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Intruder Alert System

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ABSTRACT

This study aimed to design, fabricate, and evaluate an Intruder Alert System for improving proximity awareness in welding workspaces. A developmental and quantitative descriptive design was employed in selected welding shops and construction sites in Kidapawan City, North Cotabato, Philippines. The prototype integrated ultrasonic sensors, microcontrollers, audible alarms, and visual indicators. Performance was assessed through repeated detection trials at distances of 0.4–2.2 meters, while an expert-validated five-point questionnaire evaluated design, safety, and convenience among 50 purposively selected welders. Data were analyzed using frequencies, percentages, and modes. Across four sensors and tested orientations, detection succeeded in all ten trials at each distance from 0.4 to 1.6 meters (100%), declining to 30% at 1.8 meters, 10% at 2.0 meters, and 0% at 2.2 meters. Respondents rated the device highly acceptable across design, safety, and convenience (overall mode = 5 in each category), although ventilation, workflow interference, and sustained operation required improvement. The system therefore demonstrated reliable short-range detection and favorable user acceptability as a supplementary workplace warning device. Sensor optimization, improved thermal management, and extended operational testing are recommended. Findings are limited by purposive sampling in one locality, restricted detection distances, and the absence of direct injury-reduction outcomes. The prototype contributes a practical technological option for occupational hazard awareness, supporting SDG 3 (Good Health and Well-Being), SDG 8 (Decent Work and Economic Growth), and SDG 9 (Industry, Innovation and Infrastructure) through potential improvements in workplace safety and industrial innovation.

Keywords: *Detection Accuracy, Intruder Alert System, Occupational Safety, Proximity Detection, Ultrasonic Sensors, Welding Safety*

1. INTRODUCTION

Welding is essential to construction, manufacturing, and metal fabrication but exposes workers and nearby individuals to occupational hazards, including intense radiation, high temperatures, flying sparks, electrical shock, and hazardous fumes. These risks require appropriate protective equipment, environmental controls, and effective workplace safety procedures (Canadian Centre for Occupational Health and Safety [CCOHS], 2024a, 2025). Recent research has emphasized the importance of technological interventions that improve hazard detection and provide timely warnings in high-risk work environments (Demeke et al., 2025; Mastrolembo Ventura et al., 2023). Despite existing safety measures, the unexpected entry of individuals into active welding areas remains a concern, particularly in confined or busy workspaces. Such situations may expose bystanders to hazards and interrupt welding operations. To address this concern, the present study developed an Intruder Alert System integrating ultrasonic sensors, a microcontroller, audible alarms, and visual indicators to detect nearby objects or individuals and provide immediate warnings. The study focused on the system's design, fabrication, detection performance, and acceptability among welders in Kidapawan City, North Cotabato.

Research Problem

Welding environments require continuous hazard awareness because workers and nearby individuals may be exposed to radiation, burns, electrical hazards, and other occupational risks. Habibi et al. (2025) identified eye injuries, burns, radiation exposure, and inadequate protective practices as significant concerns in welding operations. Similarly, CCOHS (2025) emphasizes that appropriate protection is necessary for welders and other individuals near welding activities. Although conventional safety measures provide essential protection, they do not necessarily provide immediate electronic warnings when individuals approach hazardous work areas. Recent developments in proximity monitoring demonstrate the potential of sensor-based systems to detect intrusion risks and support workplace safety. However, their effectiveness depends on detection accuracy, operational range, reliability, and suitability for the intended environment (Demeke et al., 2025). The problem addressed in this study was the need for a practical, portable, and relatively inexpensive intrusion warning device specifically designed for welding workspaces. The research therefore examined whether an ultrasonic sensor-based Intruder Alert System could be successfully developed, demonstrate satisfactory detection performance, and achieve user acceptability in terms of design, safety, and convenience.

Assumptions of the Study

The study was guided by the assumption that ultrasonic sensing technology could identify nearby objects or individuals within a predetermined detection range and activate an appropriate warning mechanism. This assumption is consistent with the use of ultrasonic sensors for noncontact distance measurement and object detection, although their effectiveness depends on sensor characteristics, object properties, and environmental conditions (Qiu et al., 2022; Khaleel et al., 2024). It was further assumed that audible and visual warnings could improve awareness of potential intrusion into active welding areas and that welders with relevant experience and technical knowledge could provide meaningful evaluations of the system's design, safety, and convenience. These assumptions served as the basis for the prototype's development and evaluation rather than as established evidence of accident prevention.

Objectives of the Study

The general objective of this study was to design, fabricate, and evaluate an Intruder Alert System intended to improve intrusion awareness and support safety during welding operations. Specifically, the study aimed to develop and fabricate a functional sensor-based warning device; determine its performance in terms of detection range per location and detection accuracy; describe the respondents' demographic and occupational profiles in terms of gender, welding

experience, Technical Education and Skills Development Authority (TESDA) certification, knowledge and familiarity with welding operations, and welding engagement; and evaluate the system's acceptability in terms of design, safety, and convenience.

Theoretical or Conceptual Basis

The study was anchored on the ultrasonic time-of-flight principle, which explains how distance can be determined by measuring the time required for ultrasonic sound waves to travel toward an object and return to a receiver. Qiu et al. (2022) established that ultrasonic ranging systems use reflected sound waves and signal-processing methods to estimate object distance. Similarly, Khaleel et al. (2024) demonstrated the application of the HC-SR04 ultrasonic sensor in distance measurement and examined approaches to improving its accuracy. In the developed Intruder Alert System, ultrasonic sensors transmit acoustic pulses and receive reflected signals from objects within the monitored welding area. The microcontroller processes the resulting distance measurements and activates audible and visual warning indicators when the programmed detection conditions are satisfied. This mechanism supports proximity-based monitoring without requiring physical contact with the approaching object. The study also adopted an Input–Process–Output (IPO) conceptual framework. Inputs comprised relevant literature, technological components, materials, tools, equipment, and development resources. The process involved planning, designing, fabricating, testing, revising, and evaluating the prototype. The output was a functional Intruder Alert System intended to improve awareness of potentially unsafe proximity during welding operations. The framework reflects the application of sensor-based monitoring technologies to workplace safety, as demonstrated in related research on proximity warning systems (Mastrolembo Ventura et al., 2023).

The study aligns primarily with SDG 8 (Decent Work and Economic Growth), particularly Target 8.8, which emphasizes safe and secure working environments. By developing an automated warning system for welding workspaces, the research contributes to occupational safety awareness and offers a potential supplementary measure for minimizing exposure to workplace hazards. It also supports SDG 3 (Good Health and Well-Being) through its intended contribution to injury-risk awareness and prevention and SDG 9 (Industry, Innovation and Infrastructure) through the development of a practical, sensor-based technological solution for industrial safety. These connections are consistent with the broader sustainable development priorities outlined by the United Nations Department of Economic and Social Affairs (2024). In terms of sustainability, the study contributes primarily to occupational health, technological innovation, and institutional safety practices by exploring an accessible warning technology suitable for welding workshops and technical-vocational settings. Its potential long-term contribution lies in supporting safer work environments and encouraging affordable safety innovations. However, reductions in actual injury rates and broader sustainability outcomes were not directly measured in this study.

2. METHODOLOGY

Research Design

The study utilized a developmental research design for the systematic planning, designing, fabrication, testing, and refinement of the Intruder Alert System. A quantitative descriptive approach was employed to evaluate the system's performance and acceptability based on assessments from experienced welders. The development process covered 12 weeks, including planning and designing, material preparation, fabrication, testing and revision, and final evaluation. The system's detection range and accuracy were assessed through performance testing, while its design, safety, and convenience were evaluated using a structured questionnaire.

Research Locale or Study Setting
The study was conducted in selected welding shops and construction sites in Kidapawan City, North Cotabato, Philippines. These locations provided practical settings for evaluating the Intruder Alert System among individuals engaged in welding activities. The study focused on welding environments where occupational hazards and unexpected entry into active work areas present potential safety concerns.

Participants or Data Sources
The respondents consisted of 50 welders selected through purposive sampling based on their experience and familiarity with Shielded Metal Arc Welding (SMAW). Of these, 16 were shop-based welders, while 34 were on-call welders. Their occupational backgrounds provided relevant perspectives for evaluating the prototype. Respondent characteristics included gender, welding experience, Technical Education and Skills Development Authority (TESDA) certification, knowledge and familiarity with welding operations, and welding engagement. The study also utilized performance-testing observations to assess the system's detection capability.

Research Instruments or Materials
The primary research instrument was a researcher-developed questionnaire designed to assess the Intruder Alert System's acceptability in terms of design, safety, and convenience. It employed a five-point Likert scale, with five representing the highest rating and one the lowest. Three professionals validated the instrument, yielding an overall mean validation score of 4.9, interpreted in the original study as highly valid. The questionnaire also included space for respondents' comments and suggestions. The prototype incorporated four HC-SR04 ultrasonic sensors, Arduino Uno ATMEGA328P microcontrollers, servo motors, buzzer alarm modules, LED indicators, rechargeable 3.7V batteries, charging modules, switches, electronic enclosures, and tripod supports. Assembly tools included a soldering iron, soldering wire, screwdrivers, a multimeter, and a hot glue gun. The total project cost was ₱12,524.00, comprising ₱6,840.00 for materials, ₱5,000.00 for labor, and ₱684.00 for contingencies.

Data Gathering Procedure
The research began with the planning and design of the Intruder Alert System, followed by the procurement and assembly of electronic components. The ultrasonic sensors were connected to the Arduino microcontroller, which was programmed to process distance measurements and activate audible and visual warnings when an object entered the predetermined detection range. The components were initially tested using a breadboard before permanent assembly and installation inside protective enclosures. The prototype underwent testing and revisions to improve detection coverage and minimize unwanted alarms. Modifications included replacing the initial laser sensor with ultrasonic sensing technology, installing protective sensor housings and wave guides, and adjusting servo motor configurations to address detection limitations and unwanted activation. Performance testing covered distances from 0.4 to 2.2 meters across four sensor locations, examining detection responses and alarm activation at different distances and sensor orientations. Following prototype testing, the researcher requested permission from welding business owners to conduct the evaluation. Upon approval, selected welders assessed the system using the validated questionnaire. The completed questionnaires were collected, consolidated, and prepared for statistical analysis to determine the system's acceptability in terms of design, safety, and convenience.

Data Analysis
Data were analyzed using descriptive statistics, including frequency counts, percentage distributions, and mode. Frequencies and percentages were used to describe respondents' demographic and occupational characteristics, while the mode was employed to determine the

most frequently selected acceptability rating for each evaluation criterion. The five-point Likert scale was used to interpret respondents' assessments of the system's design, safety, and convenience. Detection performance was evaluated based on the recorded responses of the ultrasonic sensors at specified distances, including their ability to activate the audible alarm and visual indicators.

Ethical Consideration

The researcher obtained permission from welding business owners before administering the evaluation questionnaire to selected respondents. Data collection was conducted within the approved welding establishments and involved individuals with relevant welding experience. The original manuscript did not explicitly document informed consent procedures, confidentiality measures, voluntary participation safeguards, or formal research ethics approval. Consequently, these procedures cannot be reported as completed without additional supporting documentation.

3. RESULTS AND DISCUSSION

3.1 Development and Performance of the Intruder Alert System

3.1.1 Design of the Intruder Alert System

The Intruder Alert System was successfully designed by integrating ultrasonic sensors, Arduino microcontrollers, servo motors, buzzer modules, LED indicators, and rechargeable batteries. The system was configured to monitor designated welding areas and activate audible and visual warnings when objects entered the programmed detection range. Its design incorporated protective enclosures, sensor mounting mechanisms, and arrangements intended to provide up to 180-degree detection coverage. The findings demonstrate the feasibility of integrating sensor-based detection and automated warning mechanisms into a portable welding safety device. Kim et al. (2023) demonstrated that proximity warning systems incorporating distance estimation and automatic alerts can support hazard awareness in industrial work environments. Similarly, Mastrolembo Ventura et al. (2023) emphasized the potential of proximity detection technologies to improve safety monitoring in construction settings. These studies support the practical relevance of the developed system as a supplementary safety intervention.

3.1.2 Fabrication of the Intruder Alert System

The system was successfully fabricated through the systematic assembly, installation, testing, and refinement of its electronic components. Initial testing involved connecting the sensors, microcontrollers, power supply, and alarm mechanisms before permanent installation. The prototype underwent modifications involving sensor housings, wave guides, and servo motor configurations to improve detection coverage and minimize unwanted activation. The assembled device was enclosed in protective housing intended to reduce exposure to dust, sparks, and heat. The successful fabrication demonstrates the feasibility of constructing an ultrasonic sensor-based warning device using relatively accessible electronic components. Rihmi et al. (2024) established the applicability of HC-SR04 ultrasonic sensors in low-cost distance measurement systems while highlighting the influence of target characteristics on measurement accuracy. These findings support the technological basis of the prototype, although its suitability for prolonged welding operations requires consideration of environmental conditions and sensor reliability.

3.1.3 Detection Range of the Intruder Alert System

Performance testing demonstrated consistent detection across Sensors A, B, C, and D at distances ranging from 0.4 to 1.6 meters, with all ten repetitions successfully activating the alarm and light indicators at each tested distance. Detection decreased to three successful responses out of ten at 1.8 meters and one out of ten at 2.0 meters. At 2.2 meters, all sensors failed to detect the target. The same detection pattern was recorded for the left and right sensor positions. The results indicate that the system's effective detection range was limited to 0.4–1.6 meters under the tested conditions. Qiu et al. (2022) explained that ultrasonic ranging performance depends on reflected acoustic signals and measurement conditions. Teixeira Júnior et al. (2024) further demonstrated that ultrasonic sensor measurement errors can increase with distance and temperature variations. These findings provide a relevant technical explanation for the reduced detection consistency at greater distances and suggest the importance of sensor calibration and environmental assessment.

3.1.4 Detection Accuracy of the Intruder Alert System

The Intruder Alert System achieved 100% successful detection across all four sensors within the 0.4–1.6-meter range. Detection success declined to 30% at 1.8 meters and 10% at 2.0 meters, while no successful detections were recorded at 2.2 meters. The results were consistent across the tested sensor positions, indicating stable short-range detection but reduced reliability at greater distances. The findings confirm that the prototype performed consistently within its tested effective range but exhibited substantial limitations beyond 1.6 meters. Khaleel et al. (2024) examined improvements in HC-SR04 ultrasonic measurement accuracy, demonstrating the importance of sensor performance optimization. Similarly, Rihmi et al. (2024) showed that ultrasonic measurement accuracy varies according to target properties. These findings support the need for further calibration and performance evaluation before extending the system's operational detection range.

3.2 Demographic and Occupational Profile of the Respondents

3.2.1 Gender and Welding Experience

All 50 respondents (100%) were male. In terms of welding experience, 37 respondents (74%) had three or more years of experience, eight (16%) had two years, and five (10%) had one year. The findings indicate that the respondents were predominantly experienced male welders with substantial practical exposure to welding activities. The results reflect the male-dominated composition of the selected sample. Decker et al. (2024) examined gender differences among welding students and highlighted the relevance of gender-related perceptions and self-efficacy in welding education. The respondents' practical experience also provided a relevant background for evaluating the prototype, although the findings cannot establish that experience alone determines the quality of safety assessments.

3.2.2 TESDA Certification and Welding Safety Knowledge

Among the respondents, 40 (80%) possessed Shielded Metal Arc Welding National Certificate II (SMAW NC II), while ten (20%) had no TESDA certification. All 50 respondents (100%) reported performing welding-related tasks, recognizing common welding hazards, understanding standard safety practices and safety zoning, and having sufficient knowledge to evaluate welding-related safety devices. These findings indicate that the respondents possessed relevant occupational backgrounds and self-reported safety knowledge. Nalugya et al. (2022) found that welding safety knowledge was associated with protective practices, although knowledge did not

always translate into consistent safety behavior. Similarly, Magoha et al. (2024) emphasized the importance of occupational safety knowledge, training, and protective measures among welders. These studies support the relevance of respondents' welding backgrounds while indicating that reported knowledge should not be interpreted as direct evidence of consistently safe workplace practices.

3.2.3 Welding Engagement

The respondents consisted of 34 on-call or freelance welders (68%) and 16 shop-based welders (32%). The findings show that most participants were engaged in project-based or on-call welding activities, while a smaller proportion worked in established welding shops. The distribution indicates that the study incorporated perspectives from different welding employment arrangements. Magoha et al. (2024) documented occupational safety challenges among informal welders and emphasized the importance of practical safety interventions in small-scale welding settings. The findings suggest that the developed system may be relevant to welders operating in different workplace arrangements, although its performance across these settings requires further testing.

3.3 Acceptability of the Intruder Alert System

3.3.1 Acceptability in Terms of Design

The Intruder Alert System obtained an overall mode of 5, interpreted as Highly Acceptable in terms of design. Respondents provided favorable assessments of the protective enclosure, sensor placement, internal component arrangement, materials, maintenance accessibility, and overall technical design. In particular, 46 respondents (92%) rated the protective enclosure and overall design highly acceptable. However, ventilation and overheating prevention received a mode of 3, indicating Moderate Acceptability, while physical dimensions, mounting stability, and visual indicator placement received a mode of 4. The findings indicate that the system's general configuration was favorably evaluated, although thermal management and certain physical design features require improvement. von Querfurth et al. (2025) emphasized the importance of sensor integration and feedback mechanisms in advanced welding technologies. Their findings support the relevance of appropriate component configuration and monitoring capability, while the relatively lower ventilation rating in the present study identifies a specific area requiring further refinement.

3.3.2 Acceptability in Terms of Safety

The Intruder Alert System achieved an overall mode of 5, interpreted as Highly Acceptable in terms of safety. All ten safety indicators received modal ratings of 5, including warning recognition, hazard awareness, immediate safety response, operational consistency, and protection of individuals near welding activities. Notably, 47 respondents (94%) strongly agreed that the alert mechanism enabled immediate safety action, while 46 respondents (92%) gave the highest rating to improved hazard awareness and overall safety acceptability. The findings demonstrate favorable user perceptions of the system's potential to support safety awareness during welding operations. Sivakumar et al. (2024) developed a real-time proximity warning system incorporating auditory and visual alerts for workers in hazardous environments. Similarly, Velmurugan et al. (2023) explored sensor-supported technologies for addressing risks associated with close-proximity arc welding. These studies support the relevance of automated warnings as supplementary safety measures. However, the present findings represent perceived safety acceptability rather than direct evidence of reduced workplace injuries.

3.3.3 Acceptability in Terms of Convenience

The Intruder Alert System obtained an overall mode of 5, interpreted as Highly Acceptable in terms of convenience. Respondents favorably assessed its installation, operational controls, automatic functioning, portability, response time, battery capacity, and general practicality. Automatic operation and overall convenience received the highest rating from 47 respondents (94%) and 46 respondents (92%), respectively. However, workflow interference and consistency during prolonged use received modal ratings of 4, indicating areas requiring improvement. The results indicate that respondents generally considered the system practical and manageable for welding applications, although uninterrupted workflow and sustained performance remain concerns. Kim et al. (2023) demonstrated the relevance of alert logic and worker feedback when developing proximity warning technologies for occupational settings. Their findings reinforce the importance of considering operational usability alongside detection performance, particularly when warning systems are intended for routine workplace activities.

3.4 Operational Limitations and Areas for Improvement

The results identified several limitations affecting the Intruder Alert System. Detection performance declined beyond 1.6 meters, with unsuccessful detection at 2.2 meters. User evaluations also identified concerns related to ventilation, potential overheating, workflow interference, and consistency during prolonged operation. These findings indicate that, despite favorable overall acceptability, the prototype requires improvements in detection range, thermal management, and sustained functionality. These limitations emphasize the need for additional calibration, environmental testing, and design refinement before wider workplace implementation. Teixeira Júnior et al. (2024) demonstrated that temperature and measurement distance affect ultrasonic sensor accuracy, while Kim et al. (2023) highlighted the importance of evaluating warning-system performance under practical operating conditions. Accordingly, the developed system represents a promising supplementary welding safety device, but its broader effectiveness remains dependent on further technical improvement and validation.

4. CONCLUSIONS AND RECOMMENDATIONS

The study successfully designed, fabricated, and evaluated an Intruder Alert System as a sensor-based warning device for welding workspaces. Performance testing demonstrated consistent detection across all four sensors, achieving 100% detection accuracy within 0.4 to 1.6 meters, although effectiveness declined at greater distances and detection failed at 2.2 meters. The evaluation involving 50 purposively selected welders in Kidapawan City revealed high acceptability in terms of design, safety, and convenience, with an overall mode of 5 across all three dimensions. These findings indicate that the system is functional, practical, and favorably perceived as a supplementary safety device for monitoring unexpected entry into welding areas. However, concerns regarding ventilation, detection range, workflow interference, and prolonged operation indicate opportunities for technical improvement. Overall, the study contributes a practical prototype that supports intrusion awareness in welding environments, although its capacity to reduce actual workplace accidents remains unverified.

Based on the findings, improvements should prioritize extending the system's effective detection range beyond 1.6 meters through sensor upgrades, recalibration, or integration of additional detection technologies. The prototype's enclosure should be refined by improving ventilation and incorporating suitable heat-resistant materials to address concerns regarding potential overheating. Further adjustments to alert sensitivity and sensor positioning are recommended to minimize interference with welding activities while maintaining reliable warning responses.

Extended operational testing should also be conducted to assess consistency, battery performance, and functionality during continuous welding operations. Welding shop operators and technical-vocational training institutions may consider evaluating the improved prototype as a supplementary safety measure within designated welding areas. Future researchers may investigate wireless monitoring, mobile notifications, adaptive detection zones, and complementary sensing technologies to enhance system functionality. Additional evaluations across different welding environments, including larger industrial facilities, are recommended to determine the system's reliability, adaptability, and practical applicability under varied operating conditions.

The study was limited to 50 purposively selected welders from welding shops and construction sites in Kidapawan City, North Cotabato, restricting the generalizability of its acceptability findings. Performance testing covered detection distances of 0.4 to 2.2 meters under the prototype's specified testing conditions. Acceptability was assessed through a researcher-developed questionnaire using descriptive statistics, without direct measurement of accident reduction or long-term workplace safety outcomes. Furthermore, concerns regarding ventilation, workflow interference, and prolonged operation were identified but not comprehensively evaluated through extended testing. Future investigations may address these limitations through broader respondent participation, varied welding environments, and more extensive performance assessments.

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