Applying Image Analysis Techniques to Optimize the Production of Cork Stoppers

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Abstract. This paper presents how image analysis techniques, namely a simple edge element detector and an effective digital straight line segment detection strategy, can be applied to produce from images of cork sheets information about texture to be considered by a mechanic actuation system in order to best position the sheets for sectioning. The paper also briefly discusses how these techniques can be implemented into transputer networks and presents a complete illustrative example.

1 Introduction

The principal stages usually required for the production of cork stoppers can be summarized as follows: a) the bark of the oak-cork tree is removed (approximately each nine years), dried and cut into sheets of typical sizes varying between 200x150x15mm and 1200x600x60mm; b) the sheets are cut manually using an electric saw fitted with a special blade into strips of a pre-determined thikness (normally about 40mm), depending on the length of the stoppers required; c) the stoppers are then obtained by punching a hollow cylinder successively along each strip and d) stoppers are cleaned, reduced to exact sizes and sorted. In current systems, stages b) and c) are critical and involve highly-skilled manual work. As a natural material, cork may contain many types of defects (cracks, insect damage, etc.) which must be avoided in the cutting and punching operations. An automatic approach has been reported by [Davies et al. (1991)] but this work does not deal with the handling and cutting of sheets into strips. The present paper addresses the automation of that stage with reference to visual inspection requirements.

Cork sheets are flexible, of irregular shape and curvature and need to be manipulated at high speeds (typically 10 seconds/sheet) guided by a vision system that identifies the two-dimensional outline, its shape and position. Each cork sheet has an optimum direction for cutting which is perpendicular to the preferred orientation of the grain, seen as mostly parallel 'grooves' running on the external surface of the cork sheet. The vision system should also be able to detect and reject pieces of unsuitable size and with high instances of defects.

The present paper presents a possible approach for the determination of preferred orientations based on image analysis techniques using first-order statistics of linear surface features. Figure 1 presents a block diagram of the automation system.

Figure 1 presents a block diagram of the adopted automation system. The image is acquired by a fixed camera and, after eventual pre-processing for its enhancement, is edge detected in order to produce the boundaries of the grooves to be fed into the digital straight line segment detector; the polar histogram describing the distribution of groove orientations is derived from the parametric information about the detected digital straight line segments and the preferred orientation is determined and sent to the control system which positions and cut the cork sheet.

The involved image analysis techniques as well as their respective implementation in transputer networks are described and discussed in some detail in the following sections; a complete illustrative exam-

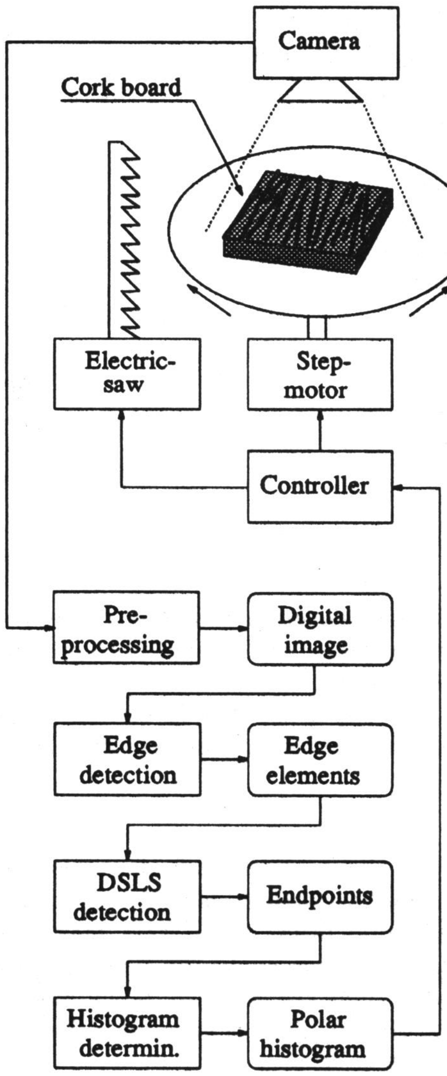

Figure 1: Block diagram of the system for automatic sheet sectioning.

ple is also provided.

2 Determination of the Preferred Orientation

Although some edge detection techniques have been proposed which are optimal within some theoretical conditions, e.g. [Canny (1986)], there is no such a thing as an optimum general edge detector. Unfortunately, the versatility and performance of edge detectors has generally proven to be related to its algorithmic complexity. Being a simple and relatively effective edge detector, and mainly because it has allowed acceptable results when applied to typical cork images, the 3x3 Sobel operator [Schalkoff (1989)] has been adopted for the present application. It should be observed that gradient-based operators such as Sobel could provide some information about the grooves orientation but it would neither be able to discriminate between edge elements which belong to straight and non-straight boundaries nor determine the extention of the grooves, which is essential for the identification of eventual defects in the cork surface.

The binary Hough transform, is a variation of the standard Hough transform [Illingworth–Kittler (1988), Duda–Hart (1972)] for digital straight line detection based on a quadruple slope-intercept parameterization [Costa (1992), Costa–Sandler (Feb. 1990)], namely the UNIQUAD parameterization which consists of a single expression and a set of four coordinate transformations. The binary Hough transform can be defined as the operator which generates a digital straight line segment in the UNIQUAD discrete parameter space, a set of four accumulator arrays, for each feature point in the image. Provided that the image and the accumulator arrays dimensions are integer powers of two, the binary Hough transform presents interesting features such as optimal compaction of the accumulator arrays [Costa–Sandler (Sep. 1990)] and suitability for parallel execution in integer arithmetic without any rounding error, products or table look-ups – in fact it demands less additions than typical standard Hough transforms [Costa (1992)]; such features favour the effective implementation of the binary Hough transform in software. Experimental evaluations [Costa (1992)] have indicated that the binary Hough transform presents accuracy comparable to other Hough transforms. The effective backmapping strategy described by Gerig and Klein [Gerig–Klein (1986)] has been adopted henceforth in order to reduce the amount of false peaks in the accumulator arrays.

The underlying reason for the Hough transform suitability for parallel implementations resides in the fact that the adjacency of the image feature points is not considered during its execution, which means that these points can be processed fully independently and in any order. However, this Hough transform inherent feature also implies that clusters of aligned but disconnected feature points are detected as digital straight line segments, and that endpoints of actual digital straight line segments can not be determined.

A possible way to circumvent this shortcoming consists of performing some post-binary Hough transform connectedness analysis. In the present approach, for each detected peak (assumed to be any cell in the accumulator arrays with count larger or equal to a given threshold), a unidimensional histogram is built by projecting the image feature elements which contributed to the peak onto the x- or y-axis according to the slope indicated by the respective peak; the connectedness of such histograms can be easily verified by an algorithm which looks for consecutive runs of feature elements [Costa (1992), Costa–Sandler (1991)]. Every group of connected feature points with projection larger than a given threshold is confirmed as an actual digital straight line segment; a maximum gap, G, should be allowed for discontinuities in order to compensate for eventual distortions or noise in the image.

The determination of the polar histogram can be straightforwardly obtained from the slope parameter of the detected digital straight line segments; in order to best express the orientation of the grooves in the image, the votes into the histogram are weighted in terms of the length of the respective digital straight line segment. An angular threshold D is adopted for the smallest possible difference between preferred orientations corresponding to two or more regions in the same sheet surface. Thus, any peak exceeding another given threshold P is averaged in the region D^o wide around the peak in the polar histogram. Any peak can correspond to either a preferred orientation or a defect; the distinction between these can be verified by analysing the detected digital straight line segments which have the orientation specified by the respective peak.

3 Implementation in Transputer Networks

The choice of transputers as processing elements presents the advantage of allowing the system power to be increased by just adding new transputers to the available links; the transputer also provides direct support for bitwise operations including binary shifts, which are essential for the binary Hough transform.

The inherent simplicity of the adopted edge detector allows its straightforward implementation into linear or mesh transputer networks by distributing uniform segments of the original image amongst the processing elementss and afterwards combining the results into a single transputer; for exact execution an one-pixel overlap should be allowed between columns and lines of the image segments.

One of the simplest and most effective ways of parallelising the BHT execution amongst several processing elements consists of assigning each processing element to process a range of the slope parameter [Costa (1992), Costa–Sandler (July 1990)] in such a way that every processing element will process the same image feature element. This strategy also adapts well to pipelined transputers – it has been verified [Costa (1992), Costa–Sandler (July 1990)] that, at least for a small number of transputers, an almost linear speed-up can be achieved with this strategy, which indicates that the part of the execution time required to transmit the image feature points coordinates to the PEs via the serial links does not represent a substantial overhead.

The connectedness analysis can also be effectively accomodated into such MIMD architectures by keeping a copy of the image feature elements into the memory of each PE, which can determine and analyse the histograms corresponding to each of the detected peaks resulting in the portion of the accumulator array in its associated memory. Such a strategy is supported by the facts that at least one megabyte of memory is usually provided for each transputer and that the x- and y-coordinates of the image feature elements have anyway to be broadcast to the processing elements during the Hough transform. The descriptions of all the digital straight line segments detected by each processing element are then sent to a master transputer which determine the histogram and send information about the preferred orientation and eventual defects to the alignment and cutting control system.

4 A Complete Illustrative Example

Figure 2 presents a complete example of the determination of the preferred orientation of the straight grooves in the sheet image: the original image (a) is edge-detected (b) and fed into the digital straight line segment detection algorithm – the detected digital straight line segments are depicted in (c), to be used for constructing the final polar histogram (d), in this case within a precision of 5^o.

It can be verified that almost every digital straight line segment in 2(b) with length larger than the adopted threshold of 5 pixels has been successfully detected and represented in 2(c). We have from Figure 2(d) that the preferred orientation is of about $65{,}74^o$, which means that the sheet should be cut at about 155.74^o. The overall execution time for the polar histogram determination by a single transputer was about 20.4 s, of which 7.03 s were spent on edge detection, 13.35 s on digital straight line segment detection and 0.039 s on histogram determination.

5 Concluding Remarks

This paper has presented how image analysis techniques have been applied to optimize the production of cork stoppers; these techniques as well as their respective implementation in transputer networks have

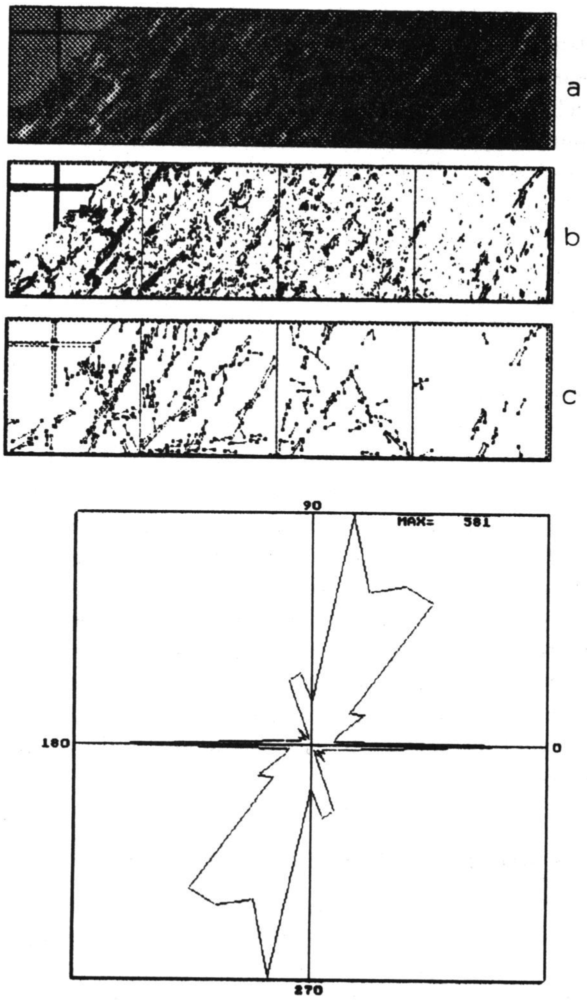

Figure 2: Illustrative example of cork texture analysis: original image (a); edge detected image (b); detected digital straight line segments (c) and polar histogram expressing the orientations of the digital straight line segments in the image (d).

been described and a complete illustrative example presented.

We are currently investigating alternative means of determining the preferred orientation and optimal noise reduction techniques based on Kalman filtering.

A project for the implementation of the described system in the Portuguese industry is currently submited to the European Community. The adaptation of the proposed strategy to other similar tasks such as wood cutting is almost straightforward.

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