Monitoring of Personal Protective Equipments of Mine Personnel using Deep Learning

Project report submitted to
Indian Institute of Technology, Kharagpur

For the partial fulfilment of the award of the degree
Of

B.Tech in Mining Engineering

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Under the guidance of
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CERTIFICATE

This is to certify that the project entitled **"Monitoring of Personal Protective Equipments for the safety and security of Mine Personnel using Deep Learning"** submitted by **Vinit Kumar**, Roll No. **15MI33017**, to Indian Institute of Technology, Kharagpur, for the award of the Bachelor of Technology, is a record of bonafide research work carried out by him under my supervision and guidance.

Prof. Debasis Deb
Department of Mining Engineering
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ACKNOWLEDGEMENTS

First, I want express my sincere gratitude to the head of the department, Prof. Debasis Deb, for his patience, time, and great support during my study. I would like to thank sir for providing me the opportunity to do my B.tech project under his guidance. I have learnt a lot about the safety aspect of Mines and the application of Artificial Intelligence to ensure and optimize the same. Finally, I would like to thank our colleagues of the department who rendered their help and guided and supported me during the period of my project work.

Contents

1) Introduction

The mining industry is known worldwide for its highly risky and hazardous working environment. Technological advancement in ore extraction techniques for proliferation of production levels has caused further concern for safety in this industry. Research so far in the area of safety has revealed that the majority of incidents in hazardous industry take place because of human error, the control of which would enhance safety levels in working sites to a considerable extent.

Workers in underground coal mines are prone to several risk conditions during their work which may cause loss of life or serious injury which has a direct and indirect cost for employees and employers. Accidents in underground mines can often have serious catastrophic consequences. Over the years, the Directorate General of Mines Safety (DGMS), mining companies, research institutes and academics have made constant efforts to prevent accidents in Indian mines by proposing solutions, such as additional regulations, improved training, advanced technology and reliable equipment.

The trend of fatal accidents occurring in Indian underground coal mines is higher than in the USA's and Western Australia's underground coal mines, as shown below :

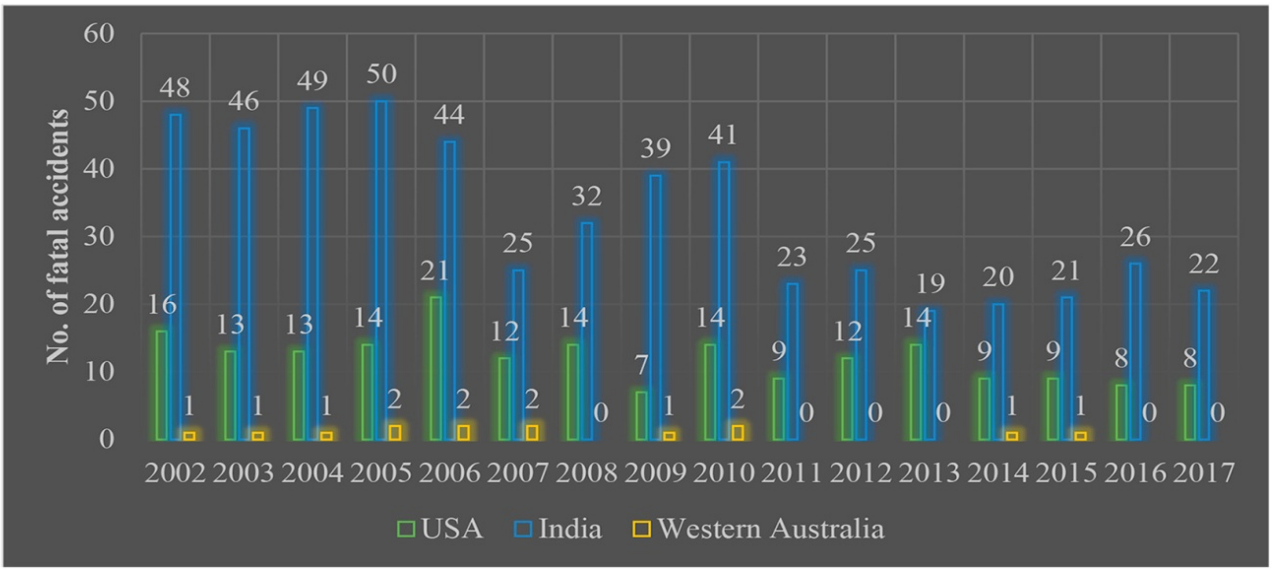

Fig 1: Comparison of fatal accidents in USA, India and Western Australia

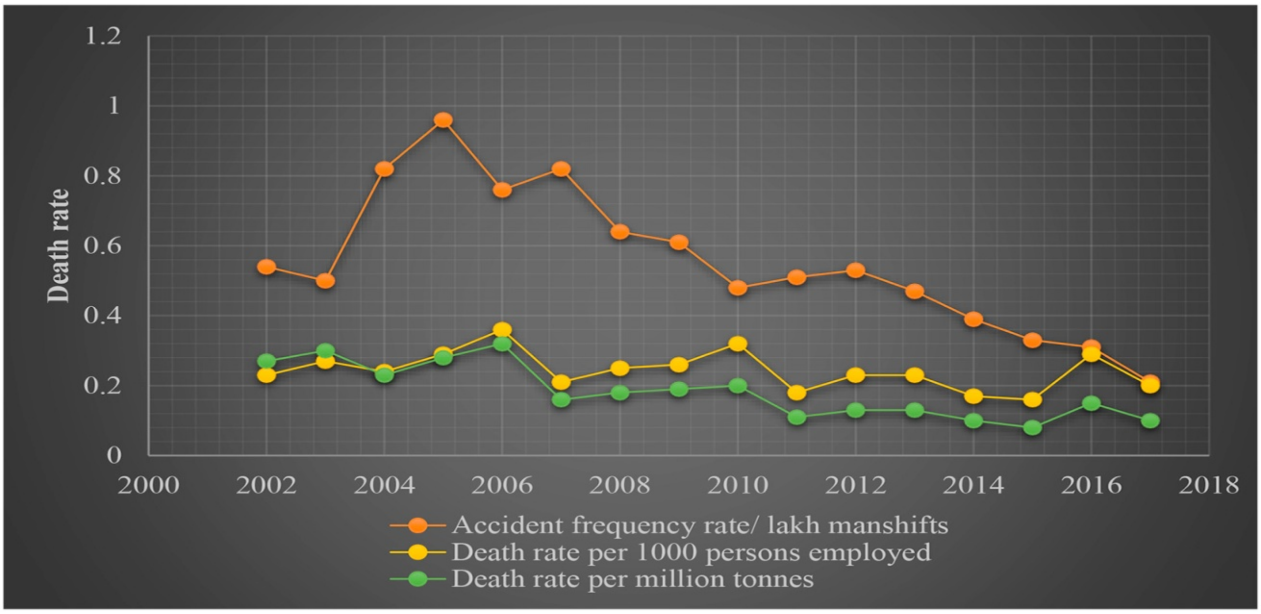

Fig 2: Death rate year-wise per man shifts, per 1000 persons employed and per million tones.

Not only safety, the theft of platinum, gold or diamonds poses a substantial threat to the economy of any country where the Mining industry exists. Mines provide employment for local and migrant workers and it is their employees that have to be protected against illegal miners and product theft. Additionally, the safety of genuine mine employees is at risk as they are exposed to threat and corruption from the illegal miners.

Currently used security precautions and measures include: access control systems with cards (proximity or bar-code) for time and attendance, physical security guards, CCTV solutions, metal detectors. The above security measures still allow unauthorised access; therefore, new technological systems have to be introduced. The implementation of biometric technologies in the mining industry has been taking place over the last ten or more years in India. There has been continuous search for the 'perfect' biometric system to fulfil the stringent requirements and challenges of the mines. Systems such as hand geometry, fingerprint, iris and facial recognition provided varied results.

2) Objectives Of The Project

The objectives of this project are:

- Developing a software for the Face Recognition of the Miners deployed in the Mines.
- To ensure the safety and security of the Mine Personnel by detecting whether the PPE i.e. personal protective equipments like helmet, jacket and gum boots are being used.
- To avoid the entrance of unidentified personnel in to the mines using Computer Vision with Deep Learning.
- Study on how Deep Learning architectures be used in the field of safety aspect in the Mining Industry.
- Merging the Face Recognition system with PPE detector.
- To train the model and tune the architecture and its parameters for an increased and robust performance.

3) Literature Review

3.1 Face Recognition system for Authentication

Access control systems utilise tokens, such as cards, with additional CCTV cameras and security guards. All of the above mentioned measures will not be enough to prevent unauthorised access because the above systems do not identify or verify individuals, but rather use PIN numbers (of the cards) or rely on decisions made by humans that are not reliable or are open to collusion.

A stringent analysis of possible implementation of fingerprint, iris and facial recognition provided thorough understanding of what can be expected from the performance of the available solutions.

After a thorough investigation and based on hands-on experience of other installations of hand geometry, fingerprint and iris recognition, the final verdict on what is the best biometric technology in the mining industry turned out to be facial recognition.

Table I highlights the main commonly identified properties of the three major biometric technologies.

System	Strengths	Weakness
Fingerprint Recognition	**Capable of high levels of accuracy** Fingerprint recognized as a distinctive identifier **Ergonomic,easy-to-use devices** Placement of finger is an easy process **Ability to enroll multiple fingers** 10 fingers' scan provides more information Range of deployment environments Small devices Variety of solutions for logical and physical access control	**It is not an ideal solution for every situation** **Inability to enroll some users** Manual laborers, elderly population, certain ethnic and demographic groups, children **Performance deterioration over time** Some systems' error rates have gone from non-existent to 25% over 6 weeks because of daily wear **Physical contact required** Users are concerned about germs

Face Recognition	**Ability to leverage existing equipment** Mostly software-based technology capable of using existing high quality CCTV cameras and photo ID systems **Ability to enroll static images** In large-scale facial-scan deployments there is an existing database of facial images Surveillance applications need only one **Ability to operate without physical contact** The only biometric solution capable of identification without subject co-operation	**Acquisition environment effect on matching accuracy** Direct lighting, camera position and quality can reduce accuracy **Changes in physiological characteristics that reduce matching accuracy** Changes in appearance might have an impact on some systems that are not robust. Eyeglasses, hats and scarves can cause users to be falsely rejected in some systems
Iris Recognition	**Resistance to false matching** Potential for high level of accuracy **Stability of characteristic over time** Iris does not change over a person's lifetime	**Difficulty of usage** Enrollment and verification require fairly precise positioning of the head and eyes. **False rejection failure to enroll** A percentage of users are unable to enroll in iris scan systems Concern that exposure to the technology may damage eyesight

3.2 *Personal Protective Equipment (PPE)*

PPE, Personal Protective Equipment, are the tools that ensure the basic health protection and safety of users. PPE is any device or appliance designed to be worn by an individual when exposed to one or more health and safety hazards. PPE includes all clothing and other work accessories designed to create a barrier against workplace hazards, and using PPE requires hazard awareness and training on the part of the user. Employees must be aware that the equipment does not eliminate the hazard; if the equipment fails, exposure will occur. To reduce the possibility of failure, equipment must be properly fitted and maintained in a clean and serviceable condition.

Employers are required to assess the workplace to determine if hazards that require the use of head, eye, face, hand, or foot protection are present or are likely to be present. If hazards or the likelihood of hazards are found, employers must select, and have affected employees use, properly fitted PPE suitable for protection from these hazards. Before doing work requiring the use of PPE, employees must be trained to know when PPE is necessary, what type is necessary, how it is to be worn, and what its limitations are, as well as its proper care, maintenance, useful life, and disposal.

Head Protection

Protective hats for head protection against impact blows must be able to withstand penetration and absorb the shock of a blow. In some cases, hats should also protect against electric shock.

Foot and Leg Protection

For protection of feet and legs from falling or rolling objects, sharp objects, molten metal, hot surfaces, and wet slippery surfaces, workers should use appropriate foot guards, safety shoes, or boots and leggings.

4) Algorithms And Techniques

Face detection is differentiating the face from any other objects (inter-class variability) and Face Recognition is differentiating one's face from the other (intra-class variability)

4.1 HOG Algorithm

Histogram of oriented gradients (HOG) has been used to detect the faces in the video frame. This method is based on the evaluating well normalised local histograms of image gradients orientation in a dense grid. Every Single pixel in the input image is considered at a time and for every single pixel, the directly surrounding pixels are observed. The primary goal is to figure out how dark the current pixel is, compared to the pixels directly surrounding it.

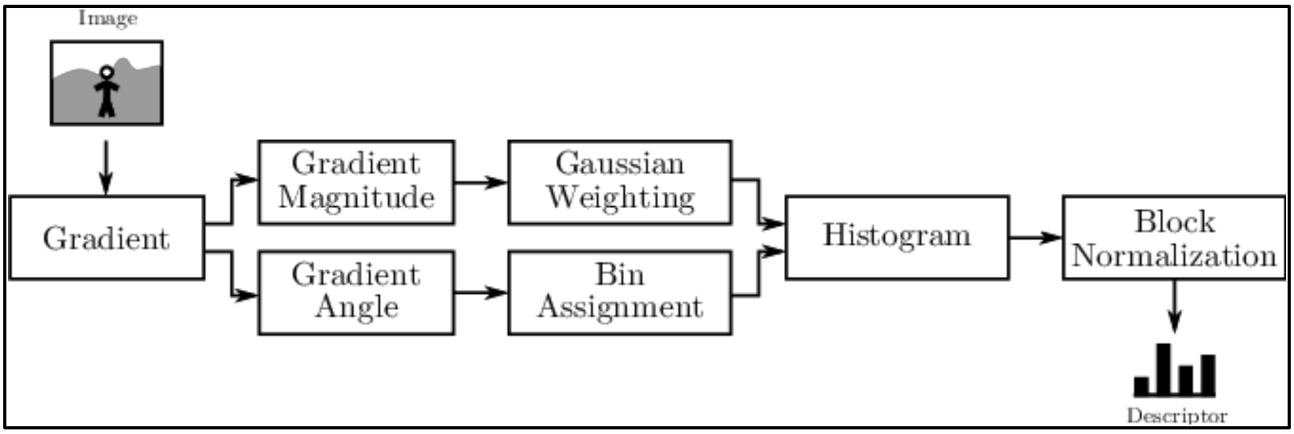

Fig 3: HOG Algorithm

Then an arrow is drawn depicting the direction in which the image is getting darker. By the end of the process, every pixel would be replaced by an arrow. These arrows are called gradients and they show the flow from light to dark across the entire image for extracting the desired patterns, the image is broken into small squares and in each square the gradient point in each major direction (up, down, up-right, down-right etc) are counted up and replaced with strongest arrow direction. The end result is turned into a very simple representation and to find faces in this Hog image, part of the image which looks most similar to a known Hog pattern is extraction

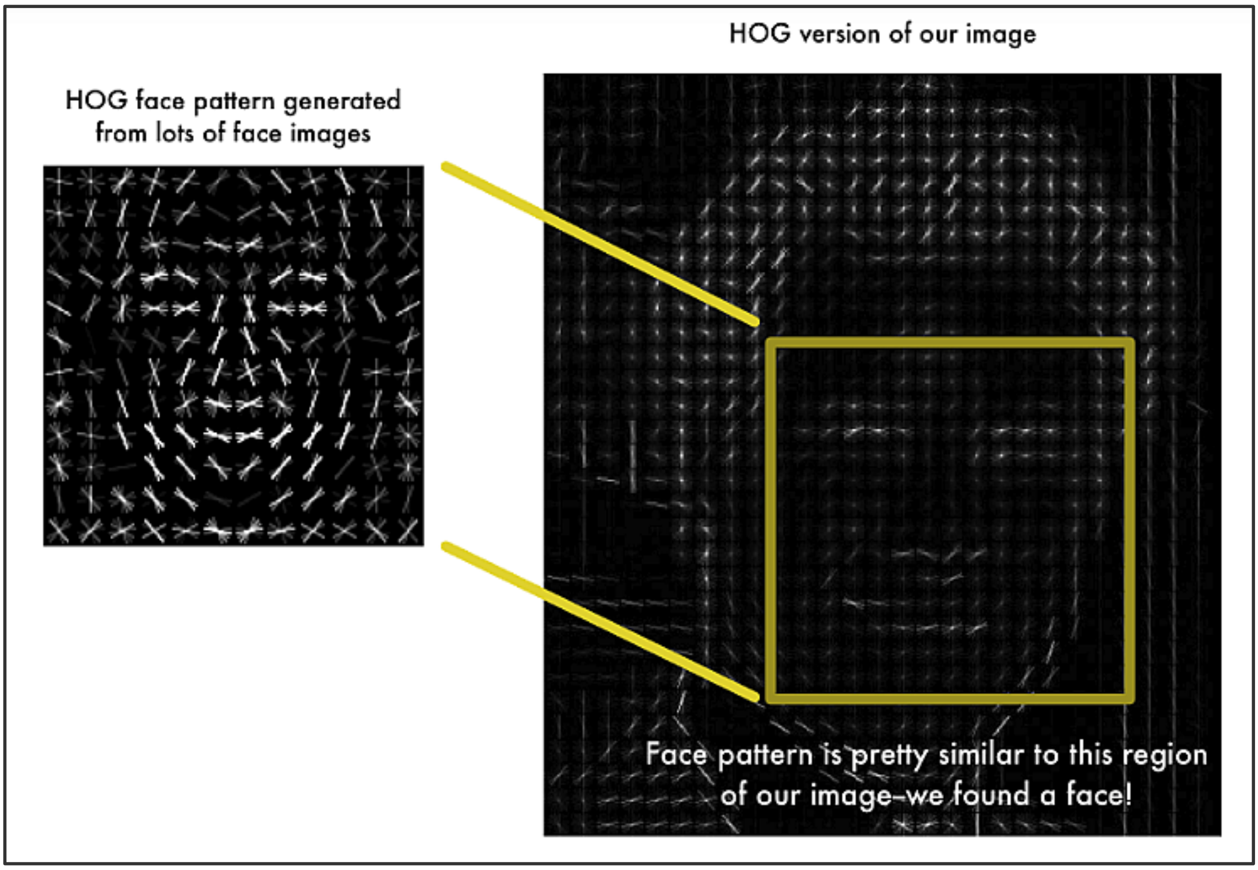

Fig 4: Hog Patterns for the face

4.2 Face Landmark Detection and Deep Convolutional Network

Face landmark detection used for preprocessing the images before going into the network. A convolutional network is trained to generate 128 measurements for each face which could be nose size, eye color, distance between eyes etc. Testing process works by looking at three faces at a time.

Sometimes in traditional methods, face recognition misses matching because there are invariance factor resulted from human pose, hairstyle, acne arising, fatter etc. Hence face recognition based on facial geometric landmarks was developed and seems promising to solve these problems.

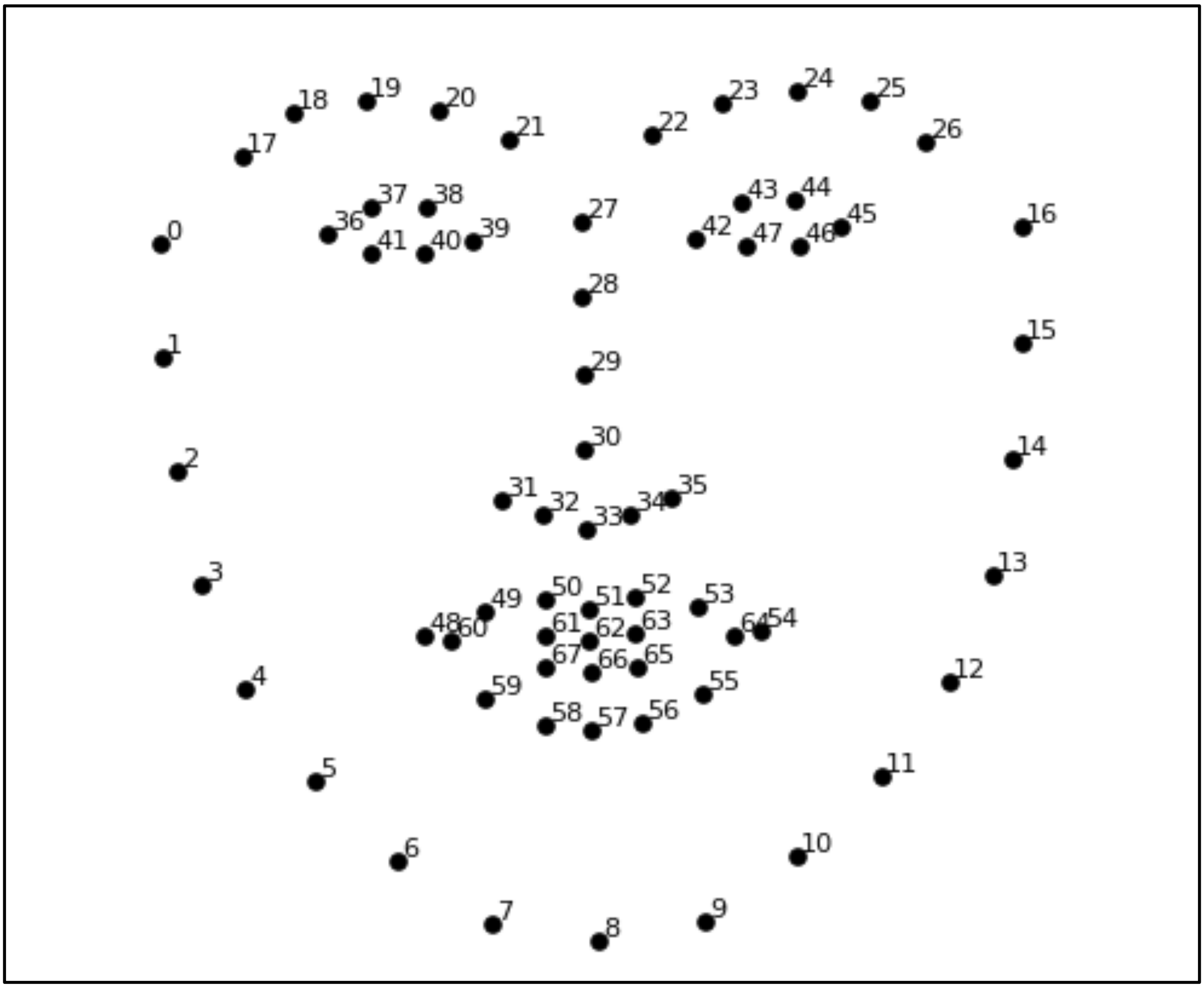

Fig5: Considered Location at Face

The following figure shows the real time locations considered by the algorithm:

Fig6: Real Time location considerations at Face

Steps of testing

- Load a training face image of a known person
- Load another image of the same personal
- Load a picture of totally different person.

Then the algorithm looks at the measurements it is currently generating for each of those three images. It then tweaks the neural network slightly so that it makes sure the measurement it generates for 1 and 2 are slightly closer and that of 2 and 3 are highly further apart. Pertained models has been used to generate these 128 measurement which are called embeddings.

5) Methodology

5.1 Data Collection

- Image of the person is taken while running video-frame by web-camera
- Images are labeled and saved in separate location in the database.

5.2 Face Detection and Recognition

- Convert the image in grayscale as we don’t need color data to find faces.
- Use the HOG algorithms to encode the image using the simplified image, find the part of the image that most looks like a generic HOG encoding of a face.
- Figure out pose of the face by finding out the main landmarks (68 points) in the face
- Once the landmarks are found out, use them to wrap the image so that the eyes and the mouth are centered.
- Pass the centroid face through a neural network model that knows how to measure features of the face. Save those 128 measurements.

- Looking at the faces we have measured in the past, see which person is the closest measurement to the face's measurement. That's the match!!

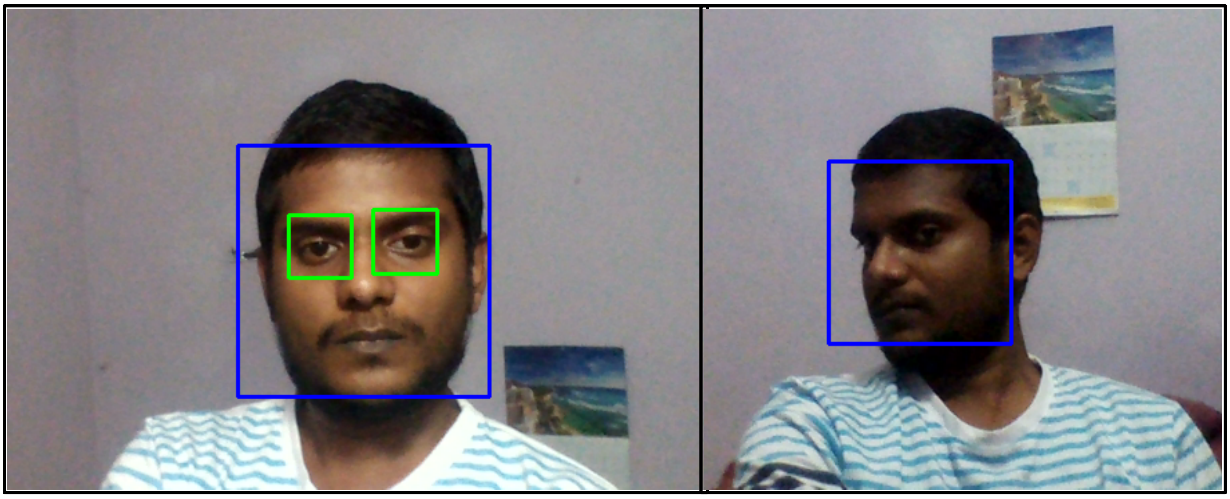

Fig7: Front Face, Side Face and Eye Detection

6) Challenges Faced

Major Challenges faced are:

- The major challenge was computation. Deep learning models are power hungry and require GPU's for training and it takes a long time to train as well.
- Variations in lightning conditions, occlusions
- Wearing of spectacles
- Having more facial hair
- Changing facial expressions, Pose, orientations, camera characteristics

7) Results

- It is easy to use, non intrusive and friendly as miners only have to look at their own reflection in the mirror where the camera works in the background.
- It is very accurate with very fast throughput of hundreds of persons (the station camera takes a picture of the person requiring access, and the image is recognized within 0.3 seconds)
- No contact is required to acquire biometric features (fingerprint is not suitable due to dust on fingers and cuts, and possible germ contamination due to touching the finger scanner)
- Reliability and scalability
- No possibility of clocking fraud
- Log file generated from attempts of deception (time and date stamped).
- Audit report on individuals with live face verification proof
- A name is connected to the individual’s face

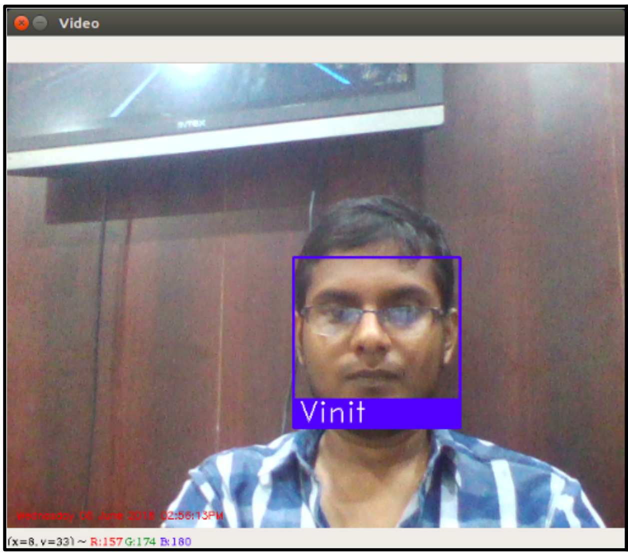

Fig 8:In proper Lighting Condition

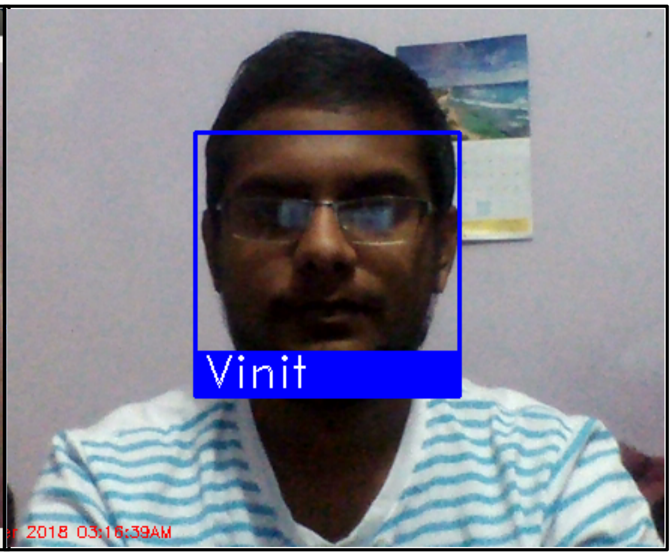

Fig 9:In dim Light

Fig 10:Head in upper direction

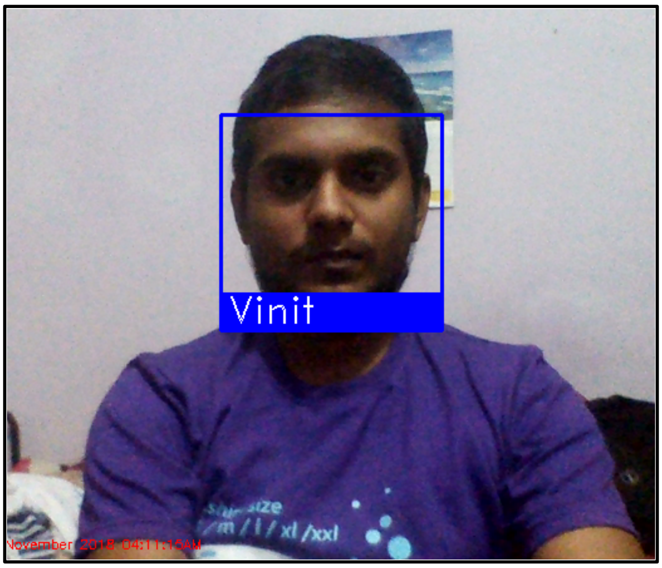

Fig 11:Without spectacles

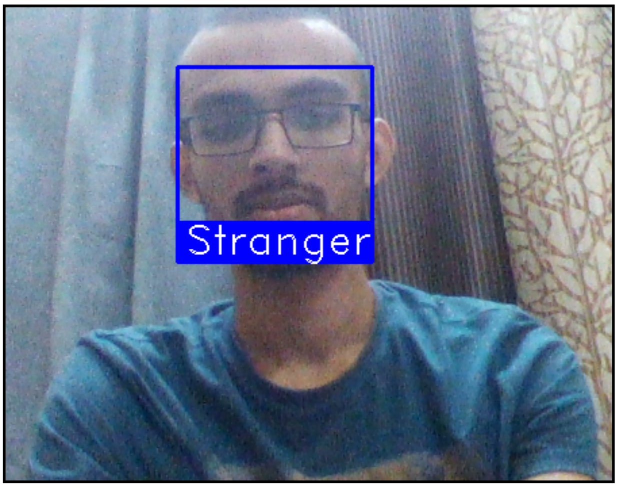

Fig 12:Before Training

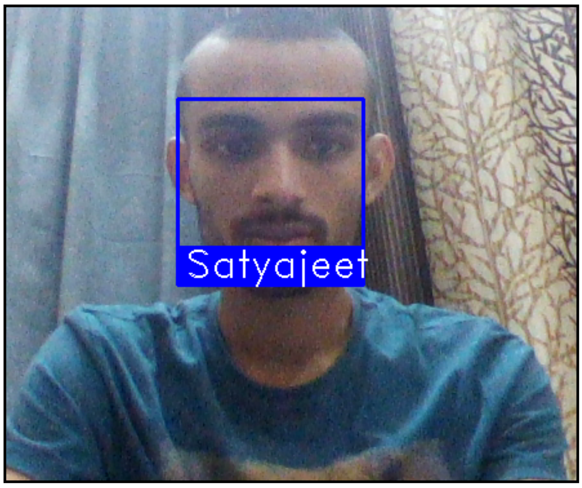

Fig 13:After Training

7.1 Helmet Detection Result

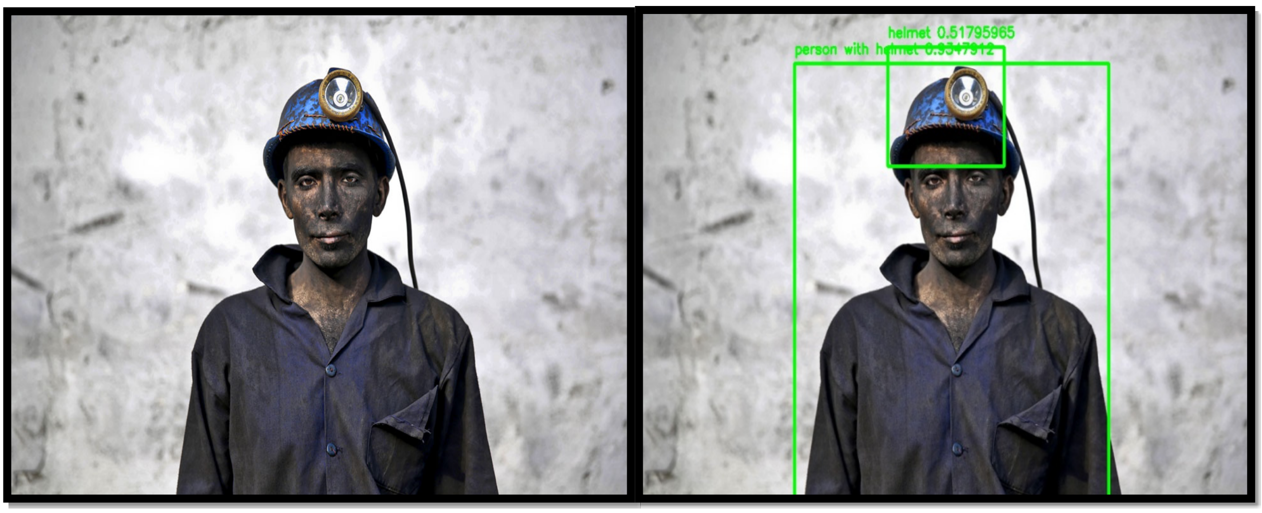

Fig 13 : Image before detection and after detection, detected with 93% accuracy

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