Combining Sketch and Tone for Pencil Drawing Production

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Fundamental Pictorial Language

Popular Artistic Forms

High in real-work

Pencil Sketch
Episode of <The Pacific>

VISUAL EFFECTS SUPERVISOR
JOHN E. SULLIVAN

SPECIAL EFFECTS SUPERVISOR
JOSSE WILLIAMS
Outline

- Previous work
- Observation (Two stages)
- Framework (Pencil drawing prior included)
- Discussion
- Comparison and Results
- Conclusion
Outline

• Previous Work
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• Conclusion
Previous Work (Model-based)

[Accurate Line and Contour] → [Pencil Line Drawing]

[Sousa and Buchanan 1999] [Lake et al. 2000] [Lee et al. 2006]
Previous Work (Model-based)

Surface Normal
Lighting Information
Geometry Information

Automatic Hatching Generation
Previous Work (Image-based)
Previous Work (Image-based)
Previous Work (Image-based)

- Li and Huang 2003
- Sun et al. 2007
- Gao et al. 2010
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Observation

First Stage

Second Stage

Human Drawing Procedure
Observation

Structure + Tone =
Our Framework

Stroke Structure Generation

Tone Rendering
Our Framework

- Gradient
- Line Drawing
- Tone Mapping
- Texture Rendering
Our Framework (Line Drawing)

Gradient

Line Drawing

Texture Rendering

Tone Mapping
Our Framework (Line Drawing)
Our Framework (Line Drawing)
Our Framework (Line Drawing)

How to simulate it?
Our Framework (Line Drawing)

• Sketching cannot be achieved by
  • detecting direction of each pixel and
  • extending edges along their direction
Our Framework (Line Drawing)

• A naive method

Pixel Direction \( \theta = \arctan \left( \frac{\partial_y I}{\partial_x I} \right) \)
Our Framework (Line Drawing)

• A naive method

• Extent along their Direction
Our Framework (Line Drawing)

Our Robust Edges Direction Classification
Our Framework (Line Drawing)

Our Robust Edges Direction Classification

red \[ \text{arg max}\left\{ C_1, C_2 \right\} = 1 \]
blue \[ \text{arg max}\left\{ C_1, C_2 \right\} = 2 \]
Our Framework (Line Drawing)

- Why it works?
Our Framework (Line Drawing)

Input
Our Framework (Line Drawing)

Gradient
Our Framework (Line Drawing)

Pixel direction classification (8 directions)

\[ C_i(p) = \begin{cases} 
G(p) & \text{if } \text{argmax} \{ \psi_i \otimes G \}(p) = i \\
0 & \text{otherwise}
\end{cases} \]
Our Framework (Line Drawing)

\[ S = \sum_{i=1}^{8} \psi_i \otimes C_i \]
Our Framework (Line Drawing)
Our Framework (Line Drawing)
Our Framework (Line Drawing)

• Why it works?
  • Robust pixel direction classification
  • Convolution line shaping
Our Framework (Line Drawing)

For Texture

Gradient

Ours
Our Framework (Line Drawing)
Our Framework (Line Drawing)

Gradient
Our Framework (Line Drawing)
Our Framework (Tone Mapping)
Our Framework (Tone Mapping)
Our Framework (Tone Mapping)

Ernest W. Watson “The art of pencil drawing”, 1968
Our Framework (Tone Mapping)

Why is it?

The underlying mechanism is complex
Our Framework (Tone Mapping)

Three-layer structure
Our Framework (Tone Mapping)

Bright Layer: artists do not draw anything
Our Framework (Tone Mapping)

$P_1(v) = \begin{cases} 
\frac{1}{\sigma_b} e^{\frac{-1-v}{\sigma_b}} & \text{if } v \leq 1 \\
0 & \text{otherwise}
\end{cases}$

Bright Layer: artists do not draw anything
Our Framework (Tone Mapping)

Mid-tone Layer: different pressure
Our Framework (Tone Mapping)

Mid-tone Layer: different pressure

\[ P_2(v) = \begin{cases} 
\frac{1}{u_b - u_a} & \text{if } u_a \leq v \leq u_b \\
0 & \text{otherwise}
\end{cases} \]
Our Framework (Tone Mapping)

Dark Layer: visually most salient
Our Framework (Tone Mapping)

\[ P_3(v) = \frac{1}{\sqrt{2\pi}\sigma_d} e^{-\frac{(v-\mu_d)^2}{2\sigma_d^2}} \]

Dark Layer: visually most salient
Our Framework (Tone Mapping)

\[ P(v) = \frac{1}{Z} \left[ \omega_1 P_1(v) + \omega_2 P_2(v) + \omega_3 P_3(v) \right] \]

Unknown Parameters

<table>
<thead>
<tr>
<th>Bright layer</th>
<th>Mild-tone layer</th>
<th>Dark layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\sigma_b)</td>
<td>(u_a)</td>
<td>(u_b)</td>
</tr>
<tr>
<td></td>
<td>(\mu_d)</td>
<td>(\sigma_d)</td>
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</table>
Our Framework (Tone Mapping)

\[ P(v) = \frac{1}{Z} \left[ \omega_1 P_1(v) + \omega_2 P_2(v) + \omega_3 P_3(v) \right] \]

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<tr>
<td>( \sigma_b )</td>
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<td>( \mu_d )</td>
</tr>
<tr>
<td>9</td>
<td>105</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>225</td>
<td>11</td>
</tr>
</tbody>
</table>

Maximum Likelihood Estimation
Our Framework (Tone Mapping)

\[ P(v) = \frac{1}{Z} \left[ \omega_1 P_1(v) + \omega_2 P_2(v) + \omega_3 P_3(v) \right] \]

\[ \omega_1 : \omega_2 : \omega_3 = 29 : 29 : 42 \]
Our Framework (Texture Rendering)

- Gradient
- Line Drawing
- Tone Mapping
- Texture Rendering
Our Framework (Texture Rendering)
Our Framework (Texture Rendering)
Our Framework (Texture Rendering)

Input

Guess Hatch Direction
Our Framework (Texture Rendering)

Input

Guess Hatch Direction
Our Framework (Texture Rendering)

Tonal texture case
Drawn by Katja, 2008

No Guess!
So it is robust to all cases!
Our Framework (Texture Rendering)

Tonal texture

Pencil Tone

Pencil Texture Transfer
Our Framework (Texture Rendering)

Pencil Texture Transfer
Our Framework (Texture Rendering)

Multiplication Model
Our Framework (Texture Rendering)

- In multiplication model

\[ P(x)^{\beta(x)} \approx J(x) \]

Repeated drawing

Tonal Texture

Tone Mapping result
Our Framework (Texture Rendering)

• In multiplication model, we require:

\[ \beta(x) \log[P(x)] \approx \log[J(x)] \]
Our Framework (Texture Rendering)

- In multiplication model, we require:

\[
\min_\beta \left\| \beta \log[P] - \log[J] \right\|^2_2
\]
Our Framework (Texture Rendering)

• In multiplication model, we require:

\[
\min_{\beta} \left\| \beta \log[P] - \log[J] \right\|_2^2
\]

• We also require: Local Smoothness

\[
\min_{\beta} \left\| \nabla \beta \right\|_2^2
\]
Our Framework (Texture Rendering)

Objective function

\[ \beta^* = \arg \min_{\beta} \left\{ \| \beta \log [P] - \log [J] \|_2^2 + \lambda \| \nabla \beta \|_2^2 \right\} \]
Our Framework (Texture Rendering)

- Rendering Result

\[ S = P^{\beta^*} \]
Our Framework (Tone Mapping)
Our Framework (Combination)
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Sun et al, Efficient Region-Based Pencil Drawing, 2007
Ours
Gao et al., Automatic Generation of Pencil Sketch for 2D Images, 2010
Comparison with Software
http://clipping-path-studio.com/downloads/InstantPhotoSketchSetup.exe
More Results
Input
• Color Pencil Drawing

- Y Channel
- U Channel
- V Channel
• Color Pencil Drawing
Output (color)
Output (color)
Conclusion

• An effective and robust image-based pencil drawing system

• Pencil drawing priors: crossing junction, pencil tone transfer, tonal pencil texture rendering
Thank you

Annecy, France