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Dangerous Goods Detection and Warning Approach Based on Image Processing Techniques

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Abstract: Hazardous substances are widely used in many sectors such as industry, logistics, agriculture and energy, but they carry potentially serious risks. Accurate identification of these risks before the materials start transportation processes is critical to prevent potential accidents and minimize risks. This study presents an approach to preventing accidents that may occur in the transport of dangerous goods to ensure rapid, effective intervention in case of possible accidents and to take early precautions. Optical Character Recognition (OCR) technology, one of the image processing techniques, is used in the study. Dangerous goods labels were detected with the help of OCR algorithms and the texts on the label were successfully detected. The detected texts, especially the United Nations (UN) numbers specific to hazardous substances, were matched with a previously created database. Based on the UN numbers matched with the database, the properties of the relevant substance, response conditions, precautions to be taken and other critical information were retrieved from the database and presented to the users. This information is matched with visual outputs and transferred to the user through warning systems. In the study, a dataset of 600 images containing hazardous material labels with various background conditions was used. In the tests performed on the dataset, the performance of the system was evaluated by calculating accuracy metrics. The results show the effectiveness of the OCR-based approach in detecting and processing hazardous material labels. This study provides an important contribution for safe transportation and rapid response processes, especially in large-scale logistics operations.

Key words: Image processing, dangerous goods, optical character recognition.

Görüntü İşleme Tekniklerine Dayanan Tehlikeli Madde Tespit ve Uyarı Yaklaşımı

Öz: Tehlikeli maddeler, sanayi, lojistik, tarım ve enerji gibi birçok sektörde yaygın olarak kullanılmakla birlikte, potansiyel olarak ciddi riskler taşımaktadır. Bu risklerin, maddeler taşımacılık süreçlerine başlamadan önce doğru bir şekilde belirlenmesi, olası kazaların önlenmesi ve risklerin minimize edilmesi açısından kritik öneme sahiptir. Bu çalışma, tehlikeli madde taşımacılığında meydana gelebilecek kazaların önlenmesi, olası kaza durumlarında hızlı, etkili müdahale sağlanması ve erken önlem alınmasına yönelik bir yaklaşım sunmaktadır. Çalışmada, görüntü işleme tekniklerinden biri olan Optik Karakter Tanıma (Optical Character Recognition-OCR) teknolojisi kullanılmıştır. Tehlikeli madde etiketleri OCR algoritmaları yardımıyla tespit edilmiş ve etiket üzerindeki metinler başarılı bir şekilde algılanmıştır. Algılanan metinler, özellikle tehlikeli maddelere özgü Birleşmiş Milletler (United Nations-UN) numaraları, önceden oluşturulan bir veri tabanı ile eşleştirilmiştir. Veri tabanı ile eşleştirilen UN numaraları üzerinden, ilgili maddeye ait özellikler, müdahale koşulları, alınması gereken önlemler ve diğer kritik bilgiler veri tabanından alınarak kullanıcılara sunulmuştur. Bu bilgiler, görsel çıktılarla eşleştirilerek uyarı sistemleri aracılığıyla kullanıcıya aktarılmıştır. Çalışmada, tehlikeli madde etiketlerini içeren ve çeşitli arka plan koşullarına sahip 600 adet görselden oluşan bir veri seti kullanılmıştır. Veri seti üzerinde yapılan testlerde, doğruluk metrikleri hesaplanarak sistemin performansı değerlendirilmiştir. Elde edilen sonuçlar, OCR tabanlı yaklaşımın tehlikeli madde etiketlerinin algılanması ve işlenmesindeki etkinliğini göstermiştir. Bu çalışma, özellikle büyük ölçekli lojistik operasyonlarında, güvenli taşıma ve hızlı müdahale süreçleri için önemli bir katkı sunmaktadır.

Anahtar kelimeler: Görüntü işleme, tehlikeli madde, optik karakter tanıma.

1. Introduction

Dangerous goods are encountered in many areas of daily life and are transported to the relevant points through various transport routes. These substances are generally transported by different transport methods such as road, maritime, railway and airway, and urban transport is mostly carried out by road. The vehicles used in the transport of dangerous goods and the materials transported are identified by dangerous goods labels issued in accordance with international standards. These standards are determined depending on the mode of transport and the risks involved in the transported material and require compliance with internationally accepted regulations [1]. Due to the nature of the transported material, potential hazards can pose significant risks to both people and the

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environment. Therefore, many factors such as human factors, organizational processes, equipment used and safety measures taken play a critical role in the transport of dangerous goods. Various analysis methods are used to identify and manage these risks. For example, Quality Function Deployment (QFD) method can be used as an effective tool for the assessment and prioritization of risks in the transport of hazardous materials [2]. In the transport of dangerous goods, the safety of people and property is always considered as a priority issue. All individuals and organizations involved in the transport process are obliged to act in accordance with internationally recognized agreements, applicable laws and regulations. These regulations provide a framework based on detailed provisions to ensure safety and responsibility during transport. An example of a template based on transport-related provisions is presented in Figure 1 [3].

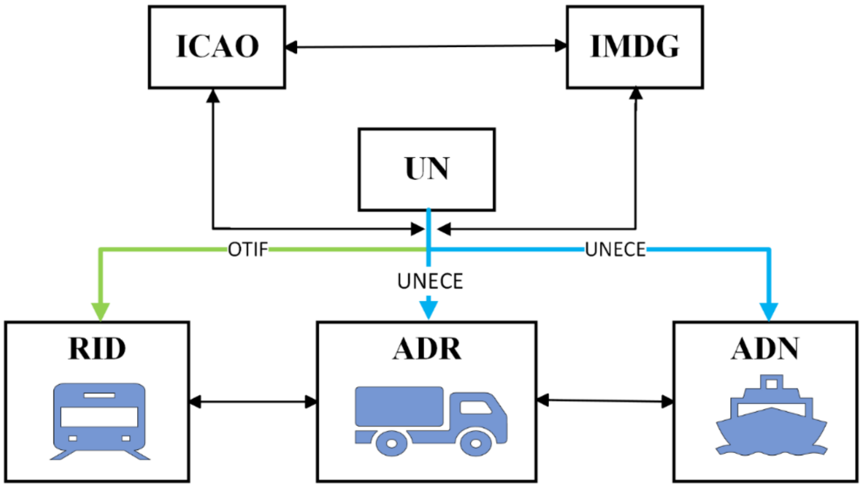

Figure 1. International regulations in the transport of dangerous goods.

The transport of dangerous goods is a critical part of international trade and is controlled by various international regulations to ensure environmental and human safety. These regulations have been developed by different organisations according to the modes of transport. While UNECE (United Nations Economic Commission for Europe) sets the standards for ADR (European Agreement Concerning the International Carriage of Dangerous Goods by Road) for road transport and ADN (European Agreement Concerning the International Carriage of Dangerous Goods by Inland Waterways) for inland waterways transport, OTIF (Intergovernmental Organisation for International Carriage by Rail) establishes the regulations for railway transport within the scope of RID (Regulations Concerning the International Carriage of Dangerous Goods by Rail). The UN provides the basic model regulations for all regulations. UNECE develops both ADR and ADN regulations. The OTIF organisation establishes the RID regulation. ICAO (International Civil Aviation Organization) and IMDG CODE (International Maritime Dangerous Goods Code) develop specialised regulations to implement these rules in air and maritime transport respectively. These regulations aim to minimise risks and promote safe transport by providing common standards for the classification, packaging and transport of dangerous goods. A summary template is presented in Figure 1 within the scope of these regulations.

- UNECE → ADR
- OTIF → RID
- UNECE → ADN
- ICAO → ICAO-TI (Technical Instructions for the Safe Transport of Dangerous Goods by Air)
- IMO (International Maritime Organization) → IMDG

There are many hybrid studies in the literature to reduce the risks during the transportation of hazardous materials and precautions should be taken in advance to reduce these risks [4]. For this purpose, the proposed study detects the UN number of hazardous substances with image processing technique. By matching the detected UN number with the data in the database simultaneously, information such as response actions against the hazardous substance, cleaning of the substance, hazards of the substance, first aid and properties of the substance are obtained. Due to the increase in the demand for hazardous material transportation in recent times, it brings along some risks [5]. In order to prevent accidents, to evaluate and identify some of the basic factors that constitute the risks among themselves and to prevent accidents in the world from happening again, measures should be taken for hazardous materials within the scope of the purpose [6].

Image processing techniques are used for various purposes according to the topics investigated. Labels identifying the properties of hazardous substances can be detected with an image processing technique. One of the studies on this subject tried to detect hazardous substance labels using two techniques [7]. Hazardous substance label detection has also been done by applying the HND-Net method [8]. At the same time, there are studies in literature that publish large data sets for hazardous substance labels [8]. In this study, the importance of hazardous materials is emphasized. In addition to using image processing methods to detect the labels of hazardous substances, it is also possible to determine what the hazardous substance is [9]. In another study, Optical Character Recognition (OCR) technology was developed in hybrid technology that reads labels using OD technology [10]. In addition, Shahin et al. [11] proposed an MBID-based OCR model to extract label information visible in images captured by a fixed camera in an industrial environment. Their proposed system used an approach to process illumination variations in images including low contrast, distorted, darker and brighter images. Artificial intelligence-based studies are also available in the literature [12]. More comprehensive OCR studies and reviews can be found in the research paper by Memon et al. [13] and other studies published in the literature. According to literature studies, there are gaps in hazardous substances to reduce risks [4]. The proposed approach enables automatic detection of hazardous material labels and simultaneous display of precautionary and response information. It provides an effective approach and instant information for the detection of hazardous substances. A robust and efficient approach for the detection of hazardous substance labels must be created. For this, a warning and prevention approach based on OCR is proposed. Diversification of the dataset and evaluation of the accuracy metrics are crucial for the proposed approach to work efficiently and achieve robust and reliable results. In the field of image processing, hazardous material detection serves several critical purposes, including security and environmental monitoring. Furthermore, the study evaluating the performance of image matching methods for hazardous material detection has contributed to the development and evaluation of this work, providing valuable insights into the effectiveness of such approaches [14]. The main contributions of this study are summarized as follows:

- In existing literature, there is a limited number of studies on automatic detection of hazardous material labels. The application of OCR technologies to this field is rare, especially in hazardous material transport and emergency response. This paper fills this gap and presents a system for both text detection and hazardous material feature identification.
- Tesseract makes an important contribution to literature by demonstrating the use of OCR technologies such as EasyOCR and EAST in a specific application area such as hazardous material detection. Such specific applications extend the potential of OCR in different sectors.
- Many OCR studies in the literature have been tested with images captured under relatively clean and ideal conditions. However, this study examined the detectability and accuracy of hazardous material labels in practical scenarios using a challenging dataset. This gives better validity to the real world.
- Accurate and fast identification of dangerous goods information is vital in emergency situations. The study provides a solution to fulfil this requirement, aiming to reduce response times and increase safety.
- The system offers not only text detection, but also additional functionalities such as the identification of hazardous substances via a database and the provision of warning information. This is a unique solution in the field of industrial safety and logistics.
- This technology has many ready-made libraries and software tools. It is the most suitable and simplest solution method for the detection of a fixed hazardous substance label without requiring any technology. Methods such as deep learning were not preferred since any complex solution proposal would affect the functioning of the system.

This study fills a gap in literature and offers significant original value in areas such as hazardous materials management and emergency response. It also provides a starting point that can contribute to technological progress by providing the infrastructure for future automated systems.

1.1. Review of Label Identification Technologies: Why OCR?

When the studies in the field of OCR are examined in literature, there are other methods used depending on some technologies. When these methods are analyzed in terms of their advantages and disadvantages in Table 1, the reason for the preference of the OCR technology used in the study is clearly seen. Comparisons are available below:

1. **RFID (Radio Frequency Identification):**
   Advantage: Dangerous goods labels can be detected faster if they have RFID tags on them. RFID can be considered more reliable, especially when the physical condition of the labels is poor or the visibility is reduced [15].
   Disadvantage: However, RFID tags may not be available on every hazardous material and installing this system may require higher costs.

2. **Barcode and QR Code Based Identification:**
   Advantage: Barcodes and QR codes enable quick extraction of information from visual data. In addition, the accuracy of these codes is generally high.
   Disadvantage: Hazardous substance labels may not always have these codes. Also, the majority of existing labels are text-only, making the use of OCR more logical.

3. **Image Recognition with Machine Learning:**
   Advantage: With deep learning techniques, elements such as shapes, colors or symbols in tags can be detected at a more complex level. Thus, not only text but also symbols and color coding can be recognized.
   Disadvantage: Machine learning-based image recognition requires large data sets and lengthy training processes. The probability of false positive and negative results is higher than with OCR. OCR is faster and generally more accurate in text-based systems.

4. **Manual Control and Manual Identification:**
   Advantage: Manual checks and identification by the human eye ensure accurate label reading and flexibility in complex situations.
   Disadvantage: This method is time-consuming and prone to human error. Manual control is not sustainable in large-scale operations. Preferring automated methods (such as OCR) over manual identification is more advantageous in terms of speed and accuracy.

5. **Dangerous Goods Labeling Detection with Internet of Things:**
   Internet of Things (IoT) devices enable the detection of hazardous substance labels using wireless technologies such as sensors and radio frequency. Using technologies such as RFID, sensors and smart tags, hazardous materials can be continuously monitored.
   Advantage: IoT devices can continuously monitor the location and condition of hazardous materials from anywhere in the world. Through RFID tags or sensors, environmental conditions such as temperature, humidity, vibration can be monitored, enabling the safe transportation and storage of hazardous materials by controlling businesses with a large supply chain or distribution network. IoT systems continuously collect and analyze data without the need for human intervention. It reduces human error and automates processes.
   Disadvantage: IoT systems often require high hardware and infrastructure costs. Elements such as RFID tags, sensors, network connectivity and data storage solutions are costly. IoT-based systems can be complex to deploy and require constant maintenance and monitoring. Securing networked devices can also create an extra workload. IoT devices can be vulnerable to cyber-attacks. Security vulnerabilities in monitoring and managing hazardous material labels can pose a significant threat.

Table 2 presents comparative performance metrics of methods based on OCR technology used in different studies in the literature. This table provides researchers with information about which methods are more effective in which contexts by evaluating different studies with metrics such as accuracy, success rate, error rate. The table aims to guide research and development in this field by providing a comprehensive comparison of how OCR technology performs in various application areas. This data is an important reference for researchers to identify the strengths and weaknesses of existing methods.

Table 1. Methods used in literature.

Technology	Real-time	Data Types	Accuracy	Scalability	Security	Flexibility
OCR	Not in real time	Text-based data	Medium; good label cleaning and pre-treatment	Limited; difficult at high throughput (our data is fixed)	Low risk; image data only	Limited; restricted to certain text formats
IoT	Real-time data monitoring and notification	Various types of data (sensor data, location data, etc.)	High; dependent on sensor accuracy	High; many devices can be added	High risk; cyber security vulnerabilities	High; adaptable to a wide range of applications
RFID	Real-time, instantaneous data reading	Tag data, location data	High; depends on the condition of the label and the reader	Medium; many objects can be identified	Medium risk; requires physical security	Medium; limited uses
Machine Learning	Not in real time	Various data types (image, audio, text)	High, depending on the training data set	High; continuously updatable with new data	Medium risk; safety of the model is important	High; applicable in different areas
Deep Learning	Often not in real time	Wide range of data types (image, audio, text)	High; better with big data	High; expandable with new data	Medium risk; model security and data privacy are important	High; adaptable to a wide range of applications
Barcode and QR Code	Real time	Text-based and numeric data	Medium; depends on damage condition	Medium; stores a limited amount of data	Low risk; requires physical security	Low; limited to certain code formats

Table 2. Some comparative metric performance values according to studies based on OCR technology in the literature.

Study	Year	Area	Accuracy
[16]	2023	CNN-Based OCR	90.54% accuracy and 2.53% loss value
[17]	2021	Adobe Acrobat, ABBYY FineReader, Tesseract	ABBYY: ~3%, Tesseract: ~5%
[18]	2023	PyTesseract, Microsoft OCR, Google vision, Google Drive OCR, EasyOCR	PyTesseract: ~5%, EasyOCR: ~2%
[19]	2023	Tesseract, Keras-OCR, EasyOCR,kraken	PyTesseract: ~4%, EasyOCR: ~5%
[20]	2022	GoogleOCR, Tesseract, ABBYY Finereader, Transym	ABBYY: ~5%, Tesseract: ~4%
[21]	2024	EAST, Easy OCR, Keras OCR, and Tesseract OCR	Easy OCR: ~5%, Tesseract: ~6%

The content of the paper is organized as follows. In Section 2, a general framework for hazardous material detection is established and the proposed approach is described. The algorithm and schematic of the approach discuss the details of how it is implemented in practice. Section 3 presents the results and discusses the recommendations and the results obtained are shown in tabular form. Section 4 explains the conclusions of the study and future work.

2. Materials and Methods

In this study, image processing techniques are used to detect hazardous material labels. A hybrid structure was created by combining image processing techniques and OCR techniques. Tesseract, EasyOCR and EAST (Efficient and Accurate Scene Text Detector) libraries are preferred in the proposed approach written in Python. In the proposed project, the data used in image processing is preprocessed and cleaned. The images are read and the UN number of the hazardous substance is extracted from the hazardous substance label with image processing. Previously, a database containing warning information was created for use in the study. The UN number extracted from the hazardous substance matches the relevant data in the database and the information of the substance is displayed. Information such as the hazards of the hazardous substance, first aid information, how to intervene in an emergency, and the previous storage status of the substance were displayed on the screen and transferred to the user. Image processing techniques and OCR techniques were used to match the correct information and achieve a good result. The parameters were tested under different images, platforms and conditions to assess their reliability. The best results and values in the parameters were selected. Speeds and image formats were evaluated.

In order to evaluate the metrics used in OCR technology, the input image is read in the software. The UN number is extracted from the read image with OCR and it is checked whether it correctly accesses the relevant data in the database. If the image does not match, error information is returned with control commands. It is very important to evaluate the accuracy of OCR technologies with appropriate metrics. Evaluation metrics such as Character Error Rate (CER) and Word Error Rate (WER) are used here to evaluate the performance within the system. CER is obtained by comparing the results obtained from OCR technology with the rate of erroneous characters compared to all characters. In an excellent OCR performance, the CER value usually takes values between 0% and 1%. WER is obtained by measuring the ratio of incorrectly detected words compared to the whole text [22].

2.1. Proposed Approach

UN numbers of hazardous substance labels were used for the detection of hazardous substances. First, the hazardous substance labels were detected and then the UN number was obtained by extracting the characters from the detected label. The UN number obtained was matched with the database we had previously created and the relevant data of the dangerous substance was displayed. EAST text detector was used for hazardous substance detection. Then, with the help of EasyOCR, the characters were extracted and displayed on the screen. Pre-processing was done to get better results from the images. Text detection and reading was ensured by bringing them to certain sizes. The reason for choosing the EAST text detector in the first stage is that EasyOCR sometimes gives inaccurate results in text detection. EAST was chosen to make this problem more effective. Both are used in image processing to detect and identify text. However, they have different features. With Tesseract, the textual character is detected and a connection to the database is established with the UN number. All this processing is done in Python language. For the accuracy evaluation, the results obtained from the image given as input and the UN numbers matched in the database are considered. If there are non-matching images in the program, the software generates output with the control commands given in the software. Each image was evaluated according to its output and accuracy values were measured. Figure 2 shows the general flowchart of the proposed approach.

Data collected from different sources were used in the study. Images and result outputs were displayed. The database was structured according to the UN number and information on the precautions and characteristics of the hazardous substance was pre-recorded in the database. The UN numbers extracted from the hazardous substance labels were matched with the corresponding UN number in the database and the warnings, recommendations and precautions related to the hazardous substance were displayed.

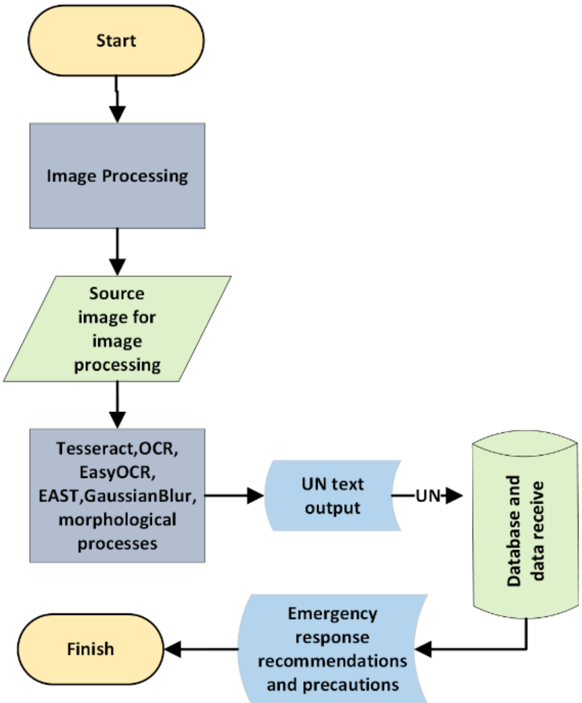

Figure 2. General flowchart of the proposed approach.

2.2. Dataset Description

The dataset used in the study was collected from Google images and websites with datasets [23,24]. The collected dataset was used to match the results for hazardous substance detection and the database created. The data in the database contains similar information such as emergency response situations and substance properties according to the potential risks of the hazardous substance. This study aims to create a warning approach that can produce efficient and reliable results using image processing techniques. After hazardous substance detection, information should be extracted from the database to provide warnings and precautions. In addition, the change in the shape of the images should be determined to be successful on images obtained from bad environmental conditions. The collected data was constructed to fulfil all these requirements and some examples from the dataset are given in Figure 3. The proposed study has made a scientific contribution in terms of the risks of hazardous materials and the precautions to be taken in advance. The dataset consists of 600 images with different backgrounds and taken from different angles [23]. The backgrounds include images of sawdust, wooden floors, images taken in containers, hand-held hazardous material labels and hazardous material labels placed on surfaces such as brick walls. The dataset is based on 8 different combustible materials. Some of the images were obtained in high resolution (5184 x 3456) and in different lighting conditions (dark, bright, blurred). The performance of the presented image processing technique under different conditions is also evaluated.

The images were preprocessed to facilitate hazardous material detection. A series of pre-processing steps were applied to improve the processability of the colour images, which are difficult to read in between. Firstly, the colour images were converted to grayscale (black and white) format so that the analysis is based on intensity information instead of colour information. Gaussian blurring and Otsu thresholding methods were applied on the converted greyscale images. Gaussian blurring reduced the high frequency noise in the image and created a smoother structure. The Otsu thresholding method, on the other hand, allows the detection of prominent objects more easily by determining an automatic threshold according to the intensity values in the image. At this stage, the process was customized by setting manual threshold values. Unnecessary contour areas in the obtained images were filtered and only the areas important for the analysis were left on the image. A resizing step was performed to process the images in a standardized size. In addition, smoothing filters were used to smooth the pixels in certain regions of the images and to obtain a more consistent structure. The removal of noise pixels on the images made certain regions clearer and more distinct. Angular corrections were made for image curvatures to improve accuracy, especially in edge and contour regions. This helped to remove geometric distortions in the image and provided a more regular structure for analysis. After preprocessing, characters were extracted by image processing. According to the results obtained, the information extracted from the database was displayed.

Figure 3. Sample images from some of the data sets used.

2.3. Image Processing Techniques

In this study, OCR-based image processing techniques are used. OCR is a technology that enables the extraction of text and characters from documents, images or any text-containing sources. It stands out for creating an automated system. Among the OCR-based technologies, EasyOCR, Tesseract and EAST [25] provide different features and outputs. Each model used in OCR technology has its own advantages, disadvantages and differences. However, various challenges such as blurred images, rotated text or images taken from different angles are important factors that can affect the performance of these models. In order to overcome these challenges, OCR models such as Tesseract, EasyOCR and EAST were used to produce image outputs and the results of each step are presented in Figure 4. Figure 4 visualises the preprocessing stages of the image processing and the output of these models during the text extraction process. These results provide an important perspective to understand and compare how different models perform in challenging scenarios. Thus, a more informed assessment of which model is more suitable for a particular application can be made.

Comparative studies of existing models are available. Performance measurements can be analysed through these studies and accuracy values can be examined in detail [26]. Especially by looking at the results presented in Figure 5, the text extraction process and accuracy values can be followed. In Figure 5, the text extraction processes performed using EAST and EasyOCR methods and the accuracy performances of these methods are visualised. This visualisation provides an important reference for understanding the strengths and weaknesses of different OCR models.

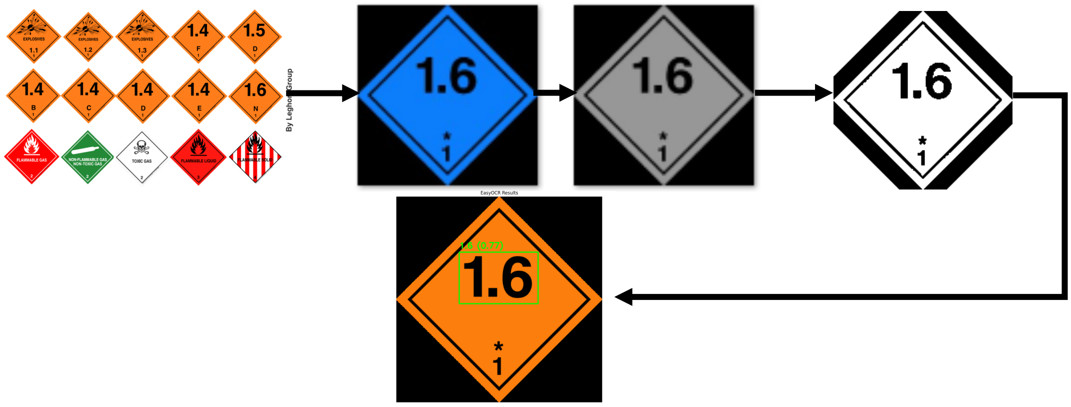

Figure 4. The results of the pre-processing stage of image processing and the image of text extraction using EAST, EasyOCR.

Figure 5. Text extraction and accuracy values using EAST, EasyOCR.

Tesseract OCR is an open-source OCR engine developed by Google. It generally works fast and gives good results in high resolution images. It gives better results in alphabetic character recognition. Some of the hazardous substance labels contain both numeric and textual characters. EasyOCR is Python based and runs under the OpenCV library. In terms of speed, Tesseract runs faster than EasyOCR on CPU, while EasyOCR runs very fast on GPU.

EastOCR works well with noise images. Performance measurements are performed on degraded images [27]. It determines where the text is located. Usually EastOCR is used first, i.e. it detects where the text is on the image. Then the text is recognized using OCR engines (EasyOCR, Tesseract etc.). In this work, detection and recognition are performed separately. In order to achieve better results, the images were resized, blurred according to certain thresholds and some morphological operations were applied.

The relevant image was read in the software. The read image is pre-processed using certain image processing techniques. Image processing techniques were used to output the preprocessed image. The output obtained after image processing is displayed by extracting the relevant data from the database we have created. OCR technologies were created by testing threshold parameters on images. The best threshold values were determined. Figure 6 shows the image processing schematic.

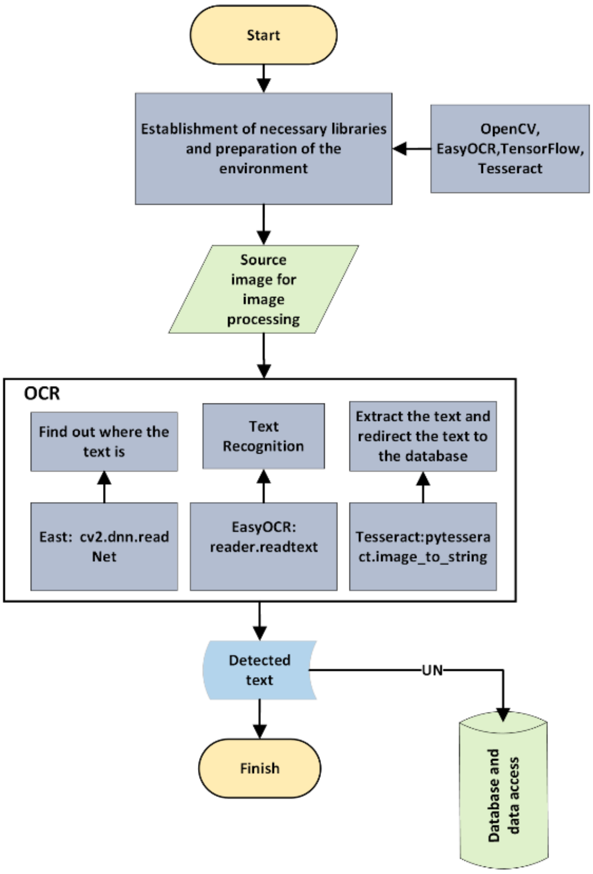

Figure 6. Image processing flowchart.

3. Results and Discussion

OCR technologies are an effective method often used to extract text from images, but they do not always produce perfect results. The accuracy of OCR algorithms is affected by many factors such as image quality, text or characteristic features, image preprocessing techniques and the infrastructural capability of the OCR technology used. For example, OCR systems may have difficulty in finding text in low resolution images, when there is an excess of noise pixels, or when text is skewed, blurred, or on a complex background [28]. Such conditions can lead to misrecognition of characters or word errors in the character recognition process for OCR technologies. This can result in increased character and word error rates, especially when compared to the original texts in the database [29]. Therefore, in OCR-based data extraction systems, it is generally not possible to provide perfect and one hundred per cent accuracy for each data set. However, preparing the collected data in accordance with the same conditions and requirements can increase the consistency and accuracy of the results. For example, significant improvements in OCR accuracy have been observed when preprocessing techniques such as thresholding, noise removal, image resizing and text straightening are used [30]. Research on reducing the error rates of OCR systems is ongoing [31]. In particular, deep learning-based OCR algorithms use more complex network structures and data enrichment techniques to improve text recognition accuracy [32]. However, in order to detect and correct errors that occur during the text extraction process, error analysis methods have been developed that compare OCR outputs with the original texts stored in the database. Such comparisons enable the calculation of character and word-based error rates and the evaluation of system performance. In conclusion, effective preprocessing steps and modern algorithms need to be developed to improve the accuracy of OCR technologies and reduce errors. In particular, when working with data collected and processed at the same thresholds, the results are expected to be more consistent and accurate. In this context, efforts to improve OCR accuracy are ongoing and improvements in the information retrieval process may offer more advanced solutions in the coming years.

The application of OCR technologies to detect the safety precautions and labelling information of dangerous goods has become an important research area in recent years. In this study, EasyOCR, EAST and Tesseract OCR methods are used for the detection of hazardous substance labels and their performances are evaluated. The aim of the study is to improve the accuracy of textual information obtained from visual labels and to contribute to safety measures by matching this information with critical details of hazardous substances in a database. In the study, data was collected from 600 images obtained under different conditions and these images were processed using OCR technologies. The outputs obtained were compared with the real original values and the accuracy and error rates were evaluated. The total CER was used to determine the error rates. This rate is calculated by the following formula (Equation 1):

$$\text{CER} = \frac{\text{number of deleted characters} + \text{number of added characters} + \text{number of modified characters}}{\text{total character counter}} \quad (1)$$

According to the results, 580 out of 600 images were correctly matched, while 20 images were incorrectly matched. The main reasons for the incorrect results are the presence of more than one label in the images and low-resolution conditions. In particular, conditions such as low resolution and blurriness negatively affected the text recognition performance of OCR technologies. In such cases, it has been observed that optimizing the parameters for each image increases the accuracy rates. In the evaluations, it was found that very successful results were obtained when the CER were between 1% and 10% [33]. In particular, EasyOCR and EAST approaches allow more precise parameter settings to minimize error rates in low resolution data, which is one of the prominent advantages of these technologies.

Table 3 presents the detailed results of the correct match rates, while Table 4 summarizes the OCR errors encountered in the images with 20% of incorrect matches. The majority of false matches occurred in cases where there were multiple tags and the resolution was low.

Table 3. Error rate on the image.

Total Number of Images	Number of Images with Incorrect Output	Character Error Rate (%)
600	20	(50 / 1200) * 100 ≈ 4.17

Table 4. Image counts according to OCR technology.

OCR Technology	Number of Images with Incorrect Output
EasyOCR	6
Tesseract	10
EAST	4

The innovations and added value of the study of using Tesseract OCR, EAST OCR and EasyOCR for the detection of hazardous substance labels to show safety measures and label information can be emphasized as follows:

- The combination of three different OCR technologies (Tesseract, EAST, EasyOCR) on the same problem stands out as a methodological innovation. Each OCR algorithm has different advantages; therefore, combining them all in a single framework is an innovative approach.
- Hazardous material labels contain specific safety symbols, classifications and numbers. Digitally recognizing these labels with OCR technologies and then using this data to automatically display safety measures and other information about the label is an innovation that increases speed and safety in business processes and in the event of any danger or accident.
- The use of fast, real-time algorithms such as EAST OCR makes it possible to recognize and process hazardous material labels instantaneously. This is a critical innovation for fast decision-making, especially when transporting or storing hazardous materials. This is very important in the safety and logistics phases.

- Manual inspection and classification of hazardous material labels is a process prone to human error. The integration of OCR technologies automates this process and reduces the error rate.
- Detecting hazardous material labels used in the industry with OCR and instantly checking their compliance with safety standards contributes to automatic reporting and monitoring systems.
- Hazardous material labels detected with OCR technology can be digitally stored and traceable. This adds an additional dimension to the studies on the traceability of hazardous substances in the literature and ensures data security. Digitized data provides a safer way in inspection processes and transportation of dangerous goods.

In conclusion, this work presents important methodological and practical innovations on the detection of hazardous substance labels with OCR technologies and the display of safety precautions and other information. It provides a broad perspective in both academic and industrial environments.

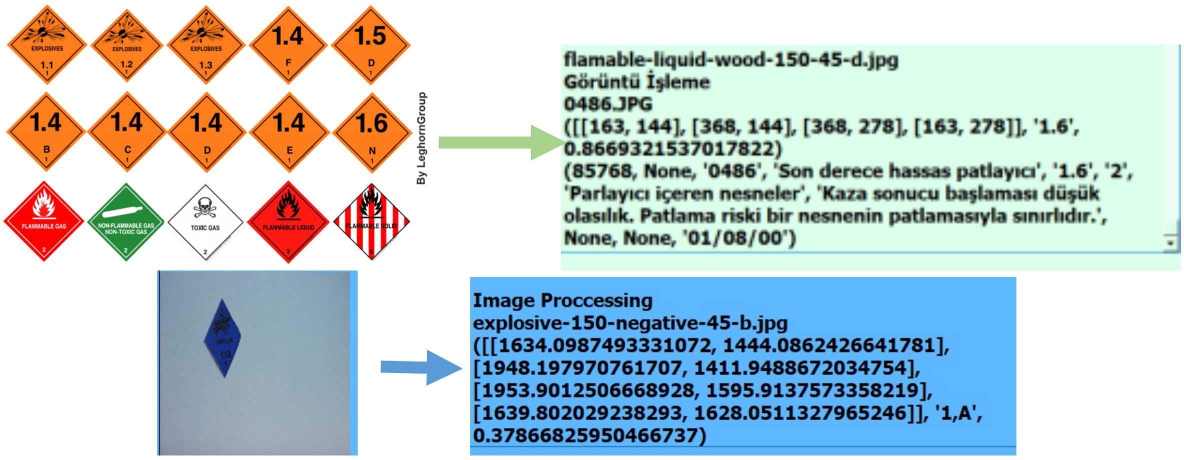

Figure 7. Result values as a result of the image given to the system.

The evaluation of OCR accuracy is commonly assessed using the CER, with thresholds defined as follows: good OCR accuracy corresponds to a CER of 1–2% (i.e., 98–99% accuracy), average OCR accuracy falls within a CER range of 2–10%, and poor OCR accuracy is characterized by a CER exceeding 10% (i.e., below 90% accuracy) [22]. In this study, an OCR performance with a CER of approximately 4.17% was obtained, which aligns with the "average OCR accuracy" category as outlined in the literature. This result is consistent with the CER range of 2–10% and indicates an adequate level of performance according to standard OCR accuracy evaluation criteria. Additionally, it is worth noting that a CER of up to 20% is often considered acceptable for general applications. The findings of this study are closely aligned with those reported in similar works in literature. To further enhance the accuracy, EasyOCR and EAST methods were implemented, yielding improved performance compared to the initial results presented in Table 2. These improvements demonstrate the effectiveness of the proposed methods for applications such as label detection and information extraction. Furthermore, the results highlight the competitive performance of the proposed approach in comparison to existing methods reported in the literature.

4. Conclusion

This study focuses on the automatic detection of labels for hazardous substances, with the aim of managing safety measures and potential risks. The proposed approach enables the rapid detection of which hazardous substance is present, its properties and first response information in the event of an accident. For this purpose, Tesseract, EasyOCR and EAST text detectors were used as image processing methods and effective results were obtained. The study was tested on a large dataset and the hazardous material labels in more than 600 images were successfully detected and the relevant warning information was retrieved from the database. Furthermore, the method proved its effectiveness in terms of both accuracy and processing time, demonstrating its potential to provide a fast and reliable solution, especially for emergency situations. The results of the study are considered as an important step in the development of warning systems for hazardous substances and offer a practical solution compared to other studies in this field.

In future studies, it is considered to be integrated with barcode technology and transformed into remote controlled robot systems through unmanned vehicles. It is important to minimize the human factor and work efficiently by relying on financially automated systems.

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