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# Assessment of conformal use of personal protective equipment by object and human pose recognition

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## Abstract—

On construction sites, workers are exposed to a wide range of hazards. To reduce risk and prevent severe work accidents, the use of PPE (Personal Protective Equipment), such as hard hat or harness has been adopted by the industry. Monitoring the use of PPE is an inherently difficult task since its protective effectiveness depends on whether it is conformally worn. In recent years, the advent of deep learning for the tasks of object detection and human pose analysis has enabled the rise of discriminative and all-purpose PPE detectors. However, most of earlier works solely focus on detecting the equipment irrespective of their positioning. By assessing conformal PPE usage based on the combined output of object detection and articulated human pose extraction we can combine learning with domain expertise, which allows a straightforward, in-field application of the approach that attains high quantitative performance.

## I. INTRODUCTION

According to the Occupational Safety and Health Administration (OSHA), in the USA, the construction industry suffered from 1008 worker fatalities, which represent 21.1% of the fatalities in private industries. The two main causes of death were falls and being struck by object, causing 338 and 112 deaths respectively [OSHA, 2018]. While controlling and trying to contain hazards at their origin is the best way to protect employees, this can only be done to an extent.

In this context and to alleviate the risk of accidents, regulations and safety legislation have been adopted, notably regarding the use of personal protective equipment (PPE). Such equipment comes in various shapes and forms to protect against a wide range of hazards, often including items related to physical, noise or chemical protections. However, only 64% of workers wear the required equipment at all times [Farooqui et al., 2009], either due to negligence or inconvenience.

## II. PROPOSED APPROACH

Using domain knowledge to analyse a person's pose in relation to certain objects of interest, we can assess the conformal use of PPE by its proximity to certain body parts. By comparing the position of an equipment in question and the nearest most relevant body parts, it is possible to deduce whether it is properly worn through measurements in image space. The absolute scale of these measurements can be determined very accurately if needed by making use



Fig. 1. Example of PPE detection in context using our approach.

of the overlapping human pose, however, making use of relative measurements only is sufficient for the problem into consideration.

In our framework, object detection and pose estimation are performed by using the state-of-the-art deep neural networks YOLOV3 [Redmon and Farhadi, 2018] and OpenPose [Cao et al., 2018] respectively. The former is used to localize various personal protective equipment in an image, the latter to localize the body limbs.

In detail, we explored two alternatives for the detection of hard hats, work shoes and harnesses. The first consists in assessing the degree of overlap between detected objects and relevant human joints (see II-A) while the second is based on asserting a number of conformal tests that need to be verified (see II-B).

### A. Object - joints overlap

The bounding box associated to each detected object determines how many and which body parts are found in each box. This provides an overview of the relative position of each object with respect to one's posture, that is finely determined at the level of the head and the feet via OpenPose through a number of joints. We adopted this approach for the detection of hard hats and shoes, requiring that a sufficient number of relevant body limbs are located within the object's bounding box. Indicative results of hard hats and shoes detection are given in Fig. 1. This solution is only suitable if the equipment in question can overlap with limbs which can be obtained from pose estimation.

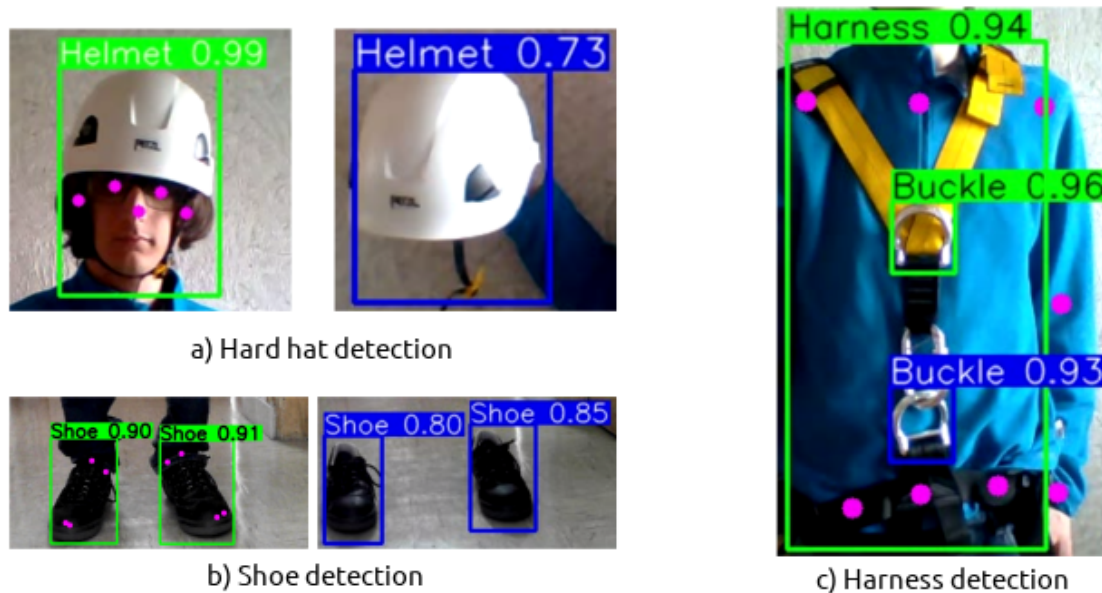


Fig. 2. Example of various correctly worn equipment (green) and incorrectly worn (blue).

### B. Harness and buckle detection

Some types of equipment either do not overlap with joints or the assessment of correct use goes beyond relative position estimation, as in the case of harnesses. In particular, a harness is considered properly worn if one of its buckle is located in the upper side of the torso. To introduce this constraint, we used 6 key points detected on the torso: The neck; left and right shoulders; left, mid and right hip. Checking whether the buckle is closer to neck than the middle hip would be sufficient, however, the detection of every body limb is not guaranteed.

The approach that we employed consists in asserting the validity of the following three conditions: (a) The buckle is closer to the neck than the middle hip; (b) The buckle is closer to the left shoulder than the right hip; (c) The buckle is closer to the right shoulder than the left hip. If the majority of these tests is positive, a buckle is deemed to be conformally worn. An example of harness and buckle detection is given in Fig. 1.

## III. RESULTS

We evaluated the performance of joint object detection and human pose estimation. For this experiment, 418 pictures of people properly wearing hard hats, harness and shoes were collected.

The purpose of this test is to demonstrate the capacity of our implementation to detect whether the PPE are conformally worn.

A qualitative result is provided in Fig. I. Both the YOLOV3 and Tiny-YOLOV3 with path aggregation networks [Liu et al., 2018] configurations show high recalls.

The combination of human pose estimation and object detection enables the extraction of complex and robust in-

Configuration	Helmet	Harness	Shoes
Tiny-YOLOV3 + PAN	93.3%	91.3%	95.6%
YOLOV3	95.8%	90.2%	94.4%

TABLE I

FRAMEWORK EVALUATION: COMPARISON BETWEEN TINY YOLOV3 AND YOLOV3 ON DETECTING WHETHER PPE ARE CONFORMALLY WORN.

formation in images. Such information would be difficult to obtain with object detection alone. However, pose estimation comes at a computing cost and increases the time required to handle an image. In the future, instance segmentation algorithms, such as Mask R-CNN [He et al., 2017], could be used to extract finer details from images.

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