Panoramas

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Marc Levoy
Computer Science Department
Stanford University
What is a panorama?

• a wider-angle image than a normal camera can capture
• any image stitched from overlapping photographs
• an extreme aspect ratio on a normal shot
Outline

- capturing panoramas
- stitching together a panorama
- perspective versus cylindrical projection
Panoramic cameras

- Flatback panoramic camera
- Swing-lens panoramic camera
Swing-lens panoramic images

San Francisco in ruins, 1906

101 Ranch, Oklahoma, circa 1920
Panoramic cameras

To avoid parallax errors, rotate around center of perspective.

- Flatback panoramic camera
- Swing-lens panoramic camera
- SLR on panning clamp
- Motorized pan-tilt head
Parallax errors

Photoshop aligned on the background, so only foreground objects exhibit severe parallax errors
Lee Frost, Val D’Orcia, Tuscany, Italy

Fuji GX 617
Lee Frost, Volubilis, Morocco
Lee Frost,
Vertical Panoramas,
Santorini
Matthew Scott, Cuernos del Paine, Chile
gigapan.org, Scanning Electron Micrograph (SEM) of barnacle
Stitching images together to make a mosaic
What kind of transformation do we need?

- translation?
- rotation?
- perspective!
Quick review of perspective projection

- all that matters is position of c.p. and orientation of p.p.

These three image formation methods will produce the same perspective view on the p.p. (except for the size of the view)

- pinhole camera
- photographic camera
- Albrecht Dürer’s drawing glass

= center of perspective (c.p.)
= projection of feature in scene onto picture plane (p.p.)
Reprojecting an image onto a different picture plane

The sidewalk art of Julian Beever

- The view on any picture plane can be projected onto any other plane in 3D without changing its appearance as seen from a common center of projection.
Reprojecting panoramic images to a common picture plane

- the common picture plane of the mosaic replaces having had a wide-angle (non-fish-eye) camera in the first place.
Homography

- perspective mapping between two p.p.'s using the same center of projection is called a homography
  - input and output x,y positions are related by a $3 \times 3$ matrix
- **step 1**: find corresponding features in a pair of image
- **step 2**: compute perspective from 2\textsuperscript{nd} to 1\textsuperscript{st} image
- **step 3**: warp 2\textsuperscript{nd} image so it overlays 1\textsuperscript{st} image
- **step 4**: blend images where they overlap one another
- repeat for 3\textsuperscript{rd} image and mosaic of first two, etc.
Stitching images together to make a mosaic

- **step 1**: find corresponding features in a pair of images
- **step 2**: compute perspective from the 2nd to the 1st image
- **step 3**: warp the 2nd image so it overlaps the 1st image
- **step 4**: blend images where they overlap one another
- repeat for the 3rd image and the mosaic of the first two, etc.

Take CS 223B: Computer Vision (Win)

Take CS 148: Introduction to Computer Graphics (Aut)

Also CS 448A: Computational Photography (Win)
Example: the Matterhorn

common picture plane of mosaic image

perspective projection
Using 4 shots instead of 3
Cylindrical panoramas

- even works for 360° panorama

- project each image onto a cylinder

- a cylindrical image can be stored as a rectangular image
Cylindrical panoramas

- even works for 360° panorama

- project each image onto a cylinder
- a cylindrical image can be stored as a rectangular image
- to view without distortion, reproject part of the cylinder onto a picture plane representing the display screen
  - if your FOV is narrow, this view won’t be too distorted

(Flash demo) http://graphics.stanford.edu/courses/cs178/applets/projection.html
Back to the Matterhorn

cylindrical projection

surface of cylinder
Back to the Matterhorn

surface of cylinder

blended
As mentioned in class, Photoshop does not perform the perspective reprojection shown here. Instead, it leaves you with the raw cylindrical image shown in the previous slide. On this image, straight lines are not straight, and the edges of the original photographs appear as curves. This is not a correct linear perspective. However, some panorama viewing software does perform this perspective reprojection, e.g. Microsoft’s HDView (Google for it).
As I mentioned in class, the sequence of (1) projecting one or more images to a cylindrical surface, and (2) reprojecting that cylindrical image back to a planar surface, produces an image with no distortion, i.e. it is a correct linear perspective. However, it might be rather wide-angle, as shown in the previous slide. Unless you view this image with your face close to the display, which would be the correct viewpoint for such a wide-angle perspective, it will seem distorted. We covered this issue in the first lecture of the course. To reduce the requirement that you must place yourself so close to the display, you should crop the reprojected panorama, as is done in this slide. The resulting image is not so wide-angle, and can be viewed from a normal viewing distance without seeming distorted.
Spherical panoramas

- projections are to a sphere instead of a cylinder
- can’t store as rectangular image without distortion
Recap

- panoramas can be captured by a camera with a wide planar back, a cylindrical back and a moving slit, or a rotating camera
  - rotate around the center of perspective to avoid parallax errors
- to assemble panoramas from a rotating camera, use corresponding features to compute a perspective warp that projects the images to a common picture plane, then blend them together
- for very wide angle or 360° panoramas, project the images to a common cylindrical surface, which can be stored as an ordinary (wide) rectangular image
  - reproject them to a picture plane for display
- spherical panoramas are possible, but cannot be stored as rectangular images without distortion

Questions?
Slide credits

✶ Fredo Durand
✶ Alyosha Efros
✶ Steve Seitz
✶ Rick Szeliski

AHHHH...

Uh-oh. Something is seriously wrong here.

The laws of perspective have been repealed!

Objects no longer diminish in size with distance!

LINES do not converge toward any point on the horizon!

All spatial relationships are lost! It's impossible to judge where anything is! Oh no!

Calvin, quit running around and crashing into things, or I'll sell you to the monkey house!

...and now she's lost perspective.