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# Real-time line detection through an improved Hough transform voting scheme

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**Abstract**

The Hough transform (HT) is a popular tool for line detection due to its robustness to noise and missing data. However, the computational cost associated to its voting scheme has prevented software implementations to achieve real-time performance, except for very small images. Many dedicated hardware designs have been proposed, but such architectures restrict the image sizes they can handle. We present an improved voting scheme for the HT that allows a software implementation to achieve real-time performance even on relatively large images. Our approach operates on clusters of approximately collinear pixels. For each cluster, votes are cast using an oriented elliptical-Gaussian kernel that models the uncertainty associated with the best-fitting line with respect to the corresponding cluster. The proposed approach not only significantly improves the performance of the voting scheme, but also produces a much cleaner voting map and makes the transform more robust to the detection of spurious lines.


*Keywords:* Hough transformation; Real-time line detection; Pattern recognition; Collinear points; Image processing

## 1. Introduction

Automatic detection of lines in images is a classic problem in computer vision and image processing. It is also relevant to computer graphics in applications such as image-based modeling [1,2] and user-interfaces [3]. In vision and image processing, line detection is a fundamental primitive in a wide range of applications including camera calibration [4], autonomous robot navigation [5], industrial inspection [6,7], object recognition [8], and remote sensing [9]. The Hough transform (HT) [10,11] is an efficient tool for detecting straight lines in images, even in the presence of noise and missing data, being a popular choice for the task. By mapping each feature pixel to a set of lines (in a parameter space) potentially passing through that pixel, the problem of identifying line patterns in images can be converted into the simpler problem of identifying peaks in a vote map representing the discretized parameter space. Although conceptually simple and despite the efforts of many researchers in using hierarchical approaches [12,13], affine-transformation-based approaches [14] and FFT architectures [15], real-time performance has only been achieved with the use of custom-designed hardware [16–18]. Moreover, the peak-detection procedure may identify spurious lines that result from vote accumulation from non-collinear pixels. This situation is illustrated in Fig. 1(c), where redundant lines have been detected, while some well-defined ones have been missed.

This paper presents an efficient voting scheme for line detection using the HT that allows a software implementation of the algorithm to perform in real time on a personal computer. The achieved frame rates are significantly higher than previously known software implementations and comparable or superior to the ones reported by most hardware implementations for images of the same size. The proposed approach is also very robust to the detection of spurious lines. Fig. 1(d) shows the result obtained by our algorithm applied to the input image shown in Fig. 1(a). These results are clearly better than the ones obtained

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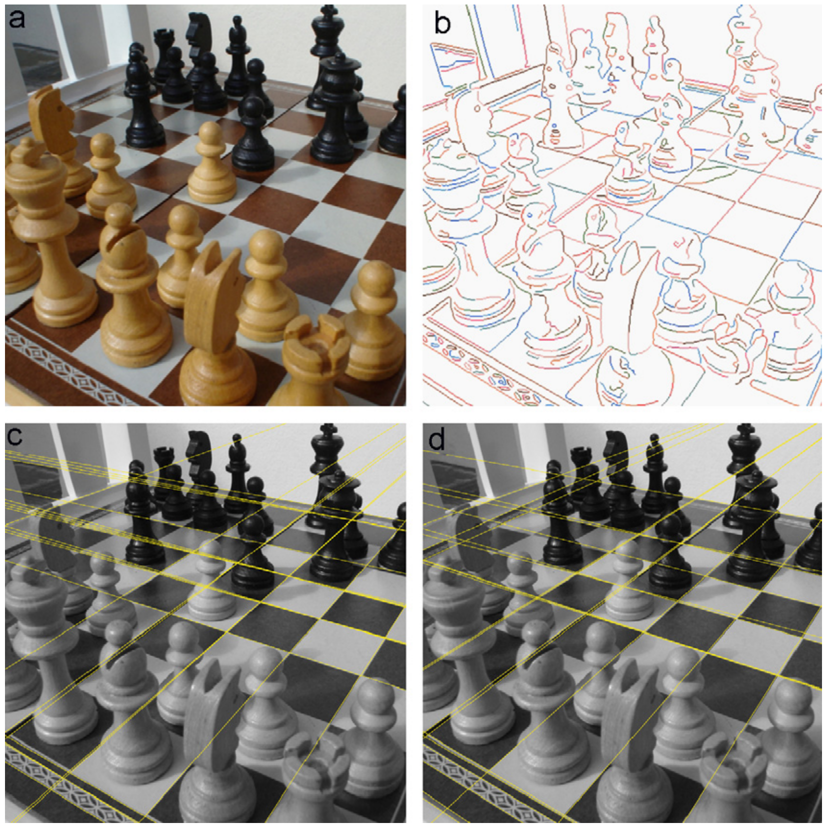


Fig. 1. Line detection using the Hough transform (HT). (a) Input image with $512 \times 512$ pixels. Note the folding checkerboard (see the dark folding line on the left of the clear king). Since the checkerboard halves are not properly aligned (level), its rows define pairs of slightly misaligned lines that cross at the folding line. (b) Groups of pixels used for line detection, identified using a Canny edge detector [19]. Note that the folding line produces two parallel segments. (c) Result produced by the gradient-based HT at 9.8 fps. Note the presence of several concurrent lines (not only two) along the rows, while some important ones are missing. (d) Result produced by the proposed approach at 52.63 fps. Note the fine lines detected at the bottom-left corner and at the upper-left portion of the image. Images (c) and (d) show the 25 most-relevant detected lines.

with the use of the state-of-the-art HT technique shown in Fig. 1(c). For instance, note the fine lines on the bottom-left corner and on the upper-left portion of the image in (d). Those results are achieved by avoiding the brute-force approach of one pixel voting for all potential lines. Instead, we identify clusters of approximately collinear pixel segments and, for each cluster, we use an oriented elliptical-Gaussian kernel to cast votes for only a few lines in parameter space. Each Gaussian kernel models the uncertainty associated with the best-fitting line for its corresponding cluster. The kernel dimensions (footprint) increase and its height decreases as the pixels get more dispersed around the best-fitting line, distributing only a few votes in many cells of the parameter space. For a well-aligned group (cluster) of pixels, the votes are concentrated in a small region of the voting map. Fig. 2(b) and (d) shows the parameter spaces associated with the set of pixels shown in Fig. 2(a). Since the influence of the kernels is restricted to smaller portions of the parameter space, the detection of spurious lines is avoided.

The central contribution of this paper is an efficient voting procedure for detection of lines in images using the HT. This approach allows a software implementation to perform in real time, while being robust to the detection of spurious lines.

The remaining of the paper is organized as follows: Section 2 discusses some related work. Section 3 describes the proposed approach, whose results, advantages, and limitations are discussed in Section 4. Section 5 summarizes the paper and points some directions for future exploration.

## 2. Related work

Hough [10] exploited the point-line duality to identify the supporting lines of sets of collinear pixels in images. In his approach, pixels are mapped to lines in a discretized 2D parameter space using a slope–intercept parameterization. Each cell of the parameter space accumulates the number of lines rasterized over it. At the end, the cells with the largest accumulated numbers (votes) represent the lines that best fit the set on input pixels. Unfortunately, the use of slope–intercept requires a very large parameter space and cannot represent vertical lines. Chung et al. [14] used an affine transformation to improve memory utilization and accelerate Hough's algorithm. However, the results are not real-time and, like the original one, the algorithm cannot handle (almost) vertical lines.

Duda and Hart [11] replaced the slope–intercept with an angle–radius parameterization based on the normal equation of