Chapter 105
A Multi-Stage Framework for Classification of Unconstrained Image Data From Mobile Phones

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ABSTRACT

During the past decade, the number of mobile electronic devices equipped with cameras has increased dramatically and so has the number of real-world applications for image classification. In many of these applications, the image data is captured in an uncontrolled manner and in complex environments and conditions under which existing image classification techniques may not perform well. In this paper, the authors provide a detailed description of an efficient multi-stage image classification framework that is robust enough to remain effective also under challenging imaging conditions, and demonstrate its effectiveness in the context of classification of real-world images of dumpsters captured by mobile phones in the metropolitan city of Hyderabad. Their system is able to achieve accurate classification of the cleanliness state of the dumpsters by utilizing a multi-stage approach, where the first stage is the efficient detection of the dumpster and the second stage is the classification of its state. The authors provide a detailed analysis of the performance of the system as well as comprehensive experimental results on real-world image data.

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INTRODUCTION

Image classification is a common task in computer vision, and various techniques for image classification have been proposed over the years. With the dramatic increase in the popularity of mobile electronic devices equipped with cameras, such as smartphones, there is a growing number of real-world applications for image classification. Nevertheless, some of these real-world applications aim to classify images captured in an uncontrolled manner and in complex environments, conditions under which existing image classification techniques may not perform well.

Recently, the municipality of the Indian metropolitan city of Hyderabad has established an e-Governance workflow for municipal tasks such as repairing street lights, cleaning city streets, and cleaning local parks. One of the more important tasks is collection of waste from the streets: Sanitation teams are supposed to collect the trash from dumpsters located around the city on a daily basis. Supervisors allocated to different regions of the city use smartphones to capture images of the dumpsters through a mobile application. The captured images (along with associated metadata) are submitted to an online server and can be accessed publicly through a portal. The city uses the processed information to submit reports and penalize third-party contractors for service-level agreement infractions when identified. However, the manual reports provided by the supervisors include incorrect information regarding the cleanliness of the dumpsters. As a result, the municipality is very interested in automated means for analyzing the images captured by the supervisors in order to validate the manual feedback and take corrective actions if required. The task is therefore to perform binary classification of the dumpster images captured by mobile phones (see Figure 1) to one of the following classes: 'clean' (if trash is not visible from the bin opening), and 'unclean' (if trash is visible from the bin opening).

Following the definition of the task, we are interested in learning a classifier with a feature set that can discriminate between clean and unclean bin openings. Namely, the classifier needs to discriminate between two different states of the dumpster, where the object of interest is the dumpster itself. In comparison, conventional image classification techniques are usually suited to discriminate between two different classes of objects or scenes, and generally fail to achieve adequate accuracy when applied to

Figure 1. An example of (a) 'Clean' dumpster vs. (b) 'Unclean' dumpster. The region that discriminates between the two cleanliness states (the bin opening) is marked in white.

(a) (b)