Automating Tactile Graphics Translation

Computer Vision
CSE 455
2009

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Atmospheric Science

William Skawinski
Professor, Chemistry

Blind Scientists and Engineers

H. David Wohlers
Professor, Chemistry

TV Raman
Computer Science
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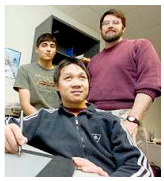

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Nihon University

UW
Students

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Math Major

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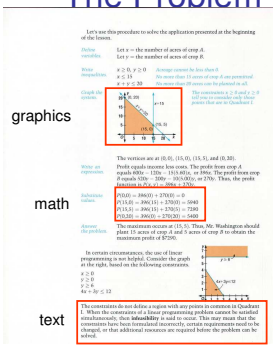
Ph.D. Student
CSE

The Problem



Outline

- Tactual Perception
- Text
- Math
- Graphics
- Problems
- Thanks
- Demo

Tactile Perception

- Resolution of human fingertip: 25 dpi
- Tactual field of perception is no bigger than the size of the fingertips of two hands
- Color information is replaced by texture information
- Visual bandwidth is 1,000,000 bits per second, tactile is 100 bits per second

Braille

- System to read text by feeling raised dots on paper (or on electronic displays). Invented in 1820s by Louis Braille, a French blind man.

Critical fact: Fixed height and width

a b c z

and the with mother

th ch gh

Z 3 Mode characters: cap and num.

Tiger Embosser

- 20 dpi (raised dots per inch)
- 7 height levels (only 3 or 4 are distinguishable)
- Prints Braille text and graphics
- Prints dot patterns for texture
- Invented by a blind man, John Gardner

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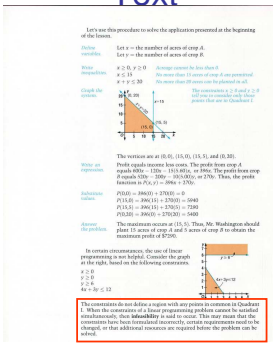
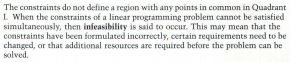
Text



Text Translation

Text Image



Optical Character Recognition (OCR)

Text

```
The constraints do not define a region with any points in common in Quadrant
I. When the constraints of a linear programming problem cannot be satisfied
simultaneously, then infeasibility is said to occur. This may mean that the
constraints have been formulated incorrectly, certain requirements need to be
changed, or that additional resources are required before the problem can be
solved.
```

Braille Translation (Duxbury)

Speech Synthesis (Jaws)

Braille

Speech

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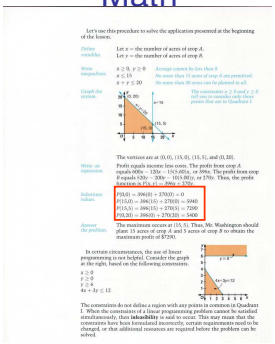
Math



Math Translation

Math Image

$$P(0,0) = 396(0) + 270(0) = 0$$
$$P(15,0) = 396(15) + 270(0) = 5940$$
$$P(15,5) = 396(15) + 270(5) = 7290$$
$$P(0,20) = 396(0) + 270(20) = 5400$$

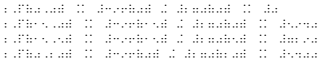
Math OCR (Infty Reader)

Latex

```
\begin{eqnarray*}
P(0,0) = 396(0) + 270(0) = 0\\
P(15,0) = 396(15) + 270(0) = 5940\\
P(15,5) = 396(15) + 270(5) = 7290\\
P(0,20) = 396(0) + 270(20) = 5400
\end{eqnarray*}
```

Braille Translation (Duxbury)

Nemeth Code



Math Translation Examples

$$\sum_{i=0}^{\infty} x^i = \frac{1}{1-x}$$

```
\sum_{i=0}^\infty x^i = \frac{1}{1-x}
```

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

```
\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}
```

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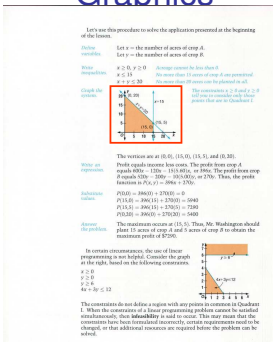
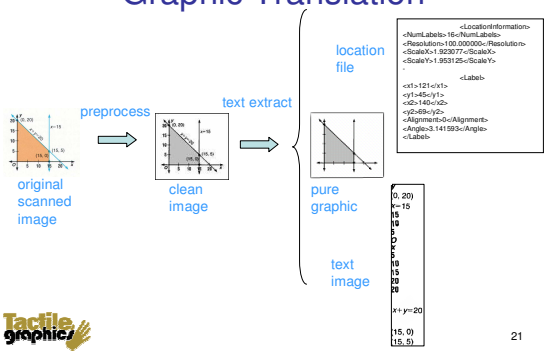
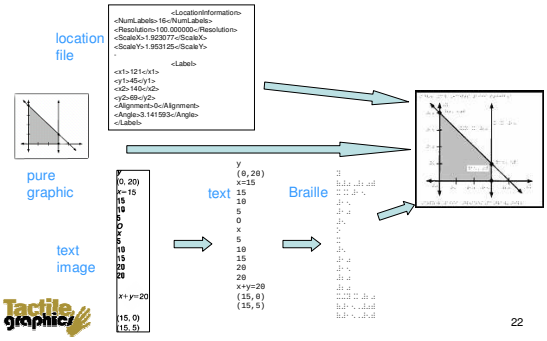
Graphics



Graphic Translation

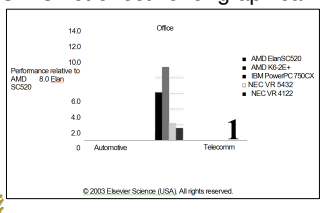


Graphic Translation



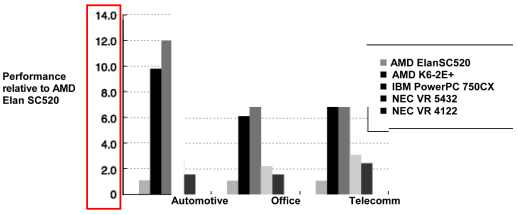
Finding Text

- Why not just use standard optical character recognition (OCR)?
  - OCR is not effective for graphical images.



ABBYY FineReader 7.0 Professional Edition

More OCR



ScanSoft OmniPage Pro 14.0

Find Text Letters

- Uses the following principles
  - Text in an image is usually in one font
  - Fonts are designed to have a uniform density at a distance.
  - In the absence of noise an individual letter tends to be connected component of one color. Exceptions are i and j.
- Use machine learning to determine which connected components are letters.

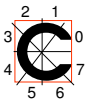
Features

Century Gothic

W = width of bounding box
H = height of bounding box
A = area of bounding box
R_i = i-th radial slice density

A = W • H

R_i = number of black pixels in i-th slice where a slice is an angle of 360/n. The total number of slices is n.

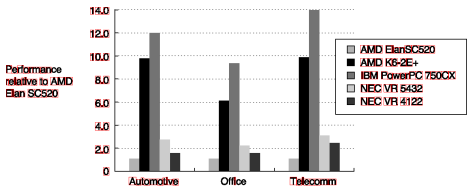


Center is center of mass of black pixels

Machine Learning

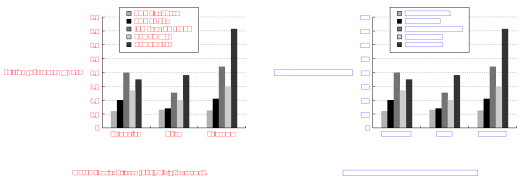
- Training:
  - Sample the connected components and compute their features.
  - Use these features to train a Support Vector Machine (SVM).
- Finding:
  - For a new connected component compute its features.
  - Feed these features into the SVM.

Example



Trained on a different images from the same book. About 200 letters in the training set.

Find Text Blocks



Group characters logically

- Extracting a set of isolated characters from an image is insufficient
  - Need groups of Braille characters for easier placement
- Challenges
  - Text can be at many angles
  - Individual characters may be aligned along multiple axes

Our approach

- Step 1: User provides training set
  - Software examines defining features
- Step 2: Automatically find similar groups in remaining images
  A. Minimum spanning tree
  B. Discard useless edges
  C. Discard inconsistent edges
  D. Create merged groups

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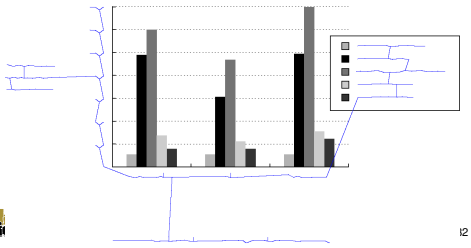
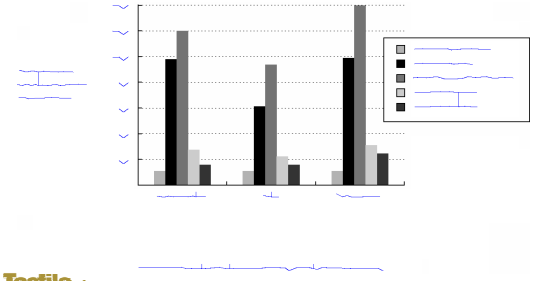
Minimum spanning tree (1)

Treat the centroid of each connected component as a node



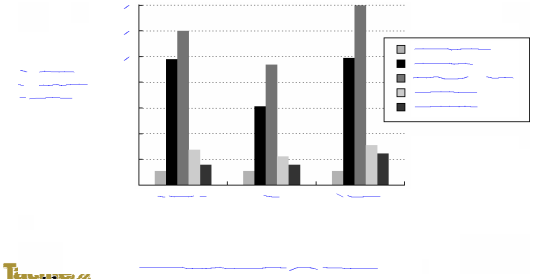
12

Discard useless edges (2)



33

Discard inconsistent edges (3)



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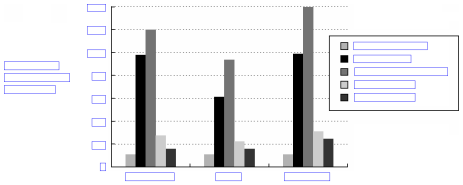
Final merge step (4)

Merge only if the resultant group is consistent



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OCR on Text Image

Image of text boxes

14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
Performance
relative to AMD
Elan SC520
Automotive
Office
Telecomm
© 2003 Elsevier Science (USA). All rights reserved.
AMD ElanSC520
AMD K6-2E+
IBM PowerPC 750CX
NEC VR 5432
NEC VR 4122

OCR →

Text

14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
Performance
relative to AMD
Elan SC520
Automotive
Office
Telecomm
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AMD ElanSC520
AMD K6-2E+
IBM PowerPC 750CX
NEC VR 5432
NEC VR 4122

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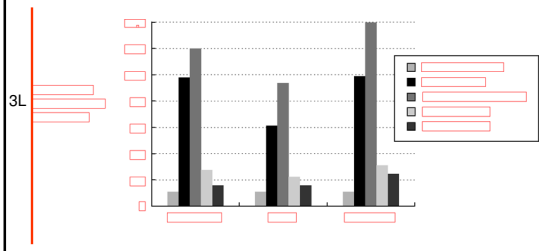
Braille Placement

- Text boxes of Braille will be of different size than the original text boxes
  - Mode characters
  - Contractions
  - Braille is fixed width

Example (Left justified) Example (Right justified) Example (Centered)

37

Example Plane Sweep



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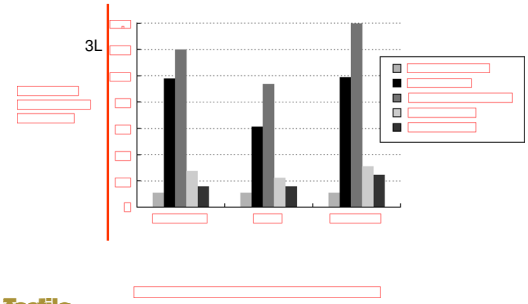
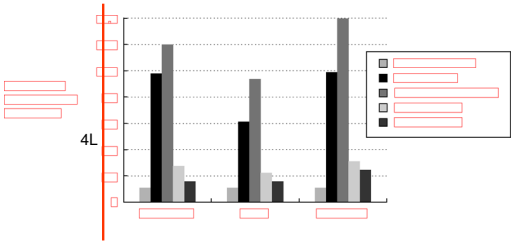
Example Plane Sweep



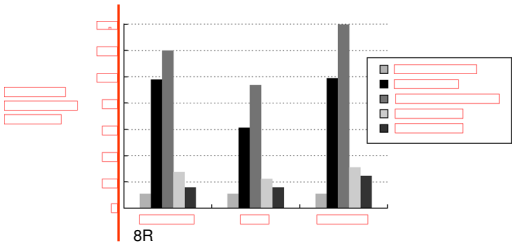
39

Example Plane Sweep

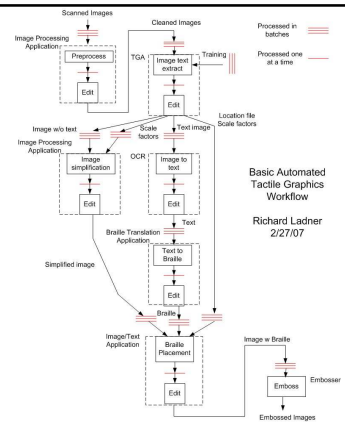


40

Example Plane Sweep



41



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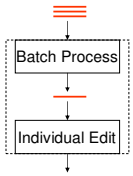
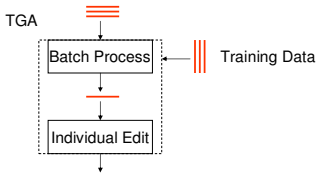
Subtask Pattern



- TGA batch process
- Photoshop and Illustrator scripts
- Omnipage batch manager
- Duxbury command line

Tactile Graphics Assistant



Available Books

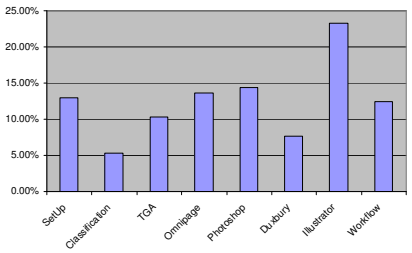
- *Computer Architecture: A Quantitative Approach, 3rd Edition*
  Hennessy and Patterson
  2002 Elsevier
  25 minutes per figure
- *Advanced Mathematical Concepts, Precalculus with Applications*
  Gordon-Holliday, et al.
  1999 Glencoe/McGraw-Hill
  6.3 minutes per figure
- *An Intoduction to Modern Astrophysics*
  Carroll and Ostlie
  1996 Addison-Wesley
  10.2 minutes per figure
- *Discrete Mathematical Structures*
  Kolman, Busby and Ross
  2003 Prentice Hall
  8.8 minutes per figure

Time per Figure

	Discrete Math		Precalculus		Astronomy	
	Min		Min		Min	
SetUp	425	10.3%	660	9.8%	1110	18.3%
Classification	245	5.9%	390	5.8%	270	4.4%
TGA	595	14.4%	570	8.4%	585	9.6%
Omnipage	714	17.3%	660	9.8%	945	15.6%
Photoshop	800	19.4%	975	14.4%	660	10.9%
Duxbury	225	5.5%	630	9.3%	450	7.4%
Illustrator	770	18.7%	1335	19.7%	1845	30.4%
Workflow	350	8.5%	1545	22.8%	210	3.5%
Total	4124	100.0%	6765	100.0%	6075	100.0%
	num figs	467	num figs	1080	num figs	598
	min/fig	8.8	min/fig	6.3	min/fig	10.2

Ave 7.9 min/figure

Work Balance



TGA Workflow

- Advantages
  - Much faster production
  - Batch processing instead of one figure at a time
  - Much tedious work is avoided
- Disadvantages
  - May be of lower quality than custom translation
  - A lot of technology needs to be mastered

One-offs vs. Mass Production

1916 Woods Dual Power

1906 Reo

Model T

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- Text
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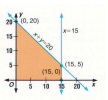
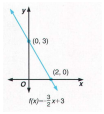
Problem solving

- Each book present a set of unique problems.
- We consider a few today
  - Classification of figures
  - Legends and colors
  - Text at an angle
  - Math in figures
  - Grids

Classes

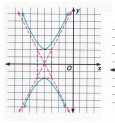


Clean area
83

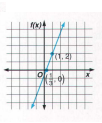


Clean lines
648

Complex
62

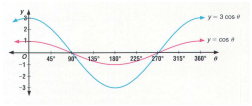


Grid clean
15

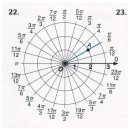


Grid overlap
113

No text
41



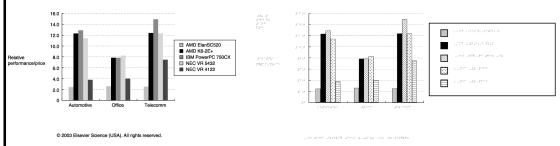
Overlapped text
94



Radial
53

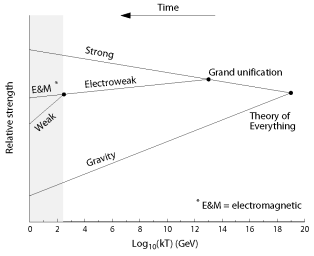
Legends and Colors

- Legends may have to be enlarged.
- Colors may have to be replaced with textures.

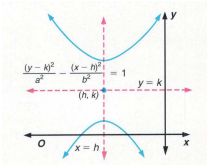


Angled Text

- Braille should be printed horizontally.



Math – Infty Reader



$\frac{(y-k)^2}{a^2} - \frac{(x-h)^2}{b^2} = 1$

$y = k$

y

x

(h, k)

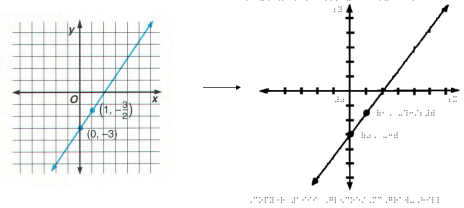
O

$x = h$

Extracted Math Image

Grids

- Grids may not work well in tactile form.



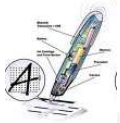
TGA Technology

- Tactile Graphic Assistant
  - C++
  - Machine Learning (Support Vector Machine)
    - Learns features of text from positive and negative examples.
  - Computational Geometry
    - Text justification
  - Free executable
  - Licensable source code

Technologies in the Future

- Include Audio with Touchpads

- Digital Pen and Paper



- Electro-rheological fluid displays

Outline

- Text
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- Workflow
- Problems
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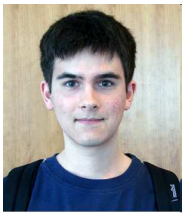
- Demo

CSE Undergraduate Students

Terri Moore 2004 | Andy Jaya 2004 | Eileen Hash 2004 | Jacob Christenser 2004 | Satria Krisnandi 2005 | Matthew Renzelmann 2005

Mahalakshmi Ramasamy 2005 | Jack Hebert 2005 | Veneta Tashev 2006 | Cian Malone 2007 | Dana Wen 2008 | Kris Weber 2008

Current Undergraduate Student



Josh Scotland

CSE Graduate Students

Sahngyun Hahn

Chandrika Jayant

Thanks To

- Dan Comden
- Sheryl Burgstahler
- Raj Rao
- Melody Ivory
- Ethan Katz-Basset
- Zach Lattin
- Stuart Olsen
- Many others

Thanks To

NSF

DHHT

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