

Automating Tactile Graphics Translation

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Blind Scientists and Engineers



Kent Cullers, Ph.D.
Physics



Cary Supalo
Grad Student
Chemistry



Geerat Vermeij, Ph.D.
Evolutionary Biologist



2

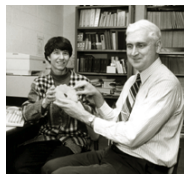
Blind Scientists and Engineers



Bill Gerrey
Electrical Engineering
Inventor



Imke Durre, Ph.D.
Atmospheric Science



William Skawinski
Professor, Chemistry



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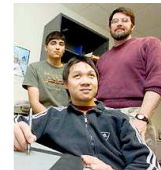
Blind Scientists and Engineers



H. David Wohlers
Professor, Chemistry



TV Raman
Computer Science
Google



Victor Wong
EE Grad Student



4

Blind Scientists and Engineers



Chieko Asakawa
Computer Scientist
IBM



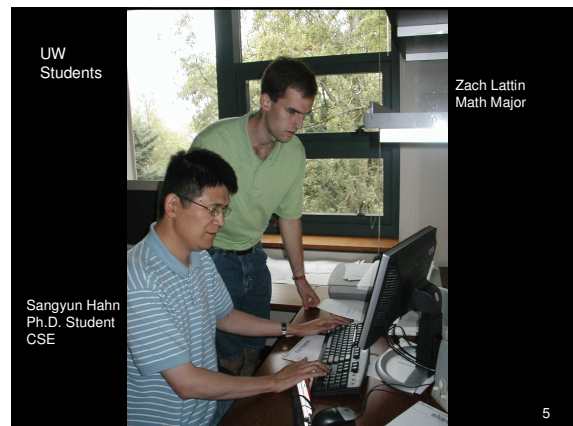
Hideji Nagaoka
Computer Scientist
Tsukuba U. of Tech



Katsuhito Yamaguchi
Physics
Nihon University



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The Problem

Let us use the procedure to solve the application presented at the beginning of this lesson.

Given: Let x = the number of acres of crop A,
 Let y = the number of acres of crop B.

Required: $x \geq 0, y \geq 0$
 Average cost per bushel of crop A is \$2.00
 Average cost per bushel of crop B is \$1.50
 The maximum amount of crop A that can be planted is 25
 The maximum amount of crop B that can be planted is 20

Objective: Minimize the cost of the crop.

Constraints: $2000x + 1500y \leq 25,000$
 $1000x + 1000y \leq 20,000$
 $x \geq 0, y \geq 0$

The vertices are at (0, 0), (15, 0), (15, 1), and (0, 20).
 Find the cost function for each. The costs from crop A
 from (0, 0) = \$0, (15, 0) = \$30,000, (15, 1) = \$31,500, (0, 20) = \$30,000. Thus, the points
 (15, 1) and (0, 20) are the best.

Answer: (15, 1) = \$31,500 = 25,000 + 1,500 = 26,500
 (0, 20) = \$30,000 = 25,000 + 1,500 = 26,500

The minimum cost is \$26,500. Then, 1500 bushels of crop A and 1000 bushels of crop B should be planted.

To convert the output of the crop programming to an output that can be used in a spreadsheet, consider the graph at the right, based on the following constraints:

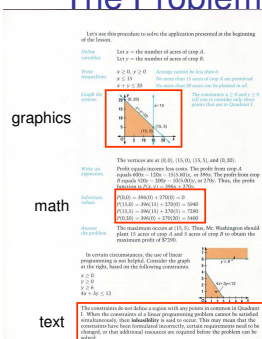
$x \geq 0$
 $y \geq 0$
 $2x + 3y \leq 12$

The constraints do not define a region with any points. In contrast to Question 1, when the objective of a linear programming problem cannot be satisfied, the constraints are infeasible. In this case, the constraints do not define a region with any points. In this case, the constraints do not define a region with any points. In this case, the constraints do not define a region with any points.

graphics

math

text



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Outline

- Tactual Perception
- Text
- Math
- Graphics
- Tactile Graphics Workflow
- Demo

Tactile graphics

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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

Tactile graphics

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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.

Tactile graphics

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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



Tactile graphics

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Tactile graphics

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Text

Let's use the procedure to solve the application presented at the beginning of the lesson.

Define variables: Let $x =$ the number of axes of type A, and $y =$ the number of axes of type B.

Write constraints: $x \geq 0, y \geq 0$ (Always consider the first axis.)
 $4x + 3y \leq 60$ (The number of axes of type A cannot exceed 60.)
 $x + y \leq 30$ (The number of axes of type B cannot exceed 30.)

Graph the constraints: The feasible region is shaded in the graph.

Write the objective function: The objective function is $P(x, y) = 396x + 270y$.

Check the vertices: The vertices are at (0,0), (15,0), (15,5), and (0,20).
 Profit at (0,0) = $396(0) + 270(0) = 0$
 Profit at (15,0) = $396(15) + 270(0) = 5940$
 Profit at (15,5) = $396(15) + 270(5) = 7290$
 Profit at (0,20) = $396(0) + 270(20) = 5400$

Answer: The maximum profit is \$7,290, which occurs at (15, 5). Thus, Mr. Washington should plant 15 axes of type A and 5 axes of type B to obtain the maximum profit of \$7,290.

In conclusion: 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.

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Text Translation

Text Image

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.

↓ **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

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Outline

- Tactual Perception
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Math

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Math Translation

Math Image

$$\begin{aligned}
 P(0,0) &= 396(0) + 270(0) = 0 \\
 P(15,0) &= 396(15) + 270(0) = 5940 \\
 P(15,5) &= 396(15) + 270(5) = 7290 \\
 P(0,20) &= 396(0) + 270(20) = 5400
 \end{aligned}$$

↓ **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

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Math Translation Examples

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

↓

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

↓

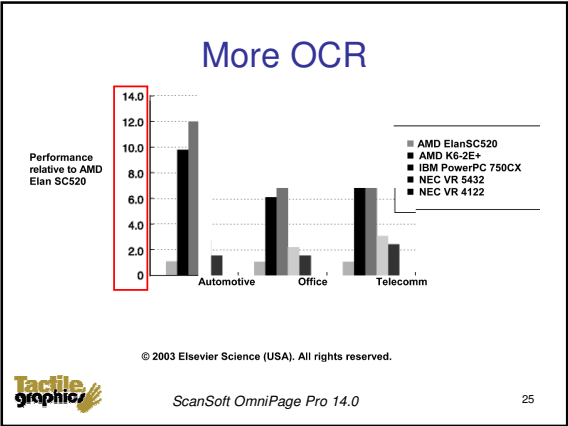
$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

↓

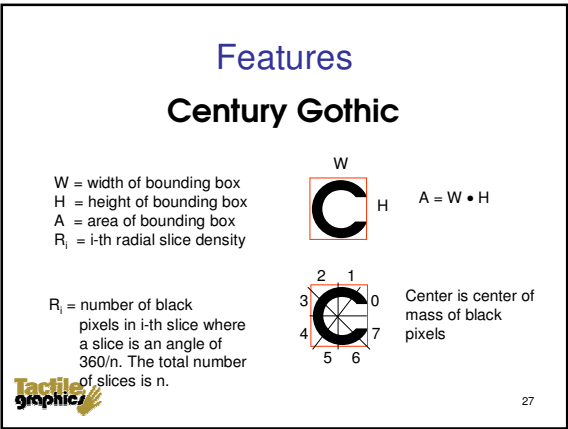
$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

↓

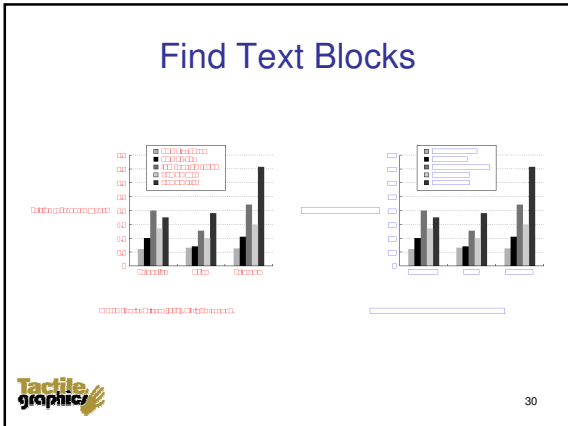
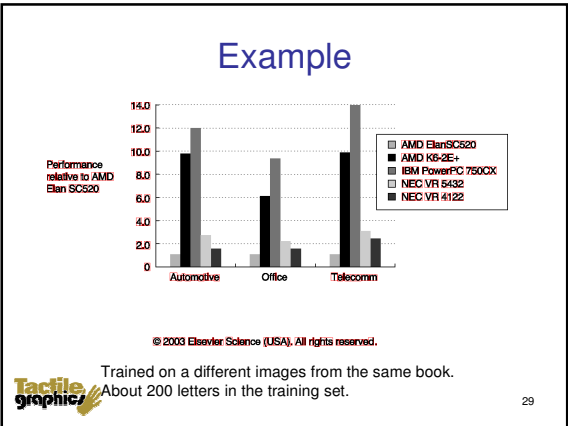
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- ### Finding Text Letters
- Uses the following principles
 - Text in an image is usually in one font
 - Fonts are designed to have a uniform density at a distance.
 - In the absence of noise an individual letter tends to be connected component of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



- ### 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.



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



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Our approach

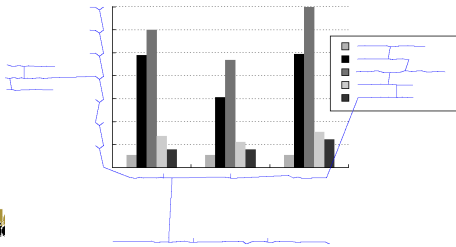
- Step 1: User provides training set
 - Software examines defining features
- Step 2: Automatically find similar groups in remaining images
 - A. Minimum spanning tree
 - B. Discard useless edges
 - C. Discard inconsistent edges
 - D. Create merged groups



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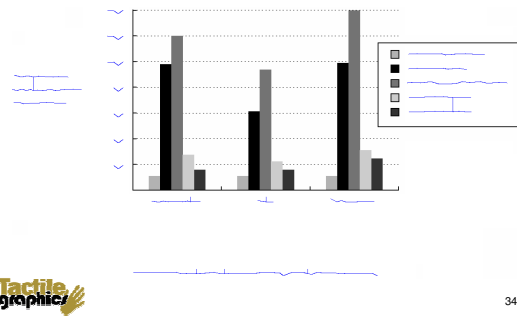
Minimum spanning tree (1)

Treat the centroid of each connected component as a node



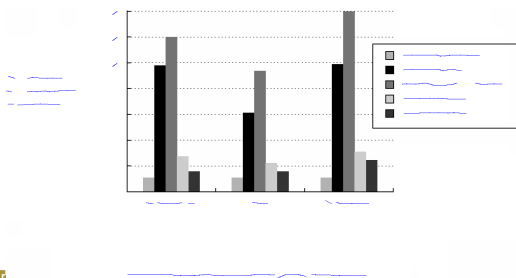
33

Discard useless edges (2)



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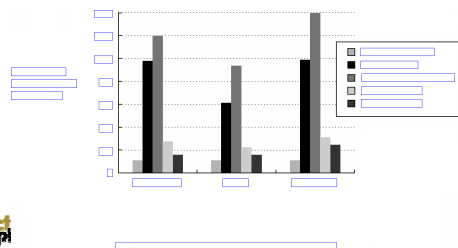
Discard inconsistent edges (3)



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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
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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

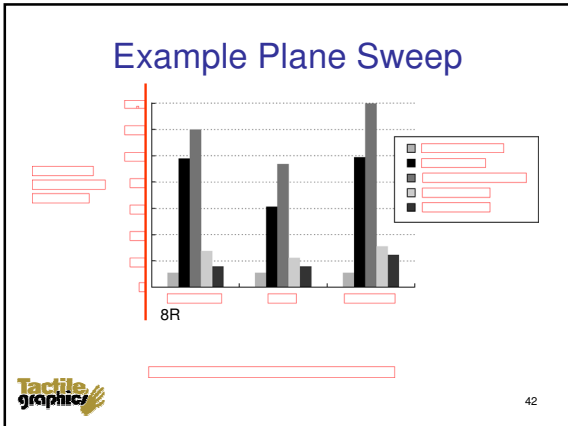
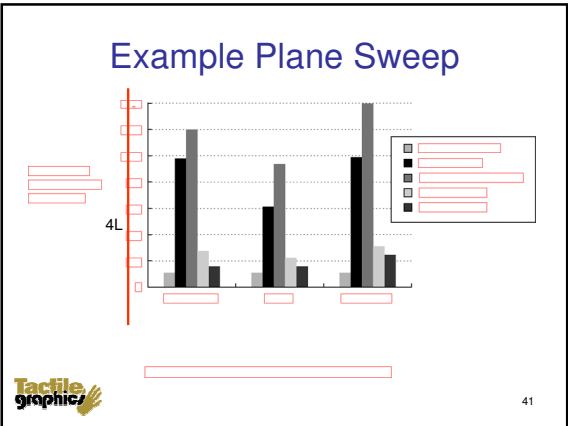
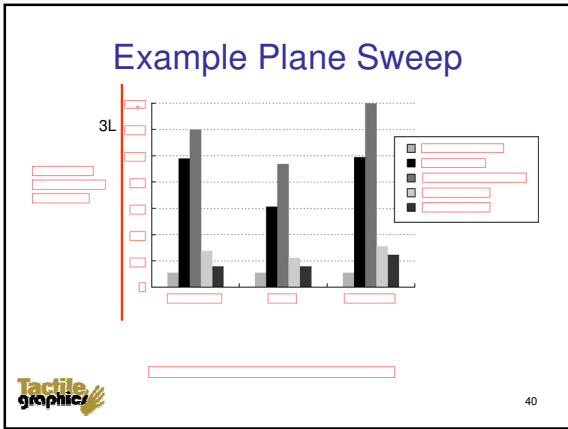
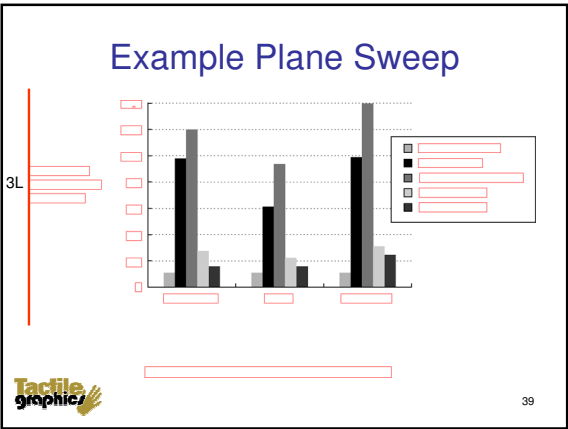
Example

Right justified

Example

Centered

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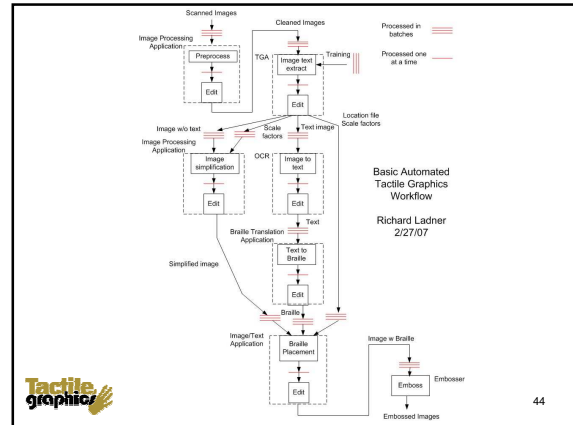


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- Text
- Math
- Graphics
- Tactile Graphics Workflow
- Demo

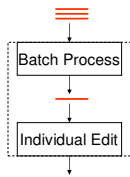


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Subtask Pattern

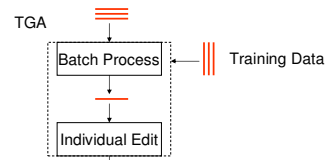


- TGA batch process
- Photoshop and Illustrator scripts
- Omnipage batch manager
- Duxbury command line



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Tactile Graphics Assistant



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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 Introduction 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



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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



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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



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One-offs vs. Mass Production



1916 Woods Dual Power



1906 Reo



Model T



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Outline

- Text
- Math
- Graphics
- Workflow
- Problem solving



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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



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Classes



Clean area
83

Clean lines
648

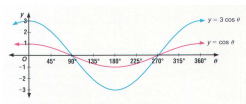
Complex
62

Grid clean
15

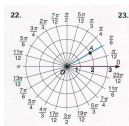
Grid overlap
113



No text
41



Overlapped text
94



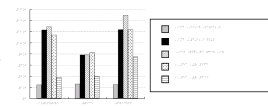
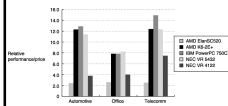
Radial
53



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Legends and Colors

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



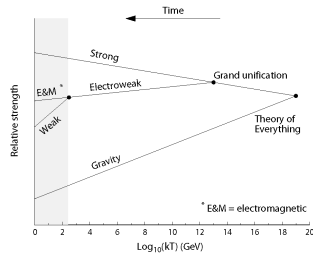
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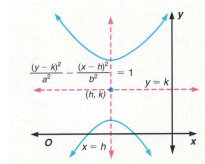
Angled Text

- Braille should be printed horizontally.



Math

- Image → Math Image via TGA → LaTeX via Infy Reader → Nemeth via Duxbury



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

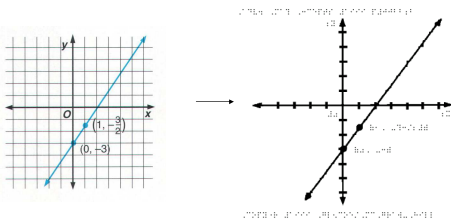
$$y = k$$

$$x = h$$

Extracted Math Image

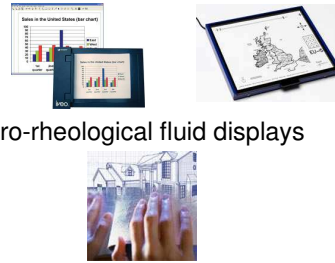
Grids

- Grids may not work well in tactile form.



Future Research

- Include Audio with Touchpads
- Electro-rheological fluid displays



Demo of TGA