Panoramic and High Resolution Photography

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Agenda

- Panoramic and high-resolution...what are they?
- Why bother?
- How to, part 1: Technique, composition, equipment
- How to, part 2: Combining the image using software
- PTAssembler Overview
- “Advanced” topics: distortion, perspective, projection, stacking
- Now what? Presentation and display
What Are We Talking About?

- High Resolution Photography
  - More detail than any single photograph
  - My approach: “Stitching” images together

- Panoramic / Mosaic: What's the difference?
  - Scenes with wide aspect ratio are often called “panoramas”
  - Scenes comprised of multiple rows are often called “mosaics”
  - May or may not have very wide field of view
  - Distinction is arbitrary...I use the terms interchangeably
Single Row “Panoramic” Image
Little Lakes Valley

6 images
Multiple Row “Mosaic” Image
Jefferson Memorial

20 images
Panoramic Image
Washington Monument

- Wide field of view (170 degrees), wide aspect ratio (3.25:1), 6 images
Panoramic Image
Sunset on Cook Strait

- Normal field of view (60 degrees), wide aspect ratio (2.1:1), 4 images
Panoramic Image
Washington Monument Dawn

- Narrow field of view (18 degrees), wide aspect ratio (2.75:1), 5 images
Mosaic Image
Jeffrey Pine, Yosemite

- Wide field of view
  - (140 degrees)
- “Standard” aspect ratio
  - (4:3)
- 24 images
Mosaic Image
Air Force Memorial

- Wide field of view
  - (110 degrees)
- Square aspect ratio
  - (1:1)
- 4 images
Mosaic Image
Wisconsin Avenue

- Narrow field of view
  - (25 degrees)
- “Standard” aspect ratio
  - (5:4)
- 9 images
Vertical Panoramic Image
Colorado Wildflowers

- Field of view:
  - 40 x 100 degrees
- Aspect ratio:
  - 1:2.5
- 5 images
Macro Panoramic Image
New Zealand Fern

- Normal field of view (34 degrees), wide aspect ratio (2.6:1), 5 images
Panoramic Image
Cannon Beach Sunset

- Wide field of view (144 degrees), wide aspect ratio (2.4:1), 6 images
- Motion within one frame
Why?

- High Resolution / Detail
  - Pictures within pictures
- Unusual/Impossible Aspect Ratio
  - Aspect ratio fits composition, not vice-versa
- Unusual/Impossible Images
  - Field of view not constrained by camera/lens
  - Projection choice not constrained by camera/lens
  - More sophisticated perspective adjustments
  - Exposure/Focus blending
Why Not?

- Time consuming
  - Capturing images
  - Processing images
- Space consuming
  - More Equipment and Technology Needed
- Inappropriate for some subjects
- Science versus art? “Real” versus “manipulated”?
Detail

- “Gigapixel Images”: 1000 megapixels or more, hundreds of images

240 images
Detail

- Titles on spines can be read from across the Library of Congress
- Intricate detail in building can be studied in detail
- First Gigapixel
- Created 2003
- Displayed 2004
- 11 x 7 feet
Detail

- More detail = larger, sharper prints
- Difference is visible even in “normal” size prints (e.g. 11x14 inches)
- Difference is very obvious in “large” prints (e.g. 20x30 inches +)
Scale: How Much, How Big?

- 15 megapixel camera, 20% overlap between images
- 5 Image, Single row panorama: ~66 megapixels
  - 15000x4400 pixels
  - 50x15 inches, printed at 300 ppi
- 50 Image, 4 row mosaic: ~600 megapixels
  - 30000x20000 pixels
  - 100x66 inches (8x6 feet), printed at 300 ppi
Good Subjects

- Anything stationary! My favorites:
  - Architecture
  - Landscapes
- Macro
- Motion can be easily handled if contained within a single frame
  - motion can sometimes be an advantage in creating “empty” scenes
- Aspect ratios of more than 3:1 or 4:1 can often disappoint
Stitching vs Big Cameras

- “Pixels” do not necessarily equal “Detail”
  - Scanning at increasingly high resolutions produces increasingly large files with less and less additional detail
  - Film vs digital: different MTF characteristics
  - Large camera lens quality
  - Depth of field and diffraction

- “Big camera” practitioners: “Gigapixl Project”, Clifford Ross
Challenges

- Capturing and creating panoramic images presents a few additional challenges compared to “regular” photography
Parallax

- Parallax errors occur when the camera is not rotated around the "entrance pupil" (aka "nodal point").
- Parallax errors are visible when the foreground and background appear to "shift" relative to each other.
Parallax

- Using of a “panoramic tripod head” to rotate camera around “entrance pupil” will eliminate all parallax errors.
- The greater the distance between foreground and background, the more parallax errors are likely to be noticeable.
- Hand-held panoramas are possible if:
  - Rotation around a point close to entrance pupil
  - Subject matter is flat, or foreground isn't too close
  - "Smart"/manual blending to disguise errors
Changing Light

- Shooting at “interesting” times of day can be a challenge because light changes very quickly
  - Favorite time to shoot architecture: 30-40 minutes after sunset
  - Favorite time to shoot landscapes: hour before and after sunset
- Shoot as quickly as possible
- Shoot one direction (not zig-zag) when shooting mosaics
- Shoot from darker to lighter regions as light diminishes
- Partly cloudy conditions require patience, speed or luck!
  - Lots of overlap can help
New Friends

• Good technique requires:
  – Tripod with “big” panoramic tripod head
  – Long lenses
  – Many photos
  – Stay in the same position for extended period

• Attracts attention of security guards and curious onlookers
Challenges: Depth of Field

- Creating high resolution images with large DOF is a challenge.
- Large mosaics require long focal length lenses.
- Long lenses produce images with shallow DOF (all else equal).
- Smaller apertures increase DOF, but also increase diffraction (blur).
- Trade-off between diffraction (blur) vs DOF puts a limit on the degree of detail and DOF possible in large images.
Challenges: Depth of Field

- Can't the problem be solved by a large format camera? No!
- Counter-intuitive conclusion: At any given print size, the trade-off between DOF and diffraction is identical regardless of sensor/film size.
How To...Part 1

- The first step in creating a panorama is capturing the images.
How To: In The Field 1

- Use a panoramic tripod head to eliminate parallax errors
- Set exposure for brightest part of scene and lock aperture, shutter speed, ISO
- Manual focus or auto-focus and then lock focus
- Lock white-balance
- No filters
- Use portrait orientation to maximize vertical resolution
How To: In The Field 2

- Shoot, rotate, shoot...repeat as necessary!
  - Make sure current image overlaps previous image
  - Mosaics: zig-zag versus one direction
- Overlap by 10-40%.
  - More overlap = more latitude for blending, but...
  - ...more overlap = “Wasted pixels”
- Pay attention to moving subjects, light changes, etc.
  - Make sure nothing is moving at edge of frame
  - Wait (if possible) for scene to clear
Hand-held panoramas

- Become a human panoramic tripod head
- Rotate around a finger
- Easier with point-n-shoot than DSLR
- Use burst mode in low light to ensure sharp images
Composition

- Standard rules mostly apply (mosaics, in particular)
- Don't forget the foreground!
- People provide a sense of scale
- Picture within a picture
- "Seeing" the whole by looking at the parts can be difficult at first
- Adjustments after shooting:
  - Different projections may give a very different feel
  - Different perspective corrections
  - Different cropping
Camera Equipment

• Use whatever you have!
• My preference:
  - Must have full manual control (exposure, focus, white-balance)
  - Small and light (“pro” = heavy, “consumer” = light)
  - Image must be sharp from edge to edge (no blurry corners)
  - High resolution / pixel density (APS-C vs full-frame)
  - Large dynamic range / Raw file format
  - Good noise performance at lowest ISO
  - Accurate focus (or good manual focus)
  - Telephoto more important than wide-angle
  - Bracketing
  - Mirror lockup/self-timer/cable release
Camera Equipment

- What I don't care about (much):
  - High ISO (ISO 400+) capabilities (I use a tripod)
  - Many frames per second (one frame per second is plenty)
  - Many focus points (one is fine, if it works!)
  - Fast / tracking auto-focus (my subjects don't move much)
  - Heavy / “Pro” body (more weight/attention than I want)
  - Fast lenses (e.g. F2.8, F1.8)
  - Exotic flash options
  - Face detection
Lens Choices

- What focal length should you use?
  - Answer A. It doesn't matter!
  - Answer B. Depends how big a picture you want
  - Answer C. Start with scene, work backwards to lens choice
- Wide angle scenes can be assembled from multiple telephoto images....but not vice-versa.
- Does a tilt/shift lens make things easier? No!
- Fisheye lenses? Yes...if your software can handle them. Good choice for 360 degree work.
- Wide aperture lenses? Not particularly important.
- Blurry corners/edges and vignetting cause problems.
- Polarizers: typically not a good idea for wide angle panoramas.
Tripod Equipment

- Any tripod should work if a panoramic head can be attached.
- Panoramic tripod head can be quite simple if only single row panoramas are desired...rotation around nodal point in one direction only.
- Panoramic or spherical tripod head:
  - Expensive: Nodal Ninja series (~ $250-$500)
  - Inexpensive: Panosaurus (~ $70)
  - Cheap/Free: “DIY” solutions
- May be able to get away without a panoramic head under some circumstances.
Current Equipment

- **Cameras:**
  - Canon Rebel T2i DSLR (50%)
  - Canon G10 Digicam (50%)
- **Lenses:**
  - Canon 17-40 F4 L (25%)
  - Tamron 28-75 F2.8 (35%)
  - Canon 70-200 F4 L (35%)
  - Canon 300 F4 L (5%)
  - Canon 1.4x, 2.0X Teleconverters
  - Canon 100mm F2.8 macro
- **Tripods:** Feisol CT-3441S tripod, Slik Compact XL
- **Panoramic Heads:** Nodal Ninja 5, Panosaurus
Computer Equipment

- Nothing exotic needed
- Storage space
  - More is always better
  - DVD versus hard-drive versus others?
  - Store as little as possible
- Memory: 2GB is plenty under most circumstances
  - Pixel does not equal Byte!
- 32bit / 64bit software and file formats impose limits
  - Image dimensions versus file size
- Multi-core / Multi-processor machines may or may not help
- Inadequate hardware can often be remedied by patience or better software
How To...Part 2

- Once the images are captured, they need to be assembled using computer software
“Automagic” Panoramic Software

● “Automagic” Etymology: Blend of automatic and magic; from the principle (often called Clarke's third law) that any sufficiently advanced technology is indistinguishable from magic.
● Works pretty well under some circumstances.
● Great way to start.
“Automagic” Panoramic Software

Shortcomings may include:

- Misalignments may be hard to correct
- Projection may not be configurable
- May not support multiple row mosaics
- Lens distortions may not be corrected
- “Featureless” images can often cause positioning problems
- Perspective may not be adjustable
- Blending may be naïve
- No support for exposure/focus blending
- No support for manual blending to resolve “problem areas”
PTAssembler

- How hard could sticking a bunch of pictures together be?
- 8 years, 100000 lines of code, many hours!
PTAssembler Conceptual Overview

- Identify common features (control points) in overlap region
- Use control points to deduce camera position for each image in scene (and deduce lens distortion amount).
- Remap (warp) images using position information and desired output projection
- Blend remapped images into a final panorama.
- Crop and adjust.
PTAssembler: Source Images

6 Component Images can't be aligned by simple positioning
Manual Positioning Won't Work

- Some portions of images align, but not all parts of all images
- Something more sophisticated is needed!
PTAssembler: Identify Control Points

- Control points identify common features in overlap regions
- Can be created manually (by you) or automatically (the computer)
PTAssembler: Deduce Position

PTAssembler uses the Control Points to deduce the position (yaw, pitch and roll) of each image in the project
PTAssembler: Image Position

- Yaw: Left / Right
- Pitch: Up / Down
- Roll: Rotation
PTAssembler: Aligning Images

Once the positions are known, the images can be “warped” and positioned on a spherical surface (shown here in 2 dimensions) where they are perfectly aligned.
PTAssembler: Projection

- The image on the spherical surface is “projected” onto a 2 dimensional surface, using the user's chosen projection.
- The net result is that original images have been significantly “warped” to allow images to align perfectly.
Projection in a Nutshell

- Rectilinear projection can “project” one hemisphere (180 degrees) onto a 2 dimensional surface.
- Imagine a light source originating at center of translucent sphere, projecting onto a flat surface.
PTAssembler: Rotating The Sphere

- If desired, the sphere can be rotated (imagine rotating a globe) before projection
PTAssembler: Different Perspectives

- The position of the images on the spherical surface alters the final perspective
PTAssembler: Perfect Perspective

- Perspective can be adjusted “by eye” or more accurately using horizontal and vertical line control points
- The correct positioning on the sphere ensures perfect perspective
Theory vs Practice: In practice, residual misalignments and color/light differences require “sophisticated” blending to disguise
PTAssembler: Blending

- Intelligent blending: “Multiresolution spline”
- Fine detail (e.g. brickwork) is blended over a narrow transition to minimize “ghosting”
- “Featureless” areas (e.g. sky) are blended over a wide transition to help smooth color/brightness discontinuities
- Seam line is chosen to minimize evidence of misalignments/motion
- PTAssembler uses:
  - Enblend
  - Smartblend
PTAssembler: Final Result

- Cropping: PTAssembler determines best cropping region
- Final adjustments to taste!
PTAssembler: Single Images

- All the examples shown here are for panoramas comprised of multiple images, but...
- PTAssembler can create “single image panoramas” that allow you to apply any of the projections, distortion corrections, perspective adjustments and other features to a single image.
Distortion

- Very overused term...means different things to different people!
- Perspective “Distortion” is:
  - A “natural” consequence of using wide angle rectilinear lenses
  - “Distortion” in an artistic/visual sense, but not in a mathematical sense
  - Can be manipulated/adjusted via projection choice
Distortion

- Optical Distortion: Deviation from mathematically correct projection
- Often visible in zoom lenses, particularly cheaper ones
- Can usually be easily corrected using software
More About Perspective Correction

- Standard camera: Vertical lines converge or diverge if camera is pointed up or down
- Standard camera: Horizontal lines converge or diverge if camera is pointed left or right.
- Software allows for the “correction” of perspective, similar to (but more flexible than) “shift” lenses
Perspective Control

- 10 (handheld) images taken from ground level pointing up towards top of multi-story building
Perspective Control

- Top image: Rendered as seen from ground

- Bottom image: Rendered as seen from “head on”
Perspective Control

- Ability to manipulate panorama to ensure vertical and horizontal lines are positioned correctly
- Comes “for free” with panorama creation...perspective is explicitly determined by positioning of panorama
- Can be used to create images as seen from “impossible” locations
- No light falloff or other optical problems using software perspective control
- [http://en.wikipedia.org/wiki/Perspective_control](http://en.wikipedia.org/wiki/Perspective_control)
More About Projections

- Three dimensional world can be displayed differently on two dimensional surface (paper or monitor) using different “projections”
- Cartographers have used numerous projections for centuries
- Photographers traditionally have only used one projection!
Projections

- Most camera lenses uses “rectilinear” projection (sometimes called “gonomic” or “perspective” projection).
- Only projection that renders all straight lines in 3D world as straight in 2D image.
- Cannot represent images with field of view > 180 degrees.
Projections

- Cylindrical projection (used by some rotating/scanning cameras) can handle scenes with more than 180 degrees
- Horizontal lines above or below the horizon are “bowed”
- Vertical lines are straight
Projections

- Numerous other projections can be created by software, unavailable/impossible with hardware (camera lenses)
- “Rectilindrical” projection...a configurable hybrid of rectilinear and cylindrical (shown here with a 130 degree scene)
Projections

- “Recti-perspective” projection can display up to 360 degrees (180 degrees shown here).
- Radial lines (converging towards vanishing point) are straight.
- Vertical lines are straight, horizontal lines are curved above or below horizon.
Projections

- “Recti-cylindrical” hybrid projection: Rectilinear in one region, gradually transitioning to cylindrical in another region.
- This image covers more than 200 degrees, but retains straight lines in Jefferson Memorial and steps.
Projections

- Different projections can be used to inject a little photographic humor!
- 180 degrees, “rectilindrical” projection
Stacking Images

- Images can be “stacked” to overcome camera limitations
- Focus stacking ("focus blending") allows creation of images with more depth of field than possible with any single image
- Exposure stacking ("exposure blending") allows creation of images with greater dynamic range than possible with any single image
Exposure Blended Images in Panoramas

- Bottom row of images captured twice, using different exposures
- Each image in bottom row was “exposure blended”
Exposure Blended Images in Panoramas

- Exposure blending (right) used on bottom row to control highlights. Differences visible in Coke machine and windows.
Focus Blended Images in Panoramas

- 116 source images
- 24 “focus blended” stacks
Focus Blended Images in Panoramas

- 261 source images
- 64 “focus blended” stacks
- 1 gigapixel
PTAssembler: Workflow
PTAssembler

- Panoramic Stitching software
- Fast image stitching, unlimited output size, image count
- Support for 20+ projections, different lens types, distortion correction, perspective adjustments, etc.
- Offers completely automated creation and/or complete manual control over:
  - Control point creation/location
  - Image Positioning/optimization
  - Blending
  - Stacking
- Support for numerous plugins, file formats, etc.
Presentation and Display

- After the panorama has been created, what next?
Displaying Images

- **Online/Web**
  - Resize for display
  - Zoomable viewers
  - Immersive viewers

- **Prints**
  - Mounting
  - Framing

- **Books**
  - Contain many square feet of printed surface
  - Can be used to display a single image
http://www.tawbaware.com/maxlyons
Online Presentation (2/2)

- http://www.maxlyons.net
Printing (1/3)

- Not my area of expertise!
- Continuous tone printing technology:
  - Oce Lightjet
  - Durst Lambda
  - Print at 200-300 pixels per inch
  - No paper or machines capable of printing more than 72 inches in shorter dimension
  - Prints on conventional photographic paper
- Inkjet technology:
  - May offer higher resolution?
  - Smaller paper sizes
Printing (2/3)

- WHCC (Minnesota)
  - Long and wide panoramic images
- A&I (California)
  - Large mosaic prints (dimensions larger than 30 inches)
- El-Co Color Labs (New Jersey)
  - Very affordable prints up to 60x30 inches
- EZPrints (Georgia)
  - Panoramic prints 6 or 12 inches tall
- Dugal Photo Lab (New York)
  - The “gold standard”: Big prints, big frames, big dollars
Printing (3/3)

- Face Mounted Plexiglass:
  - Aluminum back
  - Adhesive
  - Print
  - Transparent adhesive
  - Plexiglass

- 72 x 78 inches

- 1 gigapixel image had to be “shrunk” to ½ gigapixel to be printed at 300 ppi.
Printed Presentation

- Books
Sales/ Clients

• Sales via web site
  – http://www.tawbaware.com/maxlyons
  – http://www.maxlyons.net

• Clients
  – Collectors
  – Advertising
  – Corporate
PTAssembler: Coming Soon

- Assembling scenes taken from multiple viewpoints
Links and More Reading

- Software: http://www.tawbaware.com/
- PTAssembler: http://www.tawbaware.com/ptasmlbr.htm
- Photographs: http://www.tawbaware.com/maxlyons
- Photographs: http://www.maxlyons.net
- Latest Updates: http://www.tawbaware.com/maxlyons/cgi-bin/latest.pl?format=html
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