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# Automatic Landmark Selection Based on Feature Clustering for Visual Autonomous Unmanned Aerial Vehicle Navigation

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***Abstract*****—**The selection of specific landmarks for an Unmanned Aerial Vehicles' Visual Navigation systems based on Automatic Landmark Recognition has significant influence on the precision of the system's estimated position. At the same time, manual selection of the landmarks does not guarantee a high recognition rate, which would also result on a poor precision. This work aims to develop an automatic landmark selection that will take the image of the flight area and identify the best landmarks to be recognized by the Visual Navigation Landmark Recognition System. The criterion to select a landmark is based on features detected by ORB or AKAZE and edges information on each possible landmark. Results have shown that disposition of possible landmarks is quite different from the human perception.

***Keywords*****—**Clustering, edges, feature points, landmark selection, X-Means.

## I. Introduction

THE use of Unmanned Aerial Vehicles has increased in the past few years in a great number of military and civil applications. As the use of UAVs increased, studies regarding the autonomous flight of the UAV became an academic field of great interest for researchers [1]. Even though the Global Positioning System and Inertial Measurement Unit (GPS/IMU) is the most common autonomous navigation system used nowadays [2], it can face serious drawbacks, due to vulnerabilities on the GPS signal and due to the integral drift of the IMU. Some examples of drawbacks are the attenuation of GPS signal on the Ionosphere, and the Equatorial plasma bubbles [3]; signal jamming; and signal multipath [2]. Any of those aspects result in a loss of precision for the navigation, which can produce unexpected events for the UAV.

A possible redundant and alternative navigation system to the GPS/INS is a computer vision based system [4], [5]. These systems use images captured during flight, process them and extract necessary information for the navigation. The main vision-based navigation systems developed yet are visual odometry [6], template matching [4], Simultaneous Localization and Mapping [7], [8] and Landmark Recognition [9], [10]. Each of them has a different aspect that works better for the navigation, depending on the flight conditions and the route area.

Landmark recognition is a promising method for autonomous navigation using images [5], [9], [10]. The aim of the system is to recognize landmarks captured by the onboard UAV vision system in real-time when flying over specific locations, thus supporting the navigation system to accomplish a planned mission. It needs, then, a previous knowledge of the flight area and the previous selection of landmarks in this area.

A person can easily select a landmark in an image, based on visual criteria, such as colors, edges and on how the objects in the scene can be differentiated from its surroundings. Usually a human operator chooses salient, usually man-made infrastructures as landmarks, such as bridges, factories, crossroads, and others [11]. However, the landmarks selected by a human operator do not necessarily have the attributes that computers use to automatically recognize the landmarks. The aim of this work, then, is to develop an automatic landmark selection algorithm taking into consideration the attributes a computer vision system uses to find the landmark, in order to have a higher true positive recognition rate.

## II. Selection Based on Features

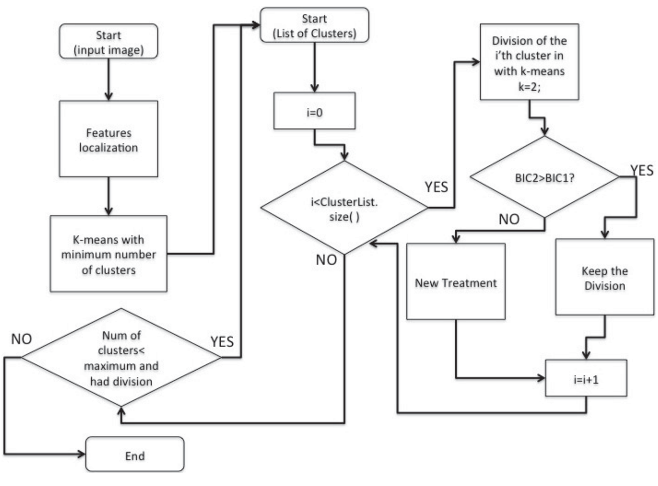


Fig. 1 Flowchart of the X-Means Algorithm proposed

There are several recognition algorithms that can be applied to recognize landmarks; most of them are based on object recognition [11]–[13]. Most recent works [10], [14] are exploring feature-based detection and descriptor extracting algorithms for the landmark recognition, both with artificial and real landmarks. A feature-based recognition algorithm briefly consists in three steps [1]. Firstly, it identifies the features of the pattern image (landmark) and in the query

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image (aerial image), which are salient points in the image, obtained by an algorithm such as FAST [15] or Hessian Matrix [16] for example; secondly, it computes the descriptors of each feature, based on its neighborhood; and finally, it matches the features from the query image with the ones on the pattern image using their descriptors. This matching is a many-to-many matching, and it is evaluated by a distance function, in which the best matches have the lower scores. Because of this matching process, it is believed that the success for recognizing a landmark depends on how many features a landmark has, because it would increase the probability of inliers in the matching process. It is possible, then, to understand that a good landmark for the computer would be regions of the flight area that would concentrate a high number of features.

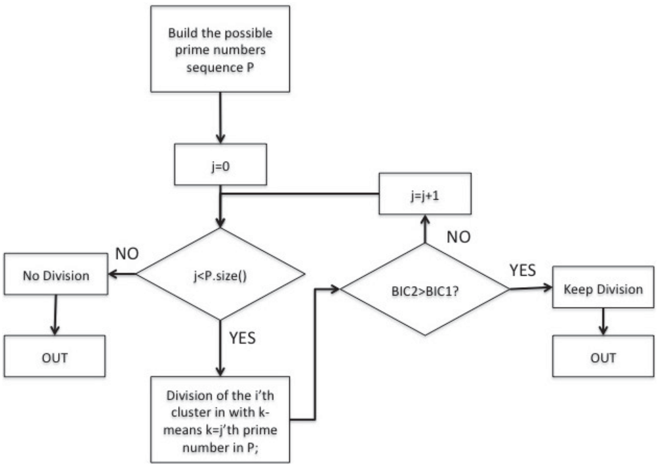


Fig. 2 Flowchart of the New Treatment Box, with the Prime Numbers

Supporting this hypothesis, Zhang and Miao [17] show an approach in the use of features for object recognition. They use a self-adaptive kernel-clustering algorithm to specify clusters in a image with the purpose of obtaining better matching results. This shows that the features in an object have a spatial correlation, that can be used also for the landmark selection.

Landmark selection is mostly found in the literature for robots navigation and others non-aerial perspectives [18], [19]. In Feng et. al. [20], it is also proposed an automatic landmark selection using feature extraction with the purpose of a better feature matching for landmark recognition on the lunar surface. The challenge in this works is that the similar and textureless terrains on the lunar surface forces them to form landmark patches with clustering algorithms, since distinctive landmarks are difficult to find.

Based on Feng et. al. [20] and Zhang and Miao [17], this works implements a self-adaptive clustering algorithm to find the best landmarks in a possible flight area for a UAV. These possible landmarks can be used to plan a route for an UAV flight based on a visual-aided landmark recognition navigation system. This work developed modifications on a previously developed clustering algorithm, the X-Means [21].

There are several drawbacks on using X-Means as it was implemented in the literature. The main aspect is the clusters division in only two subclusters, which may not represent properly how the landmarks may be on the flight area image. This work, then, proposes a different approach considering that there may be other spatial configurations for the subclusters,as presented in Figs. 1 and 2.

The division now can be performed not only in two subgroups, but also in any prime number of subgroups, as in Fig. 2. So the proposed algorithm tests sequential divisions in prime number groups, until it finds a solution with a higher BIC result. This division, though, is also limited by the mean number of Features each subcluster may have. It is not interesting to have groups with a small amount of features, since they would not represent a good landmark for the algorithm.

In Silva Filho [10], there is a second part for the landmark recognition, which uses the edges of the image to perform a correlation between the landmark candidate with the actual landmark to be recognized. For the selection process, then, it is also important to evaluate if the resulting cluster of features is on a part of the image that has distinct edges for the recognition. So the region for each cluster was cropped and had the edges extracted. The amount of edges, then was evaluated in a Edge Factor Function as in Fig. 3. This function was empirically constructed.

## III. Experiments and Results

Tests were performed using four images: one aerial image, a mosaic made with aerial photos of a possible flight area, and two satellite images of a possible flight route. Those images were obtained in different conditions and with different sources, in order to test the applicability of the method in a general matter.

Figs. 4-7 shows the result for the algorithm proposed and compares with the algorithm in [22], which proposed the BIC modification. Comparing each pair of images, the separation of clusters was better than the former X-means implementation with just the BIC modification, since the mean distance of the features to their cluster center was smaller than in the previous implementation. This means that the groups were more connected and better separated.

At the same time, the use of Edge Detection on each possible landmark obtained in each cluster, and the proposed Edge Factor also proved to be a suitable tool to prioritize the best landmarks, as in the literature: salient, usually man-made infrastructures [11]. Fig. 8 shows the result for the Aerial image. At the same time, there are some drawbacks on the edge factor, such as shadows and the size of the landmark candidate, which would result in a high factor, but still would not be a good landmark.

On the other hand, both strategies served to understand that landmarks can be extended not only to an object itself, but also to a region with possibly an object or part of it. That way, the route for the UAV may have more landmarks that a human operator would indicate.

## IV. Conclusion

The proposed X-Means was able to divide the features of the image in a proper manner, in which landmarks could

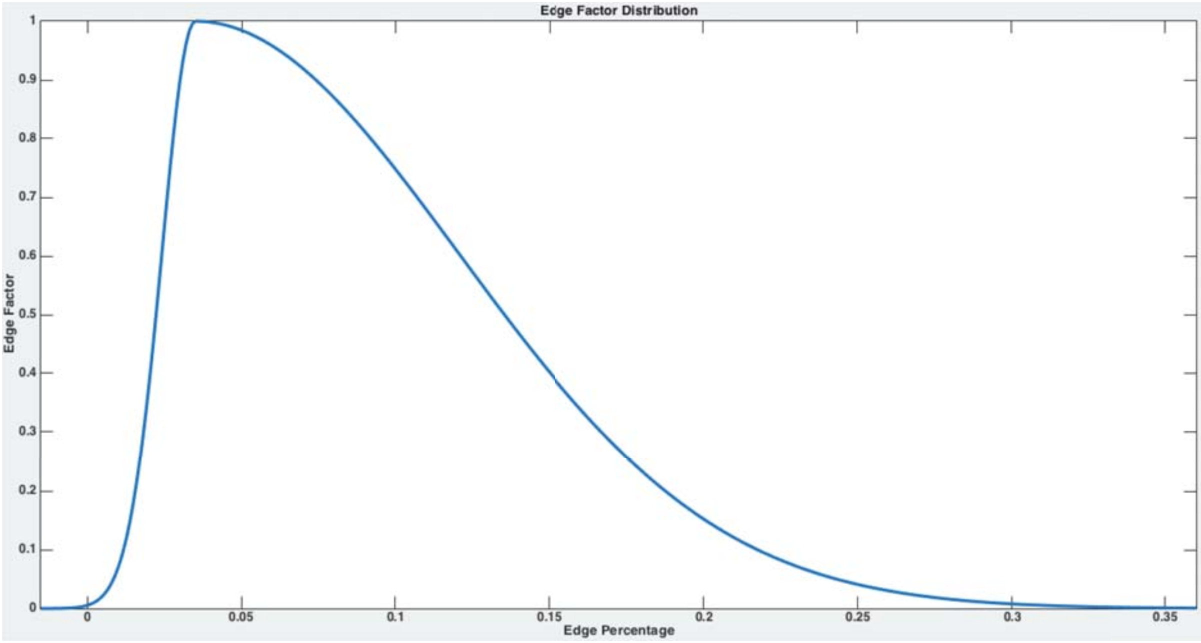


Fig. 3 Edge Factor Distribution


Fig. 4 Landmark Selection for the Aerial Frame using ORB. (a) is the Result for the X-Means in [22] and (b) is the result for the Proposed X-Means

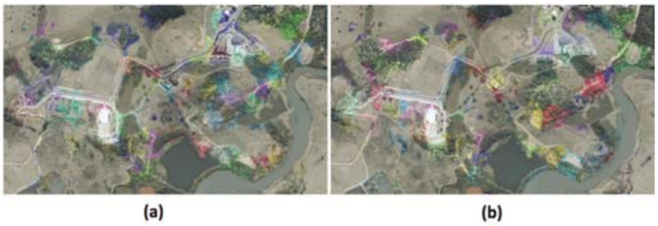


Fig. 5 Landmark Selection for a Satellite Image using AKAZE. (a) is the Result for the X-Means in [22] and (b) is the result for the Proposed X-Means

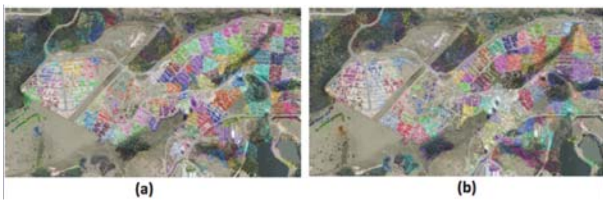


Fig. 6 Landmark Selection for a Satellite Image using AKAZE. (a) is the Result for the X-Means in [22] and (b) is the result for the Proposed X-Means

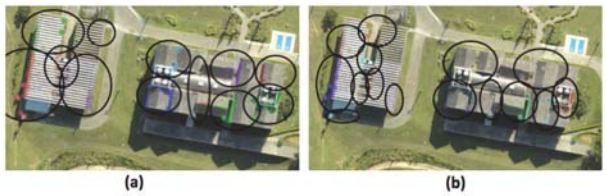


Fig. 7 Landmark Selection for the Aerial Mosaic using ORB. (a) is the Result for the X-Means in [22] and (b) is the result for the Proposed X-Means

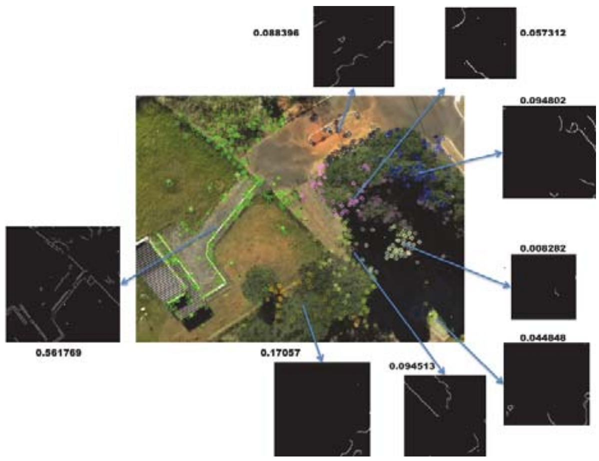


Fig. 8 Landmark Selection for the Aerial Frame using AKAZE, with the resulting Edge Detection and Edge Factor

be determined. The results showed results compatible with what a human operator would separate, but also expanding the landmark definition for the route planning. It is, then, expected that better recognition of landmarks for an autonomous vision-based flight will be achieved. Simulation tests are being developed in order to prove that landmarks automatically

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selected have better recognition rate than the ones selected by a human operator, but preliminary results are quite promising. In-flight tests are, though, still necessary to validate the assumption, and are the subject of future works.

Even though it is strictly necessary, the edge factor is still under development and further analysis and implementations, though, are still in need. As future works, also an automatic route-planning algorithm based on landmarks and on the parameters of the landmark selection will be developed, and tested onboard.

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