An Application of Image Recognition Technology Based on Deep Learning in Safety Review of Reservoir Dam Metal Structure

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Abstract. The safety review calculation of the gate is an important job in the safety evaluation of metal structures. In accordance with the requirements of the specification, this paper has developed an intelligent software for metal structures safety review calculation, which can automate the calculation process and generate a review evaluation report. In order to simplify the labor of the manual input of a large number of gate review calculation parameters, this paper used a deep-learning-based image recognition technology to partially realize the collection of the information relevant to the calculation from the drawings of metal structures, laying the foundation for later realization of the fully intelligent gate safety review.

1. Introduction

As a water-retaining structure that intercepts the flow of river and channels to raise the water level or regulate the flow, reservoir dam is an important engineering measure to control the temporal and spatial distribution of water resources and optimize the allocation of water resources. Zhejiang Province has many mountains and few plains, which is suitable for the construction of reservoirs to give full play to the comprehensive benefits of flood control, irrigation, and power generation. At present, Zhejiang Province has 5 large (1) reservoirs, 29 large (2) reservoirs, 158 medium reservoirs, and at least 4105 small reservoirs. A comprehensive and reasonable assessment of the safety status of these reservoirs and dams can provide good technical support for the scientific dispatch and safe operation of reservoirs, and is of great significance for ensuring social public safety. Therefore, the Ministry of Water Resources promulgated and implemented *the Reservoir Dam Safety Appraisal Measures* on August 1, 2003. The appraisal content mainly includes evaluation of the engineering quality, dam operation management, the standard for flood control, structural safety of the dam, seepage safety, seismic safety, metal structure safety and comprehensive dam safety[1].

As an important job of the safety appraisal of reservoirs and dams, the safety review calculation of gates is an important component of the safety evaluation of metal structures. According to *the Guidelines for Safety Evaluation of Reservoirs and Dams (SL 258)*, the calculation and analysis of gates should focus on reviewing the strength, stiffness and stability of the structure[1]. The method of calculation, load combination and control standards shall be implemented in accordance with *the Code for Design of Steel Gates for Water Conservancy and Hydropower Engineering (SL 74)*. Specifically, the gate calculation review content mainly includes: gate panel thickness and converted stress, main beam strength and deflection, secondary beam strength and deflection, radial steel gate arm strength, radial steel gate main frame stability, lifting lugs and hinge strength, the force of opening and closing gates,

etc[2]. In order to simplify the above calculation process and improve the efficiency of metal structure safety review, the author developed *the Metal Structure Safety Review Intelligent Entry and Report Generation Software (Registered Copyright No. 6064630)*. The advantages of the software are as follows:

Firstly, it is developed in the Java programing language, and has all material mechanics formulas and parameter tables coded in the program, which overcomes the shortcomings of traditional methods using Excel spreadsheets that are poor in encapsulation and scalability.

Secondly, the SQLite3 embedded database is used to store the section steel parameters into the database, which is convenient for users to quickly check and use the geometric and mechanic parameters of a specific steel section.

Thirdly, applying the Browser-Server architecture, the HTML, CSS, and JavaScript languages are used to develop the Internet user interface. Users of this software only need to install the chrome browser in order to run the software without having to setup an installation environment.

Finally, it can intelligently generate safety review reports for gates.

In the process of undertaking the safety review job of the metal structure of the dam safety assessment of water conservancy projects, the author found that the archives kept by the reservoir management unit are mostly paper documents. Even electronic documents are mostly scanned images, making it difficult for the computer to quickly process information. Usually engineers have to identify important information from these gates drawings and enter the data manually. Although the calculation software has been developed in accordance with relevant specifications, which has improved the work efficiency to great extent, the manual input of parameters of the materials, positions, and cross-sectional shapes of the horizontal and vertical beams, rubber seal strips and other components of the gate is still tedious and error-prone. According to preliminary statistics, the review calculation of a plane gate requires at least 86 key parameters such as materials, locations, and calculation conditions, and the review of a radial steel gate requires at least 105 key parameters. If paper document information can be intelligently imported into metal structure safety review calculation software through computer technology, work efficiency will be greatly improved.

Image recognition technology based on deep learning provides effective information technology methods for solving the problems above. In recent years, breakthroughs in deep learning technology have brought about considerable progress in image recognition technology, especially Optical Character Recognition (OCR) technology. Zhi Tian et al. proposed Connectionist Text Proposal Network (CTPN), which can accurately locate text areas in natural scene pictures[3]. Jianqi Ma et al. used Rotation Region Proposal Networks (RRPN), which can effectively perform horizontal text detection[4]. Yuchen Dai et al. adopted Fused Text Segmentation Networks (FTSN)[5], and Yuliang Liu et al. adopted Deep Matching Prior Network (DMPNet), which can support oblique text detection[6]. Baoguang Shi et al. used Convolutional Recurrent Neural Network (CRNN) and Connected Temporal Classifier (CTC) and achieved effective recognition of variable length text[7].

In this paper, CTPN, CRNN and CTC are used in combination to extract important engineering information relevant to gate safety review calculation from the metal structure drawings, which can realize the automation of the calculation input process to a certain extent.

2. Model Architecture of Neural Networks

2.1. Connectionist Text Proposal Network(CTPN)

A 3×3 spatial window is slided through the last convolutional map(conv5)of the VGG16 model. The sequential windows in each row are connected by a Bi-directional LSTM (BLSTM) recurrently. The RNN layer is connected to a 512D fully-connected layer, followed by the final output layer, which jointly predicts text/non-text scores，y-axis coordinates and side-refinement offsets of k anchors.

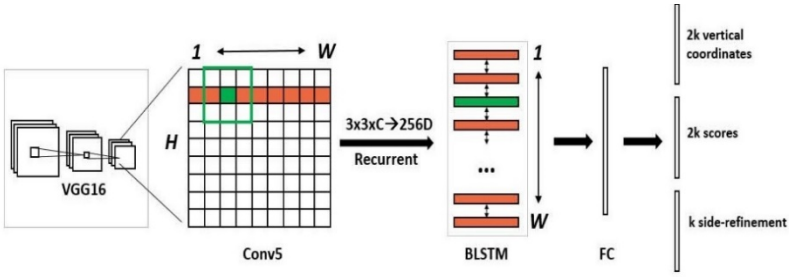

Figure 1. Architecture of CTPN

2.2. Convolutional Recurrent Neural Network (CRNN)

CRNN mainly includes three parts:

(1) Convolutional layers, which are mainly used to extract spatial features of images.

(2) Recurrent layers, which use deep bidirectional LSTM to extract sequence features.

(3) Transcription layers, which are used to convert the prediction result of each frame into the final tag sequence.

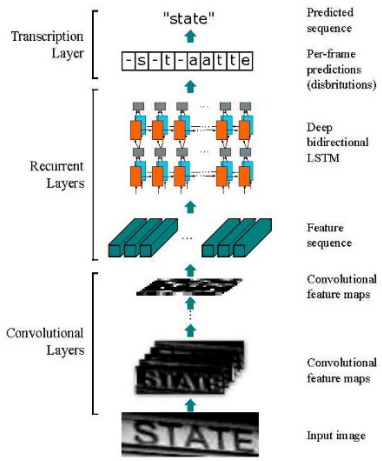

Figure 2. Architecture of CRNN

2.3. Connected Temporal Classifier (CTC)

Concatenated temporal classifier (CTC), a tool for sequence modeling which is widely used in the fields of speech recognition and optical character recognition, is currently the main method for variable-length annotation learning in the field of machine learning. Its main advantage is that there is no need to carry out cumbersome position labeling of sequence fragments, and the optimization of the objective function can be smoothly realized by labelling sequence tags.

3. Training dataset

The experiment uses International Conference on Document Analysis and Recognition Dataset 2013 (ICDAR 2013) as training data for CTPN network. The multi-directional text recognition data set (HUST-TR 400) is used as the training data of the CRNN+CTC network.

4. Graphs for Inference

This test uses drawing pictures of the layout, the master plan and the detailed structure of the radial steel gate of the spillway of the Baixi Reservoir in Ningbo City, Zhejiang Province. The table area or text area of the pictures above are used to test the image recognition performance of this model.

5. Experiment result and analysis

5.1. Connectionist Text Proposal Network (CTPN)

After 70,000 training steps of this model, during which the gradient optimization process is involved, the model training loss convergence curve is shown in Figure 3. The figure shows that: (a) the initial loss of the model at the beginning of this training (0 to10000) is relatively large, ranging from 0.8 to 1.0; (b) the loss of the model in the middle period of this training (10000 to 67000) is gradually reduced, though overfitting occurs at individual step lengths, where the loss is large; (c) the model loss gradually stabilizes below 0.2 in the final training period (67000 to 70,000).

After training, we applied the model to the pictures for detection, and the detection performance can be shown from Figure 4 through 7. From Figure 4 through 7 we do the analysis as follows:

Firstly, the scene text detection model has an excellent performance on the recognition job of the plain text information area without tables (Figure 6), and can achieve accurate recognition.

Secondly, the model does not perform well enough in the detection of the text area in the table, as shown in Figure 5, where picture areas of many serial numbers and quantity information cannot be accurately identified.

The reason for the different performance of the model upon plain text pictures and table text pictures is that the images of the CTPN model training data set are all text areas in the natural scene, and there is no table boundaries around them. Therefore, the model has a better recognition effect on Figure 6, while the detection performance of Figure 4, 5, and 7 needs to be improved.

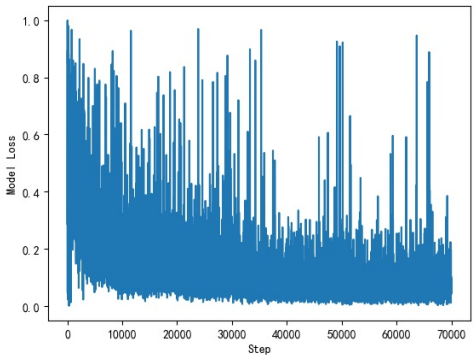

Figure 3. Convergence of CTPN model during training.

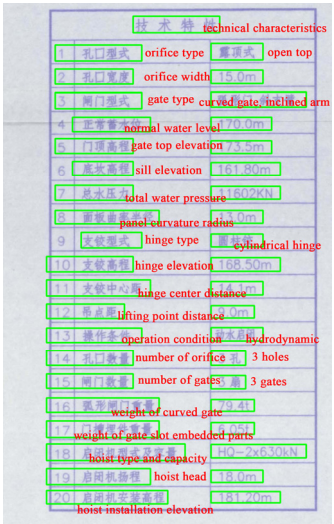

Figure 4. Table area of sluice layout graph.

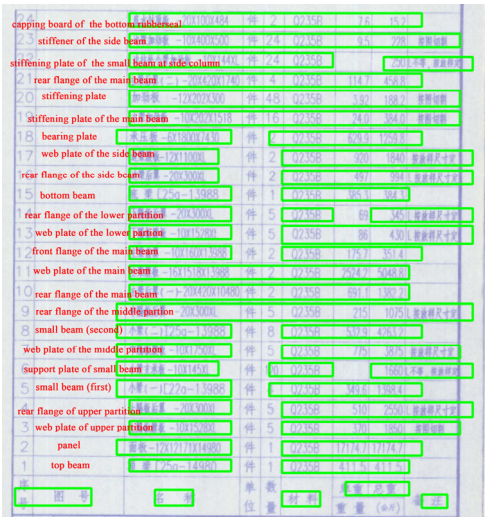

Figure 5. Table area of sluice structure layout graph.

Figure 6. Text area of sluice master plan graph.

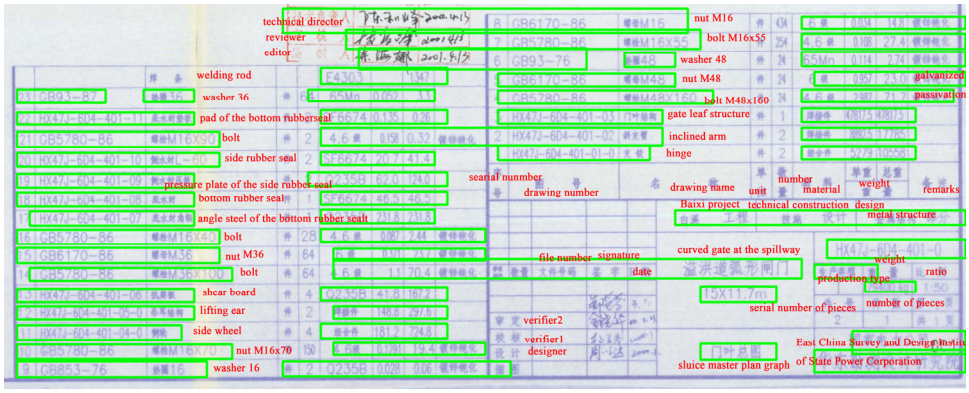

Figure 7. Table area of sluice master plan graph.

5.2. Convolutional Recurrent Neural Network (CRNN) and Connected Temporal Classifier (CTC)

The convolutional recurrent neural network *(CRNN) and Connected Temporal Classifier (CTC)* uses a pre-trained Chinese character recognition model to perform Chinese character recognition on the text area extracted by the CTPN model in 4.1. The pictures of texts after recognition are shown in Figure 8.

As shown in Figure 8 (a) to (d), we can get:

Firstly, the overall performance of this model when doing text recognition on plain text information areas without tables (Figure 8(c)) and regular table text areas (Figure 8(a) to (b)) is good, based on which we can effectively extract important engineering information.

Secondly, the model does not perform well when doing recognition on text areas in the irregular table. As shown in Figure 8(d), because the table is arranged irregularly, multiple columns of information are mixed together, and engineering information cannot be effectively processed. However, the overall accuracy of Chinese character recognition is high.

技术特性 (Technical Characteristics)
1 孔口型式 露顶式(1 Orifice type open top type)
2 孔口宽度 15.0m(2 Orifice width 15.0m)
3 闸门型式 弧形门，斜支臂(3 Gate type Radial door, inclined arm)
4 正常蓄水位 170.0m(4 Normal water storage level 170.0m)
5 门顶高程 173.5m(5 gate top elevation 173.5m)
6 底坎高程 161.80m(6 sill elevation 161.80m)
7 总水压力 11602KN(7 Total water pressure 11602KN)
8 面板曲率半径 13.0m(8 Panel curvature radius 13.0m)
9 支铰型式 圆柱铰(9 hinge type cylindrical hinge)
10 支铰高程 168.50m(10 Hinge elevation 168.50m)
11 支铰中心距 14.1m(11 Center distance of hinge 14.1m)
12 吊点距 9.0m(12 Lifting point distance 9.0m)
13 操作条件 动水启闭(13 Operating conditions dynamic)
14 孔口数量 3 孔(14 Number of ports 3 holes)
15 闸门数量 3 扇(15 Number of gates 3)
16 弧形闸门重量 79.4(16 Radial gate weight 79.4)
17 门槽埋件重量 6.05t(17 Door slot embedded parts weight 6.05t)
18 启闭机型式及容量 HQ-2x630kN(18 Hoist type and capacity HQ-2x630kN)
19 启闭机扬程 18.0m(19 Hoist head 18.0m)
20 启闭机安装高程 181.20m(20 Hoist installation elevation 181.20m)

(a)

24 底水封顶板-20X100X484 件 2 Q235B 7.6 15.2
边梁加劲板-10X400X500 件 24 Q235B 9.5 228 按图切割
边柱处小梁加劲板-10X144XL 件 124 Q235B 250 (不等，按放样定
主后翼(二)-20×420×1740 件 件 4 Q235B 114.7 458.8
加劲板-12X202X300 件 48 Q235B 302 188.2 按图切割
主梁加劲板-10X202X1518 件 16 Q235B 24.0 384.0 按图切割
承压板-6X1800X7430 件 2 Q235B 6299 1259.8
边梁腹板-12X1100XL 2 Q235B 920 1840 按放样尺寸定
边梁后翼-20X300XL 2 Q235B 497 994 L 按放样尺寸定
底梁[25g-13988 Q235B 3853 384.3
下隔板后翼-20X300XL Q235B 69 345 L 按放样尺寸定
下幅板板-10×1528× 5 Q235B 86 430 L 按放样尺寸定
主梁前翼-10X160X13988 Q235B 175.7 351.4
主梁腹板-16X1518X13988 件 2 Q235B 2524.2 5048.8
主梁后翼(一)-20X420X10480 件 2 Q235B 691.1 13822
中隔板后翼-20X300XL 件 5 Q235B 215 1075 L 按放样尺寸定
小梁(二)I250-13988 3 Q235B 532.9 4263.2
中隔板腹板-10X1750XL 件 5 Q235B 775 3875 按放样尺寸定
小梁支承板-10X145X 件 120 Q235B 1660 (不等按放样定
梁(-)[220-13988 件 4 Q235B 349.6 1398.4
4 上隔板后翼-20X300XL Q235B 510 2550 L 按放样尺寸定
上隔板腹板-10X1528XL 件 5 Q235B 3701 1850 按图切割
2 面板-12X12171X14980 1 件 Q235B 17174.71 117174.7
顶梁[250-14980 1 件 Q235B 411.5 4115
图号 材料 单重 总重

24 Bottom water capping plate-20X100X484 pieces 2 Q235B 7.6 15.2
Side beam stiffening plate-10X400X500 pieces 24 Q235B 9.5 228 Cut according to the picture
Small beam stiffening plate at the side column-10X144XL piece 124 Q235B 250 (varies, according to stakeout
Main rear wing (2)-20×420×1740 pieces 4 Q235B 114.7 458.8
Stiffening plate-12X202X300 pieces 48 Q235B 302 188.2 cut according to the picture
Main beam stiffening plate-10X202X1518 pieces 16 Q235B 24.0 384.0 Cut as shown
Bearing plate-6X1800X7430 pieces 2 Q235B 6299 1259.8
Edge beam web-12X1100XL 2 Q235B 920 1840 According to the loft size
Side beam rear wing-20X300XL 2 Q235B 497 994 L according to the loft size
Bottom beam [25g-13988 Q235B 3853 384.3
Lower baffle rear wing-20X300XL Q235B 69 345 L according to the loft size
Lower board -10×1528× 5 Q235B 86 430 L is determined according to the stakeout size
Main beam front wing-10X160X13988 Q235B 175.7 351.4
Main beam web-16X1518X13988 pieces 2 Q235B 2524.2 5048.8
Main beam rear wing (1)-20X420X10480 pieces 2 Q235B 691.1 13822
Central partition rear wing-20X300XL piece 5 Q235B 215 1075 L is determined according to the loft size
Trabecular (2) I250-13988 3 Q235B 532.9 4263.2
Middle partition web-10X1750XL piece 5 Q235B 775 3875 According to the loft size
Trabecular support plate-10X145X pieces 120 Q235B 1660 (varies according to stakeout
Beam (-) (220-13988 pieces 4 Q235B 349.6 1398.4
4 The rear wing of the upper baffle-20X300XL Q235B 510 2550 L is determined according to the loft size
Upper partition web-10X1528XL piece 5 Q235B 3701 1850 Cut according to the picture
2 Panel-12X12171X14980 1 piece Q235B 17174.71 117174.7
Top beam [250-14980 1 piece Q235B 411.5 4115
Drawing number material unit weight total weight

(b)

说明
1.图中高程、桩号以 m 计，尺寸以 mm 计。
2.闸门出厂前应进行整体组装，组装的允许偏差应符合《水利水电工程钢闸门制造安装及验收规范》(DL/T5018-94)的 8.5 节的规定.
3.抗剪板应在斜支管与门叶结构相连接后再焊，焊缝为三面连续角焊缝.焊缝高度 16mm，抗剪板与接触板端面必须接触紧密.
4.吊耳在闸门工地组装时焊于门叶面板上，采用焊，焊缝高度为 16mm.
5.闸门涂装前必须进行表面预处理，其基体金属清洁度等级不低于 So2 号级，粗糙度值在 40-70pm，/底层涂料为 702 环氧富锌漆一道，干膜厚度 30um，中间层 842 环氧云铁底漆一道，干膜厚度 100pm，面漆：670-3 氧化橡胶漆一道，干厚 100pm.
Description
1. In the figure, the elevation and pile number are in m, and the size is in mm.
2. The gate should be assembled as a whole before leaving the factory, and the allowable deviation of the assembly should comply with the provisions of Section 8.5 of the "Specification for Manufacturing, Installation and Acceptance of Steel Gates for Water Conservancy and Hydropower Engineering" (DL/T5018-94).
3. The shear plate should be welded after the diagonal branch pipe is connected to the door leaf structure. The weld is a three-sided continuous fillet weld. The height of the weld is 16mm, and the end surface of the shear plate and the contact plate must be in close contact.
4. The lifting lugs are welded to the door leaf panel during assembly at the gate site, and the weld height is 16mm.
5. Surface pretreatment must be carried out before the gate is painted. The cleanliness level of the base metal is not lower than So2 level, and the roughness value is 40-70pm. /The primer is a 702 epoxy zinc-rich paint, and the dry film thickness is 30um. One middle layer of 842 epoxy mica primer, dry film thickness of 100pm, top coat: 670-3 oxide rubber paint, dry thickness of 100pm.

(c)

焊条 E4303 1347 5 GB6170-86 螺母 M48 24 6 级 0957 23.0 镀锌钝化
23 GB93-87 垫面 36 64 65Mn 0.052 133 4 GB5780-86 螺栓 M48X160 4.6 级 2987 71.7 镀锌钝化
22 HX47J-6D4-401-11 底水封垫板 2 SF6674 0.135 0.26 3 HX47J-6D4-401-03 门叶结构焊接件 478175 478175
21 GB5780-86 螺栓 M16X90 4.6 级 0.158 0.32 镀锌钝化 2 HX47J-6D4-401-02 斜支 焊接件 88925 17785
20 HX47J-6D4-401-10 侧水封 L-60 2 SF6674 20.7 41.4 HX47J-6D4-401-01-0 支铰 组合件 5279 10558
19 HX47J-6D4-401-09 侧水封压板 2 Q235B 62.0 124.0 重量
18 HX47J-6D4-401-08 底水封 SF6674 46.5 46.5 母 白溪工程 技施设计 金属结构部分
17 HX47J-6D4-401-07 底水封角钢 Q235B 231.8 231.8
16 GB5780-86 螺栓 M16X40 4.6 级 0.087 2.44 镀锌钝化 溢洪道弧形闸门 15X11.7m HX47J-6D4-401-0
15 GB6170-86 螺母 M36 6 级 0371 23.7 镀锌钝化 生产 英型 重量人 例
14 GB5780-86 螺栓 M36X100 4.6 级 1.1 170.4 镀锌钝化 数量 文件号码 签字 |日期 79400kg 150
13 HX47J-6D4-401-06 抗剪板 Q235B 41.8 167.2 件号 件数 第
12 HX47J-6D4-401-05-0 吊耳结构 焊接件 148.8 297.6 2 共 审定
1 H1×475-604-401-04-0 侧轮 组合件 181.2 724.8 校核 门叶总图 国家电力公司 004 华东勘测设计研究院
10 CB5780-86 螺栓 M16X70 4.6 级 0.1201 19.4 镀锌钝化 设计 2
9 GB853-76 垫围 16 2 Q235B 0.028 0.06 镀锌钝化 描图

Electrode E4303 1347 5 GB6170-86 Nut M48 24 Class 6 0957 23.0 Galvanized passivation
23 GB93-87 pad 36 64 65Mn 0.052 133 4 GB5780-86 bolt M48X160 4.6 grade 2987 71.7 galvanized passivation
22 HX47J-6D4-401-11 Bottom water sealing plate 2 SF6674 0.135 0.26 3 HX47J-6D4-401-03 Door leaf structure welding parts 478175 478175
21 GB5780-86 bolt M16X90 4.6 grade 0.158 0.32 galvanized passivation 2 HX47J-6D4-401-02 oblique support welding piece 88925 17785
20 HX47J-6D4-401-10 Side water seal L-60 2 SF6674 20.7 41.4 HX47J-6D4-401-01-0 Hinge assembly 5279 10558
19 HX47J-6D4-401-09 Side water seal pressure plate 2 Q235B 62.0 124.0 Weight
18 HX47J-6D4-401-08 Bottom water seal SF6674 46.5 46.5 Mother Baixi Project Technical construction design Metal structure part
17 HX47J-6D4-401-07 Bottom water sealing angle steel Q235B 231.8 231.8
16 GB5780-86 Bolt M16X40 Class 4.6 0.087 2.44 Galvanized passivation Spillway arc gate 15X11.7m HX47J-6D4-401-0
15 GB6170-86 Nut M36 Grade 6 0371 23.7 Galvanized passivation Production British type weight
14 GB5780-86 bolt M36X100 4.6 grade 1.1 170.4 galvanized passivation quantity file number signed | date 79400kg 150
13 HX47J-6D4-401-06 Shear plate Q235B 41.8 167.2 Piece number Piece number
12 HX47J-6D4-401-05-0 Welding parts of lifting lug structure 148.8 297.6 2 total approval
1 H1×475-604-401-04-0 Side wheel assembly 181.2 724.8 Check gate leaf general plan State Power Corporation 004 East China Survey, Design and Research Institute
10 CB5780-86 bolt M16X70 4.6 grade 0.1201 19.4 galvanized passivation design 2
9 GB853-76 pad circumference 16 2 Q235B 0.028 0.06 galvanized passivation tracing

(d)

Figure 8. Text recognition Results of graphs for inference.

6. Conclusion

We utilized a model for engineering information extraction, which combined CTPN and CRNN and CTC. CTPN is used to perform text areas detection and CRNN and CTC are used jointly to achieve text recognition results based on text areas detection results mentioned before. In summary, this model has better performance on pictures of plain text areas and regular table areas than those of irregular table areas. At this stage, the experiment results achieved so far showed that this model can be reliably used to extract important engineering information in order for the computer to process so as to automatically feed these parameters into another calculation model, which is used to perform the mechanical calculation on gates.

7. Future works

The CTPN model training data set can be improved in the following works. Adding table pictures for text areas detection training may achieve better results, thus improving the overall performance of the whole model.

Acknowledgments

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