Research on Power Line Inspection by Visual Based Navigation

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Abstract. In this paper, the advances obtained through a research process based on the development of a visual based navigation model for an UAV (Unmanned aerial vehicle) with application in power line tracking for inspection are presented. The main contribution expected is the method for line tracking through UAV navigation. In this process, a new line detection method based on a computer graphics process was created. The method is validated with synthetic and real images. Additionally, a virtual environment for real time simulation and line detection was created. The results obtained in the line detection process are promising.

Key words: Inspection, power line detection, navigation, UAV.

1 Introduction

Countries like Spain, United Kingdom, China and Australia spent efforts and resources in the development and implementation of technologies for the power line inspection. As well as these, and considering that, Colombia dedicate an important part of its economic development to the natural resources utilization, specially electric energy, it is important to make efforts in developing methods for improving the different processes of electrical infrastructure inspection and maintenance.

According to the power line failure, there are different methods for power line inspection; the main methods are: manual, manned flights and, recently, UAVs; see Figure 1.

Power line detection is an important task in the inspection of electrical infrastructure prior to maintenance, for this reason, there is an interest in developing methods that reduce costs, risks and the logistic problems of manual inspection including manned flights [1], [2], [3] by using UAVs [4]. The UAVs can be used for capturing images from different views that have to be processed in order to detect power lines [5]. It is good to mention that there are companies that

(a) Manual[4]

(b) UAVs[5]

Fig. 1. Types of power line inspection.

offer different services and products for electrical inspection, including UAVs; see Figure 1.

There are different methods for line detection that have been used in power line detection for UAV images. These are based on edge and ridge detectors, magnitude and gradient orientation, voting schemes, line support regions, growing regions and chain codes [6–11]. The classical method for line detection is the Hough transform [7], which can detect lines in well contrasted and segmented images. This method was used in combination with a PCNN (Pulse-coupled Neural Network) for removing background and clustering for power line detection [12]. In the work of Zhang [13], a process for power line detection and tracking based on Hough transform with Kalman filter is presented. In this case, they use the Otsu threshold method obtaining better results than PCNN filters.

It is good to mention that some works of line detection have a post processing stage for connecting line segments or cluster interest lines [13], [14]. Recently, a method for line detection based in region growing, ridge filters and chain codes was developed in [11].

According to all of the above, this paper is organized as follows: Section 2 presents the research problem to solve, Section 3 explains the research methodology, Section 4 exposes the main contribution and finally, Section 5 presents the results achieved and their validity.

[4] Source Argano group `http://www.arganogroup.com`.
[5] Source Aibotix GmbH `http://www.aibotix.es`.

2 Research problem to solve

Taking into account the importance of line tracking in an automated inspection process, the development of a process of servo-visual control for line tracking is proposed. This process includes the development of a line detection method, since it is required to accomplish the line tracking in order to achieve automatic inspection systems [5]. Additionally, we have not seen many works that approach the line tracking implementation. We also consider that the geometric scene understanding can be very useful for this problem, since it can allow the UAV to make decisions for navigating in complex environments.

The line detection techniques mostly used are: Hough Transform, Line Segment Detector (LSD) [9], Edge Drawing Lines (EDLines) [10] and approaches based on steerable filters and growing regions [14].

The pole detection is an important aspect in the process of inspection, since its detection can help to select the regions where the power lines are located. The graph cut image segmentation combined with priori knowledge and Radon Transform have been used for this task [15].

On the other hand, in the area of visual servoing with UAVs, the works of [16], [17], [18], [19], use feature descriptors such as SIFT and SURF in order to find key points for navigation and reconstruction.

In vision systems, the problem of visual odometry is very important. One approach for this is to incrementally retrieve the path pose to pose and to optimize over the last n poses. In addition to this, by means of visual simultaneous localization and mapping (VSLAM), it is possible to achieve an estimation of the robot trajectory [20]. This implies the maintenance of an environment map and the detection of a robot when it returns to a previous visited area.

Based on the above related work, the main goal of this research is to develop an UAV vision based navigation for power line detection and tracking and a 3D reconstruction of the surroundings; specifically:

- *To develop an algorithm for power line detection.* A comparative analysis of the existent method such as Hough transform, LSD and EDLines is proposed. A linking of line segments stage is considered.
- *To develop a visual servoing system for line tracking from an UAV.* In this process the use of visual servoing is considered. This allows the UAV to locate itself in order to navigate along the power line. Additionally, the use of geometric scene understanding (GSU) is proposed in order to generate control actions during the navigation.
- *To develop a VSLAM for navigation in power line surrounding.* We consider that the three-dimensional reconstruction of the environment of the power line can be useful for the inspection and maintenance. For this, we plan to use features such as SIFT and SURF. For the correspondence stage, RANSAC and ICP algorithms will be used in order to find the correspondences and compute the geometric transformation between images and GPU processing techniques for rendering.

3 Research Methodology

The methodological process is composed of three stages: in the first one, a relevance analysis of line detection methods is considered and the creation of a new line detection method is proposed; the second one, is a validation of real time detection in a flight simulator, and, in the third one, the evaluation in a real platform is contemplated.

Due to the fact that many UAV navigation tests will be performed, it is necessary to develop virtual environments for simulating these tests under different conditions. This kind of simulations comprise dynamical models of the UAV, as shown in [21]. These have also been used for SLAM[6], as shown in [22, 20]. This provides different possibilities for the start of operations avoiding damages to the device, as well as the incorporation of other flight platforms and different scenarios.

There are some platforms for UAV simulation such as USARsim[7]; another option is to use ROS (Robot Operating System)[8] as shown in [21]. For the development of this project, we decide to use a gazebo simulator called Tumsimulator, that was developed at the Technical University of Munich[9].

The activities to perform as a part of the research methodology are divided into three specific goals explained in the following subsections.

3.1 Power Line detection

- To acquire a dataset of power lines; see Figure 2.
- To implement state of the art line detection algorithms in CPU.
  - Hough.
  - LSD.
  - EDLines.
- To create a new line detection method.
- To validate this method with real images of power lines.
- To analyse the paralelizable stages of this algorithm.
- To implement the new line detection method in CUDA [10].
- To create a virtual environment: It is a scenery with different configurations of power lines. A set of towers and poles will be created by using a 3D modeling software; see Figure 3.
- To validate the line detection method with synthetic images taken from the virtual environment.

[6] Simultaneous localization and mapping
[7] usarsim.sourceforge.net
[8] http://www.ros.org
[9] http://wiki.ros.org/tum_simulator
[10] CUDA is a parallel computing platform and programming model invented by NVIDIA

Fig. 2. Some images of the acquired dataset

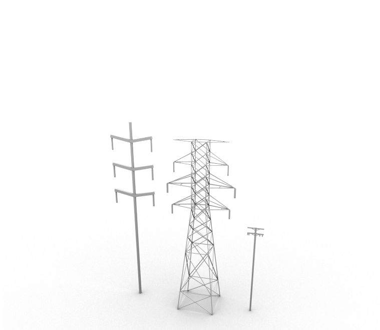
3.2 Power Line tracking

- To create a set of videos of power lines.
- To adjust the parameters in order to detect lines in real time.
- To implement the line detection method in a real time flight simulator for UAVs that continuously renders and processes images of scenes.
- To create a technique that allows a virtual UAV of the simulator to track the power line by using the detected lines. This can be a visual servoing algorithm.
- To validate the technique in the virtual environment.
- To validate the technique in a real platform.

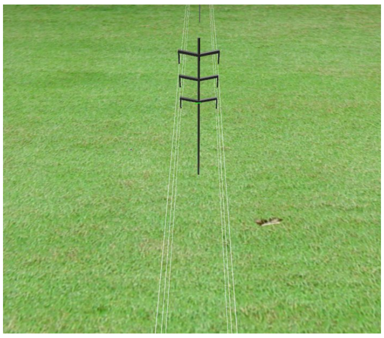
3.3 VSLAM for navigation in power line surroundings

- To implement a set of 2D feature descriptors.
- To implement a set of algorithms for feature correspondence.
- To evaluate the performance of the selected feature descriptors with the different correspondence algorithms for images of power lines.
- To compute the homography matrix and perform 3D reconstruction of different scenes.
- To implement a VSLAM process in a real platform. In first instance we plan to use an AR-DRone 2.0 platform[11], after that a bigger UAV such as Pelican[12], will be used.
- To evaluate the performance of the system under different environmental conditions.

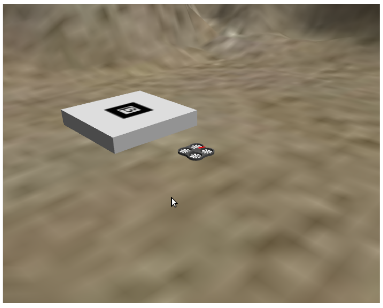
[11] http://ardrone2.parrot.com/
[12] http://www.asctec.de/uav-applications/research/products/asctec-pelican/



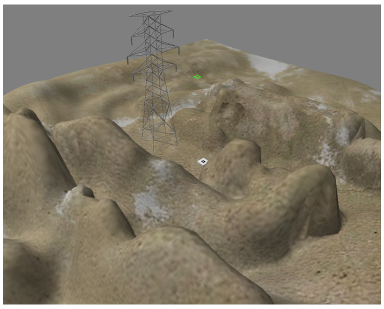
(a) 3D Models



(b) A scene for testing



(c) UAV simulated



(d) Virtual environment

Fig. 3. Development of the virtual environments for simulation.

4 Main contribution

The main contribution of this work, is the development of a visual based navigation model for UAVs with application in power line tracking for inspection and 3D reconstruction of the surroundings.

For this reason, it is necessary to develop a vision system composed of computer vision techniques for detecting and tracking objects of interest, such as lines and towers, in order to validate the model.

One derivative contribution of this work is the creation of a new line detection method.

The algorithm is composed of a valid point detector. This is a method that locates points that belong to a line in a segmented image; see Figure 4. This algorithm is based in computer graphic primitives and location of symmetric points in lines. It requires the use of a circle drawing.

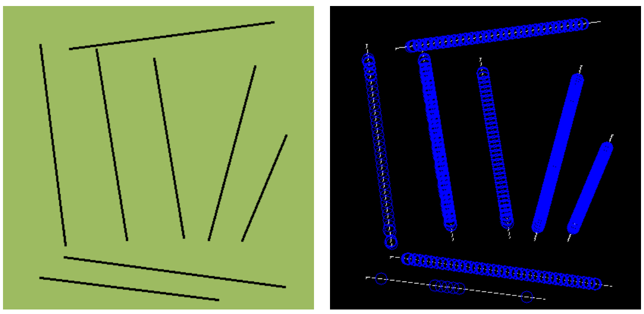
The process comprises the following stages:

- To segment the image with an edge detector, the Canny or a Steerable filter may be used.
- For all pixels at the image that are different than background:
  1. To search valid points by using a circle drawing algorithm.

2. If is a valid point obtain a value of Dx and Dy (see Figure 4.
3. Move towards the symmetry direction by using the values of (Dx, Dy).
4. While (Valid Point)
   - Move the position (x, y) to the values of $(x + skip \cdot Dx, y + skip \cdot Dy)$.
   - To search valid points by using a circle drawing algorithm.
5. Save first and final points.
6. Trace a line between the first and final point, in order to erase the pixels associated to the line in the segmented image.

The main parameters of this method are the following:

- Search radius: this is the circle radius which depends on the length of the line and the size of the image. It has to be larger than 3 pixels in order to capture more details.
- Percent of points detected: when a valid point is selected, it is necessary to take into count how many points are found in a straight line between its two end points. The points are obtained by using primitives for line tracing such as DDA or Bresehnham [23].
- Skip value: This is an increment of skip from a valid point to another. It has a way to control the velocity of the process and its accuracy. This value can be close to the circle diameter.



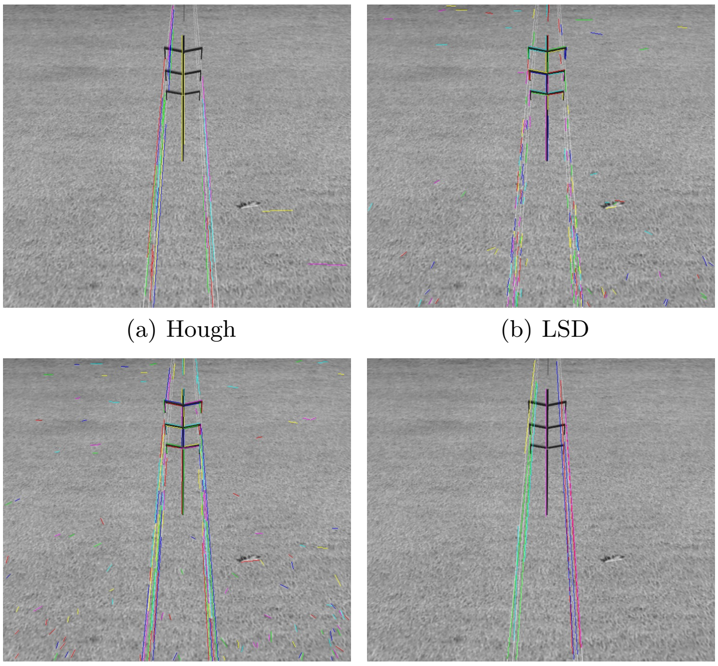
(a) Original (b) Valid points

Fig. 4. Obtainment of valid points.

5 Results achieved and their validity

A new method for line detection based in the computer graphics approach for drawing circles was developed. This method allows to obtain key points of lines by using a symmetry analysis in a circle based search.

This method is validated with synthetic images (see Figure 5) and real images (see Figure 6), obtaining satisfactory results.



(a) Hough (b) LSD

(c) EDLines (d) Proposed

Fig. 5. Comparison between different methods for the image in the Figure 3(b).

One advantage of this method, is the use of integer arithmetic in most of the process. The time of response of the line detection is enough for real time processing 10 to 60 milliseconds, approximately, in images of 800×600 pixels.

A three dimensional model of the power lines was built in order to generate synthetic images of power lines with different points of view; see Figure 3.

It is important to mention that by using virtual environments, it is possible to create different configurations of the scene for validating computer vision techniques.

Finally, an integration of the virtual environment of simulation with the computer vision techniques is obtained. In Figure 7, the process of segmenting and line detection is shown.

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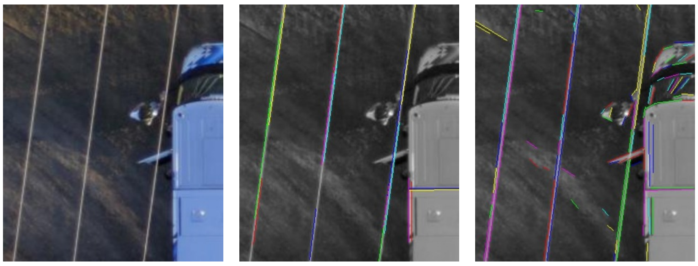
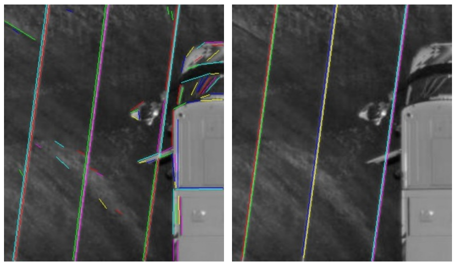
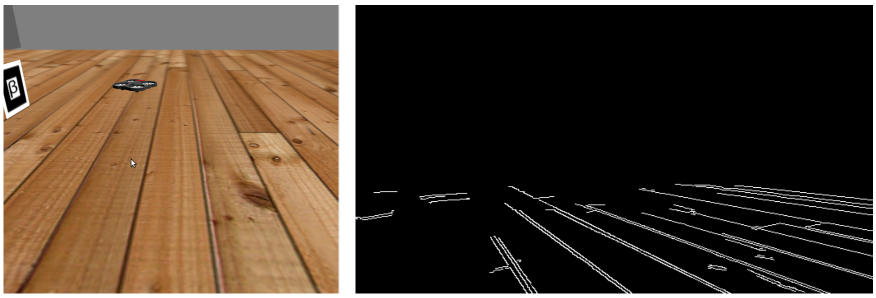


(a) original (b) Hough (c) LSD



(d) EDLines (e) Proposed

Fig. 6. Result for detecting lines in real images segmented using canny and different methods for detection.



(a) Virtual environment (b) Segmentation in real time

(c) Line detection in real time

Fig. 7. Results of integration of simulator with computer vision techniques.