Innovative: International Multi-disciplinary Journal of Applied Technology
(ISSN 2995-486X) VOLUME 03 ISSUE 3, 2025

Development and Implementation of a Passive Infrared (PIR) System for Protecting Workers from Ultraviolet (UV) Rays

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Abstract:

Ultraviolet (UV) radiation poses significant health risks to outdoor workers, including skin damage, eye disorders, and increased cancer risk. Existing protective measures, such as sunscreen and clothing, are often insufficient or inconsistently applied. This study addresses this gap by developing a Passive Infrared (PIR) system designed to detect harmful UV exposure and alert workers in real-time. The system integrates PIR sensors, UV sensors, and a microcontroller-based alarm mechanism, ensuring timely warnings to prevent overexposure. Findings from laboratory and field tests indicate that the system effectively detects UV intensity variations and enhances compliance with protective measures. The results suggest that implementing PIR-based safety systems in occupational environments can significantly reduce UV-related health risks, improving worker safety and productivity.

Keywords: Ultraviolet radiation, Passive Infrared (PIR) system, occupational safety, UV exposure detection, real-time monitoring, worker protection.

1. Introduction

Ultraviolet (UV) rays are found in sunlight and have a wavelength shorter than visible light and longer than X-rays. Solar UV exposure has been positively linked with increased risk of skin conditions, including skin cancer, photo conjunctivitis, and premature aging of the skin. In addition, it has also been attributed to eye damage. These concerns have brought about changes in lifestyle and attitudes towards greater UV protection, which in turn have intensified the incorporation of safety measures in various societies. Behaviors such as slipping on sunglasses, wearing hats with a wide brim, and applying sunscreen are deemed standard practice. However, global skin cancer figures indicate that a significant number still do not provide protection against sunlight, especially as the UV environment continues to grow through the usage of light sources, including UV-tanning apparatus and artificial light. There is therefore a critical need for solutions that could help minimize these consequences. Technology is advancing rapidly and has been recognized as playing a critical component in preventing hazards, including those that depend on safety from injury [1]. The way individuals experience work conditions is understood to improve with time, which in turn leads to enhanced performance. Nevertheless, it has also sparked a conversation on improving the safety of employees, particularly in a world that is becoming more closely interconnected and impatient. Industries, in order to ensure they remain at the forefront of these improvements, have been obligated to execute safer equipment and training. The intention behind deploying such accidents is to safeguard employees and also mitigate some of the liability of the employer. This study will investigate the development and implementation of a UV alarm system and its effectiveness in a simulated environment.

1.1. Background and Significance

Passive infrared system for the protection of workers from ultraviolet rays is the innovative project that can be used in many sectors including construction, agriculture, mining, manufacturing, engineering, and health sector. The increasing risks of ultraviolet (UV) exposure reflect the growing awareness of extensive occupational health and safety implications in many industrial sectors. UV rays are considered the most dangerous harmful radiation for human health, and protection against UV is necessary in many aspects of daily life. The number of research studies and analysis reports on UV rays and methods to protect against it have been increasing rapidly over recent years. The European Union (EU) has strictly regulated the maximum amount of UV exposure in the workplace since 2011. However, traditional solutions including sunscreen, long-sleeved clothing, and hats can only provide limited protection to workers in outdoor working environments [1]. Sun Protection Factor (SPF) is widely recognized as the common way to describe protective effects of sunscreen. However, even very strong sunscreens can reduce damages from UV to human skin by only 55%. Statistical data on mill workers, welders and road workers, and skin cancer victims reveals that more than 118,000 and 37,000 people died of deaths directly related to excessive UV exposure in those two groups of workers, respectively. These reports illustrate the urgent need of industrialized and innovative systems for protection of works against excessive UV exposure [2]. The Passive Infrared System can significantly reduce the occurrence of such work-related time bombs. The system utilizes the capability of a PIR sensor in detecting human presence. Placement of a PIR sensor near a UV sensor and a buzzer on machines generates alarms when a person approaches wearing a UV detector. UV detection continues until the person is no longer detected or the person activates a stop switch. System will be designed to be cheap and wireless, so that it can be easily implemented in various industrial sectors where workers are harmed due to excessive UV exposure. [3][4]

1.2. Objective of the Study

The primary objective of this research is to develop and implement a Passive Infrared (PIR) system to enhance the protection of workers against ultraviolet (UV) rays. The effectiveness of this system at reducing risks associated with exposure to UV rays will be also investigated. The focus will be on analyzing the existing systems to protect workers in the construction field from exposure to UV rays and developing a new PIR system to provide complete protection for workers. Initially an extensive review of existing UV protection measures will be conducted to highlight their main advantages and limitations. As a continuation, a comprehensive requirement and design specification for the PIR system, which enhances existing measures and overcomes their limitations, will be presented. Subsequently, the investigation will cover the accommodation an evaluation of the proposed PIR system and testing of its technology to ensure that it works properly. Preventive measures will support its effectiveness in the workplace. The final outcomes of this research include a development of innovative technology that effectively reduces risks associated with the exposure to UV rays and an improvement in workplace safety standards and practices. As a result, the risks associated with the exposure of outdoor workers to UV rays, especially workers in the construction field, will be significantly reduced [5].

2. Fundamentals of UV Radiation

Ultraviolet (UV) radiation encompasses a portion of the electromagnetic spectrum extending in energy from 3.1 to 124 eV. It falls between the vacuum ultraviolet and the longer wavelength end of the soft X-ray region. It is a powerful technology employed for disinfecting water, surfaces, foods, and air; polymerizing inks and coatings; and causing photochemical changes in drugs, colorants, and other substances. UV is an ideal complement to filtration, so that while airborne microorganisms encounter resistance to filtration, they can be inactivated or destroyed by exposure to UVC, whose wavelength ranges from 200 to 280 nm [6]. UV overlooked application is a passive technology to disinfect surfaces in the food industry and in public health settings. UV protection is required in welding. However, in other industrial processes, workers are exposed to UV light during the entire photo-shift time and do not use any protective clothing. One such case is the curing process of paints, lacquers, and adhesives, as UV radiation is used to dry the solvent-based components of these products. Not all exposure to UV radiation is for beneficial purposes though. Some of its biological effects have raised concerns over public health issues. It is the main cause of long-term health effects such as various types of skin cancer, pre-mature aging, and lens opacities leading to cataracts. It often causes immediate effects too, notably sunburn, by far being the most common result of excessive exposure to UV radiation. Many of these effects are believed to be photochemical, being caused primarily by the formation and reactivity of chemical species subsequently to initial absorption of UV radiation. Since the maintenance of health is considered to be of greater value than wealth, the natural concern over those effects has been about protecting the skin from the harmful effects of UV residing in sunlight, especially in occupational settings. To mitigate health problems caused by overexposure to UV radiation, many countries have promulgated laws and guidelines aimed at keeping the exposure limit of such radiation under acceptable levels. In order to develop a reliable device to objectively monitor the dose of thin UVB and UVC that reaches the skin, it is necessary to understand the biological effects and the damage done by exposing the skin to UV radiation. For such effects, it is essential to appreciate the mechanisms that underlie the damaging effects of UV radiation on the biological system before examining the current state of art passive UV dosimeters, to develop and verify a new protection technology. [7][8]

2.1. Types of UV Radiation

The sun is the source of the main natural illumination around the globe. However, it also emits the so-called ultraviolet (UV) radiation that is responsible for causing unpleasant health effects on long exposure. There are three main types of UV rays depending on the wavelength range: UVA (wavelength 315 nm to 400 nm), UVB (wavelength 280 nm to 315 nm) and UVC (wavelength 100 nm to 280 nm) [9]. The longer the wavelength, the lower the energy, and so, the UVA rays are the most common. Yet, they penetrate the skin more profoundly, making it vulnerable to irreversible long-lasting damage. They are also regarded as posing the risk of developing skin cancer. As for UVB, they are mostly responsible for causing sunburns. However, they also bear some dangerous effects, such as an increase in pigmentation and the capability of causing skin cancer, including melanoma. Nonetheless, their energy is lower than that of the shorter wavelength rays. It means that their harmfulness is limited to the skin superficial layers in the absence of amplifying elements. As for the latter, UVC rays are the most dangerous. With a significantly high energy, they are not to be taken lightly. However, little UVC radiation manages to pass through Earth's atmosphere to reach its surface. It is a good thing, as prolonged exposure to this kind of rays is in fact hazardous. These kinds of UV rays are used with intent for sterilizing purposes. That is to say that it kills germs - it stops them from multiplying and incubating. Some molds and yeasts are also killed if they are treated with UVC; and so are certain insects and vermin. In this context, UVC radiation is being used increasingly for the aforementioned purposes. There are also known harmful effects of overexposure to UVC rays. One of those is the risk of developing cataracts in the eyes. As such, they are protected under the OSHA regulations.

This harmful radiation is not only natural but also artificially generated. Besides being present in sunlight, the risky UV rays are also emitted by special artificial sources. For instance, some tanning lamps have the capability of giving off these harmful rays. There are even industrial-grade line-lamps used for detecting flaws or particular substances, whose emission also includes UVC radiation. People exposed to these kinds of rays tend to use sun-tanning agents, thinking they are protected. When in fact, most of these creams only function to shield against either UVA or UVB rays. This brings up the need for a reliable passive infrared system capable of making sure that workers and everyone around them are not exposed to harmful levels of this unseen risk.

2.2. Health Effects of UV Exposure

Ultraviolet (UV) radiation is one of the major hazards arising from solar exposure in occupational settings where workers are involved in outdoor activities [10]. Either directly from the sun or by reflection from water, sand or other bright surfaces, UV radiation is radiated as sunlight or it is not perceived in terms of heat. It poses different health effects on humans and biological systems. Possible adverse effects on human health due to excessive solar UV exposure can be both acute (occurring a few hours after the exposure) and long-term chronic (accumulative throughout life). Acute sunburns are the most evident health effect of solar UV exposure. They cause eyes and skin irritation and damage, leading to redness, inflammation and, possibly, blisters and pain. Owing to DNA damage effects, a serious long-term consequence that solar UV radiation can cause is skin tumors. Despite the role that ultraviolet B (UVB) radiation plays in this scenario, there is evidence that also ultraviolet A (UVA) exposure contributes to the increased risk of cutaneous cancers like melanoma and basal cell carcinoma. Regarding eyes, a full appreciation of the potential harm that solar ultraviolet radiation can cause began to develop more recently. Nevertheless, concerns have been raised about damage to the eye caused by UVR. Early effects include photo keratitis and photo conjunctivitis, while long-term effects include cataracts, an increased risk of eye tumors and the reduction of the immune system effectiveness. Besides eyestrain and temporary problems, cumulative exposure to solar UVR can cause retinal injuries. Similar to the biological effects of the other types of UVR, retinal injuries are caused by the photochemical impact on ocular tissues of long-wavelength UVR. Exposure to solar UVR has a series of deleterious effects on different biological tissues in humans with possible significant impacts on psychology and social aspects as well. Skin disorders due to the adverse effects of excessive sunlight recline discomfort and significant psychological implications, particularly if it is about visible harm to the individual. This represents also the case of many types of cancer. Concerns about the risk of solar UVR are significant not only for direct exposure (e.g. outdoor workers, sunbathers), as the increased risk of damage poses also two secondary exposed populations (e.g. workers simply spending some time outdoor for any reason, people spending their free-time outdoor). Industrialized countries show further concerns about solar UVR exposure due to the strong social stigma of some types of skin damages, such as melanoma. There is the need for a collective strategic approach to the problem that should involve researchers, designers, and regulatory bodies, as well as employers and workers in order to minimize the rising risk. Nonetheless, awareness and knowledge about potential risk caused by exposure to excessive outdoor UV radiation have not affected prevention habits and personal behaviors as it was expected. Reasonable justifications such as job duties, weather conditions, or unawareness of the harm should no longer be accepted, being nowadays available really affordable resources and technology. A passive infrared (PIR) controlled protective system has been developed for avoiding the risk of harmful exposure to solar UVR, particularly targeting workers who are involved in outdoor activities. [11][12]

3. Overview of PIR Technology

Occupational safety and protection need continuous innovation in terms of devices and control procedures. In this context, modern Passive Infrared (PIR) technology can significantly help to make the working environment safer, especially when workers have to face acute or long exposures to harmful agents. By using a PIR system in different settings, various protective actions can be undertaken ranging from a simple advice to a worker, to a warning message in the event of a dangerous situation. In the most critical cases, a PIR installed system could automatically cut off the power supply of the dangerous equipment. In line with the above, the development and implementation of a PIR-based system aimed at protecting outdoor workers from UV rays is described. In its classical application field for anti-intrusion systems, Passive Infrared (PIR) technology is based on the use of sensors capable to detect the infrared radiation emitted by objects, particularly humans. This technology has been deeply improved in the past few years, one of the latest applications being an intelligent personal safety system for workers based on a network of PIR sensors installed in a work area. The sensors can detect workers in a place where heavy machinery operates, and they can give an alert to the machinery's operator. By developing this technology, safety conditions in industrial environments may be dramatically increased. PIR technology can be applied in a very large range of sectors in which the workplace can be dangerous for the operators. The opportunity to interact in a "smart way" with the external environment thus makes PIR technology a very useful tool in different scenarios. With this configuration, the PIR system has been installed outside and it is able to determine whether the irradiated UV level is dangerous and thus suggest protection actions to the worker. It is clear how this flexible technology with limited constraints about the space configuration could find other useful applications in other outdoor workplaces [13]. Some of these possible applications are presented as well as different additional protection actions toward workers' safety. Furthermore, the implementation of this technology together with additional technological processes can improve workplace safety even more.

3.1. Principles of PIR Sensors

Passive Infrared (PIR) sensors are electronic devices able to detect changes in infrared radiation. As warm-bodied individuals emit this type of radiation, PIR sensors can detect their presence, and this is what is used in intruder alarms. In a PIR sensor, two materials are in direct contact, one positive and the other negative. These materials generate a Pyro-electric effect that is used to produce electric charge when IR radiation heats them. This charge generates a potential difference that is measurable with an operational amplifier and an external FET. An optical filter in front of them allows to maintain the Pyro effect acting as a band-pass filter for IR radiation, where a change in capacitance is produced. In this way, the PIR sensor needs to connect two or three leads: one input, one power, and sometimes a reference to fix op-amps offset. The capability of a PIR sensor to detect a good UV worker depends on a number of parameters: first of all the lens of the sensor, it will define the coverage as well as the field of view, so it is important to choose the proper sensor accordingly to the required area to protect. Lenses can also contain some optic elements to increase sensitivity. The second important parameter is the sensor placement and mounting height [13]. Sensors should be placed at a proper height to maximize coverage, but too high can lead to shadow areas. Finally there is the problem of calibration, it is needed to set-up properly the sensitivity of the sensor in terms of lux. This is done with added elements of control to the sensor, able to modify a potentiometer; it is normally done with a Demonstration Board directly connected to the sensor. After all these verification operations, there is the possibility to move the sensor to the work environment. Keeping in consideration all these operative indications, the new PIR solution demonstrates some strong points: quick response, typical timing can be achieved in the range 50÷60 ms; low maintenance requirement; the capability to detect each movement in the coverage, the sensor is able to detect any individual movement in the area it is monitoring. This is opposed to other PIR sensors that use technology based on a single pyro element and a single FET that are able to detect only the warmest presence, and are not suitable for an outdoor work environment. In some cases, the use of this technology is such that, during the summer, an employer going to guard a parade of soldiers is able to work at 40 °C. As with the UVC-4 system, there is the capability to divide the equipment in different groups of coverage in such a way to observe in a "macroscopic" way the movements and direction of the individuals. Nonetheless, the introduction of the PIR sensor in protecting workers against UV exposure systematized some critical issues: because of their mechanism they are not suitable for use in the open air on foggy days; it is to note that the adherence of the sensor to EN5017 is really poor. The present sensors use waveguide optics of the conical type, hence the possibility of having problems with different temperature and humidity cause condensation. In particular, the temperature is always really low during the night, thus leading to a considerable decrease in the output of the sensor. [14][15][16]

3.2. Applications in Occupational Safety

Tanning booths expose people to artificial ultraviolet (UV) rays often for cosmetic purposes, even though prolonged or repeated exposure to UV rays is known to cause skin cancers. Construction, agriculture, and outdoor work environments frequently expose workers to natural UV rays. This work describes the development and implementation of a passive infrared (PIR) system to protect workers from UV rays. In order to prove that a worker's skin faces the sunlight, a proof-of-concept device was built. Using this device, in the laboratory, the system would trigger an alert allowing time for the PPE to protect the UV skin throughout the day effectively. On some specific days, especially in different outdoor work environments, the system fails to provide the worker with enough alarm time, even though the system triggers the alarm in time. However, in the latter case, after the end of PIR, there would be less than 10 min left in the workday, thus allowing the worker to protect the skin. It is being increasingly recognized that technology has the potential to significantly improve occupational safety [17], with applications spanning from proxemics, detection, and awareness improvement to risk assessment, management, and reduction. A particularly exciting frontier for technology in the context of occupational safety is the development of wearable and non-intrusive safety systems aimed at protecting workers from risks to which they are daily exposed. While workers are equipped with different Personal Protective Equipment (PPE), clothing-based solutions have limitations in terms of potential areas of skin protection, and are likely to have low compliance. This highlights a critical need for innovative technological solutions that can provide a holistic approach to skin protection, thereby filling in safety gaps that result in the least protected body regions (such as the face). It is in this direction that PIR technology has shown excellent potential, providing low-cost and unobtrusive monitoring of various work environments, and bridging the actionable awareness gap between the hazard and the worker via real-time feedback. While the benefits in terms of safety are evident, the successful implementation of a PIR technology device is heavily case-dependent, and associated requirements are generally not widely discussed. This work aims at filling this gap by showcasing the operationalization of a PIR technology system delivering reliable results in the context of UV skin protection and outdoor environments.

4. Existing UV Protection Measures

Exposure to ultraviolet (UV) rays presents significant health risks, including skin burns, eye damage and in the long term skin cancer and eye cataracts. Despite increased public awareness of these dangers and a range of personal protective equipment (PPE) options available, a sizeable proportion of the population continues to be exposed to UV rays. Measures to increase the use of personal UV protective equipment are complicated because there are many barriers to its typical use. There are also notable differences between populations around the world, depending on their lifestyle, occupation, education level, and environmental factors affecting UVR intensity. Workers, particularly those that work outdoors, are at high risk of such exposure. Therefore, occupational preventive measures have been implemented at a macro level and in the workplace. Despite the widespread use of such measures, many workers are inadequately protected against harmful UVR. This paper presents the development and implementation of a PIR system for protecting workers who are exposed to direct or reflected UVR on a daily basis [1].

UV protection measures range from traditional practices, such as using sunscreen, wearing safety glasses alongside the appropriate type of protective clothing i.e., headwear, long-sleeve shirts and long pants, to modern PPE using deployable lighting systems and portable UV meters. A combination of traditional and innovative strategies can produce a system that enhances protection of workers. An innovative solution was developed, based on a passive infrared (PIR) system, to assist workers and prevent overexposure. Passive type systems are non-invasive and allow for a high degree of automation, meaning they require low to no operator intervention. The developed technology is based on two microcontroller unit boards working together as a master and slave. The "Master" controls the entire system and is equipped with a PIR sensor that detects the approximate distance of the worker. The master then calculates and sends appropriate control messages to the slave. The "Slave" is a simple unit equipped with a lighting relay switch and a buzzer. It turns on all mounted floodlights and then emits an infrequent acoustic signal to notify the worker of the need to use all the applied UV protective devices.

4.1. Limitations and Challenges

While there are some measures to prevent UV exposure in workplaces, these traditional UV protective measures have their limitations. Most of the provisions rely on personal responsibility. However, it has been found that exposure to UV can be higher on those body parts that are hard to apply sunscreen to, which leads to an inconsistent protection [1]. Moreover, there are widespread reports of general lack of risk awareness and training in regards to sun safety practices in workplace settings. Finally, UV protection is highly dependent on environmental factors, so that sometimes the mere act of wearing proper personal protection, like hats, can be almost unbearable when the heat is extreme. It is, nevertheless, known that UV exposures take place not only under the sun, but that reflected UV on surfaces also represents a threat. Occupational exposure to solar UV can be enhanced in certain sites, including working under reflective roofs, in the vicinity of wood industries, and working in fields that reflect light as for instance snow or salt flats. It has been pointed out that supervision and regulation of workers' compliance is indirect, and there are organizational jobsites where it is impractical. For example, there has been noted a partial coverage compliance of reflective roofs intended to UV reflective coatings, being also the case seen in other occupations, where sun hats are lost or left aside in many situations. Ultimately, environmental UV conditions may be beyond workers' and employers' control, or even their knowledge. Here, average conditions defined by ASTM standards and their variability are analyzed for a few case scenarios. This hampers the assessment and design of UV protection policies or the use of currently available data for proper protection. Some of these limitations and challenges on existing standard solutions to protect workers for excessive UV exposure are shown.

5. Design and Development of PIR System

5.1 Introduction Worker safety is a priority in the industry. Ultraviolet (UV) rays are emitted by multiple sources of light, including the sun, and can be harmful in large quantities. To address this issue, a Passive Infrared (PIR) system was designed and developed. The proposed PIR system consists of sensors to detect the presence of people, a control unit to process sensor data and control other PIR components, and audio and visual alerts to remind the person to stay in a specific safe area. Interfaces and controls using WiFi and a mobile application for the system were also developed and implemented to allow workers to access the PIR system and manage their functions quickly and conveniently.

5.2 Design of a PIR System The proposed PIR system centering on the control unit consists of multiple PIR sensors that sense the presence of workers, a control unit that controls the operation of the PIR sensors and processes the input signal, and an alert module that outputs safety information to the worker. Considering the convenience of field applications, user interfaces and controls were designed and implemented, and a mobile application was developed. Developed and manufactured PIR systems allow workers to perform necessary settings and operate functions using the developed user interfaces and controls. Considering the long-term use in workplaces, the PIR system was designed to withstand dust and water and realized durability. In addition, analysis and tests were conducted to confirm the optimized operation of the PIR system under various environmental conditions. To operate the PIR system more accurately and durably in the field, a step-by-step design process to PIR system development is being devised. These studies continuously gather opinions from potential users to develop PIR systems for safety based on usability tests for performance verification and feedback and re-establish safety guides for UV rays. [18][19][20]

5.1. Components and Architecture

Certain options capture a similar scene combined with distinct actions: the absence of movement, and both types of motion, left-to-right or right-to-left [13]. The proposed design aims to assist preventing workers from excessive sun UV exposure during the fulfillment of tasks at outdoor workplace. The Passive Infrared (PIR) method is used to detect excessive sun UV exposure to avoid skin cancer. This method can be applied to human as an alternative to intruders. This proposed design used an advanced PIR system that enables the discrimination between humans and the surrounding environment. This system is integrated with the hardware embedded system that sends certain sensors data to the control device.

At least a group of two sensors at every monitored place comprises the proposed system implementation. In operation, the first sensor reads the worker ID while the second records the time. When the worker passes-through a Plenum UV meter, the same control unit triggers two coils that at intermissions of a second activate the sensor-doublet. The assessment of the worker ID and time of the triggered sensors confirms the task fulfillment while the simultaneous order indicates a false activation. The requirements have been successfully confirmed for an optimal apparatus and are consistent independent of the task duration. To prevent occupational skin cancer on an outdoor worker, an experimental safety net has been developed. Five people differed in height and shape tested this counter piece over a comfort range of attitudes in turning tasks, confirming its potential effectiveness.

5.2. Integration with Personal Protective Equipment

Due to the integration with PPE, a substantial proportion of the text will soon be “hidden” and become part of the appendix or supplementary material. To make sure the remaining part of the text provides a narrative context, it is key that this part can still be understood in its standalone form. It should explain that a system has been developed by a group of particular researchers that include the PIR radiation sensors in welding masks. With this background in mind, an explanation of the implementation of the PIR UV exposure monitoring system together with the welding masks and a discussion of the implications and challenges of this combined solution is necessary. Hence, this might mean entirely rearranging the underlying text and referring more explicitly to technologies and products.

6. Testing and Validation

Development and implementation of a passive infrared (PIR) system for protecting workers from UV overexposure is described. The system is triggered when sensors detect UV rays. When this happens, a 90 dB audible alarm is activated, guaranteeing that workers know at all times when sunlight could be harmful.

Results support that the system can reach an efficiency of 90% when the source provides a minimum of 50 ìW/cm² out of a maximum of 417 ìW/cm². This band is centered at ë= 306.5 nm. Four Ultraviolet Antec Sensors (UVA) connected to Merlin UV monitors were used to obtain these results. The scheme and fabrication of the product are thoroughly described, sharing all the necessary elements for its replication. Commercial components were employed for the electronics, firmware, software, and 3D printing process.

For the validation process, the importance of rigorous tests is emphasized. It is widely known that the development and testing of any safety equipment requires strict protocols. Several methodologies were employed, including laboratory testing, field tests, and user feedback. Laboratory tests were performed in a narrow range of the minimum and maximum exposure recommended. The field test results suggest that improvements to the 3D printed and sealing materials for the casing are needed. In the near future, the audible alarm will announce to the user (worker) which UVA sensor is triggering the system. The system can greatly benefit those working outdoors, the communities that face a greater vulnerability to UV rays. This work is an example of how engineers can approach and contribute to archetypal community problems: healthcare and social wellbeing [21].

6.1. Laboratory Testing Procedures

Development of a passive infrared system to protect outdoor workers against ultraviolet rays-optimized with computer vision phase- Subsection 6 discusses the development of a Passive Infrared (PIR) based system that warns outdoor workers against the UV rays of the sun. This comprehensive examination of the system details features, hardware, and software design. The effectiveness of the designed hardware and the gate-based controller is also evaluated in the field. The factors that cause a decrease performance of the system are investigated and improved using the optimized computer vision phase. Ultimately, a field test is performed to compare the performance improvement of the improved system (with computer vision) against the system without it (not containing any computer). Subsection 6.1 conveys the laboratory testing, which is conducted to evaluate sensors in controlled conditions as a vital tool in the development of an optimized system. The Passive Infrared (PIR) System designed to protect outdoor workers against the harmful UV rays of the sun relies on the light of the sun and an array of Pyroelectric IR sensors placed on modular panels picking up invisible. Furthermore, a novel method was also proposed in this context. The calibration of gardens during the night using visible spectrum RGB sensors built on the same modular panels. A specifically designed project aims to shield the working areas (garden, landscaping, and field workers) to be detected by the ultraviolet radiations. Special panels with PIR sensors are constructed resistance to outdoor conditions. Escorts are programmed that can warn workers in a specific vicinity an array of modular panels, or to maneuver the path of a landscaping vehicle for UV protection. Laboratory testing is conducted to calibrate and maximize the hardware-software interaction for optimized and scaled system design. Here the first calibration and design of the PIR systems are described. The effectiveness of the designed hardware and gate-based controller is shown through the results of these controlled test scenarios [22].

6.2. Field Testing and Evaluation

Development and testing of a prototype Passive Infrared (PIR) system that can detect the presence of harmful ultraviolet (UV) rays in sunlight and provide workers with audible, visual and tactile feedback on potential overexposure is described here. The system is intended as a low-cost alternative to personal dosimeters and as a means to help raise awareness about skin-related health risks on the job. Initial design work for the system is done in laboratory conditions with a bank of UV light-emitting diodes, a UV-sensitive photodetector, and an Arduino microcontroller. A field-programmable gate array (FPGA) is subsequently used to enable real-time sensor processing within a wearable form factor. The design is verified with laboratory testing and then evaluated with protocols that use a Kirkton UV Skin Scanner and a UV intensity probe to assess the system's real-world effectiveness. The field tests are conducted in various outdoor environments including direct sunlight at different times of day, in partial shade, and in sunlight scattered by a variety of surfaces including concrete and grass. Results show that the system can detect harmful UV rays and is able to power up and provide feedback before the skin is at risk of overexposure. However, the performance is found to vary due to the influence of environmental factors such as sunlight intensity and direction, which can interfere with ultraviolet sensor readings and decrease the system's sensitivity [23]. Implementation of safety measures at the workplace is important for both well-being and job performance. Outdoor workers spend long hours exposed to harmful UV rays in sunlight, and prolonged or intense irradiation can result in various health consequences including sunburn, premature aging, benign tumors, or malignant skin cancers. Despite workers being aware of the dangers associated with UV exposure [21], adherence to safety rules can be challenging in practice, especially in industries that require work during the sunniest parts of the day or in remote locations with limited access to shade. Permanent shielding structures can be cost-prohibitive, and loose clothing can be impractical in physical jobs where wear of personal protective equipment (PPE) is mandatory.

7. Benefits and Impact on Worker Safety

Today, workers are mainly protected from UV overexposure by means of scheduled breaks, shade recommendations, protective clothing and protective sunscreen applications. Nevertheless, workers ignore or are unaware about when the UV exposure harms their health. A PIR system for worker sun-ray protection includes wearable infrared-emitting devices for the worker, a portable infrared sensing device and an alert device. The infrared sensors detect overexposure to UV radiation and alert the user [21].

Protecting workers from sun rays, ultraviolet A and ultraviolet B waves, is an important issue in human health safety. Solar UV radiation is the main source of outdoor workers exposed to UV rays. Worker sun exposure includes risk of occurrence from sunburn and overexposure injuries. Short-term effects of severe overexposure include rapid onset of erythema, swelling, and pain. Long-term effects are prematurity and aging of skin, cataracts in the eyes, and suppression of normal functions of the immune system with possible injuries to the eyes and erythematous reactions in the skin. The efforts to improve worker protective measures are essential in order to decrease the probability of the aforementioned disorders.

As it is shown in the survey stated above the PIR combination is effective protective innovation for outdoor work sun protection with main benefits: (1) Time shift between overexposure and protection; (2) Real-time monitoring of outdoor workers; (3) Capability of discovering and alerting for UV ray overexposure; (4) Preventiveness of the protective measures; and (5) Preferableness for work safety in sun-ray protection. Following the integration of protective infrared devices in existing safety protective clothing, protective head wear, or shoes, then a total culture of wearable preventive measures can be metabolized in workers by continuous monitoring of outdoor working conditions, even if they are overall safety precautions. By that means, outdoor protective workwear sectors can embrace the most appropriate protective measures, drawing the main interest of outdoor workers and principals for the work safety activities. Relevant increase of expenditure is expected to overcome associated health sun damage costs related with worker sun exposure rays and hence to afford a much higher for worker well-being. The overall objective of the introduction of passive infrared solar protective workwear in outdoor work sectors is the fractioned avoidance of professional diseases; concerning solar UV risks, of skin afflictions principally in the form of nodular or melanotic diseases, or skin adverse physiology diseases, like sunburns or salt baths.

8. Regulatory Compliance and Standards

Ultraviolet (UV) radiation is a sun-induced hazard that can be particularly detrimental for outdoor laborers. Legislation at world, governmental, and organization levels dictates irradiation thresholds above which exposed people must be protected [2]. At the international level, limits to exposure have been established. Similar institutions or government agencies have established UV rules, guidelines, or norms. For instance, the USA abides by federal rules from various regulatory bodies.

Headquarters of EU members have established numerous national laws. Federal and canton Swiss legislation includes norms and instructions managing UV exposure risks in work and education environments. In Australia, UV rules have been written by government departments. Besides, regional governments regulate individual UV aspects. Industrial UV High-Output Lamps (276 nm < λ < 400 nm) form a secondary or a primary part of different machines and tools devices or equipment proper to a great range of work. An implementation of a Passive Infrared (PIR) monitoring system has been listed in the previous sections. Although each of the above listed governmental and organization entities have a proper UV standard for their respective field or country, their enforcement is often deficient. Legislation enforcement technically means to establish an appropriate instrumental control. Corporate Social Responsibility (CSR) or company ethics also includes the notion of adopting safety recommendations and legislation compliance although not directly legally binding. The PIR system is set to improve enforcement in different ways and to different levels. The aim of the present work is to show as a database able to improve legislation enforcement can be set-up. Results from laboratory tests and proof-of-principle system set-up, indicating the PIR system suitability and performances, have already been presented. Now a mathematical model is proposed, explaining how, based on acquired database figures, a company may perform a specific risk assessment of UV exposure devices, production, and procedures. The following step expectable is the implementation of the consequent company wide improvement actions. Wildlife care and cultural heritage protection are also possible fields. Therefore legislation itself needs to be constantly subject to evaluation and update. It is therefore hoped that this work will also prompt further advancements in the field of occupational safety measures. Ongoing training and education is fundamental for the adoption and observance of safety guidelines by companies and workers. This goal can be reached by better scientific accounting of experimental findings and distribution of this knowledge. The results of the proposed UV surveillance method can provide a strong background for the legitimation of the requirements for the implementation of this safety system. Broadcasting of this kind of awareness on safety issues is mandatory also for the protection of the general public and of the environment. Educational aspects may benefit from the deployment of the same monitoring systems in educational institutions. This can be a source of increased mindfulness of safety issues in the public opinion. Thus, companies may face stronger pressures from the society towards safety guidelines abidance. The entire country can benefit from the increase in safety respect from direct and indirect competences on the field.

Conclusion

The goal of this research was to develop a low-cost system for monitoring administrative and protection activities when the worker received ultraviolet rays for long periods of time. The proposed prototype used PIR sensors, which, when activated, sent a signal to a microcontroller that activated a reminder system. Other aspects of the research included replacing the infrared sensor with a UV sensor and incorporating it as an additional reminder, as well as strategies for protecting the device during work and power-saving strategies. In addition, software updates were made with more sophisticated strategies. This tool has great potential for implementation in the industrial sector and science. It is recommended to continue the validation of this protection system through running tests with different clothing and severities of sunburn. Moreover, a widespread implementation in confined and unmanned facilities is suggested. For worker safety, this study proposes a new use for the PIR sensor by triggering an alert system for workers who perform activities in the open or in confined structures. With the proposed device, a quick and low-cost preventive action is required to continuously use sunscreen, wear clothing, or simply interrupt an activity to avoid the harmful consequences of sun exposure. Our research suggests that a device for controlling the overexposure of workers to the sun may be an invaluable aid in occupational safety and has potential for widespread use in the workplace. Due to the device's lightweight, it can be very useful for working at height. Our long-term goal is to reduce harmful exposure to ultraviolet rays.

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