Radar Visualization Pipeline Report

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Abstract

Abstract of project

Contents

1 Introduction

We built a compact ultrasonic “radar-style” scanner that turns echo timing into a live 2D visualization. An ultrasonic pulse is emitted and the return echo duration encodes time-of-flight, which the microcontroller converts to distance. By sweeping the sensor with a servo, each measurement becomes an (*angle*, *distance*) pair that can be rendered in polar form. The project is primarily an educational end-to-end system that makes the hardware–software stack observable: sensing, embedded processing, USB serial transport, OS I/O abstraction, and real-time visualization.

2 Planning

3 Hardware

4 Servo Sweep Control

5 System Overview: From Echo to Visualization

Figure 1 summarizes the end-to-end pipeline. The ultrasonic sensor returns an *echo pulse width*, i.e., a time duration proportional to the time-of-flight. The Arduino controls the servo sweep via PWM, triggers the sensor, measures the echo duration (e.g., with `pulseIn`), converts it to a distance in centimeters, and transmits one newline-terminated ASCII record per measurement (`angle,cm`). Over USB the payload is a byte stream which the operating system exposes as a serial device (e.g., a COM port on Windows). The Processing program opens this port, frames the incoming bytes into lines, parses angle and distance, and updates the visualization state used for rendering.

Figure 1: End-to-end pipeline from sensing on the Arduino to visualization on the host.

6 Visualization

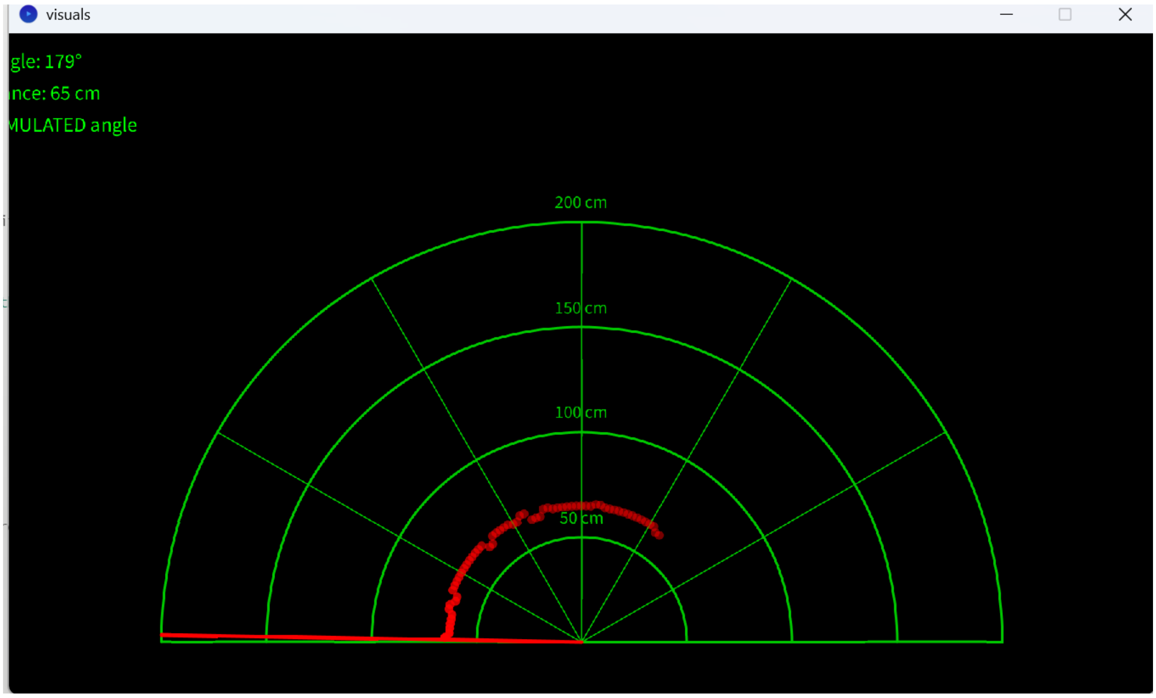


Figure 2: Final Processing-based radar visualization (grid, sweep line, and detections).

The goal of the visualization is to make streamed sensor measurements immediately interpretable as a radar-style scan. The display renders a half-circle field of view (0°–180°) with a moving sweep line representing the current scan direction. Each incoming measurement (*angle*, *distance*) is mapped to polar coordinates: the angle determines the direction of the sweep and the distance determines the radius of a "blip" point. A static background grid (concentric arcs and radial dividers) provides scale and orientation (Figure 2).

6.1 Implementation path

We initially prototyped the UI in C using `raylib`. While rendering worked well, the end-to-end path was unstable due to low-level serial I/O handling on Windows (port selection, timing after reset, partial lines, and port contention). To reduce OS-specific complexity and iterate faster, we switched to Processing, whose serial library directly supports line-based framing and event-driven reads.

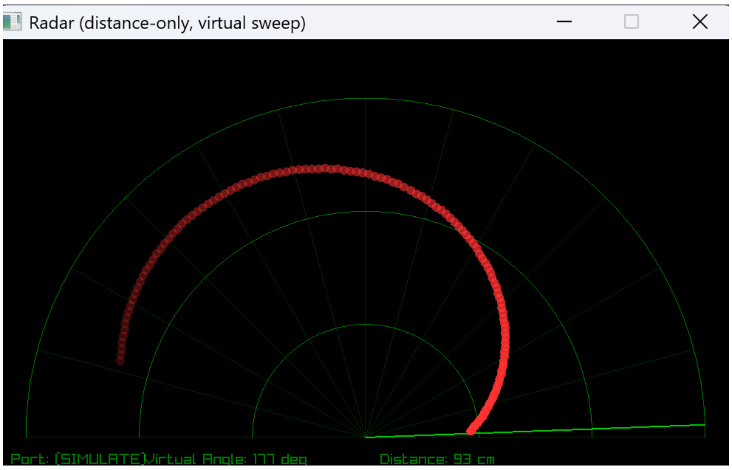
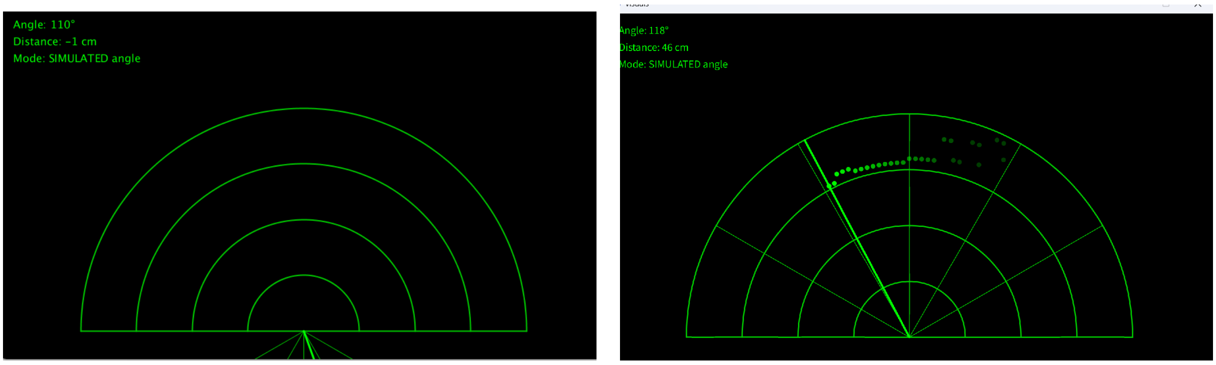


Figure 3: C/`raylib` prototype in simulated sweep mode (no robust sensor-driven end-to-end path).

6.2 Serial parsing and “bucket” state

Processing treats the serial connection as a continuous byte stream but frames it into complete records using newline termination. Each line is trimmed, split by comma, and parsed into numeric values (*angle* and *distance*). Invalid readings are encoded as `-1` and interpreted as “no detection”.

To prevent unbounded accumulation of points and to mimic a radar refresh, the scan area is discretized into small angle slices (“buckets”) of fixed width (e.g., `ANGLE_BUCKET_DEG`). Each bucket stores the most recent distance for that slice and is overwritten when the sweep returns. If a `-1` reading arrives for a slice, the corresponding bucket is cleared. This keeps memory bounded and creates the intuitive behavior that detections persist briefly and disappear naturally on rescan.



(a) Early Processing iteration used to validate coordinate mapping and sweep direction.

(b) Intermediate iteration with a fading persistence effect per bucket.

Figure 4: Processing visualization iterations during development.

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7 Conclusion

We implemented an end-to-end ultrasonic "radar-style" system that turns echo time-of-flight into a live 2D visualization. This project made the full stack tangible: the Arduino converts timing signals into structured serial records, USB transports them as bytes, the operating system exposes the device as a serial port, and Processing frames, parses, and renders the stream into an interpretable scan display.

A key lesson was building robustness across layers and constraints. We observed practical serial-port behavior (e.g., exclusivity and startup noise) and designed the software to handle imperfect input. Since the servo was not available during early visualization work, the Processing program supports both a simulated sweep and a servo-driven angle mode, switching automatically when angle data is present.

Division of labor. All group members contributed to assembling the hardware setup. Sandro implemented the main Arduino sensing and communication code and built the stand/chassis. Senanur developed the Arduino servo sweep control. Aiysha implemented the Processing visualization, including parsing and bucket-based rendering.

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8 Declaration of Authorship

ChatGPT was used solely to improve the clarity and coherence of the report's language. All ideas, analyses, and interpretations presented reflect the group's own work and research.