

Model-Based Automatic Extraction of Lighting Aids in Airport Runways

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Abstract

Automatic extraction of relevant objects in runway images is a more difficult task than appears at first. Our work contributes with a practical solution to this problem when artificially lighted runway images are available. We use a multilevel runway model which considers different sources of knowledge and achieves to improve the reliability of the runway hypotheses. The proposed system has taken into account the standards for lighting aids in runways, and has been tested on a variety of images giving a good performance.

Keywords

Multilevel runway model, lighting aids, image segmentation, context knowledge, recognition

1. Introduction.

In this paper, we describe a technique for automatic recognition of lighting aids in artificially illuminated images corresponding to airport runways. Runways are not merely homogeneous strips in the image due to the existence of marking aids, changes in the

surface material and the presence of other objects such as aircrafts or automobiles. In general, diurnal runway images are rather complex due to the large number of objects present in them. Night runway images are, in a certain sense, simpler since many non-relevant components disappear and important components are artificially lighted. Lighting aids are facilities which provide visual guidance for landing. The proposed solution using night images can be useful in applications of practical importance, like the automatic maintenance of runway lights or to assist the pilot in planes not equipped with ILS (Instrumental Landing System).

Another work related to the detection of runways in airport complexes and aerial images as been reported by Huertas et al. [4]. The motivation of their work is twofold. First, they consider the specific task of runway detection of practical importance for a variety of applications. Second, the problem domain provides a rich testbed for experiments in building high-performance visual “expert” systems. Baumgartner et al. [1][2] have

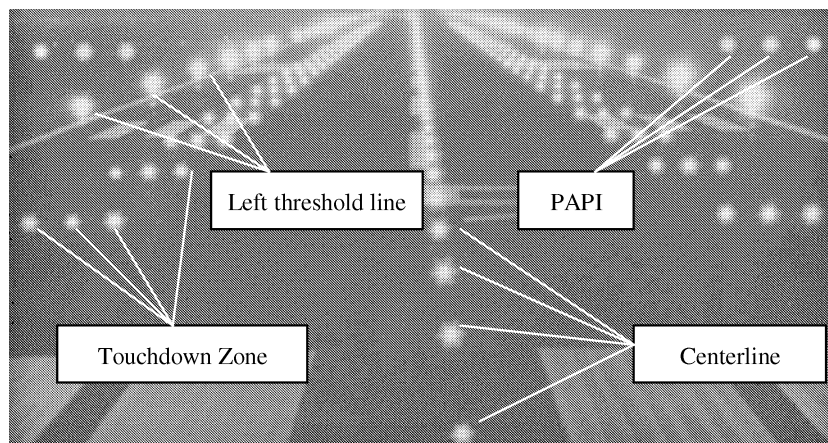


Figure 1. Runway image example with labelled visual aids.

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proposed a multi-resolution approach for automatic segmentation of roads from digital aerial imagery. Their work also introduces a model of road objects, and considers the notion of context which represents the relations between roads and other objects like buildings, trees, and cars.

The rest of the paper is organized as follows. In Section 2, we describe the proposed runway model to recognize the relevant lighting aids. Section 3 offers a sketch of the segmentation method applied to runways lights as well as some ideas about the developed implementation. Section 4 shows an application example. Finally, conclusions and future work are given in Section 5.

2. Proposed model for the automatic extraction of lighting aids in runways.

The automatic extraction of lighting aids is carried out using images acquired from the runway start (like an human pilot sees it) in conditions of low luminosity of the background (i.e. night images) and favourable weather. A runway is viewed as a collection of light points of different colours and intensities in these images. Figure 1 shows an example image of a runway view where different types of approach lights are labelled as components of different categories of lighting aids.

In digital image processing applications, the use of models or specific representations adapted to the needs of recognition tasks, can reduce the inherent complexity of the images to be analyzed [6]. The

proposed model of relevant lighting aids in runways is designed as a component of a more general airport complex model [4]. It contains a variety of objects: transportation networks (runways, roads), building structures (hangars, terminals, storage warehouses), and mobile objects (aircrafts, automobiles). Similarly, a runway model should include a set of concrete flagstones (runway base), and a set of navigation aids classified as electronic ones (DME, ILS) or visual ones (signs, paint lines, light markings).

In this paper, we only consider a model for relevant lighting aids related to the runway surface itself (we do not consider here the approximation lighting aids). This model, used for the extraction of relevant runway lights, is shown in Figure 2. A more detailed description of the proposed runway model, which relates to the ICAO (International Civil Aviation Organization) specifications [5], can be found in [3].

Our model of visual aids is organized into three levels: real world, geometry and material, and image. As shown in Figure 2, these levels define different points of view of the same reality. The *real world level* consists of the considered components on a natural language description. A runway according to this level consists of flush centerline lines, several threshold side lines, two lateral precision approach path indicator lights (PAPI), and two rows of transverse light bars called touchdown zone lights (TDZ) which are located symmetrically about the runway centreline. The objects in the real world level are connected to the objects in the geometry and material level by means of the concrete relation which connects

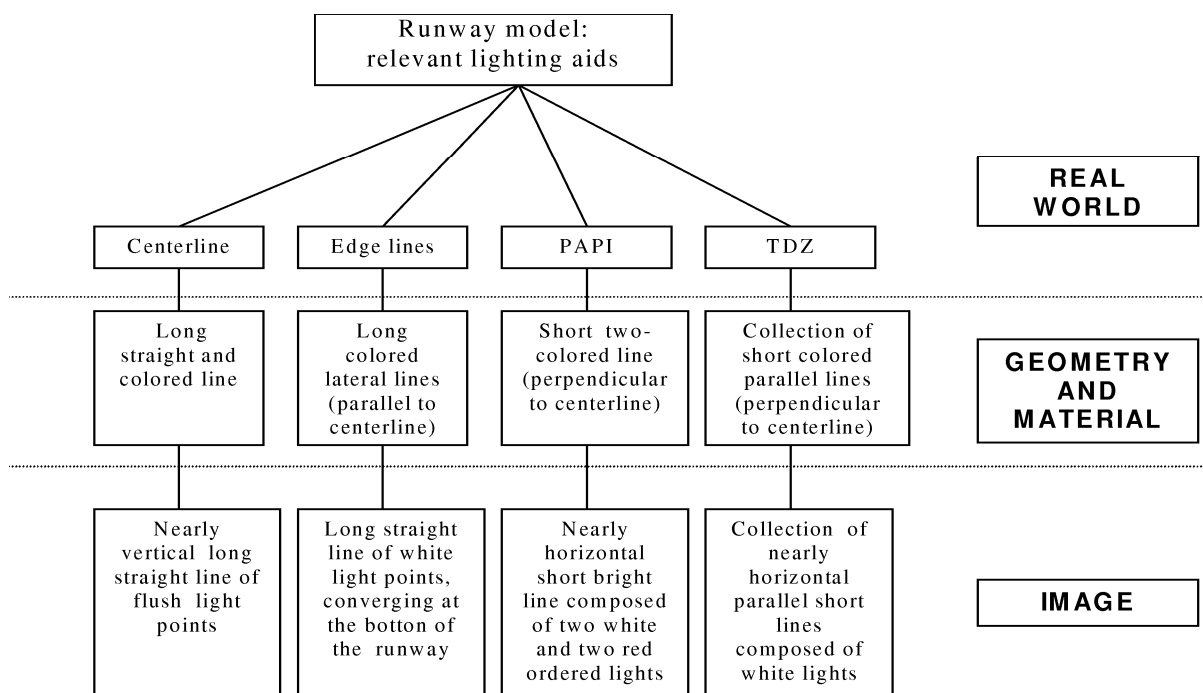


Figure 2. Proposed multilevel model of visual aids in runways.

concepts defining the same object on different levels. The *geometry and material* level is an intermediate level which represents the three-dimensional shapes of objects as well as their material. This level has the advantage that allows to represent objects independently from viewpoint and sensor characteristics. *Image level* describes the model objects by means of their shapes and intensity values in the images. For example, an individual TDZ is viewed at this level like a horizontal short line composed of several bright lights.

3. Sketch of the segmentation method for automatic extraction of relevant light markings.

The block diagram depicted in Figure 3 summarizes our model-based runway segmentation technique. In this figure, the main processing stages are represented in the left side of the diagram, and the corresponding results are in the right side. Each processing stage is divided in small substages that are not represented in the diagram. For example, the low-level segmentation of light points includes the following substages: a) computation of a threshold corresponding to the light points, b) segmentation of these light points, c) search of relevant points and possible gathering with neighbour points, d) estimation of centers and radius of the resulting groups of points, and e) numbering of these groups. The result of this stage is a database of possible runway lights. This database is used in the next stage of the proposed algorithm (see Figure 3). A detailed description of all the stages of the method and their corresponding implementations can be found in [3].

The developed system has been written in C, using

TINA [7]. The TINA algorithm development libraries have been developed over a number of years to simplify the task of vision algorithm implementation and evaluation.

4. Application example.

As an application example of our framework, we consider the runway image of Figure 1 (by removing the included labels). When an image is loaded, light points are searched by means of an initial segmentation process. Due to image perspective, it is not always possible to segment individual light points which are in some cases grouped together. After this stage, an image with detected groups of light points is obtained. These groups are numbered, and the corresponding center and radius of each light group is estimated. This preprocessing stage is necessary for the determination of visual aids, which needs a database of possible runway lights. The next significant stage is the search of light points corresponding to the runway centerline. The output is a hypothesis of the best centerline. Figure 4 presents the output of the proposed segmentation method for the image of Figure 1 (we have omitted some images of intermediate stages in the application of the algorithm, which can be found in [3]). In Figure 4, the best estimated centerline starts with light group with number seventy-six and ends with the light group number two. Next stage is the classification of light groups according to their position with respect to the centerline. Then, the rest of lighting aids are estimated according to the proposed model (PAPI, TDZ and edge lines). It is worthwhile to estimate the runway end, which approximately corresponds to the intersection of the different edge lines with the

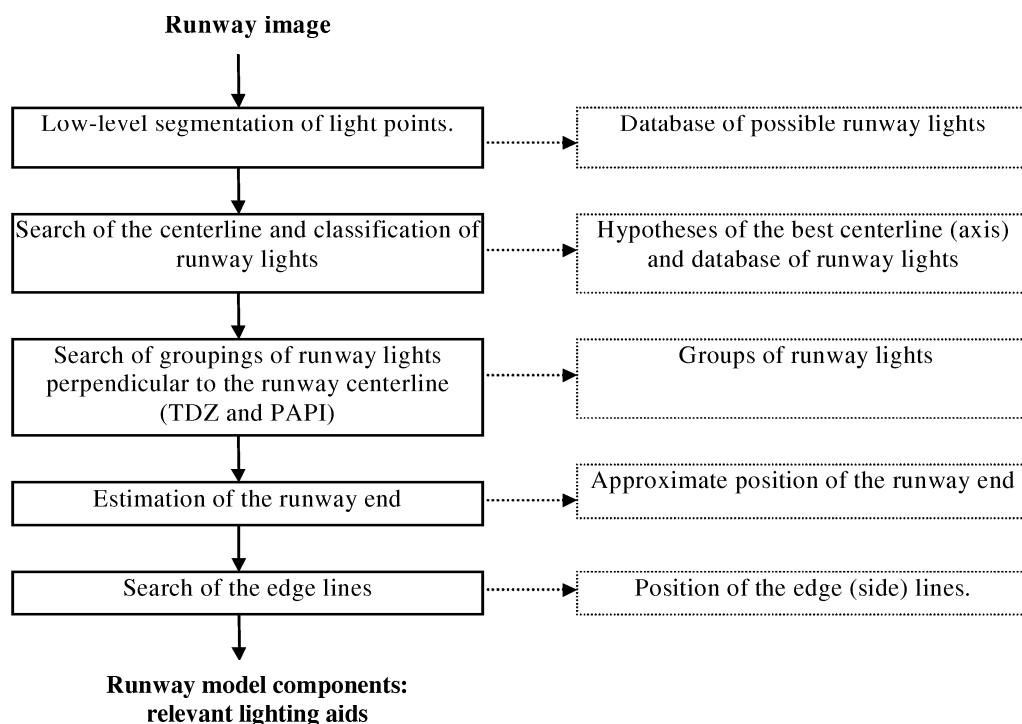


Figure 3. Block diagram of the proposed method for automatic extraction of relevant lighting aids.

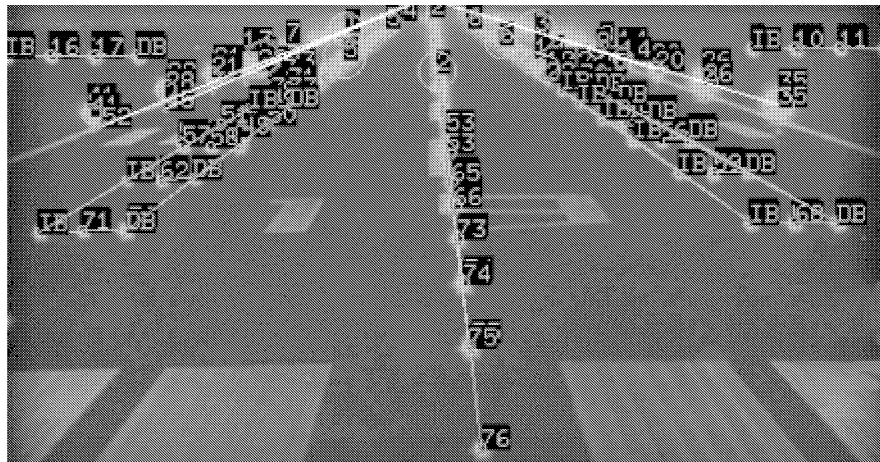


Figure 4. Final segmentation result with detected visual aids.

runway centerline. This point can be outside the original image, but always is placed along the centerline. Figure 4 shows all detected relevant lighting aids (as labelled in Figure 1). Note that the complete recognition process is driven by the proposed model of Figure 2.

We have tested the robustness of our system by removing a reduced set of different light points, and by using some images with the position of the runway centerline slightly rotated (between $\pm 20^\circ$). In general, it was always possible to validate the runway model hypotheses for the considered images (see [3]).

5. Conclusions and future work.

We have described a technique, based on a multilevel model of a runway, to automatically extract the relevant visual aids in runway images. The proposed runway model uses the geometry, shape, and relative position of considered lighting aids as the source of knowledge for a suitable automatic extraction of considered elements in runway images. The use of artificially-illuminated night runway images makes possible the segmentation process since non-relevant elements in the scene are not an obstacle (i.e. possible mobile objects or even runway standard painting markings) for the recognition of illuminated relevant objects (centerline, edge lines, PAPI and TDZ). Moreover, the use of classical computer vision techniques[6], applied to the considered problem offers a practical and low-cost solution. Our approach could be used to detect fused lights and to assist in the maintenance of relevant lighting aids.

We also believe that this system can be extended with the inclusion of all visual aids inside an airport complex (i.e. approximation visual aids, obstacle lights, ...). Another future

extension for the proposed system is to analyze the quality of illumination emitted by each individual light point (shape of light beam, colour, and intensity), in order to increase the reliability of maintenance operations. Finally, it would be possible to adapt the proposed system to work with image sequences of runways. When the automatic recognition task is carried out in real-time, then it would be possible to assist an automatic pilot for automatic landing, in small airports without ILS, using the adapted system.

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