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Design Project of Medical Equipment with Artificial Intelligence

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Abstract

The goal of creating cutting-edge medical devices is deeply based on technological advances and innovative design principles. People increasingly want to improve their quality of life, ensure their safety, health, and take full advantage of technological developments. Diagnostic and restorative directions of medicine are among those fields that are constantly evolving. Patients with various health issues, including both physical and mental challenges, are at the center of these developments, requiring ongoing care to manage their conditions effectively. This study focuses on integrating advanced technologies, particularly Artificial Intelligence (AI), into the medical field to enhance diagnostic device functionality, accuracy, and connectivity. The primary objective is to develop medical equipment that simplifies the diagnostic process, improves efficiency, and enhances the accuracy of clinical assessments. The methodology is based on the systematic design and optimization of diagnostic tools incorporating AI-driven data analysis, which enables more accurate and personalized patient assessments. As a result of the study, four therapeutic medical devices integrating infrared radiation and Artificial Intelligence (AI) have been designed. These devices are developed to enhance patient care and improve overall quality of life by providing advanced noninvasive diagnostic and therapeutic solutions. Experimental evaluations confirm that all four devices operate exclusively through non-invasive methods, thereby minimizing patient discomfort, pain, and the risk of infection or post-procedural complications. The application of infrared radiation technology demonstrates high precision and reliability in medical diagnostics, while AI-driven analysis contributes to enhanced efficiency and the personalization of therapeutic interventions.

Keywords: AI in Design, Design Research, Healthcare Design, Medical Equipment, Noninvasive Technology.

Introduction

The design and development of cutting-edge medical devices are fundamentally driven by rapid technological advancements and innovative design principles aimed at improving the quality of human life. In an era characterized by digital transformation and data-driven decision-making, the healthcare sector has undergone an unprecedented transition toward intelligent, patient-centered solutions. As individuals increasingly seek to enhance their well-being, ensure safety, and benefit from technological progress, the demand for sophisticated and reliable medical devices continues to expand. Both diagnostic and therapeutic branches of healthcare are evolving rapidly to meet these needs, emphasizing not only functionality and precision but also user comfort, accessibility, and ethical responsibility. Individuals with chronic or acute health conditions often require continuous monitoring and tailored care, as their challenges may arise from complex physiological or cognitive origins. Consequently, the intersection of technology, design, and medicine has become a focal point for innovation and interdisciplinary collaboration.

In recent decades, the integration of information technologies, sensor systems, and artificial intelligence (AI) into healthcare has significantly transformed the design and functionality of medical devices. It has been shown in past studies that traditional medical technologies, although effective in specific contexts, often suffer from major limitations such as delayed response times, lack of real-time data processing, and restricted adaptability to individual patient needs (1). To address these limitations, more intelligent, responsive, and patient-centered systems have been developed. Through the ability to process extensive datasets and identify complex diagnostic patterns, AI has emerged as a new paradigm in

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medical device development. It has been demonstrated that AI-driven methods enable predictive modeling, automated diagnostics, and adaptive feedback mechanisms that improve both precision and reliability, while also facilitating continuous monitoring and preventive care (2).

Alongside these technological advances, non-invasive diagnostic approaches—particularly those based on infrared imaging and sensing—have gained substantial attention for their potential to enhance patient comfort and safety while maintaining diagnostic accuracy. Infrared radiation technology has been found effective for detecting physiological parameters such as temperature fluctuations, blood flow, and metabolic activity without direct physical contact. This technology offers notable advantages, including minimal intrusion, high sensitivity, and suitability for extended monitoring (3). Such features are particularly significant for vulnerable patient populations, including infants, elderly individuals, and persons with restricted mobility, for whom non-contact monitoring represents a critical improvement in safety and convenience.

Despite considerable progress, several challenges remain within the field of medical device development and implementation. Diagnostic inaccuracies, incomplete patient data, and limited understanding of rare or complex medical conditions continue to hinder clinical precision and patient outcomes. Furthermore, it has been observed that many technological advancements are being developed in isolation, with AI-based systems and non-invasive diagnostic tools rarely integrated into cohesive frameworks. This fragmentation has limited the emergence of comprehensive, user-centered medical devices capable of combining intelligent computation with ergonomic and aesthetic design. Additional constraints such as high production costs, patient discomfort, and stringent regulatory requirements further complicate the widespread adoption of advanced technologies in clinical practice.

Evidence from past studies indicates that although AI-based systems have achieved significant improvements in automated diagnostics and individualized treatment optimization, the seamless integration of AI with infrared-based and other non-invasive technologies remains underexplored. It has been reported that prior investigations often focused either on refining algorithmic models for disease detection or on improving sensor precision for thermal imaging applications. However, the importance of human-centered design and interdisciplinary collaboration has often been overlooked, resulting in devices that may be technologically advanced but lack usability, affordability, or accessibility for diverse patient populations. This situation highlights a clear gap in the literature, emphasizing the need for a holistic design framework that unifies clinical expertise, data-driven technology, and design methodology into a single, cohesive approach.

The present study addresses this gap by proposing an integrated design framework that combines AI-driven analysis with infrared radiation technology to create advanced, non-invasive medical devices. The overarching goal is to develop intelligent diagnostic systems that enhance accuracy, operational efficiency, and patient comfort, while promoting real-time, adaptive monitoring. The specific objectives of the study are: to explore the embedding of AI algorithms within infrared-based medical devices to improve diagnostic precision; to design ergonomic and user-friendly prototypes aligned with modern design standards and patient needs; and to evaluate the functional and conceptual effectiveness of these devices through modeling and simulation.

The novelty of the present research lies in its interdisciplinary methodology, which bridges the fields of design, engineering, and medical science. By merging these domains, a new generation of medical devices can be developed that balances technological sophistication with human-centered usability. Unlike previous research that treated technological or clinical components in isolation, the proposed approach emphasizes the synergy between functional design aesthetics, intelligent automation, and patient well-being. Through the integration of AI and infrared sensing within a unified system, this study introduces a new paradigm in medical device design—one that prioritizes technological innovation alongside ethical responsibility, comfort, and long-term sustainability.

Ultimately, the significance of this research lies in its contribution to advancing healthcare accessibility, diagnostic efficiency, and patient-centered innovation through intelligent design integration. The incorporation of AI enables early detection, individualized treatment planning, and remote health monitoring, while the use of infrared technology ensures non-invasive operation and high diagnostic fidelity (4). Together, these innovations support a vision of next-generation healthcare that empowers patients to receive continuous, reliable, and compassionate care enabled by intelligent technologies. The interdisciplinary framework proposed in this study serves as a foundation for future developments, fostering collaboration among designers, engineers, and healthcare professionals to redefine the potential of medical devices in the 21st century.

Methodology

The research was carried out through a combination of theoretical analysis, comparative study, experimental modeling, and user-centered evaluation. The theoretical foundation was established through an extensive review of scientific literature published in internationally recognized journals, focusing on the latest technologies and innovations in medical device design and healthcare product development. Insights derived from these studies were instrumental in shaping the conceptual and methodological direction of the present project.

The investigation relied on a detailed analysis of scientific publications, with particular attention to advancements in continuous glucose monitoring, non-invasive blood glucose sensors, and wearable medical technologies. It has been reported that significant progress has been made in biosensors, electrochemical detection, and non-invasive diagnostic methods; however, persistent challenges such as calibration frequency and sensor stability continue to limit performance (5, 6). Studies on wearable health technologies have emphasized the importance of ergonomics, patient safety, and psychological comfort, particularly for long-term monitoring applications (7). It has also been demonstrated in ergonomics research that user-centered design, when implemented during the early stages of product development, substantially improves device adoption and reduces operational errors (8). These findings collectively formed the theoretical basis of the present study.

To contextualize existing technologies, a comparative analysis of international prototypes of blood glucose monitoring devices was conducted. The comparison included parameters such as sensor technology, invasiveness, accuracy, user interface design, and ergonomic performance. It has been found in earlier reviews that although improvements in user comfort and convenience have been achieved, issues remain in the accuracy and long-term stability of non-invasive glucose measurement (9,10). Furthermore, it has been indicated in clinical evaluations of portable glucose meters that, despite meeting established regulatory accuracy thresholds, challenges persist in usability and accessibility, particularly for elderly or visually impaired users (11).

During the experimental phase, 3D computer-aided design (CAD) software was employed to develop conceptual models and optimize component integration. The prototypes were refined using advanced visualization tools, including 3D simulations, to represent device handling and interface interaction in a realistic manner. It has been stated in design science research that digital prototyping supports iterative development and contributes to precision and design optimization (12). Published benchmarks for glucose monitoring devices—such as response times, power consumption, and optical interference thresholds—were used to validate the feasibility of design iterations. This approach ensured that the new prototypes not only enhanced user experience but also aligned with technical parameters established in contemporary biomedical literature.

To ensure practical relevance, user-centered evaluations were conducted through surveys and semi-structured interviews with diabetic patients. The collected feedback revealed common difficulties related to pain caused by invasive devices, handling problems due to age-related dexterity limitations, and anxiety regarding the accuracy of readings. These findings correspond with observations reported in prior studies, where psychological and ergonomic barriers were identified as major obstacles in routine glucose monitoring among diabetic patients.

The resulting design integrates modern biosensor technologies with ergonomic and user-friendly features. It addresses the technical challenges highlighted in the literature while directly incorporating feedback from end users, thereby contributing simultaneously to academic discourse in healthcare product design and to the practical advancement of medical device innovation.

Results and Discussion

As a result of the research, four medical devices were developed, each utilizing the same core technology and internal structural concept. Every device incorporates a digital data display, an infrared radiation spectral sensor, a battery module, and a monitoring block. These integrated components collectively ensure the functional performance and reliability of the designs.

The non-invasive glucometer developed in the study operates on the principle of infrared radiation technology, providing a painless and comfortable approach to measuring blood glucose levels. The process is based on the controlled emission of an infrared beam onto the skin surface through a specialized sensor plate. The heat exchange between the skin and the infrared membrane is analyzed, and the resulting data are processed to determine the glucose concentration, which is then displayed on the digital screen (13).

The system is powered by a replaceable battery that can be easily changed by the user, eliminating the need for professional servicing. It has been designed to ensure safety and hygiene, which makes it particularly appropriate for home use. Due to its compact form and efficient operating mechanism, the device enables rapid glucose measurement without requiring additional accessories, unlike conventional invasive glucometers (14).

The ergonomic design of the device adheres to established standards in medical device development, incorporating only essential components to maintain functionality and reduce complexity. Activation occurs when the user places a thumb on the designated sensor area, which has been shaped ergonomically to ensure correct positioning. The surface of this area includes a groove with a fingerprint-like pattern specifically designed to minimize optical interference with the infrared beam (15). Upon contact, the sensor captures the necessary biometric data, which are then processed through embedded algorithms before being transmitted to the display interface. The digital display module is calibrated to present glucose readings in standardized units consistent with diabetes management protocols.

The structural layout and external appearance of the non-invasive glucometer are illustrated in Figure 1, demonstrating the integration of ergonomic form, technological functionality, and compactness suitable for personal medical use.

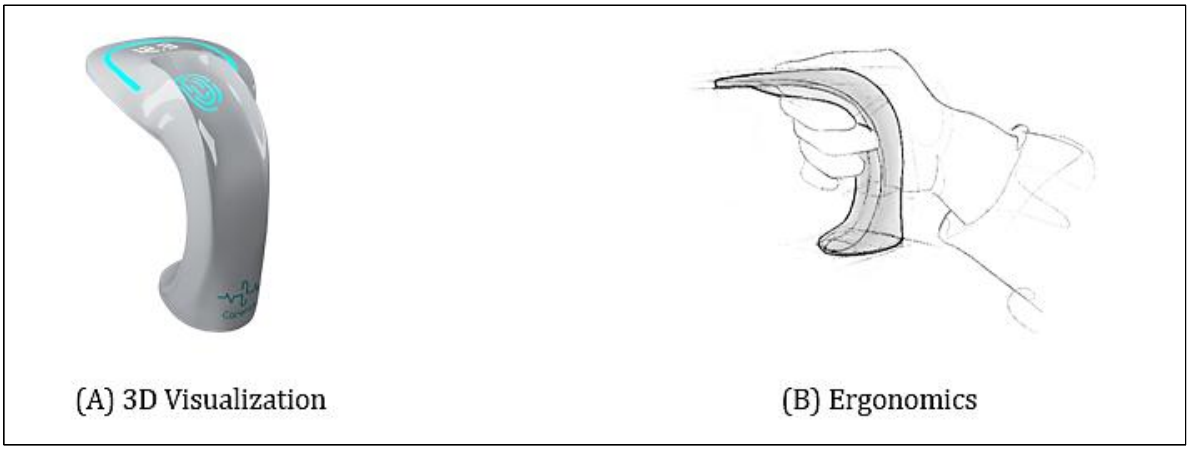

Figure 1: Non-invasive Glucometer

Blood Pressure Measurement Device

The blood pressure measurement device was designed with consideration for usability across various age groups. During its development, a range of ergonomic standards was applied to ensure optimal comfort, ease of use, and efficient maintenance, while also enhancing portability. A key distinguishing feature of this device lies in its minimalist configuration, which eliminates non-essential components that could impede functionality. In contrast to traditional pressure gauges, the design does not require a fabric cuff, a bracelet-style attachment, or a separate stethoscope (16).

The device functions through the combined use of infrared radiation and AI-based analytical systems to produce accurate physiological data. When properly positioned on the elbow, it initiates a non-invasive infrared examination that extracts specific information related to blood composition for subsequent analysis. The collected data are processed through AI algorithms trained on extensive datasets to evaluate the user's cardiovascular condition, and the final readings are displayed numerically on the integrated screen (17).

The operational mechanism relies on infrared light to detect subtle variations in blood volume within the arm. With each cardiac cycle, blood flow changes alter the absorption of infrared light by the tissue. The infrared plate directs the appropriate radiation beam to the skin, registers variations in heat transfer, and transmits the acquired signals for computational analysis (18).

The device casing is fabricated from medical-grade plastic selected for its lightweight, durable, and biocompatible characteristics (19). This material ensures user comfort and safety by minimizing the risk of allergic reactions or surface irritation. It is widely adopted in medical device manufacturing for its chemical resistance, capacity for sterilization, and adaptability to complex molding requirements. The system operates on a replaceable battery, allowing users to maintain device functionality independently without the need for technical support.

The finalized prototype of the blood pressure measurement device is presented in Figure 2, illustrating its ergonomic configuration, streamlined structure, and integration of non-invasive diagnostic technologies.

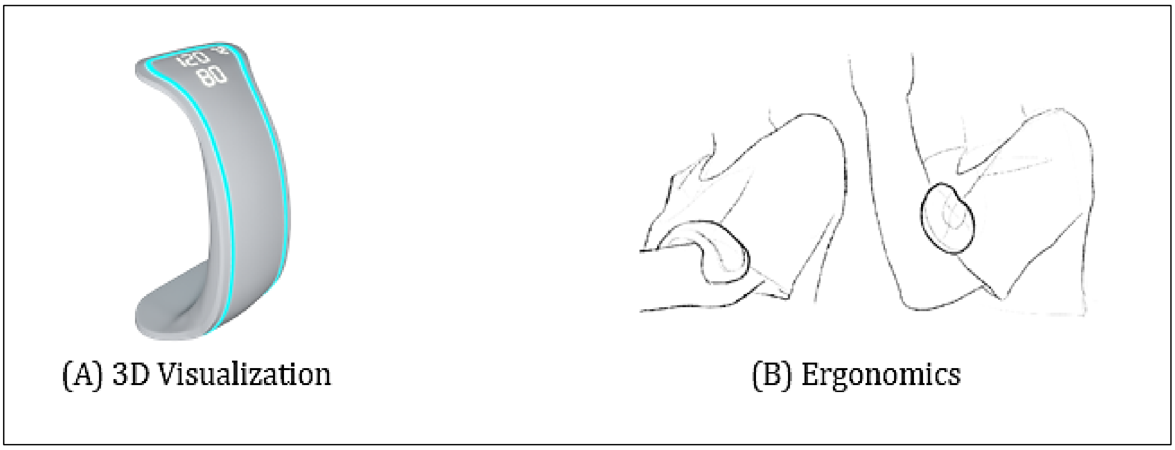

Figure 2: Blood Pressure Measurement Device

Infrared-based Thermometer

The operating principle of the thermometer is grounded in infrared (IR) technology, following the same scientific basis as conventional non-contact infrared thermometers. Although such devices are widely utilized in clinical and domestic environments, issues related to accuracy and consistency have been frequently reported in prior research (20). To overcome these limitations, the present design integrates a dual infrared sensor configuration that enables internal calibration, thereby enhancing the reliability and precision of temperature measurement (21).

When positioned in contact with the ear or forehead, the thermometer activates automatically. During operation, two independent temperature readings are obtained through infrared radiation detection. The raw data are subsequently processed by an embedded calibration mechanism in conjunction with artificial intelligence algorithms. The final temperature value is derived algorithmically from the refined data and presented visually on the digital display. For situations in which direct screen observation is impractical, an integrated audio system provides verbal output of the measured temperature, ensuring accessibility for users of varying needs.

This configuration offers a rapid, hygienic, and user-friendly alternative to conventional thermometric techniques. From an ergonomic standpoint, the structural form of the device aligns with the anatomical contours of the human head to secure accurate contact points and ensure measurement stability. A medical-grade silicone layer has been incorporated along the inner surface to prevent slippage, enhance comfort, and provide gentle yet secure adherence to the forehead and the area behind the ear.

The thermometer has been engineered specifically to assess temperature through the temporal artery, located on the forehead above the eyebrow. This artery, which branches from the carotid artery, is characterized by continuous blood flow and rapid responsiveness to temperature fluctuations, reaching up to 50°C, making it a dependable site for estimating core body temperature (22). Its superficial placement and accessibility further reinforce its suitability for precise, non-invasive thermal evaluation.

The infrared-based thermometer prototype is illustrated in Figure 3, demonstrating the integration of ergonomic design, AI-assisted calibration, and dual-sensor infrared technology for improved diagnostic accuracy.

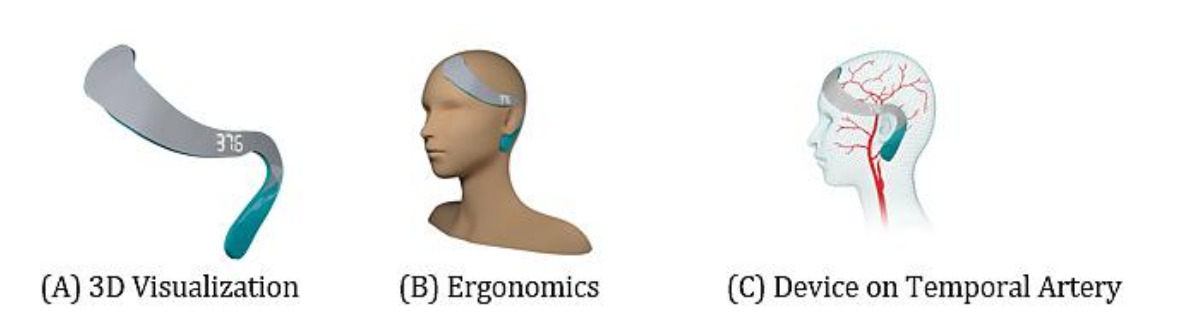

Figure 3: Infrared-based Thermometer

Pulse Oximeter

The pulse oximeter in this system operates on the principle of infrared photoplethysmography, with accuracy and data interpretation enhanced through the integration of artificial intelligence. Controlled pressure is applied to ensure sufficient tissue contact, facilitating precise detection of blood oxygen saturation (SpO_2) (23). The design of the oximeter has been harmonized with the rest of the diagnostic equipment, incorporating consistent material selection and color schemes to produce a unified aesthetic and functional appearance.

Functionally, the device emits light at both infrared and red wavelengths through a body part, typically the fingertip or earlobe. A photodetector positioned opposite the light source measures the intensity of transmitted light. Oxygenated hemoglobin (HbO_2) and deoxygenated hemoglobin (Hb) exhibit distinct absorption characteristics: oxygen-rich hemoglobin absorbs more infrared light and transmits more red light, whereas oxygen-poor hemoglobin demonstrates the opposite behavior. By calculating the ratio of absorbed red to infrared light, the device determines the percentage of oxygen saturation in the blood (SpO_2).

In addition to SpO_2, the pulse oximeter records pulse rate by detecting periodic changes in blood volume at the measurement site, corresponding to cardiac cycles (24). The collected data are processed internally and presented in real time on a digital display, providing clear and accessible readouts of both parameters.

The final pulse oximeter prototype is illustrated in Figure 4, demonstrating the integration of infrared photoplethysmography, AI-assisted analysis, and ergonomic design for accurate and user-friendly physiological monitoring.

These instruments constitute a standard set of therapeutic diagnostic devices commonly employed during initial clinical evaluations. Measurement of blood pressure, blood glucose, body temperature, and blood oxygen saturation provides clinicians with critical baseline data for the identification of a wide range of acute and chronic conditions. As such, these devices are considered essential in both clinical and home-based settings (25).

The equipment set not only facilitates routine diagnostic procedures but also supports continuous patient monitoring, thereby contributing to improved health outcomes and enhanced therapeutic effectiveness.

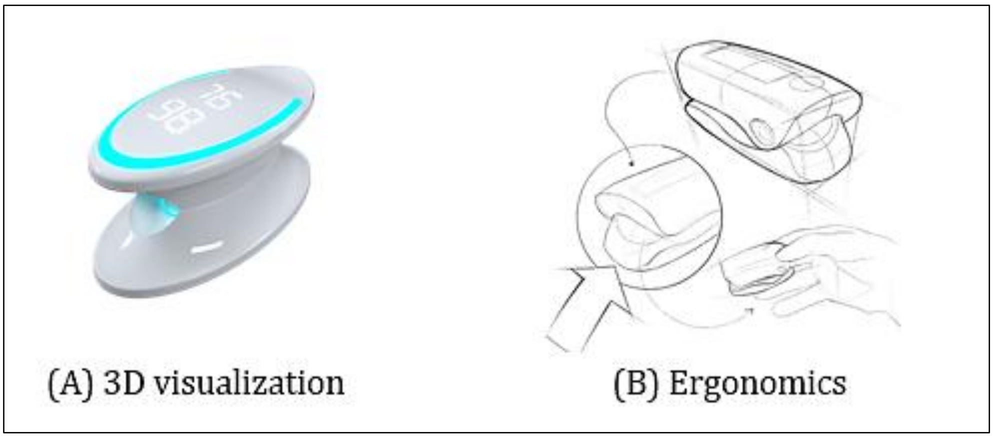

Figure 4: Pulse Oximeter

Artificial intelligence has been integrated into the design of these medical devices, leveraging infrared (IR) technology for enhanced data acquisition and interpretation. Deep learning techniques, particularly convolutional neural networks (CNNs), are employed for the analysis of thermal images, enabling the detection of inflammation, circulatory disorders, and infections (26). Classical machine learning models, including support vector machines (SVMs), are applied for pattern recognition in non-invasive glucose monitoring, stress assessment, and fatigue evaluation (27). Continuous monitoring is further supported through recurrent neural network (RNN) architectures, such as long short-term memory (LSTM) models, which analyze dynamic infrared signals and heart rate variability. Collectively, these AI methodologies improve the accuracy, usability, and adaptability of infrared-based diagnostics, facilitating patient-centered care and remote healthcare applications.

Conclusion

The continuous pursuit of improved quality of life and patient well-being has driven ongoing research, design, and implementation of advanced medical devices. This study focused on the development of non-invasive diagnostic technologies, with particular emphasis on the integration of infrared radiation and artificial intelligence within therapeutic medical instruments. The four devices developed are intended to enhance patient care while improving the practicality and accessibility of routine health monitoring.

A fundamental characteristic of these devices is their entirely non-invasive mode of operation. By eliminating the need for penetrating procedures, patient discomfort is substantially reduced, the risk of infection is minimized, and potential post-procedural complications are prevented. The combination of infrared technology and AI enables accurate, real-time data collection and analysis, providing clinicians with reliable information to support diagnosis and treatment planning.

The incorporation of ergonomic principles throughout the design process is critical to device usability. Comprehensive ergonomic assessments ensure that the devices are intuitive, accessible, and comfortable for patients, thereby improving compliance and overall user experience.

The advancement of non-invasive, AI-enabled medical devices represents a significant contribution to modern healthcare. These innovations prioritize patient comfort and safety while simultaneously equipping healthcare providers with efficient, data-driven tools to deliver high-quality, evidence-based care.

Abbreviations

AI: Artificial intelligence, 3D CAD: Three-Dimensional Computer-Aided Design, IR: Infrared Radiation, CNNs: Convolutional Neural Network, SVMs: Support Vector Machines, RNNs: Recurrent Neural Networks, LSTM: Long Short-Term Memory

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Author Contributions

Artashes Melikyan: Data Curation, Proofreading. Ani Atsharyan: Project Administration. Ashot Baghdasaryan: Conceptualization, Methodology. Anahit Petrosyan: Literature Review, Validation. Luiza Petrosyan: Formal Analysis, Visualization. Tatevik Paytyan: Review, Editing.

Conflict of Interest

The authors declare no conflict of interest.

Declaration of Artificial Intelligence (AI) Assistance

No generative AI or AI-assisted technologies were used in the writing of this manuscript.

Ethics Approval

This article is based on theoretical analysis and publicly available sources; therefore, ethical approval was not required.

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