A1 Texture Synthesis
Due Mon Sep 26

Implement application of texture synthesis
Image analogies, Hole-filling, Patchmatch Structured hybrids ….

Adequate to implement, best solutions go beyond:
Every technique has some limitations (well written papers usually describe some of them). Develop techniques to address one or more limitations?

Sometimes different papers present different techniques for addressing the same problem. Implement competing techniques and compare their strengths and weaknesses.

It may be possible to combine ideas from multiple papers to produce a new hybrid technique that addresses a new problem. Develop a new way to combine the texture synthesis techniques your have read about to solve a new problem.

1 person = 1 paper,
2 people = 1 paper + issue from list above or 2 papers,
3 people = 2 papers + issue from list above
Implement Light Fields or HDR/Tone-Mapping

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What is Light?

Electromagnetic radiation (EMR) moving along rays in space

- \( R(\lambda) \) is EMR, measured in units of power (watts)
  - \( \lambda \) is wavelength

Useful things:
- Light travels in straight lines
- In vacuum, radiance emitted = radiance arriving
  - i.e. there is no transmission loss
What Do We See?

3D world

2D image

Point of observation

Painted backdrop
On Simulating the Visual Experience

Just feed the eyes the right data
- No one will know the difference!

Philosophy:
- Ancient question: “Does the world really exist?”

Science fiction:
- Many, many, many books on the subject, e.g. slowglass from “Light of Other Days”
- Latest take: The Matrix

Physics:
- Slowglass might be possible?

Computer Science:
- Virtual Reality

To simulate we need to know:
- What does a person see?

The Plenoptic Function

Q: What is the set of all things that we can ever see?
A: The Plenoptic Function (Adelson & Bergen)

Figure by Leonard McMillan
Grayscale snapshot

- $P(\theta,\phi)$
- intensity of light
  - Seen from a single view point
  - At a single time
  - Averaged over the wavelengths of the visible spectrum

(\text{can also do } P(x,y), \text{ but spherical coordinate are nicer})

Color snapshot

- $P(\theta,\phi,\lambda)$
- intensity of light
  - Seen from a single view point
  - At a single time
  - As a function of wavelength
2D: Image

What is an image?

All rays through a point

Panorama?

Image

Image plane
Spherical Panorama

All light rays through a point form a panorama
Totally captured in a 2D array -- $P(\theta, \phi, \lambda)$
Where is the geometry???

See also: 2003 New Years Eve
http://www.panoramas.dk/fullscreen3/f1.html

Panorama Viewer

http://www.panoramas.dk/US/golden-gate.html
A movie

$P(\theta, \phi, \lambda, t)$

is intensity of light

- Seen from a single viewpoint
- Over time
- As a function of wavelength

Holographic movie

$P(\theta, \phi, \lambda, t, V_x, V_y, V_z)$

intensity of light

- Seen from ANY viewpoint
- Over time
- As a function of wavelength
The Plenoptic Function

\[ P(\theta, \phi, \lambda, t, V_X, V_Y, V_Z) \]

Can reconstruct every possible view, at every moment, from every position, at every wavelength

Contains every photograph, every movie, everything that anyone has ever seen! It completely captures our visual reality! Not bad for a function…

Sampling Plenoptic Function (top view)

Just lookup -- Quicktime VR
Ray

Let’s not worry about time and color:

\[ P(\theta, \phi, V_x, V_y, V_z) \]

- 3D position
- 2D direction

How Can We Use This?

Lighting

Surface

No Change in Radiance

Camera
Ray Reuse

Infinite line
- Assume light is constant (vacuum)

4D
- 2D direction
- 2D position
- non-dispersive medium

Only Need Plenoptic Surface

Figure 1: The surface of a cube holds all the radiance information due to the enclosed object.
Synthesizing Novel Views

Lumigraph / Lightfield
Outside convex space

Slide by Rick Szeliski and Michael Cohen
Lumigraph - Organization

2D position
2D direction

Lumigraph - Organization

2D position
2D position
2 plane parameterization
Lumigraph - Organization

2D position
2 plane parameterization

Hold s,t constant
Let u,v vary
An image
Lumigraph / Lightfield

Idea 1
Move camera carefully over s,t plane
Gantry (see Lightfield paper)
Lumigraph - Capture

Idea 2
Move camera anywhere
Rebinning (see Lumigraph paper)

Lumigraph - Rendering

For each output pixel
determine s,t,u,v

either
use closest discrete RGB
interpolate near values
Lumigraph - Rendering

Nearest
closest s
closest u
draw it

Blend 16 nearest
quadrilinear interpolation

Light field photography using a handheld plenoptic camera

Ren Ng, Marc Levoy, Mathieu Brédif,
Gene Duval, Mark Horowitz and Pat Hanrahan
Conventional versus light field camera

Subject
Main lens
Photosensor

Subject
Main lens
Photosensor

Conventional versus light field camera

$uv$-plane
$st$-plane
Prototype camera

- Contax medium format camera
- Kodak 16-megapixel sensor
- Adaptive Optics microlens array
- 125µ square-sided microlenses

\[ 4000 \times 4000 \text{ pixels} \div 292 \times 292 \text{ lenses} = 14 \times 14 \text{ pixels per lens} \]
Digitally stopping-down

- stopping down = summing only the central portion of each microlens

Digital refocusing

- refocusing = summing windows extracted from several microlenses
Example of digital refocusing
Digitally moving the observer

• moving the observer = moving the window we extract from the microlenses

Example of moving the observer
Moving backward and forward

3D Lumigraph

One row of s,t plane
i.e., hold t constant

\begin{align*}
s,t & \quad u,v
\end{align*}
3D Lumigraph

One row of $s,t$ plane

i.e., hold $t$ constant
thus $s,u,v$
a "row of images"

$P(s,t)$

by David Dewey
Other ways to sample Plenoptic Function

Moving in time:
- Spatio-temporal volume: \( P(\theta, \phi, t) \)
- Useful to study temporal changes
- Long an interest of artists:

Claude Monet, Haystacks studies

Space-Time Images

Other ways to slice the plenoptic function...
Stanford Multi-Camera Array

- 640 × 480 pixels × 30 fps × 128 cameras
- synchronized timing
- continuous streaming
- flexible arrangement
Demo #1: High Speed Video

- N cameras, each running at 30Hz
- Stagger the frames of cameras by $1/N^{th}$ of a frame
- Align images to single perspective

Video: 52 cameras, 1560 Hz
Demo #2: High Resolution Video

- 12 × 8 array of VGA cameras
- total field of view = 29° wide
- seamless stitching
- cameras individually metered

Tiled Video: 7 Megapixels
Camera Array: Portable Version

- 48 cameras in 16 x 3 layout
- 2m wide baseline

Synthetic Aperture Focusing: Scene

- distance to occluder: 33m
- distance to targets: 40m
- field of view at target: 3m
Synthetic Aperture Focusing
Digital refocusing

• refocusing = summing windows extracted from several microlenses

Suppressing Contributions of Occluders

Figure 11: Matted synthetic aperture photography. (a) A sample image from one of 90 cameras used for this experiment. (b) The synthetic aperture image focused on the plane of the people, computed by aligning and averaging images from all 90 cameras as described in the text. (c) Suppressing contributions from static pixels in each camera yields a more vivid view of the scene behind the occluder. The person and stylized toy are more clearly visible.
Figure 12: Hybrid synthetic aperture photography for combining high depth of field and low motion blur. (a-c) Images captured of a scene simultaneously through three different apertures: a single camera with a long exposure time (a), a large synthetic aperture with short exposure time (b), and a large synthetic aperture with a long exposure time. Computing (a + b - c) yields image (d), which has aliasing artifacts because the synthetic apertures are sampled sparsely from slightly different locations. Masking pixels not in focus in the synthetic aperture images before computing the difference (a + b - c) removes the aliasing (e). For comparison, image (f) shows the image taken with an aperture that is narrow in both space and time. The entire scene is in focus and the fan motion is frozen, but the image is much noisier.

Hybrid Synthetic Aperture – High DOF/Low Motion Blur