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Unsupervised Feature Learning for Objects of Interest Detection in Cluttered Construction Roof Site Images

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Abstract

In the roof contracting industry, safety violations continuously lead to fall injuries and fatalities. Occupational Safety and Health Administration (OSHA) suggests standard protective measures, but they are often not followed due to factors such as tight budget and lack of training. To alleviate this situation, we propose to develop a system that can automatically check the compliance of fall protection standards through machine vision and learning techniques to exploit day-to-day site images collected by the surveillance videos and site engineers. As an initial effort, this paper focuses on evaluation of an unsupervised feature learning and image classification method i.e., Convolutional Neural Networks (CNN) to detect objects of interest (roofs, roofers, guardrails, and personal fall arrest systems) in a large number of unordered and cluttered construction site images. To isolate different objects, we initially segment each image using Gaussian Mixture Model (GMM) and pass the resulting segments as input into CNN. This enhances the feature distinction between different objects and augments the inter-class variability. Then, we extract large feature sets in a hierarchical manner and classify images based on the acquired object features. Experiments results signify the promising performance of the CNN method in terms of accuracy. This research demonstrates potential of this method and paves the way towards applying it in the next research development required to achieve our ultimate goal.

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Keywords: Convolutional neural networks; roof site image classification; unsupervised learning; deelp learning; construction safety

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1. Introduction

In the construction industry, roofers suffer from a high incidence rate of fatal injuries [16,8,6]. According to [12,26], one third of all fall related fatal injury cases in construction are reported from roofing related activities. According to the report by the U.S. Bureau of Labor Statistics [7], forty percent of accidents in construction site are related to falls, slips and trips. Thanks to challenges such as tight budget [21], low education [24], and lack of training [23], the contractors and roofers continuously violate the standards of fall protection released by the U.S. Occupational Safety and Health Administration (OSHA). To implement the compliance of the fall protection standards, OSHA generally dispatches professional compliance officers to perform inspections [25]. This is a significant step in incident prevention but the construction industry is lager in terms of the number of jobsites [17], limiting the manpower of compliance officers needed for such purpose. This makes the manual compliance checking process slow, expensive, and therefore the effects sometimes are limited.

On the construction sites, surveillance videos and logs of work in photos are widely used for tasks such as keeping record of working progress and inspecting performance of ongoing work. The prevalence of using and documenting such data provides an opportunity to perform the safety inspection process in an automatic and cost-effective manner. Therefore, we propose to develop a system that can automatically check the compliance of fall protection standards through machine vision and learning techniques. Such a system holds the promise to serve as supplementary means by which the site safety performance with respect to fall can be measured and relevant violations can be caught. In this paper, we primarily focus on recognizing various objects of interest in a roofing construction site – the workplace where roofers perform their jobs in site photos with the aid of object detection, which is a key component in developing the said system.

Specifically, we aim at detecting four different objects of interest: roofs, roofers, guardrails, and safety gear – personal fall arrest systems (PFAS) using a deep learning technique of Convolutional Neural Networks (CNN). By using CNN, we can automatically learn the features and then use them to classify an object class in a given image. To this end, we initially train the CNN by using images that are segregated into four categories based on the object they contain. We ensure that these images contain just a single object class by extracting only that part of a cluttered image which contains the object of interest. We use a bounding box to isolate the object from the cluttered image. Once these isolated object images are available for training, CNN learns all the necessary features for a single object class. As a part of testing, since the images are cluttered, we segment them by using GMM-based segmentation. This segmentation logically divides a given image into various segments and they are sent to the trained CNN for testing. CNN tests individual segment to each of the four objects of interest and results in the output.

The reminder of this paper is organized as follows. First, we present the related work in object detection, especially using CNN as an object classifier. Then we introduce the CNN workflow, which is followed by detailed description of experimental design, results and analysis. Last, we conclude and discuss future work to our method.

2. Research background

2.1 Deep learning

Deep learning is a new area of machine learning research, which has been introduced with the objective of moving machine learning closer to one of its original goals: artificial intelligence. Deep learning methods aim at learning feature hierarchies with features from higher levels of the hierarchy formed by the composition of lower level features [4]. Automatically learning features at multiple levels of abstraction allows a system to learn complex functions mapping the input to the output directly from data, without depending completely on human-crafted features [9]. This is especially important for higher-level abstractions; which humans often do not know how to specify explicitly in terms of raw sensory input. The ability to automatically learn powerful features will become increasingly important as the amount of data and range of applications to machine learning methods continues to grow [3].