Floating Points – A Method for Producing Stipple Drawings

Introduction
- What is a Stipple Drawing?
  - An image made up of many points grouped semi-randomly to simulate shading, texture

Stipple Drawings
- Can be very powerful and convey lots of geometric and texture information
- Are common in Archeology texts, Dictionaries, and even newspapers (e.g. WSJ)
  - Easily Reproduced
  - Cheap to Print
  - Compact Storage
- Typically takes many hours or even days using several tens of thousands of dots

How to Control a Stipple
- Detail through:
  - Varying dot spacing
  - Varying dot size
  - Varying dot shape (rare)
  - Inverse stippling
    - White dots against black background

Noli Novak - nolinovak.com
Deussen, et al.
- They generate stipple drawings in a three-step process:
  1. User defines edges manually.
  2. System places stipples roughly using a dithering algorithm (Pulse Density Modulation).
  3. Stipples are relaxed using Lloyd's algorithm.
  4. User manipulates stipples using various brushes and tools, effectively "detailing" the image.

Introduction

Background
Salesin, Salisbury, et al
- Created pen & ink illustrations based on 'procedural textures' - that is, hatching strokes.
- They consider this a kind of halftoning that simulates tone based on stroke patterns
- Strokes follow features of the original image

Ostromoukhov
- Swiss Federal Institute of Tech.
- Created stippled drawings.
- Random point set is connected to springs and positions are altered iteratively by force relaxation.
- Voronoi regions stippled based on grey level

Winkenbach and Salesin
- Draw hatching along parametric curve of surface.
- Hatching strokes with various widths for tone.
- Drew stipple patterns along strokes.
- Used more than one hatching direction.
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- Introduction
- Background
- Approach
  - Place Initial Dots: Pulse Density Modulation
  - Relax dots into Voronoi mass centers
  - “The Editor”
- Results
- Conclusions
- ...Extras?

Initial Dot Placement

- Surveyed a variety of dithering algorithms.

- Halftoning through Pulse Density Modulation
  - Generate pulses of size \( S \) by growing a region \( A_m \) of the input image \( I(x,y) \) until reaches the amount \( I = S I_0 \), where \( I_0 \) is some normalization constant.

\[
I = \int_{A_m} d(x,y) \, dx \, dy
\]

- Essentially, grow a pulse until it covers a certain amount of intensity.

After Initial Dot Placement

- Points are moved by iteration using Lloyd’s method, which removes artifacts of halftoning.
  - 1) Compute Voronoi diagram \( O(n \log n) \)
  - 2) Intersect Voronoi with region boundaries
  - 3) Move each point to the center of mass of its Voronoi region \( O(n) \)
  - 10 to 20 iterations are normally required for a “pleasing distribution”

Table 1: Time needed for one relaxation step (measured on
SGI Indigo at 10000 100 MDLs)

<table>
<thead>
<tr>
<th>Dots</th>
<th>100</th>
<th>1000</th>
<th>10,000</th>
<th>30,000</th>
<th>60,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>0.07</td>
<td>0.57</td>
<td>2.9</td>
<td>6.16</td>
<td>13.4</td>
</tr>
</tbody>
</table>

- Introduce Randomness
  - Move dots away from even positioning by applying a jitter vector to each dot in dependancy to the size of it's Voronoi region.
  - Dots in dark areas are moved less, helping to avoid too much irregularity.
Comparing to Hand-Drawn Techniques

“The Editor”
- UI like that of a normal paint program which allows for:
  - Segmenting the image manually
  - Placing initial dots with a brush
  - Contouring/Detailing the dot distribution by varying dot size, shape, or by moving dots.
- Brushes:
  - Edit - add/remove dots on per dot basis or on #/sec
  - Relaxation - relax dots towards an even distribution
  - Jitter - add random offset to dot location as % of average dot-to-dot distance
  - Shape - change size/shape

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Results
- Images produced and their particulars
Conclusions
...Extras?

Results
- Grasshopper - 60,000 dots
- 8 hours to produce, mostly in segmentation and fine-tuning.

- Stone Bridge - 12,000 dots
- 2 hours.

- Ancient Statue - 6,000 dots
- 4 hours.
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  - Future Work
  - Opinions
  - Extras?

Conclusion

- Future Work
  - Automated Segmentation.
    - Most of the work goes into manual segmentation so it would be nice to automate.
    - Even better possibilities with a 3D reference source
  - Various brush shapes and directions.
  - Relaxing dots along lines (1 dimensional) for hatching techniques.

Opinions

- Better halftoning techniques exist now.
- Results still depend heavily on the artist
- Relaxation is slow!
- Large dots can produce nice images.

Extras

- Weighted Voronoi Stippling – NPAR 2002
  - Adrian Secord, University of British Columbia
  - Direct descendant of Deussen, et al.
  - Uses voronoi diagram as in Deussen, but can pre-compute the stippling distribution for different constant tonal values to reach near-realtime video.

Weighted Voronoi Stippling