4D construction learning environment

virtual tour making

3. Equipment and software

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1 Overview

This guide is for project teams who are producing virtual tour surveys of a construction site that is to be included in the suite of online UQ 4D construction learning environment (4Dcle) sites. The overall goal of a 4Dcle project is to document the construction (or refurbishment) process of a selected building for (online) use in teaching and learning activities by educators and students of professions related to the construction industry.

The finished quality of a virtual tour is entirely constrained by the quality of the original photographic images. The aim of this guide is to provide a briefing, drawn from prior projects' experience, on minimum requirements, with some recommendations, for suitable photographic equipment and image processing hardware and software.

Separate guides cover the processes for a) establishing camera positions (nodes) on and around the site; b) panorama photography; c) processing the images – 1) stitching node images and rendering the panoramas and 2) assembling the panoramas (using PanoTour) into virtual tours. Download from http://4dconstruction.architecture.uq.edu.au/

2 Photographic equipment

Choosing photographic equipment for creating a 180 x 360˚ virtual tour (VT) needs consideration of a number of interrelated factors, beyond budget constraints. Key points:

- More photos per node (camera position) take more time to shoot and process but fewer photos limit the depth of field (and zoom capability) in the assembled virtual tour
    - Fisheye lenses, compared to e.g. wide angle lenses, tend to need fewer photos per node and produce images that are easier to stitch
- Sensor type in camera body matters to lens selection for field of view and diagonal angle of view as well as pixel density (image resolution) and related issues of colour depth, dynamic range and low-light ISO, all of which affect image quality.
    - Crop-frame sensors affect the field of view of a lens
    - Medium pixel density produces less 'noise' and thus quicker processing
- A stable tripod is essential and set-up time is minimised with a good levelling base but most important is the panoramic head, which should include marked rails and notched rotator and must permit adjustment of mounted camera and lens so that the entrance point of lens, at selected focal length, is centred over rotator
    - an adjustable manual spherical head is most versatile, although a fixed spherical head can work as well with a suitable fisheye lens

2.1 Lens

Lens choice for VT use is based on desired number of photos to be shot at each panoramic node (camera position). This includes deciding on suitable field of view or focal length (see https://www.lifewire.com/what-is-focal-length-493730 for easy-to-read explanation) and angle of view. With a:

- short focal length (e.g. circular fisheye, 4.5 mm on APS-C format sensor or with an 8 mm on a 24x36 sensor), the panorama can be shot in 3 photos but the panorama after stitching is likely to be small and lack depth
- long focal length (such as 14mm wide angle prime), you will need to shoot two horizontal rows of 8 images plus the zenith and the nadir (18 photos) to compensate for loss of field and angle of view
- full format fisheye (e.g. a 10.5 mm on an APS-C sensor or, depending on the brand, a 15 or 16 mm on a 24x36 sensor), in portrait position will shoot a full panorama in 6 horizontal shots, plus one shot each at zenith and nadir for a complete sphere.

2.2 Sensor and Camera body

The sensor in the camera body is also relevant to lens selection. A full frame sensor will not affect the focal length of the lens. However, a crop-frame (APS-C) will affect the field of view by the sensor's crop factor. For most Canon APS-C sensors the standard crop factor is x1.6,

Nikon uses x1.5 and Olympus uses x2. The image below (sourced from http://www.peachpit.com/articles/article.aspx?p=2264647&seqNum=5) demonstrates the different outcomes using Canon kit.

Figure 1: Comparison of full frame and crop-frame sensors

The image area outlined by the red border represents the photograph produced using a 17mm focal length on a full frame sensor. The area outlined in green represents the outcome using the same 17 mm lens on an APS-C sensor. The x1.6 crop factor results in a change in perspective roughly equivalent to using a 28mm focal length. The focal length is not actually magnified; rather, the sensor crops the lens field of view on all sides, changing the perspective captured and saved.

Sensor size and pixel density matter for resolution (sharpness of detail) and image size (zoom capacity in the virtual tour). While the number of Megapixels on a sensor corresponds roughly to pixel density, a higher pixel density may not translate into a better VT outcome. In spherical panoramic photography, particularly with fisheye lenses, focal length only corresponds with the field of view at the centre of the image. To the sides, it is angular distance from the optical axis that maps to a linear distance on the sensor i.e. compressing objects at edge of image and darkening image corners (vignetting). The smaller the pixel, the less light falls on it at any aperture, so although optical vignetting can be partly compensated by adjusting focal length and aperture, pixel vignetting cannot (https://photographylife.com/what-is-vignetting). Standard size sensors in 20-25Mp range usually have adequate pixel and image size.

The figure below shows how different focal lengths (e.g. on the Canon EF 8-15mm f4 L F/Eye Zoom) map to a full frame (35.9 x 24 mm) versus a x1.6 crop frame (22.5 x 15 mm) sensor.

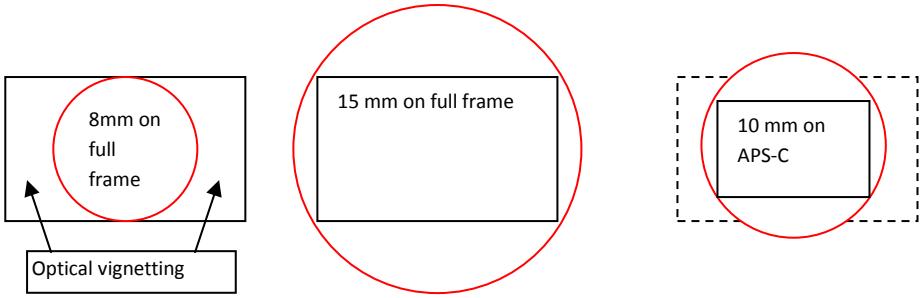

Figure 2 Mapping of focal length to alternate sensors

The Canon APS-C sensor provides a maximum resolution of 5472 × 3648 pixels. The standard full frame (35.9 x 24 mm) provides resolutions up to 6240 x 4160 pixels.

In general, to achieve a reasonable quality zoom capacity in a virtual tour viewed on a PC monitor (e.g. 1280×720 pixels), the stitched panorama image needs to be 12-17,000 pixels wide. The stitching process will consume 20- 30% of each image in overlap, discounting any vignette cropping. Taken vertically (portrait) with appropriate lens and focal length, 6 shots around the rotating axis should be sufficient, even on a crop-frame sensor. A zenith shot, however, will improve overall outcome, especially at interior nodes.

Recommendation

For 180x360° panorama, 6 photos (zenith & nadir additional) on a 20-25 Mpx sensor with

- 10mm fisheye e.g. Canon 8-15mm Fisheye, Nikkor 8-15 mm Fisheye or Nikkor 10.5 mm DX on APS-C sensor camera body e.g Canon 70D or 760D , Nikon D7200
- 14-15mm fisheye e.g. Canon 8-15mm Fisheye, Nikkor 8-15 mm Fisheye on full frame sensor camera body like Canon 5D Mark IIV or Nikon D610/D750

2.3 Tripod and head(s)

A tripod is essential for level shooting at nodes and ensuring a similar camera height perspective across each survey. The panorama head selection is important.

2.3.1 Tripod Legs

While anything reasonably stable with adequate load capacity could do, look for a light weight tripod, with adjustable height (to at least 1.5 m) that provides a solid platform for the panoramic head, your camera and heaviest lens. An integrated levelling base or a central tilting column is desirable. Check before purchase that the panoramic head of your choice and, if video is in your shooting plan, the video head, can be easily mounted on the tripod.

Suggestions include models from Manfrotto (e.g. BeFree) and Benro but others are available.

2.3.1.1 Levelling base

Set-up time is minimised with a good levelling base so, if not already integrated in the tripod or your choice of head, consider purchasing one e.g. Manfrotto 338 or Benro LBA2 levelling base. Main criteria to look for are

- stability
- accuracy to +- 5°
- quickness of set-up
- weight and bulk.

2.3.2 Panoramic head

The panoramic head is a key item in the rig for the 4Dcle virtual tour surveys. The head should include marked rails and a notched (click stop) rotator and must permit adjustment of the mounted camera and lens so that the entrance point of the lens at any selected focal length (no/least parallax point) can be centred over the rotary axis of the head (rotator).

There are three categories of panoramic heads:

- Cylindric heads - two stages slide at 90°, enabling mono-range panoramas
- Spherical heads - two stages slide but one is placed on a tiltable arm, enabling multi-range panoramas
- Motorized heads - enabling gigapixel multi-range panoramas almost automatically.

An adjustable, manual, spherical head is most versatile. For example, the Novoflex VR Slim System will handle single or multi-row shoots using a variety of lenses on light-medium weight camera bodies, and includes horizontal and vertical rotators, both with click stops.

A fixed spherical head (mostly for pole use) can also work on a tripod, with a suitable fisheye lens. These mono-range heads tend to be lighter in weight and have fewer moving parts, although a rotator is essential. For instance, the Fanotec Nodal Ninja R series (with various models like R1 or R20 package) uses a fisheye lens-specific ring clamp with optional adaptors for zenith or nadir shots. Available in static and adjustable tilts (R1) with rings to fit most fisheye lenses, this series is suited to ultra wide fisheye lenses (like Canon 8-15mm) shooting very quick panoramas (4-6 shots), such as the 4Dcle surveys.

Recommendation
Nodal Ninja R Series (like R20 package or R1, both with optional adaptor for zenith shots). Rotator R1 has an adjustable tilt option on head. NB: Do not order/purchase prior to selecting and testing fisheye lens.

2.3.3 Video head

If the project teaching and learning activity plan (story board) includes video of e.g. interviews with key personnel or specific construction processes (not suitable for time-lapse photography and image processing), you will need a video head. There are pros and cons for

each variety including fluid heads. If you have selected a Manfrotto Befree tripod, a Manfrotto Befree video head might be on the list. Check https://www.imaging-resource.com/articles/smooth-operators-10-top-rated-video-tripod-heads for reviews prior to making a choice.

2.4 Other Accessories

One or more additional lenses are needed for general purpose photography, such as individual equipment scenes or video of processes and interviews. Most camera bodies come packaged with a general purpose lens. Negotiate for a lens that suits the project (story board purposes). Suggestions are:

- For APS-C cameras:
    - All-purpose: Canon EF-S 18-135mm IS STM f3.5-5.6 or, for Nikon body, Nikkor 18–200 mm f/3.5–5.6 Zoom
    - Wide angle/low light e.g. Canon EF-S 10-18mm F4.5-5.6 IS STM Zoom
- For Full frame cameras
    - All-purpose: Canon EF 24-105mm f/4L IS II USM Lens or AF-S NIKKOR 28-300mm f/3.5-5.6G ED VR
    - Wide angle/low light Canon EF 24-70mm f/2.8L II USM or 24-70 f/4L IS Lens or Nikon 24-70mm f/2.8G ED or Tamron's 24-70mm f/2.8 VC lens

2.4.1 Other useful items:

- SD memory card e.g. SanDisk Extreme Pro 64GB Micro SD 95MBS
    - Or two 32GB cards
- Flash unit for individual equipment scenes e.g. Canon Speedlite 600EXII-RT Flash unit or Nikon equivalent for Nikon body

3 Image processing software and hardware

There is a large supply of image processing applications, ranging in ease of use as well as price. Generally, the software for stitching and rendering the panorama images is a separate application to the software for linking the panoramas into virtual tours. All of these softwares put significant pressure on the hardware used. A PC with 64-bit operating system using 2Ghz processor, multi-core processors and a recent graphics card (Graphics Processing Unit: GPU) is a time-saving boon.

3.1 Process 1: Stitching and panorama rendering

Among applications for stitching and rendering panoramas, AutoPano, PTGui and Hugin are well-regarded. Hugin is a free, open-source, application, with both a good reputation and large community of users providing tips and troubleshooting help. The user interface is not very friendly. Many key actions are done manually and require intermediate or better skills in both photography and photo-editing. PTGui is towards top of the range in price, offering

functionality, with an unfussy interface, aimed at professional users. The main competitor, AutoPano has specialised more towards automated processing in a user friendly interface. For 4Dcle purposes, the 'regular' versions are quite adequate.

Recommendation

- AutoPano Pro (or Giga) for stitching and rendering panoramas

3.2 Process 2: Creating survey virtual tours

The 4Dcle has been tailored to the specific format and structure of Kolor PanoTour VT output. There is no current plan to adapt the site build process to other output formats.

PanoTour comes in two versions: 'regular' without krpano license and Pro including a full krpano license. For 4Dcle project needs (minimum processing and no graphical embellishments), the Pro version is both more expensive and over specified. So, unless later plans include developing and publishing other virtual tours outside the 4D 'stable', the regular PanoTour version is all that is needed.

Required

- PanoTour for creating virtual tour data files for the 4Dcle build scripts

3.3 Hardware for image processing

Considerable time can be spent waiting for processing outcomes in both the panorama and virtual tour rendering processes. To minimise this type of processing time over the project, access to a PC using a 64-bit operating system, 2Ghz processor, with multi-core processors, minimum 2Gb of RAM and a recent graphics card (Graphics Processing Unit : GPU) is very helpful. See http://www.kolor.com/wiki-en/Enhancing_Autopano%27s_performance for latest tips on enhancing computing performance.