To identify hot spots in power lines using infrared and visible sensors

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Abstract. The detection of power transmission lines is highly important for threat avoidance, especially when aerial vehicle fly at low altitude. At the same time, the demand for fast and robust algorithms for the analysis of data acquired by drones during inspections has also increased. In this paper, different methods to obtain these objectives are presented, which include three parts: sensor fusion, power line extraction and fault detection. At first, fusion algorithm for visible and infrared power line images is presented. Manual control points describe as feature points from both images were selected and then, applied geometric transformation model to register visible and infrared thermal images. For the extraction of power lines, we applied Canny edge detection to identify significant transition followed by Hough transform to highlight power lines. The method significantly identify edges from the set of frames with good accuracy. After the detection of lines, we applied histogram based thresholding to identify hot spots in power lines. The paper concludes with the description of the current work, which has been carried out in a research project, namely *SCIADRO*.

Keywords: Image analysis, Visible Images, Infrared Images, Image registration, segmentation, Unmanned Aerial Vehicles, Hot spots

1 Introduction

Defect detection in power lines at an early stage can save the life and ultimately cost of the power system maintenance. During the past, the inspection of power lines were mainly carried out by foot patrolling which is time consuming, expensive and unsafe method. Unmanned Aerial Vehicles (UAVs) provides an alternate solution which reduces both the risk and the cost. More recently, thermal camera mounted on UAVs emerges as the most smart and convenient solution of power line inspection. Thermal and infrared (IR) imaging has gained recognitions in the field of power systems during the last two decade. It has been used for testing and inspection of different electric parts and also for preventive maintenance work. Infrared imaging uses infrared sensors to capture images of thermal objects based on temperature variations. The camera stores the infrared pictures of the objects as thermal and infrared images that the human can see in order to understand the conditions of the objects. In general, thermal imaging is considered as a robust, non-destructive and contact less methodology to inspect power lines as the inspection can be performed by keeping some distance and hence there is no need to halt or cut down electric supply during the inspection. More recently, UAV based power line inspection utilizes modern flight control techniques and image processing to carry out fast inspection from some distance. Compared with conventional inspection methods, UAV based inspection is more advanced and low-cost. Based on GPS data of both the UAV and towers, the embedded algorithm can also perform automatic tracking of power lines [1]. Later, these thermal images undergo different statistical and morphological processing to highlight hot spots in cables and insulators.

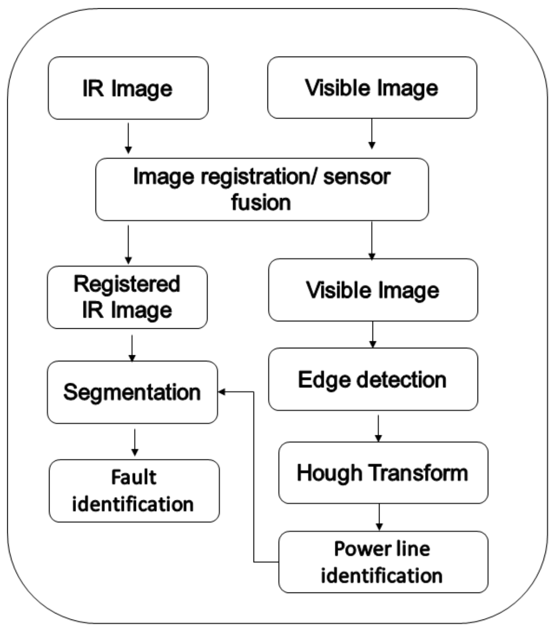

Fig. 1. Block Diagram of complete processing.

In this paper, we use different morphological methods to identify these hot spots in power lines. Several methods have been proposed in the past to identify hot spots in electrical equipments e.g. Hongwei et al. had presented a fusion algorithm for the infrared and visible power lines image [2]. Vega et al. presented a system based on a quadrotor helicopter for monitoring the power lines [3]. Lages et al. captured video streams from both an infrared and visible cameras, simultaneously [4]. They used both statistical and morphological methods to highlight the hot spots in the lines. Oliveira et al. discussed in detail the generation of hot spots in the transmission lines and later they had also used the same thresholding based segmentation to highlight hot spots [5]. Similarly, Wronkowicz had proposed an automated method for the hot spot detection from IR images of power transmission lines, without any reference temperature value [6]. A brief survey of some of these methods are given in [7, 8].

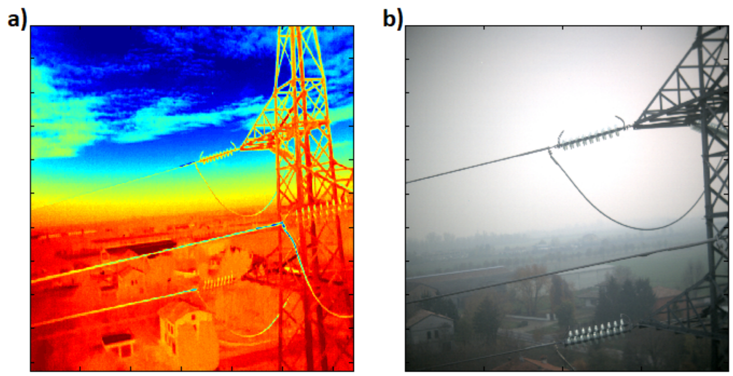

Fig. 2. a) Infrared image of the tower and power cables. b) Visible image of the tower and power cables.

2 The SCIADRO project

This paper deals with the ongoing work being done in SCIADRO [1], a research project. The main idea of our work in the SCIADRO project is to provide a tool to support simultaneously the detection of the infrastructure components. Also, such algorithms should be specifically designed for the collaborative setting of an UAV swarm. The image processing aims at detection and analysis of the main components of the electrical infrastructure: electric towers, insulators, and conductors. Thermal data and images in the visible spectrum have been acquired by a drone flying at a distance of approximately 10 mt from the power lines, with different cameras, near Parma (Italy) in December, 2017. Data include also a small number of images containing common defects. These data have been used to test our methods for the detection of the infrastructure and the diagnosis of its status. At this stage, two tasks have been implemented and partially tested on real data: *i* Sensor fusion: we had applied control point selection based image registration to use both thermal and visible images to identify hot spots; *ii* detection of power lines by image processing applied to RGB images.

3 Methods

In this work, we used infrared and visible images to identify hot spots in power lines. The block diagram of processing is shown in Fig. 1. Images acquired by visible and infrared sensor as shown in Fig. 2 have different field of View, therefore, in order to identify faults from thermal images it is important to do sensor fusion first. We used manual control point selection followed by affine transformation to register both images. At second stage, we identified faults from thermal images by first segmenting power lines from the background using visible images. We applied Canny edge detection on visible images to identify significant transition and keeping in mind the linear characteristics of power lines we used Hough transform to segment power lines. At the last stage, we used histogram based thresholding to identify hot spots in thermal images. In the following section we provide a description of each step.

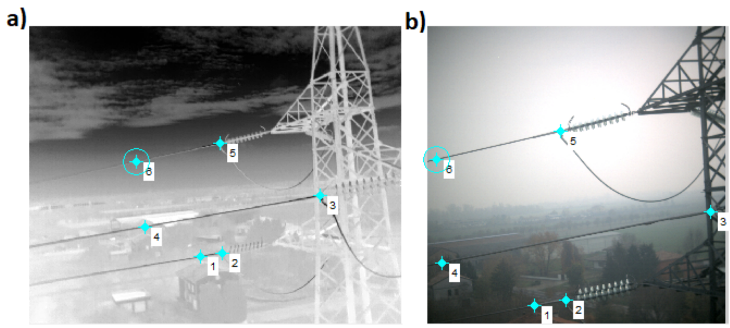

Fig. 3. Control point selection from IR and Visible image for image registration. IR image has larger FOV (field of view), so we selected IR image to be registered.

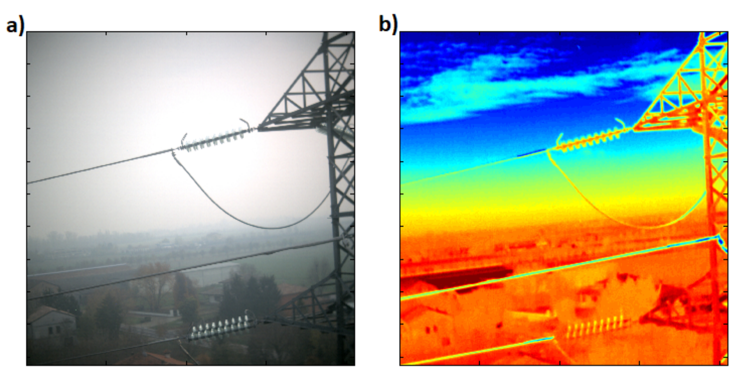

Fig. 4. Registered visible and IR image.

3.1 Image registration

Image fusion or registration is the process of extracting and integrating the information from two or more images of the same scene taken at different times, from different viewpoints, or by different sensors. This process can provide more accurate, comprehensive and reliable image information of the same scene or object, making fusion images more suitable for human eye perception or computer understanding. [2, 9]. The infrared and visible light image have different imaging principles, which can generate some problems such as infrared image has a low contrast and high noise. Therefore, in order to take an advantage of both visible and infrared image properties, it is important to register them first [10]. A brief survey of some of these techniques is given in [11].

Image registration is defined as a mapping between two or more images both spatially (geometrically) and with respect to intensity. By mathematically expressing [12]:

$$I_2 = gI_1(f(x_1; x_2)); \tag{1}$$

where I_1 and I_2 are two-dimensional images (indexed by $x_1; x_2$), $f : (x_1; x_2) \rightarrow (x'_1; x'_2)$ maps the indices of the distorted frame to match those of the reference frame, and g is a one-dimensional intensity or radiometric transform. We use fusion algorithm based on manual control point selection of the infrared and visible image shown in Fig. 3. We selected 6 points on the power lines, control tower and oscillators in both images. Also, we assume that we do not need to make any radiometric adjustments, so $g = \mathbb{1}$, the identity transform. Since there is no radiometric distortion therefore we performed affine transformation. An affine transform can perform rotation, translation, scaling and shearing operations and are linear in the sense that they map straight lines into straight lines. Affine transformation is sufficient to match two images of a scene taken from the same viewing angle but from a different position as in the present case. The detail explanation of affine transformation is given by [12]. The registerd images are shown in Fig. 4

4 Power line detection

In this work, keeping in mind the typical linear characteristics of power lines, we applied Hough transform on visible images to identify power lines. Several methods based on Hough transform had been proposed in the past to identify power lines as in [14, 13]. The images were processed following the steps listed here:

1. Preprocessing to improve contrast in the image.
2. Detection of edges by using Canny edge detector.
3. Hough transform to detect all lines in the images.
4. Extraction of power lines.

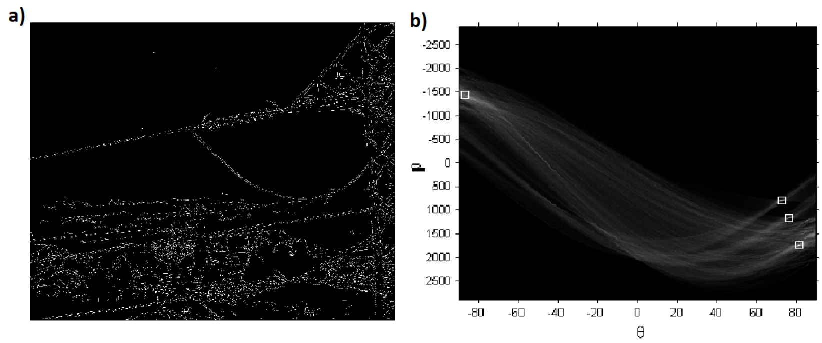

Fig. 5. a) Edge detection by canny edge detector, b) Detected peaks with Hough transform, where peaks correspond to the length of the line. ρ is the perpendicular distance of the peak to the origin and θ correspond to the angle. Occurrence of all positive angled peaks correspond to power lines.

As explained before, we had analyzed images acquired by a camera mounted on the drone flying close to the electric power lines. By way of example, an image is shown in Fig. 2. After image registration, we applied Canny edge detector to identify edges and remove unwanted objects from the background of interest area. Canny edge detection algorithm [15] consists of the following steps:

1. In order to smooth the image, Gaussian filtering is applied to reduce noise effects by convolving image with Gaussian filter.
2. Image gradient magnitude and direction are computed.
3. Non-maxima suppression, according to the gradient direction, to get unilateral edge response and to preserve local maxima as these maxima correspond to the edges. (The output of maxima suppression contains some local maxima which correspond to noise elements)
4. Double threshold method, in order to detect and connect edges.

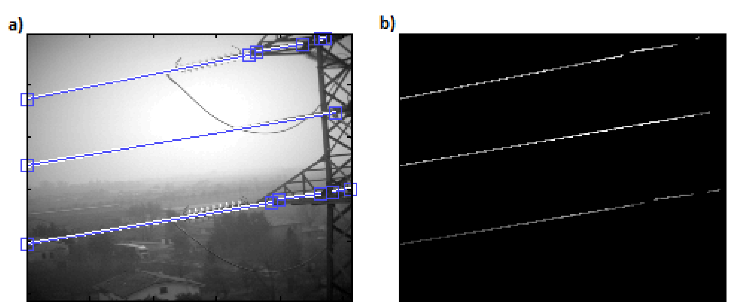

Fig. 6. a) detected lines after thresholding in Hough space, b) Segmented power lines.

The results obtained by using the Canny edge detector is shown in Fig. 5a, power lines along with sharp edges of background were detected. The next step is to highlight only those edges which correspond to power lines. Hough transform is used to detect parameterized shapes through mapping each point to a new parameter space in which the location and orientation of certain shapes could be identified [16]. In this work we applied Hough transform to identify power lines, as the method identifies all straight lines in the image, maybe including roads, buildings etc. Therefore, in order to discriminate power lines from other linear object we applied clustering in the Hough space. The method usually parametrizes a line in the Cartesian coordinate to a point in the polar coordinate using the point-line duality equation:

$$x \cos\theta + y \sin\theta = \rho \qquad \rho \geq 0 \quad 0 \leq \theta \leq \pi \tag{2}$$

Where (x, y) is the point in image in Cartesian coordinates. ρ is the perpendicular distance of the peak to the origin and θ correspond to the angle to the origin. Before detecting power lines in the Hough space, we applied the Canny edge detector to identify all edges in the images. Fig. 5b highlights the detected peaks: here we filtered the three nearly perpendicular θ peaks corresponding to power lines. The detected power lines were segmented from the scene as shown in Fig. 6.

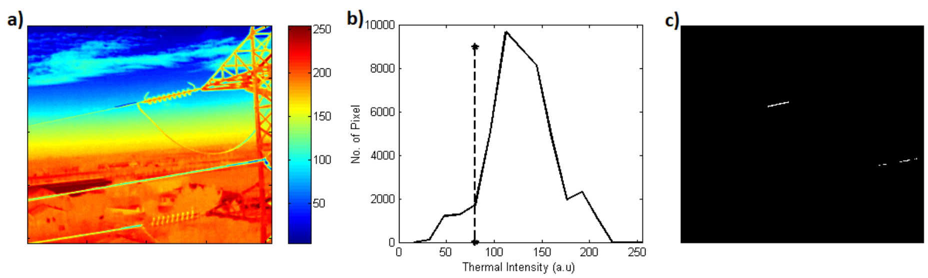

Fig. 7. a) IR image, b) Histogram of thermal intensity and selected threshold to highlight fault area, c) Histogram based thresholding of IR image to identify hot spots in power lines.

4.1 Histogram base thresholding

At the final stage, we applied histogram based thresholding on the segmented image in Fig. 6. As both visible and infrared images are registered, therefore by using the segmentation of power lines in visible image, we mapped power lines from infrared images too. The histogram of segmented infrared image is shown in Fig.7b. We applied thresholding on infrared thermal intensity and it results shown in Fig.7c in highlighting hot spots present in the image. Although at this stage, we used intensity value of infrared images but in future we intend to use actual temperature value from the infrared image to classify the severity of damages in the wire.

5 Conclusions

In this work, we have identified hot spots in power transmission lines. Thermal and images in the visible spectrum have been acquired by a drone flying at a distance of approximately 10 mt from the power lines, with different cameras, near Parma, Italy in December, 2017. The acquired images from multiple sensors have different field of View, therefore, we registered both images. We used manual control point selection and applied affine transformation for image fusion. Power lines from visible images were identified using Canny edge detection Hough transform and finally, we used histogram based thresholding to identify hot spots in thermal images. The method has significantly identified hot spot from the images and in future we intend to improve this work and to use more data set to test propose method.

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References

1. Gotta Alberto et al, UAVs and UAV swarms for civilian applications: communications and image, International Conference on Wireless and Satellite Systems, pp. 115-124, Springer, 2017.
2. Hongwei Li et al., Research on the Infrared and Visible Power-Equipment Image Fusion for Inspection Robots 2010 1st International Conference on Applied Robotics for the Power Industry Delta Centre-Ville Montral, Canada, October 5-7, 2010.
3. L. Vega, et al, Power Line Inspection Via an Unmanned Aerial System Based on the Quadrotor Helicopter, IEEE Mediterranean Electro technical Conference, Beirut, Lebanon, 13-16 April 2014.
4. W. F. Legas and V. Scheeren, An embedded module for robotized inspection of power lines by using thermographic and visual images, CARPI ETH Zurich, Switzerland. September 11-13, 2012.
5. J. H. Oliveira et al, Robotized Inspection of Power Lines with Infrared Vision, 2010 1st International Conference on Applied Robotics for the Power Industry, Montral, Canada, October 5-7, 2010.
6. A. Wronkowicz A., Approach to automated hot spot detection using image processing for thermographic inspections of power transmission lines. Diagnostyka. Vol. 17, pp. 81-86, 2016.
7. Jalil et al, Power Lines Inspection via Thermal and Infrared Imaging, Advanced infrared technology and applications, Quebec, Canada 2017.

8. J. Katrasnik et al., A survey of mobile robots for distribution power line inspection, IEEE Transactions on Power Delivery, vol. 25, pp. 485493, 2010.
9. Rui et al, Registration of Infrared and Visible Images Based on Improved SIFT, ICIMCS '12, September 09 - 11 2012, Wuhan, China
10. Liu Xiang zeng et al, SAR Image Registration Based on Affine Invariant SIFT Features[J]. Opto-Electronic Engineering201037(10)121-124.
11. Kyungsu Kim, Survey on Registration Techniques of Visible and Infrared Images, IT Convergence ractice (INPRA), volume: 3, number: 2 (June), pp. 25-35.
12. Glenn Hines et al, Multi-image registration for an enhanced vision system, NASA Langley Research Center, Hampton.
13. Candamo et al., Detection of thin lines using low-quality video from low-altitude aircraft in urban settings, IEEE Transactions on aerospace and electronic systems, volume 45, 2009.
14. Li et al., Towards automatic power line detection for a UAV surveillance system using pulse coupled neural filter and an improved Hough transform, Machine Vision and Applications, volume 21,pages 677- 686, 2010.
15. J. Canny, A computational approach to edge detection, IEEE Transactions on Pattern Analysis and Machine Intelligence, volume 8, pages 679-698, 1986.
16. P. V. C. Hough, Method and Means for Recognizing Complex Patterns US Patent 3,069,654, 1962, Ser. No. 17,7156 Claims.