Designing a construction safety system using artificial intelligence

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Abstract: As a significant part of the national economy of a country, the construction industry is closely related to people's lives. In recent year, with the booming development of the construction industry, the rate of safety accidents on construction sites is also on the rise. The management of potential safety hazards in construction sites has attracted more and more attention of people. As a kind of personal head protection equipment, the helmet is required to be worn by every worker in construction sites. But for now, the wearing of workers' helmets mainly depends on manual supervision, which is very inefficient. With the development of economy and the progress of science and technology, Artificial Intelligence technology has been widely used, which can provide a certain technical support which is more efficient for the management of construction site safety issues. Thus, this article proposed a safety detection and early warning system for the supervision of the wearing of workers' helmet by using artificial intelligence technology. In my work, I will implement the YOLO algorithm which is a useful object detection algorithm to realize the processing and analysis of real-time surveillance video. And I will realize the linkage control of intelligent detection and early warning through the combination of real-time monitoring and the system, in order to improve the efficiency and accuracy of safety management on the construction sites and reduce the incidence of safety accidents.

1. Introduction

The construction industry is an important part of a country's national economy, and the safety of construction is a significant issue for the long-term development of the construction industry. At this stage, there are many potential safety problems in the current construction field, and the maintenance of order and safety issues at the construction site are still the focus of the construction site management and control. Based on the traditional concept, the safety supervision in the field of construction is completed by the subjective consciousness of management personnel. They usually judge the wearing condition of workers' safety equipment especially the wearing of helmets, according to their own experience, knowledge and understanding of safety behavior. Therefore, people find that this kind of traditional safety supervision methods not only need to invest a lot of manpower, but also the accuracy and efficiency of supervision is not so good. Thus, the incidence rate of construction site accidents is still high today (shown in Table 1). Traditional safety management urgently needs to innovate and change the current mode. With the rapid development of artificial intelligence technology, it is very feasible to apply artificial intelligence technology to the safety management of construction sites. I will design a safety detection and early warning system for the supervision of the wearing of workers' helmet by using artificial intelligence technology.

1.1 Application of YOLO in object detection

The application of artificial intelligence technology will greatly improve the supervision efficiency and accuracy of workers' wearing safety facilities, and quickly upload the detection results to the safety management command center, so as to realize the linkage of object detection and safety early warning. In this system, I will realize the linkage between the real-time monitoring video and the helmet object recognition system. I will take screenshots of the real-time monitoring video every once in a while and

take these screenshots as samples. In this way, YOLO algorithm will be used to carry out object detection to judge whether the workers wear safety helmets in accordance with the regulations or not. In today's construction field, some construction companies have begun to apply object detection to safety management, but this technology still has many limitations. For example, there are many objects similar in shape to safety helmets on the construction site, such as safety cones, which may appear in the screenshots obtained from sampling, thus causing inaccurate detection of safety helmets wearing. To solve this problem, I will also train the Artificial Intelligence with false data so that it can accurately determine whether some objects are the safety helmets or some other confusing objects like safety cones.

Month	Number of accidents	Number of deaths
1	40	53
2	8	13
3	43	55
4	52	70
5	43	46
6	84	92
7	30	32

Table 1. A summary table of construction safety accidents in China from January to July 2019(data from https://www.sohu.com/a/330546356_807898).

2. Related works:

2.1 YOLO algorithm

The reason why we choose YOLO algorithm is that the detection speed of YOLO algorithm is much higher than other algorithms in the two-stage and one-stage. Although the accuracy may not be as good as other algorithms, the speed of implement will be faster that others [1].

The YOLO algorithm, which concludes Bige-YOLO and Tiny-YOLO. In our system, we need to get the recognition result in the fastest time. [2] According to the experiment, Bige-YOLO and Tiny-YOLO were used to identify real-time video respectively, and it was found that different YOLO models had different detection accuracy and processing speed for videos with different resolutions. Bige-YOLO took longer time than Tiny-YOLO, but its accuracy was higher than Tiny-YOLO. Therefore, the appropriate algorithm should be selected according to the practical situation.

2.2 Safety warning system

[3]The author put forward the feasible scheme of power grid real-time security early warning system, the use of parallel and distributed computing technology, from multiple sides for grid "triage" implementation, real-time automatic tracking and determine the power grid security level, quickly find out all kinds of potential safety problems, and then through the "consultation", real-time comprehensive security early warning report, show the dispatcher, greatly improve the ability of real-time grid security early warning.

[4] Aiming at the problem of pedestrian protection in serious traffic accidents, a real-time pedestrian detection and early warning system based on side pedestrian features is proposed. The system is composed of detection module and early warning module. The early warning module integrates the information of pedestrian distance, vehicle speed and angular speed to judge the collision risk of pedestrians ahead. The system and algorithm are used to verify the pedestrians crossing the street in the complex background of urban environment.

2.3 Face recognition technology

[5] Firstly, the background and development of computer face recognition technology are briefly reviewed, and then the recognition methods of face image are classified and summarized according to different recognition features. In my future work, I want to apply face recognition to the algorithm and

correlate it with a large database to achieve more accurate and effective supervision of each individual helmet wearer. Through the analysis and comparison of various recognition methods, this paper summarizes several factors that affect the practical application of face recognition technology and puts forward several important aspects that need to be considered in the successful research and development of face recognition technology, and then looks forward to the future development direction of face recognition technology.

2.4 Safety Helmets Detection System

In this section, the article designs a system for supervising the wearing of helmets on construction sites, which can be used to identify whether workers are wearing helmets in accordance with the regulations by calling up real-time monitoring video from the site. Let us assume a situation: We had a construction site, and we divided it into zones A, B, C, and D (shown in Figure 1). In addition, each zone is equipped with a surveillance camera that can completely cover the area, and a safety alarm and light are equipped near each camera.

There was a lot of work of machine learning we need to do. First of all, it needs to input a lot of training data to train the system to detect the target object quickly and accurately. In this system, the most important thing is that we need to carry out machine learning on the system with the helmet as the training data, because the helmet is the main detection object in the object detection system. Besides, there are many objects similar in shape to safety helmets on the construction site, such as safety cones, which may appear in the screenshots obtained from sampling, thus causing inaccurate detection of safety helmets wearing. Thus, in order to avoid misjudgment in the process of object detection, the safety cone is used as the training data set for machine learning of the system. In addition, we also should do the machine learning to make sure if the system could detect the face of worker accurately and being able to associate face with ID/names, is different function than detecting whether any person wears a helmet or not, which would make the supervision to be more efficient. We may need another powerful facial recognition system trained with labeled data, person's ID and their face picture.

In this system, we have several steps to realize whether workers wear safety helmets in accordance with the regulations. First of all, we need to link the real-time surveillance video with the object detection system, that is, after certain processing of the surveillance video, the sample will be immediately uploaded to the helmet wearing detection system. In this system, the core algorithm we use is YOLO algorithm, which is an algorithm for object detection of images. We first should convert real-time surveillance video into images to serve as the sample data set of the system. Therefore, we need to take screenshots of the video at regular intervals to obtain a sufficient number of samples for testing. This process is the sampling process shown in Figure 2. After that, these screenshots will be sent as sample data to the Construction Site Safety Management and Control Center to do the helmets detection. This is process is the Transmission shown in Figure 2. In the Construction Site Safety Management and Control Center, the core step of the helmets wearing detection will be implemented, which is the system will use the YOLO algorithm to determine whether the safety helmets are on the screenshot obtained from the video sampling. Assume the number of the safety helmets in the data set is n, and the system will count the number of the face of people. If the number of faces is also n, which is equal to the number of the safety helmets, then we can safely get the conclusion that all workers shown in the screenshot are wearing the safety helmets according to the regulations. Otherwise, if the number of helmets does not equal to the number of faces shown in the screenshot, then it means that there exists some workers not wear the safety helmets or wear the helmets against the rule. In terms of different detection results, we will take different measures. If all workers are wearing the safety helmets correctly, then the sample data will pass the test. If not, the system will give a feedback signal, and this signal will be fed back to the area responsible person, and at the same time trigger the safety warning system, alarm and warning light. After that, the leader of area team will take appropriate action to solve this problem, such as take a meeting or establish certain penalties for workers who do not wear safety helmets as required

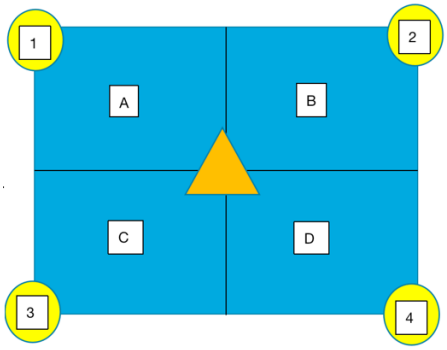

Figure 1. (A, B, C, D represents 4 zones; 1,2,3,4 represents the location of monitors; the triangle represents the management and control center).

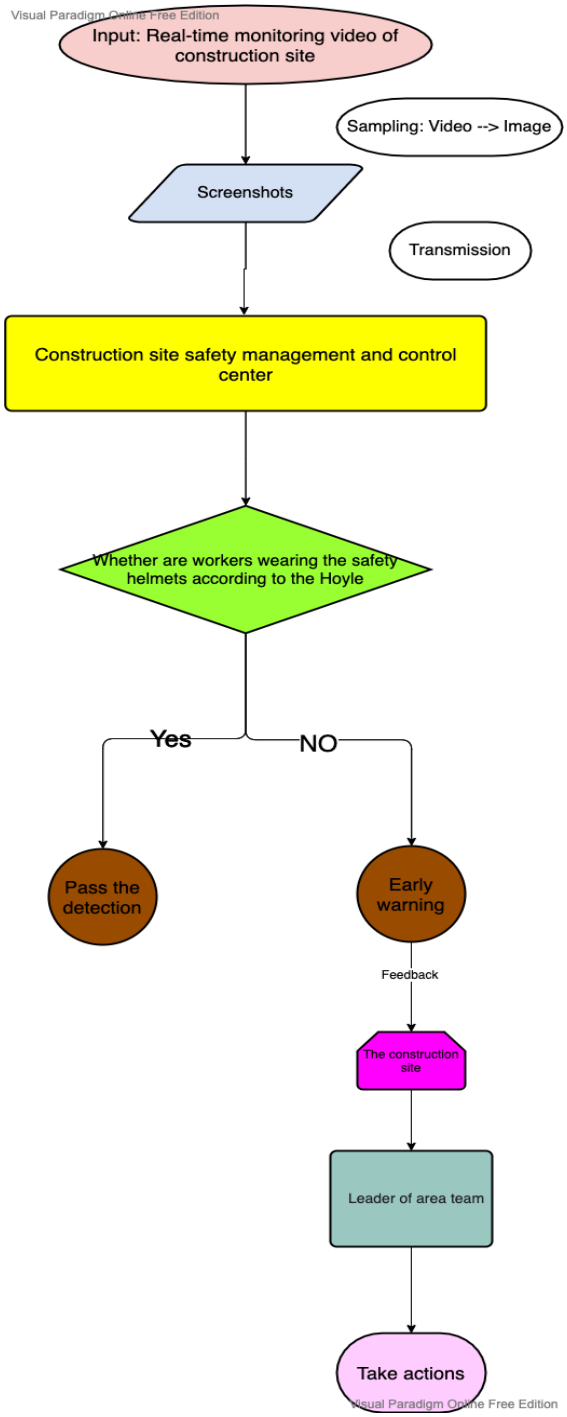

Figure 2. The process of the system.

3. Object detection algorithms

This section compares the RCNN and yolo algorithms in terms of principles, analyzes their respective advantages and disadvantages, and selects the yolo algorithm, which runs faster, from practical application scenarios while ensuring a certain level of accuracy.

In this system, I mainly use the Yolov3 algorithm [6] to do the object detection. There are two most popular categories of object detection algorithms in recent year. Selective search or CNN network (RPN) is required to generate Region Proposal first, and then classification and regression are performed on Region Proposal. One is the R-CNN algorithm based on Region Proposal (R-CNN, Fast R-CNN, Fast-R-CNN), which is two-stage. The other category is YOLO, SSD and other one-stage algorithms, which only use a CNN network to directly predict the categories and positions of different targets. The first kind of method is more accurate, but the speed is slow, but the second kind of algorithm is faster, but the accuracy is lower. In construction sites, we need to get feedback results faster. If a worker fails to pass the helmet wearing detection, the faster detection speed can trigger the early warning system earlier, so as to remind the supervisor in the shortest time, thus minimizing the accident rate and ensuring the safety of the workers. Since we chose to take screenshots of video data as the sampling process, the accuracy of YOLO in image detection is high enough, so the necessity of using R-CNN with higher accuracy but larger memory consumption is not obvious. Therefore, based on the needs in the field of construction in reality, I think the practicability of YOLO algorithm is higher than that of R-CNN.

The comparison between YOLO [7] and Faster R-CNN [8], R-FCN [9], SSD [10] and Retina-net [11] is shown in the Table 2, and we can see that the fps of YOLO is larger than almost all the other algorithms. And YOLOv2 [12] is even faster than YOLO. As we can see, with the update of YOLO algorithm, algorithms should be faster from version to version, so the speed of implement of YOLOv3 [6] should be the best choice for our system, which could detect the circumstance of the wearing of helmets of worker fastest. (Shown in Table 3 and Table 4). For normal video stream, it is running at 30 fps so one could argue that even SSD500 is enough since you don't need full 30fps. Maybe even faster R-CNN is okay, especially when workers in the video stream are not moving super-fast so one detection per second could have been sufficient. The other point is that yolo is smaller than R-CNN, so it can run on low computing device. I imagine you will need a powerful computer to run R-CNN while yolo can be running on a low power embedded device. Maybe even faster R-CNN is okay, especially workers in the video stream are not moving super-fast, but yolo is smaller than R-CNN, so it can run on low computing device. I imagine you will need a powerful computer to run R-CNN while yolo can be running on a low power embedded device. Because the construction site also belongs to the business field, need to consider the cost and profit, if we can use lower cost to achieve our identification requirements, then we can get more profit

Detection Frameworks	Train	mAP	FPS
Fast R-CNN	2007+2012	70.0	0.5
Faster R-CNN VGG-16	2007+2012	73.2	7
Faster R-CNN ResNet	2007+2012	76.4	5
YOLO	2007+2012	63.4	45
SSD300	2007+2012	74.3	46
SSD500	2007+2012	76.8	19
YOLOv2 288 × 288	2007+2012	69.0	91
YOLOv2 352 × 352	2007+2012	73.7	81
YOLOv2 416 × 416	2007+2012	76.8	67
YOLOv2 480 × 480	2007+2012	77.8	59
YOLOv2 544 × 544	2007+2012	**78.6**	40

Table 2. VOC 2007 for YOLOv2 [7].

	backbone	AP	AP_{50}	AP_{75}	AP_S	AP_M	AP_L
Two-stage methods							
Faster R-CNN+++ [3]	ResNet-101-C4	34.9	55.7	37.4	15.6	38.7	50.9
Faster R-CNN w FPN [6]	ResNet-101-FPN	36.2	59.1	39.0	18.2	39.0	48.2
Faster R-CNN by G-RMI [4]	Inception-ResNet-v2 [19]	34.7	55.5	36.7	13.5	38.1	52.0
Faster R-CNN w TDM [18]	Inception-ResNet-v2-TDM	36.8	57.7	39.2	16.2	39.8	**52.1**
One-stage methods							
YOLOv2 [13]	DarkNet-19 [13]	21.6	44.0	19.2	5.0	22.4	35.5
SSD513 [9, 2]	ResNet-101-SSD	31.2	50.4	33.3	10.2	34.5	49.8
DSSD513 [2]	ResNet-101-DSSD	33.2	53.3	35.2	13.0	35.4	51.1
RetinaNet [7]	ResNet-101-FPN	39.1	59.1	42.3	21.8	42.7	50.2
RetinaNet [7]	ResNeXt-101-FPN	**40.8**	**61.1**	**44.1**	**24.1**	**44.2**	51.2
YOLOv3 608 × 608	Darknet-53	33.0	57.9	34.4	18.3	35.4	41.9

Table 3. COCO for YOLOv3 [6].

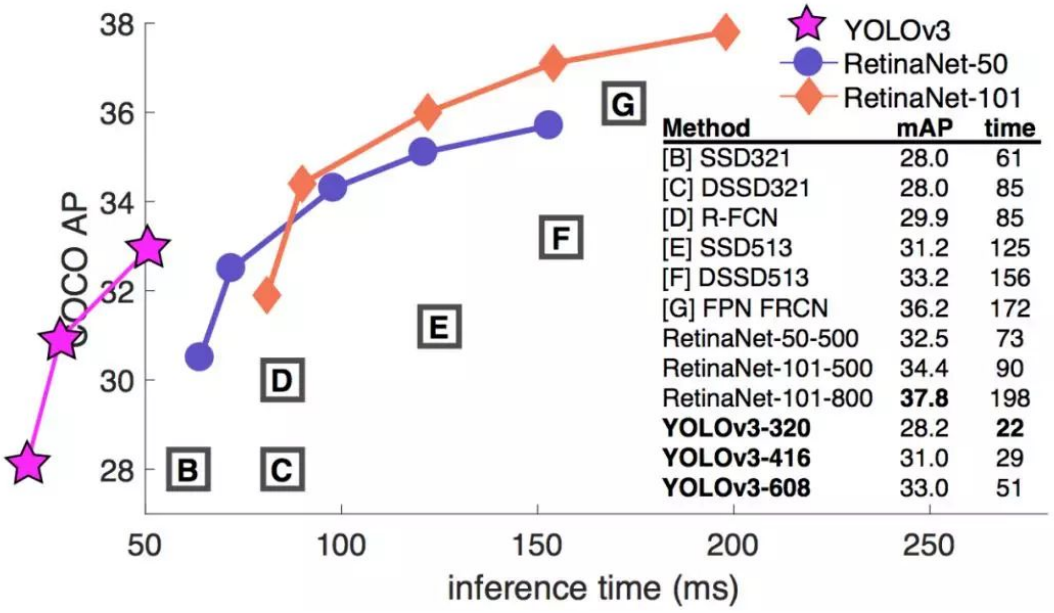

Table 4. Performance of YOCO2 on COCO [6].

4. Conclusions and Future Work

4.1 EasyMonitor

Below is some detection instances checked by the Baidu EasyMonitor [13]. In Figure 3, we can see that the system accurately identifies workers wearing hats and workers without hats, so it can be proved that the accuracy of object detection carried out by YOLO algorithm is sufficient. Also, In Figure 4, we can see that the system can recognize different colors of helmets, which will greatly reduce the number of mismatches. In Figure 5, as mentioned above, the safety cone, the most likely confusing object to be detected wrong in the system detection process, was not misjudged as a safety helmet in the test process, which means the system can still accurately identify the workers without safety helmets when there is a safety cones in the screenshot but there is someone who does not wear safety helmets, thus further ensuring the accuracy of detection.

Figure 3. Safety helmet wearing detection situation.

Figure 4. Safety helmet wearing detection situation.

Figure 5. Safety helmet wearing detection situation.

In this work, I propose a joint system of helmet wearing detection and early warning system, through which the system can be applied to the field of construction, the limitation of safety supervision through manpower in the traditional concept can be solved to a certain extent. In the traditional way of safety supervision, supervision behavior is often affected by people's subjective consciousness, resulting in inaccurate identification results and low supervision efficiency, and there may be many kinds of omission of judgment. By applying this system to actual production, the accuracy of helmet identification and supervision efficiency can be improved to a great extent, thus reducing the occurrence of safety accidents to the greatest extent. And according to the actual needs in construction production, I chose the YOLO algorithm as the main algorithm of the object detection system, so that the system can detect the helmet in the shortest time under the condition of meeting the accuracy, and quickly feedback the results to the leader of corresponding zone, meanwhile, triggering the safety early warning system, and allow each leader to take measures to reduce the occurrence of not wearing the helmets.

Besides, here are many objects similar in shape to safety helmets on the construction site, such as safety cones, which may appear in the screenshots obtained from sampling, thus causing inaccurate detection of safety helmets wearing. Thus, I will also do some machine learning for the system by giving the dataset of safety cones to it, which will make the system can distinguish the safety helmets and the safety cones accurately. After the system is put into the field of actual construction, I will further improve the system according to the experimental results.

In the case of frequent safety accidents and severe construction safety management problems, the combination and promotion of artificial intelligence technology and construction safety problems can

effectively improve the safety management efficiency of the construction industry, and also provide a way to promote the steady development of the construction industry. Creating a comprehensive artificial intelligence building construction safety management system has become a new trend in the safety management of the construction industry in the future. At the same time, we will find from the relationship between the safety management of the construction industry and the development of artificial intelligence that science and technology is the first productive force is not an empty talk, so we also understand the importance of vigorous development and the application of science and technology

In the future, this system can be combined with face recognition technology and big data technology, by collecting the face information of each employee to build an employee information database, directly identify the face information of the construction workers who are not wearing helmets at the construction site and record it into the safety system, each time the record is not worn will affect the bonus of the employees, which can enhance the safety awareness of the employees and motivate them to take the initiative to take precautions and wear helmets consciously, which can reduce the task volume of the leaders' supervision work.

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