Automating Tactile Graphics Translation

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The Problem

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

Outline

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
- 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

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Math Translation

Math Translation Examples

\[
\sum_{i=0}^{\text{area}} 1 - x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}
\]

Text Translation

The new畅言 Pickle group has any points in common is Quadrant
1. When the constraints of a linear programming problem cannot be satisfied simultaneously, the infeasibility is said to exist. This may mean that the constraints have been formulated incorrectly, simple inequalities must be changed, or that additional resources are required before the problem can be solved.

Math Translation

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\]
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Automating the Process

• CS contributions
  – Machine learning
  – Computational geometry algorithms
  – Computer vision
  – Optimization algorithms
• Example
  – 1,080 figures
  – 6.5 minutes per figure

Finding Text

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

• OCR is not effective for graphical images.
Features

**Century Gothic**

- $W =$ width of bounding box
- $H =$ height of bounding box
- $A =$ area of bounding box
- $R_i =$ number of black pixels in $i$-th slice where a slice is an angle of 360$\circ$. The total number of slices is $n$.

$C = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$

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.
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

Minimum spanning tree (1)

Treat the centroid of each connected component as a node

Discard useless edges (2)

Discard inconsistent edges (3)

Final merge step (4)

Merge only if the resultant group is consistent
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
- Right justified
- Centered
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Subtask Pattern

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

Tactile Graphics Assistant

- TGA batch process
- Training Data

Available Books

  Hennessy and Patterson
  2002 Elsevier
  25 minutes per figure
- Advanced Mathematical Concepts, Precalculus with Applications
  1999 Glencoe/McGrav-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

Time per Figure

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num figs 467   num figs 1080   num figs 508
min/fg 8.8     min/fg 6.3     min/fg 19.2
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

Outline

• Text
• Math
• Graphics
• Workflow
• Problem solving

Problem solving

• Each book presents 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

- Image → Math Image via TGA → LaTex via Infty Reader → Nemeth via Duxbury

Grids

- Grids may not work well in tactile form.

Future Research

- Include Audio with Touchpads
- Electro-rheological fluid displays

Demo of TGA