

Arduino Based Missile Radar System for Missile Defensive Real Time Visualisation

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ABSTRACT:

This paper presents the design and implementation of an Arduino-based missile radar system for defensive applications with real-time visualization. The proposed prototype integrates an ultrasonic sensing module, servo motor, and microcontroller to emulate radar-based object detection and tracking. The ultrasonic sensor continuously scans the surrounding environment by rotating through a defined angular range using a servo motor, enabling the detection of nearby objects based on distance measurements. The collected data is processed by the Arduino Uno and transmitted to a computer via serial communication for real-time visualization. A graphical interface on the PC displays the detected objects in a radar-like format, providing intuitive monitoring of object position and movement. The system incorporates a basic decision-making module to simulate defensive responses, such as identifying potential threats based on proximity. The regulated power supply ensures stable operation of all components. This prototype demonstrates a cost-effective and scalable approach to radar-based detection systems, suitable for educational and research purposes. While not intended for real-world missile defense deployment, the system provides a practical foundation for understanding radar principles, embedded system integration, and real-time data visualization. Future improvements may include advanced sensors, wireless communication, and intelligent threat classification algorithms.

Keywords: Arduino Uno, Radar System, Ultrasonic Sensor, Servo Motor, Real-Time Visualization, Embedded Systems, Object Detection.

INTRODUCTION:

Modern surveillance systems demand continuous, reliable sensing across varying conditions, yet advanced approaches such as Video-SAR involve high computational complexity, significant cost, and challenging implementation, limiting their accessibility in academic and small-scale environments. This work is motivated by the need to translate core radar principles into a simplified, affordable platform that supports real-time monitoring and analysis. To address this, a compact Arduino-based radar prototype is developed, integrating an ultrasonic sensor and servo mechanism for object detection and scanning, with real-time visualization on a computer. The system offers a low-power, modular, and practical framework that enables understanding of embedded radar concepts and supports further research in intelligent sensing and data processing [13]. Efficient multi-target tracking in netted collocated MIMO radar systems is constrained by the complexity of dynamic sensor scheduling and limited power and bandwidth resources, often leading to reduced tracking accuracy and inefficient utilization. This work is motivated by the need to improve tracking performance through intelligent resource management without increasing system burden. To address this, an adaptive framework integrating sensor scheduling with joint power and

bandwidth allocation is proposed. By employing a modified particle filter and using predicted posterior Cramér–Rao lower bound as an optimization metric, the complex problem is reformulated into solvable convex structures, enabling improved tracking precision and overall system efficiency [1]. Traditional missile-borne radar systems struggle to achieve accurate two-dimensional imaging in forward-looking modes due to limitations in azimuth resolution and dependence on Doppler effects. This work is motivated by the need to overcome these constraints and enhance imaging performance for target detection and tracking. A novel approach based on vortex electromagnetic waves carrying orbital angular momentum is introduced to enable improved spatial resolution. By employing FFT and sparse recovery algorithms, the proposed method achieves both range and azimuth resolution independently of Doppler bandwidth. The results demonstrate enhanced imaging capability, offering a promising direction for advanced radar system design and real-time applications [2]. Traditional ground-to-air missile systems relying on infrared sensors are susceptible to interference from flares and chaff, resulting in unreliable target tracking. This work is motivated by the need to enhance tracking robustness through alternative sensing techniques. A computationally efficient seeker is proposed that switches to camera-based tracking when infrared signals are disrupted. The method employs simple line detection to initialize a target bounding box, followed by continuous tracking using lightweight image-based algorithms. This approach ensures stable and accurate tracking without being affected by countermeasures, while maintaining real-time performance and low computational overhead, making it suitable for practical defense applications [4]. RD-log-FDA radar systems face challenges due to range–angle dependency, leading to unstable beam gain and increased sidelobe levels that affect detection performance. This work is motivated by the need to improve beamforming stability and enhance resolution in complex environments. An optimized beam space design approach is proposed by adjusting array element spacing and frequency offsets, with particle swarm optimization employed to determine optimal parameters. The method effectively stabilizes beam gain, reduces sidelobe interference, and improves parameter estimation accuracy. Simulation results confirm that the proposed approach enhances overall radar performance, offering a reliable solution for advanced radar signal processing and target detection applications [6]. The increasing use of drones in civilian and military applications has introduced serious security concerns due to their potential misuse in surveillance, attacks, and unauthorized operations. This work is motivated by the growing need for effective countermeasures to detect, track, and neutralize such threats. A comprehensive review of anti-drone systems is presented, analysing their classification, working principles, and deployment challenges across different environments. The study highlights limitations in existing technologies and emphasizes the importance of improved system integration and regulatory support. It further outlines future directions for developing advanced, reliable, and scalable anti-drone solutions to strengthen national defense and public safety [8]. Traditional beehive monitoring techniques often suffer from noise interference and limited accuracy due to reliance on single sensing methods. This work is motivated by the need for a non-intrusive and reliable system capable of capturing comprehensive hive activity. A combined sensing approach is proposed, integrating Doppler radar to monitor external bee movement and a piezoelectric sensor to detect internal vibrations. By correlating these measurements and applying principal component analysis, the system improves event detection accuracy while reducing false alarms. The proposed method provides an effective solution for continuous and precise monitoring of beehive conditions, supporting advancements in smart agricultural and environmental sensing applications [11]. High-power laser systems used for short-range target interception often face limitations due to thermal blooming and atmospheric disturbances, reducing their effectiveness. This work is motivated by the need to enhance energy delivery

and targeting precision through coordinated operation. A distributed laser aiming strategy is proposed, where multiple laser sources synchronize to focus on a single target point using shared positional data obtained from radar systems. This coordinated approach improves attack efficiency and minimizes directional errors. Simulation results demonstrate enhanced performance in target engagement, highlighting the effectiveness of synchronized multi-laser systems as a promising solution for advanced defensive applications [9].

LITERATURE SURVEY:

Yang et al. (2021) introduced a two-dimensional forward-looking missile-borne radar imaging method using vortex electromagnetic waves with orbital angular momentum, achieving improved range and azimuth resolution; however, the approach relies heavily on simulation and lacks real-time validation. Li et al. (2022) explored adaptive resource allocation in MIMO radar systems, focusing on tracking accuracy, but did not address imaging limitations in forward-looking scenarios. Kim (2020) proposed camera-based missile tracking to overcome infrared limitations, yet it lacks radar-based spatial resolution. Khosravi and Samadi (2021) studied Video-SAR for surveillance, but high computational complexity remains a major limitation for practical deployment [2]. Li et al. (2022) proposed an adaptive sensor scheduling and resource allocation framework for netted collocated MIMO radar systems, improving multi-target tracking accuracy using a modified particle filter and PCRLB-based optimization; however, the approach involves high computational complexity and lacks real-time implementation validation. Yang et al. (2021) focused on forward-looking radar imaging using vortex electromagnetic waves, but did not address dynamic resource allocation in multi-target scenarios. Kim (2020) introduced camera-based tracking to enhance robustness against interference, yet it does not consider radar resource optimization. Khosravi and Samadi (2021) explored Video-SAR systems, though their methods require significant processing power, limiting practical deployment [1]. Kim (2020) proposed a computationally efficient ground-to-air missile seeker that switches from infrared sensing to camera-based tracking when interference such as flares occurs, using simple line detection and lightweight object tracking algorithms to ensure real-time performance; however, the approach depends heavily on visual conditions and may be affected by poor visibility or occlusions. Li et al. (2022) focused on radar-based multi-target tracking with optimized resource allocation but did not address vision-based tracking challenges. Yang et al. (2021) introduced advanced radar imaging techniques, yet lacked integration with hybrid sensing. Khosravi and Samadi (2021) explored Video-SAR systems, though computational demands limit real-time deployment [4]. Wu et al. (2020) investigated a multi-agent system architecture for hypersonic target detection and recognition, integrating intelligent information processing and data fusion to enhance system robustness and response speed; however, the approach introduces increased system complexity and lacks practical real-time implementation validation. Li et al. (2022) focused on adaptive sensor scheduling for multi-target tracking but did not address high-speed hypersonic scenarios. Yang et al. (2021) proposed advanced radar imaging techniques, though without intelligent multi-agent coordination. Kim (2020) introduced vision-based tracking methods, yet they are not suitable for high-speed targets. Khosravi and Samadi (2021) explored Video-SAR systems, but computational demands remain a challenge [3]. Yoon et al. (2021) proposed a handheld IR-UWB radar system integrated with an IMU sensor for non-contact vital sign monitoring, where motion-induced noise is reduced through calibration, significantly improving measurement accuracy; however, the approach is primarily validated in controlled environments and may face challenges in dynamic real-world conditions. Wu et al. (2020) explored multi-agent systems for target detection but did not address motion

compensation in sensing. Li et al. (2022) focused on adaptive radar resource allocation without considering handheld instability. Kim (2020) introduced vision-based tracking methods, which lack robustness in non-visual scenarios. Khosravi and Samadi (2021) studied Video-SAR systems, though high computational complexity limits portability and real-time use [10]. Chauhan et al. (2022) presented a comprehensive review of anti-drone systems and defense strategies, analysing various detection, tracking, and mitigation techniques across military and civilian domains; however, the study primarily focuses on theoretical classification and lacks implementation-specific insights for low-cost or real-time systems. Wu et al. (2020) explored intelligent multi-agent frameworks for target detection but did not address drone-specific threats. Li et al. (2022) investigated radar-based tracking optimization without considering drone countermeasures. Kim (2020) proposed vision-based tracking methods, which may be limited in long-range detection. Khosravi and Samadi (2021) studied advanced radar imaging, though high computational requirements remain a challenge [8]. Jiang et al. (2022) investigated a 120-GHz radar sensor network for monitoring industrial forging processes, demonstrating accurate state estimation and reliable performance in harsh environments; however, the system requires complex infrastructure and is not optimized for low-cost or portable applications. Chauhan et al. (2022) reviewed anti-drone systems but did not address industrial sensing scenarios. Li et al. (2022) focused on radar resource allocation for tracking, lacking application in process monitoring. Kim (2020) proposed vision-based tracking, which may not perform well in industrial environments. Khosravi and Samadi (2021) explored Video-SAR systems, though high computational requirements limit practical deployment in embedded systems [12].

PROPOSED METHODOLOGY:

The proposed system is designed to emulate a radar-based missile detection and visualization platform using an embedded architecture. The core of the system is an Arduino Uno, which coordinates sensing, motion control, and data transmission. An ultrasonic sensor is mounted on a servo motor to perform angular scanning over a predefined range. The servo motor rotates incrementally, allowing the sensor to sweep the surrounding area and capture distance measurements at each angle. The ultrasonic sensor emits acoustic pulses and measures the echo return time to estimate the distance of objects. These measurements, along with corresponding angular positions, are processed by the Arduino and formatted into serial data. A regulated power supply ensures stable operation of all hardware components. The processed data is transmitted to a computer system via serial communication, where a custom visualization interface renders the environment in a radar-like display. Detected objects are plotted based on distance and angle, enabling real-time monitoring. The system continuously updates the scan cycle, creating a dynamic representation of object movement. To simulate defensive functionality, threshold-based logic is applied to identify objects within a critical range, indicating potential threats. This approach provides a structured framework for understanding radar principles, real-time sensing, and embedded system integration, while maintaining simplicity and cost efficiency suitable for experimental validation.

BLOCK DIAGRAM:

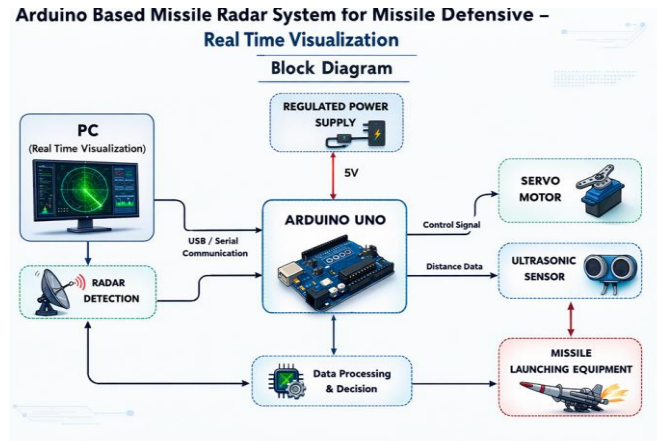


FIG 1: BLOCK DIAGRAM

HARDWARE WORK FLOW:

ARDUINO UNO:



FIG 2: AURDINO

The Arduino Uno serves as the central processing unit of the system, responsible for coordinating sensing, motion control, and communication tasks. It is built around the ATmega328P microcontroller, which provides sufficient computational capability for real-time data handling in embedded applications. In this system, the Arduino reads distance data from the ultrasonic sensor, controls the angular movement of the servo motor, and formats the collected data for transmission. Its digital and analog input/output pins allow seamless interfacing with multiple components. The board operates with low power requirements and offers a stable platform for rapid prototyping and reliable execution of control logic.

ULTRASONIC SENSOR



FIG 3: ULTRASONIC SENSOR

The ultrasonic sensor is used to detect objects by measuring the distance between the sensor and the target. It operates by emitting high-frequency sound waves and calculating the time taken for the echo to return after reflecting from an object. This time-of-flight measurement is converted into distance using the speed of sound. In the proposed system, the sensor continuously scans the environment as it rotates, enabling spatial mapping of nearby objects. It provides non-contact sensing, making it suitable for real-time detection applications. Its simplicity, accuracy within short ranges, and low cost make it an effective choice for prototype radar emulation.

SERVO MOTOR



FIG 4: SERVO MOTOR

The servo motor is responsible for rotating the ultrasonic sensor across a defined angular range, enabling scanning of the surrounding environment. It operates based on pulse-width modulation signals received from the Arduino, which precisely control its position. The motor moves in small angular increments, allowing the system to capture distance measurements at different orientations. This controlled rotation mimics the sweeping mechanism of conventional radar systems. The servo ensures repeatable and accurate positioning, which is essential for consistent data acquisition and visualization. Its compact size and ease of integration make it well-suited for embedded sensing applications requiring directional movement.

POWER SUPPLY UNIT



FIG 5: POWER SUPPLY UNIT

The power supply unit provides a stable and regulated voltage to all system components, ensuring consistent performance and preventing damage due to voltage fluctuations. It converts the input power source into suitable levels required by the Arduino, sensor, and motor. Proper regulation is essential for maintaining accuracy in sensor readings and reliable motor operation. Any instability in power can lead to incorrect measurements or erratic behaviour. In this system, the power supply is designed to support continuous operation during scanning and data transmission. A well-regulated supply enhances the overall efficiency, durability, and safety of the embedded system.

SERIAL COMMUNICATION INTERFACE:**FIG 6: SERIAL COMMUNICATION INTERFACE**

The serial communication interface enables data exchange between the Arduino and a computer system for real-time visualization. It transmits processed data, including distance and angular position, in a structured format through a USB connection. This communication channel ensures continuous data flow, allowing the external software to render a radar-like display. The interface supports real-time monitoring and analysis without significant delay. It plays a critical role in bridging the embedded hardware and visualization platform. Its simplicity and reliability make it a widely used method for transferring data in embedded systems, especially in applications requiring live feedback and graphical representation.

RESULT AND DISCUSSIONS:

The developed Arduino-based radar prototype successfully demonstrates real-time object detection and visualization within a controlled environment. The ultrasonic sensor, combined with servo-driven scanning, was able to detect objects within its effective range and provide consistent distance measurements across multiple angular positions. The real-time data transmission to the computer enabled continuous plotting of detected objects in a radar-like interface, offering a clear representation of object location and movement. The system showed stable performance under normal operating conditions, with minimal delay in data acquisition and visualization. The angular resolution depended on the step size of the servo motor, where smaller increments improved detection accuracy but slightly increased scan time. Distance measurement accuracy was influenced by environmental factors such as surface texture and object orientation, which affected the reflection of ultrasonic waves. The threshold-based detection logic effectively identified objects within a predefined range, simulating basic defensive behaviour. However, the system is limited by the short range and sensitivity of the ultrasonic sensor, making it suitable primarily for small-scale applications. Despite these limitations, the prototype validates the feasibility of low-cost radar emulation and provides a practical foundation for further enhancements, such as integrating advanced sensors, improving signal processing, and enabling wireless communication for extended applications.

CONCLUSION:

The developed system demonstrates a practical and low-cost approach to radar-based object detection and real-time visualization using embedded hardware. The integration of sensing, controlled scanning, and data representation validates the feasibility of implementing basic radar principles in a simplified form. Although the system performs reliably within its operational limits, it is constrained by sensor range and environmental factors. Future work can focus on incorporating higher-range sensors, advanced signal

processing techniques, and wireless communication for improved performance. Additionally, integrating intelligent algorithms for object classification and threat assessment can extend its applicability toward more realistic surveillance and defense-oriented systems.

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