

Automatic Pneumatic Bumper & Brake Actuation before Collision

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Abstract:

The technology of pneumatics has gained tremendous importance in the field of work place rationalization and automation from old-fashioned timber works and coalmines to modern machines hops and space robots. It is therefore important that technicians and engineers should have a good Knowledge of pneumatic system, air operated valves and accessories. The aim is to design and develop a control system based an intelligent. Electronically controlled automotive bumper activation system is called "AUTOMATIC PNEUMATIC BUMPER".

This system is consisting of IR transmitter and Receiver circuit, Control Unit, Pneumatic bumper system. The IR sensor issued to detect the obstacle. There is any obstacle closer to the vehicle (within 4 feet), the control signal is given to the bumper activation system. The pneumatic bumper system is Used to product the man and vehicle. This bumper activation system is only activated the vehicle speed above 40-50 km per hour. This vehicle speed is sensed by the proximity sensor and this signal is given to the control unit and pneumatic bumper activation system.

Keywords: Automatic Pneumatic bumper, air operated valves ,IR transmitter, control unit, proximity sensor.

I. Introduction

Road accidents are increasing due to heavy traffic and human error Drivers may not react quickly enough to sudden obstacles. This system helps reduce accidents by acting automatically. Sensors detect obstacles before a collision occurs. Brakes are applied automatically using a pneumatic system. A pneumatic bumper moves forward to reduce impact force.

A recent Kaveri travels bus accident near Kurnool, Andhra Pradesh on October 24, 2025, due to negligence of driver. Recently Hari Krishna travels bus accident near Markapuram Andhra Pradesh on 26 March 2026, Due to negligence of driver. The target is a safety system based on the pneumatic actuation of the vehicle bumper. This system guarantees passenger safety within the vehicle. The ultimate objective of this model is to absorb impact force while a collision takes place without passing force to the car body. It minimizes the severity of the damage caused by the vehicle crash and improves the safety of vehicle insiders. Several scientists performed different experiments with stroke models and stroke content. The bumpers absorb the force of impact that is the cinematic energy generated by the collision during deformation. Therefore, the material for the bumper is important in restricting the impact force.

II. Literature Review

Many researchers have worked on improving vehicle safety systems using automation, sensors, and pneumatic mechanisms. The following studies provide a foundation for the development of an automatic pneumatic bumper and braking system.

Intelligent Pneumatic Bumper Systems: A study on automatic pneumatic bumper systems explains that pneumatics plays an important role in automation and vehicle safety. The system uses sensors to detect obstacles and activates both the bumper and braking system when the obstacle is within a short distance.

Smart Automatic Braking with Pneumatic Bumper. Another research work introduced a system using IR sensors, control unit, and pneumatic actuators. When an obstacle is detected, both the brake and bumper area activated simultaneously, especially at higher speeds (above 40 km/h). This study highlights: Faster response compared to human reaction Improved safety distance between vehicles Reduced accident probability. This research shows that combining sensor detection with pneumatic actuation can significantly reduce collision impact.

Automatic Pneumatic Bumper and Braking System. A detailed study emphasizes that most accidents occur due to delayed braking by drivers. To solve this, an automatic system is designed that: Detects obstacles using sensors Applies brakes automatically Extends a pneumatic bumper to absorb impact The use of pneumatic cylinders and solenoid valves makes the systems simple and effective..

Development of Pneumatic Collision Avoidance System: Research shows that traditional bumpers are rigid and fail under high impact, transferring force to passengers. To overcome this: A retractable pneumatic bumper is introduced Automatic braking is integrated the system reduces force transmitted during collision.

Automatic Braking System Using Sensors: Another study focuses on automatic braking systems using optical/ultrasonic sensors. It explains that: The system continuously scans surroundings Brakes are applied when an obstacle is detected It helps prevent accidents due to rash or distracted driving.

USR. Intelligent Braking System Concepts: Earlier research on intelligent braking systems suggests that automation improves reliability over manual braking. Pneumatic systems are preferred because: They are simple Easy to maintain, Provide quick actuation

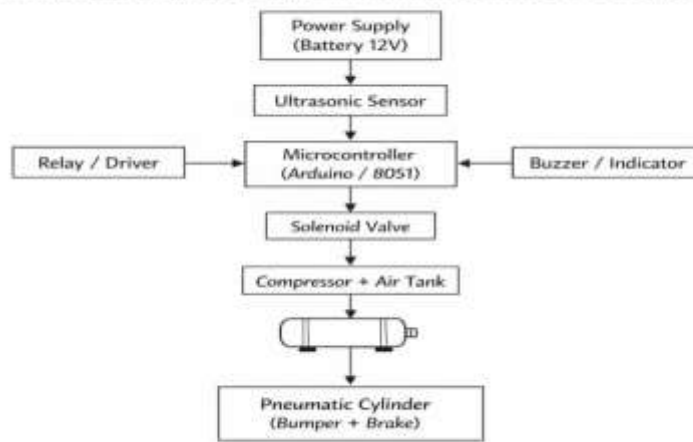
General Advances in braking technology Modern braking research (like electro-mechanical braking systems) shows a trend toward automated and sensor-based braking technologies for better safety and control in vehicles.

III. Problem Statement

To design and develop an automatic collision avoidance system Build a system that detects obstacles ahead of a vehicle and responds automatically. To implement sensor-based obstacle detection. use sensors (like ultrasonic or IR sensors) to continuously monitor the distance between the vehicle and obstacles. To reduce accident impact using a pneumatic bumper system develops a pneumatic mechanism that activates and extends the bumper before collision to absorb impact. To apply automatic braking system Integrate a braking mechanism that is triggered automatically when an obstacle is detected with critical distance. To minimize human error in driving Reduce dependence on driver reaction time by automating safety responses. To improve vehicle safety and reduce damage Protect passengers and vehicle components by reducing collision force. To ensure quick response time using embedded systems Use a micro controller to process sensor data and activate the system instantly. To create a cost-effective and efficient safety solution design the system using affordable components for practical real world application.

IV. Methodology

Automatic Pneumatic Bumper and Brake Actuation Before Collision



Pneumatic Systems in Automobiles

A pneumatic system is a type of automation system that uses compressed air to perform mechanical work. It is widely used in industries and vehicles because of its simplicity, reliability, and fast response.

A pneumatic system converts the energy of compressed air into motion. This motion can be used to move, lift, push, or control mechanical components. In automation, pneumatic systems help in performing tasks automatically without manual effort.

Main Components of a Pneumatic System

1. Compressor: It compresses atmospheric air and stores it at high pressure.
2. Air Reservoir (Tank): Stores compressed air for continuous supply.
3. Control Valves (Solenoid Valves): Control the flow and direction of compressed air.
4. Actuators (Pneumatic Cylinders): Convert compressed air into mechanical motion (linear or rotary).
5. Pipes and Fittings: Transport compressed air from one component to another.

Air is compressed using a compressor and stored in a tank. The compressed air flows through valves when activated. The valves direct air into a pneumatic cylinder. The cylinder moves (extends or retracts), producing mechanical action. This action is used to perform automated tasks.

Components Used

Ultrasonic Sensor



An ultrasonic sensor is an electronic device that measures distance by using high-frequency sound waves (ultra sound). These waves are not audible to humans. It is widely used in automation and safety systems for detecting obstacles

Working Principle

1. The ultrasonic sensor works based on the echo principle:
2. The sensor transmits ultrasonic sound waves using a transmitter.
3. These sound waves travel through the air and hit an object (obstacle).
4. The waves are reflected back (echo) to the sensor.
5. The sensor receives the echo using a receiver.
6. The time taken for the echo to return is measured.
7. Distance is calculated using the formula.

Pneumatic Cylinder

A pneumatic cylinder is a mechanical device that uses compressed air to produce linear motion (back-and-forth movement). It's widely used in automation and machinery to move, push, pull, or lift objects. Pneumatic cylinder, also known as air cylinder is a mechanical device which uses the power of compressed gas to produce a force in a reciprocating linear motion.

Like in a hydraulic cylinder something forces a piston to move in the desired direction. The piston is a disc or cylinder and the piston rod transfers the force it develops to the object to be moved. Engineers sometimes prefer to use pneumatics because they are quiete, cleaner, and do not require large amounts of space for fluid storage. Because the operating fluid is a gas, leakage from a pneumatic cylinder will not drip out and contaminate the surroundings, making pneumatics more desirable where cleanliness is a requirement. For example in the mechanical puppets of the pneumatics are used to prevent fluid from dripping on to people below the puppets.



Air Compressor

An air compressor is a machine that takes ambient air from the surroundings and discharges it at a higher pressure. It is an application of a gas compressor and a pneumatic device that converts mechanical power (from an electric motor, diesel or gasoline engine, etc.) into potential energy stored in compressed air, which has many uses a common application is to compress air into a storage tank, for immediate or later use. When the delivery pressure reaches its set upper limit, the compressor is shut off, or the excess air is released through an over pressure valve. The compressed air is stored in the tank until it is needed. The pressure energy provided by the compressed air can be used for a variety of

applications such as pneumatic tools as it is released. When tank pressure reaches it slower limit, the air compressor turns on again and re-pressurizes the tank. A compressor is different from a pump because it works on a gas, while pumps work on a liquid.



Solenoid Valve

A solenoid valve is an electro mechanical device used to control the flow of a liquid or gas. It is comprised of two features: a solenoid and a valve. The solenoid is an electric coil with free-moving Ferro magnetic material in the center of the coil, often referred to as a“ plunger. When voltage is applied to the coil, the solenoid is energized. This action creates a magnetic field that either attracts or repels the plunger and causes it to translate linearly. The movement of the plunger alters the position of the components within the valve body to control the specific flow, direction, and pressure of fluid moving through the valve. When current or voltage is removed from the coil, the magnetic field collapses and all internal elements return to their de-energized position.

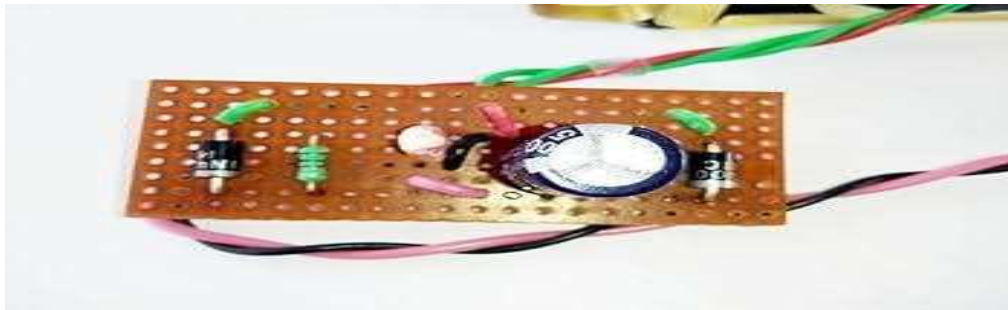
Common Uses for Solenoid Valves: Solenoid valves are a part of everyday life .They control the flow of water in dish washers, the flow of Propane to ignite a gas stove top, and even the flow of fuel in a car engine. These valves are available in a wide range of configurations depending on the system in which they are used and their intended function.



Zero PCB

A zero PCB(printed circuit board) refers to a type of board used in electronics that does not have any printed or pre-defined circuits on it. It's essentially a bare board, also known as a general-purpose PCB, or bread board. This PCB has multiple thin layers stacked together, enabling complex circuits. The material used depends on the application, ranging from fiber glass to advanced materials like ceramic or Teflon. It's popular in compact electronic devices such as phones, laptops, and tablets due to its reduced size.

Specialized applications such as aerospace and military technology also use it. For optimal use, designers should keep their layouts simple. Tiny components can lead to space constraints and intricate design can make assembly more difficult and costly. The Zero PCB Board has become a superhero of the electronics world. The bicycle frame is the primary structural component of the self-charging electric bicycle system, serving as the foundation that supports and integrates all mechanical and electrical elements into a single functional unit. It is designed to provide strength, rigidity, and stability while maintaining a light weight structure to ensure efficient operation and ease of handling. The frame accommodates key components such as the electric motor, battery, solar panel mounts, controller unit, and wiring, ensuring proper alignment and secure placement during motion. Material selection for the frame, typically steel or aluminum alloy, plays a crucial role in determining durability, load-bearing capacity, and resistance to external stresses such as vibrations and impacts encountered during riding.



Relay Module



A Relay module is an essential electronic tool used in various devices to act as a switch between low-powered digital electronics and high-powered devices. In the UK, relay modules are often used to switch 230V AC mains loads—making them a popular choice for home-automation projects (e.g., smart lighting and heating controls). It allows digital circuits and microcontrollers like Arduino to control motors or lighting circuits. Act as a switch that opens or closes electrical circuits when activated by a signal. It consists of two internal metal contacts that do not connect with each other. However, an internal switch connects these contacts to complete an electrical circuit, allowing current flow. To activate the relay, a voltage power current is applied to an electromagnetic coil. This pulls the metal contacts together and allows current to flow on the other side of the relay. Can be used in various applications, such as mains switching, automating electrical appliances and lights, isolated power delivery, and high current switching. They are often integrated with microcontrollers like Arduino, ESP32 and Raspberry Pi, enabling projects like motion sensor lamps, smart watch car remotes, touch less doorbells, and more. It comes in

different types, including Electro mechanical relays and solid-state relays. Relay modules can be different types and price range, and have different channel types, such as single-channel, dual-channel, four-channel, or eight-channel relays.

DC Motors

DC motors convert direct current electrical energy into mechanical rotation using magnetic fields. They consist of a stationary stator (field magnets) and a rotating armature, featuring precise speed control, high starting torque, and versatility for applications ranging from toys and robotics to electric vehicles and industrial automation.

Bumper Structure

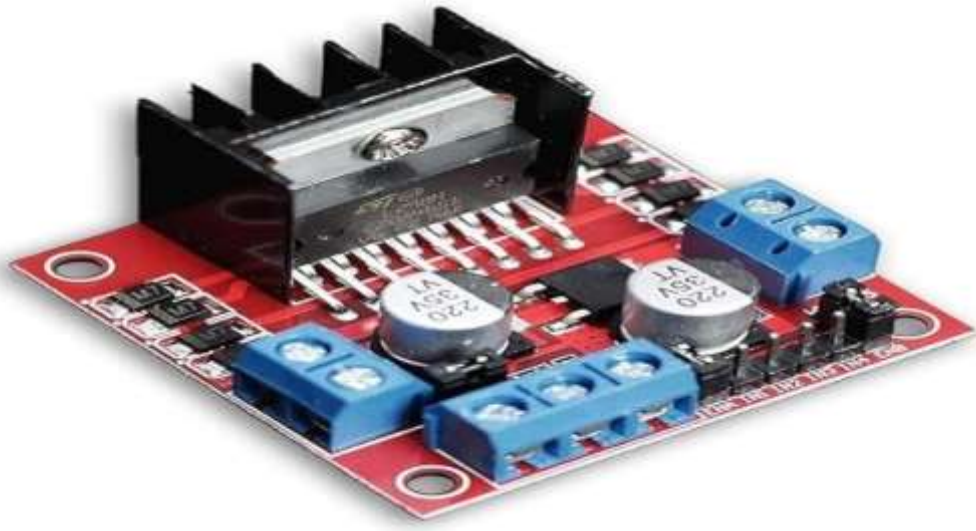
A bumper is a structural component attached to the front and rear of a vehicle, designed to absorb impact during low-speed collisions and minimize damage. Modern bumper typically consist of a plastic outer cover, reinforcement bars, and foam energy absorbers, protecting the vehicle's body and enhancing pedestrian safety

2. G Battery

A battery is a device that converts stored chemical energy into electrical energy using Electro chemical cells, acting as a power source for devices. It consists of an anode, cathode, and Electrolyte, with ions moving through the electrolyte while electrons flow through an external circuit. Batteries are broadly classified in to primary (single-use) and secondary (rechargeable)



Motor Drive Module: The item in the image is an L298N Motor Driver Module. Technology: It uses a dual H-bridge driver chip, allowing it to control the speed and direction of two DC motors or one step per motor independently. Voltage range: The module can operate with a driving voltage between 5V DC and 35V DC. Current Capacity: It supports a maximum driving current of 2A per channel features: It includes a large heat sink for heat dissipation and a non board 5V regulator that can power small micro controllers like Adriano



ARDUNIO UNO

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Const int trigPin=3; const int echoPin=4; int cm = 0;
Int last Valid=50;
//-----TIME LOGIC-----
Unsigned long start Time=0; bool object Detected=false; bool bumper Done = false; void setup() {
Serial. begin(9600);
PinMode(trigPin,OUTPUT); pin Mode(echoPin,INPUT);
Pin Mode(11,OUTPUT);//speed PWM
pin Mode(5,OUTPUT);//pneumatic relay
digital Write(5,HIGH);//OFF(active LOW relay) pin Mode(6,OUTPUT);
pin Mode(7,OUTPUT); pin Mode(8,OUTPUT); pin Mode(9,OUTPUT); stop Motors();
delay(2000);//sensor stabilize(VERY IMPORTANT)
}
Void loop (){
cm=get Distance();
Serial. Print ("Distance :"); Serial.println(cm);
//-----SPEEDCONTROL if(cm>125CCcm<=400){
Move Forward();
Analog Write (11,255);
}
Else if (cm>100CCcm<=125){
Move Forward();
Analog Write (11,230);
}
Else if (cm>50CCcm<=100){
move Forward();
analog Write(11,210);
}
Else if (cm>20CCcm<=50){

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```
move Forward();
analog Write(11,190);
}
Else if(cm<=20CCcm>10){ move Forward();
Analog Write(11,120);
}
Else {
Stop Motors();
Analog Write (11,0);
}
//-----TIME BASED BUMPER LOGIC-----
//STEP1:Object enters detection zone→starttimer if(cm<=120CCcm>20){
if(!object Detected){
start Time= millis();
object Detected=true;
Serial.println("TimerStarted");
}
}
//STEP2:Object very close→check reaction time
if (cm<=10CC object Detected CC !bumperDone){ unsigned long reactionTime=millis()-startTime;
Serial.print("Reaction Time:");
Serial.println(reaction Time);
if(reactionTime<10000){//adjust if needed Serial.print ln("BUMPER ACTIVATED");
stopMotors();
digital Write(5,LOW);//RELAY ON(open pneumatic) delay(4000);
digital Write(5,HIGH);//RELAYOFF delay(2000);
bumper Done=true;
}
Object Detected=false;//reset after check
}
//STEP3:Reset system if object goes away if(cm>150){
Object Detected=false; bumper Done =false;
}
delay(50);
}
//=====DISTANCE FUNCTION=====
Intget Distance()
{
Long duration;
int distance;
DigitalWrite(trigPin,LOW); delay Micro seconds(2);
DigitalWrite(trigPin,HIGH); delayMicro seconds(10); digitalWrite(trigPin,LOW);
duration=pulse In(echoPin,HIGH,30000); if(duration==0){
```

```

distance=last Valid;
}else{
distance=duration*0.034/2;
}
if(distance<=0||distance>400){
distance = lastValid;
}else{
lastValid=distance;
}
return distance;
}

//=====MOTOR FUNCTIONS=====

Void move Forward(){  digitalWrite(6,HIGH);  digitalWrite(7,LOW);  digitalWrite(8,HIGH);
digitalWrite(9,LOW);
}

Void stop Motors() { digitalWrite(6,LOW);
digitalWrite(7,LOW); digitalWrite(8,LOW);
digitalWrite(9,LOW);

```



Mechanism

Working Principle

The ultrasonic sensor works on the principle of sound wave reflection, commonly known as the echo principle. It consists of two main parts: a transmitter and a receiver. The transmitter generates high-frequency ultrasonic sound waves, which travel through the air toward an object placed in front of the sensor. When these sound waves hit an obstacle they get reflected back toward the sensor.

The receiver section of the ultrasonic sensor detects this reflected signal known as the echo. The sensor then calculates the time taken for the sound waves to travel from the transmitter to the object and back to the receiver. Using this time the distance between the sensor and the object is calculated with the help of the speed of sound in air. The formula used is distance equals speed of sound multiplied by time divided by two. The division by two is necessary because the sound travels to the object and then returns to the sensor.

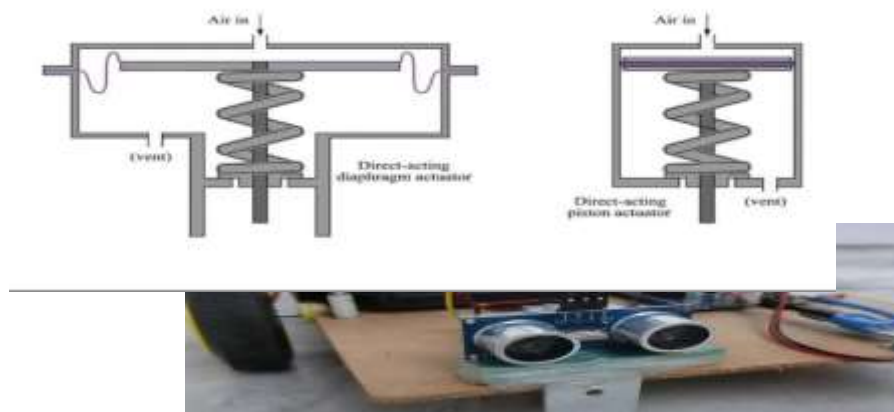
In practical applications like our project, this distance information is continuously monitored. When the detected distance becomes less than a predefined safe limit, the system sends a signal to the controller.

This triggers automatic actions such as applying brakes and activating the pneumatic bumper to prevent or reduce the impact of a collision.

Sensor Detection System

The system uses an ultrasonic sensor to measure the distance between the vehicle and objects ahead. It works in real-time and provides accurate distance data to the control unit. This helps the system take quick decisions without human involvement. The ultrasonic sensor continuously emits high-frequency sound waves. These waves travel forward and hit an object (if present). The reflected waves (echo) return to the sensor. The sensor calculates the distance based on the time taken for the echo. This distance data is sent to the micro controller. If the distance is below a preset safe limit, the controller triggers: automatic braking Pneumatic bumper actuation

Pneumatic Actuation process



Basic principle

Pneumatic actuation process is the sequence by which compressed air is used to generate controlled mechanical motion (linear or rotary) in an actuator, typically to move a valve, cylinder or robotic joint. Pneumatic actuators convert energy from compressed air in to mechanical force and motion. Compressed air enters a chamber (piston-type or diaphragm-type), creating pressure on a movable element (piston or diaphragm). This pressure generates a force $[F=P \times A]$ (pressure $\times$ effective area), which pushes the piston/diaphragm and produces linear or rotary output motion. Typical process steps: Air compression and conditioning Air is compressed by a compressor, then dried and filtered so that clean, dry air is supplied to the system. Regulators control pressure; lubricators may add oil to reduce wear in the actuator.

Air supply to the actuator: Compressed air is routed through directional control valves (solenoid-operated or manual) to the actuator port(s). In a single-acting actuator, air pressure moves the piston in one direction, and a spring returns it when air is exhausted. In a double-acting actuator, air is applied alternately to both sides of the piston to extend and retract it.

Brake Activation Mechanism

When the vehicle is moving, the ultrasonic sensor continuously monitors the distance in front. If an obst-

When an obstacle is detected within a predefined safe limit, the sensor sends a signal to the microcontroller. The microcontroller then processes this data and immediately sends a command to the relay or motor driver. This cuts off the power supply to the DC motor or reduces its speed, which results in braking action. In some setups, the motor is completely stopped, while in others, the speed is gradually reduced to avoid sudden jerks. This automatic response helps prevent collision and improves safety. The Brake Activation Mechanism in a pneumatic automatic bumper and brake actuation system uses sensors to detect obstacles and pneumatically apply brakes before collision, enhancing pre-crash safety.

Result

Performance Analysis

Pneumatic automatic bumper and brake actuation systems enhance vehicle safety by detecting imminent collisions and deploying compressed air mechanisms for braking and impact absorption before impact occurs.

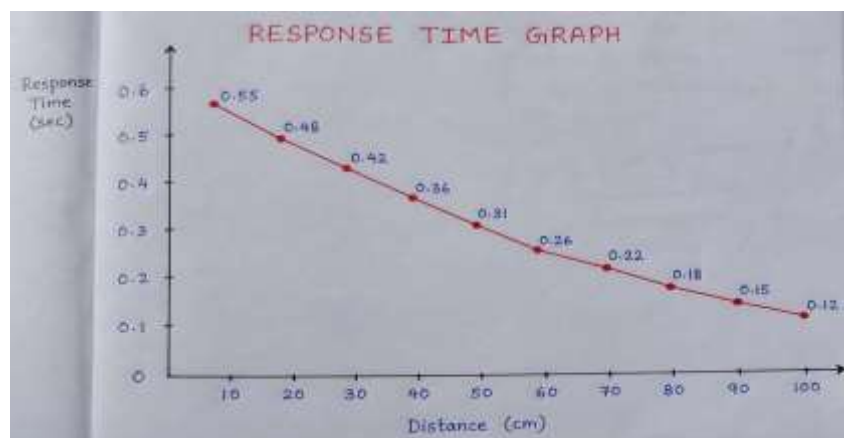
System Components: These systems typically integrate ultrasonic or infrared sensors to detect obstacles within 1-2 meters, a microcontroller for real-time processing, solenoid valves for pneumatic control, and actuators linked to brakes and bumpers. The pneumatic bumper inflates rapidly using a compressed air reservoir, creating a cushion that absorbs 40-60% of impact force at speeds like 60 km/h. Braking actuation uses air pressure to engage hydraulic or mechanical brakes, reducing collision speed by up to 50% in tests.

Performance Metrics: Key metrics include response time under 0.2 seconds, impact force reduction of 40-60%, and deceleration rates of 0.8-1.2 g during emergency stops. Simulations at 56-64 km/h show extended crush zones from bumper deployment, lowering crash pulse severity and occupant injury risk. □ Reliability stems from pneumatic systems' quick actuation and low failure rates in harsh conditions.

Test Results

Crash tests at 60 km/h against rigid barriers demonstrate 40-60% force reduction with optimal bumper configurations. Integrated autonomous emergency braking (AEB) with pneumatic bumpers improves avoidance rates and minimizes damage in offset collisions. Challenges include air reservoir size limits for repeated use and sensor accuracy in adverse weather.

Response Time Measurement



Response Time Measurement in pneumatic automatic bumper and brake actuation before collision The response time in pneumatic automatic bumper and braking systems is critical to collision mitigation,

with the total system activation often required to occur within 1 second to effectively supplement human reaction. Individual component response times are significantly faster, as solenoid valves commonly employed in these circuits feature response times of less than 20 milliseconds.

System Response Phases.

The total time from obstacle detection to full system deployment consists of several sequential stages, each contributing to the overall latency:

- Sensor Detection:** Infrared or ultrasonic sensors monitor the area in front of the vehicle, typically triggering at a threshold distance of 1–1.2 feet (approx. 30 cm).
- Control Signal Processing:** The micro controller processes the sensor input and sends an electrical signal to the solenoid valves; this phase occurs nearly instantaneously in modern electronic control units.
- Pneumatic Actuation:** Upon receiving a signal, the solenoid valve opens, allowing compressed air to enter the pneumatic cylinder to extend the bumper or apply brakes. This mechanical deployment typically completes within 50–100 milliseconds.

Braking Efficiency

Braking efficiency refers to how effectively and quickly a vehicle can be stopped after the braking system is activated. In your Automatic Pneumatic Bumper and Brake Actuation Before Collision project, it measures how well the system reduces speed or stops the vehicle when an obstacle is detected. Braking efficiency is the ratio of actual deceleration achieved to the maximum possible deceleration, expressed as a percentage.

Distance detection accuracy

In pneumatic automatic bumper and brake actuation systems, distance-detection accuracy typically falls in the range of about ± 5 –20 mm for ultrasonic sensors and ± 10 –50 mm for IR (infrared) sensors, depending on the sensor type, mounting, and environmental conditions.

Typical sensing ranges and accuracy

Ultrasonic-based systems sense obstacles in the 0.1–1 m range with distance resolution of roughly 1–5 mm per step, but accuracy can degrade in wet, dusty, or high-noise environments due to reflections and attenuation. IR-based systems commonly work up to about 1–1.2 m, with practical accuracy more in the ± 10 –50 mm band; they are sensitive to ambient light, target color, and surface reflectivity.

How this affects collision-avoidance performance

Many lab-scale pneumatic bumper-and-brake prototypes activate the pneumatic bumper and brake when an obstacle comes within a range of 300–900 mm, using the sensor distance to trigger the pneumatic circuit via a microcontroller. Experiments show that the system can reliably stop or substantially reduce impact when the sensed distance is ≥ 100 –250 mm, but at very short ranges (e.g., 50 mm) the bumper may extend and absorb the impact while the vehicle cannot fully stop, hence the bumper protects the car body rather than fully avoiding contact.

Design implications for accuracy to improve distance-detection accuracy, papers recommend: Using ultrasonic sensors with short-range, high-frequency pulses. Calibrating sensor-to-distance curves and applying simple error models in the micro controller. Combining data from speed and proximity sensors to adjust actuation thresholds depending on vehicle speed (e.g., higher activation distance at higher speeds). If you tell me whether you're redesigning an IR-based or ultrasonic-based system (and your target speed and vehicle size), I can help you compute a more precise safe activation distance and expected error budget.

Advantages

Enhanced Safety: Activates bumper and brakes automatically before impact, reducing collision severity

for both occupants and pedestrians.

Fast Response: Ultrasonic sensor + microcontroller can react faster than human reflexes in emergency scenarios.

Dual Protection: Combines braking with an extending bumper, giving 2 layers of impact mitigation vs. braking alone.

Low-Cost Components: Uses Arduino Uno/Nano, ultrasonic sensors, and pneumatic parts which are relatively inexpensive and available.

Scalable Design: Future scope includes AI-based object detection, speed control, and ECU integration for real vehicles

Limitations

1. Dependence on sensor accuracy
2. Limited speed and activation range
3. One-directional protection
4. Performance in dense traffic
5. System reliability and maintenance
6. Limited energy absorption and structural design

Applications

Automobiles, Industrial vehicles, Public transport vehicles, Military vehicles, Automated guided vehicles, Robotic and proto type system, Smart transportation systems, Parking assistance systems

RESULT SUMMARY

This work "Automatic Pneumatic Bumper and Brake Actuation before Collision" was successfully designed and tested. The system effectively detects obstacles using an ultrasonic sensor and responds automatically without human intervention. During testing, the sensor accurately measured the distance between the vehicle and obstacles. When the object came within the predefined limit, the micro controller processed the signal quickly and activated both the braking system and pneumatic bumper. The braking mechanism was able to stop the vehicle within a short time, while the pneumatic cylinder extended the bumper to reduce the impact force. The response time of the system was found to be significantly faster compared to manual human reaction. The overall performance of the system was reliable under normal conditions. It demonstrated good efficiency in preventing collisions at low speeds and reducing damage during impact.

Future Scopes & Conclusion

FUTURESCOPE:

The Automatic Pneumatic Bumper and Brake Actuation Before Collision system can be further improved and expanded in several ways:

1. Integration with Advanced Sensors

The system can be enhanced by using radar, LiDAR, or camera-based sensors for better accuracy and long-range detection.

2. AI and Machine Learning

Incorporating artificial intelligence can help the system predict obstacles, analyze driving patterns, and make

e smarter decisions.

3. High-Speed Vehicle Application

The current model is suitable for low-speed applications. Future improvements can make it effective for high-speed vehicles with advanced braking control.

4. Fully Automated Vehicles

This system can be integrated in to self-driving cars as a part of advanced safety and collision avoidance systems.

5. Improved Pneumatic System

Using faster actuators and better air pressure control can improve bumper response time and efficiency.

6. Compact and Commercial Design

The system can be redesigned in to a compact and light weight module for real-world vehicle implementation.

7. Wireless Communication

Adding IoT or wireless systems can enable vehicle-to-vehicle communication to prevent accidents in advance.

CONCLUSION

The research work “Automatic Pneumatic Bumper and Brake Actuation before Collision” has been successfully designed and implemented. The system effectively detects n obstacles using sensors and automatically activates the braking mechanism along with a pneumatic bumper. The combination of automatic braking and impact absorption provides dual protection, significantly reducing the chances of accidents and minimizing damage. The system also reduces dependency on human reaction, which is one of the major causes of road accidents. The experimental results show that the system has fast response time, reliable performance, and good efficiency for prototype-level applications. It proves to be a cost-effective and practical safety solution. Overall, this project demonstrates the importance of automation in vehicle safety and has strong potential for further development and real-world implementation

VIII. References

1. Rajput, R.K., A Textbook of Automobile Engineering, Laxmi Publications.
2. Jain, R.K., Production Technology, Khanna Publishers.
3. Bolton, W., Mechatronics: Electronic Control Systems in Mechanical Engineering, Pearson Education.
4. Ganesh Babu, M., and others, “Automatic Pneumatic Bumper and Braking System,” International Journal of Engineering Research Technology (IJERT).
5. S. Vijayalakshmi et al., “Design and Fabrication of Automatic Pneumatic Bumper,” International Journal of Mechanical Engineering.
6. K. Karthik et al., “Automatic Braking System Using Ultrasonic Sensor,” International Journal of Scientific Research (IJSR).
7. Manufacturer Datasheets: Ultrasonic Sensor (HC-SR04) Arduino Microcontroller
8. Solenoid Valve Online Resources:
9. IEEE Xplore Digital Library Science Direct
10. Google Scholar