PPEs Compliance Technology to Legalize the Automated Monitoring of Safety Standards

F. (Firas) Habbal[a], F. (Fawaz) Habbal[a], A. Al Nuaimi[b], A. Al Shimmari[b], A. Safi[b], and T. AbuShqair[b]

[a]College of Business Administration, American University in the Emirates, UAE
[b]Ministry of Infrastructure Development, UAE
E-mail: Firas.Habbal@aue.ae, Fawaz.habbal@aue.ae, Abdullah.alnuaimi@moid.gov.ae, Anwaar.Alshimmari@moid.gov.ae, Ammar.safi@moid.gov.ae, Tala.AbuShuqair@moid.gov.ae

Abstract –

Governments are always looking to monitor safety violations on construction sites. Those violations are not only causing numerous injuries and deaths to workers but also delays and subsequently costs to the project developers. In the hierarchy of control, personal protective equipment (PPE), albeit the least effective, is still one of the most visible and therefore fundamental controls to protect workers from workplace hazards. While PPE should be monitored at all times by the related authorities and project organizations, adequately trained staff and availability to monitor projects often fails short. Therefore, monitoring the right use of PPE electronically has yet to become a recommended practice for safety and health programs. This paper examines the application of legalizing smart hard hat to monitor the use of PPE among construction site workers. Using automated cameras and detection technology the PPE will be detected and analyzed. The proposed approach then automatically identifies violators and safety alerts will be issued correspondingly. The developed technology has been tested on real sites. Results from these tests were used for legalizing this technology for everyday construction application in the UAE.

Keywords –

smart hart hard hat; automation in construction; construction safety; site surveillance technology, legalization, personal protective equipment, worker rights

1 Introduction

Infrastructure development is one of the most important industry to any government and to secure this industry is a major concern for all official department, due to harsh working environment and huge amount of workers, governments are striving to maintain level of safety in any site and enforce the use or personal protective equipment among all labors, however, those personals fail to comply to those rules which lead to catastrophic incidents. According to global statistical data the rate of injuries and death in construction is almost three times higher in construction comparing to other industries [1]. This paper proposes a new method of legalizing smart hat and responds to a frequent question Why government are still using manual inspections to record PPE violations? This question reflects the vision of Ministry of Infrastructure Development in UAE and encourage using innovative technologies to reduce number of injuries and deaths caused by careless site foremen and un educated labors. The proposed technologies can fundamentally redefine government responsibilities with social responsibilities. It will also improve the usage of PPE which has not been really developed since the eighties. The construction industry has reported the highest number of casualties among different industries [2]. Many scholars and governmental reports around the world studied the fatal injuries caused by poor attention to personal safety equipment among workers [3][4]. Therefore to minimize such injuries and causalities in construction sites one of the most important strategic goal of MOID [5]. As a result monitoring workers safety has been a top priority for all governmental sectors in the world and became an important pillar to evaluate the construction sites and companies, nevertheless using technology in this matter has become an urge for its accuracy and fast respond. It is with those information enforcing smart hard hats will lead to monitor safety measures everywhere by creating live on time feed to the concern departments and control workers biometrics and to prevent potential violation. The liberty mutual Safety Index (2018) stated that top 10 causes of injuries in workplaces and those injuries amounted of almost $60 billion dollars [6] (Figure 1)

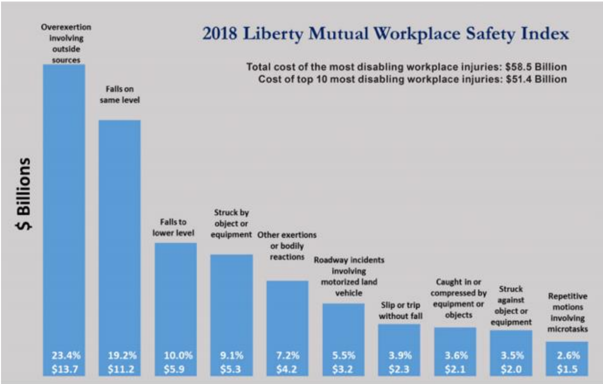

Figure 1. Top 10 causes and cost of the most disabling US workplace injuries

Workers in major cities and developed countries such as United Arab of Emirates are experiencing very safe environment and less work hazards base on very strict regulations in UAE, while employers are trying to avoid any direct or indirect fines might cause by not setting the right on site regulations and force all workers to follow the government safety regulations. According to research done by Grandview Research the market value of PPE is nearly $34 Billion in 2014 with potential growth of 7.2% [7] (Figure 2).

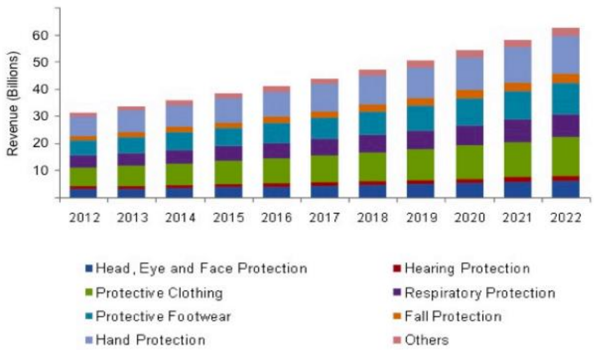

Figure 2. Potential growth of PPE market

Hard hats are designed to protect workers, resist shock, object penetrations, and electrical hazards and this only if workers are using them properly, site marshals with governmental inspectors are expecting the amount of injuries to be reduced since all workers are using the right PPEs [8], however controlling large amount of workers in big constructional sites are almost impossible every time and injuries actually are increasing and study showed that almost 47% of workers injuries are caused by not using the right PPE and no actual monitor took in place to prevent such unfortunate incidents [9]. This paper examines the effects of legalizing smart hard hats to remotely monitor any PPE violations in construction sites and using systematic tools to provide 24/7 surveillance for to detect any workers who are not using their assigned PPE or not using them properly. Studies showed that using smart hard hats for visualizing PPE usage had significant factor for reducing violations and this will lead to reduce number of fatal injuries among site workers [10].

2 Literature review

2.1 Smart Hard Hat

Using smart hard hats will satisfy the needs of safety of clients and will develop a functioning tools to keep the end users safer using the latest technology [11]. Teizer and Reynolds [12] studied the usefulness of smart hard hats to help workers avoid contact with hazard equipment using radio frequency and wireless microprocessors to warn workers once they are close to specified equipment's. Shrestha et al. [13] created a framework to visualize construction safety and detection algorithm. She used CCTV cameras and server side connection to detect workers without their PPEs. Dey S. [14] invented a smart safety gears to calibrate with smart sensors attached to wearable protection equipment, the method is to control the surroundings and measure signal based on the quantity of the element measured. Edirisinghe [15] explained the future context aware using smart sensors technologies in construction sites and real time safety. Gubbi et al. provided evidence that the world is moving to utilize latest technology in enable connectivity of day to day devices and enable IoT for better human enhancements [16] . Par el Al. [17] studied that workers in construction sites need to fulfil 2 main conditions the outline of a person and using PPEs, by using image processing technology to identify whether the person detected is a valid worker or not, In this experiment workers are identified by validating their PPEs from the image processing system can determine whether the person detected is a random person or a worker.

2.2 Image detection

Several research studied image detection for safety measures. [18] used camera features to detect different cues and facial expressions to trigger related warnings for specific incidents. Dai et al [19] developed a software which detect mobile sensors that read personal behaviour and record users action and compare collected data with typical patterns to store any unfamiliar activities. [20] addressed the power of automated visualization using 4D to analyse the relation between Virtual design construction (VDC) with Geographical location (GIS) to detect any faults or errors among construction sites. Qi et al. proposed a tool for maintaining safety suggestion based on images collected from checking construction sites. [22] studied number of images need to be collected and frequently captured in construction sites to be detected and analysed to produce valid information about how construction sites are performing their daily tasks. Many scholars have developed visual data collection to monitor safety among construction sites using image processing, table (1) list some prior work that used image automation to detect image information.

Table 1. Level automation for image detection [22]

Application	Data Analytics
Damage Assessment	• Image Based 3D reconstruction • Image segmentation & object classification • Machine learning classification
Infrastructure inspection	• Geometric recognition • 3D image processing
Urban Monitoring	• 4D image registration • Orthophoto mapping
Road Assessment	• 3D image based
Geo hazard Investigation	• Orthophoto mapping • Visual interpretation

3 Research Methodology

The paper methodology of PPE monitoring is to collect images data from cameras attached to the smart hard hat including personal traits and PPE availability as well as recording workers face detection and automated object recognition to detect whether is the worker is using the right PPE on the right time at the assigned place as illustrated in figure (3).

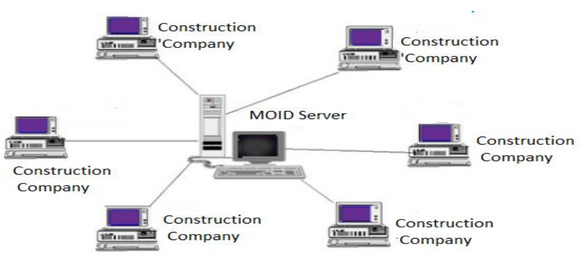

Figure 3. Framework to collect data and send data to MOID server

After the PPE checking by the cameras attached to the smart hard hat, the cameras will identify safety measures system will generate real time report and upload it to the MOID inspection portal and propose the corrective action such as site admin warnings and record fine on the contractor with incident details and visual evidence stored in database.

This paper will study the usage of smart hard hat by analysing three pillars

- Face detection to analyze if the workers already registered in MOID server for the construction site
- PPE object recognition to validate the usage of the correct and valid safety equipment
- Real time report to record all incompliance incidents and record it into MOID database and site manager.

Figure 4. Smart hard hat with detection camera

3.1 Detection device

The detection process of workers and their protective equipment's will rely on face detection and object recognition applications installed into the smart hard hat. The concept is to use the camera attached to the smart hard hat as shown on figure (4) to scan across each worker on site and store several images for each individual to read the data collected independently and analyse it based on the safety standards of MOID. This strategy has two main advantages

- Detecting worker profile: it retrieves the worker data from the database to understand his role and main job functionalities.
- Detecting equipment: over the construction sites many types of equipment should be used as per the safety standards shown on table (5) will be detected and analyzed for its existence

Table 2. List of safety standards

PPE Required	PPE required
Eye gaggles	Grinding, hammering, chopping, abrasive blasting, and punch press operations
Face Cover	Pouring, mixing, painting, cleaning, syphoning, and dip tank operations
Head and Body Cover	Building maintenance; utility work construction; wiring; work on or near communications
Feet	Construction, plumbing, smiting, building maintenance, trenching, utility work, and grass cutting
Hands	Building maintenance; utility work construction; wiring; work on or near communications

3.2 Standards Matching

The system will match serious of standards added by MOID safety department and compare it to a certain measures among construction site. The system will check the similarity and calculate the efficiency of the smart hard hat daily reports. Due to the unified design and shapes of safety equipment, the application will match the images detected on site and match it with template design stored. The template matching algorithms defined as detector (D) and true result (TR) of image detected and template matching (TM) of total image frames per second (n) and (TD) represents safety marshals detection.

$$D = tr\left(\frac{tm}{n}\right)/td\left(\frac{tm}{n}\right)$$

The algorithm will compare the use of smart hard hat detection with traditional way of inspection which use of human inspector or safety marshal to be available on site.

4 System Application

As per one epitome, construction site must be observed during working hours continuously so that workers must be saved from unforeseen situation, casualties and approach of illegal personnel on sites. Staff movement at a building site is followed utilizing electronic hardware incorporated into smart hard hat worn by supervisors at the site.

These smart Hard Hats must be manufactured observing all the requirements e.g., power for long working hours, perfectly working in any activity during construction and environment of construction sites. The smart hard is including an external hard shell joined to the inward shell adjusted to fit supervisor, must not hinder during his routine activities nor too heavy to carry all day long.

The inward shell compromising of most important technical part for smart hard hat having HD camera, environmental interaction sensors (accelerometer, gyroscope), wireless connection (sim card), power source, distress alert, geometric location, pulse measurement. Utilizing Smart Hard Hat technology we can sure to make environment safe and following MOID rules on every construction site.

As prerequisite all construction companies registered with MOID need to record their employees' data on MOID server.

Here we will choose cloud computing for efficient performance as it optimizes the computation partitioning of a data stream application between mobile and cloud to achieve maximum speed/throughput in processing the streaming data. This data storage framework is able to combine and extend multiple databases and Hadoop to store and manage diverse types of data collected from database or either by sensors and RFID readers [23].

On construction sites one or more supervisor wearing smart hard hat will be observing environment while performing his duties. Meanwhile, smart hard hat is in continuous state of detecting and monitoring workers, worn by supervisor situated at the construction site using face detection technology. Meanwhile, a broad range of high-resolution embedded cameras in combination with the development of commercial AI systems allows for a full replacement of traditional security and identification measures with face recognition and provide all above functionality with its additional features. The camera attached to the helmet is able to monitor individual, and looking beyond face recognition, to human analytics. As well as, provides face detection, identification and verification, emotion, age, gender, sentiment, ethnicity and multi-face detection, attention measurements and face grouping in real time.

As soon as human is detected by the hat, it will capture image so that his traits will be examined under the rules of MOID. Smart hard hat being powered by battery and wireless connection will capture working employee and process image on construction sites.

Firstly, the head areas are caught from human pictures. At last, with red, yellow, blue, white and non-helmet image samples, helmet identification based on image processing is used to detect whether workers are wearing helmets or not and to distinguish the shades of helmets if helmets exist. Then, Jackets will be detected due to high reflective clothing workers wear on construction sites. We propose and assess a framework for recognizing people wearing reflective apparel on construction sites by estimating their directions in 3D space under a wide scope of various light settings during image captured process. If the employee is wearing safety helmet and jacket, it will validate the working employee and if employee is not wearing safety jacket or helmet, smart hard hat will generate alert for MOID server. An alert for MOID server must be latency free, in this regard, we present Mobile Fog, a high level programming model for the future Internet applications that are geospatially distributed, large-scale, and latency-sensitive. Upon validating employee uniform for work, smart hard hat will also recognize employee as register worker or not, again smart cameras will play the role by its powerful system to identify registered employee within fraction of Nano seconds and generate alert for MOID server dependent on the individual data got after recognition process fails.

For instance, the alert may caution MOID and specific work force that they violate rules at the building site or non-registered worker is working on site. Alternatively, workforce action might be intermittently checked and revealed as shown in figure (5).

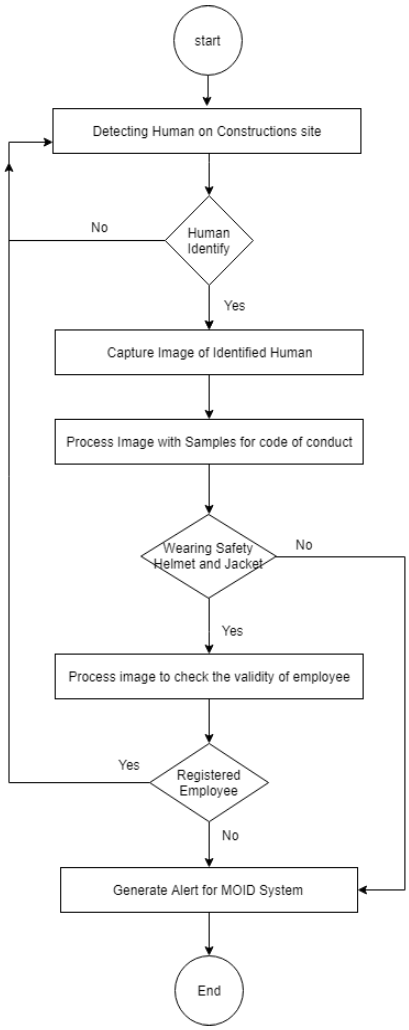

Figure 5. System notification workflow

4.1 System Reporting

The application of smart hard hat is based on wearable device (Safety helmet) which will be used by safety marshals or foreman on each site, and this will allow the user to monitor all site personal without disturbing their daily tasks. The smart helmet will keep recording all objects and human and compare all values with the stored database with the safety module.

4.2 Face detection

The technology will address the face detection using stored meta data, face images, which will be compared with the video captured. In order to communicate with the nature of images collected to a remote node from the camera arrangement. The accuracy of the face detected identify the image frame or field and include the image position. This method will use key frames to recover facial structure, and rely on image similarity which has been collected and stored in the server. Then the image structure will refine the collected results and add the new data to the targeted database. Based on the results the hat will analyse the face detected along with geolocation of the image taken to evaluate the difference and trigger the notification command.

Figure 6. Face recognition using smart hard hat

4.3 Object Detection

The main goal of smart hard hat detection is to detect objects attached to face of the workers, this goal will check if protective equipment exist at 3 main positions on the worker body

- Focus on the upper area of the worker face
- Focus on the center area of the worker body

The results refer to the degree of the safety equipment with respect to the x-axis, the values between (-1 and 1) indicate if the PPE location is correct relatively to the body and head position. The system will store up to 8 images per second in real time, then the object detection will compare its results with the data collected from the face detection to report whether any safety violations has been registered. In case of no equipment detected a red alert will be raised and report will be generated with incident details and sent to both Ministry Safety Department and site manager.

Figure 6. Face recognition using smart hard hat

4.4 Results & findings

Based on the technology described above, the experiment was divided into two sections: (1) validating construction workers PPE using human inspectors and (2) use smart hard hat to generate safety reports, results are shown on table (3) and (4). The study included 3 sites with over 1500 worker.

Table 3. No. of violations reported per day

Sites	Smart Detection	Site Marshal
Site 1	128	85
Site 2	63	25
Site 3	176	63

As seen on table (3) site marshals are not very accurate on their safety violations reporting as workers are moving around and located in different locations, while using smart camera detection the violations are automatically detected and process time of recording and analysing the image is much faster.

Table 4. Accuracy ratio for different type of detection

Sites	Precision (%)	Speed (s)
Head	95.1	0.201
Body	97.2	0.190
Hand	87.4	0.204
Shoes	56.3	0.204

Table (4) is testing the accuracy of the whole body detection and classify the objects into four categories: head, body, hand, shoes. The result shows that the highest accuracy is the body vest detection for its clear view and because of the reflected stripes it is easy for the camera to detect, however the shoes or feet detection is showing the lowest accuracy as not all images are able to detect the lower body parts of the workers and sometimes the workers shoes are too dirty to be detected.

5 Conclusion

The technology proposed to detect safety violations involves image detection and object recognition. The implementation of the application involves smart hard hat with internet based camera attached to the hat and involves database management for the safety template comparison. The main goal of this research is to legalize the smart hard hat among construction sites by generating real time automated reports and sent to both ministry safety department and site managers, this technology will provide daily reports of safety compliance and will increase the safety awareness among workers.

The system will analyse real-time images for the construction sites and detect workers who are not complying to the safety standards by comparing images taken on sites with standardized templates added by the ministry of infrastructure to reduce number of violations and relatively reduce number of injuries reported.

6 Recommendations

In the future research studying smart hard hat with its application using IoT to generate better understanding of workers daily behaviour in order to reduce number of incompliance, this will produce more accurate data and more automated results for more accurate monitoring for registered construction sites. Additionally further study needed for the effects of data signals transmitted from the hat technology to find better and faster data collection, this study will be able to provide better data analytics should the worker face any drop of negative impact. Furthermore, market analysis to determine the demand for this technology will be also required and would create better applications.

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