A Marker-Based Image Processing Method for Detecting Available Parking Slots from UAVs

Matteo D'Aloia[1(✉)], Maria Rizzi[2], Ruggero Russo[1], Marianna Notarnicola[1], and Leonardo Pellicani[3]

[1] Masvis srl, Conversano, Italy
{matteo.daloia,ruggero.russo,marianna.notarnicola}@masvis.com
[2] Politecnico di Bari - Dipartimento di Ingegneria Elettrica e dell'Informazione, Bari, Italy
maria.rizzi@poliba.it
[3] Dyrecta Lab srl, Conversano, Italy
leonardo.pellicani@dyrecta.com

Abstract. Due to the considerable number of vehicles in many cities, parking problem is a long-term phenomenon and represents one of the main causes of traffic congestion. Unmanned Aerial Vehicles (UAVs) can handle automatic monitoring of traffic, pollution and other interesting services in urban areas non-invasively. UAVs are usually equipped with one or more onboard cameras and with other electronic sensors. In this context, a method for parking slot occupancy detection in parking areas is presented. For recognition of free parking spaces, pictures of urban areas captured by the onboard camera of the UAV are georeferenced and processed for marker detection. The implemented system shows good results in terms of robustness and reliability. Moreover, it paves the way for an improved management of urban spaces.

Keywords: Image processing · Shape recognition · Smart parking · UAV · Urban areas · Marker detection

1 Introduction

Unmanned Aerial Vehicles (UAVs), commonly called drones, are currently proposed for civil applications with strong involvement in smart city applications. An interesting application of UAVs is the management of parking areas and specifically the detection of parking slot occupancy.

Bad management of free parking slots can cause various problems such as traffic congestion, increase of exhaust emissions and pollution. Moreover, searching for a free parking slot can be time consuming and stressful for citizens. To solve these issues as far as possible, some cities are adopting smart parking systems. Current smart parking systems are based on installation of multiple cameras and/or multiple sensors; they imply costs related to materials, installation and periodic maintenance. Moreover, in the case of sensor networks, battery discharging could represent a problem [1].

The use of drones in monitoring parking lots in urban areas allows patrons to set-up a cost effective and scalable monitoring system based on few units that continuously monitor the whole city by contiguous areas.

V. Murino et al. (Eds.): ICIAP 2015 Workshops, LNCS 9281, pp. 275–281, 2015.
DOI: 10.1007/978-3-319-23222-5_34

Data retrieved from aerial images by UAVs could be employed to develop mobile applications that give live information on parking availability, zone by zone in a city. In this way, both citizens would have a better everyday city live and city governments would be able to develop better plans of dynamic parking fees based on live and more detailed parking status.

In this paper, authors suppose that all parking slots are labeled with a proper marker (a white distinctive shape printed on asphalt). Images captured by camera installed on UAV are analyzed to recognize markers independently from the camera point of view, so occupancy of parking slots of a given urban area is detected.

For marker recognition phase, shape matching technique is adopted. Tests carried out have shown high reliability in counting of parking slots. The implemented tool processes aerial images with unknown point of view. As in many cases, the reliability of detection phase depends on image quality. Generally, image quality is not a main issue in this context because drones can be equipped with high resolution imagery systems. On the other side, the developed method is scale-invariant, rotation-invariant and contemplates a certain degree of perspective distortion. Furthermore, it is relatively insensitive to changes in light conditions.

In the following sections, the procedure for parking slot detection is presented in details.

2 Parking Status Recognition

Nowadays, a lot of choices for occupation state monitoring of parking spaces are indicated.

Among current methods, techniques based on hardware integration in urban architecture are achieving a certain amount of success as a result of their reliability. The most diffuse system uses sensor networks; every sensor is able to recognize presence or absence of a vehicle on the associated spot region. Installation and maintenance costs are the main drawback of this solution. In fact, every parking slot shall be equipped with a sensor which is often put beneath the road surface. Moreover, all sensors are equipped with independent energy sources that need periodic replacements.

Evolution in the detection of vehicles in car park space is represented by live processing of images captured adopting cameras strategically located within the area to be monitored. Drawbacks of this solution are installation costs and presence of obstacle in field of view.

Unlike sensor-based systems, in this solution a single device controls more than one parking slot at a time, reducing the number of devices to be installed in a parking area. After installation a set up phase is necessary to locate Regions Of Interest (ROIs) in the frame. The adoption of fixed cameras allows to make easier and improve the procedure of parking status detection and to make it more reliable [3,4,5,6,7,8].

A new frontier to solve parking management problems in urban areas could be represented by the introduction of Unmanned Aerial Vehicles (UAVs) for operations of parking status recognition.

In the proposed solution, the adoption of a single UAV, enables the monitoring of hundreds of parking slots using an onboard computer vision (CV) system able to detect free parking spaces by recognizing custom markers on the ground. Every marker is related to a parking slot. While flying over an urban area, drone is able to recognize parking markers thus determining the state of parking spaces.

Adopting a non-static vision system, ROIs cannot be set a priori and pre-processing steps are required. To assure that the number of detected free parking spaces is uniquely related to a precise urban area, the onboard CV system shall perform–image analysis just on non-overlapped frames. This could be obtained using standard methods of image processing in conjunction with other data from different sources for georeferencing purpose.

The development of a robust algorithm is challenging because it should detect parking markers in changeable light conditions and despite perspective distortions.

3 Parking Markers Detection

In this section, all the image processing steps adopted in the detection algorithm are described. In Fig.1, a test image is specified. The depicted condition is recommended for testing the algorithm reliability because perspective distortion of marker printed on ground grows as the view becomes less frontal. At the end of this section, results of marker recognition for the proposed test image are indicated.

Fig. 1. Test image, a custom marker is printed on ground in a parking slot

3.1 Implemented Procedure

Reference Marker Data Import. The reference marker is analyzed and its profile is extracted (Fig. 2).

The marker profile is represented by a vector containing the distances (in pixels) of each point of the marker contour from the centroid of the marker itself (Fig. 3). Extraction of marker profile is an one-off operation. In fact, the obtained value is stored in a variable after it has been evaluated.

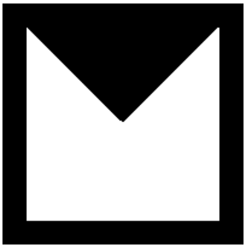

Fig. 2. Reference marker

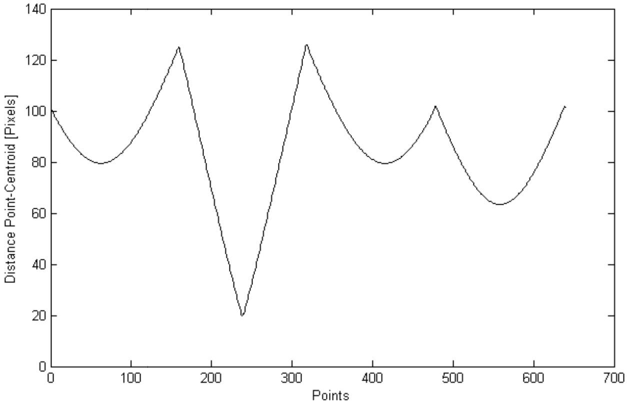

Fig. 3. Profile of the reference marker

Image Acquisition and Segmentation. The m*x*n image under test is captured by high resolution color camera, transformed in gray levels and imported in the workspace as a m*x*n matrix. Otsu's method is used to determine optimum threshold level which minimizes intra-class variance [9]. The evaluated value is used to generate a binary image. For marker detection, white blobs contained in the binary image have to be analyzed (Fig. 4).

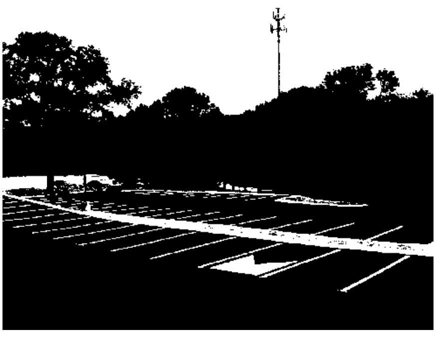

Fig. 4. Segmented image

Edge Detection and Shape Contours. Edge detection is performed on the obtained binary image using Sobel operator (Fig. 5). Therefore, a new binary image is generated whose white pixels are contour pixels. Sobel operator has been chosen for its low computational cost [10]. As is widely known, edge recognition methods, such as those based on-Sobel operator, are very sensitive to noise [11, 12]. Since in the implemented procedure, Sobel-based edge detection is performed on binary images which are characterized by maximum contrast, the algorithm high noise sensitivity is irrelevant.

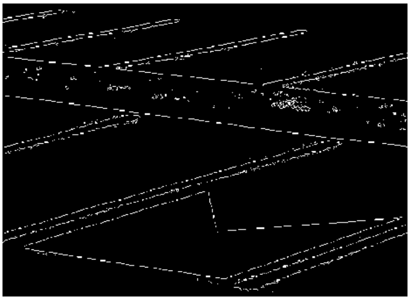

Fig. 5. Marker close-up after edge detection phase

Morphological Processing. To pick out objects to be compared with the reference marker, morphological operations are adopted

Thresholding evaluation for connected objects. The implemented procedure does not analyzed all the objects recognized as bright. In fact, based on the image height and the image resolution, the expected value of the number of contour points composing the marker is calculated. Therefore, objects having a number of contour pixels higher or lower than the expected value multiplied by a user-defined flexibility parameter, are not taken into account (Fig. 6).

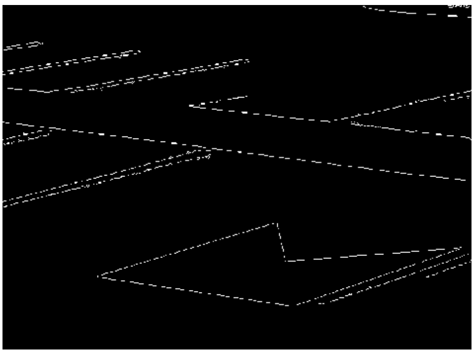

Fig. 6. Object filtering by area opening

Edge linking, Filling, and Labeling. A morphological closing operation is performed on the binary image to link any broken contour using a disk with 2 pixels radius.

The next phase realizes a morphological reconstruction; in fact every hole in any connected component is filled adopting the algorithm in [13]. In this context, holes represent every set of background points which cannot be reached by background filling starting by the image edges. The last operation performs labelling: every connected component in the binary image is labelled with a number. The same numerical value is assigned to pixels of the same object while background pixels are set to 0. The procedure adopted for object labeling is detailed in [14].

Object Warping. Because of the original reference marker is inscribed into a square, every labelled object is warped (Fig. 7). Even if this operation introduces some distortion, it makes reconstruction easier because it reduces perspective distortion and allows a more accurate comparison.

Fig. 7. Object thus isolated in the original image (left) is warped into a square (right)

Profile Extraction. Profile is extracted for each warped object adopting the same method used for reference image. For the object classification, the profile of every object is compared with the reference marker profile.

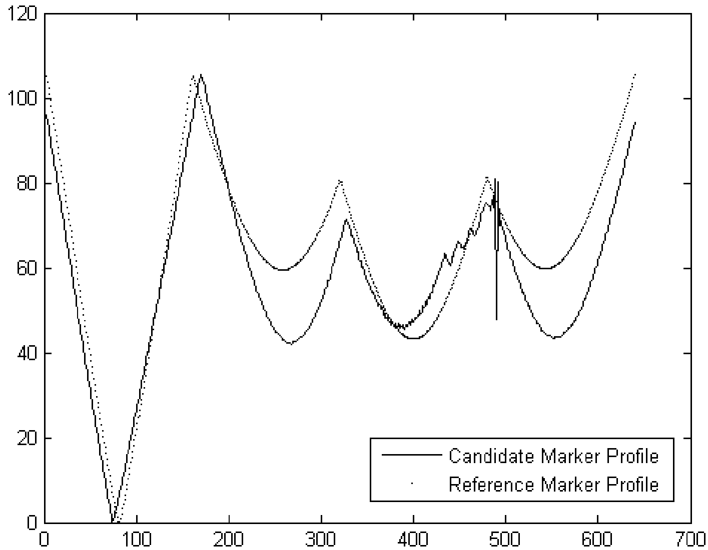

Fig. 8. Profile comparison

Profile Matching. *Offset, Scaling, Resampling, and Alignment.* To optimize the profile matching, some operations are necessary. Therefore, every object is resampled with the same number of points of the reference profile, offset between profiles is subtracted, amplitude is normalized to the maximum value of the reference profile and profiles are aligned using a dynamic time warping algorithm (Fig. 8)

Cross-correlation. Normalized cross-correlation coefficient is calculated between reference and candidate profiles. If the coefficient value is higher than a user-defined threshold, the object under test is recognized as a marker and its coordinates are stored on the original image for further uses.

The marker printed on asphalt in the test image has been successfully recognized with a cross-correlation coefficient value greater than 0.9916.

References

1. Zonouz, A.E.: Smart Parking Lot Using Quadcopter Network. https://traffic.mobilityideacontest.spigit.com/Page/ViewIdea?ideaid=400
2. Mohammed, F., Idries, A., Mohamed, N., Al-Jaroodi, J., Jawhar, I.: UAVs for smart cities: opportunities and challenges. In: International Conference on Unmanned Aircraft Systems, pp. 267–273. IEEE Press, Orlando (2014)
3. Idris, M.Y.I., Leng, Y.Y., Tamil, E.M., Noor, N.M., Razar, Z.: Car Park System: A Review of Smart Parking System and its Technology. Inform. Tech. J. **8**, 101–113 (2009)
4. Prokhorov, D.V.: Method and System for Object Recognition Based on a Trainable Dynamic System. US Patent 8705849 B2 (2014)
5. Jazayeri, A., Cai, H., Zheng, J.Y., Tuceryan, M.: Vehicle Detection and Tracking in Car Video Based on Motion Model. IEEE Trans. Intell. Transport. Syst. **12**, 583–595 (2011)
6. Klappenecker, A., Lee, H., Welch, J.L.: Finding Available Parking Spaces Made Easy. Ad Hoc Networks **12**, 243–249 (2014)
7. True, N.: Vacant Parking Space Detection in Static Images, Thesis, University of California, San Diego, La Jolla, CA (2007)
8. Michalopoulos, P.G.: Vehicle Detection Video Through Image Processing: the Autoscope System. IEEE Trans. Veh. Tech. **40**, 21–29 (1991)
9. Otsu, N.: A Threshold Selection Method for Gray-Level Histograms. IEEE Trans. Sys. Man. Cyber. **9**, 62–66 (1975)
10. Tavares, J.M.R.S., Jorge, R.M.N.: Computational Vision and Medical Image Processing: VipIMAGE 2011. CRC Press, London (2011)
11. Pham, N., Morrison, A., Schwock, J., Aviet-Ronen, S., Iakovlev, V., Tsao, M., Ho, J., Hedley, D.W.: Quantitative Image Analysis of Immunohistochemical Stains Using a CMYK Color Model. Diagn Pathol, pp. 2–8 (2007)
12. Chandrasekar, C., Shrivakshan, G.T.: A Comparison of Various Edge Detection Techniques Used in Image Processing. IJCSI International Journal of Computer Science Issues **9**, 269–276 (2012)
13. Soille, P.: Morphological Image Analysis, Principles and Applications. Springer, New York (1999)
14. Haralick, R.M., Shapiro, L.G.: Computer and Robot Vision, vol. I. Addison-Wesley, Boston (1992)