Smart Servo-Controlled Fan: IR-Based Motion Detection for Personalized Comfort

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***Abstract*—This project introduces a smart, self-balancing fan that uses infrared (IR) sensors and a servo motor, all managed by an Arduino microcontroller. It's designed for personal comfort and automation by tracking a person's position and rotating the fan to blow air in their direction. This cost-effective system is a practical example of presence detection, automated movement, and embedded control.**

***Index Terms*—IR Sensor, Servo Motor, DC Fan, Arduino Uno**

I. Introduction

Traditional fans always blow air in a fixed direction, which isn't ideal when people move around. This project solves that problem by creating a smart fan that can follow a user's position and automatically direct airflow using a servo motor. It even turns itself on when it senses someone nearby and switches off when no one's around—saving power and improving user experience.

II. System Overview and Theory

The setup uses two IR sensors placed on either side of a fan. These sensors detect a person by picking up reflected infrared light. Depending on which sensor detects presence, the Arduino figures out whether the user is on the left, right, or directly in front, and moves the fan accordingly using a servo motor. The DC fan also switches on when someone is nearby and turns off when the area is empty.

A. SG90 Servo Motor

A servo motor, such as the SG90, is a small and precise actuator used for rotating or positioning objects. It is commonly used in robotics, remote-controlled vehicles, and various automation systems. The SG90 servo motor operates using a feedback control loop to maintain a specific position. The basic working principle of the SG90 servo motor is as follows:

- PWM (Pulse Width Modulation):
  The SG90 servo motor is controlled by sending it a PWM signal. The position of the servo is determined by the duty cycle of the PWM signal, typically ranging from 0 to 180 degrees.
- Control Signal:
  The control signal is a square wave that determines the angle the motor will turn. A pulse width of 1 millisecond (ms) positions the servo to 0 degrees, while a pulse width of 2 ms positions the servo to 180 degrees. The servo interprets the length of each pulse to move to the desired position.
- Feedback Mechanism:
  The servo has an internal potentiometer that continuously checks its current position. The feedback loop ensures that the servo reaches and maintains the commanded position.
- Torque and Range:
  The SG90 is a small, low-torque servo with a typical range of 180 degrees. It is powered by a 5V supply and can provide about 1.8 kg·cm of torque.

B. IR Sensor (Infrared Sensor)

An infrared (IR) sensor works by emitting infrared light and detecting its reflection from an object. The working principle of an IR sensor can be explained as follows:

- Emitter and Receiver:
  The IR sensor consists of two main components: an infrared LED emitter and a photodiode or phototransistor receiver. The LED emits infrared light, which is reflected back by nearby objects.
- Detection:
  The receiver detects the reflected infrared light, which allows the sensor to determine if an object is present within the sensor's range.
- Output Signal:
  The output of the IR sensor is usually a digital signal, indicating whether an object has been detected. When an object is detected, the output goes low (0), and when there is no object, the output remains high (1).
- Distance Measurement:
  By measuring the time taken for the emitted light to reflect back, advanced IR sensors can calculate the distance of an object from the sensor.

C. NPN Transistor (TIP122) as a Switch

The TIP122 is a Darlington pair NPN transistor commonly used for switching high-current devices such as DC fans. Its operation in a switching role is as follows:

- Structure and Operation:
  The TIP122 has three terminals: the collector (C), base

(B), and emitter (E). It is a Darlington transistor, meaning it consists of two transistors in one package for high current gain. A small base current results in a much larger current flowing from collector to emitter.

- Switching Principle:
  When the Arduino provides a HIGH signal to the base of the TIP122 through a 1kΩ resistor, the transistor turns ON. This allows current to flow from the 5V supply, through the load (the DC fan), and into the collector-emitter path to ground. When the base signal is LOW, the transistor remains OFF, and no current flows through the fan.
- Use in Project:
  In this setup, the TIP122 acts as an efficient electronic switch. The Arduino controls the fan by sending signals to the base of the transistor, thereby turning the fan ON or OFF without directly powering it through the Arduino, which protects the microcontroller from high current loads.

III. Components Used

- Arduino Uno – Main controller
- 2x IR Sensors – To detect where the user is
- Servo Motor (SG90) – Rotates the fan
- DC Fan – Provides airflow
- NPN Transistor – Acts as a switch for the fan
- 1kΩ Resistor – Controls current to the transistor
- Jumper wires and breadboards – For circuit building

IV. Circuit Design

The IR sensors are connected to Arduino pins 2 and 3. The servo's control wire connects to pin 9, and its power comes from the Arduino's 5V output. The DC fan's positive side connects to the 5V rail, and the negative side goes to the collector pin of an NPN transistor. The transistor's base connects to pin 8 through a 1kΩ resistor, and its emitter is grounded. This power setup is enough for running both the fan and the servo.

V. Software Implementation

The Arduino program starts by setting up the sensors, servo, and fan control pin. In the main loop, it keeps checking the sensors and uses simple if-else conditions to control the fan and its direction.

Logic used in the code:

- If either sensor detects someone, turn the fan ON
- If only the left sensor detects presence, rotate the fan to the left
- If only the right sensor detects presence, rotate the fan to the right
- If both sensors detect presence, center the fan
- If neither sensor detects presence, turn the fan OFF

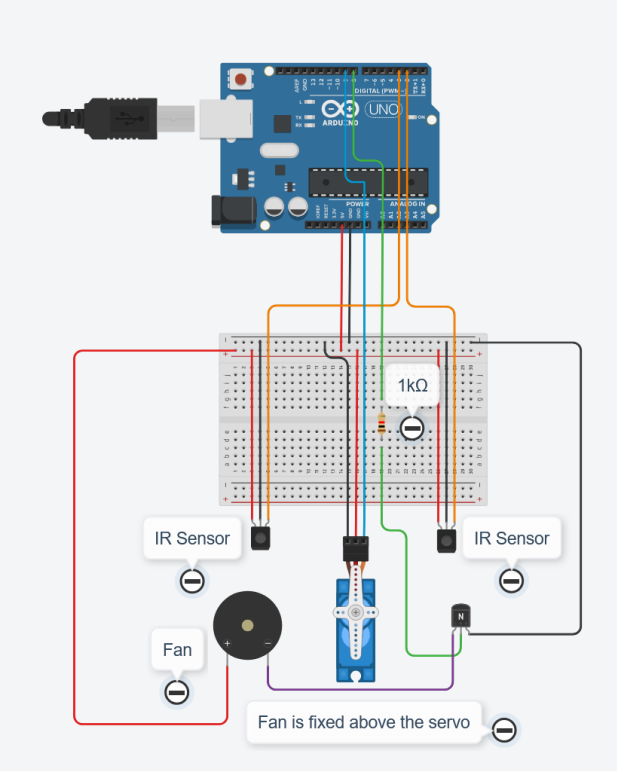

Fig. 1. Circuit diagram of the self-balancing fan system.

VI. Demonstration and Use Case

In action, this system works by tracking hand or body movement. If someone stands on the left, the fan points left. If on the right, it turns right. If both sensors detect someone, the fan centers itself. When no one is around, the fan turns off automatically.

This setup is especially useful for:

- Personal cooling
- Smart home or office automation
- Energy-saving fan solutions

VII. Conclusion

The Smart Servo-Controlled Fan is a simple yet effective demonstration of embedded systems. It shows how basic components can be combined to create smart, user-aware devices. Looking ahead, this system could be upgraded to adjust fan speed based on temperature or even controlled by voice or smartphone apps.

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