Application of artificial intelligence technology in 5G Edge IoT proxy communication terminal of power system

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ABSTRACT

With the construction of new power system, the number of new energy power stations, energy storage stations and other constructions will increase rapidly, which puts forward higher requirements for standardized operation and personnel safety in power infrastructure construction and operation inspection. The traditional safety management mode with on-site supervision as the main method no longer meets the requirements of current power grid scale, organization setting and the number of production activities. 5G edge IoT proxy communication terminal of power system is developed in this paper, which adopts the artificial intelligence technology of face recognition and safety helmet recognition, and uses the characteristics of 5G high speed, low latency, large connection and Beidou high-precision positioning, which can effectively expand the monitoring range and control ability. Using 5G edge IoT proxy communication terminal of power system to build an intelligent, all-round and information-based safety supervision and management system can effectively improve the safety supervision level of personnel at all levels of operation inspection and infrastructure construction site, realize the whole process safety control, risk analysis and early warning function of operation environment and process, and support the digital transformation of State Grid.

Keywords: 5G, artificial intelligence, face recognition, safety helmet recognition, power system

1. INTRODUCTION

The environment and personnel situation of the power infrastructure project site is complex, and it has difficulties such as scattered construction sites, construction safety management, civilized construction supervision, personnel management, and investigation and evidence collection. It is difficult for managers to manage by personnel inspection. With the continuous expansion of the scale of infrastructure projects, coupled with the characteristics of many people, scattered materials, and complex management processes on the infrastructure site, the traditional manual inspection and manual reporting work methods can no longer meet the requirements of project management and control. How to effectively manage and control the frequent occurrence of safety accidents, frequent construction quality, construction site dust, and noise disturbance on the power infrastructure project site are urgent problems to be solved at present[1].

According to the situation and characteristics faced by power grid infrastructure projects, in order to prevent on-site operators of power grid infrastructure projects from entering the live area by mistake and strengthen the construction safety risk management and control between the dangerous area and the personnel activity area, and between the live equipment area and the construction area, the comprehensive use of "safety fences" to implement effective isolation and protection measures has become an indispensable safety measure for engineering construction between the operation area and the non-construction operation area, between the entrance and exit areas of the underpass, and between the equipment and materials stacking area and the construction area. This paper discusses the use of various technical means including artificial intelligence to solve the problem of personnel management on infrastructure construction sites[2, 3].

On-site personnel management of power infrastructure is a weak link in safety management. In previous construction projects, managers basically adopted extensive management methods, which usually led to the difficulty of real-time supervision by construction personnel. An important factor leading to frequent accidents is the accidental entry of construction personnel into dangerous areas or the perfunctory duties of on-site shift personnel. This paper uses the Beidou high-precision positioning technology to grasp the position of personnel and machinery in real time, and uses virtual electronic fences to focus on management of dangerous areas. When construction personnel enter the dangerous

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area by mistake, the 5G communication terminal will issue reminders and alarm signals to notify relevant personnel to reduce the probability of safety accidents. When a safety accident occurs, it can also quickly locate the accident location and shorten the rescue time, effectively ensuring the personal safety of construction workers[4].

5G has the technical characteristics of "large connection, low latency, and high bandwidth". It is an ideal energy network communication method, and operators have already deployed 5G networks in large and medium-sized cities, which are suitable for large-scale applications. This paper discusses the development of a 5G edge IoT proxy communication terminal suitable for the power industry. It adopts artificial intelligence technologies such as face recognition and safety helmet recognition, and makes use of Beidou's high-precision positioning and 5G's high-speed, low-latency, and large-connection features. This paper takes the safety of power production as the overall goal, gives full play to the ability of intelligent management of power infrastructure sites, strengthens the ability of early warning and emergency response mechanisms, effectively reduces the frequency and serious consequences of major and major accidents, and minimizes casualties and property losses. The power 5G edge IoT agent communication terminal is an important link in the construction of a new power system. It will be used in the field of whole-process intelligent management and control of personnel on the power infrastructure construction site, the field of electronic fences, and the field of on-site management and control of power grid operation and maintenance operations. The application prospect is very broad[5].

2. DESIGN AND IMPLEMENTATION

2.1 Design goals

A power 5G edge IoT proxy communication terminal is developed that can solve the typical application scenarios of power system infrastructure sites. The device can meet the typical business applications of infrastructure site scenarios and can collect various types of sensor information on infrastructure sites. It also adopts 5G high-definition image artificial intelligence analysis, fusion recognition and diagnosis technology of multi-source data such as environmental status, face information, helmet images, intelligent vision, etc., thus realizing the safety management and control function of real-time perception of field operations by panoramic information on power infrastructure sites[6].

2.2 Hardware design of 5G edge IoT proxy communication terminal

The hardware design of 5G edge IoT proxy communication terminal is based on ARM processor, including power supply module, Beidou positioning module, 5G communication module, high-definition camera for face information collection, electronic fence area positioning camera, noise sensor module, small weather station module, access control module and sound and light alarm module, etc. The hardware design block diagram is shown in Figure 1.

2.2.1 The Power Supply Module. This module mainly completes the conversion of AC power into a stable 12V DC power supply. The design point is that the module should support three-phase four-wire input.

2.2.2 ARM Processor. The main point of the ARM processor design is to fully consider the communication method based on USB3.0 with the 5G module, and also to meet the computing power requirements of face recognition and helmet recognition.

2.2.3 Beidou Positioning Module. This module mainly completes high-precision positioning and is used for "virtual electronic fence" positioning of dangerous areas on power infrastructure sites.

2.2.4 5G Communication Module. It realizes the remote communication function between the 5G edge IoT proxy communication terminal and the cloud platform, constructs the panoramic multi-dimensional real-time perception of power infrastructure on-site monitoring, and the safety management and control of substation infrastructure on-site mobile operations.

2.2.5 Face Information Acquisition HD Camera Module. This module collects the face information of the workers who want to enter the power infrastructure construction site, downloads the pre-entered photo information of the construction workers from the cloud platform, and performs real-time comparison on the site. After confirming the illegality, the device keeps the smart lock access control closed, and sends out sound and light alarm signals, and uploads the alarm events to the cloud platform in time through 5G.

2.2.6 Electronic Fence Area Positioning Camera Module. This module realizes the electronic fence function of the dangerous area by locating and collecting the video stream information of the camera. When there is an illegal entry or when the construction worker is found not wearing a safety helmet, the device will issue an audible and visual alarm signal and report the event to the cloud platform.

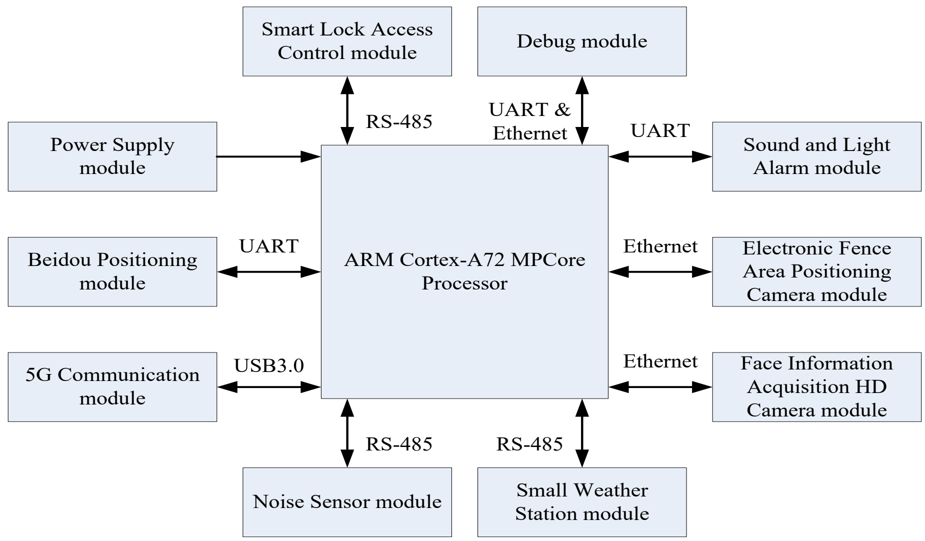

Figure 1. Block diagram of hardware design of 5G edge IoT proxy communication terminal.

2.2.7 Noise Sensor Module. This module mainly collects the noise of the power infrastructure construction site in real time. When the noise exceeds the relevant set threshold, it will issue sound and light warnings, broadcast prompts to stop related operations, and upload the events of the noise exceeding the threshold to the cloud platform.

2.2.8 Small Weather Station Module. It mainly monitors the temperature, humidity, wind speed, wind direction, air pressure and rainfall around the power infrastructure construction site in real time. When the relevant parameters exceed the threshold, for example, the wind speed exceeds the set threshold, the dangerous operation will be temporarily stopped through a broadcast notification, monitor the construction site's various monitoring parameters within the safe range to continue the construction operation to ensure the safety of the power infrastructure.

2.2.9 Sound and Light Alarm Module. This module mainly includes yellow light, red light and broadcast (horn) and other components, and performs functions such as prompting and alarming of related events.

2.2.10 Smart Lock Access Control Module. 5G edge IoT proxy communication terminal will open the smart lock after successful face recognition. When the face recognition fails for a certain number of times, it will be judged as illegal intrusion, the smart door lock will be kept closed, and the event will be reported to the cloud platform.

2.3 Face information collection and face recognition processing flow design

2.3.1 Gstreamer Processing Flow. 5G edge IoT proxy communication terminal is connected to the face information acquisition HD camera through Ethernet, the data stream is transmitted through the RTSP protocol, and the Gstreamer open-source framework is used to process the data stream. Gstreamer is a multimedia framework that supports cross-platform. The application program connects the various steps of multimedia processing in series through the pipeline (Pipeline) to achieve the desired effect. Each step is realized by means of plug-ins (plugins) based on the GObject object system through element (Element), which facilitates the expansion of various functions. We utilize Gstreamer to process RTSP data stream from webcam. First, use the rtph264depay plugin to parse out the H264 package. Second, use the decodebin plug-in to select the corresponding plug-in to decode according to the video stream encoding format. Third, use the jpegenc plug-in to encode the pictures in the video stream in jpg format. Finally, the data is output to the filesink terminal and we can get the photo. The Gstreamer processing flow is shown in Figure 2[7].

2.3.2 Face Recognition Module. The face recognition module is based on the Dlib tool, which is a cross-platform general framework based on modern C++, covering machine learning, image processing, numerical algorithms, data compression, etc. The key code of Python is shown in Table 1. The face recognition processing flow is shown in Figure 3[8, 9].

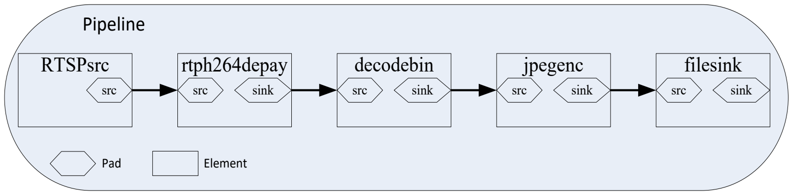

Figure 2. Gstreamer processing flow.

- First, save candidate descriptors after performing face detection on candidates, extracting keypoints and generating descriptors.
- Second, perform face detection on the face to be tested, extract key points and generate descriptors.
- Third, calculate and obtain the Euclidean distance between the test image face descriptor and the candidate face descriptor.
- Finally, according to the calculated Euclidean distance results, it is determined that the person with the smallest distance is the same person.

Table 1. The key code of Python for face recognition.

	Step	**Content**
1	Face keypoint detector	predictor_path = sys.argv[1]
2	Face recognition model	face_rec_model_path = sys.argv[2]
3	Candidate face folder	faces_folder_path = sys.argv[3]
4	Face to be recognized	img_path = sys.argv[4]
5	Load the frontal face detector	detector = dlib.get_frontal_face_detector()
6	Load face keypoint detector	sp = dlib.shape_predictor(predictor_path)
7	Load the face recognition model	facerec = dlib.face_recognition_model_v1(face_rec_model_path)
8	Descriptor extraction	for f in glob.glob(os.path.join(faces_folder_path, "*.jpg")): print ("Processing file: {}".format(f)) img = io.imread(f)
9	Face detection	dets = detector(img, 1) print ("Number of faces detected: {}".format(len(dets)))
10	Calculate Euclidean distance	for i in descriptors: dist_ = numpy.linalg.norm(i-d_test) dist.append(dist_)

2.3.3 Face Recognition Control Unlocking and Alarm Reporting Platform. The control unlocking program is compiled into a dynamic library, which will be called after the face recognition is successful in executing the unlocking function. Finally, the functions of the smart lock can be controlled by the face recognition of the on-site personnel of the power infrastructure. This can improve the work efficiency and prevent the illegal personnel from entering the construction site, and ensure the safety of the construction site of the electric power infrastructure[10].

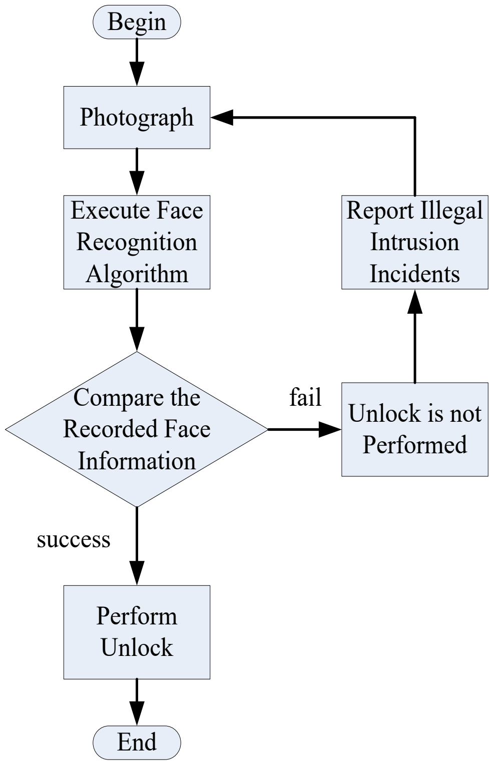

Figure 3. Face recognition control unlocking flow.

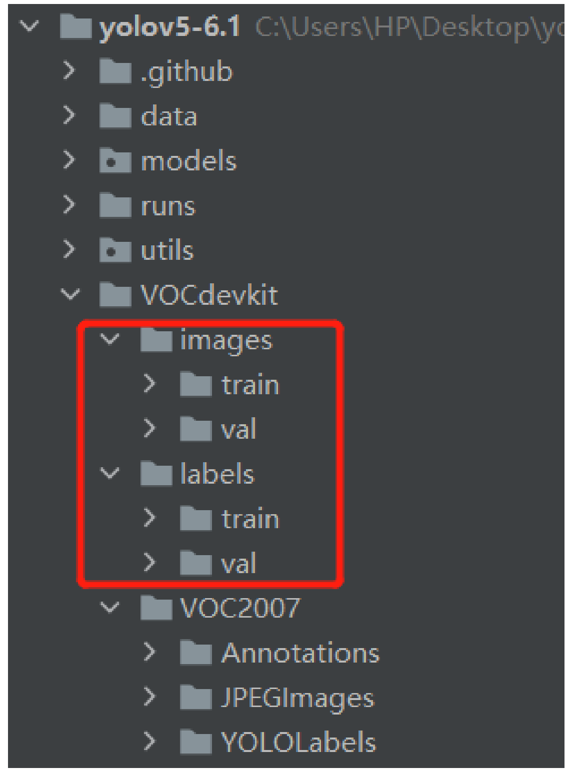

Figure 4. Prepare the dataset file.

2.4 Design of information collection and recognition processing flow of safety helmet

5G edge IoT proxy communication terminal is connected to the electronic fence area positioning HD camera through Ethernet, and the video stream is transmitted to the communication terminal for processing in real time. The training of the YOLOv5 model is mainly carried out from the following aspects[11, 12].

2.4.1 Prepare the Dataset File. First, we prepare the dataset that needs to be labeled, create a new folder named VOC2007, and create a folder named JPEGImages in it to store the image files that need to be labeled. Next, we create a label file called Annotations to store the labels; then we use the labeling tool to label the files in the JPEGImages folder, and save the generated label file to the Annotations folder. Finally, we use the complete code to divide the converted data set into training set and validation set to train our own YOLOv5 model. The directory format is shown in Figure 4[13].

2.4.2 Get Pretrained Weights. In order to shorten the training time of the network and achieve better accuracy, pre-training weights are generally loaded for network training. YOLOv5 provides several pre-training weights, and we can choose different pre-training weights according to different needs. The larger the pre-training weight, the higher the training accuracy will be, but the slower the detection speed will be. The pre-training weight used for training our own dataset this time is YOLOv5s.pt, as shown in Figure 5[14].

2.4.3 Modify Data Configuration Files and Model Configuration Files. Once the pretrained model and dataset are ready, we can start training our own YOLOv5 object detection model. This training target detection model needs to modify the parameters in two yaml files, one is the corresponding yaml file in the data directory, and the other is the corresponding yaml file in the model directory file, as shown in Figures 6 and 7[15].

2.4.4 Start Training. The parameters required are modified to train our own model. Weights are the pre-training weight, cfg is the data configuration file, data is the model training file, and epochs are the training round. Here we specify 100 rounds, as shown in Figure 8.

yolov5l.pt	89.3 MB
yolov5l6.pt	147 MB
yolov5m.pt	40.8 MB
yolov5m6.pt	69 MB
yolov5n.pt	3.87 MB
yolov5n6.pt	6.86 MB
yolov5s.pt	14.1 MB
yolov5s6.pt	24.8 MB
yolov5x.pt	166 MB
yolov5x6.pt	270 MB

Figure 5. Pretrained weights.

```
# Train/val/test sets as 1) dir: path/to/imgs, 2) file: path/to/imgs.txt, or 3) list: [pc
path: ./VOCdevkit  # dataset root dir
train: images/train  # train images (relative to 'path') 128 images
val: images/val  # val images (relative to 'path') 128 images
test:  # test images (optional)

# Classes
nc: 2  # number of classes
names: ['hat', 'person']  # class names
```

Figure 6. Modify data configuration files.

```
# Parameters
nc: 2  # number of classes
depth_multiple: 0.33  # model depth multiple
width_multiple: 0.50  # layer channel multiple
anchors:
  - [10,13, 16,30, 33,23]  # P3/8
  - [30,61, 62,45, 59,119]  # P4/16
  - [116,90, 156,198, 373,326]  # P5/32

# YOLOv5 v6.0 backbone
backbone:
```

Figure 7. Modify model configuration files.

```
def parse_opt(known=False):
    parser = argparse.ArgumentParser()
    parser.add_argument('--weights', type=str, default=ROOT / 'yolov5s.pt', help='initial weights path')
    parser.add_argument('--cfg', type=str, default='models/yolov5s_hat.yaml', help='model.yaml path')
    parser.add_argument('--data', type=str, default=ROOT / 'data/hat.yaml', help='dataset.yaml path')
    parser.add_argument('--hyp', type=str, default=ROOT / 'data/hyps/hyp.scratch-low.yaml', help='hyperparameters path')
    parser.add_argument('--epochs', type=int, default=100)
    parser.add_argument('--batch-size', type=int, default=1, help='total batch size for all GPUs, -1 for autobatch')
    parser.add_argument('--imgsz', '--img', '--img-size', type=int, default=640, help='train, val image size (pixels)')
    parser.add_argument('--rect', action='store_true', help='rectangular training')
    parser.add_argument('--resume', nargs='?', const=True, default=False, help='resume most recent training')
    parser.add_argument('--nosave', action='store_true', help='only save final checkpoint')
```

Figure 8. Start training.

2.4.5 Training Results. After training, the weights will be saved in weights/best.pt under ./runs/exp, and we can see the training results, as shown in Figure 9.

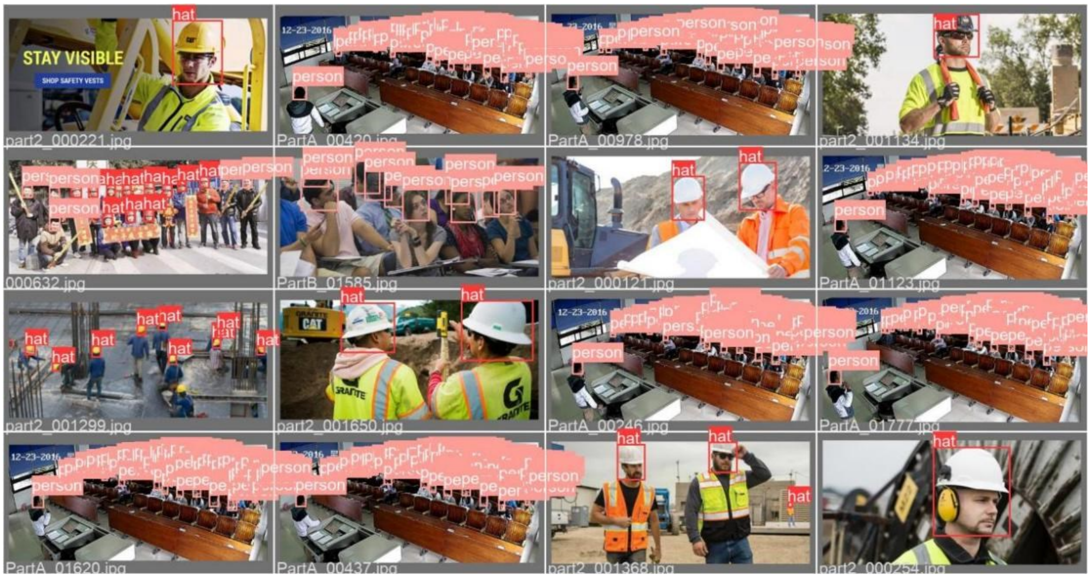

Figure 9. Training results.

3. PERFORM REASONING TESTS AND RESULTS

The best.pt file obtained by model training is transplanted into the 5G edge IoT agent communication terminal to perform inference on the picture, as shown in Figure 10. After this operation is completed, we can see that the communication terminal has completed the identification of the safety helmet on the construction site, as shown in Figures 11 and 12.

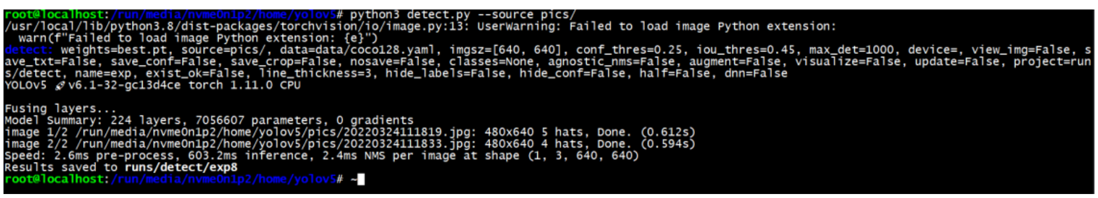

Figure 10. Perform reasoning tests.

Figure 11. Result of perform reasoning tests.

Figure 12. Result of perform reasoning tests.

4. CONCLUSION

With the increasing number and scale of substations, due to the complexity of on-site construction personnel, on-site security protection and monitoring are relatively weak. The research results of this project will focus on on-site safety management as the benchmark, highlight personnel management, and emphasize that managing and controlling operators is equivalent to controlling on-site safety. The 5G edge IoT proxy communication terminal developed by the project can provide alarms according to the safety distance of the dangerous areas around the site staff, reminding the staff to maintain a sufficient safety distance, so as to ensure the safety of the site staff. The research results of this project have the following effects: effectively improving the management level of personnel on the infrastructure construction site; helping managers to grasp the location of personnel in real time; realizing the virtual electronic fence for key management of dangerous areas; reducing safety accidents caused by construction workers entering dangerous areas by mistake.

This project actively responds to the national 5G new infrastructure strategy, which can promote the implementation of 5G applications of the State Grid, provide technical support for intelligent power transmission and transformation inspection and power Internet of Things, which are increasingly complex in business scenarios, support the development of related industries, and contribute to the development of the new economy. In addition to general applications, the results of this project can be applied to all aspects of the intelligent transportation inspection application system for power transmission, transformation and distribution, meeting the key requirements of transportation inspection services in agile connection, real-time business, data optimization, application intelligence, security and privacy protection, etc. It improves the communication performance, network coverage capability and computing capability of the IoT sensing terminal, which is an improvement and expansion of the power grid cloud platform and has good social benefits.

The results of this project will be applied to the field of intelligent management and control of personnel in the whole process of infrastructure construction, electronic fences, personnel safety management and control and other fields, and the application prospects are very broad.

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