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Novel and powerful mosaic constructor for territorial analysis using mobile robots via Binary Robust Invariant Scalable Keypoints

Pedro Pedrosa Rebouças Filho[a,*], Francisco Diego Lima Moreira[a], Leandro Bezerra Marinho[b], Jefferson Silva Almeida[a]

[a] Laboratório de Processamento de Imagens e Simulação Computacional (LAPISCO), Instituto Federal de Educação, Ciência e Tecnologia do Ceará (IFCE), Fortaleza, Ceará, Brazil

[b] Departamento de Engenharia em Teleinformática, Universidade Federal do Ceará, Fortaleza, Ceará, Brazil

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ABSTRACT

One of the most fundamental problems in mobile robotics is to build an environment map. Digital image processing techniques can be applied to extract the most important information from the environment to solve such tasks. In this work, we proposed a new approach to build mosaics using the Binary Robust Invariant Scalable Keypoints (BRISK) method from images captured by a mobile robot and an Unmanned Aerial Vehicle (UAV). Furthermore, we compared our approach with the Scale Invariant Feature Transform (SIFT) and Speed Up Robust Features (SURF) techniques to find the points of interest. The Random Sample Consensus (RANSAC) and the Least Median Square methods were used to find the homography matrix, while the Cubic and Linear Interpolation methods were applied to build the mosaic. According to the results, BRISK with RANSAC and Linear Interpolations were the fastest methods taking 15.671 ± 4.665 s, while, SIFT and SURF took 78.074 ± 5.66 and 19.494 ± 2.32 s, respectively. BRISK achieved the same values as SIFT and SURF for the metrics Mean Squared Error, Peak Signal-to-Noise Ratio and Mean Structural Similarity Index. The results were satisfactory for territorial analysis using both the robot with wheels and the UAV.

1. Introduction

Robots have emerged as an important tool to perform daily tasks combining safety and agility. Several studies have used robotics to recognize environments using data from sensors and digital image processing techniques [1–3]. Zhou and Sakane [4] proposed a method of sensor planning for a mobile robot localization problem. Ramk et al. [5] presented an autonomous system for knowledge acquisition based on artificial curiosity using a color camera. In [6], a landmark placement for accurate and reliable mobile robot navigation is presented. Garcia and Gonzalez [7] proposed an algorithm for unstructured environments based on sensor information.

Mobile robots are composed of modules that are capable of communicating with control, location, and navigation systems as well as being able to control their movements [8]. The information obtained from the environment or from a map of the environment provided by the user can be used to generate a route and execute the navigation process. Robots need to extract attributes from the environment to carry out their navigation process [9]. The navigation process determines and executes the route or path to a destination defined by the robot control system [10]. Autonomous robots are able to extract attributes from the environment using sensors [11]. Digital Image Processing (DIP) has become an important research topic in the development of mobile robots [12]. Marinho et al. proposed a novel method for localization via classification with reject option using omnidirectional images [13].

Various attributes can be obtained from a camera installed in the robot and used to determine its localization and for navigation [14,15]. In [16], the attributes from the Structural Co-occurrence Matrix (SCM) are used for navigation and location of mobile robots on topological maps. In DIP, a mosaic technique is used to join separate and adjacent images, which are automatically grouped in a single image, and consequently a larger mosaic image is produced [17,18].

Image acquisition and mosaic formations are often applied in geoanalysis. They allow the production of small single images and then unite them to generate a larger map. In the Geographic Information System (GIS), these images are acquired by remote sensors, according to Wong and Clausi [19]. Image registration is the alignment process of the different images acquired from the same scene over different time

* Corresponding author.
E-mail addresses: pedrosarf@ifce.edu.br (P.P. Rebouças Filho), diegomoreira@lapisco.ifce.edu.br (F.D.L. Moreira), leandro.marinho@ppgcc.ifce.edu.br (L.B. Marinho), jeffersonsilva@lapisco.ifce.edu.br (J.S. Almeida).

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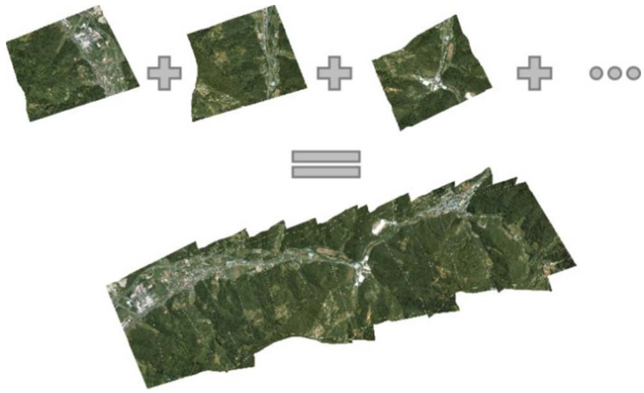

Fig. 1. Mosaic construction for Geographic Information Systems [24].

periods, different angle views or different sensors. This process is needed for image processing and some applications of computer vision, such as, object recognition, robot localization, 3D reconstruction of medical images and object tracking [20–22].

Traditionally, the image registration techniques used in remote sensing need to define the control points manually in several regions of the images [23]. These control points are then used to align an image into another image. Fig. 1 shows the result of the mosaic technique applied with Geographic Information System (GIS) images.

Recently, many studies [25–30] have proposed the use of mosaics to construct panoramic images and to obtain maps for robot navigation. In this work, we proposed a new approach to build mosaics using the Binary Robust Invariant Scalable Keypoints (BRISK) method from images captured by a mobile robot and an Unmanned Aerial Vehicle (UAV). In addition, we compared our approach with the Scale Invariant Feature Trans- form (SIFT) and the Speed Up Robust Features (SURF) methods.

2. Materials and methods

This work proposes a new approach to extract key points in the construction of mosaics using the BRISK method as shown in Fig. 2.

In the next section, the proposed BRISK method used in our approach to detect the key points and build the mosaics is discussed. Then, the SIFT and SURF methods, which were used for comparison and to demonstrate the advantages of the BRISK method, are reviewed.

2.1. Binary Robust Invariant Scalable Keypoints

According to Leutenegger et al. [31], the Binary Robust Invariant Scalable Keypoints (BRISK) method is fast and provides high quality in the detection, description and matching of keypoints. It is also invariant to rotation and scale and has a low computation cost. The modularity of the method allows it to be used with other descriptors of key points and vice versa. The BRISK method is a binary descriptor that is usually able to codify most of the information in a path as a binary string by only comparing the image intensities. This task can be fulfilled quickly, as only the intensities need to be compared.

If the hamming distance is used as a metric of distance between the two binary strings, then, correspondingly the descriptions of two paths can be made using a single.

The binary descriptor is composed of three parts: the sampling pattern, the orientation compensation and the sampling pairs. The sampling patterns are the sampling points in the region around the descriptor. The orientation compensation measures the keypoint orientation and rotates it to compensate for any rotational changes. The sampling pairs are used to determine which pairs will be compared to complete the construction of the descriptor.

The sampling pattern of the BRISK method is composed of concentric rings, as shown in Fig. 3. Gaussian smoothing is applied to each sampling point. In Fig. 3, the red circles represent the value of the standard deviation of the Gaussian filter applied at each point.

Fig. 2. Methodology proposed by the BRISK method.