller adjusts the motor speeds so that the robot turns back towards the path. This constant detection and correction loop allows the robot to continuously follow the line accurately.

## Block diagram of line follower robot




## Application

• Industrial Automation – Used in automated factories for material handling and goods transportation.

• Automated Guided Vehicles (AGVs) – In warehouses, line follower robots transport items along predefined paths.

• Medical and Hospital Services – Robots deliver medicines, meals, and supplies along marked routes

## Advantages

• Automation – Reduces the need for human effort in repetitive transportation tasks.

• Low Cost – Requires minimal components (sensors, motors, controller).

• Accuracy – Follows a fixed path precisely without deviation.

## Limitations

• Limited Navigation – Can only follow predefined paths (lines), not suitable for dynamic environments.

• Sensitivity to Surface – Performance depends on clear visibility of the line (poor in dusty or reflective surfaces).

• Low Intelligence – Lacks decision-making ability beyond path following.

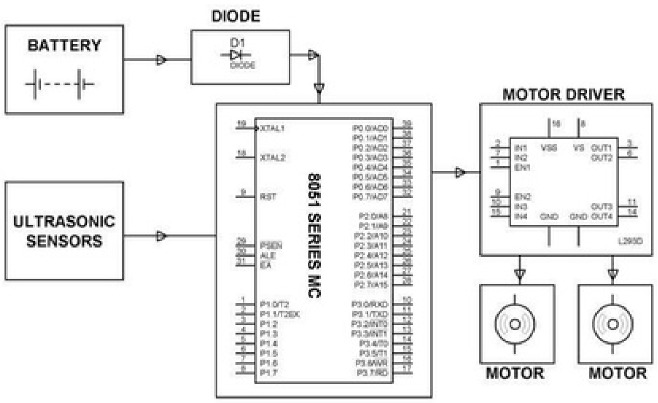
# (2) OBSTACLE AVOIDANCE ROBOT

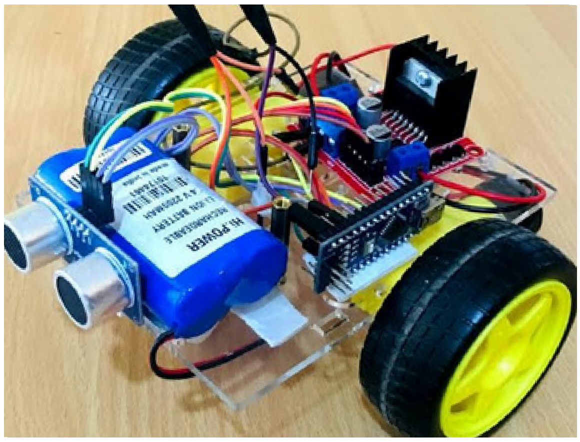
An obstacle avoidance robot is a type of autonomous mobile robot designed to detect and navigate around obstacles in its path without human intervention. Its main purpose is to move freely in an environment while preventing collisions.

## Characteristics of a obstacle avoidance Robot:

1. Autonomous Operation – Works without human control by sensing and reacting to its environment.
2. Real-Time Obstacle Detection – Continuously scans surroundings using sensors (ultrasonic, IR, or bump sensors).
3. Collision Prevention – Detects obstacles ahead and changes direction to avoid collisions.
4. Decision-Making Capability – Uses a control unit (microcontroller or simple logic circuit) to process sensor inputs and decide movement.

## Circut Diagram

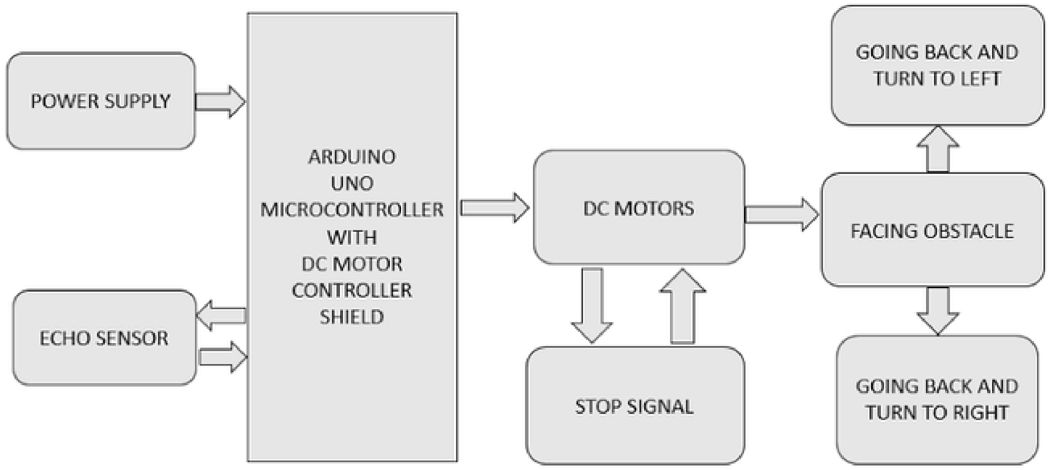


## Working principle

The working principle of an obstacle avoidance robot is based on the detection of obstacles using sensors and the automatic control of motors to change its path. The robot is usually equipped with sensors such as ultrasonic or infrared sensors, which continuously scan the area in front of it. When an obstacle comes within the sensor's detection range, the sensor sends a signal to the control unit, typically a microcontroller or a simple electronic circuit. The control unit processes this information and decides the next movement of the robot. For example, if the path ahead is blocked, the controller may stop the forward movement and turn the robot left or right until a clear path is found. This process of detecting, deciding, and acting repeats continuously, allowing the robot to navigate around obstacles and move safely without human intervention.

**Block diagram of line follower robot**




## Application

- Automation – Reduces the need for human effort in repetitive transportation tasks.
- Industrial Automation – Robots in factories avoid machinery or workers while transporting goods.
- Military and Defense – Useful in navigating rough terrains, minefields, or hazardous zones.

## Advantages

- Autonomous Navigation – Works without human guidance.
- Simple and Low-Cost – Can be built using affordable sensors and components.
- Energy Efficient – Only changes direction when needed.

## Limitations

- Limited Detection Range – Basic sensors (IR/ultrasonic) may not detect obstacles far away.
- Speed vs. Accuracy Trade-off – Fast robots may not react quickly enough to avoid sudden obstacles.
- Difficulty with Transparent/Reflective Surfaces – Sensors may give inaccurate readings with glass or shiny objects.

## SOLUTION

To overcome the challenges posed by costly and programming-dependent robots, a simple BEAM-inspired robotic system can be developed using analog circuits, basic electronic components, and solar or battery power. Instead of microcontrollers, the design relies on capacitors, resistors, transistors, and direct sensor-to-motor connections to achieve intelligent behaviors. For straight-line movement, energy from a solar cell or small battery is stored in a capacitor and released in bursts through a transistor to drive a motor, producing step-like forward motion without any programming. To enable obstacle avoidance, additional feedback is introduced using whisker or bump sensors that alter the motor response whenever the robot encounters an obstacle, causing it to stop briefly or change direction before continuing. This minimalist approach ensures low cost, simplicity, and energy efficiency while still demonstrating essential robotics concepts such as energy storage, actuation, and feedback control. As a result, the system makes robotics more accessible and beginner-friendly, allowing students and hobbyists to learn fundamental principles without the complexity of coding or advanced hardware.

## CONCLUSION

The study of straight-line and obstacle-avoiding BEAM robots demonstrates that intelligent robotic behaviors can be achieved without relying on microcontrollers, complex programming, or costly components. By using simple analog circuits, solar or battery power, and basic mechanical designs, these robots highlight the core BEAM philosophy of simplicity, efficiency, and biomimicry. The straight-line robot illustrates fundamental energy storage and release concepts, while the obstacle-avoiding robot introduces feedback-based motion control, making it more adaptive to its environment. Together, they provide an effective educational platform for beginners, hobbyists, and students to understand essential robotics principles in a hands-on and affordable way. Although BEAM robots have limitations compared to programmable systems, they remain valuable tools for teaching, experimentation, and inspiring innovation in robotics through minimalist design.