Automated Control on wearing Personal Protective Equipment

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Abstract

The cost of world-wide accidents represent approximately 4% of global Gross Domestic Product each year, which could be minimized or prevented by using adequate Personal Protective Equipment (PPE). Although wearing adequate PPE are mandatory in a number of occupations where workers are exposed to risks, experience show that supervision is necessary to ensuring it. The traditional supervision was proved not to be effective enough, making it necessary to turn on technological solutions. The objective of this work was to investigate if Radio Frequency Identification (RFID) technology is a feasible solution for monitoring the usage of PPE on construction sites, giving suggestions which tags to use and characteristics of RFID portals for field applications. The results of laboratory tests show that four antennas with correct disposition on the RFID portal are enough to ensure readability of the worker when passing through it. While six passive tags were tested, two of them were found to be ideal for this purpose: the Web Lite Wet Inlay with a rubber wrap due to its protective characteristics, and the SmartTrac Dog Bone due to its size. In conclusion, the RFID technology was found to be a feasible solution for automatically control the wearing of PPE on construction sites. There is a need for further research on construction sites.

Keywords*:* Applied Technology; Radio Frequency Identification (RFID), Occupational Safety and Health; Safety on Construction Sites.

Resumo

O custo dos acidentes de trabalho em todo o mundo representa aproximadamente 4% do Produto Interno Bruto (PIB) global a cada ano, o que pode ser minimizado ou evitado pelo uso dos Equipamentos de Proteção Individuas (EPI) adequados a atividade desenvolvida. Embora a utilização dos EPI's adequados seja obrigatória nas profissões em que os trabalhadores estão expostos a riscos, a experiência mostra que a supervisão é necessária para que o uso adequado seja garantido. A supervisão tradicional demonstrou não ser suficientemente eficaz, tornando necessário o desenvolvimento de soluções tecnológicas. O objetivo deste trabalho foi investigar se a tecnologia de Identificação por Radiofrequência (RFID) é uma solução viável para monitorar o uso de EPIs em canteiros de obras, dando sugestões de quais tags utilizar e das características

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dos portais de RFID para aplicações em campo. Os resultados dos testes de laboratório mostram que quatro antenas com disposição correta no portal RFID são suficientes para garantir a legibilidade do trabalhador ao passar por ele. Enquanto seis tags passivas foram testadas, duas foram consideradas ideais para esse fim: o Web Lite Wet Inlay com um envoltório de borracha devido às suas características de proteção, e o SmartTrac Dog Bone devido ao tamanho de sua antena. Em conclusão, a tecnologia RFID foi considerada uma solução viável para controlar automaticamente o uso de EPI nos canteiros de obras. Contudo, há necessidade de mais pesquisas nos canteiros de obras.

Keywords: Applied Technology; Radio Frequency Identification (RFID), Occupational Safety and Health; Safety on Construction Sites.

1 Introduction

Occupational accidents result in more than 2.78 million deaths and 374 million non-fatal work-related injuries and illnesses each year. According to the estimation from the International Labour Organization (ILO) **[1]**, the yearly economic cost correspond to approximately 4% of global Gross Domestic Product each year. The construction industry is the most influential industry worldwide, representing 21-31% of the workers fatalities **[2], [3]**. In this cases, Personal Protective Equipment (PPE) is the last line of defence to protect the workers from harm in potential hazardous work situations **[4]**.

The ILO described working activities of the most common worldwide occupations. This is commonly used as a base in creation of risk assessments, finally giving mandatory PPE during each construction phase for all working occupations.

Although it may seem that providing adequate PPE would resolve the problem, experience shows that many workers refuse to wear it. This could be attributed to the discomfort which workers feel while wearing the PPE and to underestimating the risk to which they are exposed. A study conducted on scaffolders found that workers failed to anchor their harness not due to poor safety attitude, but to subjective norms **[5]**. This means that safety level on wearing and using PPE is achieved primarily through supervision and therefore perceived social pressure. However, in practice, traditional supervision conducted by safety and health professionals seems not to be effective enough.

On the other hand, technology proved to be a solution for many of those effectiveness-based challenges, being able to conduct a work faster and more accurate.

One of often used technologies is the Radio Frequency Identification (RFID), which is using radio waves to identify people or objects, reading information contained in a wireless device or "tag" from distance without making any physical contact. Today, the RFID technology can be found in car keys, employee identification, medical history/billing, highway tool tags and security access cards **[6]**.

The RFID technology was found as a possible option for preventing accidents through detecting near-miss accidents on construction sites. The system was suggested for managing the access control, environmental condition (including lighting, vibration, noise) and real-time location of both the workers and equipment/vehicles **[7]** as well as supervising workers unsafe actions **[8]**.

Nevertheless, although the number of worldwide accidents is increasing, traditional supervision on wearing PPE has proved to be ineffective, and while there is technology available for introducing automatic supervision, there is still need to develop an effective and low cost solution for this purpose.

The objective of this work was to investigate if it is a feasible solution to apply RFID technology for monitoring on the usage of PPE on construction sites. Further on, through investigation on interference and readability, give suggestions on types of RFID tags and characteristics of RFID portals.

2 Methodology

The research laboratory tests were conducted in the Occupational Health and Hygiene Laboratory (LSHT) of the Polytechnic School of Pernambuco (POLI-UPE).

Implementing a geo-location system using both active and passive RFID technology was found to be impractical due to high costs of investments in infrastructure, tags, antennas and readers. Therefore, a more feasible solution was adopted, creating RFID portals which could be implemented in different zones of the construction site. Although it wouldn't be possible to continuously monitor the usage of PPE, it would allow to automatically-monitor employees whenever they enter or exit one or more controlled areas. This solution would inform the worker is allowed to enter the specified controlled area; if not, illustrating to the worker which additional parameters he should fulfill in order to be suitably prepared for entering.

Therefore, tests included the creation of a RFID portal-prototype and the evaluation of RFID tags assignment, which was analyzed through screening the volunteer who was passing through the portal by wearing tagged PPE.

2.1 RFID tags and assignment

The selection of an adequate RFID tag was determined by the market price, operation frequency and reading distance. Passive tags were chosen for laboratory tests due to the best market price, with reading distance from 5 to 10 meters, and low memory storage, which was not a limitation for the purpose of this study.

In order to minimize possible interference and ensure proper identification of tags, six types of passive tags were chosen for laboratory testing. One at a time, all six tags were placed on each of the selected PPE. The tags were illustrated in the figure 1.

This study considered the following 9 PPE: safety helmet; boots (safety, rubber, and for electric risk); gloves (welding, rubber, pigmented, and for electric risk); protective glasses; welding face-shield; reflective safety vest; earmuffs; face shield; fall protective belt.

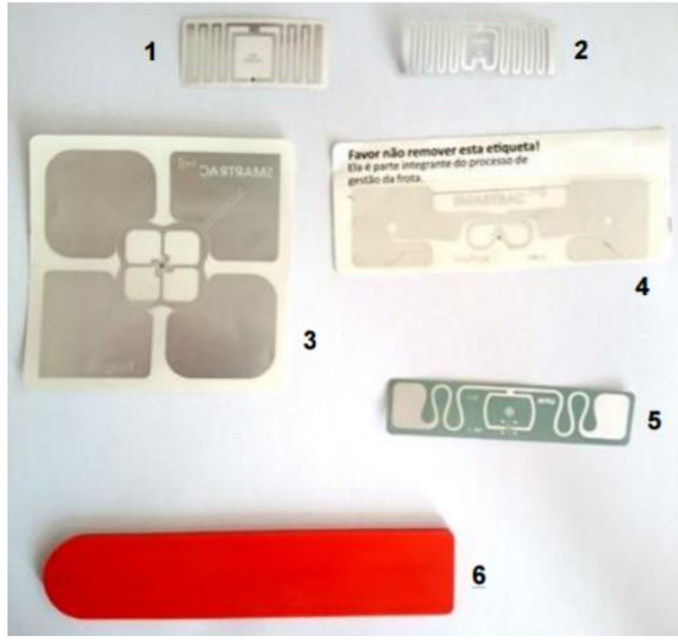

Figure 1: Types of tags considered for laboratory tests: 1. Tag Laxcen E40; 2. Tag Smartrac Web Lite Wet Inlay; 3. Tag Smartrac Frog 3D; 4. Tag Smartrac Dog Bone; 5. Etiqueta UPM Belt 292_2; and 6. Tag AlphaRed (Smartrac Web Lite Wet Inlay with a rubber wrap).
Source: The authors.

2.2 RFID portal prototype

The worldwide most commonly used walk-through portals are those in function as metal detectors, present at airports, with dimensions from 72x205 cm to 82x205 cm **[9]**.

For the purpose of this study it was decided to build a PVC frame with more comfortable passing dimensions of 100x210 cm, which is illustrated in figure 2. This would make easier for workers to pass through it, as sometimes they might be passing with different equipment or materials.

Four RFID antennas (RFID 1-4) were taped on different parts of the portal in order to screen all parts of the body where the EPI was installed.

The selection of an adequate RFID reader was determined by the frequency, reading distance, functioning and application. It was decided to use ultra-high frequency (UHF) readers, which were used in another similar previously conducted study **[10].** In addition, due to the reading distance was found to be suitable for the purpose of this study. The portal consisted of Nesslab RFID reader NL-RF1000 (working with UHF frequency between 902.75 MHz and 927.25

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MHz) and antennas Nesslab model ANT-1200CP of 12.0 dBi, with a beam width of 65°.

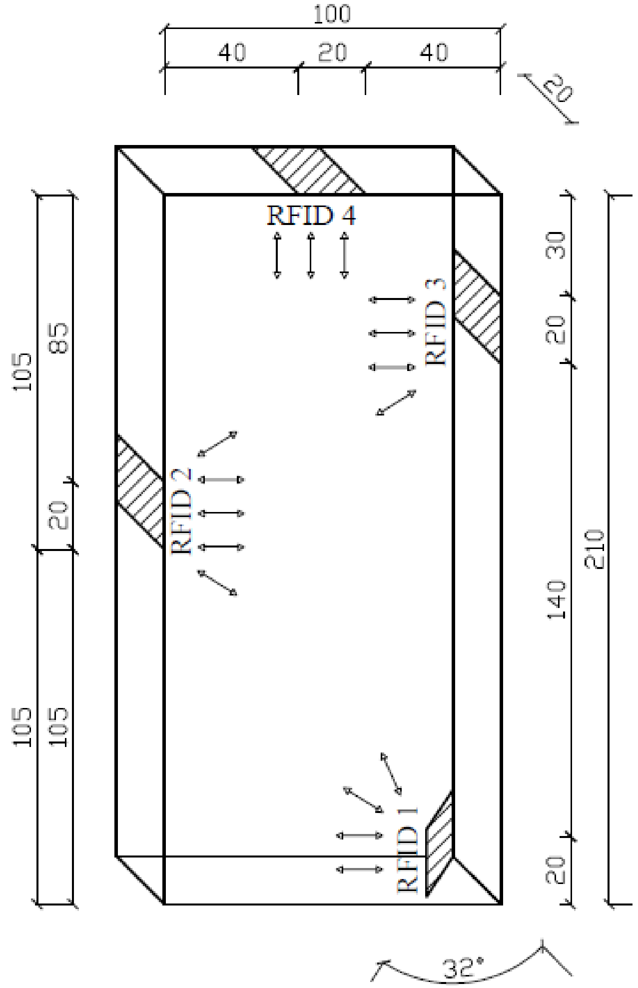

Figure 2: Illustration of the RFID Portal dimensions (in centimetres).
Source: The authors.

2.3 Data analysis

The references were searched through the databases by using the institutional IP address of the University of Pernambuco federate credentials. References were managed using the Mendeley 1.15.3. Statistical analyses were done by using excel statistical toolbox. The signal quality was ranging in a scale of 0 to 100%, where 0 was the lowest strength and 100 highest signal quality.

3 Results

The face-shield with the tag location is illustrated in the figure 3.

Figure 3: Face shield with the tag.
Source: The authors.

Laboratory tests with the volunteer wearing different personal protective equipment while passing through a RFID portal prototype were illustrated in figures 4 and 5.

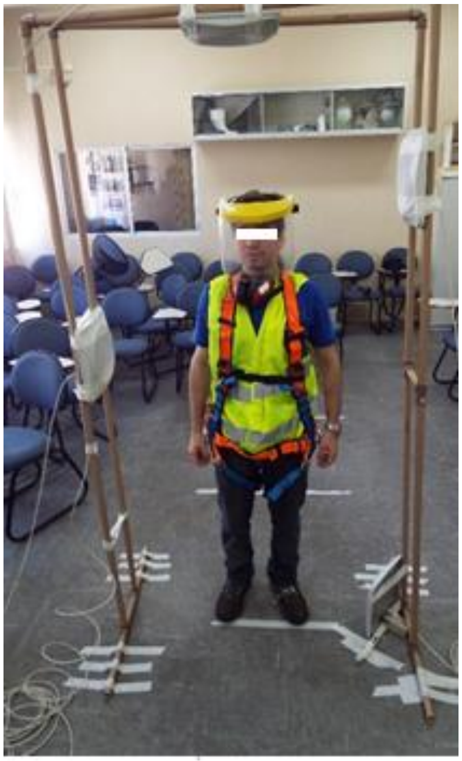

Figure 4: Preliminary laboratory test 1.
Source: The authors.

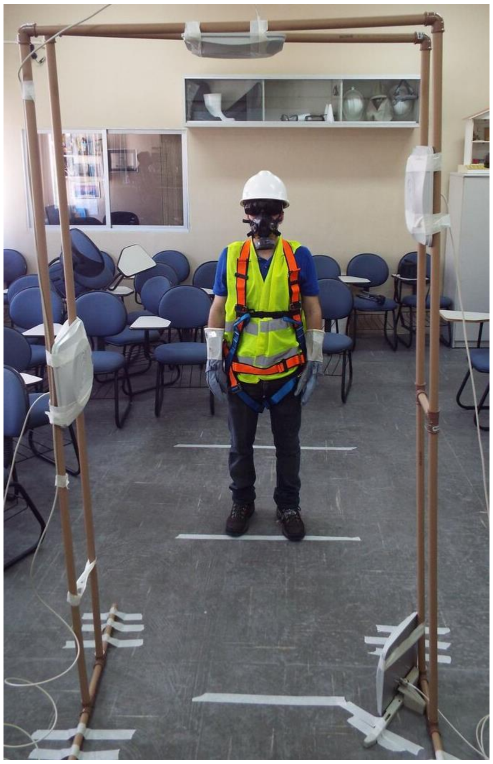

Figure 5: Preliminary laboratory test 2.
Source: The authors.

Applied PPE with results from tags with highest signal qualities were illustrated in table 1.

Table 1: Qualitative data readings from tags installed in PPE.

Number	PPE	Tags (type)	Signal Quality
01.	Helmet	SmartTrack Frog 3D	67
02.	Earmuffs	UPM BELT 292_2	59
03.	Safety boots	Web Lite Wet Inlay with a rubber wrap	59
04.	Welding face shield	SmartTrack Frog 3D	58
05.	Face shield	UPM BELT 292_2	58
06.	Welding gloves	SmartTrac Dog Bone / AlphaRed (Web Lite Wet Inlay with a rubber wrap)	54 / 50
07.	Protective glasses	UPM BELT 292_2	50
08.	Reflective safety vest	Web Lite Wet Inlay	47
09.	Fall protective belt	SmartTrac Dog Bone	46

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4. Discussion

Two tags (Web Lite Wet Inlay with or without rubber wrap and Smartrac Dog Bone) were identified in 100% of passing's through the portal, and should be therefore considered for using them in field studies. The Web Lite Wet Inlay with a rubber wrap tag is well protected with a silicone wrap, and therefore should be selected for the equipment that is exposed to the influence of different weather conditions. On the other hand, the SmartTrac Dog Bone has a compact size, and should be used for all other equipment. The tag Laxcen E40 was not identified during laboratory tests. This means that quality of the signal is too weak and should not be used for this purpose.

One study found that performance of UHF tags and readers might be reduced by a number of signal interferences, such as noise from machines, older Wi-Fi systems and devices operating at 916 MHz, by signal bouncing off metal shelving, rebar in concrete floors or diamond plates, and liquid (for example human body fluids) **[11]**. These interferences should be taken in consideration and solved prior to constructing a RFID portal as interferences in the communication could difficult readings from passive UHF tags. For example noise from machines can be resolved by adding some shielding, such as a sheet of Mylar, around the machine to block the interference. The Wi-Fi system could be upgraded or by isolating the interrogators from other signals in the environment. The metal shelving challenge could be often resolved by repositioning the antennas **[11]**.

The results from this study show that readers were more effective in identifying passive tags with larger antenna areas compared with those with smaller. This fact was potentiated when tags were installed inside gloves and glasses, vests and protective belt. There the signal quality was lowest, which could be explained to the interference in UHF readings when the tag is close to the human body (liquid). Highest signal quality was found in equipment which was put on greater distance from the human body (like helmet, earmuffs, boots and shields).

Further on, it is fundamental to properly fix tags to PPE. The VHB-type of adhesive and firm acrylic foam tape proved to be efficient for fixing tags on safety helmets, protective glasses, earmuffs, welding face-shields and face shields. However, for other types of PPE, such as clothing, boots, gloves, reflective safety vests, fall protective belts and other fabric equipment, it should be attached in other ways, such as by stitching it to the equipment. Hereby, it is important to notice that stitching on PPE should always be done in consultation with the manufacturer of the PPE, as adding, removing or changing parts might affect the performance of PPE. For example, sticking a tag on a firefighting suit using normal sewing cotton may reduce the protective-performance against fire. Therefore, further studies are needed in order to encounter the most feasible way to attach tags. Taking in consideration the hostile environment of construction sites, tags should be protected against physical damage, either by silicone wrapping, or by other flexible material through which could pass UHF's **[10]**.

Laboratory tests contributed by giving dimensions for building a RFID portal for using in construction sites (illustrated in figure 2). Four antennas with distribution as illustrated in figure 2 ensured readability of all equipment when the worker was passing through it. This is in accordance with a previous similar study **[10]**, which used four antennas although differently distributed (one screening legs and one screening trump, distributed on both lateral sides of the portal). The hostile environment of construction sites demand to additionally cover the basic portal structure (illustrated in figure 3) with wood and plywood coated in formica. This should protect the vital parts of the RFID portal from the influence of weather conditions, from hitting, cutting and tearing, improving the resistance of the structure and its durability.

Additionally, the RFID portal could be improved by installing a monitor as an essential part of the structure. This would benefit through immediate interaction with the worker, giving him warnings in real time. The portals on construction sites could be managed in two essential ways: through a network infrastructure or managed by independent computers installed in each portal present at the construction site.

An optimal solution would be to divide construction sites on areas according to risks to which workers are exposed-to in each one of the areas. It is important to consider that construction sites have different phases with a dynamic working environment, therefore with continuous changing of risks present in each one of the areas. The application of RFID portals would make easier and more effective updating information on risks and working requirements for each area and reassuring that the information gets to all of the workers.

Therefore, RFID portals should be provided on all passages when moving between areas. This would make the supervision on workers much more effective, assuring that workers are always properly equipped and with valid PPE.

Additionally, as all working activities require using of a working suit, it represents ideal equipment for placing an individual tag. This tag could access the information recorded inside the company database, giving information on medical and training attestations for each one of the workers. This would benefit to an even more effective supervision of workers, assuring proper PPE, medical and training attestations for all of the workers for working in different areas and being exposed to different risk-types. Including with monitoring the validity of each one of screened parameters, the system could remind the worker and safety professionals to re-validate the medical and training attestations, or to change the PPE.

It is necessary to use knowledge and experience gathered from this study in order to further the research on construction sites. Future studies should investigate if the RFID technology is a feasible solution in real working conditions, during different working phases, workers and when using different PPE. Further on, it is necessary to develop specific software for this purpose. Finally, the application of RFID technology as a tool for monitoring the usage of PPE on construction sites could be implemented in combination with other technological solutions, for example a dynamic construction safety risk management model **[12]** or accident occurrence prediction model **[13]**.

5 Conclusions

The RFID technology seems to be a feasible solution to automatically control the wearing of PPE on construction sites. Nevertheless, there is need to conduct further field research on a number of workers, construction sites, and further investigate on best ways to secure the RFID portal from different weather conditions, but taking in consideration not to reduce the readability of the RFID antennas inside the portal. Further on, there is a need to further investigate the ways to effectively attach tags on PPE's without affecting PPE's quality. Finally, this technological solution might be implemented with other systems in order to offer a complete solution from recognition to solving of occupational safety and health issues.

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