Graphics Recognition

A Historical Perspective and Recent Advances

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Koichi Kise and Team

IAPR/ICDAR Award

I would like to Dedicate this award to

My 70+ Students

Who Performed Much of the Research I am Recognized for Over the Past 35 Years

Thank You

Some of those who made it all possible

Representing them all here is Sameer Antani, Ph.D.

Sameer Antani: ***Video Content Characterization via Robust Recognition of Scene and Caption Text*****, Ph.D., 2001**

IAPR Leaders, Freeman, Fu, Sakai, and Pavlidis at First Meeting of the IAPR Governing Board, Kyoto, 1978

What is Graphics Recognition?

A Typical Document: Three Components

Text Regions - Recognized by OCR

Images - Processed by Image Processing

Graphics- Analyzed by Graphics Recognition

Graphics include Block Diagram, Chart, Graph, Line Art, Map, Schematic, Table, etc.

Graphics Recognition: 60 Year History

- Early Days (1955) to First IJCPR (1973)
- First IJCPR (1973) to First GRec (1995)
- First GRec (1995) to Now (2017)

IJCPR: International Joint Conference on Pattern Recognition
(Became ICPR after 1978)
GRec: IAPR Workshop on Graphics Recognition

Graphics Recognition – Early Days
1955 - 1972

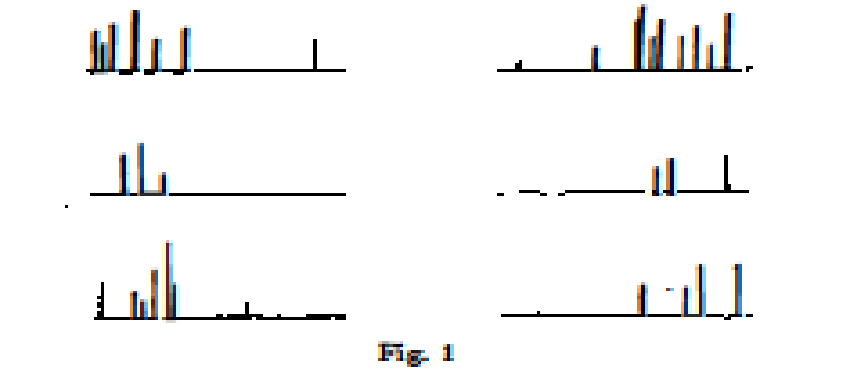
“Pattern Recognition and Modern Computers”

O. G. Selfridge, AFIPS '55 (Western) Proceedings, 1955

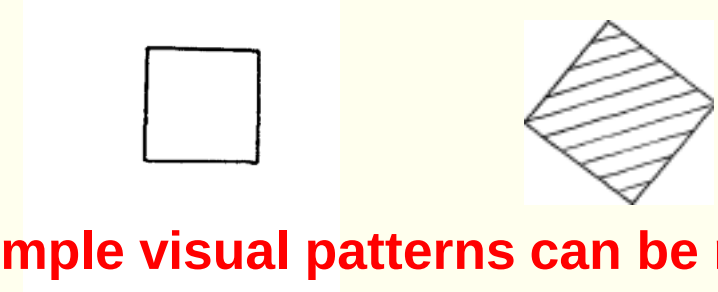
“Pattern Recognition… extraction of significant features from a background of irrelevant detail”

Describes Following Problems

Two Class Problem: Large group of **VERTICAL LINES** on **LEFT** or **RIGHT**



Recognize Oriented Rectangles by Corner Detection



Conclusion: “simple visual patterns can be recognized by the computer, and … may improve its recognition by learning”

“Pattern Recognition and Modern Computers”

O. G. Selfridge, AFIPS '55 (Western) Proceedings, 1955

“Pattern Recognition… extraction of significant features from a background of irrelevant detail”

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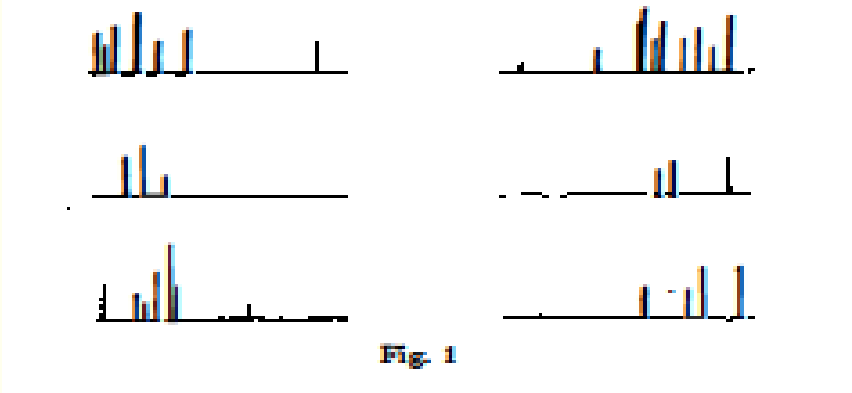
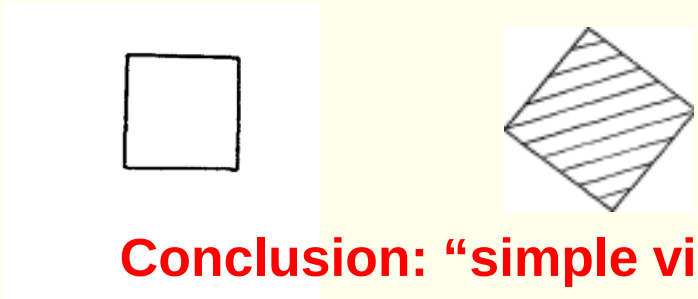


Recognize Oriented Rectangles by Corner Detection



Conclusion: “simple visual patterns can be recognized by the computer, and … may improve its recognition by learning”

"A Computer Oriented Toward Spatial Problems", 1958
"Pattern Detection and Recognition", 1959
S. H. Unger, Proceedings of the IRE

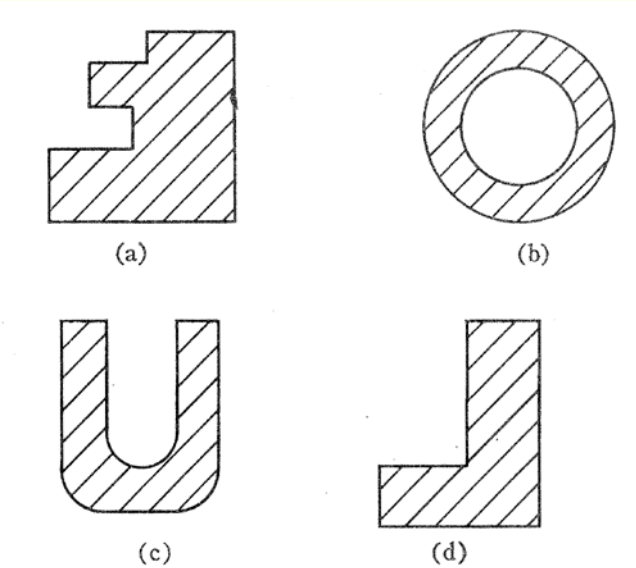
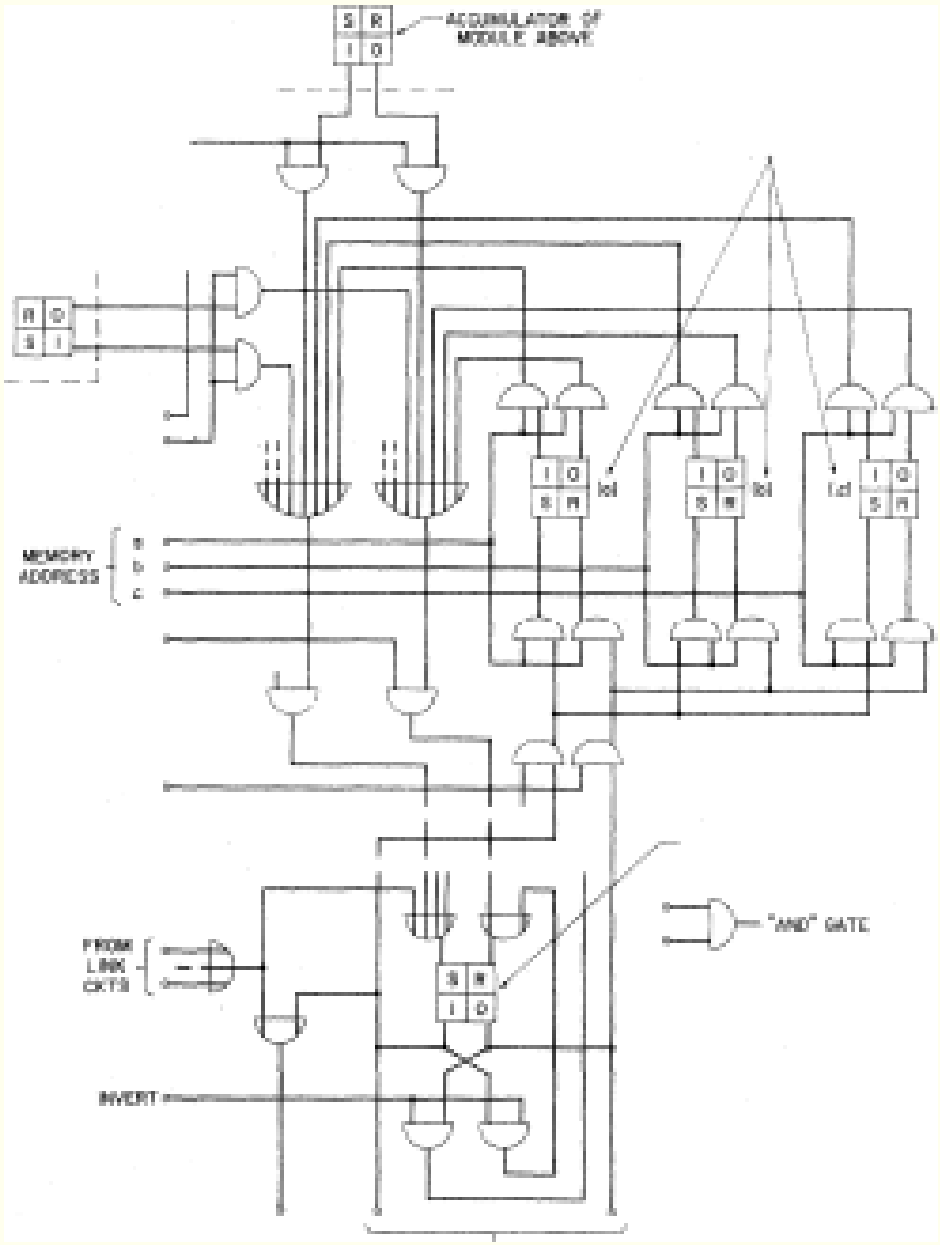


Fig. 6—Vertical concavity.

1) st a
2) slt
3) in
4) mpy a
5) link
6) st b
7) sr a
8) mpy L, U
9) sU
10) mpy b
11) exp V
12) st b
13) sr a
14) mpy L, D
15) sD

Locates all left edge points.

Yields lower inside corner points on left edge [one point is called (10) in Fig. 7(a)]. At this point the accumulator contains all vertical edges facing left which start from inside corner points as described in 10) above.



“Apictorial Jigsaw Puzzles…”

H. Freeman and L. Garder, IEEE T. on Electronic Computers, 1964

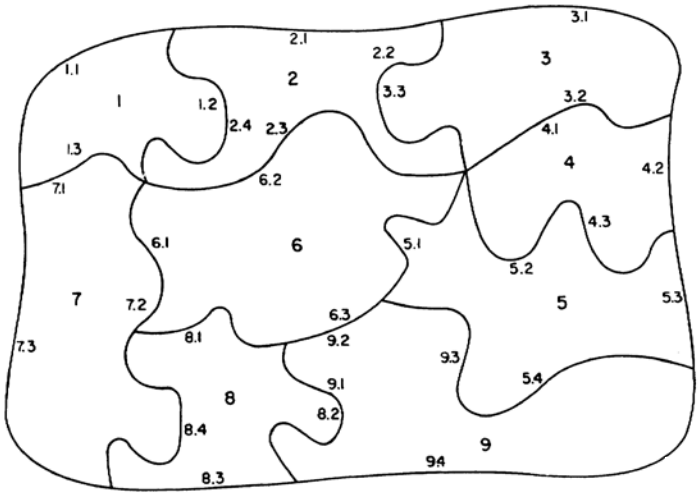
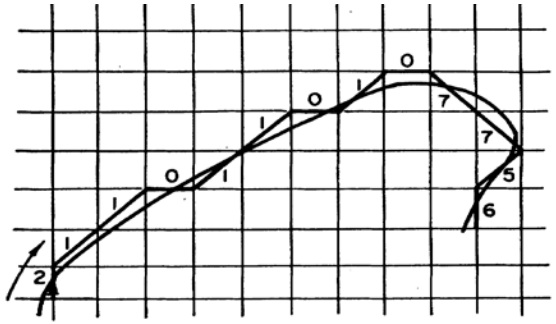
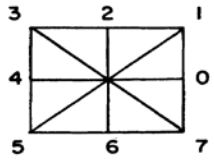


Fig. 4—Illustration of a jigsaw puzzle.



(a)



(b)

Fig. 10—Chain encoding scheme.

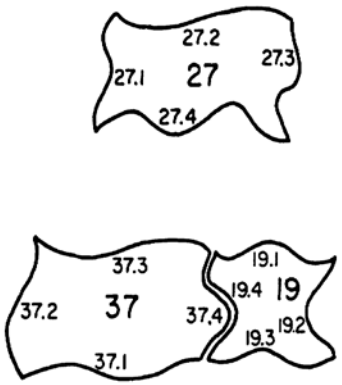
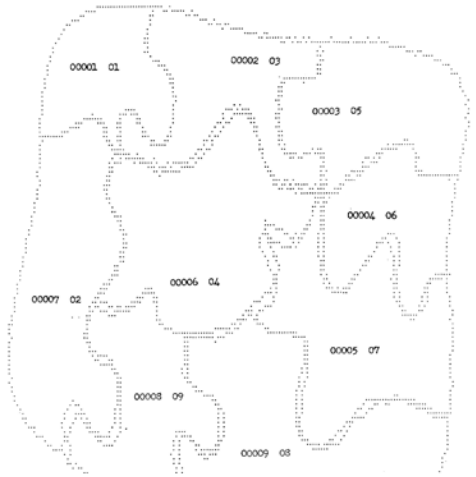


Fig. 13—Illustration of ambiguities.



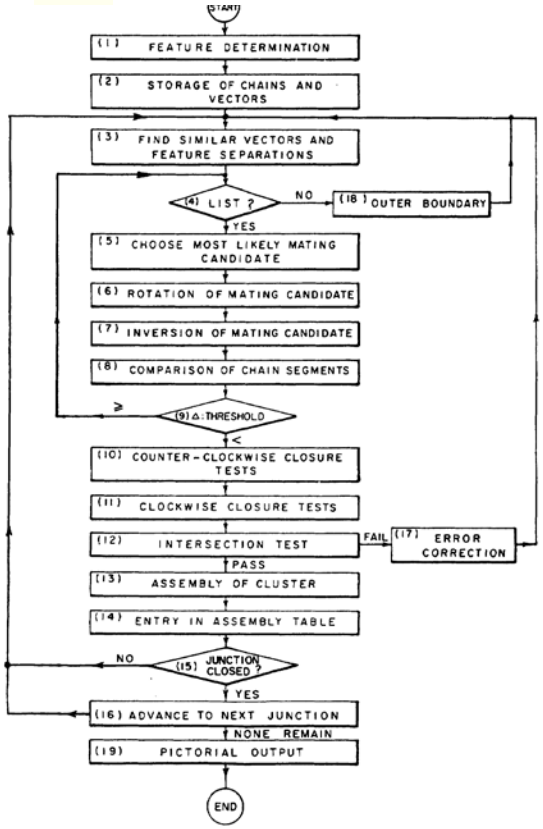


Fig. 14—Program flow chart.

TABLE I

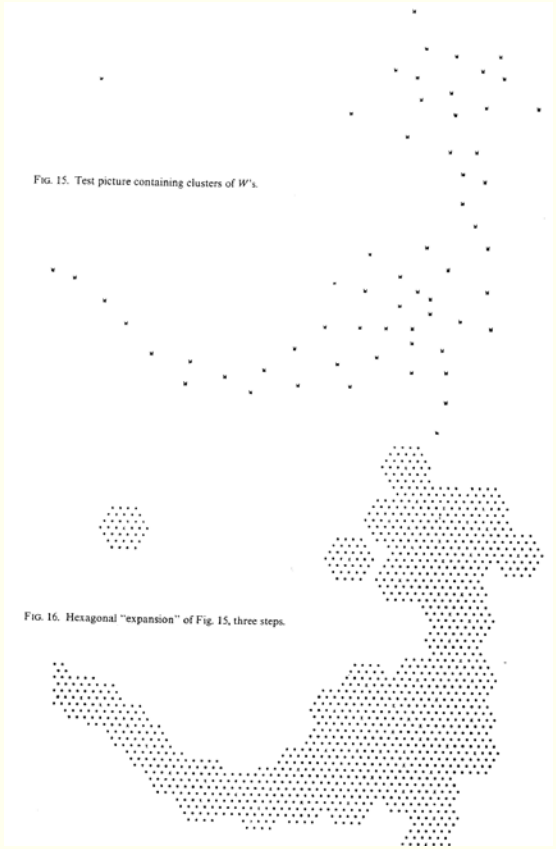
ASSEMBLY PROCEDURE FOR ILLUSTRATIVE EXAMPLE

1) Read Thresholds and Coefficients	35) Clockwise Closure Tests
2) Border Routine	36) C-Clockwise Closure Tests
3) Candidate Number 007.01	37) Intersection Test 1
4) Clockwise Closure Tests	38) Intersection Test 2
5) C-Clockwise Closure Tests	39) Chain Number 004 Matched
6) Intersection Test 1	40) Border Routine
7) Chain Number 007 Matched	41) Candidate Number 005.02
8) Border Routine	42) Clockwise Closure Tests
9) Candidate Number 002.02	43) Type 2/3 Clockwise Closure
10) Candidate Number 002.04	44) C-Clockwise Closure Tests
11) Clockwise Closure Tests	45) Intersection Test 1
12) C-Clockwise Closure Tests	46) Intersection Test 2
13) Intersection Test 1	47) Chain Number 005 Matched
14) Intersection Test 2	48) Border Routine
15) Chain Number 002 Matched	49) Border Routine
16) Border Routine	50) Candidate Number 009.03
17) Border Routine	51) Clockwise Closure Tests
18) Candidate Number 006.02	52) Type 2/3 Clockwise Closure
19) Clockwise Closure Tests	53) C-Clockwise Closure Tests
20) Type 2/3 Clockwise Closure	54) Intersection Test 1
21) C-Clockwise Closure Tests	55) Intersection Test 2
22) Intersection Test 1	56) Chain Number 009 Matched
23) Intersection Test 2	57) Border Routine
24) Chain Number 006 Matched	58) Border Routine
25) Border Routine	59) Candidate Number 008.02
26) Candidate Number 008.02	60) Clockwise Closure Tests
27) Candidate Number 003.03	61) Type 1 Clockwise Closure
28) Clockwise Closure Tests	62) Clockwise Closure Tests
29) C-Clockwise Closure Tests	63) Type 1 Clockwise Closure
30) Intersection Test 1	64) Clockwise Closure Tests
31) Chain Number 003 Matched	65) C-Clockwise Closure Tests
32) Border Routine	66) Intersection Test 1
33) Border Routine	67) Chain Number 008 Matched
34) Candidate Number 004.01	68) End of Assembly

1968: Pattern Recognition journal begins publication
First issue includes the paper
"Distance Functions on Digital Pictures"

A. Rosenfeld and J. L. Pfaltz, Pattern Recognition, Issue 1, 1968

- **Distances Functions Introduced**
  - **City Block**
  - **Square**
  - **Hexagonal**
  - **Octagonal**
  - **Euclidean**



Just Graduated with B. Eng (Electrical)
Outstanding Student Award

“Recognition of Convex Blobs”

J. Sklansky, Pattern Recognition, 1970

- Relationships among convex figures, concave figures, and their cellular images on a rectangular mosaic are presented
- An algorithm using "minimum-perimeter polygon" is described for testing the convexity

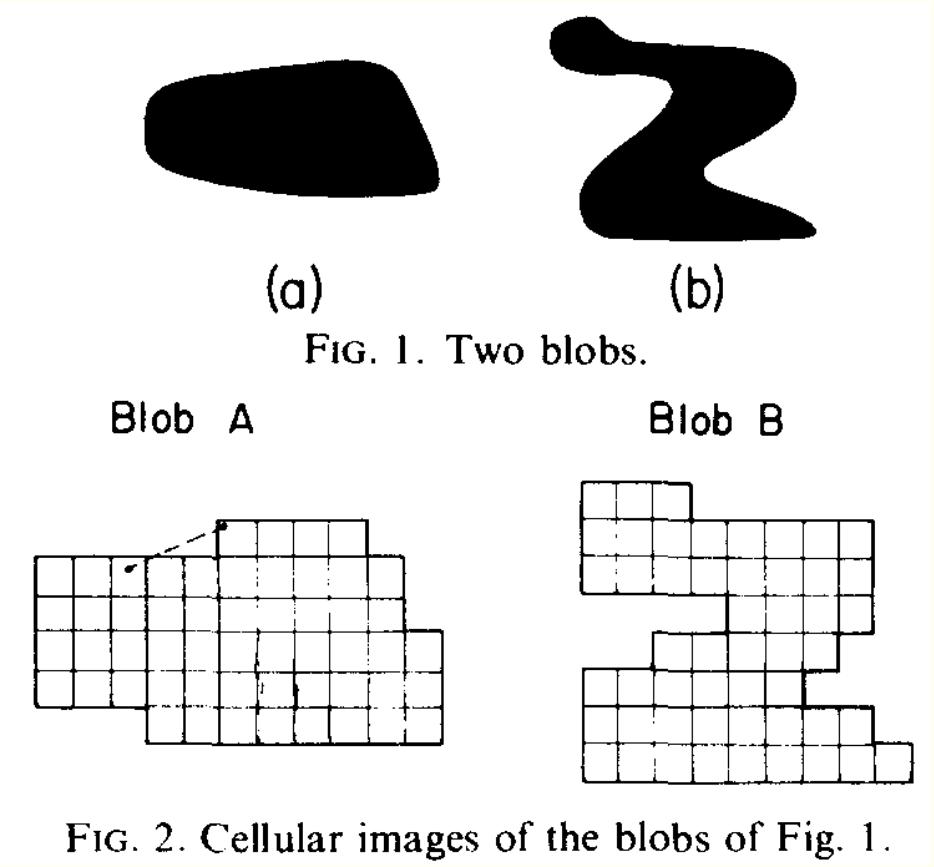


FIG. 1. Two blobs.

FIG. 2. Cellular images of the blobs of Fig. 1.

Graphics Recognition Growth to Become
An Identified Scientific Discipline
1973 - 1994

Graphics Recognition: 1970s

Pattern Recognition gets Established as a Scientific Discipline during 1970s

Several Books on PR are Published

I(J)CPR, PRIP (CVPR), IAPR and PAMI All start during 1970s

Graphics Recognition Topics frequently appear in these

Statistical, Syntactic, and Structural Methods in Pattern Recognition

Several Books were Published during 1973-78

"Pattern Classification and Scene Analysis"

R.O. Duda and P.E. Hart, Wiley, 1973

"Pattern Recognition Principles"

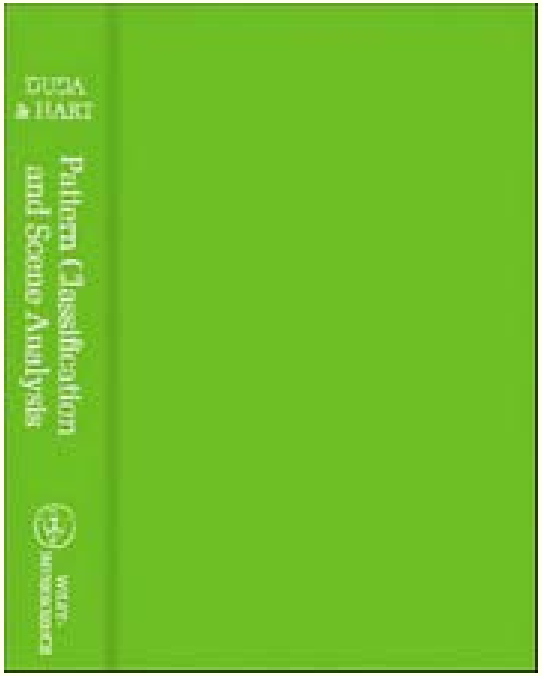
J.T. Tou and R.C. Gonzalez, 1974

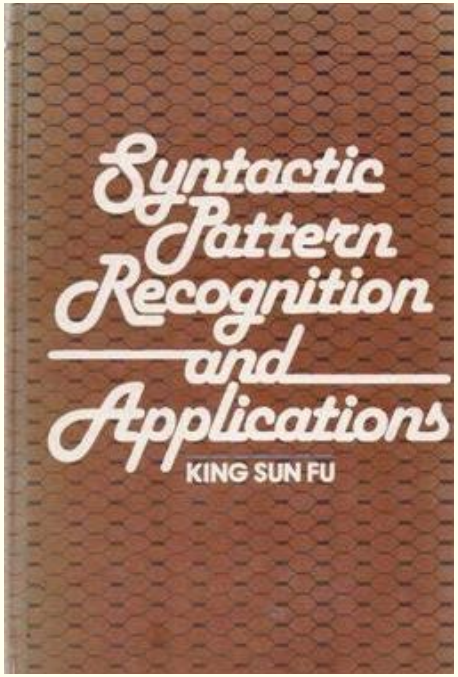
"Syntactic Methods in Pattern Recognition"

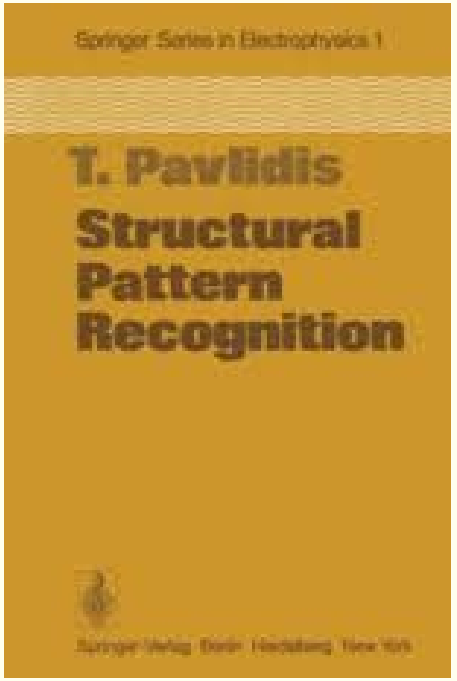
K.S. Fu, Academic Press, 1974

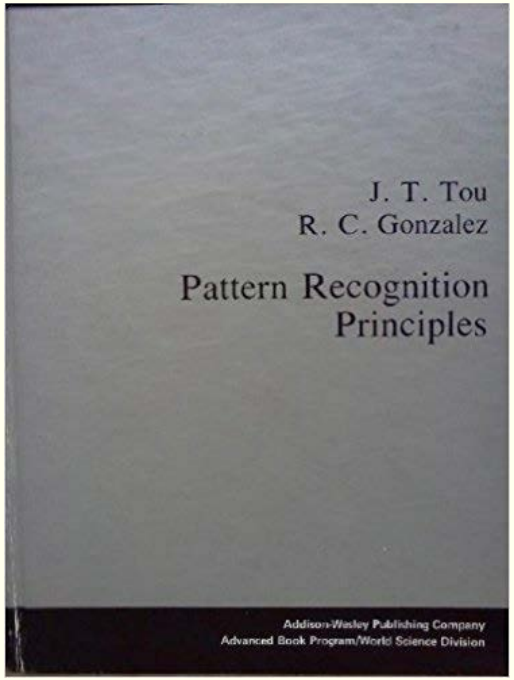
"Structural Pattern Recognition"

T. Pavlidis, Springer-Verlag, 1978





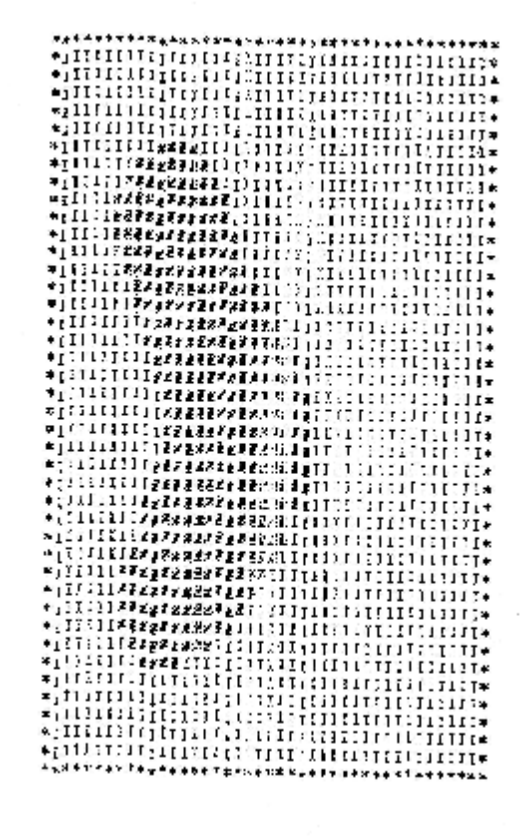




1973: First International Joint Conference on Pattern Recognition

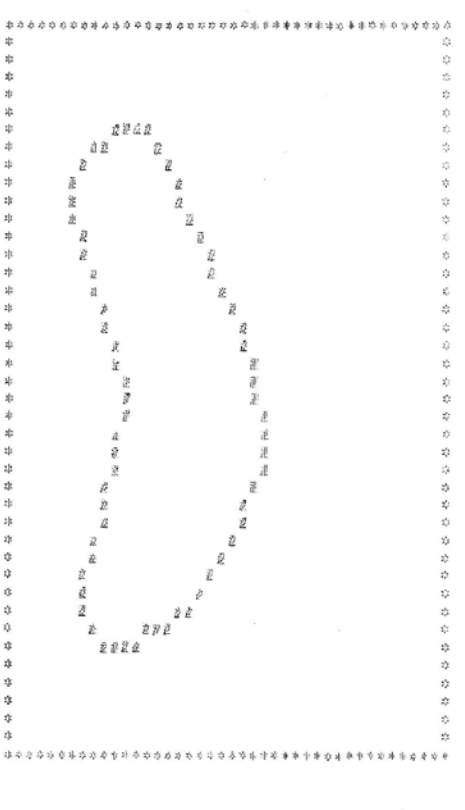
“Contour Detection in Noisy Pictures…”

A. Martelli, 1st IJCPR, 1973



Original

Noisy



Boundary

“Computer Processing of Line-Drawing Images”
H. Freeman, Computing Surveys, 1974

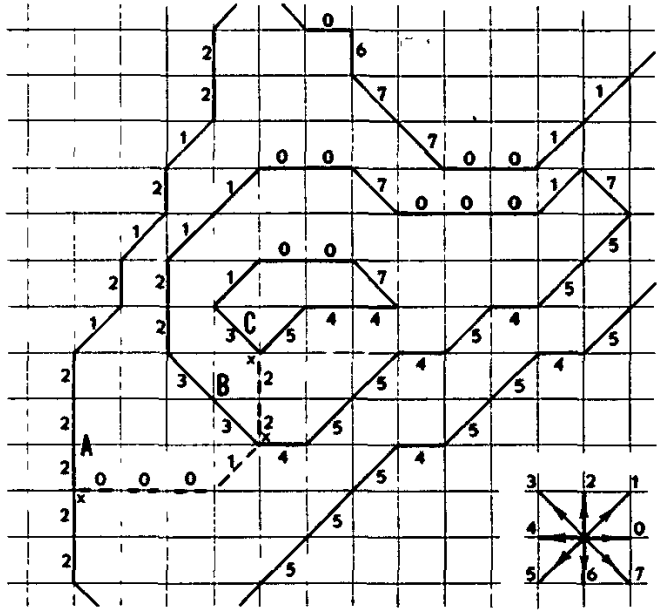


FIG. 13 Chain coding scheme (lower right), and some chain-coded boundary lines from Fig 12

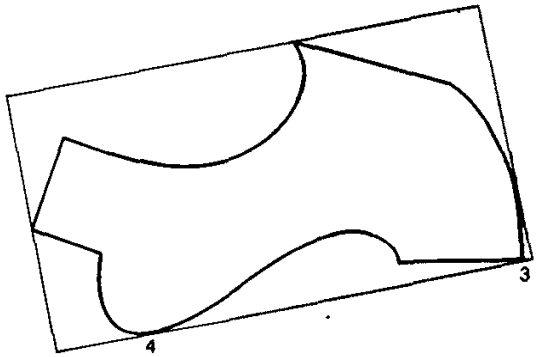


FIG 25 Determination of minimum-area rectangle

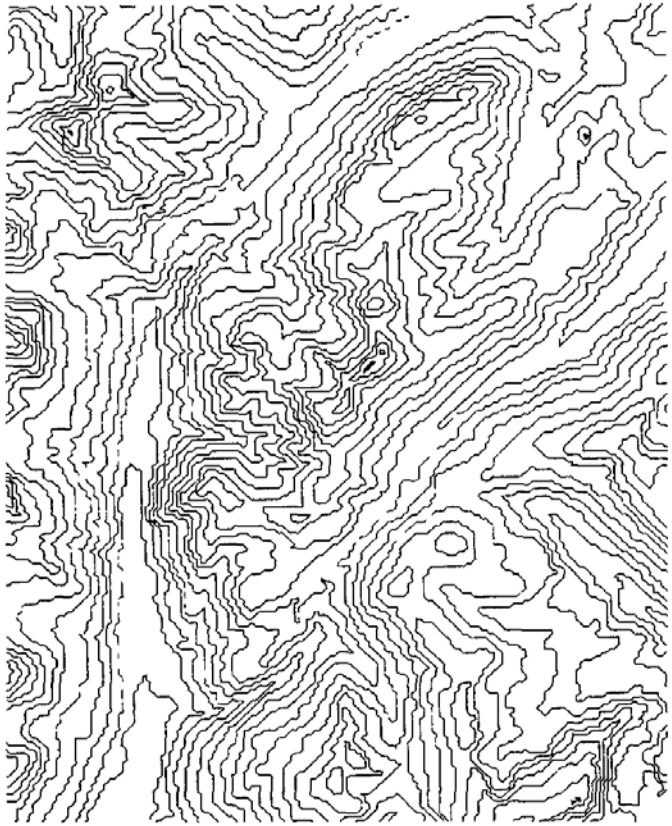


FIG. 24 Chain-encoded contour map. (From S. P Morse, “Generalized computer techniques for the solution of contour-map problems”, Ph.D dissertation, New York University, 1967)

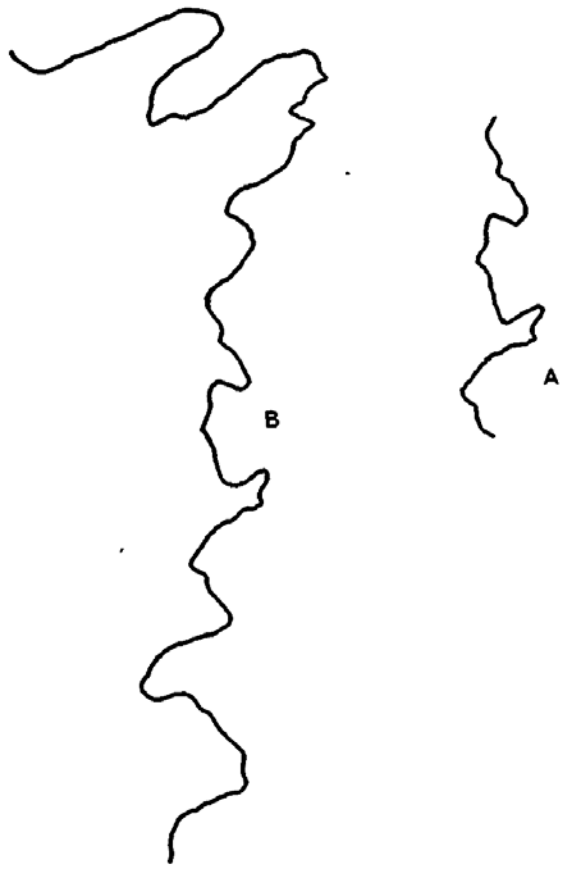


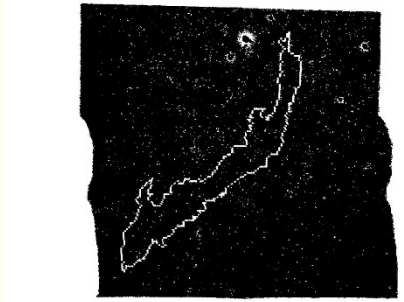
FIG 23. Illustration of the map-matching problem

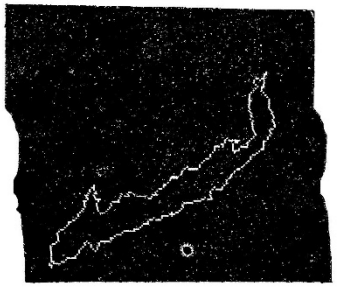
IEEE Pattern Recognition and Image Processing

PRIP Series Begins in 1977 (Changes to CVPR in 1983)

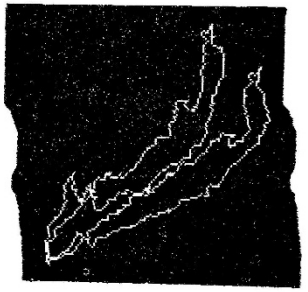
"Shape Matching using Relaxation Techniques"

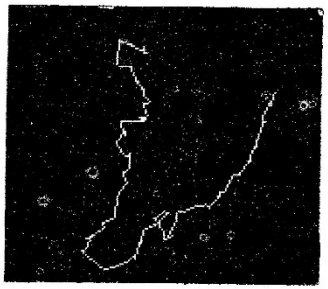
L.S. Davis, PRIP, 1977

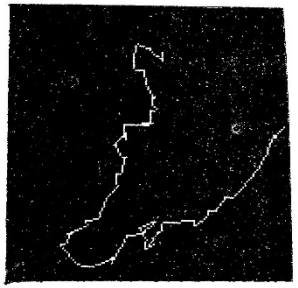




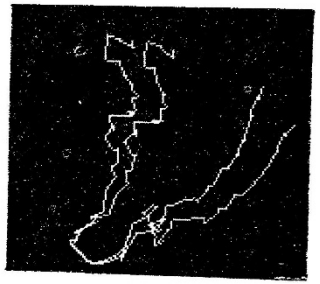
(c) Cuba

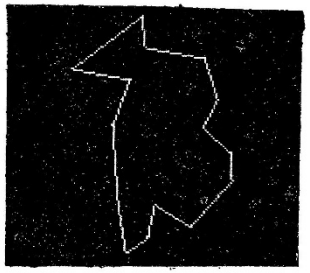


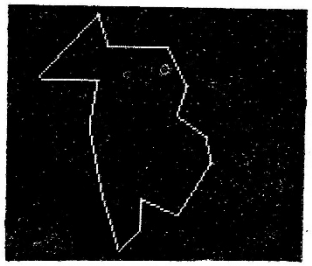




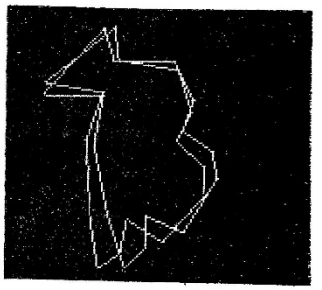
(d) Dominican Republic







(e) Guadeloupe



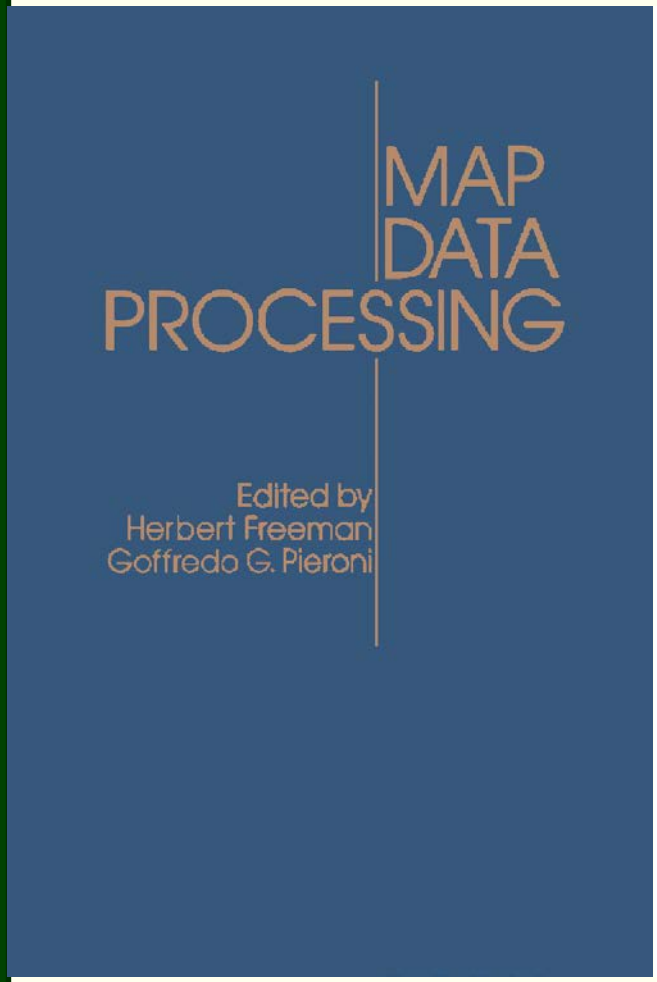
igure 1. Data Base.

Figure 2. Templates.

Figure 3. Superpositions.

"Map Data Processing: Proceedings of NATO Workshop"

Edited by H. Freeman and Pieroni, 1979



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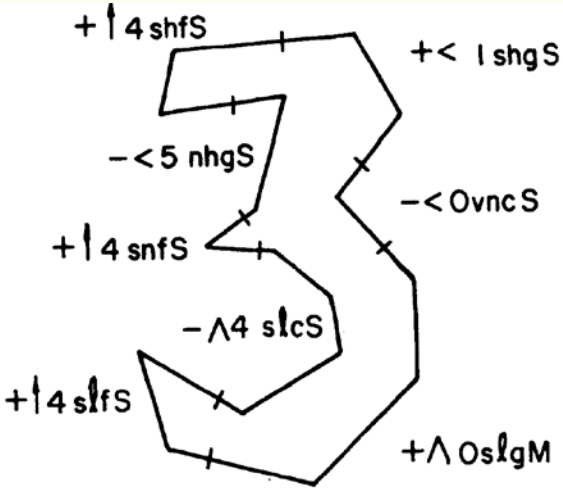
IEEE T. PAMI First Paper Published in January 1979

IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. PAMI-1, NO. 1, JANUARY 1979

A Hierarchical Syntactic Shape Analyzer

THEODOSIOS PAVLIDIS, SENIOR MEMBER, IEEE, AND FARHAT ALI



Example of encoding of the boundary of a handwritten numeral.

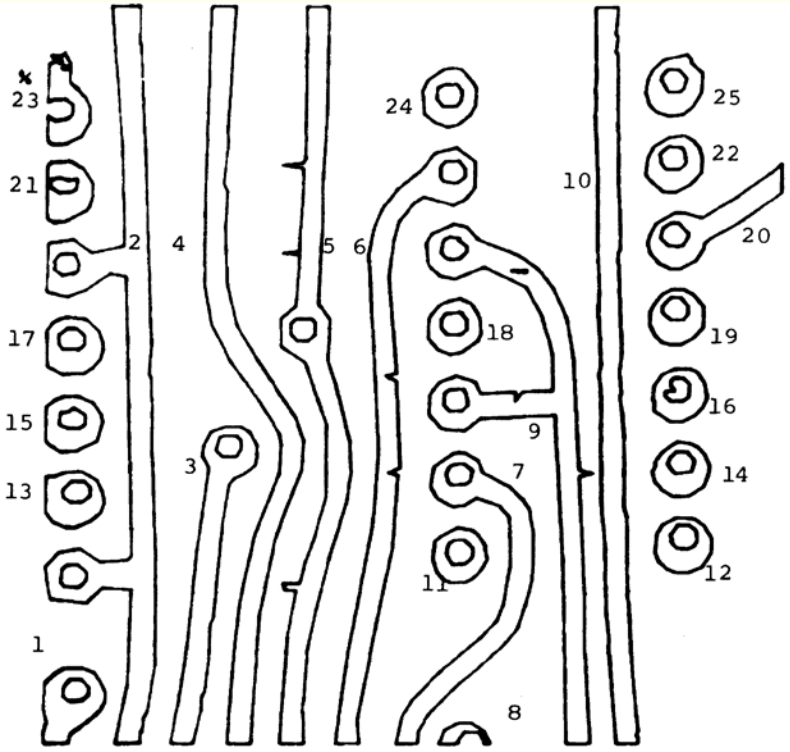


Fig. 5. Contours of a printed wiring board whose descriptions are given in Table IX. Note that the size notations in the table (L, M, S, N) are relative with respect to the size of the whole contour.

Early work in Music Recognition

"A Critical Survey of Music Image Analysis"

D. Blostein and H.S.Baird, Structured Document Image Analysis, Springer ,1992

A Comprehensive Survey of some 50 papers on Music Recognition including

- Recognition of Music Symbols
- Staff Lines
- Symbol Classification
- Relative Positions of Symbols
- Syntactic Methods (for analysis)
- Dance Notation

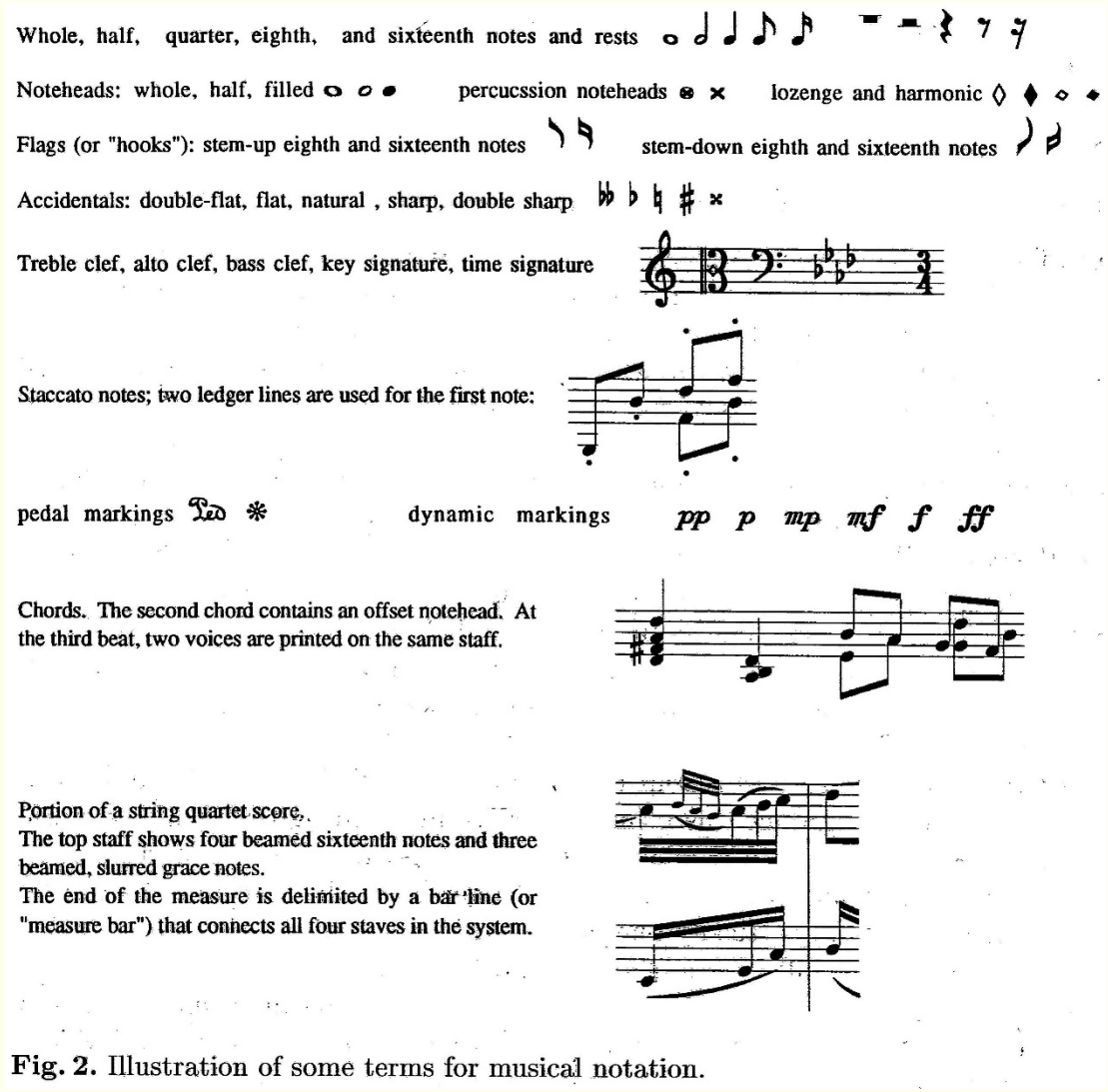
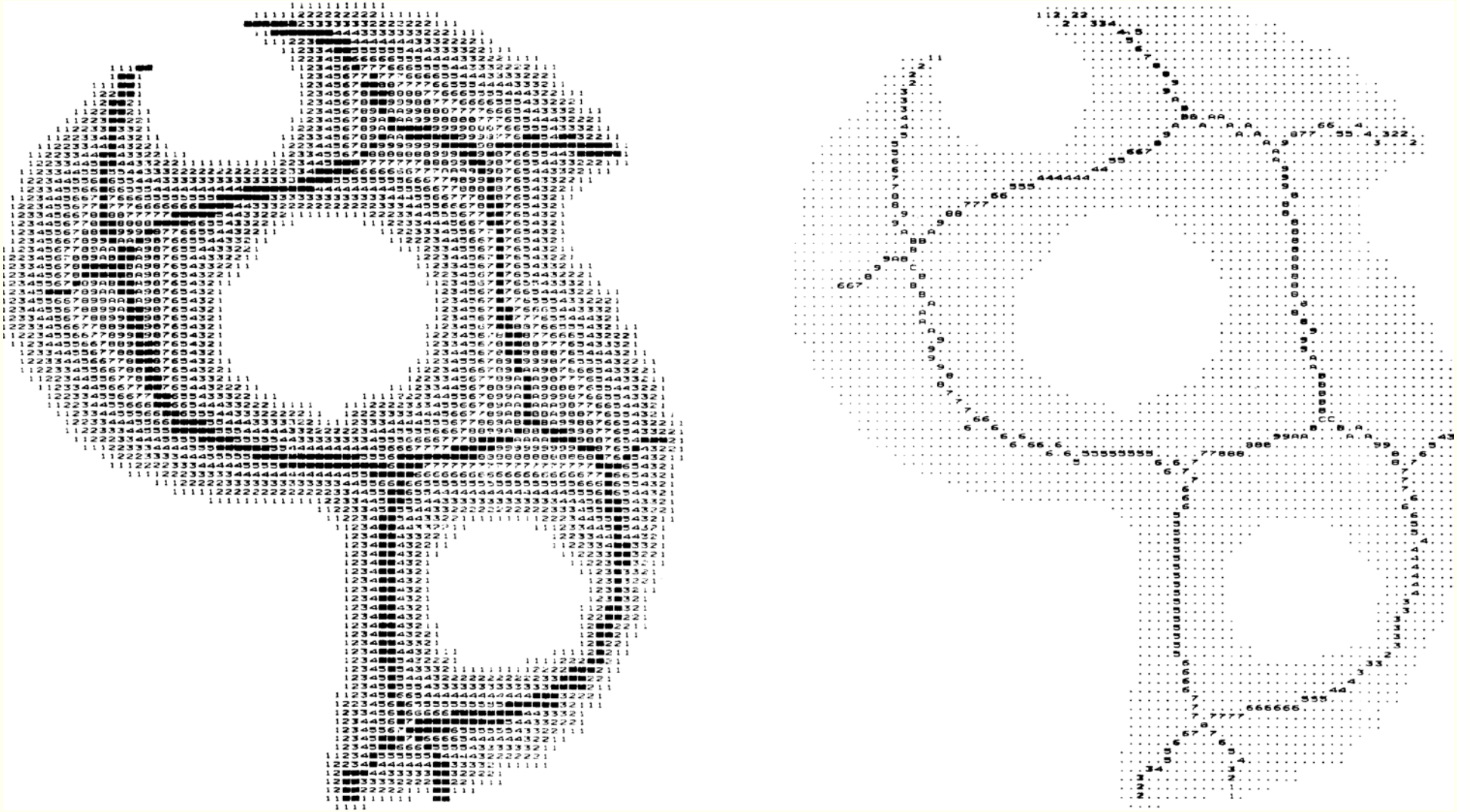


Fig. 2. Illustration of some terms for musical notation.

“A Width Independent Fast Thinning Algorithm”

C. Arcelli and G. Sanniti di Baja, IEEE T. PAMI, 1985



IAPR S+SSPR Workshops

Workshop series on

Syntactic and Structural Methods in Pattern Recognition

First event organized in 1981 by

K.S. Fu, T. Pavlidis, J.L. Mundy and J.K. Aggarwal

This complemented the Workshop series on

Statistical Methods In Pattern Recognition

These are often held in the same location

(S+SSPR 2016 held in Mérida, Mexico)

Kasturi-1981
Graduate Student at Texas Tech University
Topic: Image Restoration in Signal Dependent Noise

1982: With John F. Walkup, Advisor

Joined the Pennsylvania State University

Had to find a new topic for my research

Always interested in MAPS

Image Analysis Techniques for Cartographic Data Processing

TECHNICAL ABSTRACT (LIMIT TO 22 PICA OR 18 ELITE TYPEWRITTEN LINES)

The objective(s) of this project is (are):

Design an intelligent computer based system to "understand" and extract information from cartographic data and answer queries related to spatial features and structure of geographical data. Image analysis techniques such as region growing, line tracking and representation using conic arcs and edge

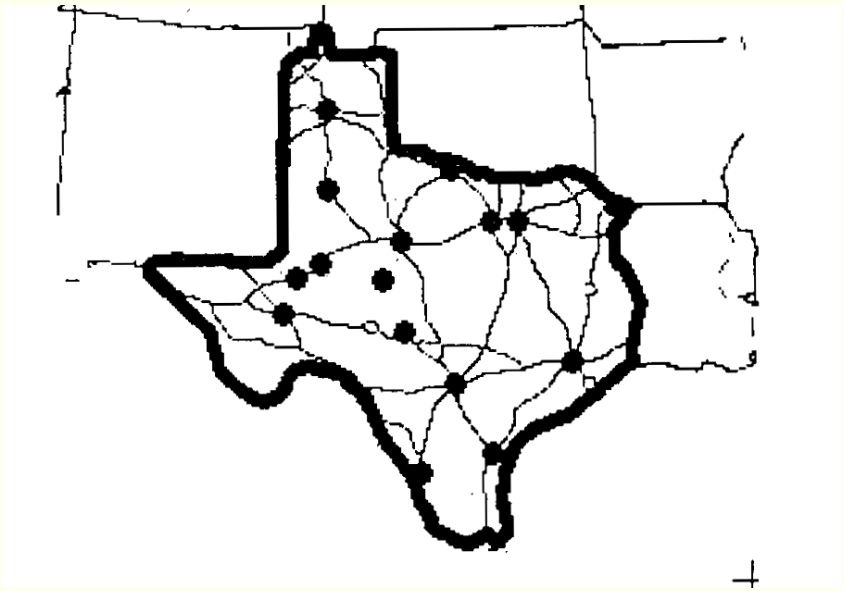
Proposal submitted in January 1983; Grant for $48,000
Received from National Science Foundation in April 1983
Finally, started working in Graphics Recognition!

Some Results from Map Analysis project (1983-87)

O. Morean and R. Kasturi, My First ICPR, Montreal, 1984

R. Kasturi and J. Alemany, IEEE TSE, 1988

Simplified Map of Western USA



Show "Roads" Within "State" Containing "Lubbock"

Map after Text String Separation

- Developed Algorithms for
  - Text-Graphics Separation
  - Symbol Recognition
  - Dashed Line Detection
  - Query Processing
  - Shortest Distance

R. Fernandez. who worked on this project, was hired to lead the Yahoo Maps project.

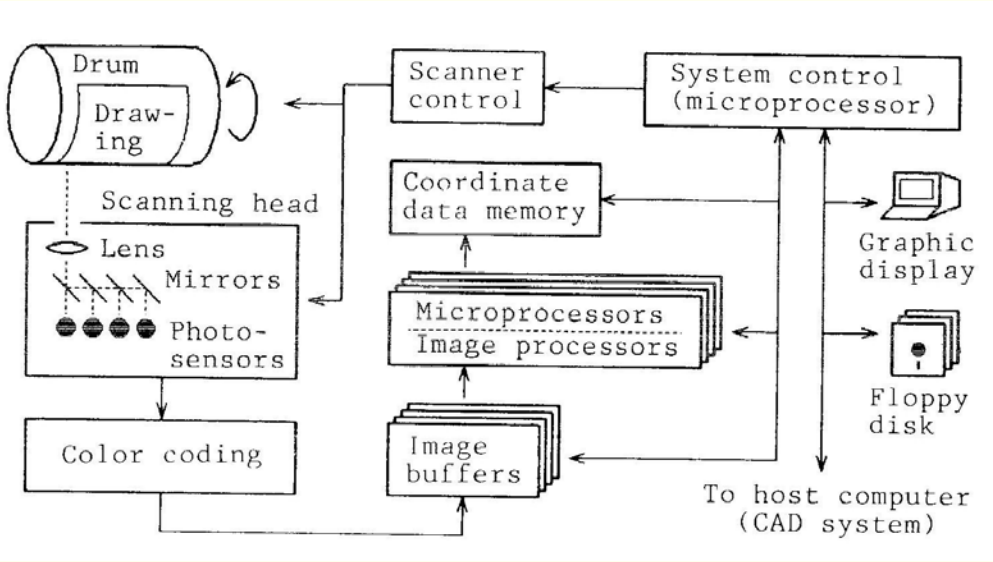
“Development of Auto-Digitizer…”

S. Kakumoto, T. Miyatake, S. Shimada, and M. Ejiri, CVPR 1983

(a)

(b)

Figure 3.10 Automatic digitizers: (a) drum-type for color drawings; (b) flatbed-type for monochrome drawings.



Hitachi Central Research Laboratory, Japan

IAPR Workshop on Machine Vision Applications, Tokyo,1990
Organized by Masakazu Ejiri

- Map and Line Drawing Processing
  - Raster-to Vector Conversion
  - Interpretation of Road Maps
  - Shorthand Recognition
  - Jigsaw Puzzle Assembly
  - Traffic Sign Detection
- Structured Document Recognition
  - Layout Structure Analysis
  - Page Reader
- Fingerprint Classification

“Model based Understanding of Document Images”

K. Kise, et al., IAPR MVA Workshop, 1990

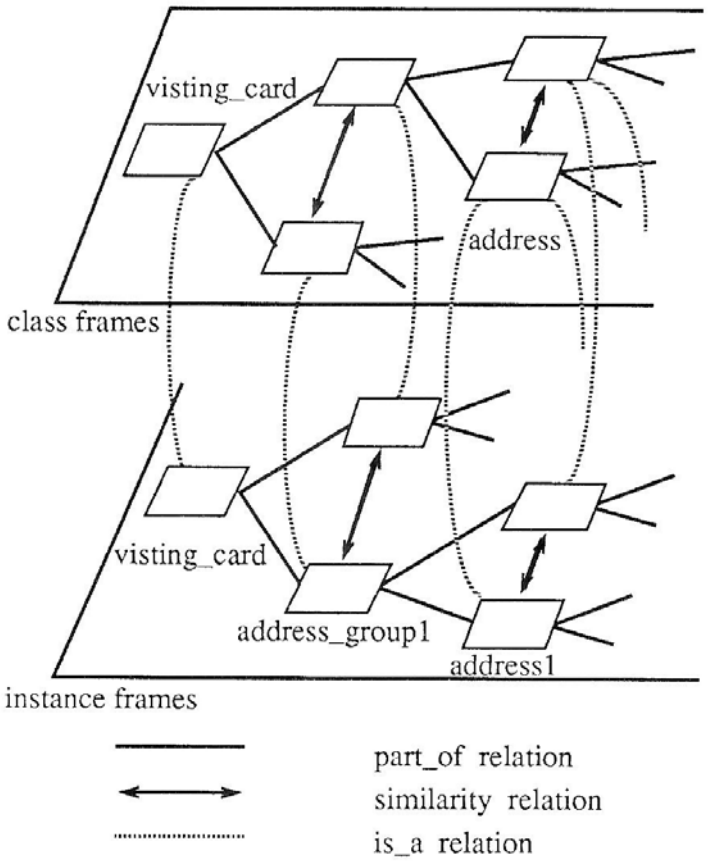
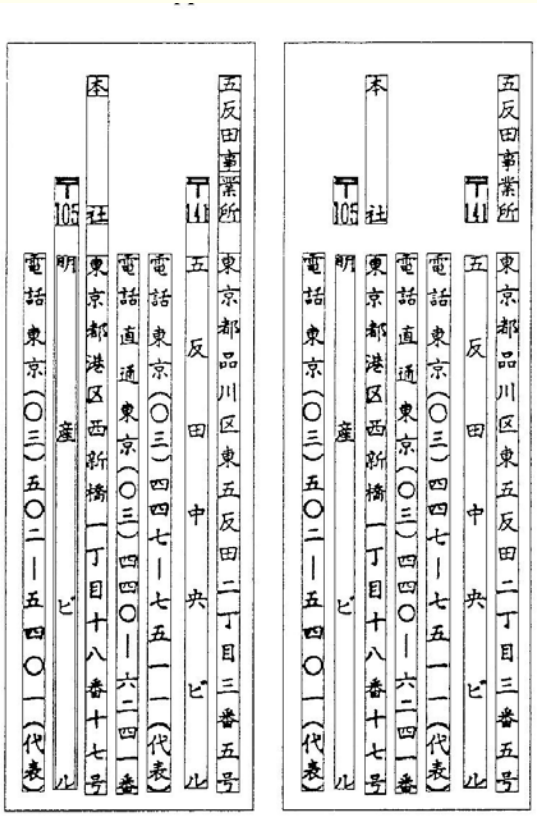


Fig. 1 Document model



(a) hypothesis generation (b) hypothesis testing

Fig. 2 Actual results

Table 2 Results of understanding

	organization	position	title	name	header	address	postcode	telephone	fax	telex	total
No. of components	100	136	130	100	41	119	119	167	10	25	947
Understanding rate	81.0%	94.9%	98.5%	89.0%	87.8%	93.3%	82.4%	74.3%	20.0%	84.0%	86.5%

"Automatic Digitizing of the Colour-Layer of Thematic Maps"

R. Espelid, et al., IAPR MVA Workshop, 1990

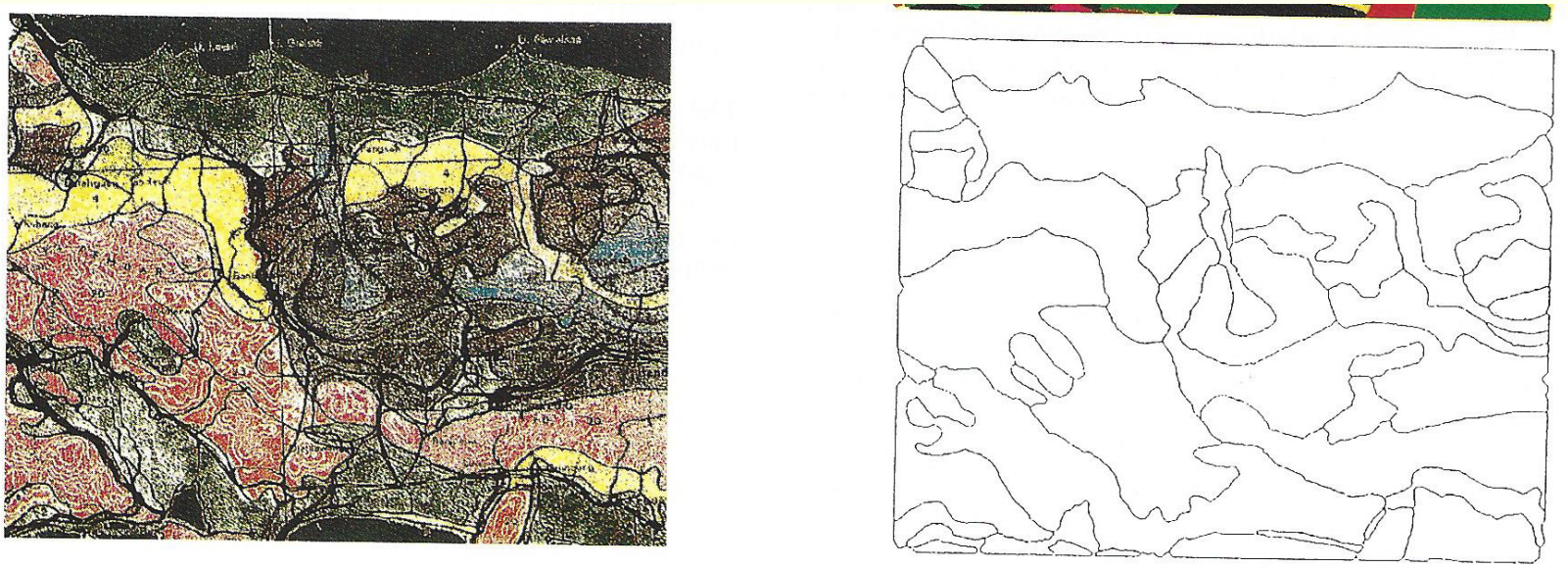


Figure 3. a) Original image. b) Thresholded image. c) Classified areas. d) Borderlines of classified areas.

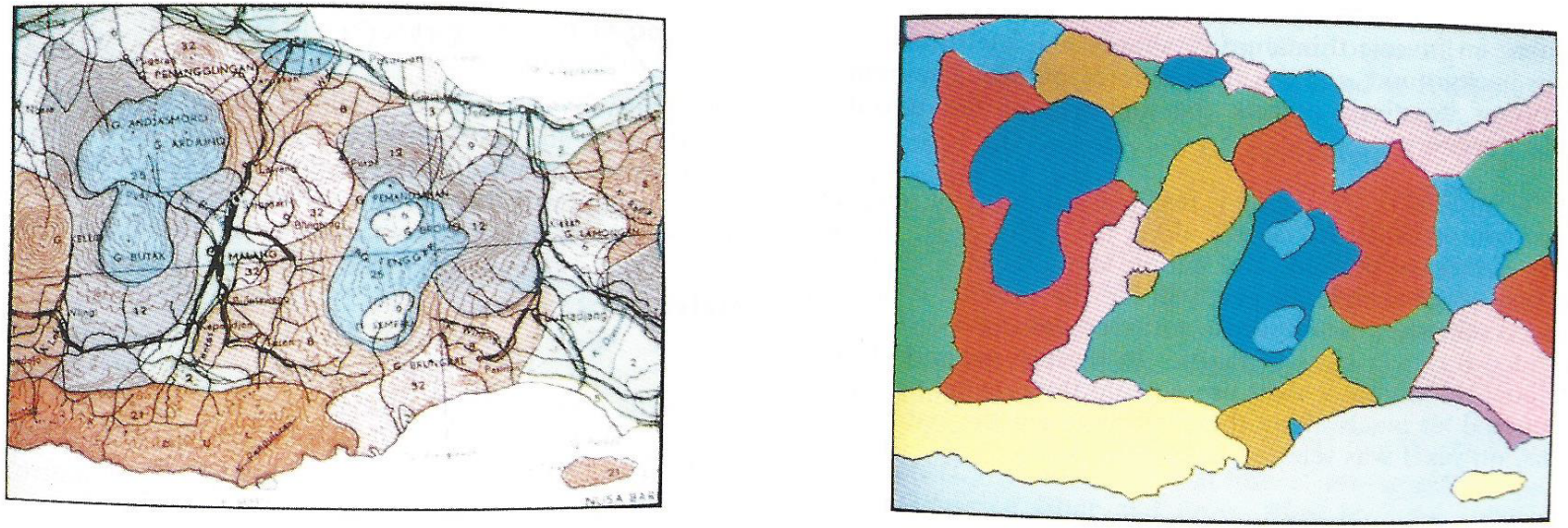


Figure 4. a) Original image. b) Classified image.

IAPR TC10

From Map and Line Drawing Processing to Graphics Recognition

- TC10 on Map and Line Drawing Processing
  - Established during early years of IAPR
  - I was appointed as its Chair by President Martin Levine in 1988
    - First Experience in Leadership Activities
- Renamed as TC10 on Graphics Recognition in 1992 to broaden its appeal
- Provided a home for researchers with interest in Graphics Recognition to exchange their experiences
- Graphics Recognition became an Identified Scientific Topic

General Purpose Graphics Recognition Project (1986-90)

Test Image (1990 PAMI)

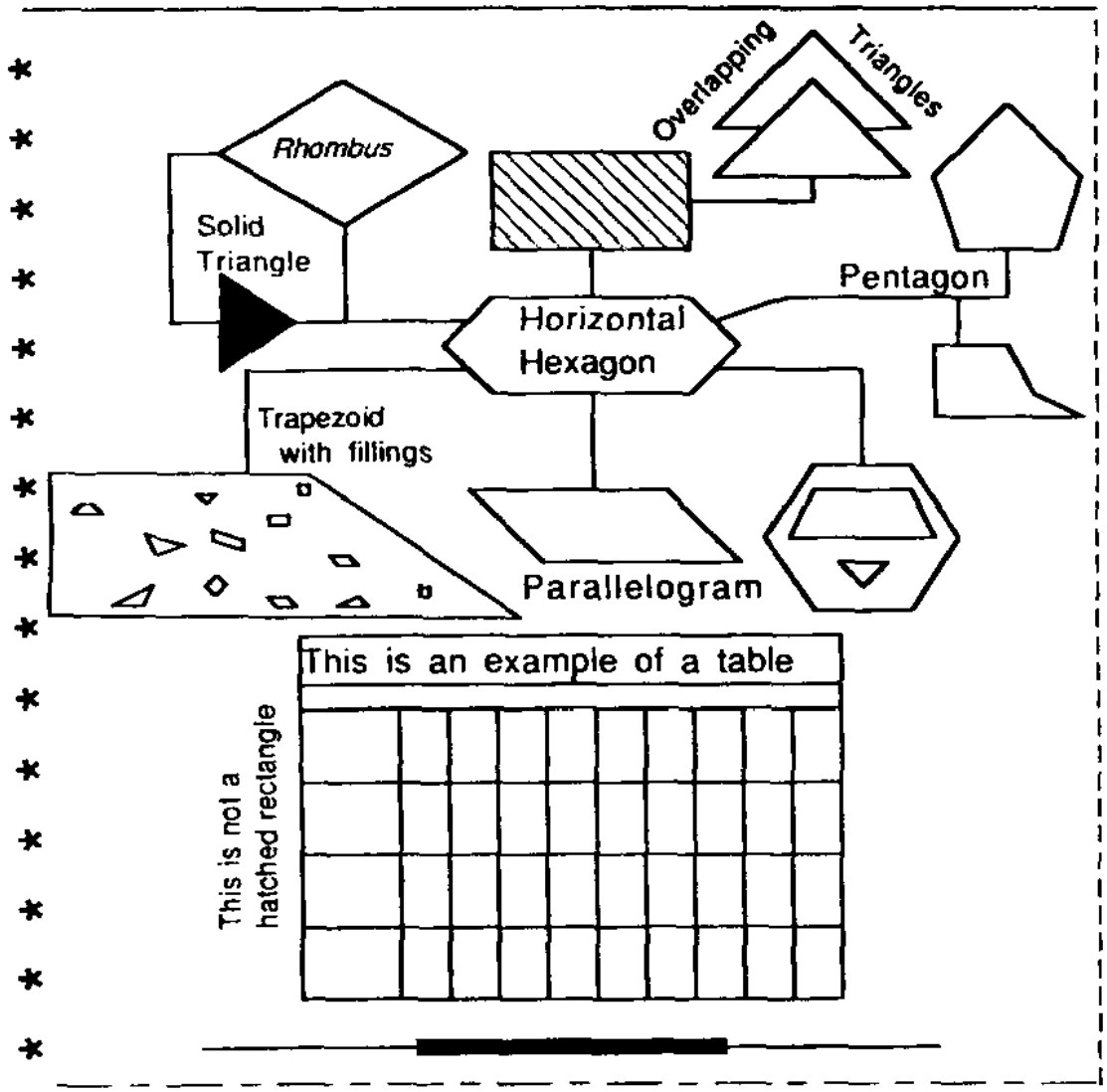
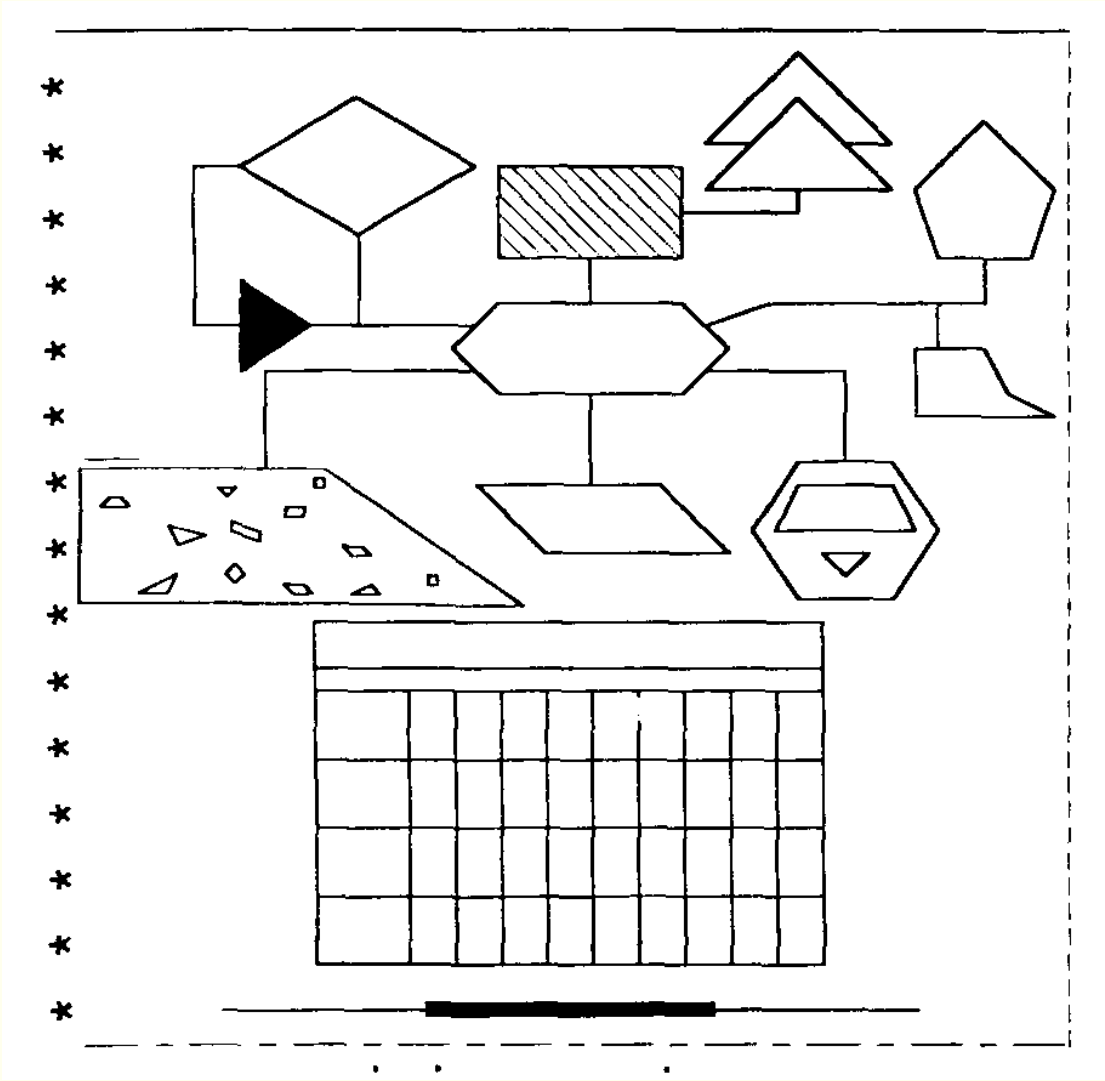


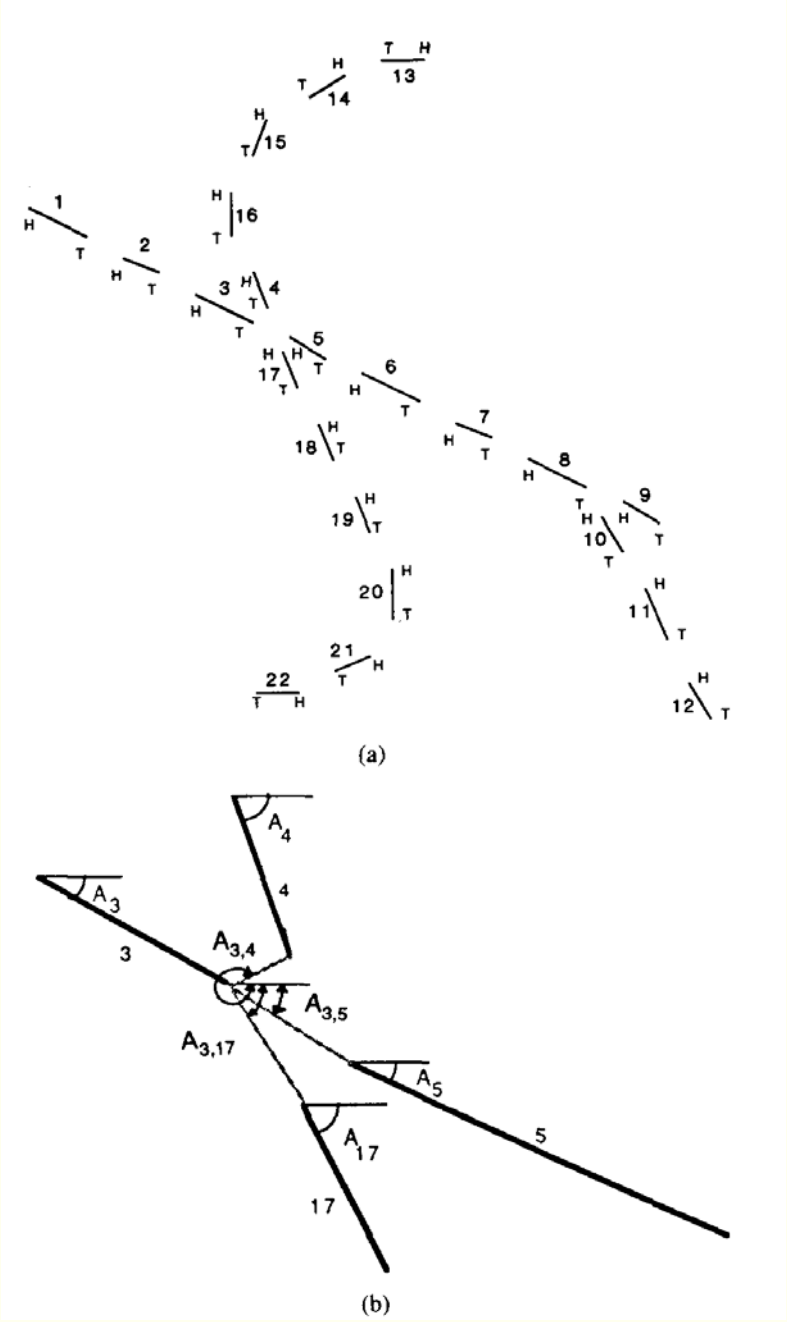
Fig. 1. Test image 1.

General Purpose Graphics Recognition Project
After Text Separation



General Purpose Graphics Recognition Project

Dashed Line Detection Algorithm



While there is a segment, L, which is not used in any line or tested for starting a new line, Do

1: Select the "Head" end of Segment L by setting Terminal = 1
2: Let S_0 = L and t_0 = Terminal
3: Select an unmarked segment S_1 having the highest priority to continue the line at t_0 end of S_0
If S_1 exists, then
Mark S_1. Locate the other end of S_1. If it is a head, then set t_1 = 1 else set t_1 = 2
Go to Step 4
elseif Terminal = 1 then
Terminal = 2
Go to Step 2 (to extend the line at the other end of starting segment L)
else
Label all the segments which belong to the current line
Clear all marks of segments which are not part of a dashed line
Continue to find other lines (by returning to the While loop)
end if
4: Select an unmarked segment S_2 having the highest priority to continue the line at t_1 end of S_1.
If S_2 exists, then
Mark S_2
If $l_{s0} \neq l_{s2}$ Or $g_{01} \neq g_{12}$ then Go to Step 4
Locate the other end of S_2. If it is a head, then set t_2 = 1 else set t_2 = 2
Go to Step 5
else
Go to Step 3
end if
5: Select an unmarked segment S_3 having the highest priority to continue the line at t_2 end of S_2
If S_3 exists, then
Mark S_3.
If $l_{s1} \neq l_{s3}$ Or $g_{12} \neq g_{23}$ then Go to Step 5.
Locate the other end of S_3. If it is a head, then set t_3 = 1 else set t_3 = 2
Label S_1 and S_2 as extensions of current line. Set $S_0 = S_2$, $t_0 = t_2$, $S_1 = S_3$, and $t_1 = t_3$.
end if
6: Go to Step 4

end while

General Purpose Graphics Recognition Project

Recognition of Shapes and their Attributes

TABLE IV
RECOGNIZED SHAPES AND POLYGONS IN TEST IMAGE 1

	Object	Attributes
1	Regular Hexagon	P: (1258, 1081), L = 133, ϕ = 1.51
2	Parallelogram	P: (727, 1268), L1 = 292, L2 = 146, Θ = 46.1, ϕ = 0
3	Trapezoid	P: (73, 1081), L1 = 718, L2 = 390, H = 217, Θ = 90.68, ϕ = -0.16
4	Rhombus	P: (339, 1791), L = 220 Θ = 30.1, ϕ = -0.45
5	Trapezoid	P: (1220, 1194), L1 = 221, L2 = 150, H = 68.6, Θ = 65, ϕ = 0.77
6	Triangle	P1: (1295, 1153), P2: (1363, 1151), P3: (1325, 1122), Isoceles
7	Triangle	P1: (1396, 1826), P2: (1106, 1831), P3: (1256, 1971), Isoceles
8	Rectangle	P: (457, 1044), W = 835, H = 564, ϕ = -0.4, Table
9	Quasi-Hexagon	P: (692,1497), L1 = 440, L2 = 303, Θ = 89.1, ϕ = 3.0
10	Parallelogram	P: (765, 1790), L1 = 297.1, L2 = 148, Θ = 89.0, ϕ = -1.35, Single hatch: a1 = 135, d1 = 30
11	Traingle	P1: (1256, 1897), P2: (1399, 1755), P3: (1108, 1753), Isoceles
12	Polygon, irregular	Number of segments: 6, Center: (1556, 1706), Coordinates of vertices....

TABLE V
SPATIAL RELATIONSHIPS AMONG OBJECTS IN TEST IMAGE 1

	Objects	Spatial Relationships
11	Triangle	Overlaps Object 7
1	Regular Hexagon	Encloses Objects 5 and 6
10	Parallelogram	Single Hatch
3	Trapezoid	Small Shape Fillings

Lines and Their Interconnections

Line	Head	Tail	From	To
Single Segment Lines				
L1	(1404,1748)	(1399,1755)	--	11
L2	(910,1416)	(911,1271)	9	2
. . .	. . .	. . .	. . .	. . .
Lines With Multiple Segments				
PL1	S1: (330,1531) S2: (260,1537) S3: (265,1791) S4: (332,1790)	(260,1537) (265,1791) (332,1790) (339,1791)	--	4
PL2	S1: (1064,1715) S2: (1252,1719)	(1252,1719) (1252,1750)	10	11
. . .	. . .	. . .	. . .	. . .

Processing Graphics Containing Circular Arc Segments

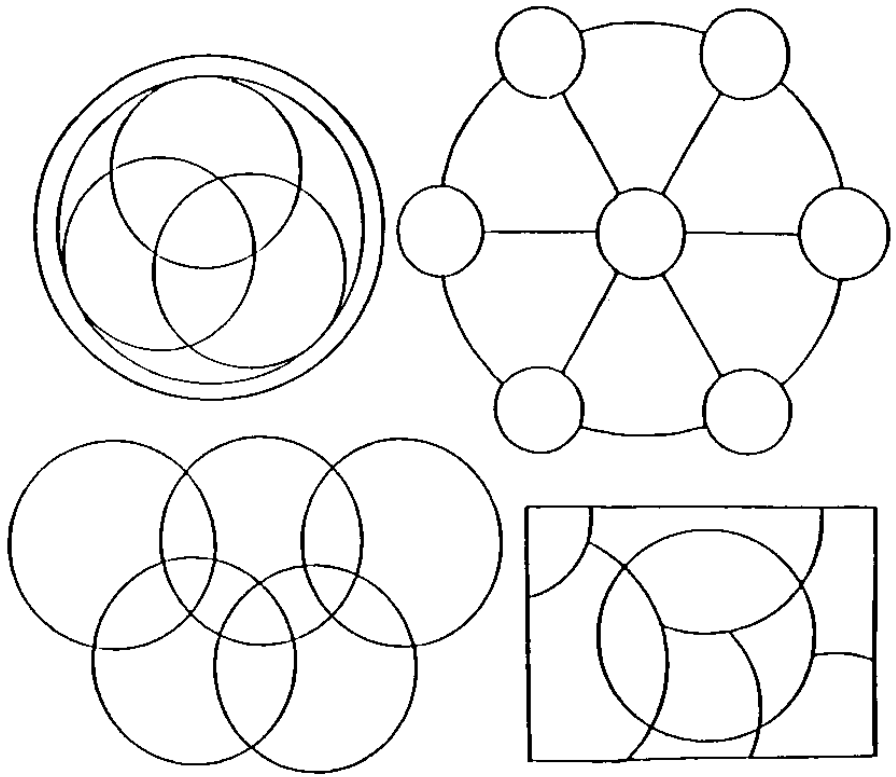


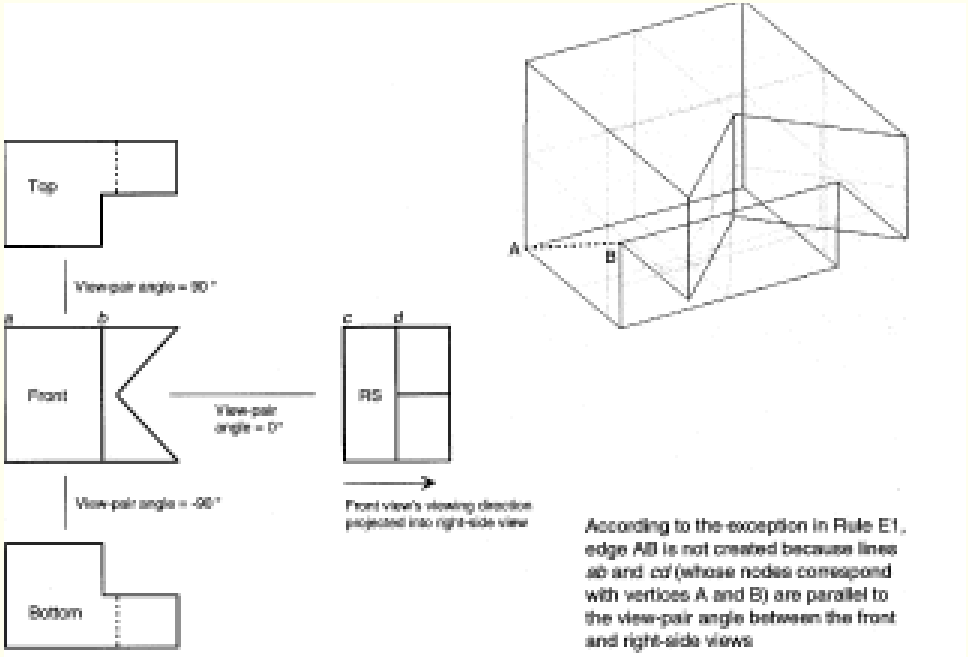
Fig. 16. Graphics containing circular arc segments.

CIRCLES DETECTED IN FIG. 16

CIRCLE	RADIUS	CENTER	
		X	Y
1	381	493	469
2	228	1193	890
3	230	1195	257
4	338	495	473
5	221	1472	687
6	233	1455	415
7	236	1418	1548
8	233	1180	591
9	95	917	1647
10	210	596	554
11	209	368	463
12	98	129	1654
13	97	529	1864
14	96	906	1190
15	92	125	1207
16	96	509	980
17	210	548	359
18	97	519	1422
19	457	509	1422
	Circle 19 is partially occluded		

Interpretation of 3-D from Orthographic Projections

P.M. Devaux, D.B. Lysak, and R. Kasturi., ICPR 1990, IJDAR 1999



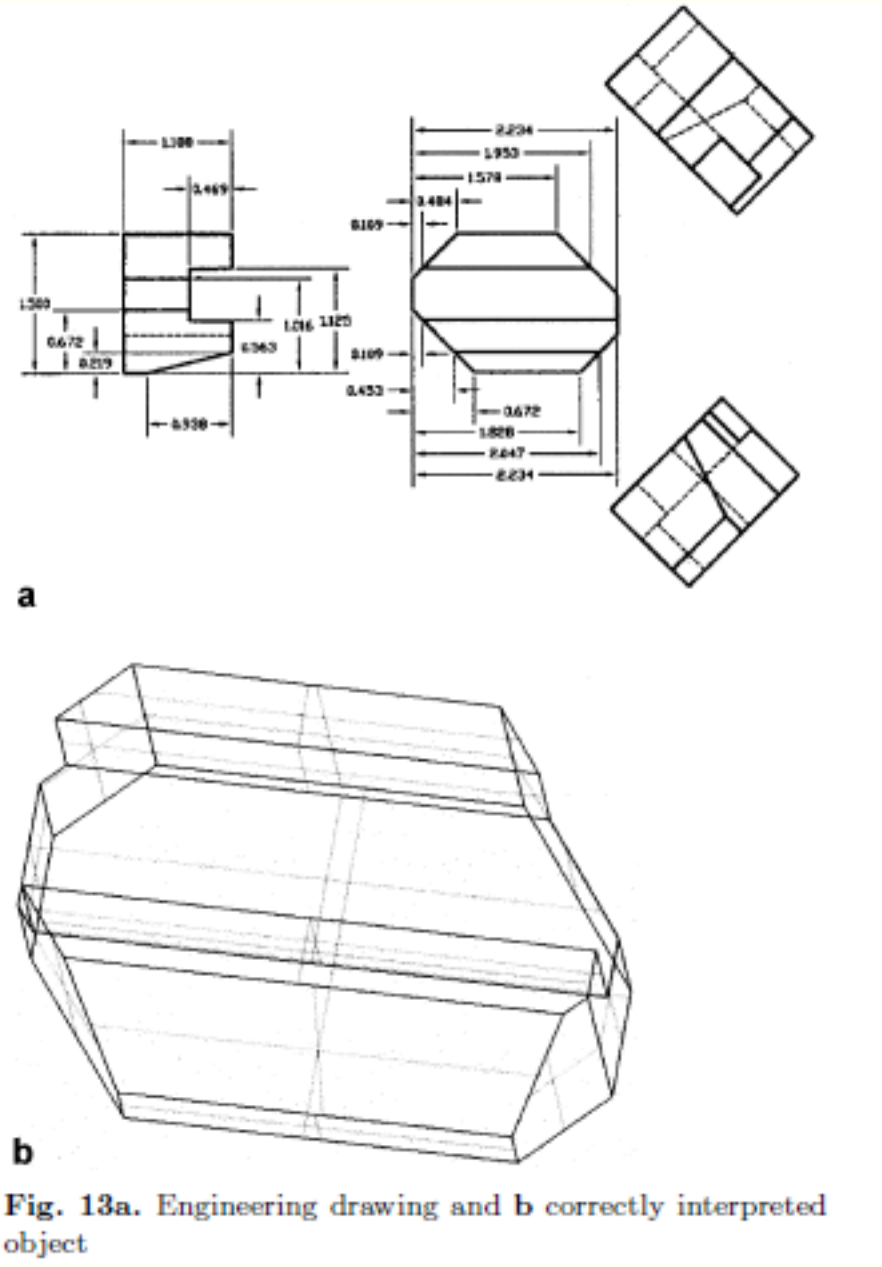
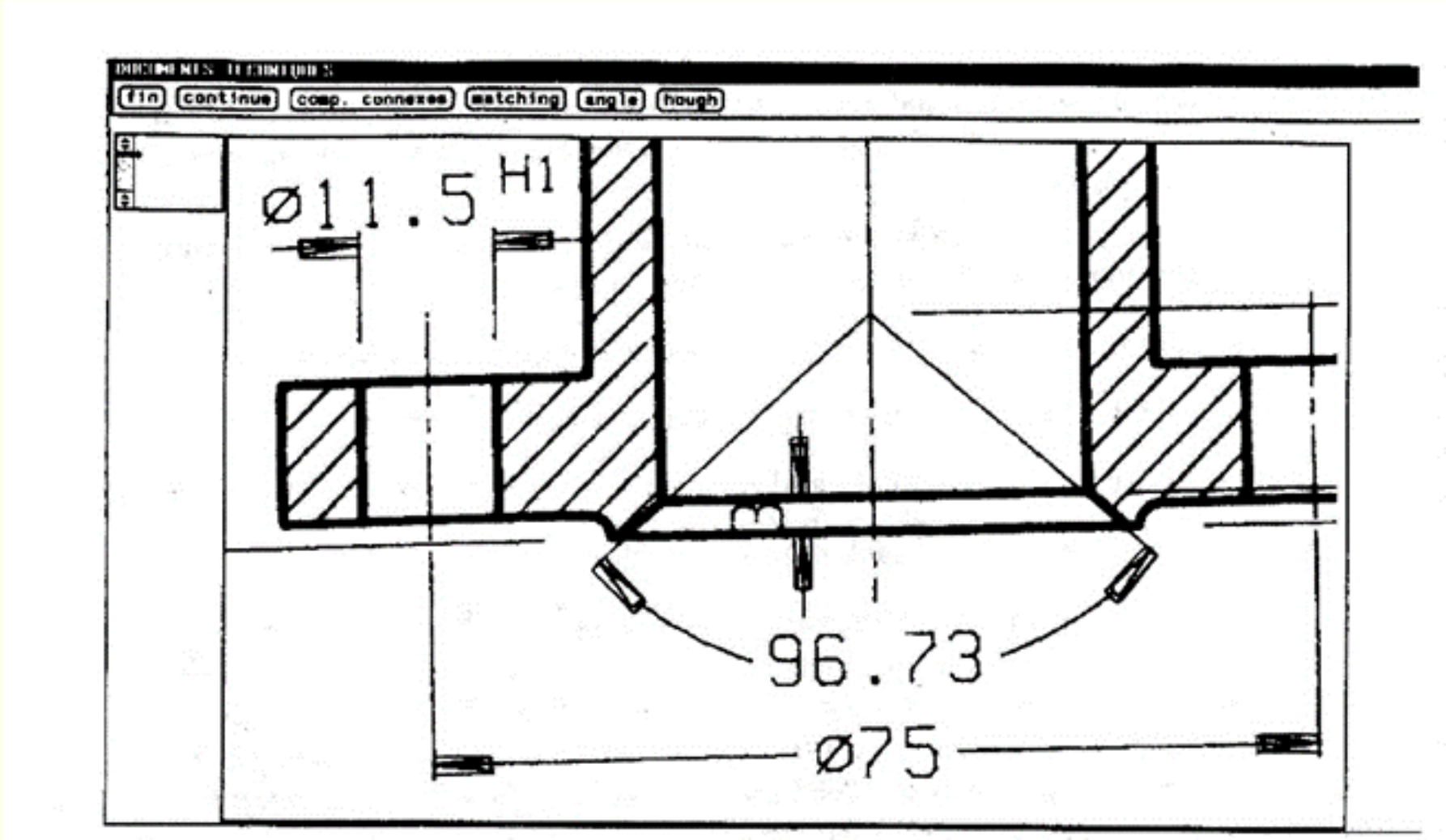


Fig. 13a. Engineering drawing and **b** correctly interpreted object

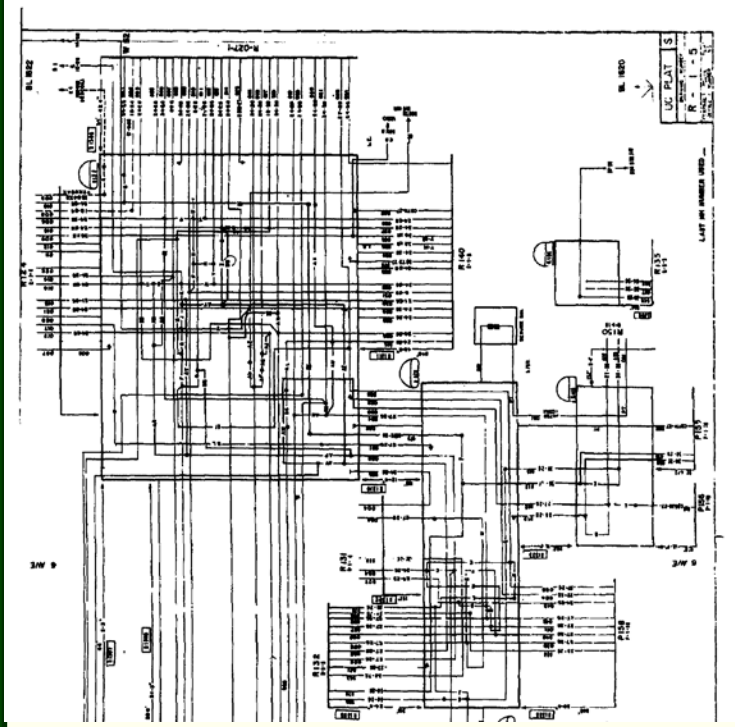
“Engineering Drawing Conversion: Arrow Detection”

Antoine, Collin, and Tombre, SSPR 1990



“Interpretation of Telephone System Manhole Drawings”

Arias, Lai, Surya, Kasturi, and Chhabra, PRL, 1994



Original Drawing

Extracted Manhole

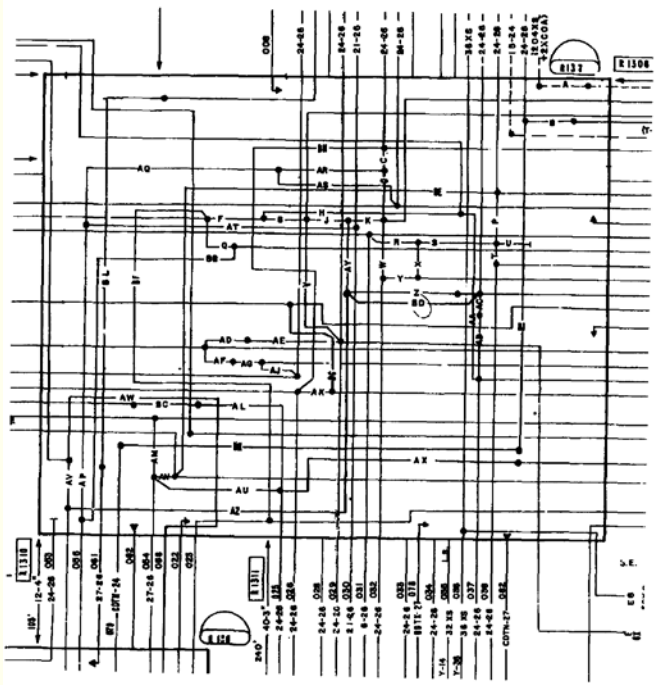


Fig. 5. Single manhole extracted from Fig. 1.

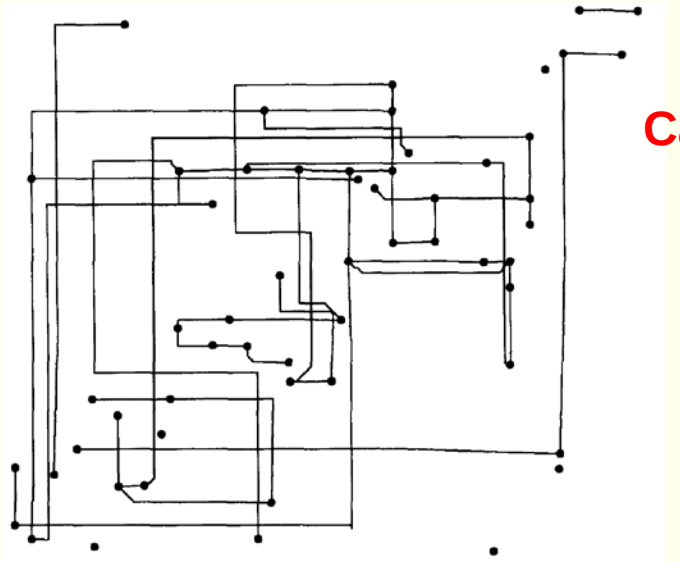


Fig. 9. Detected stubs.

Cable Connections

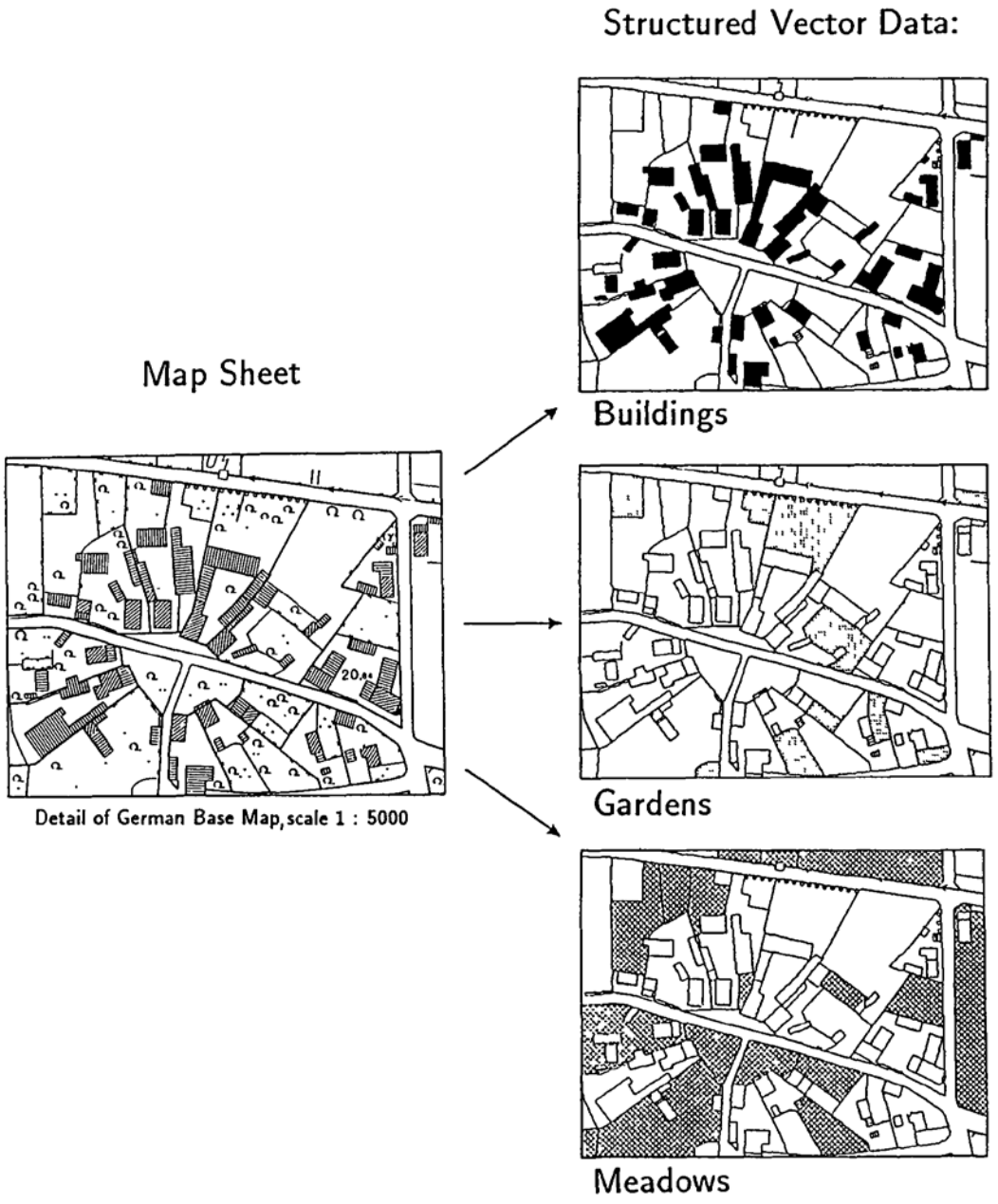
Summary Table

Cables and Stubs

Line#	type	start_x	start_y	end_x	end_y	end_1	end_2
1	cable	87	25	1299	581	open	splice#44
2	cable	151	25	1383	205	open	splice#47
3	cable	681	25	681	1137	open	splice#20
4	cable	1253	25	1253	469	open	splice#43
5	cable	590	27	590	1226	open	splice#11
6	cable	900	27	900	889	open	splice#30
7	cable	1032	27	1032	624	open	splice#34
8	cable	1120	27	1120	911	open	splice#37
9	cable	1169	27	1169	914	open	splice#40
10	cable	1212	27	1212	403	open	splice#42
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
71	stub	1383	205	1529	204	splice#47	splice#53
72	stub	1529	204	864	1067	splice#53	splice#27
73	stub	653	251	1565	247	splice#18	splice#54
74	stub	653	251	658	1094	splice#18	splice#19
75	stub	260	494	1402	305	splice#3	splice#49
76	stub	1337	364	1349	1616	splice#45	splice#46
77	stub	1212	403	1211	604	splice#42	splice#41
78	stub	1253	469	1431	470	splice#43	splice#51
79	stub	1431	470	1472	864	splice#51	splice#52
80	stub	1431	470	1429	536	splice#51	splice#50
.	.	.	.	.	.	.	.

“Automatic Digitization of Large Scale Maps”

Andreas Illert, ACSM-ASPRS, Vol. 6, pp. 113-122,1991



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Guy Lorrette
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Robert Haralick
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Georges Stamon

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TC10 (R. Kasturi, Chair)
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100+ Papers from 200+ Authors
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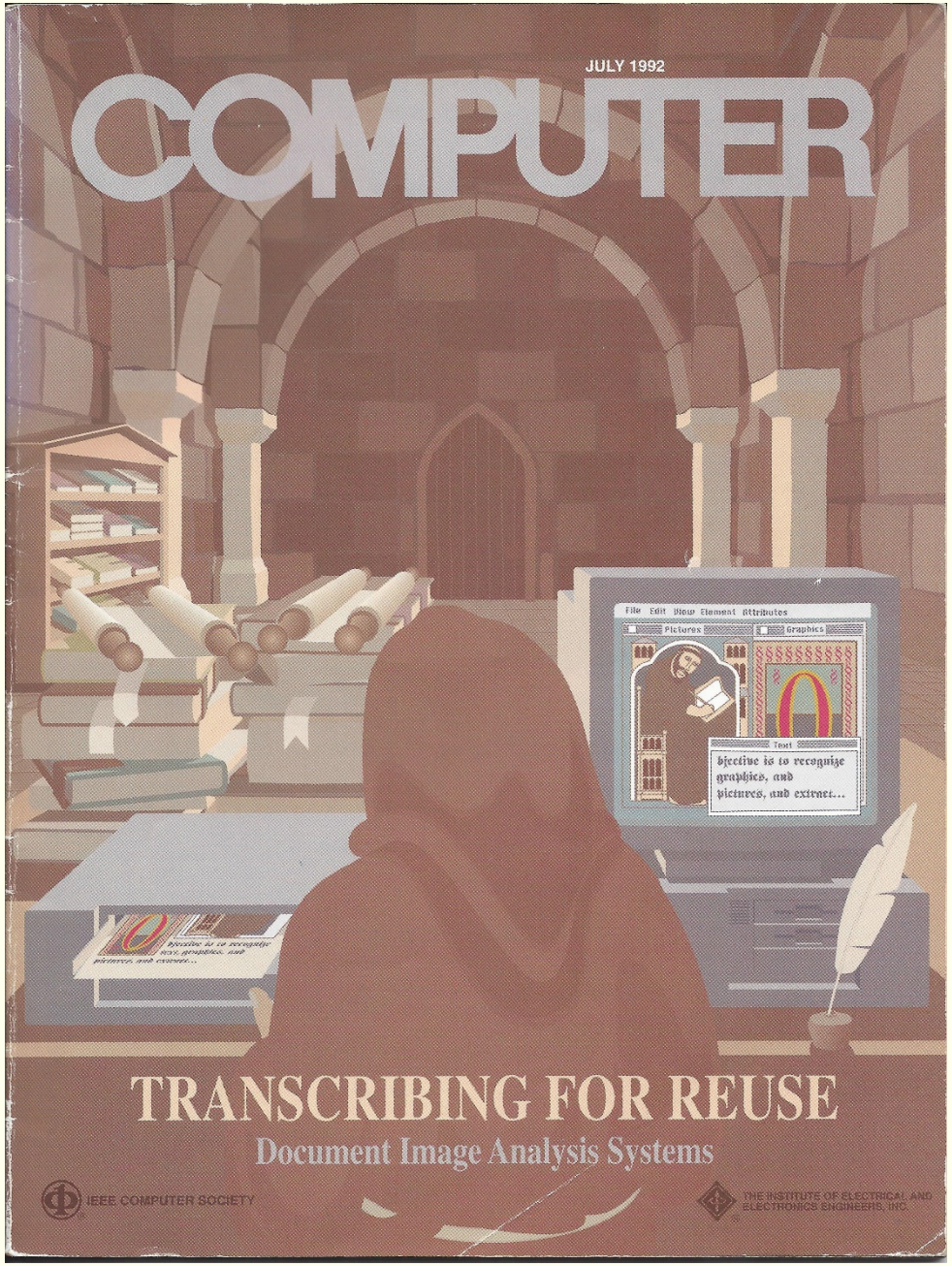
14 Sessions

Special Issue of IEEE Computer 1992

L.O'Gorman and R. Kasturi, Editors



July 1992 • Vol. 25, No. 7

ARTICLES

5 **Guest Editors' Introduction: Document Image Analysis Systems**
Lawrence O'Gorman and Rangachar Kasturi

10 **A Prototype Document Image Analysis System for Technical Journals**
George Nagy, Sharad Seth, and Mahesh Viswanathan
Intelligent document segmentation can bring electronic browsing within the reach of most users. The authors show how this is achieved through document processing, analysis, and parsing the graphic sentence.

25 **An Interpretation System for Land Register Maps**
Luca Boatto, Vincenzo Consorti, Monica Del Buono, Silvano Di Zenzo, Vincenzo Eramo, Alessandra Esposito, Francesco Melcarne, Marco Meucci, Andrea Morelli, Marco Mosciatti, Stefano Scarci, and Marco Tucci
The semantics of land register maps drive this document conversion system. However, its methods of image representation, vectorization, and symbol recognition can be generalized to other classes of line drawings.

34 **Postal Address Block Location in Real Time**
Paul W. Palumbo, Sargur N. Srihari, Jung Soh, Ramalingam Sridhar, and Victor Demjanenko
A postal automation system locates destination address blocks on letter mail pieces with a high success rate. Pipelining and multiprocessor techniques achieve real-time processing speed.

46 **Celesstin: CAD Conversion of Mechanical Drawings**
Pascal Vaxivière and Karl Tombre
A prototype CAD conversion system extracts higher level structures for knowledge-based analysis. It recognizes such entities as screws, ball bearings, and shafts.

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75 **Understanding Diagrams in Technical Documents**
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Special Issues of MVA Journal, 1992, 1993

R. Kasturi and L.O'Gorman, Editors

Machine Vision and Applications

An International Journal

Volume 5, Number 3
Summer 1992

Editors-in-Chief

Masakazu Ejiri
Ramesh Jain
André Oosterlinck
Jorge Sanz
Jack Sklansky

Special Issue: Document Image Analysis Techniques

SPRINGER 150 1842:1992 FOR SCIENCE

Springer International

138 ISSN 0932-8092 Machine Vis. Apps. 5(3) 141–248 1992
Printed on acid-free paper

Machine Vision and Applications

An International Journal

Volume 5 Number 3 Summer 1992

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Tin Kam Ho, Jonathan J. Hull, and Sargur N. Srihari

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Anil K. Jain and Sushil Bhattacharjee

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Rangachar Kasturi and Lawrence O'Gorman

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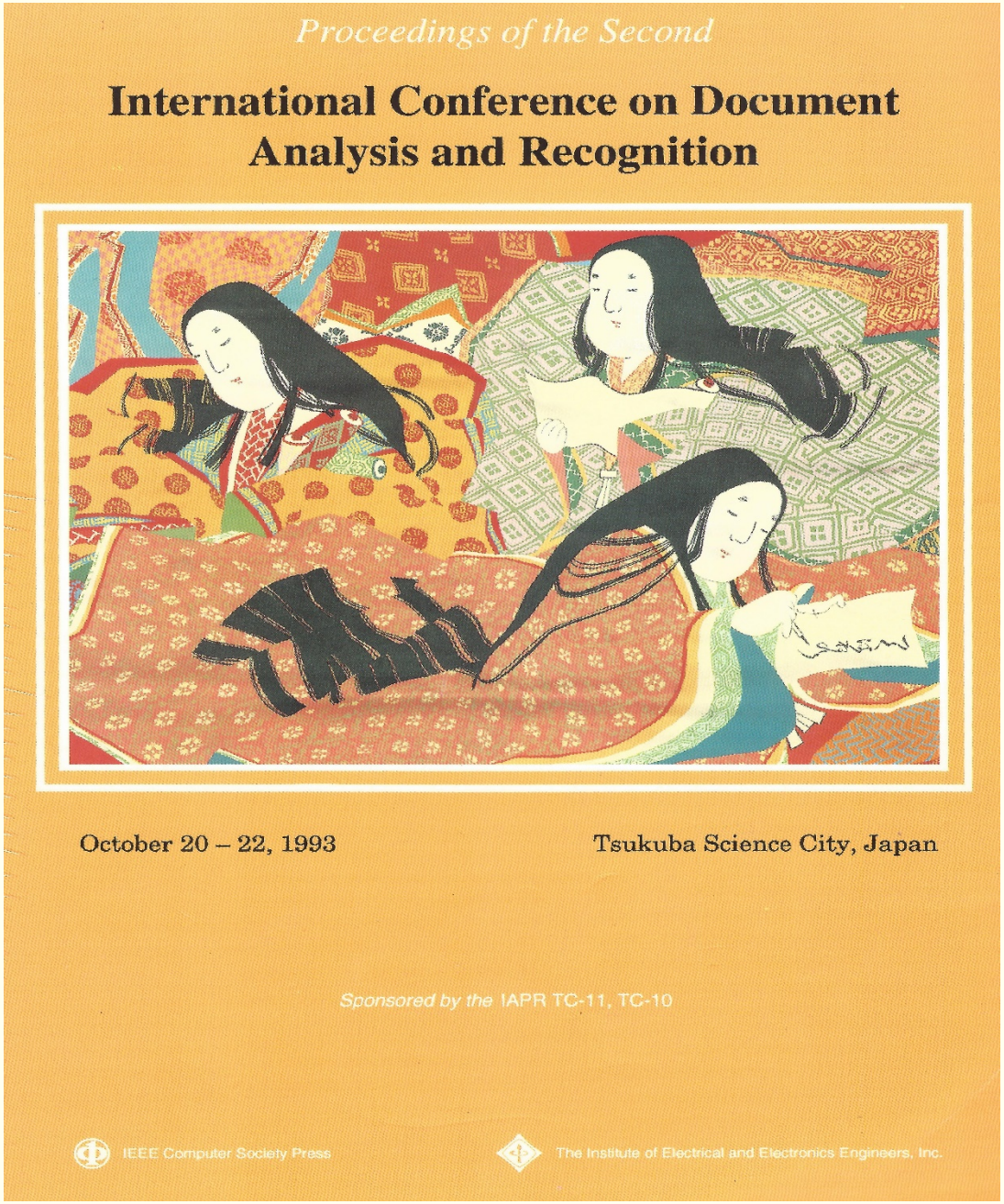
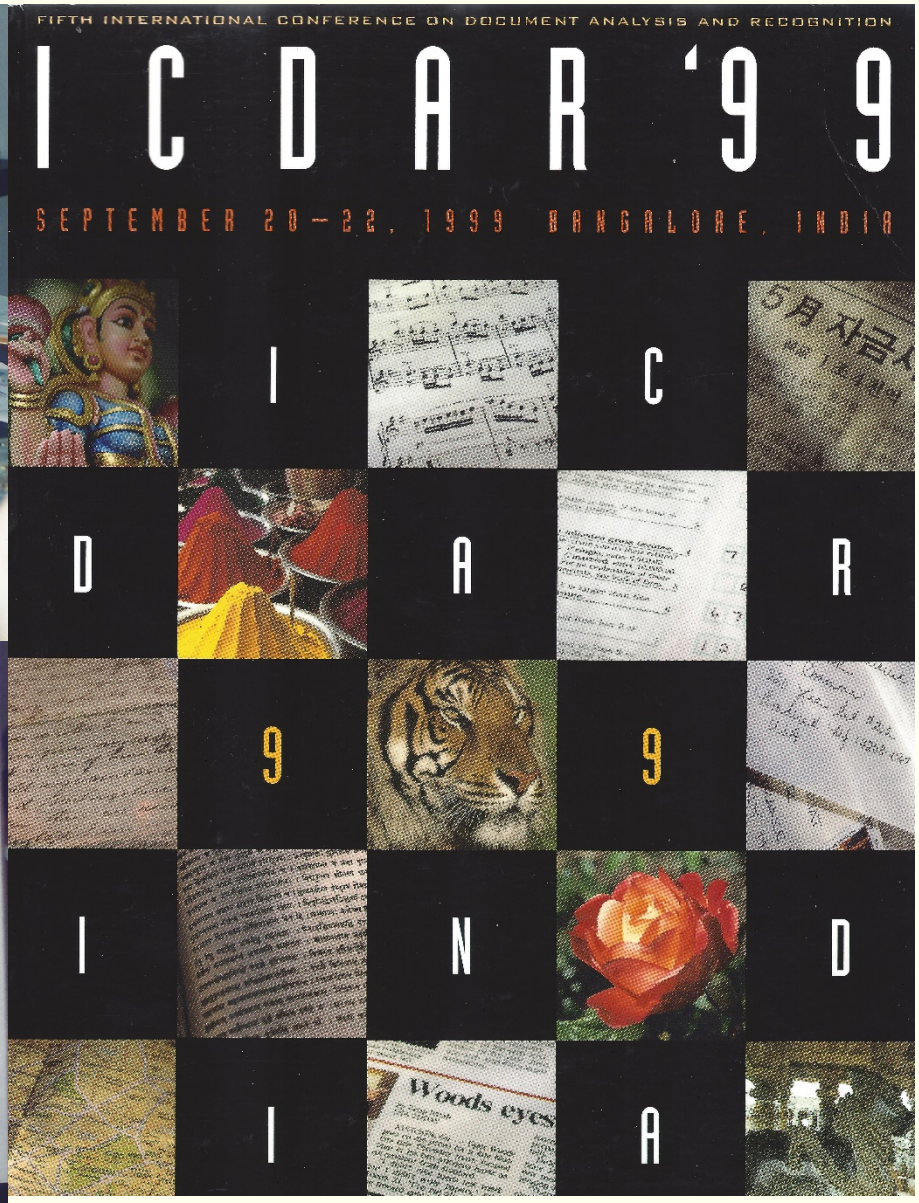


Organized by Kazuhiko Yamamoto

Next Three: Montreal,1995; Ulm 1997; and Bangalore,1999



S.N. Srihari and R. Kasturi (General Chairs)

Graphics Recognition – Recent Progress
1995 - Present

First International Workshop on Graphics Recognition
August 9-11, 1995
Pennsylvania USA

Session Topics

- Basic Techniques and Symbol-level Recognition
- Map Processing
- Engineering Drawings
- Applications of Graphics Recognition
- Performance Evaluation

Dashed Line Detection Contest

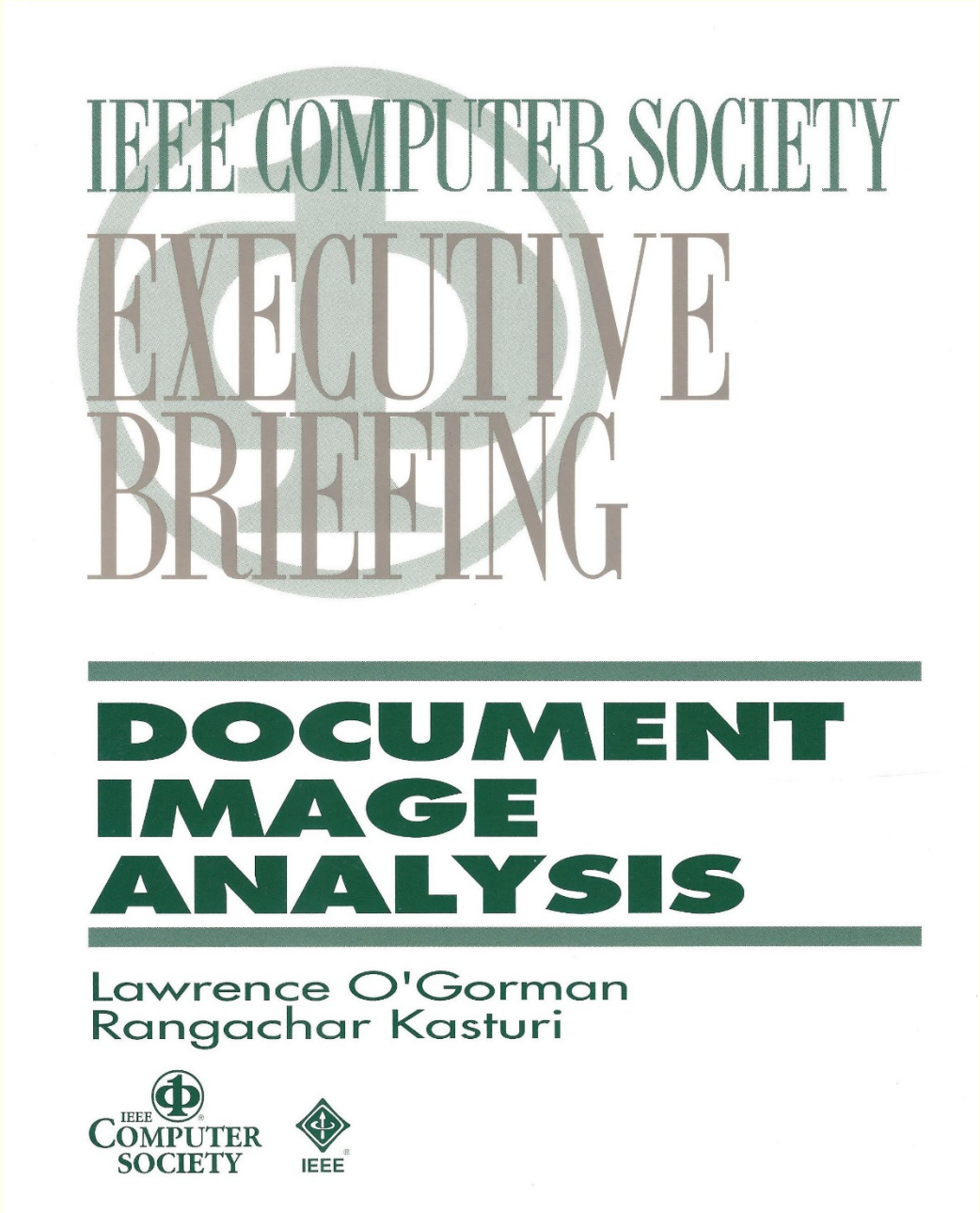
GRec Contests

- 1995: Dashed Line Detection
- 1997: Raster to Vector Conversion
- 2001: Arc Segmentation
- 2003: Symbol Recognition
- 2005: Symbol Recognition II
- 2007: Symbol Recognition III
- 2009: Arc Segmentation II
- 2011: Isolated Symbol Recognition and Symbol Spotting
- 2013: Music Scores Competition: Staff Removal
- 2013: Arc and Line Segmentation
- 2015: Engineering Drawing Challenge I
- 2017: Engineering Drawing Challenge II

GRec 1995
State College
Pennsylvania

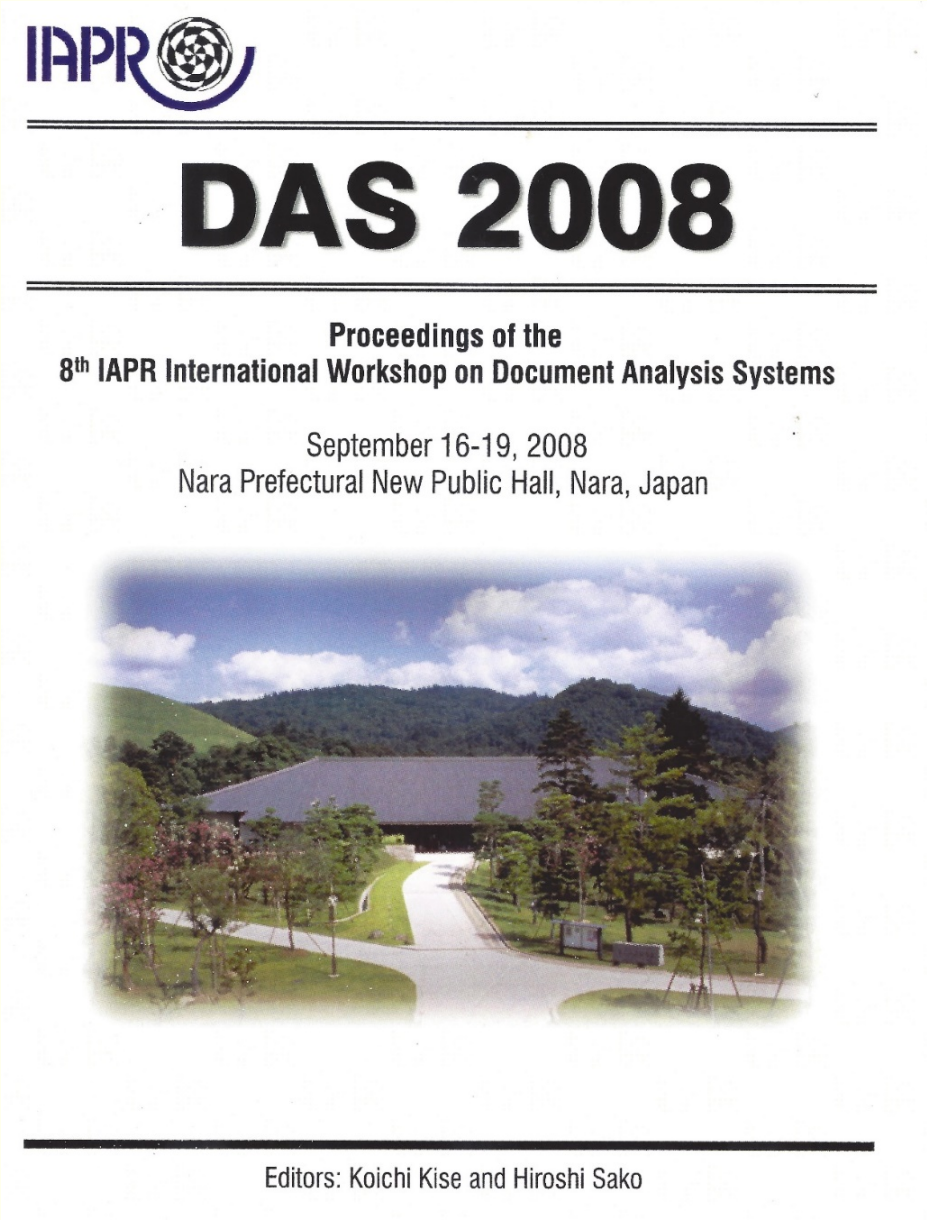
Dov Dori receiving Dashed Line Detection Award
(Winning Team: D. Dori, L. Wenyin and M. Peleg)

Document Image Analysis Tutorial Text



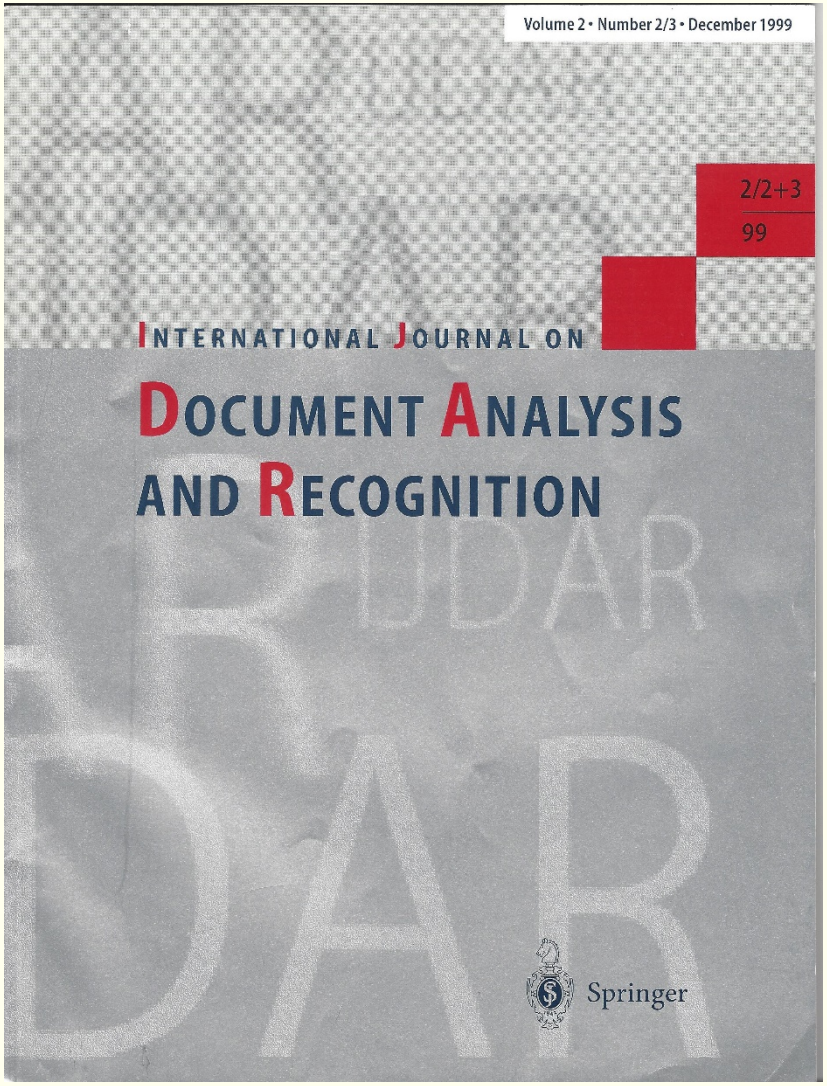
Document Analysis Systems Workshops

Begin in 1994



International Journal on
Document Analysis and Recognition

Begins Publication in 1998

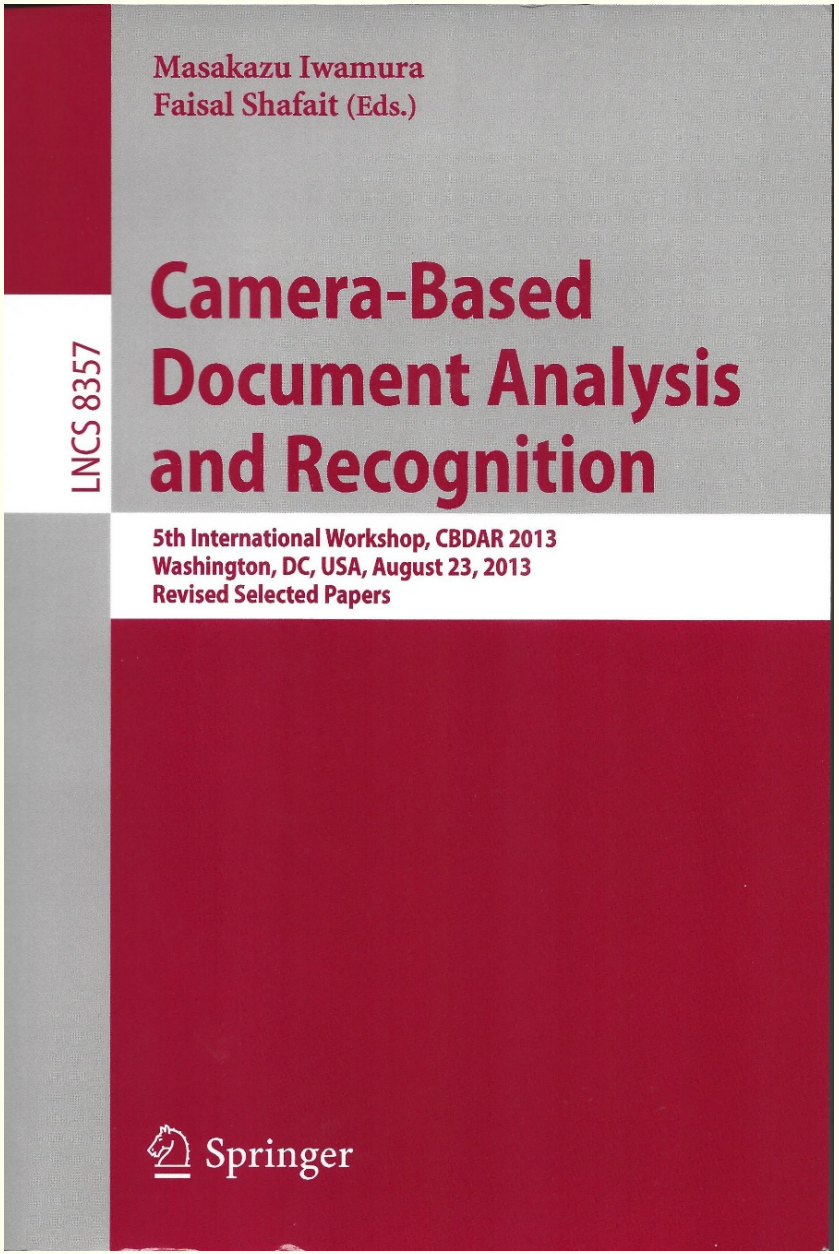


Current Editors-in-Chief: K. Kise; D. Lopresti; S. Marinai
Foundaing Managing Editor: David Doermann

Computer Vision and Pattern Recognition Laboratory

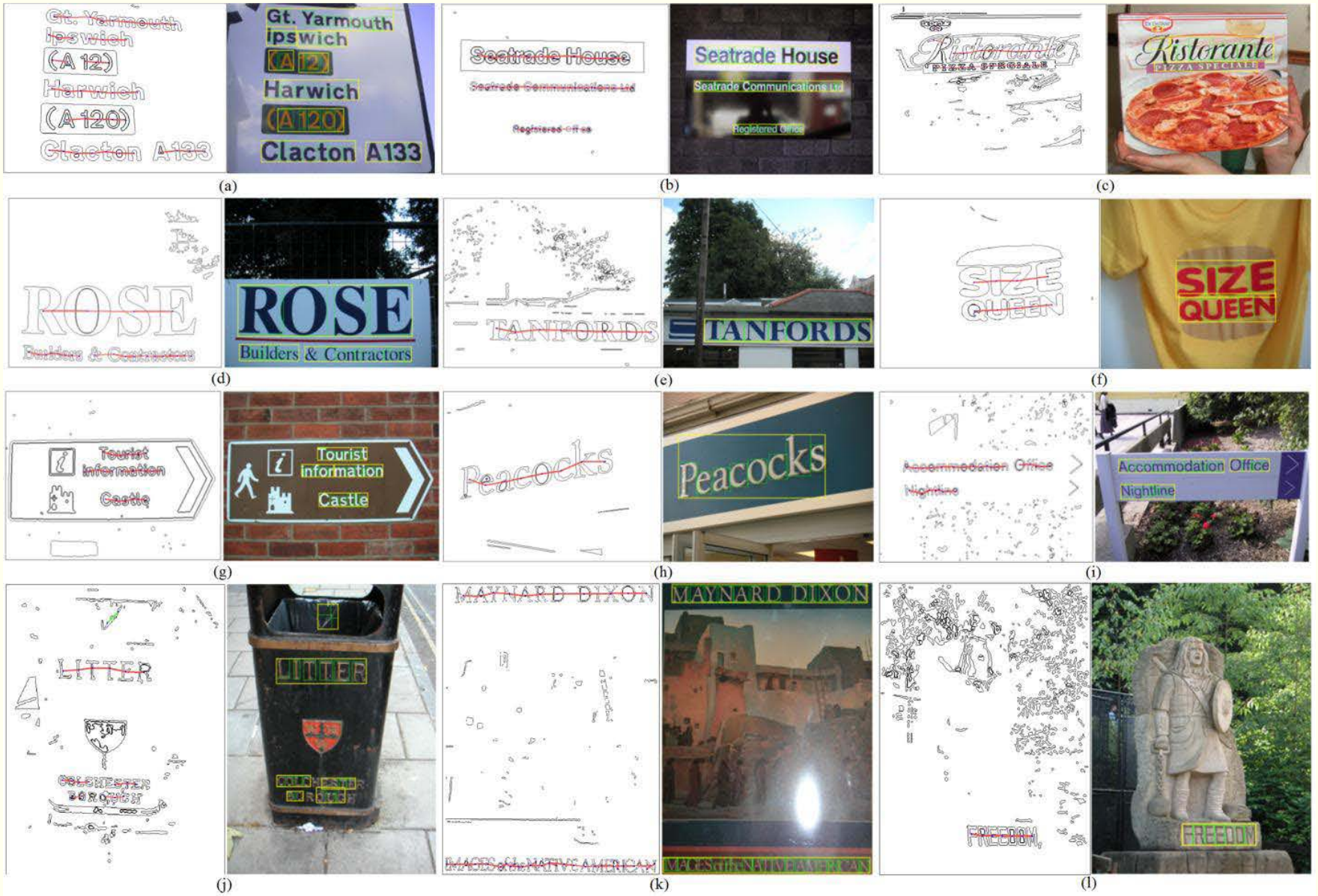
USF UNIVERSITY OF SOUTH FLORIDA COLLEGE OF ENGINEERING

New Workshop on Camera-Based Document Analysis and Recognition since 2005



Text Detection in Video/Images: An Example

J. Zhang and R. Kasturi, CBDAR 2013 and IEEE TIP 2014



Results on 2003-05 ICDAR Dataset

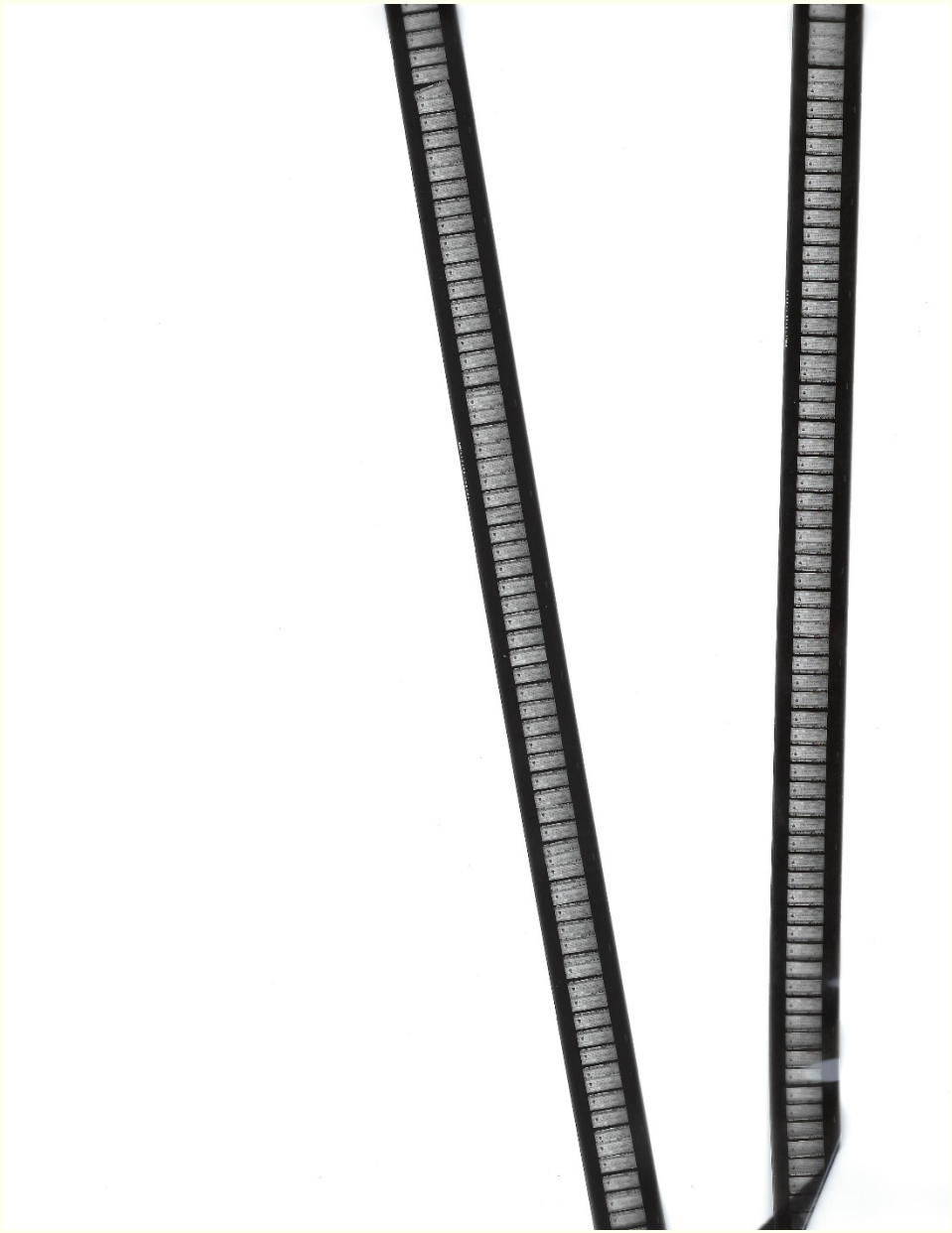
Grec 1995 to 2017

- GREC 2017, Kyoto
  - 27 papers organized into 6 sessions
  - Interpretation of engineering drawings, maps, charts, etc.
  - Symbol Recognition and Spotting
  - Optical Music Recognition
  - Interpretation of drawings, music scores, tables, etc.
  - Raster to Vector and drawings
  - Performance Evaluation and Interpretation
  - Engineering Drawing Challenge II
- GREC 1995, State College, Pennsylvania
  - Basic Techniques and Symbol-level Recognition
  - Map Processing
  - Engineering Drawings
  - Applications of Graphics Recognition
  - Performance Evaluation

Graphics Recognition Today

- Some 250 papers on GR Topics since 2007
- Fewer papers in Raster to Vector Conversion, Map Analysis, Tables, etc.
- Continuing interest in **Music Recognition** and **Historical Document Analysis**
- Increased interest in analyzing natural **Video/Image** data captured by cameras
- **Much Interest: Sketch or Example-driven Recognition (SIGGRAPH/EuroGraphics, Multimedia and CBIR Communities are Ahead of us).**

Historical Documents: An Example From U.S. National Archives

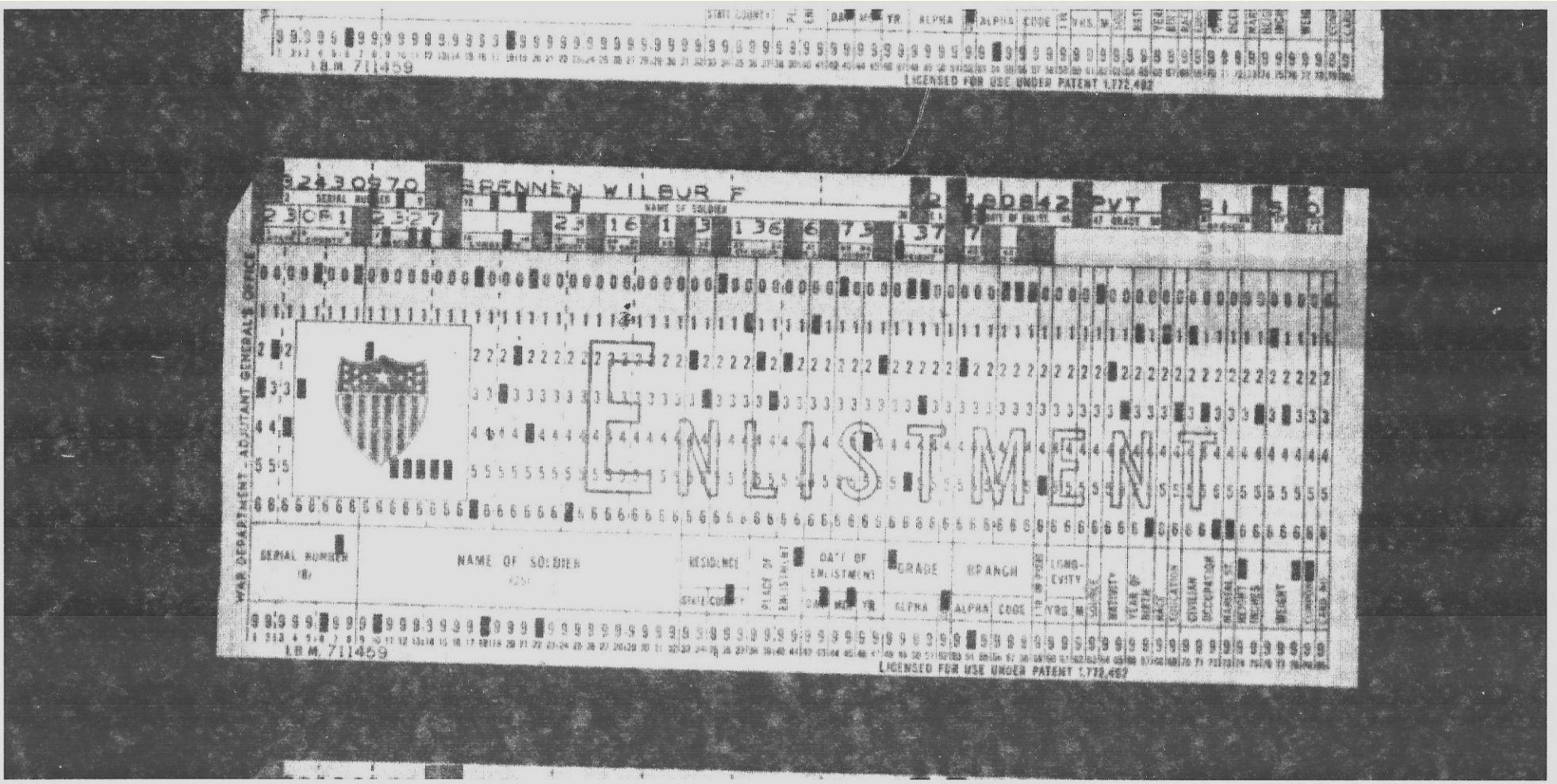


Historical Documents: One Example

Text from Microfilm Images of Punched Cards

An Example of Historical Document Processing

S.Kumar and R. Kasturi, ICPR 1992

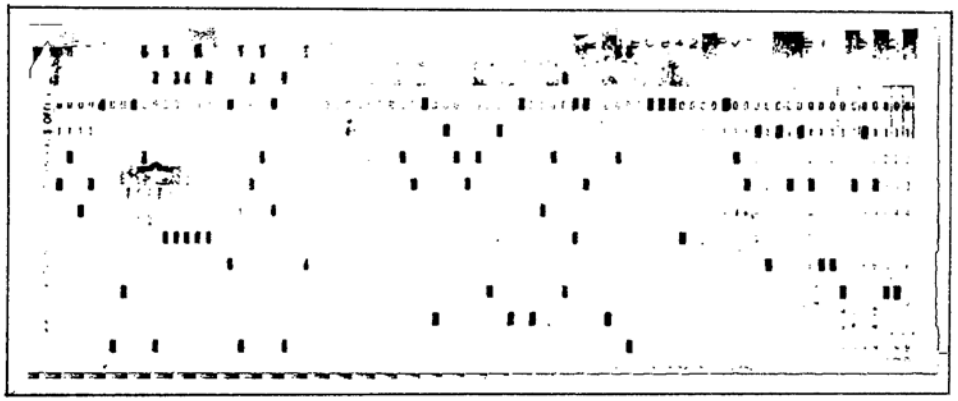


IMAGES COURTESY OF: EASTMAN KODAK COMPANY

MICROFILM SCANNED ON: KODAK IMAGELINK DIGITAL WORKSTATION WITH GRAYSCALE CAPABILITY

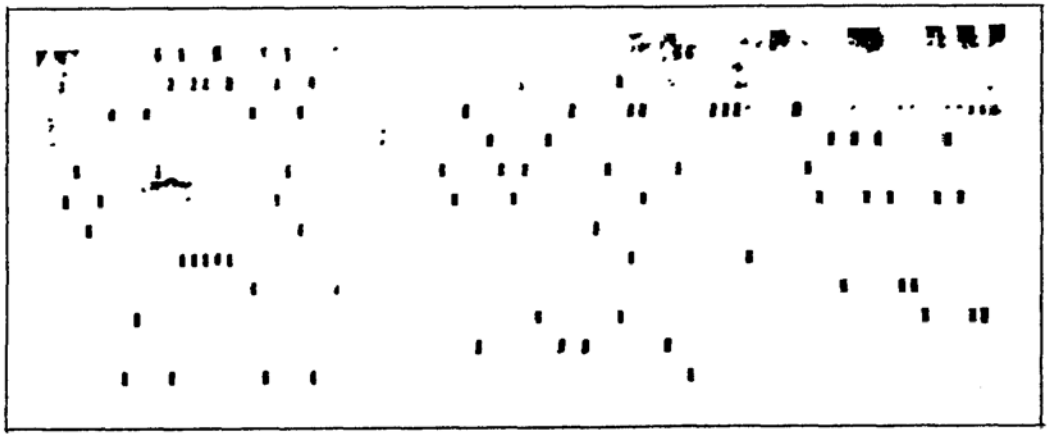
IMAGES PRINTED ON: KODAK 1550 COPIER/PRINTER

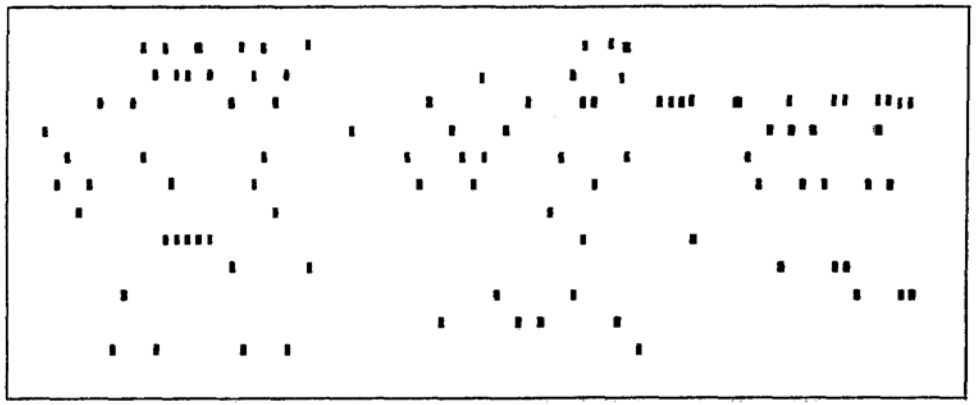
Processing Steps



Skew Correction

Morphological Processing





Final Image

Decoded Text

3243097 0BRENNEN-WILBUR-F--------23181232

7180842PV/N* T-829-0000/5* - - - 02316 0/1* 313 0/6* 0/6* 73 0/1* 0/3* 0/7* 0/7* -

One Final Thought:
Do we need an Open GR?

- We have seen the impact of Open CV in accelerating Computer Vision research.
- But most Graphics Recognition applications appears to be still built from scratch.
- Should we invest in developing an Open GR?
  - Perhaps contribute to adding Graphics Recognition tools to Open CV?
  - Build upon Other Initiatives such as Aletheia?

Thank You
Research Sponsors

U.S. Federal Government

National Science Foundation

National Security Agency

NASA

Department of Defense

Defense Advanced Research Projects Agency

Intelligence Advanced Research Projects Agency

Corporations

AT&T, Bizlink, BP, Digital, IBM, NYNEX

Kodak, Raytheon, STS, Xerox

AND

U.S. States of Florida and Pennsylvania

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Soundar Kumara

Ravi Sankar

Sudeep Sarkar

Rajeev Sharma

Leon Sibul

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Questions?

Thank You
You made it all possible

W. El-Masri: *Recognition and Description of Graphical Primitives*, MSEE, 1988

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J. Min: ***Human Activity Recognition Using Motion Trajectories,***
Ph.D., 2005

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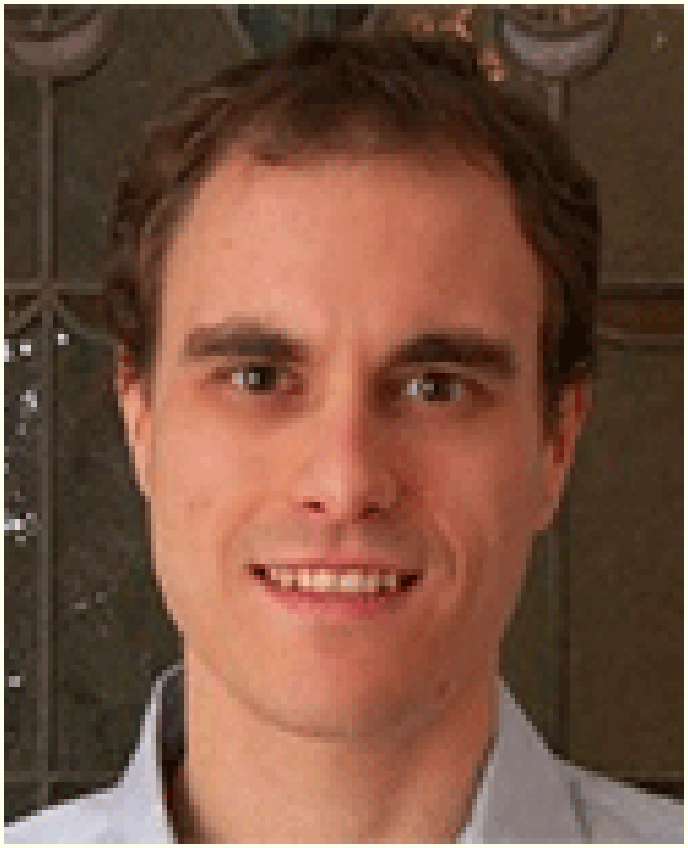

D. Crandall: *Detection of Stylized Text in Video*, M.S. CSE and BS (Honors), May 2001

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Y.L.Tang: ***An Airborne System for Runway Recognition and Obstacle Detection*****, Ph.D., August 1994**

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H. Vajaria: ***Localization and Identification of Participants in Meeting Archives*****, Ph.D., 2008**

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J. Zhang: ***Extraction of Text Objects in Image and Video Documents*****, Ph.D. 2012**

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H. Halliyal: ***Speech Recognition System for Kannada Language,***
MSEE, 1987

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M. Yang: *An Automatic Scheduler for Real-time Vision Applications*, Ph.D., Dec. 2000

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U.B. Mokate: ***An Algorithm for Recognition of Circles in Graphics*****, MSEE, 1988**

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P. Devaux: ***Experimental Verification of Automated Interpretation of Engineering Drawings*****, MSEE, May 1995**

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D.B. Lysak: ***Interpretation of Engineering Drawings of Polyhedral and Non-polyhedral Objects*****, Ph.D., 1991**

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S. Antani: ***Video Content Characterization via Robust Recognition of Scene and Caption Text*****, Ph.D., 2001**

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S.Chandran: ***Structural Recognition of Tabulated Data,***
MSCmpE, 1993

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G. Zamzmi: Infant Pain Analysis, Ph.D. 2018
Ph.D. Candidate

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H.T. Liang: ***Automatic Searching of Shortest Path in Maps*****, 1988**

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A. Prasad: ***System for Intelligent Interpretaion of Text from Telephone Company Drawings*****, MSCmpE, August 1995**

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J. Arias: ***Efficient Techniques for Line Drawing Interpretation,***
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W.C. Feng: *A Learn-By-Example Natural Language Processor*, MSCmpE, 1990.

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N. Muralidhar: ***Collection of Training Data for OCR of Kannada Characters*****, 1999**

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S. Hinduja: Pedestrian Detection in Low Quality Moving Camera Videos, MS, 2016,

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R.J. Fernandez: ***Extraction of Feature Overlays for Query Processing in a Geographic Information System*****, MSEE, 1989.**

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U. Gargi: ***Visual Content Characterization of Images and Video,***
Ph.D., Dec. 1999

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P.K. Mohanty: ***Learning from Biometric Distances Performance and Security Related issues in Face Recognition*****, Ph.D., 2007**

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J.H. Park: *Manifold Learning in Computer Vision*, Ph.D., 2005

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J. Candamo: ***Boundary Profile Representation for Objects and Their Surroundings in Outdoor Videos*****, Ph.D. 2009**

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M. Fathollahi: *Estimation of human pose categories*, Ph.D. 2017

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J. Viswanathan, Continuous Identity Assurance, MS, 2016

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T. Gandhi: ***Image Sequence Analysis for Object Detection and Segmentation*****, Ph.D., May 2000**

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L.A. Fletcher: ***Automated Text String Separation from Mixed Text/Graphics Images*****, MSEE, 1986**

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- A. Modi, Pedestrian detection at traffic intersections , MS, 2017
- V. Kamath, Survival prediction for colon cancer patients, M.S., 2005
- V. Mariano, *Video Object Detection and Matching*, Ph.D., 2003
- P.Tofani, *Segmentation of Text from Color Map Images*, MS, 1998
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- S.U.Kumar, *Text Data Extraction from Microfilm Images of Punched Cards*, MS, 1992

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- S.C.Chennubhotla, *Pose Clustering on Constraints for Object Recognition*, MS, 1991
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- C.C.Shih, *Encoding Method for Graphics Applications*, MS, 1987.
- A.R.Jham, *Application of the SVD and Wigner-Ville Distribution*, MS, 1986
- B.S.Satyanarayana, *A Frame Grabber System for Color Image Capturing*, MS, 1986
- J.Alemany, *An Image Processing System for Interpretation of Paper-based Maps*, MS, 1986

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- T.J.Amin, *A Computer-Based System for Cartographic Data Interpretation*, MS, 1985
- R.L.Tutwiler, *Adaptive Restoration of Atmospherically Degraded Images*, MS, 1985
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- Y-M.Chen, *A Users' Manual for VAX PHIGS Software*, 1991
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- G.A.Jividen, *A Survey of Image Processing Techniques for Angiograms*, 1988
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- M.I.Kahn, *Collision Free Path Planning in Unstructured, Dynamic Environments for Mobile Robots and Manipulators*, 1987
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- M.C.Chen, *Thresholding and Edge Detection Techniques in Computer Vision*, 1987
- R.T.Yu, *Design of a Voice Digitizer Circuit for IBM PC,* 1986
- O.A.Morean, *Paradigms in the Collision Free Path Planning of a Computer Controlled Mobile Robot*, 1984

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- **B.S. Honors Thesis Students**
  - Oluwabukola Akinbo, *Visual Memory Assistant Portable Facial Recognizer*, 2006
  - S. Moscariello, *Java Image Processing*, 1997
  - S.Oswald, *Hierarchical Segmentation of Video Sequences*, 1995
  - M.Lebold, *Speech Recognition System for Home Automation*, 1995
  - J.Bolch, *Color Digital Image Processing on a Personal Computer*, 1989
  - P.Gyugyi, *Automated Identification of Brain Tumors Using Magnetic Resonance Images*, 1988
  - W.R.Mandel, *Slow Scan Television Frame Grabber*, 1987
  - N.T.Nguyen, *Microprocessor Controlled Voice Synthesized Real Time Clock*, 1987

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