Visual-based Natural Landmark Tracking Method to Support UAV Navigation over Rain Forest Areas

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Abstract: Field application of unmanned aerials vehicles (UAVs) have increased in the last decade. An example of difficult task is long endurance missions over rain forest, due to the uniform pattern of the ground. In this scenario an embedded vision system plays a critical role. This paper presents a SIFT adaptation towards a vision system able to track landmarks in forest areas, using wavelet transform to suppression of nonrelevant features, in order to support UASs navigation. Preliminary results demonstrated that this method can correctly track a sequence of natural landmarks in a feasible time for online applications.

1 INTRODUCTION

The use of Unmanned Aerial Systems (UASs) in real scenarios has increased in recent decades due to its advantages when compared to manned aerial systems, especially in avoiding risks to human operators, as they are not in the cockpit, but comfortably seated miles of distance away of the operation theatre. UAS applications spans from military to civil domains and can cover a dozen of different types of missions, including border security, combat, scientific research, environmental monitoring, among many others.

In (Bueno et al, 2001), one can find results of an system prototype based on an airship designed for environmental monitoring, more specific, for the Amazon rain forest area. However, there are difficulties to operate autonomously in all-weather condition, while ensuring a safe flight, demanded better navigation systems than the ones available at that time for scientific research applications.

On the other hand, the lack of effective civil applications of UAS to help protecting the Amazon Rain forest shows that the challenges are still beyond what current solutions can provide. For instance, a relevant problem to be faced is the navigation over the Amazon due to the all-equal treetops view from above, even with good weather and long-range visibility. The problem complexity increases dramatically in the occurrence of fog or a cloudy weather (not mentioning rain). In such scenario, natural landmarks on the ground play an important role in navigation supporting system, providing to the vehicle references to be followed. Moreover, to extend off-the-shelf vision systems to treat natural landmarks is, basically, an issue of software development.

As natural landmarks, one may have clearings, river branches, or any element that contrasts from the uniform pattern of the canopy (for forests, canopy refers to the upper layer). The problem of tracking of the natural landmarks in forest areas starts to be treated (Pinagé et al., 2012), but remains a challenge.

The autonomy of an UAV increases with an embedded vision system helps to solve unexpected critical situations, e.g., loss of Global Positioning System signal (GPS), and the ability to interact with the environment using natural landmarks (Cesetti et al., 2009). The aerial navigation system can decide the next target, and change it as new and updated images of the environment become available.

This paper presents a methodology solely defined by software to track natural landmarks in real-time, among a set of predefined ones to extent UAS navigation capability in the context of the Amazon rain forest.

The paper is organized as follows. Section 2 details the method specification, describes the image processing techniques and how they are applied. Section 3 presents the preliminary results. Finally, in Section 4 concludes the paper.

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2 METHOD DESCRIPTION

The block diagram of Figure 1 shows how the steps are organized. The UAV reaches (using GPS) the search space (the neighborhood area of the reference image) by GPS and then activate the vision system.

Initially, the canopy pattern is eliminated via multiresolution analysis of images based on wavelet transform. In this case, at a larger scale it is possible to extract only the salient features and suppress the nonrelevant ones (Fonseca et al, 2008). This is necessary, otherwise during feature extraction hundreds of useless features, related to leaves, branches, and other small image elements related to a typical canopy texture, will be found.

We use multiresolution analysis to adapt the SIFT in order to eliminate the canopy pattern.

In summary, the current video frames are processed online to compare their keypoints with the ones at the reference image. This way the natural landmark is tracked. As soon as the landmark is found the vision system locks it, while preparing to search the next landmark.

2.1 Nonrelevant Features Suppression

The wavelet transform is an useful and powerful tool for image local analysis and processing. As digital images are discrete data, we use the discrete wavelet transform (DWT). This way, only really large and robust features will be well represented.

According to (Meddeber et al, 2009), the same image is represented in different resolutions and scales in each decomposition level. Thus, the nonrelevant features disappear in the low resolutions (large scales) and the biggest and really important features can be identified more easily.

In each decomposition level is created four images (sub-bands): LL, LH, HL and HH. This decomposition can be repeated recursively, reaching other levels. Therefore, LL sub-band contains maximum information compared to others sub-bands (Malviya and Bhirud, 2009), and it is considered the approximation of original image, also with the small features suppressed.

2.2 Keypoints Identification and Point Matching

The main process is the identification of keypoints in the acquired image and matching them with the reference image keypoints set. In this paper, the keypoints can be rivers, roads, its details (corners, turns, margins, etc) or any information that does not correspond only to trees.

There are automatic methods to identify keypoints, developed from algorithms that use similarity measurements. The same method applied in the identification of the keypoints of the reference image (done offline) has to be applied in the sensed video frame (during the flight). The SIFT, developed by (Lowe, 2004) was utilized in this work to generate descriptors of keypoints which are invariant to scale, rotation and partially invariant to change in illumination.

There are also other methods for automatic point identification and matching, such as SURF (Speed Up Robust Features) and ASIFT (Affine SIFT). Both are extensions of the SIFT. The SURF (Bay et al, 2006) uses integral images for image convolution and thus computing and comparing features much faster. And the ASIFT (Morel & Yu, 2009) uses the same SIFT techniques to be invariant to scale and rotation, combined with point of view simulations, which provides much more correct matches. Therefore, as confirmed by the experimental results in the next section, SIFT is by far the best suited method for feature matching to our scenario of application.

2.3 SIFT Adaptation

As wavelet advantages mentioned before, the SIFT algorithm was adapted in order to detect only relevant features for this problem, in addition to reduce your runtime. In (Kim et al, 2007), they propose a SIFT adaptation that uses *Difference of Wavelets* (DoW) for detection of local extrema. Applied to forest images, this method extract a lot of features including canopy pattern, it can be verified in the next section.

Inspired in DoW method, we use the LL sub-bands of wavelet decomposition just to be the first image of each octave in the space-scale generated by SIFT (Figure 2). This way, the wavelet transform is responsible to suppress nonrelevant features each next octave.

3 PRELIMINARY RESULTS

The software application was implemented using C++ language with OpenCV library. The images and videos used were obtained by flights over forest areas near the cities of Manaus and Belo Horizonte (Brazil).

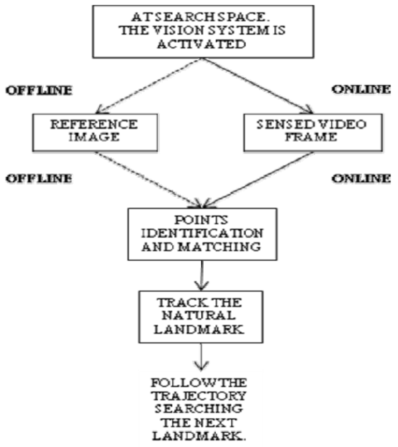

Figure 1: Natural landmark tracking scheme.

The results are obtained after the matching process between the reference image containing the natural landmark and the sensed frame that simulated the online video frame of the UAV; these input data were obtained by the same sensor, in different time, angles and altitudes.

SIFT, SURF and ASIFT algorithms were applied to detect the keypoints and afterwards match the images. These three algorithms were compared to validate their feasibility for this specific application.

Table I presents the average runtime and the accuracy rate of each algorithm. It is clear that the ASIFT has a large amount of correct matches, however, it has a computational cost unfeasible for this real-time operation. SURF, on the other hand, although fast, has many wrong matches.

SIFT presented the best trade-off between matches and computational effort, with a sufficient amount of correct matches to track the natural landmark and an acceptable runtime when considering this real-time operation.

SIFT was adapted for improve the keypoints detection by suppressing of the nonrelevant features (canopy). The DoW method detects many keypoints including the canopy (Figure 3(b)), the opposite of the objective of this work. Therefore it is not feasible for this application.

Our SIFT adaptation only substitutes the first images of each octave for the LL sub-bands obtained by *Haar* wavelet decomposition, and keeping the Gaussians for the intervals, as shown in Figure 2. The keypoints detected by our SIFT adaptation can be verified in Figure 3(c). Our SIFT adaptation has a computational cost very close to original SIFT. However, the differential of our adaptation is being able to suppress canopy pattern.

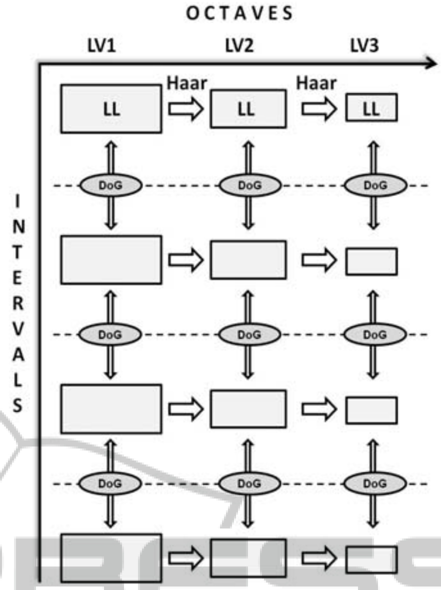

Figure 2: Our SIFT adaptation.

This paper shows one tracking test using our SIFT adaptation, which can be observed in Figure 4, which images at left are the sensed frame, and the images at right are the reference images.

Furthermore, this tracked frame will be also stored to be used as natural landmark and support next missions over the same area and similar weather conditions.

4 CONCLUSIONS

All implementations were solely based on software. The methodology combines two existing image processing techniques focusing in your importance to this application.

We could conclude that SIFT is the best of the three tested algorithms, because it does not to exceed the computational cost required for real-time systems, and does not have many wrong matches.

The runtime of the tests were very promising with respect to the feasibility of this method to an embedded vision system.

Table 1: Average runtime and accuracy rate.

Algorithm	Steps	Average Runtime (s)	Accuracy Rate (%)
SIFT	Points Detection and Matching	0,9273	97
SURF		0,0319	75
ASIFT		9,66	99

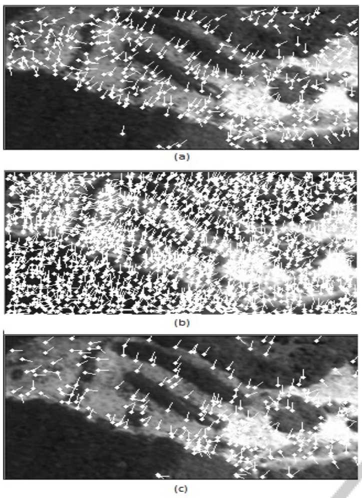

Figure 3: Keypoints detection: (a) original SIFT; (b) SIFT by DoW; (c) Our SIFT adaptation.

Our SIFT adaptation is useful for this application to eliminate canopy pattern by wavelet decomposition, detect more easily the relevant features, and thus, ensure the correct natural landmark tracking.

Next steps include the increasing of the database of images. In addition to treating the occurrence of clouds that can cause occlusion of natural landmarks. Finally, the system will be embedded for the validation during experimental flights.

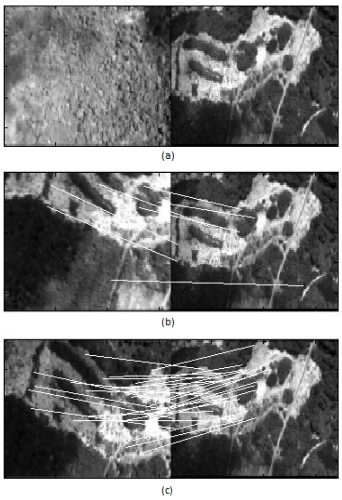

Figure 4: Tracking: (a) Any matches were found, the frame contains only clouds and tree pattern; (b) bad representation of the natural landmark; (d) final result and best representation of the natural landmark.

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