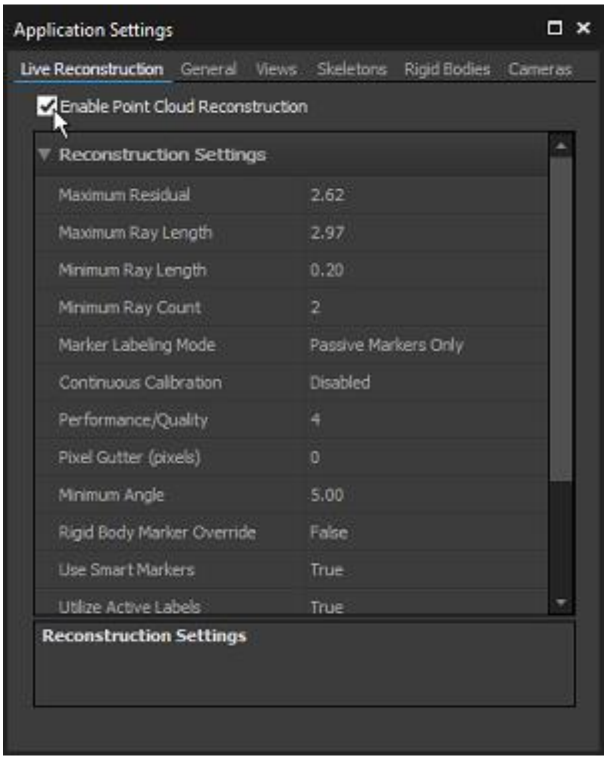
Section x: Precision capture theory

If the cameras are too close to one another, they can reflect IR light on one another, or on objects that are too close. Inversely, if they are too far, the IR light does not reach the object. The camera might also be out of focus at certain distances, which makes it difficult to differentiate markers from extraneous reflections. All these problems contribute to identifying if a reflection is in fact a marker, or distinguishing markers from each other.

Various solutions exist. First, we wish to have a clear image on the camera. The lens can be refocused. The LED intensity can be varied, as well as exposure. After these hardware solutions, the camera itself processes images with 2D Filters: discarding reflections if they do not fall in a correct size range (size threshold) and if they do not have sufficient circularity (minimum circularity). The THR setting or threshold for brightness, also determines the pixels based on their illumination intensity. What is interesting is that these filters are applied frame by frame, and therefore cannot benefit of any reconstruction over time.

Reconstruction is the process of deriving 3D points from the 2D coordinates that are obtained from camera images. This process first obtains centroid locations from one camera's individual frames, and then use each camera's centroid to triangulate a 3D position in the capture area. Various means of precision are done, and they stem from a 3D vector extending from each camera origin to its detected centroid, otherwise called a marker ray.

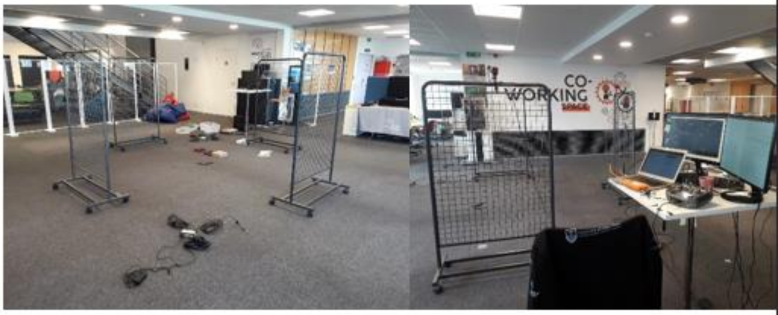
The average offset distance between the converging rays gives us a precision rating, called the residual value or mean residual. A maximum residual can be set as a "reconstruction" software setting. The length of the 3D vector also has importance, as "middle-range" lengths are preferred over "too-close" or "too far" (more likely to blur). Adding these two thresholds give two of the software filters post-reconstruction.



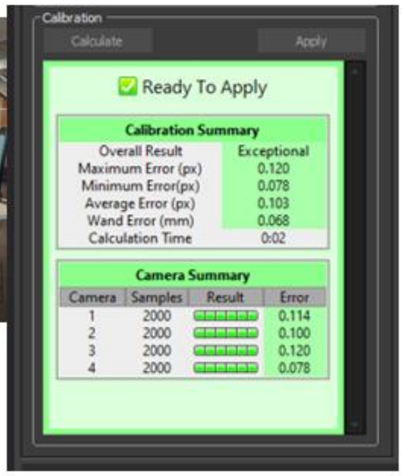
Having said this, there have been compromises that are made in the interest of reducing the amount of computation and thus risks to reduce system latency and system frame rate. The camera, by default, is in Object Mode, which means that 2D object metrics (the centroid location, the size of the markers and the roundness of the markers) are determined on-camera as the software filters mentioned earlier. This has the lowest processing latency as opposed to Precision Mode, where the marker reflections and centroid regions are sent to the host for more precise but more computationally expensive processing. This is acceptable in lower camera count environments.

The use of a camera in grayscale helps to understand what is going on, thus two Reference Modes are possible. MJPEG grayscale compresses images on-camera while raw grayscale remains uncompressed (to the risk of high streaming bandwidth).

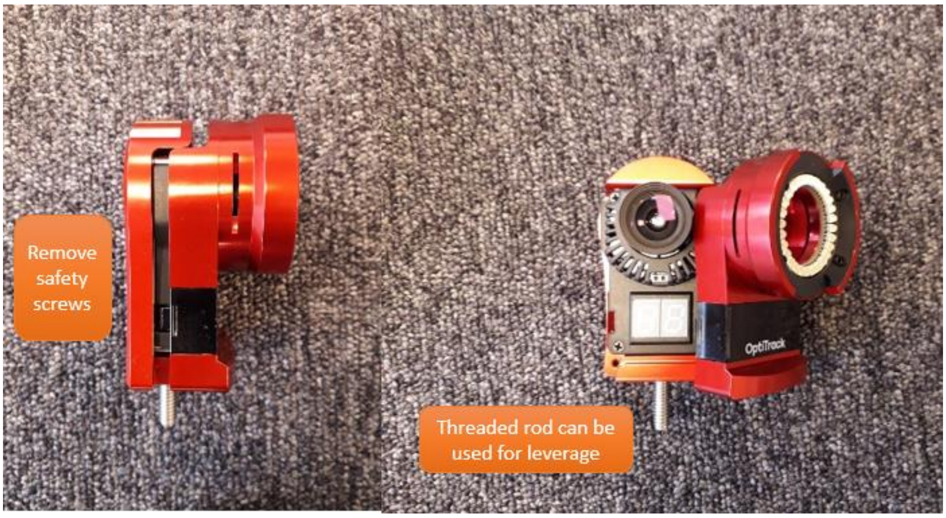
It is worth noting that a 4x4 setup with full sunlight illumination has proven to work with results seen below (see calibration section below to understand the criteria). It is at your own discretion to check if markers are detected, ***via Motive's grayscale option***. At the DVIC, we chose this second configuration as a more permanent option.



A 4x4 setup that has worked for us.



The IR reflections are not the only problem: bad camera configurations might blur the markers (poor lens focus) or contrast them poorly (poor exposure/threshold limit). This will end up affecting the calibration algorithm as it will compute the centroid of each marker badly, as seen below. For lens focus, you will need to open the camera's front casing and adjust focus directly while comparing to live output on Motive.



Removing the camera cover for lens refocusing

DVIC Note: the casing is fit very tightly, so be careful, these are $999 cameras. Ask for help from those who have focused the lens before.

DVIC Note 2: removing the casing also means there is no LED illumination of the markers. You might want to use a second camera to illuminate the markers.

Exposure and threshold values can be configured afterwards via Motive as such.

CAMERA BODY

- Width: 2.12 inches (53.8 mm)
- Height: 3.19 inches (81 mm)
- Depth: 1.67 inches (42.4 mm)
- Weight: 6.60 ounces (187 g)
- Mounting: 1/4"-20 tripod thread
- Status Indicators:
  - 2 digit numeric LEDs
  - 1 bicolor status LED

IMAGE SENSOR

- Pixel Size : 4.8 µm × 4.8 µm
- Imager Size : 6.144 mm × 4.9152 mm
- Imager Resolution : 1280 × 1024 (1.3 MP)
- Frame Rate: 30-120 FPS (adjustable)
- Accuracy: Sub-millimeter
- Latency: 8.3 ms
- Shutter Type: Global
- Shutter Speed:
  - Default: 500 µs
  - Minimum: 20 µs
  - Maximum: 7.5 ms (at 120 FPS)

IMAGE PROCESSING TYPES

- Object (Centroids)
- Precision (Grayscale)
- Segment (Thresholded)
- MJPEG Grayscale
- Raw Grayscale

LENS & FILTER

- Default Lens: 5.5mm F#1.8
  - Horizontal FOV: 56°
  - Vertical FOV: 46°
- Optional Lens: 8 mm F#1.8
  - Horizontal FOV: 42°
  - Vertical FOV: 34°
- M12 Lens Mount
- Adjustable focus w/ spring assist
- 800 nm IR pass filter
- Optional: 800nm IR pass filter w/ Filter Switcher

LED RING

- 28 LEDs
- 850 nm IR
- Adjustable brightness
- Strobe or Continuous Illumination
- Removable

INPUT/OUTPUT & POWER

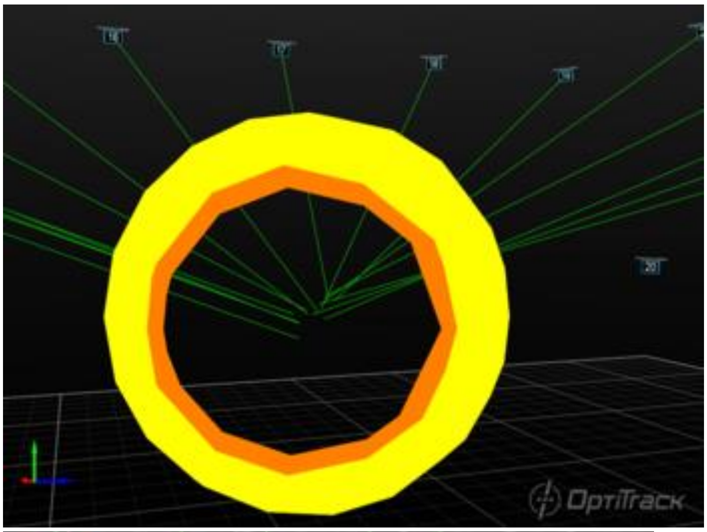
- Data: USB 2.0
- Camera Sync: USB 2.0 (via OptiSync)
- Power: USB 2.0 @ 1A

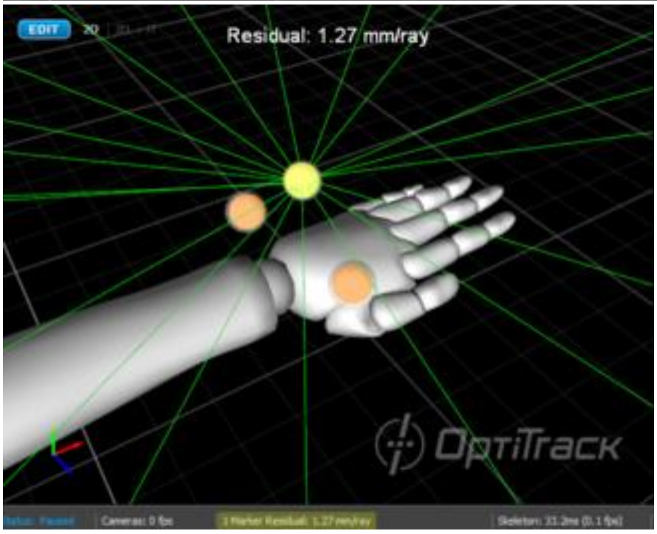
SYSTEM REQUIREMENTS

- Windows XP/Vista/7
- 1GHz processor
- 1GB of RAM
- 50MB of available disk space
- USB 2.0 Hi-speed port
- OptiHub 2 (required for IR LED power)

IN THE BOX

- 1 Flex 13 camera (part number: FL-13)
- 1 Quick Start guide





All these elements will have an effect on the computations during calibration. Before going into these, **we briefly overview the theory of precision capture to help us benchmark these calibrations.**

To define a

Residual error etc. Tabulated in the docs

Camera specifications