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Classification of X-Ray images of shipping containers

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ABSTRACT

Smuggling has long played an important role in the inefficiency of economies. To secure the borders against this illegal act, X-Ray Inspection Systems are often deployed at the borders and customs. In this paper, we present a new method for classification of shipping containers X-Ray images, produced in the inspection lines. The aim is to improve the matching accuracy of the presented manifest, which lists the claimed contents of the shipping containers, with the real contents of the container. The proposed method is based on utilizing Scale Invariant Feature Transforms (SIFT) feature vectors, Bag of visual words (BOVW) and tree augmented naive Bayes (TAN) approach for classifying containers X-Ray images. The prior research on classification of X-Ray images of shipping containers has focused mostly on working with greedy algorithms such as sliding windows for task of classification. More recent studies introduced filter banks and visual words for extraction of features. The proposed method for the first time considers the salient points and keypoints for the task of feature extraction. In addition, this paper presents a framework using the tree augmented naive Bayes based on the theory of learning Bayesian networks, which is proved to have a significant improvements upon the prior designed systems by considering the correlations among the extracted features. For experimental evaluations, our method is compared with two recently proposed methods on containers X-Ray images categorization. The results show that the proposed method is more accurate and time-efficient in categorization of X-Ray images.

1. Introduction

Goods transportation through the air and the oceans in freight containers are a large portion of the world trade volume. Along with this huge benefit, smuggling is a potential danger of unmonitored trading. According to United Nations Office, the global market approximately faces with 10% to 20% illicit trading each year. Since the smugglers do not pay the tariff levied by governments, this action leads to reducing investment in the industry and reduction in the volume of manufacturing activities. In order to ensure the conformity of the container's content with the presented information in the manifest, automatic X-Ray inspection systems are often utilized (Basu, 2014; Jaccard, Rogers, & Griffin, 2014).

Shipping containers X-Ray inspection systems are high-energy scanners, basically designed for non-intrusive inspection of vehicles, cargo and shipping containers at airports, borders and customs (Jaccard et al., 2014). Fig. 1 illustrates the structure of the X-Ray container scanners while scanning through freight container for creation of X-Ray image. After the production of X-Ray images, there is a duty for the human X-Ray operator to monitor and investigate through the images to check whether the container's content match with the claimed manifest. In this stage, there are two major problems while inspecting the shipping containers X-Ray images by human operators. First, it is difficult to recognize X-Ray images in detail, since there is the possibility of vague results when the high density parts of the goods obfuscate the other objects in the container (Zhang et al., 2014). Second, there is always possibility of illegal activities such as bribery, which can involve the operators (Pourkazemi, Sherafat, & Azari, 2013). Therefore, automated inspection systems for shipping containers X-Ray images seems to be valuable in this context. The recent studies show promising outcomes in intelligent, automated monitoring of cargoes, both in luggage and shipping containers. There are studies, such as Glowacz, Kmieć, and Dziech (2015); Mery (2013); Mery, Riffo, Zuccar, and Pieringer (2013) which focus on detection of specific items, such as gun and knife in luggage screening. These methods may not produce the best results on X-Ray images of containers. Containers X-Ray images are high-density images which do not reveal important features as clear as the luggage X-Ray images, since the volume of a container is almost 3000 times greater than a regular luggage.

There are two recent studies on classification of containers X-Ray images. Jaccard et al. (2014) presented a simple greedy method for automated car detection in X-Ray images of freight container. The authors used a random forest classifier to classify image sub-

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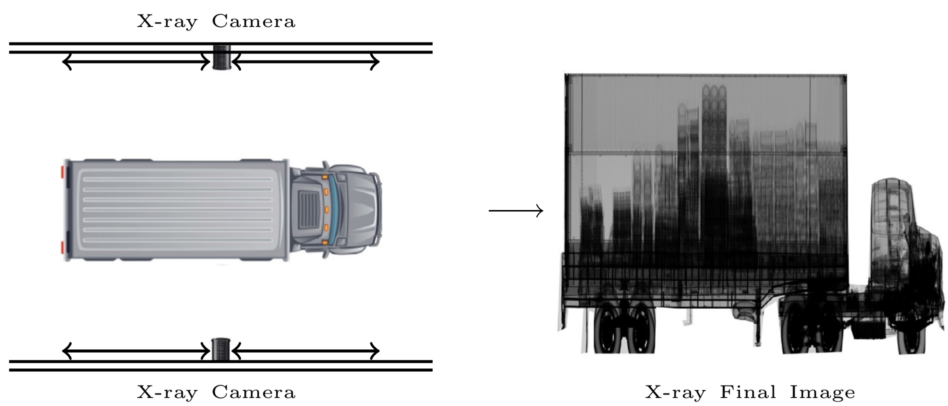

Fig. 1. X-Ray scanner inspection system.

windows as "car" and "non-car" based on image features such as intensity and log-intensity. Zhang et al. (2014) introduced a method for joint shape and texture features corresponding to the classification task of cargo X-Ray image. The authors consider all parts of the image for analysing and they considered the HSCODE established by WCO (World Customs Organization) (Zhang et al., 2014). Unfortunately, conducting these studies with high amount of training images which are not always available, coupled with using greedy approaches such as sliding, overlapping windows and transforms, make these methods highly time-consuming, impractical and inaccurate while facing with more complicated test cases.

Table 1 illustrates the comparisons among the most prominent methods. Also, the applied algorithms, strength and their weaknesses are considered for the related methods. As it was illustrated in Table 1, the shipping container's X-Ray images processing have so far been left mostly unexplored with the exception of a few studies mentioned. Possibly, the reason for lack of studies on shipping container's X-Ray images unavailability of suitable X-Ray image datasets to researchers (Jaccard et al., 2014). This article provides a novel, efficient method for categorizing shipping container's X-Ray images based on bag of visual words (BoVW) on scale invariant features transform (SIFT) descriptors, Bayesian structures, and tree augmented naive Bayes. The contributions of this work are three-fold: first, we introduce a method which uses salient points extracted from the images. This approach emphasizes on most important keypoints of the image instead of considering all parts of the image and as a result, it is highly time efficient and more accurate compared to previous studies. Second, the presented algorithm is designed and tested on a variety of real-world shipping containers X-Ray images with different positions for goods in the containers and proved to be highly accurate compared to other studies. Third, we consider the dependency between the visual words in the bag of visual words method. The elimination of such false independency assumption, leads to more accurate results. The strength of the proposed method, compared to other well-known algorithms introduced for solving the classification of X-Ray images of shipping containers problem, are as follows:

- The proposed method is based on detection of salient points and keypoints of the containers images by performing SIFT feature extractor. It is proved to be more efficient in accuracy and time-consumption compared with other greedy algorithms such as sliding windows and histograms.
- The proposed method considers the correlations among the extracted features from the containers images. Handling the correlations among the features by using tree augmented naive Bayes, not only eliminates the effects of redundant features for the task of classification, but also reduces the load of the system.
- Another comprehensive comparison with other related methods that reveals the strength of our method is the extensibility of the introduced algorithm. The extensibility of the algorithm allows it to be used with larger data sets and different type of categories by inserting new types of X-Ray containers images.
- Finally, our method enhances the running time efficiency of image classification on containers X-Ray images to approximately 5 times higher than other algorithms in average.

An important weakness of our method is that the quality of the results diminishes in the case of objects with large flat surfaces obfuscate the other objects in the container. Consequently, the proper keypoints will not be found on the images and the classification results would not be reliable. This whole phenomenon, gives rise to multiple questions for handling such cases in further studies.

2. Proposed method

Monitoring the contents of shipping containers by intelligently classifying the containers X-Ray images, is the main goal of our system. The proposed system architecture is shown in Fig. 2. We describe each part in the following subsections.

2.1. Feature extraction

Extraction of features from X-Ray images follows the same procedure for both training and testing sections of the proposed method. First, some preprocessing for X-Ray images is necessary before starting the SIFT features extraction. The process of container section extraction is responsible for reducing unnecessary parts of the X-Ray image by focusing on container section. After cropping the container section either automatically or manually, the SIFT features must be extracted from the cropped image. There are several well-known region detectors for extraction of interest points and keypoints. Mikolajczyk et al. (2005) compared six types of these detectors: detectors based on affine normalization around Harris, Hessian points, a detector of maximally stable extremal regions, an edge-based region detector, a detector based on intensity extrema, and a detector of salient regions. According to Hörster and Lienhart (2007) sparse and dense approaches are used to determine the interest points. In sparse approach, points are detected at local extremum in the difference between levels of the Gaussian pyramid. On the other hand, for the dense features, interest points are defined at evenly sampled grid points (Lowe, 2004).

SIFT was introduced as a sparse approach to extract salient points that are invariant to many common image transforms like changes in scale, orientation, position, shear, and illumination.