

Image-Based Captcha Recognition Using Deep Learning Models

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Abstract. Completely Automated Public Turing Test to Tell Computers and Humans Apart (CAPTCHA) is an important human-machine distinction technology for website to prevent the automatic malicious program attack. CAPTCHA recognition studies can find security breaches in CAPTCHA, improve CAPTCHA technology, it can also promote the technologies of license plate recognition and handwriting recognition. This paper proposed a method based on Convolutional Neural Network (CNN) model to identify CAPTCHA and avoid the traditional image processing technology such as location and segmentation. The adaptive learning rate is introduced to accelerate the convergence rate of the model, and the problem of over-fitting and local optimal solution has been solved. The multi task joint training model is used to improve the accuracy and generalization ability of model recognition. The experimental results show that the model has a good recognition effect on CAPTCHA with background noise and character adhesion distortion.

Keywords. Convolutional neural network;, CAPTCHA; Adaptive learning rate; Multi task joint training.

INTRODUCTION

With rapid development of the Internet industry, more and more network security issues happen. CAPTCHA [1] technology has a wide range of applications in network protection and information security. CAPTCHA is the abbreviation of Completely Automated Public Turing Test to Tell Computers and Humans Apart. As a network security strategy, it is mainly used for websites to prevent automatic malicious program attacks such as automatic registration spam automatic voting and so on. For humans, the recognition accuracy of effective CAPTCHAs is at least 80%, but for computers, it should be less than 0.01% [2]. The research of CAPTCHA identification can find the defects of the CAPTCHAs in time, and provide improvement suggestions for the code generation program, and increase the security of the CAPTCHAs, At the same time, as a kind of Turing test, CAPTCHA recognition combines the research results of image processing and artificial intelligence field, and plays a positive role in the development of artificial intelligence technology, such as license plate recognition and handwriting recognition.

Motivation

This paper focuses on the most widely used character-based images CAPTCHA, which is composed of random numbers and English letters. It is easy to generate, not affected by the user's cultural background, and the brute force is difficult to crack. We can create a picture containing numbers and letters by mainstream programming languages [3]. In order to increase the difficulty of recognition by computer, the CAPTCHAs need to add background noise and carry out the characters twist conglutination processing. In the field of traditional image processing, the CAPTCHA recognition technology is divided into image preprocessing, positioning, character segmentation, character recognition and other steps. However, it is difficult to establish an accurate template set because of the adhered and complicated CAPTCHA. The traditional method of extracting pixel points one by one and template matching, can only recognize simple CAPTCHAs, while there is no efficient method to recognize the adhered and complicated CAPTCHA. Therefore, a more efficient method is needed to identify such CAPTCHAs.

Nowadays, the deep learning network is widely used in scientific research. As one of the hotspots in artificial intelligence research field in recent years, it has achieved great success in many fields, such as image recognition,

speech recognition, natural language processing and target detection. Compared with the traditional pattern recognition method, the biggest advantage of deep learning is that can learn features actively without artificial design. Based on the above observation and inspiration, a convolutional neural network (CNN) algorithm [4] is proposed to identify the CAPTCHAs. For the problem of model convergence rate and global optimal solution, the adaptive learning rate is introduced to improve the learning ability of the network, and it has better convergence and robustness. The multi task joint training model is used to speed up the training speed of the model and improve the generalization ability of the model. The method of this paper directly uses images as input to CNN, do not have to split the image for the characters, active learning features in the process of network training. The experimental results show that the proposed method has a good recognition effect on CAPTCHA with background noise and character adhesion distortion.

LITERATURE SURVEY

TABLE 1. Review Paper 1

Resource Paper Name	Description	Limitations
End-to-End CAPTCHA Solving Using Sequence-to-Sequence Models	Proposed an end-to-end deep learning model using CNNs and RNNs, achieving high accuracy in solving CAPTCHAs with variable lengths and distortions.	Inefficiency with Complex CAPTCHAs

TABLE 2. Review Paper 2

Resource Paper Name	Description	Limitations
Improving CAPTCHA Recognition Using Data Augmentation and Transfer Learning	Enhanced CAPTCHA recognition by applying data augmentation and transfer learning, improving convergence and generalization.	Latency in the generation, Storage of hash value can be cost and time complexity

TABLE 3. Review Paper 3

Resource Paper Name	Description	Limitations
A Hybrid CNN and Attention Mechanism for CAPTCHA Recognition	Improved CAPTCHA recognition using a hybrid CNN and attention mechanism, showing better robustness and accuracy.	The need for large labelled datasets and computationally expensive models, especially in machine learning and OCR-based systems

PROPOSED SYSTEM

A. Contrast Normalization

Contrast normalization can avoid the neuron output saturation caused by excessive absolute input value, and ensure small values in the output data will not be swallowed. It's can enhance the generalization of the network, eliminate the influence of brightness and contrast variance effectively on the network, can greatly reduce the dependence between neighbouring factors and accelerate the convergence of the network. Before the network training, this paper extracts the image for contrast normalization. Set the brightness value of the image: to I , and the brightness value after the local contrast normalization is E , contrast normalization method [12] can be expressed as:
$$I_{ij} = \frac{I_{ij} - \mu}{\sigma} \cdot C$$
 Where, μ , σ , C , is the dimension of image blocks; C is constant 1, avoiding denominator be zero. μ , σ is the mean and standard deviation of image pixel values.

B. Multi task joint training

Multi task learning is a method of machine learning opposite to single task learning. The main goal is to improve the generalization ability by using domain specific information in the training signals hidden in multiple related tasks. Multi task learning can accomplish this task by using shared representation to parallel

training multiple tasks. Multi task learning network parameter sharing, and can reduce the number of models, improve learning efficiency. During the training of CAPTCHA recognition model, images labels are divided into multiple learning tasks, each task training one character and all tasks training together. The structure of the multi task joint training network is shown in figure.1: Fig. 1. Model of Multi task joint training

C. CAPTCHA recognition model

VGG-Net [13] is a convolutional neural network developed by Oxford visual geometry group. The model is based on the Alex-Net [14] network architecture, which deepens the convolutional layer and reduces the size of the convolution kernel. Through the improvement of these two aspects, the performance of VGG-Net has been greatly improved. According to the advantages of VGG-Net, combined with the work of this paper, we propose a deep CNN method to recognition a series of characters without pre-segmentation.

Advantages over the previous system

- Automated Feature Learning
- End-to-End Solution
- High Accuracy

Model Implementation

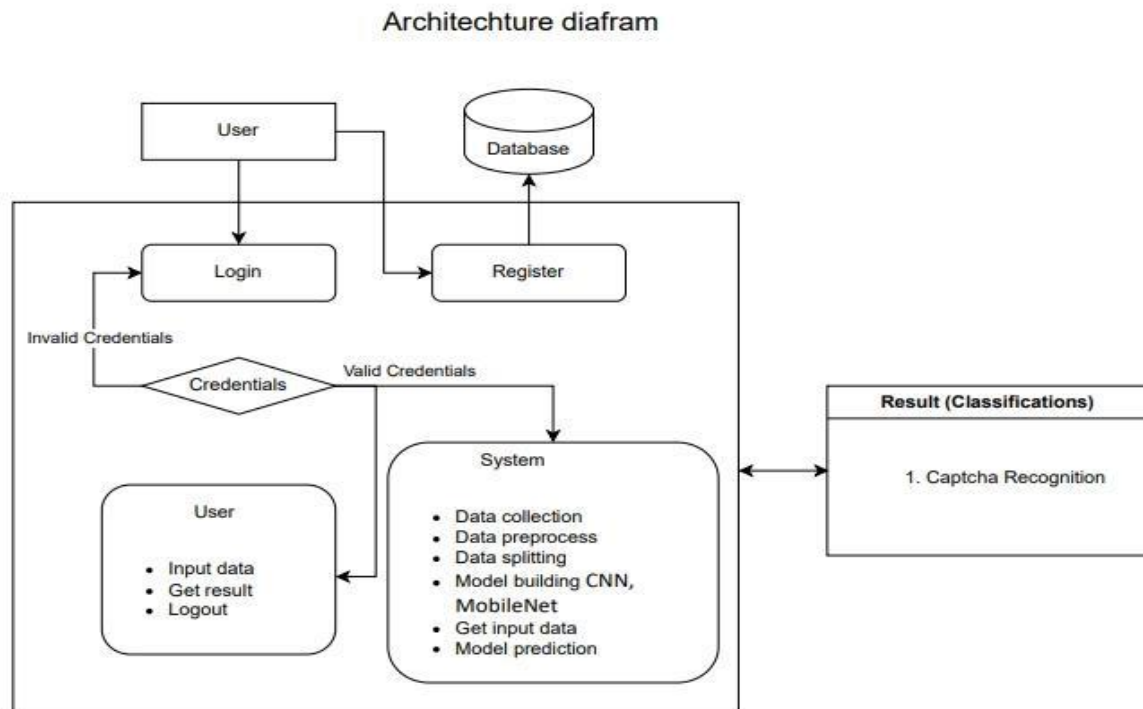


FIGURE 1. Architecture Diagram

The CAPTCHA recognition system allows users to upload CAPTCHA images through a web-based interface. The generating page accepts an image input and processes it using deep learning techniques. Once the user uploads an image and clicks the recognition button, the system transfers the data to the trained deep learning model. The model then extracts features and identifies characters within the CAPTCHA image.

Upon receiving the image, the **Convolutional Neural Network (CNN) and MobileNet model** analyze the CAPTCHA structure, segmenting individual characters and predicting them with high accuracy. Instead of relying on manual decoding, the system automatically processes the image and converts it into readable text. The recognized text is then displayed on the interface, allowing the user to retrieve the decoded CAPTCHA in real-time. The verification module ensures that the recognized CAPTCHA text is accurate and reliable. When a user uploads a CAPTCHA image, the system preprocesses it by applying grayscale conversion, noise removal, and thresholding techniques. The processed image is then passed through the deep learning model, which predicts the characters with high confidence.

This approach ensures that CAPTCHA images are processed efficiently, reducing the need for manual human intervention. The **automated verification process** strengthens the robustness of the system, making it a powerful tool for CAPTCHA decoding in various web applications.

1. System Architecture

The CAPTCHA recognition system utilizes deep learning to automatically detect and decode CAPTCHA images. The system processes image inputs, extracting features using **Convolutional Neural Networks (CNNs) and MobileNet** to achieve high accuracy in character recognition. Once trained, the model can identify and segment CAPTCHA characters in real-time. The backend is built using **Python and TensorFlow**, while the frontend is designed using **HTML, CSS, and JavaScript**, providing an interactive interface for image uploads and recognition. The process is **efficient, scalable, and adaptable** to evolving CAPTCHA patterns.

2. Data Flow and processing Lifecycle

A user uploads a CAPTCHA image via a web interface to initiate the recognition process. The image is preprocessed by applying grayscale conversion, noise removal, and thresholding to enhance clarity. The deep learning model extracts relevant features and classifies individual characters. The recognized text is then displayed on the interface. The system validates and optimizes accuracy by comparing predicted results with expected outputs. The processed CAPTCHA is stored in the database, enabling further model refinement through continuous learning and dataset expansion.

3. Model Training and Optimization

CNNs: These networks perform feature extraction and classification by applying **convolutional filters, ReLU activation, pooling layers, and fully connected layers** for precise recognition.

MobileNet: It optimizes efficiency by using **depthwise separable convolutions**, ensuring fast and accurate CAPTCHA recognition, even on resource-limited devices. The model is trained on a diverse CAPTCHA dataset, making it robust against distortions, overlapping characters, and noise.

4. Performance Enhancement Techniques

Data Augmentation: Enhancing dataset variability by applying random rotations, distortions, and transformations to improve generalization.

Hyperparameter Tuning: Optimizing learning rate, dropout rates, and batch size to **prevent overfitting and improve convergence speed**.

Transfer Learning: Leveraging pre-trained models for improved feature extraction and faster adaptation to new CAPTCHA formats.

5. Resource Optimization

Efficient Model Deployment: The trained model is optimized for real-time inference using **TensorFlow Lite**, ensuring minimal latency.

Memory Management: The system **reduces computational overhead** by processing only essential image regions, improving speed and efficiency.

6. Testing and Validation

Test Environment: The CAPTCHA recognition system was tested on a dataset containing diverse CAPTCHA formats, including text-based, alphanumeric, and distorted images. Simulated user interactions validated system performance under varied input conditions.

Performance Metrics: The model was evaluated based on **accuracy, precision, recall, and inference time** to ensure real-time CAPTCHA recognition.

Tools Used

We have integrated various tools and technologies to provide a user-friendly interface for CAPTCHA recognition. React is used for designing the user interface and front-end application to handle user interactions efficiently. Python is used to develop the backend, leveraging Flask or Streamlit to process user requests and manage model inference. The deep learning models are implemented using TensorFlow and Keras, ensuring high accuracy in CAPTCHA recognition. Additionally, MongoDB is used as the primary database to store user interactions and processed CAPTCHA results, enhancing the system's performance and scalability.

Project Specification

Category	Details
Machine Learning Framework	TensorFlow & Keras – Used for building deep learning models to analyze and recognize CAPTCHA images.
Encryption Algorithm	AES Encryption - Military-grade encryption used for securing CAPTCHA data before storing it. It ensures confidentiality even if the data is intercepted.
Deep Learning Model	Convolutional Neural Networks (CNN) with MobileNet - Chosen for its efficiency in image classification and CAPTCHA recognition, enabling high accuracy.
Preprocessing Techniques	Grayscale Conversion, Noise Removal, Thresholding - Applied to improve the quality of CAPTCHA images before model prediction.
Front-End Framework	ReactJS - Responsive and dynamic UI for CAPTCHA submission and result visualization, designed for ease of access..
Backend Logic	Python (Flask/Streamlit) - Handles request processing, model inference, and CAPTCHA decoding with minimal latency..
Database Layer	MongoDB – A NoSQL database for storing user interactions and CAPTCHA results, chosen for its scalability and flexibility.
Performance Benchmarks	1000 Captcha Recognitions per Second (CPS) - Achieved under load testing, optimizing system efficiency.
Security Protocols	Penetration Testing - Conducted to assess system vulnerabilities and ensure CAPTCHA processing is protected from adversarial attacks.
Authentication Mechanism	Role-Based Access Control (RBAC) with OAuth2.0 - Ensures that only authorized users can access CAPTCHA recognition logs.
User Interface	ReactJS UI with Role-Specific Dashboards - A custom-built interface offering different views for users based on authentication level.
Deployment Tools	Docker & Kubernetes - Used for containerizing and deploying the CAPTCHA recognition system in scalable environments.

Data Flow Model	End-to-End CAPTCHA Recognition Workflow - The uploaded CAPTCHA image is preprocessed, passed through the model, and the recognized text is verified before being displayed.
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RESULTS

The Home Page serves as the main dashboard for the CAPTCHA Recognition System. It provides an overview of the project's features, including dataset upload, model training, and CAPTCHA solving functionalities. The page also includes navigation links to other sections such as the Upload, Results, and About pages. Users can easily access key features to start using the system for CAPTCHA recognition.

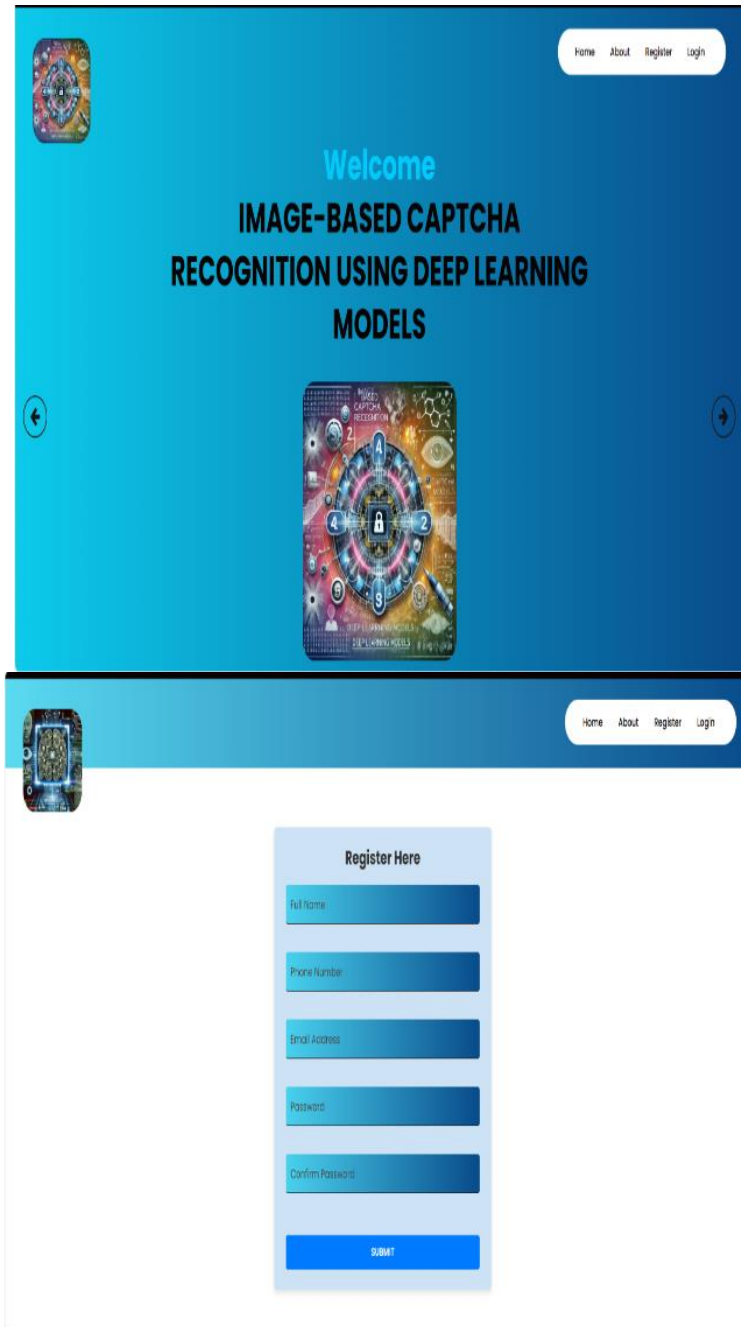


FIGURE 2. welcome and registration pages

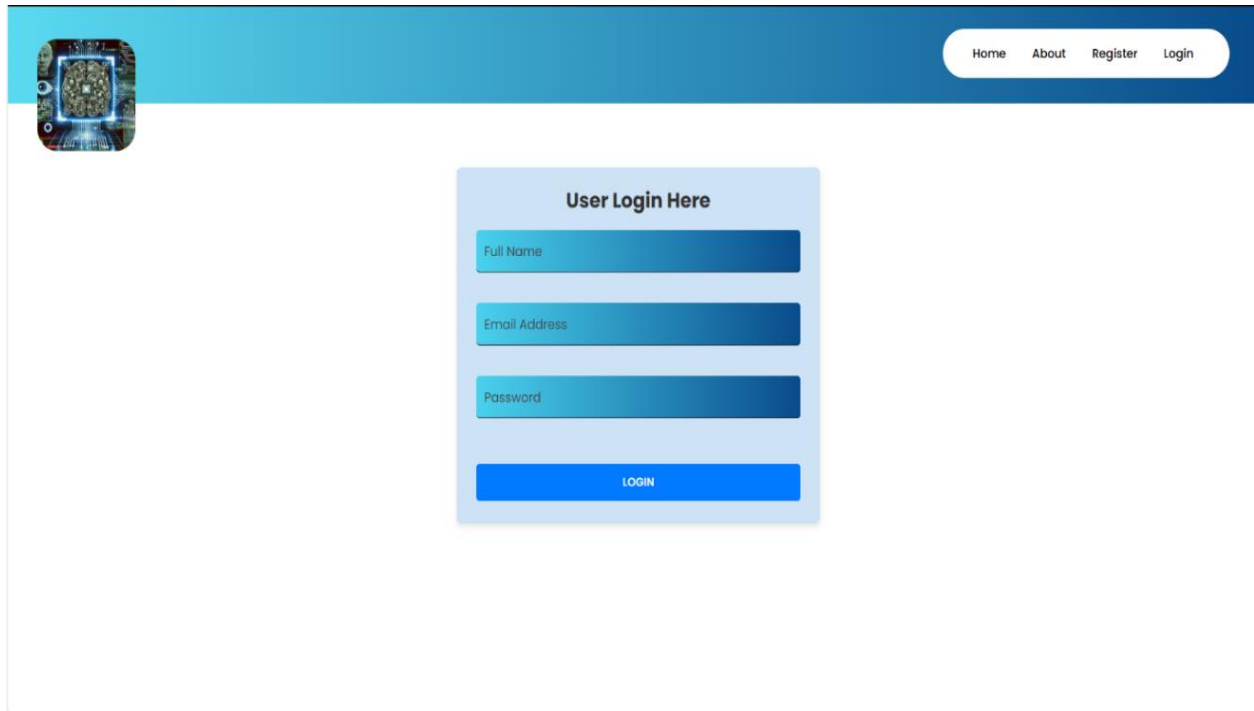


FIGURE 3. login page

Upload page:

The Upload Page allows users to easily upload a dataset for CAPTCHA recognition. It features a file selection dialog and an upload button. Once the dataset is uploaded, a preview is displayed in a table or grid format for verification, ensuring the data is ready for preprocessing and training in the system.

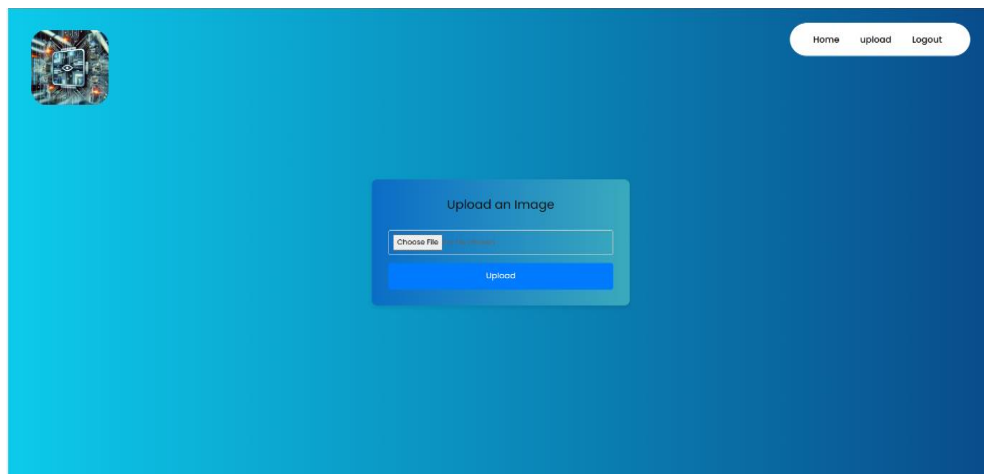


FIGURE 4. Uploading an image

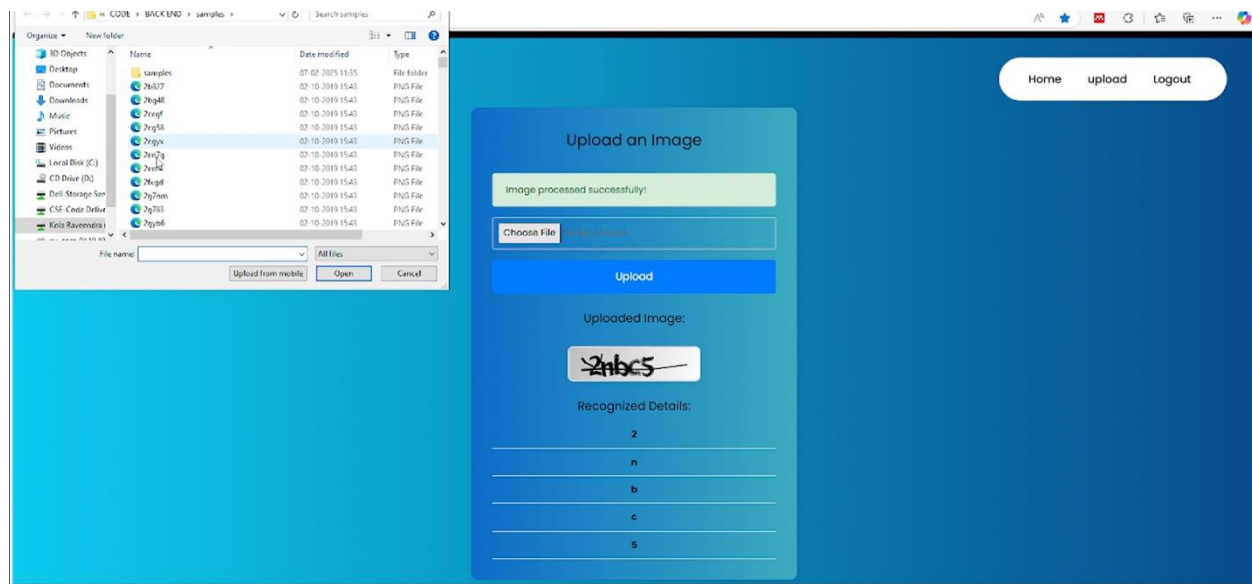


FIGURE 5. Retrieving the recognized text

CONCLUSION

The CAPTCHAs are a test method used to distinguish between humans and machines in network environment. The studies on CAPTCHA identification can better detect vulnerabilities in the security of the CAPTCHA, thereby preventing some malicious intrusion in the network. In this paper, a CAPTCHAs recognition technology based on convolutional neural network is proposed according to the CAPTCHA of images character distortion and adhesion, and all characters in the image can be recognized without segmentation. Multi task joint training model is introduced to improve network learning rate and model generalization ability, and the network structure is modularized, which can recognize the different character length of the CAPTCHA image with slight modification. Experimental results show that the proposed method has a good recognition effect, and the recognition accuracy reaches to 96.5%. In the future work, Chinese characters CAPTCHAs recognition will be added.

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