Robust Line Detection Methods

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Abstract: - Line Detection is an important problem that arises in automatic content conversion systems (among other domains). Such a system is used to generate digital documents from hard copies of books, newspapers, etc. Given a black and white image, usually obtained from a scanning device, our task is to identify groups of pixels which form horizontal or vertical lines. There are various techniques used to solve this problem. In this paper we analyze a common approach (using the Hough transform), introduce a new method and compare the results.

Key-Words: - automatic content conversion, line detection, edge detection, Hough transform, feature extraction, entity clustering

1 Introduction

In developing our automatic content conversion system, we found the need for a Line Detection subsystem implemented at application level. Ideally, this system will be able to identify straight lines in a black and white image.

Solving this task will bring us closer to our goal of successfully detecting page layout elements, such as paragraphs, columns, images, borders or tables [1][2].

This Line Detection system will accept as input a binary (black and white) image of a scanned newspaper page and will return a collection of pixel groups, each group representing a vertical or horizontal line from that image. Given that most of the times the input image will contain noise and imperfect lines (erased, dotted, interrupted, and/or crooked), the Line Detection module should also accept a set of parameters which will calibrate the method and filter out undesired lines.

The methods we present here rely on two different mathematical models, but they share the same logic, that of the Hough-transform technique.

2 Usage of the Hough Transform

The Hough transform is often used in computer vision or image processing field to find imperfect instances of geometrical shapes (lines, circles, etc) [9][10]. These shapes are found by carrying out a voting process on a parameter space. In this space, each point corresponds to a distinct object. At the end, local maxima identify the most probable shapes. For example, a straight line $y = mx + b$ can be parameterized by the point (m, b). We iterate over all pixels in the input image and through all allowed values for one of the parameters. Having assigned these values, we can solve for the second parameter and then cast a vote for this line in the parameter space (also called the accumulator).

The drawback to this approach is that vertical lines give rise to unbounded values for the parameters. For computational reasons, it is more practical to parameterize the line in terms of its polar coordinates ρ and θ [10][11][12].

The parameter ρ represents the distance between the line and the origin while θ represents the angle of the vector from the origin to the closest point on the line. Using these parameters the equation of a straight line becomes:

$$\rho = y\sin\theta + x\cos\theta$$

The idea of the algorithm is to look for lines having a particular orientation θ, then iterate over all image points (x, y) and compute the ρ parameter, that is the distance from origin to that line.

We can keep an accumulator to count the number of points that have been reported for the line (ρ, θ) and then look at local maxima to find the best fitting lines [5][6][7][8].

The Hough transform is very efficient on random noised images and is able to detect even heavily damaged lines. This is because the mathematical model used is not strictly followed, but rather applied to generate statistical indicators which are interpreted relative to each other and the most probable objects are identified.[9][13][14][15]

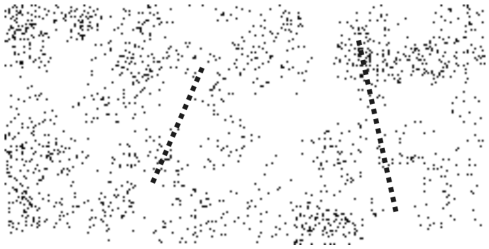

Fig. 1 – Input image

Fig. 2 – Output using standard (ρ, θ) Hough transform

3 Discrete Line Parameterization

When using the Hough transform we had difficulties overcoming a problem. Our images always contained a lot of textual regions. Within these regions, characters may form false straight dotted lines and get detected by our algorithm. To avoid this and other disadvantages of the Hough transform we devised a more restrictive parameterization. This takes into account the fact that in a digital image we only have a restricted set of possible lines. Each line can be represented by two parameters x_0 and dx (Fig. 3). It is a close analogy to the pervious (ρ, θ) parameterization: x_0 and ρ both reflect offsets while dx and θ represent angles.

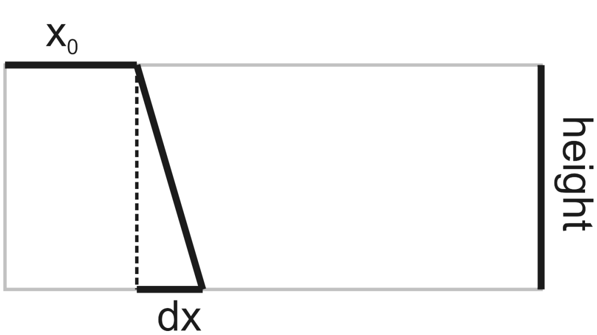

Fig. 3 – A discrete line representation

Based on this we ca proceed similarly to Hough transform and iterate over all points in the image and vote the discrete lines that pass through them.

The advantage of this method comes from the fact that it uses only integer numbers, thus the unknown parameter can be coined more accurately, discarding some of the false lines that were being picked by the more loosely Hough transform method.

4 Visual Results

Both methods were tested on our collection of scanned newspaper pages.

DER KOMMENTAR

Wichtiges Palaver

RALF NEUBAUER

Die öffentliche Aufmerksamkeit, die Gipfeltreffen beanspruchen, steht nicht selten in deutlichem Kontrast zu den Ergebnissen. So war es auch diesmal in Birmingham. Es wurde diskutiert und in der Sache hart gerungen. Konkrete Beschlüsse kamen dabei aber nicht heraus. Ob Schuldenerlaß für die ärmsten Länder, Kriminalitätsbekämpfung oder Atomtests in Indien – die Staats- und Regierungschefs der G 8 beließen es bei unverbindlichen Erklärungen.

Dennoch war das Palaver wichtig. Internationales Krisenmanagement kann nämlich nur funktionieren, wenn sich die handelnden Personen kennen und wenn sie regelmäßig ihre Positionen austauschen. Im Ernstfall muß dann keine Grundsatzdebatte geführt werden, es kann gehandelt werden.

Zumindest in einem Punkt ging der Birminghamer Gipfel zudem über einen bloßen Gedankenaustausch hinaus. Die Empfehlungen zur Reform des IWF und zur Bewältigung künftiger Finanzkrisen sind relativ konkret und weisen in die richtige Richtung. Die Entscheidungen fallen hoffentlich auf der Herbsttagung von IWF und Weltbank.

Fig. 4a – Original Image and Hough Transform Method Results

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Fig. 4b – Discrete Line Method Results

To accommodate a large variety of line types, our implementations of the two methods also accept a set of parameters. The parameters cover targeted line segment properties.

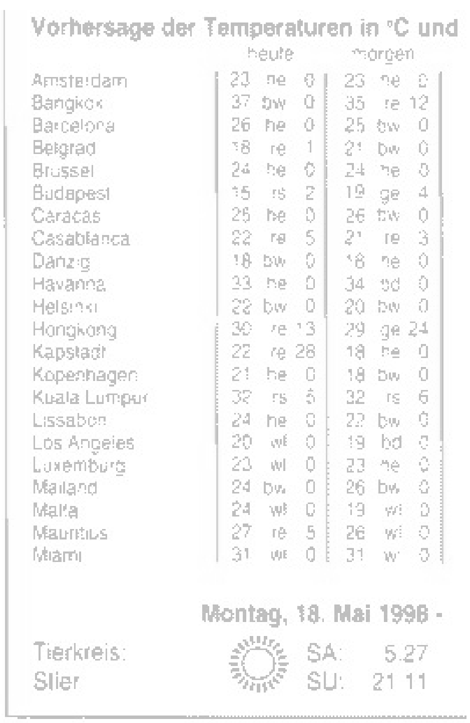
A maximum allowed deviation factor adjusts the window of the iterating parameter (θ for the Hough Transform, dx for the Discrete Line method) and helps the detection of slightly tilted lines. The imperfection can have any cause, but most likely is due to a misalignment from the scanning process.

Another calibrating parameter specifies a maximum distance in pixels which should be allowed as an interruption in the line segment. Line segments that are closer than this number of pixels and have the same orientation are grouped together to form a complete line. This is mostly helpful when detecting dotted or white noised lines.

Other parameters are used to filter out undesired and degenerated lines.

For each text, the parameters were adjusted to return the best possible results for the tested method.

The results were visually interpreted and a comparison was made for different types of images between the two methods.



Vorhersage der Temperaturen in °C und

	heute			morgen		
Amsterdam	23	ne	0	23	ne	0
Bangkok	37	bw	0	35	re	12
Barcelona	26	he	0	25	bw	0
Belgrad	18	re	1	21	bw	0
Brussel	24	he	0	24	he	0
Budapest	15	rs	2	19	ge	4
Caracas	25	he	0	26	bw	0
Casablanca	22	re	5	21	re	3
Danzig	18	bw	0	18	he	0
Havanna	33	he	0	34	sd	0
Helsinki	22	bw	0	20	bw	0
Hongkong	30	re	13	29	ge	24
Kapstadt	22	re	28	18	he	0
Kopenhagen	21	he	0	18	bw	0
Kuala Lumpur	32	rs	5	32	rs	6
Lissabon	24	he	0	22	bw	0
Los Angeles	20	wl	0	19	bd	0
Luxemburg	23	wl	0	23	he	0
Mailand	24	bw	0	26	bw	0
Malta	24	wl	0	19	wl	0
Mauritius	27	re	5	26	wl	0
Miami	31	wl	0	31	wl	0

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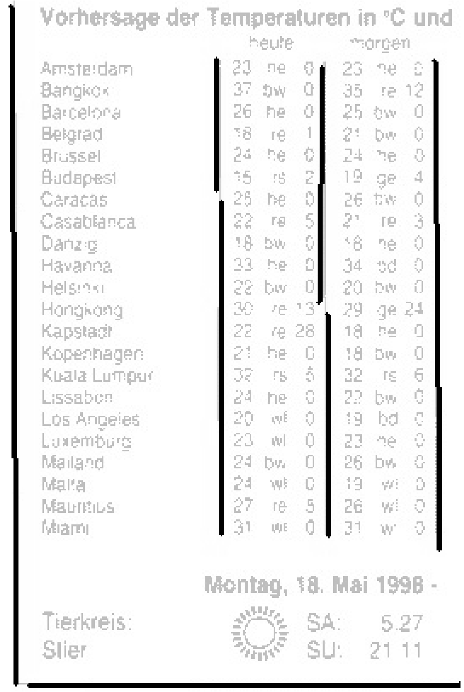
Tierkreis: SA: 5.27
Stier SU: 21 11

Fig. 5a – Original Image

The image shown in Fig. 4a is of a typical paragraph, often encountered as input. The text is left aligned and the font is normal. These causes the Hough transform method to form a line entirely of characters, an issue that rarely affects our Discrete Line method.



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Havanna	33	he	0	34	sd	0
Helsinki	22	bw	0	20	bw	0
Hongkong	30	re	13	29	ge	24
Kapstadt	22	re	28	18	he	0
Kopenhagen	21	he	0	18	bw	0
Kuala Lumpur	32	rs	5	32	rs	6
Lissabon	24	he	0	22	bw	0
Los Angeles	20	wl	0	19	bd	0
Luxemburg	23	wl	0	23	he	0
Mailand	24	bw	0	26	bw	0
Malta	24	wl	0	19	wl	0
Mauritius	27	re	5	26	wl	0
Miami	31	wl	0	31	wl	0

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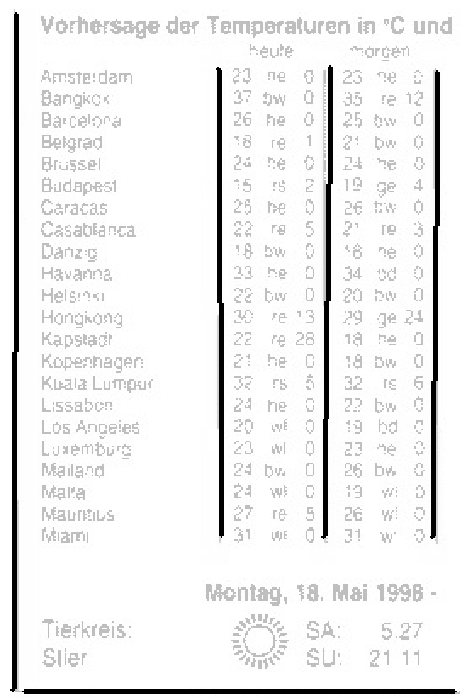
Fig. 5b – Standard Hough Transform Results



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Helsinki	22	bw	0	20	bw	0
Hongkong	30	re	13	29	ge	24
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Malta	24	wl	0	19	wl	0
Mauritius	27	re	5	26	wl	0
Miami	31	wl	0	31	wl	0

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Fig. 5c – Discrete Line Method Results

This second image underlines another disadvantage of the Hough transform method.

Since it works with real valued parameters and covers the real set of lines, the Hough transform can't tolerate the imperfections of a digital line, which is actually formed by small parallel line segments (similar to how Bresenham drawing algorithm works). It can be seen in Fig. 5b that this leads to a line being split by the method.

One of the purposes of the Line Detection module is seen in Fig. 5 where successfully detected lines are helpful in separating table columns, otherwise impossible to identify.

5 Performance

Both methods operate in optimal linear time, proportional to the resolution of the scanned image. The memory consumption is also linear. Performance improvements can be made by adopting randomized point iterations.

6 Conclusions and Future Work

We have presented here an alternative parameterization that can be used with the same logic adopted for the standard Hough transform technique. Our parameterization has the advantage that works with whole numbers, thus making calculations simpler and restricting the parameters to digital allowed values. Our tests show that this method is better suited for processing binary images which also contain large quantities of text.

Future enhancements of these methods are possible and needed. It is a non-trivial task to extract local maxima from the resulting parameter space. For this to be accurate a preceding smoothing of the table is useful.

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