Weighted Voronoi Stippling

Courtesy of Adrian Secord (NPAR ’02)

Outline
- Introduction
- Offline technique
- Interactive technique
- Summary/Extensions

Announcements
- Project presentations next Tuesday
- Next Thursday: Guest speaker
- Next Thursday: sign up for 2nd talk

Deussen et al.
- Image is segmented by user
- Within each segment:
  1st: Dithering to place stipple dots
  2nd: Lloyd’s relaxation for better spacing
- Without segmentation: blurring!

Motivation
- Input: greyscale image
- Avoid manual segmentation
- Minimize other user parameters to tweak

How? Weighted Voronoi Diagrams

Centroidal Voronoi Diagram (CVD)
- Generating site = region’s centroid
- Centroid:
  - Center of mass
  - Average of all pixel positions within a region
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- Generating site = region’s centroid
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- Lloyd’s algorithm

Weighted CVD
- Each point in plane has a density (darkness)
- Centroid calculation reflects this

Secord’s Approach
- Treat input image as density function
- Darker pixels have higher densities
- Algorithm:
  - Choose number of stipple to be used
  - Randomly seed stipple
  - Create density function from input image
  - Use Lloyd’s algorithm to create Weighted CVD
  - Output drawing after convergence

Results
Stipples vs. Pixels
- Pixels convey less info than stipples
- Recalls Hausner’s argument re: mosaics

Recalls Hausner’s argument re: mosaics
Interactive Stippling

- Algorithm thus far not interactive:
  - 5000 stipple levels: under a minute
  - 40,000 stipple levels: 20 minutes.
- Idea: sacrifice quality for interactivity

Interactive Stippling

- Algorithm:
  - Precompute N stipple levels
  - For all pixels \((x,y)\) in input image:
    - Map intensity at \((x,y)\) to stipple level \(L\)
    - Copy all stipple levels from level \(L\) that are centered in \([x-0.5,y-0.5],(x+0.5,y+0.5)\]
- Avoids “half a stipple”!
- Like a massive dither matrix covering whole image!

Interactive Stippling

Performance numbers:
- Rows: image resolutions
- Columns: number of stipple levels

<table>
<thead>
<tr>
<th>Rows</th>
<th>5000</th>
<th>10000</th>
<th>20000</th>
<th>40000</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 x 100</td>
<td>350 fps</td>
<td>300</td>
<td>200</td>
<td>150</td>
</tr>
<tr>
<td>500 x 500</td>
<td>150 fps</td>
<td>120</td>
<td>100</td>
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<td>60 fps</td>
<td>45</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>900 x 500</td>
<td>20 fps</td>
<td>20</td>
<td>20</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 1: Frames per second at various numbers of stipple levels and resolutions

Interactive vs. Offline Stippling
Outline
- Introduction
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Summary
- Weighted CVD’s
- An attempt at interactivity
- Section 2.2.1 has trick to speed up weighted CVD calculation:
  - Summed row tables for density intervals
  - Not really clear how much of a speedup this is

Open Issues
- No checking to see if we’ve gotten desired darkness
  - Problem with fixed number of points
  - Perhaps system could make suggestion?

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- No checking to see if we’ve gotten desired darkness
  - Problem with fixed number of points
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- Fixed stipple dot size
- Interactivity
- Animation

Extension
Hiller et al., “Beyond Stippling...” 2003

Extension
Hiller et al., “Beyond Stippling...” 2003
- Uses area voronoi diagrams to handle:
  - Different size points
  - Different shapes
Questions?