From Dürrer's Engravings
to
Picasso's One-Line Drawings

or On Non-Photorealistic Image Renderings via Curve Evolutions

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Presentation based on:

- Penumi & Bruckstein
- Digi DURER Visual Computer 94
- Gridless Halftoning VCGP, 1996
- Machera, Barquet & Bruckstein
- Image Flows
- One Liner Image Representations ICPR’02, NY Academy 2002

Nonphoto realistic Image Renderings
Digi-Dürer

A system to generate an engraving-like image given a picture (gray-level or color)

Why?

- Engravings are visually pleasant. See e.g. The Wall-Street Journal renderings.
- The issue is an interesting challenge.
- The solution connects to some interesting math/computer vision problems (Shape-from-shading).
FIG. 6. A man-made halftone artwork [14].

Fig. 1 Traditional copperplate engravings: an enlargement of a modern post stamp (left) and an enlargement of a modern banknote (right).
Dürer-style Halftoning

- in work with Y. Pnueli we aimed to do halftoning by attempting to imitate the methods of Engravers.

Halftoning by generating curves that have "local density" controlled by image gray level.

- Solve for the Equal Height Curves of $H(x,y)$ that obeys

$$\| \nabla H(x,y) \| = \sqrt{(\frac{\partial H}{\partial x})^2 + (\frac{\partial H}{\partial y})^2} = I(x,y)$$

a bivariate function whose EHC's are locally "parallel" to have density

input image
Low Gradient

High Gradient

Projection in Image Plane

Light area

\[ \alpha \parallel \nabla H \parallel \]

Dark area

\[ \alpha \parallel \nabla H \parallel \]
We need to solve for the ETC's of \( \mathbf{H} \) where 
\[
\| \nabla \mathbf{H} \| = I(x, y)
\]

The famous EIKONAL EQUATION

In Image Analysis this was done in solving the so-called SHAPE from SHADING problem.

There are very efficient methods to do this based on advanced "Level Set Methods".

The ETC's of \( H(x, y) \) are solved by Tracking Level Sets of another bivariate function.
Some Results
GRIDLESS HALFTONING

FIG. 1. Early halftoning using a line printer.
FIG. 2. Halftoning with clustered ordered dither.
FIG. 5. Neural network optimized halftoning [18].
FIG. 14. DigiDürer output utilizing edge/segmentation information.
FIG. 18. Gridless halftoning with dot elements.
FIG. 15. DigiDürer output utilizing edge/segmentation information.
FIG. 16. DigiDürer output utilizing edge/segmentation information.
FIG. 25. (Art-Play-1) Image generated using a 3D equidistance curve evolution rule.
FIG. 26. (Art-Play-2) Image generated using a variable terrain 3D equidistance curve evolution rule.
DEVELOPMENT:

Digital Facial Engraving

Victor Ostromoukhov (EPFL)

CG Proceedings 1999
Fig. 9 Examples of color engraving.
One Line Renderings

generate a drawing from an image that captures and “nicely connects” its main edges (contours).

Why?

- Picasso/Calder/Coeuteau made wonderful one line renderings
- The challenge: detect/trace the ‘important' contours for a given image/object and generate a ‘nice’ traversal of them
- The solution leads to interesting flaws on images & their analysis
Computers are useless. They can only give you...

... Answers

Pablo Picasso (1881-1973)
**IMAGE FLOWS:**

Given an image $I(x, y)$/gray levels (say),

what is a good way to find and trace its edges. We must estimate the gradient $\nabla I(x, y)$ and locate curves that pass through/on near/locations of high gradient ($|\nabla I|$-high).

**IDEA:** Start at every point $(x, y)$ in the image plane and flow as follows.

$$\frac{dP(t)}{dt} = \alpha \frac{(\nabla I(x, y))_x}{\sqrt{\nabla I(x, y)_x^2 + \nabla I(x, y)_y^2}} + (1-\alpha) \frac{\nabla I(x, y)_x}{\sqrt{\nabla I(x, y)_x^2 + \nabla I(x, y)_y^2}}$$

*Vector field 1* flows along equal-height curves.

*Vector field 2* flows towards high gradients.
The Vector Fields that drive the Edge Exploration

$V_2$ flow towards "steeper slopes"

$V_1$ flows along an EITC

This operator makes sense!

- Where does the flow stop?
- How do we trace the important edges?
- How do we connect "edge" curves?
The flas operator is discretized and we have:

- **Stopping Rule**: When a curve returns to itself!

- **Edge Importance**: How many initial points \((x_0,y_0)\) flow into the edge curve!

- **Connecting Edge Curves**: Edge linking algorithm.
ONE LINER IMAGE
RENDERINGS

End
Synthetic One liners provided by the above algorithm.