Computer Operated Photogrammetric Imaging System

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&

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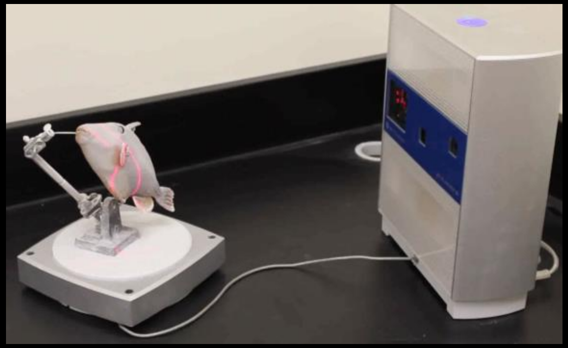
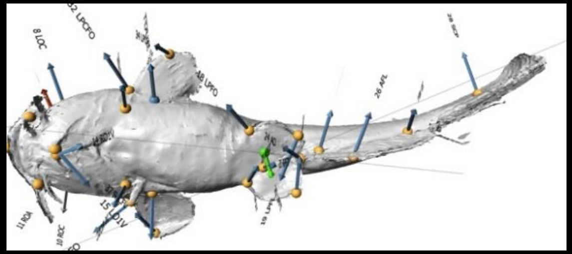
Background

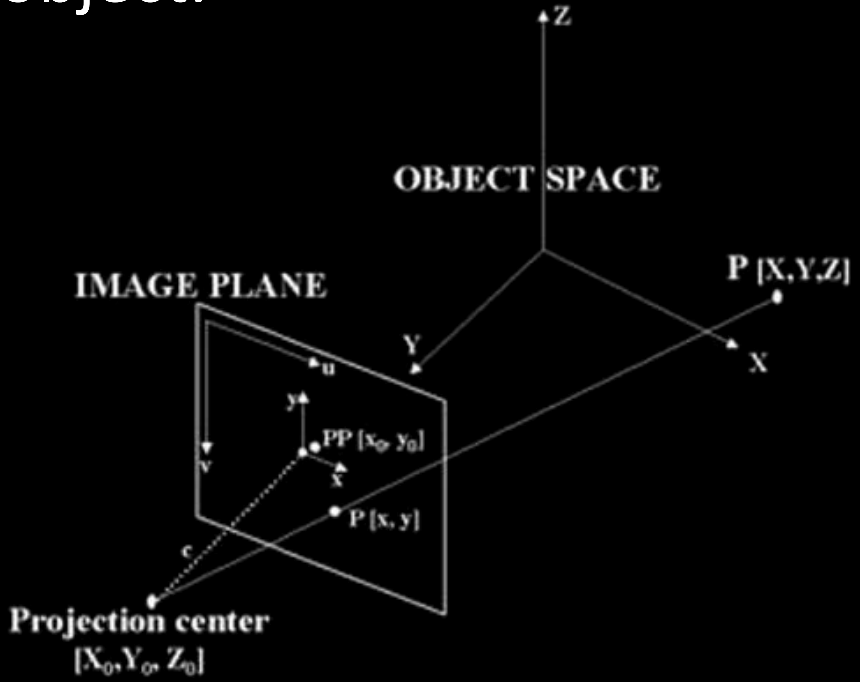
- 2010-2015: NSF Cyber-Enabled Discovery and Innovation-Type I: Machine Learning in Taxonomic Research
    - Proposed to build an annotated database of digital photographs (including dorsal, ventral and lateral views of each specimen) and laser scanned 3D surface models of select taxa from multiple fish families.
        - Species Identification
            - Images of categorized specimens representing *known* taxonomic groupings of fishes used to train a collection of statistical models to identify fish (family and species levels).
        - New species discovery
            - Images of specimens representing both *known* and *unknown* species used to train statistical models to diagnose unknown species as novel relative to known species.
    - Concluded laser scanning not ideal for fluid-preserved and/or non-rigid specimens.
    - Began experimenting with alternative techniques for 3D surface acquisition.

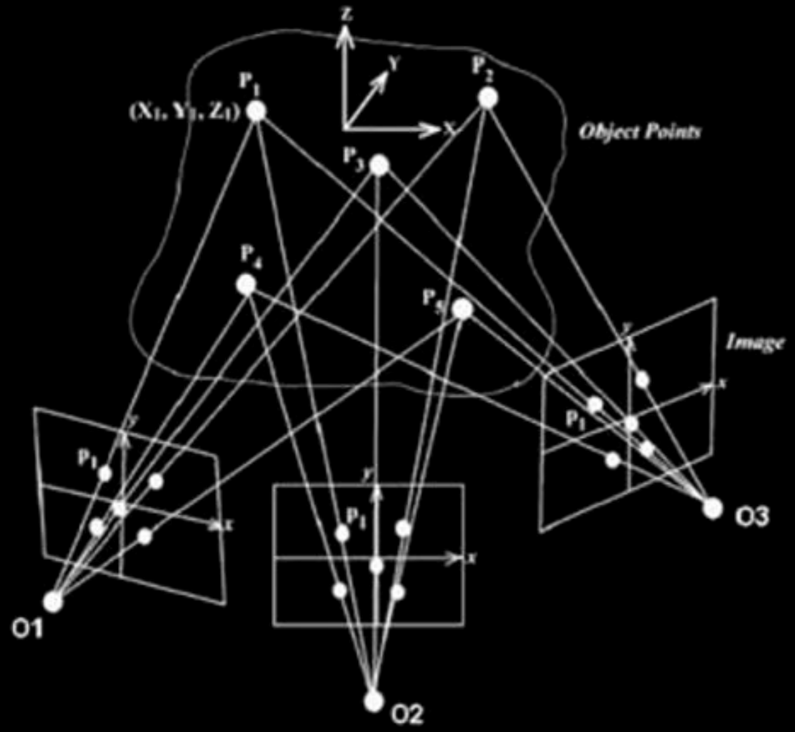




Photogrammetry

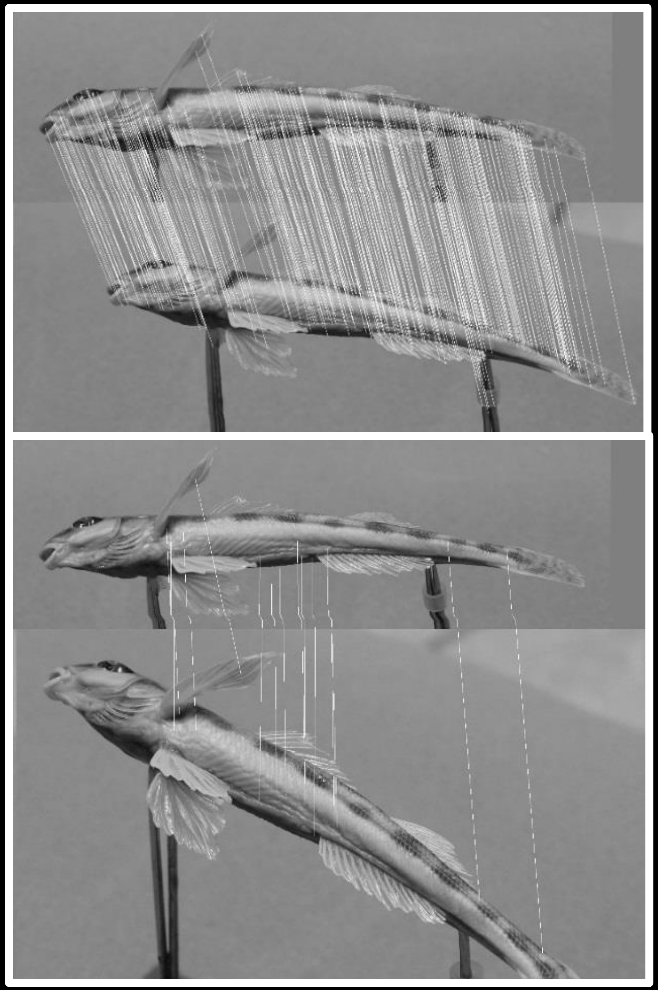
- Photogrammetry is a method of recovering the three dimensional position of points on an object’s surface from 2 or more photographs of the object.





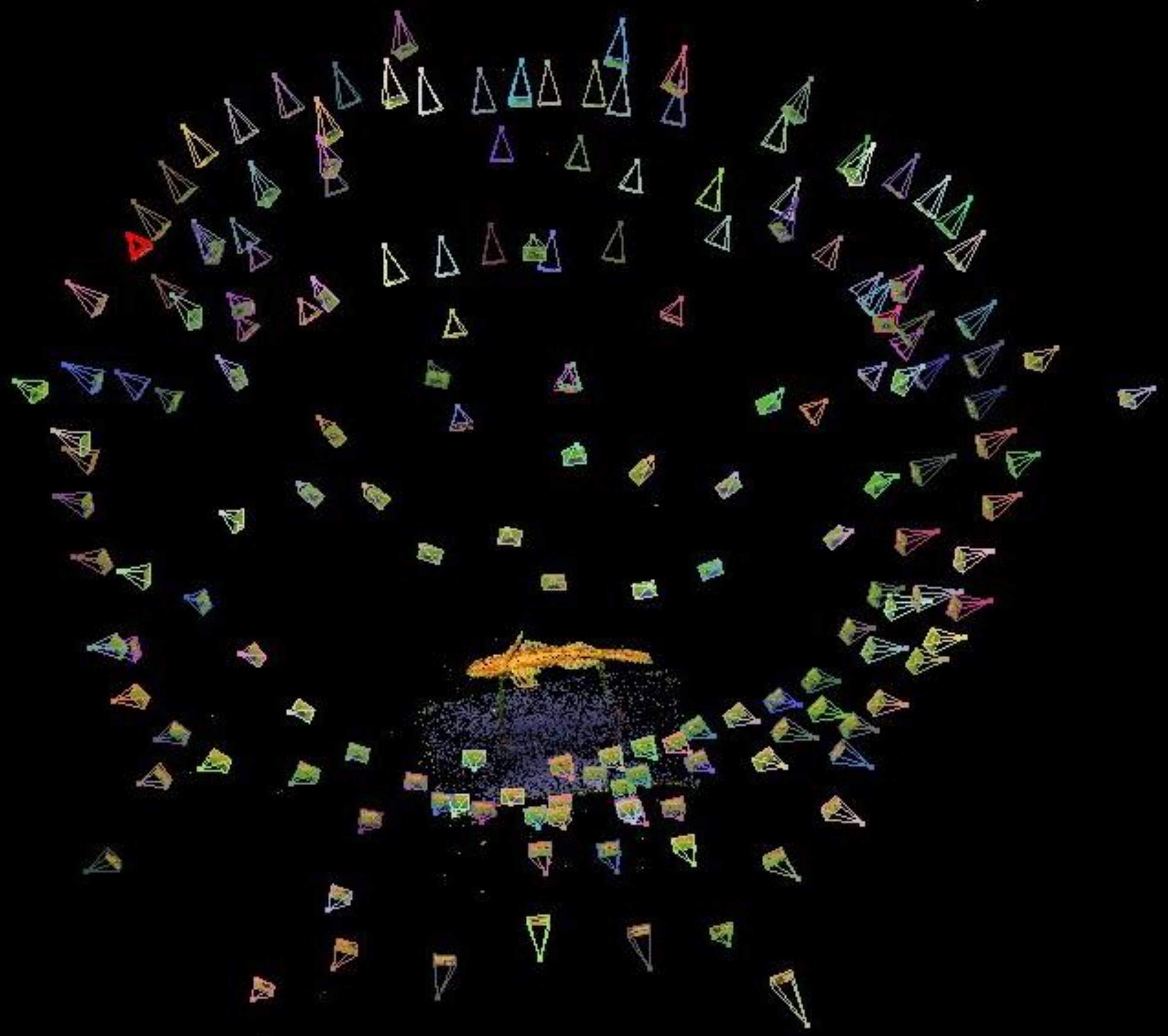
Defining & Matching Features

Features identified within an image using Scale Invariant Feature Transformation (SIFT). Scale and orientation indicated by arrows.



Matching keypoints between two pairs of images.

Results of SIFT feature detection, pairwise keypoint matching and Bundle Adjustment using Visual SfM ver 5.26.



Dense Reconstruction

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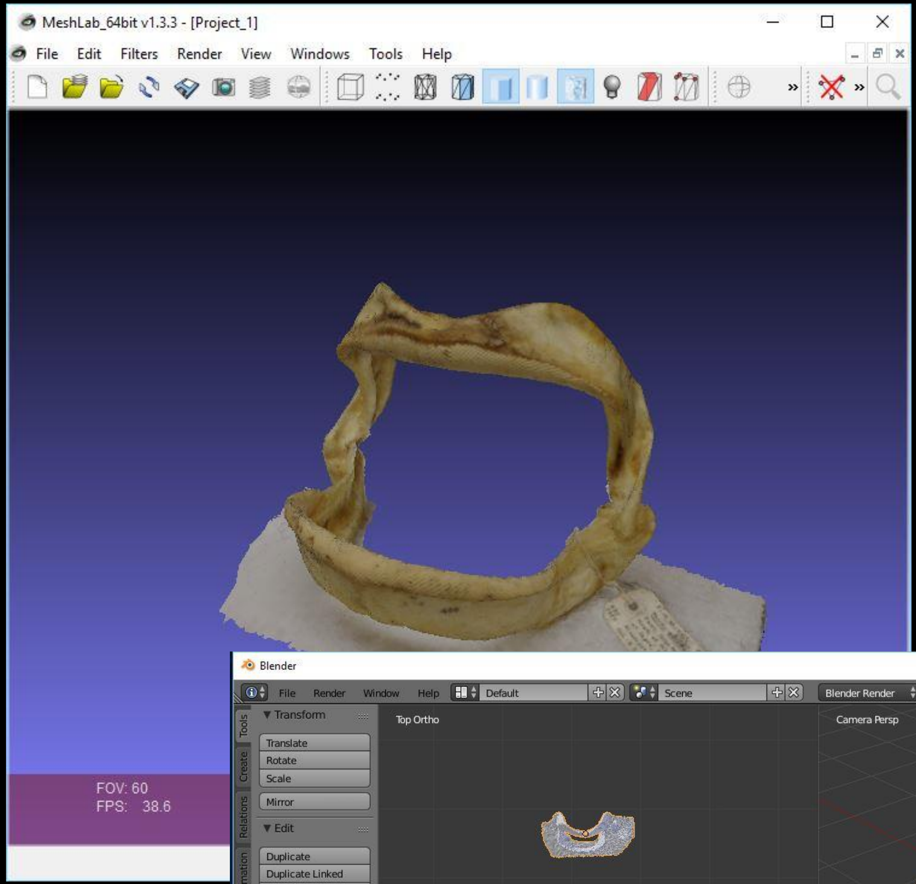
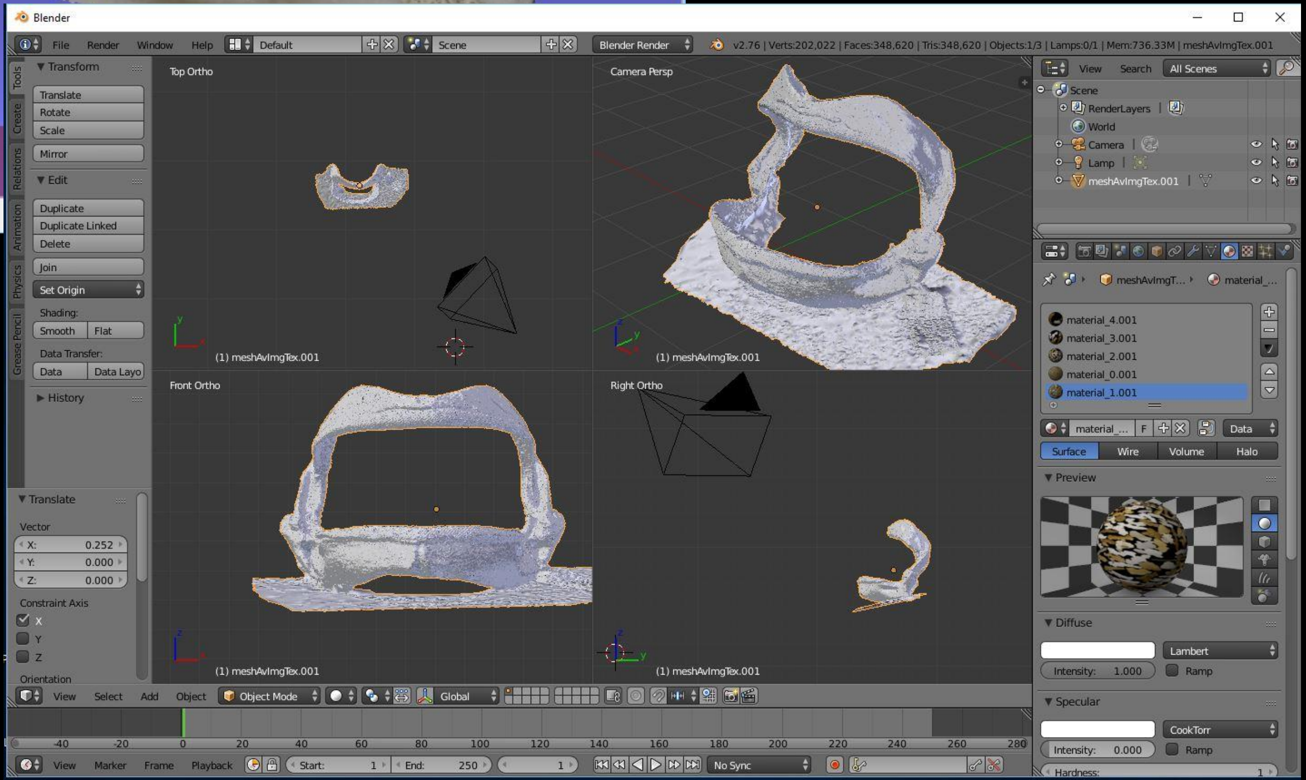
Processing input images
Loading input data
Resizing input images
Creating temp data
PSSGM autoScaleStep 2 4
nImgsInGPUAtTime 2, scales 2, gammaC 5.500000, gammaP 8.000000, subPixel 1, varianceWSH 4
Device memory - used: 694.415649, free: 3401.584473, total: 4096.000000
Device memory - used: 866.665649, free: 3229.334473, total: 4096.000000
PSSGM rc 0 of 64 elapsed time 1 minutes 28 seconds 3 miliseconds
PSSGM rc 1 of 64 elapsed time 1 minutes 20 seconds 791 miliseconds
```

CMPMVS - Multi-View Reconstruction Software

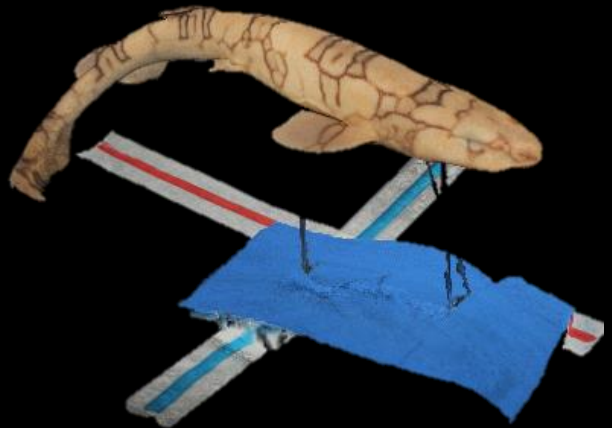
Authors: Michal Jancosek & Tomas Pajdla
Software written by: Michal Jancosek
Latest version: 0.6.0
Release date: September 28, 2012
Reference to cite:
[1] *M. Jancosek, T. Pajdla. Multi-View Reconstruction Preserving Weakly-Supported Surfaces*, CVPR 2011 - IEEE Conference on Computer Vision and Pattern Recognition 2011 (pdf).

Images & camera positions -> dense point cloud -> mesh -> textured mesh





Visualization
& Processing
with traditional
3D Software




Alternative workflows

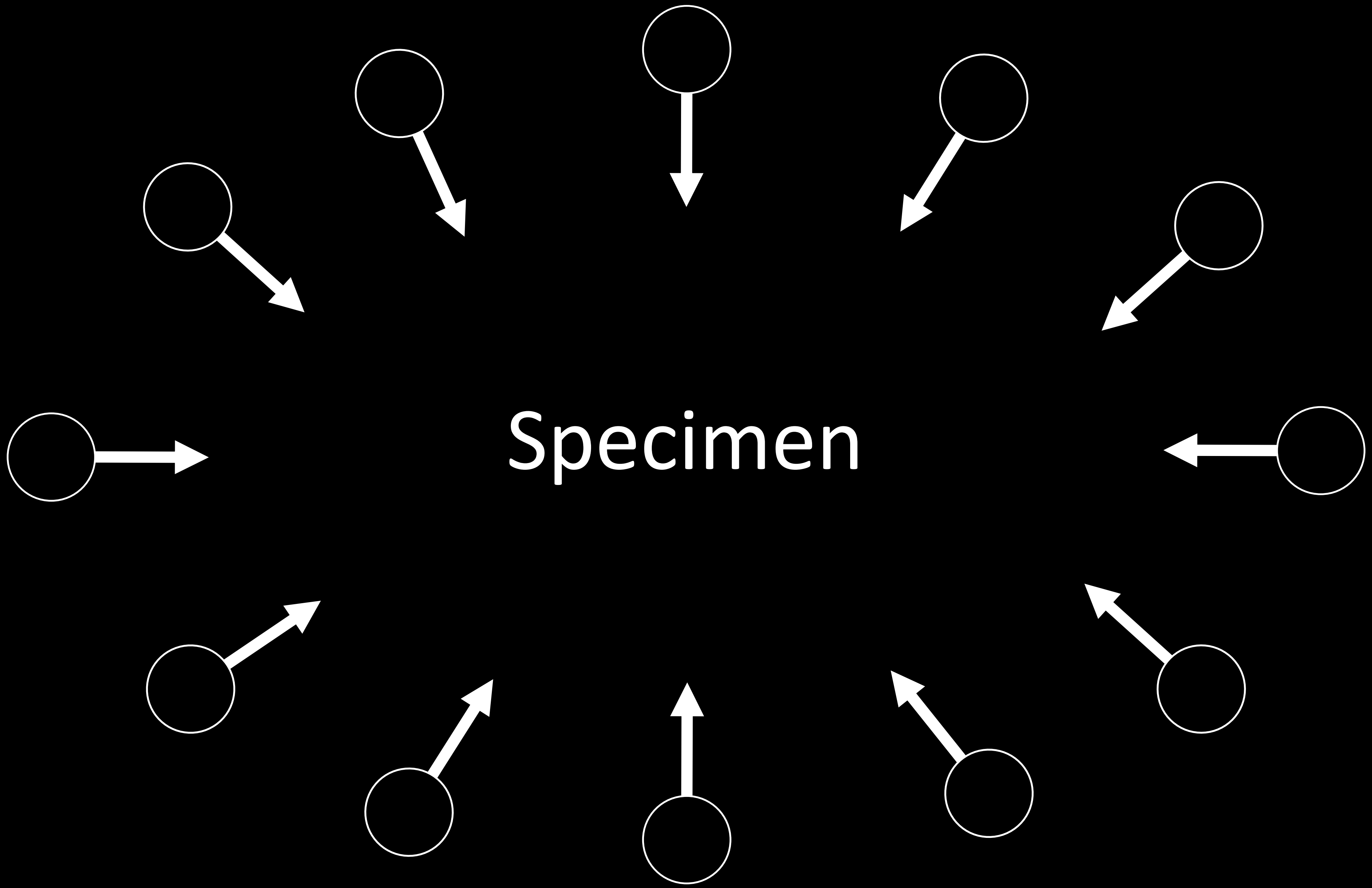
- AGIS Photoscan (proprietary)
- 3DSom (proprietary)
- Capturing Reality (proprietary)
- Python Photogrammetry Toolkit (open source)
- Theia Vision Library (open source)

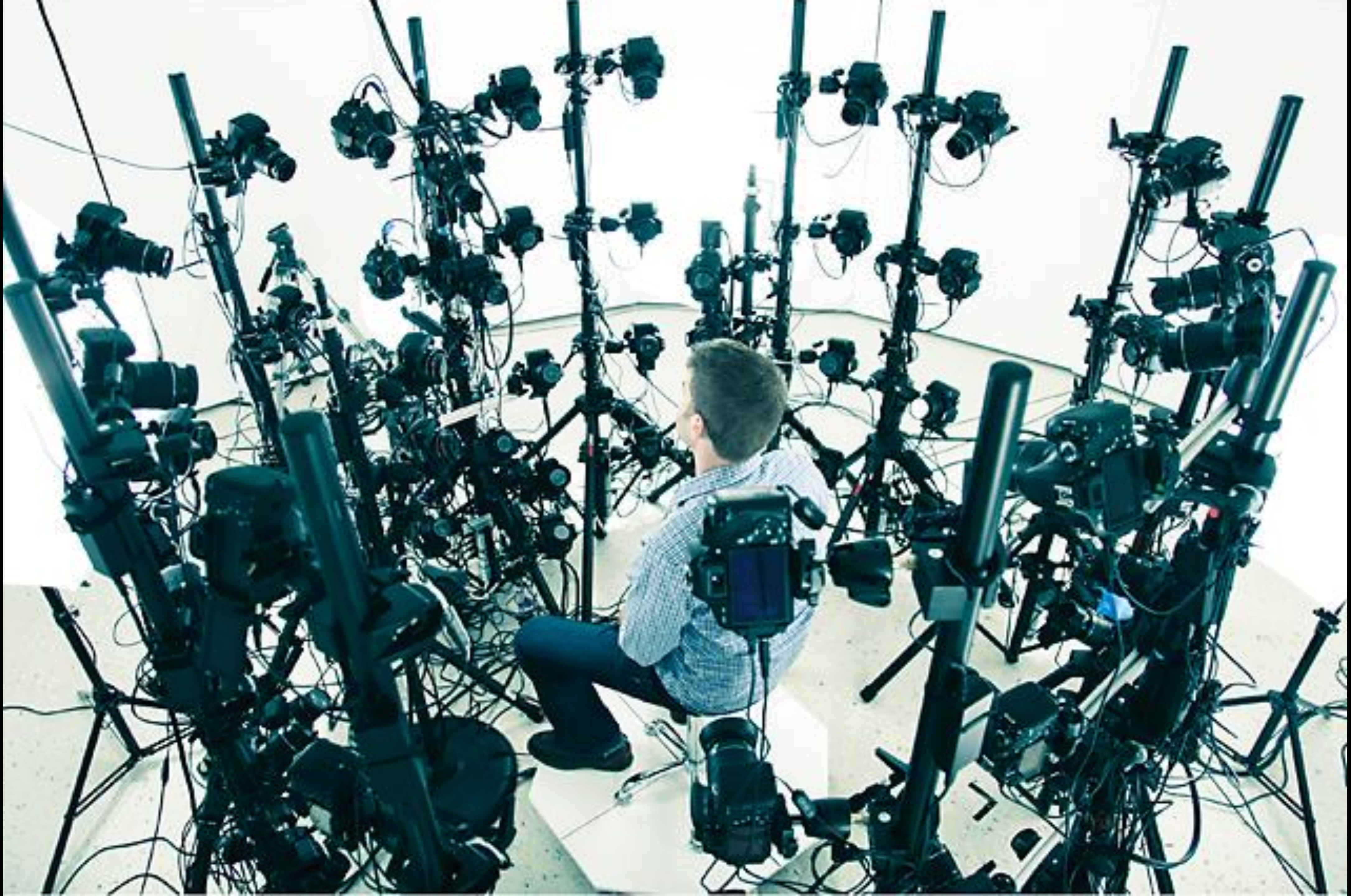
Photogrammetry

- Pros
  - Accuracy
  - Resolution
  - Color
  - Texture
  - Images can be re-processed as algorithms improve.
- Cons
  - Specimen Staging
  - Camera & Lighting Setup
  - Computationally Intensive
  - Some Post Processing & Clean Up is Usually Required

Best Practices

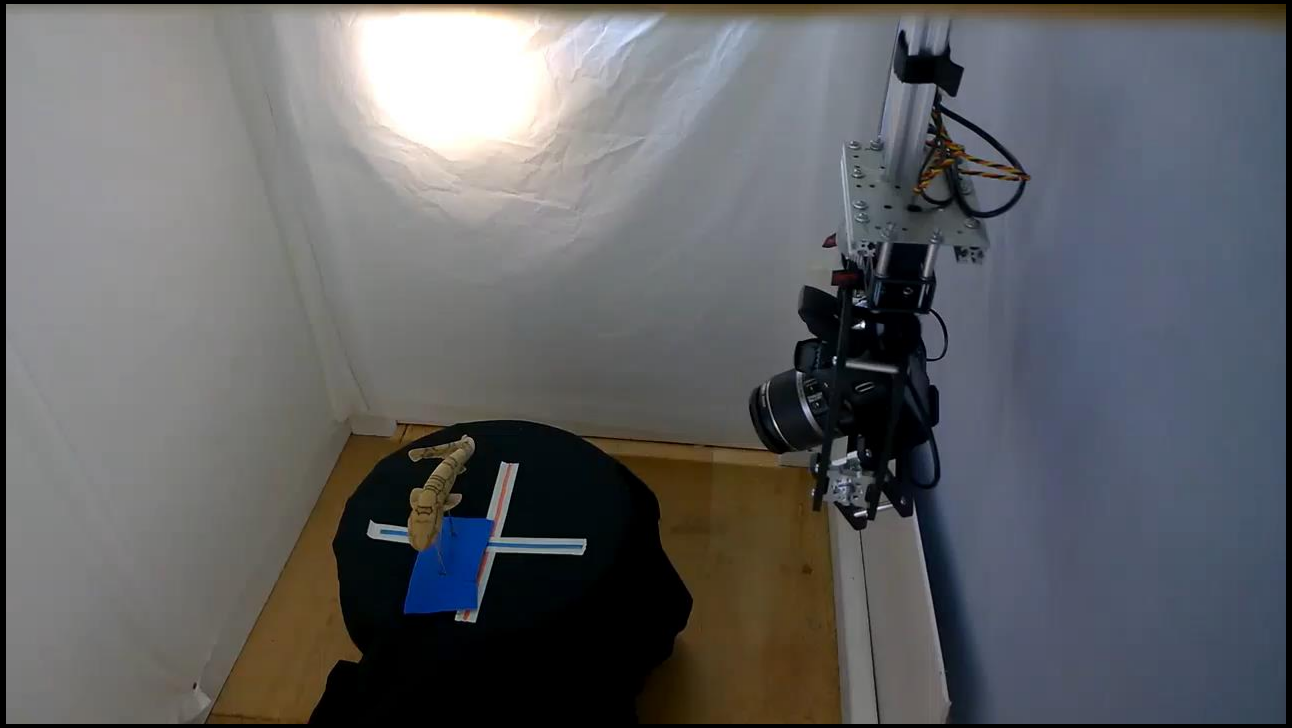
- Use high resolution photos
- Avoid blurred, out of focus photos of specimen
- Aperture should be high enough to result in sufficient focal depth
- Avoid specimens with un-textured, shiny, mirrored and/or transparent surfaces
- Avoid moving objects within the scene to be reconstructed
- Avoid any movement of the specimen


Specimen



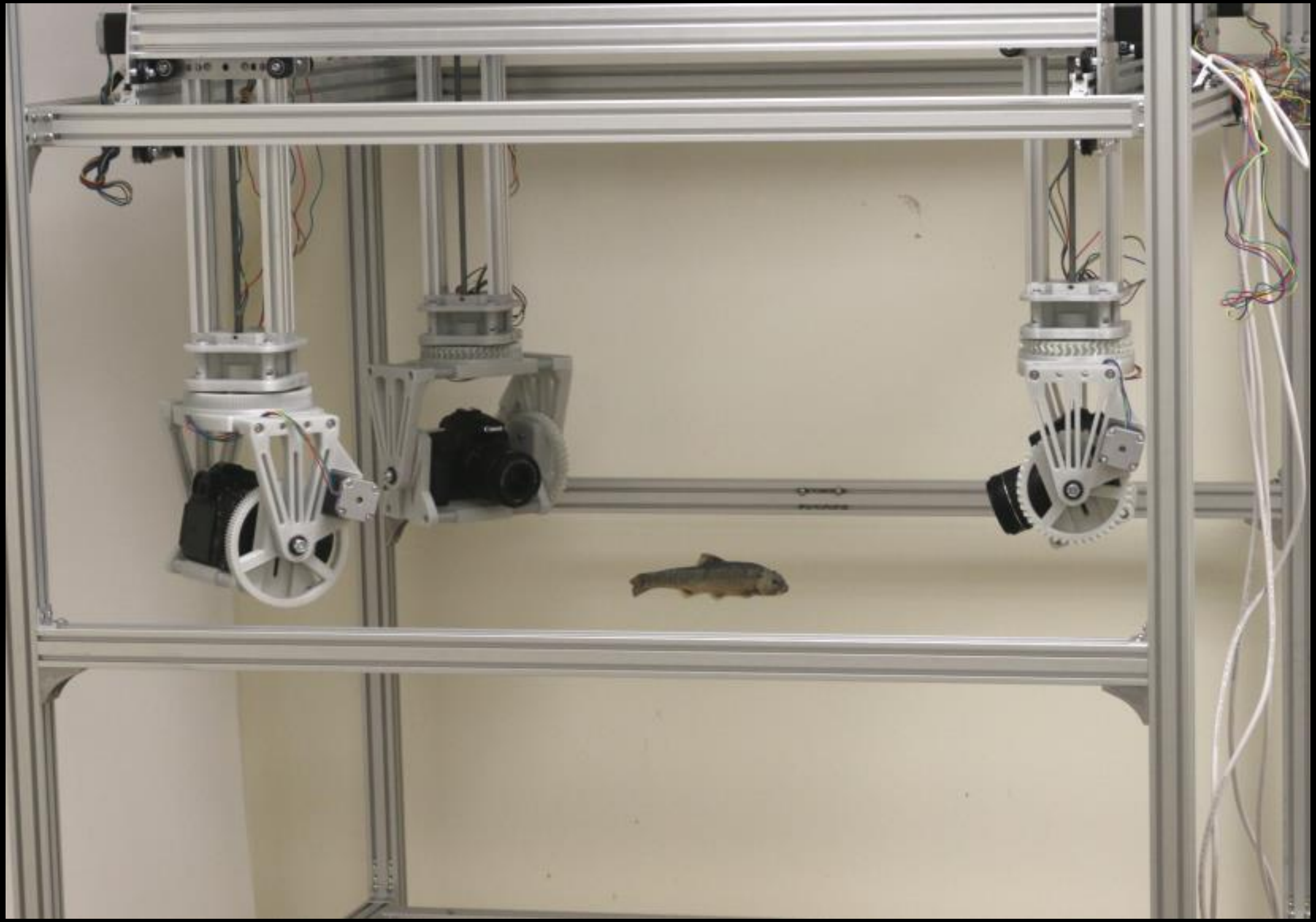
Automating Image Acquisition for Photogrammetry

- Design Principles:
  - Fast, high-resolution image capture
    - target of 5 minutes per specimen @ 200 photos
  - Accurate positioning of cameras
  - Scalable
  - Cost effective

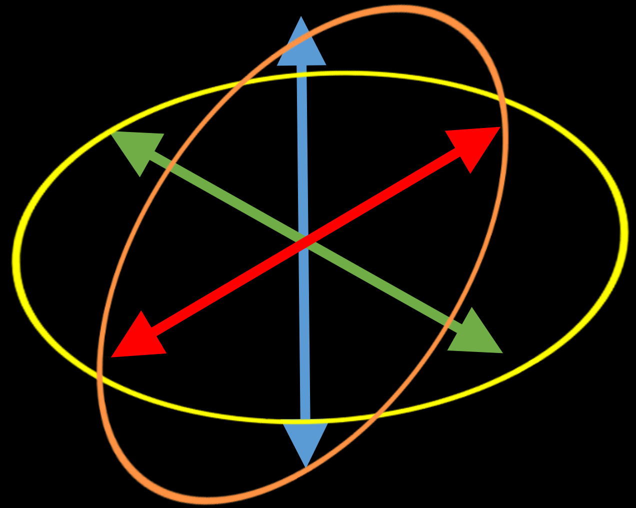


Early 1- Camera Prototype/Proof of Concept

Current Status

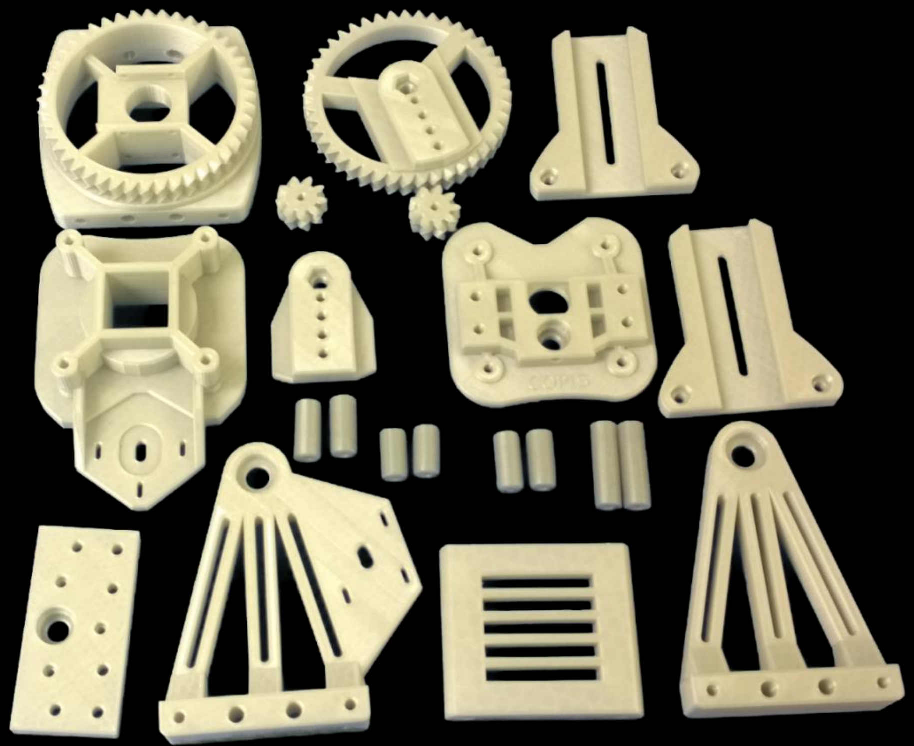


5 Axis



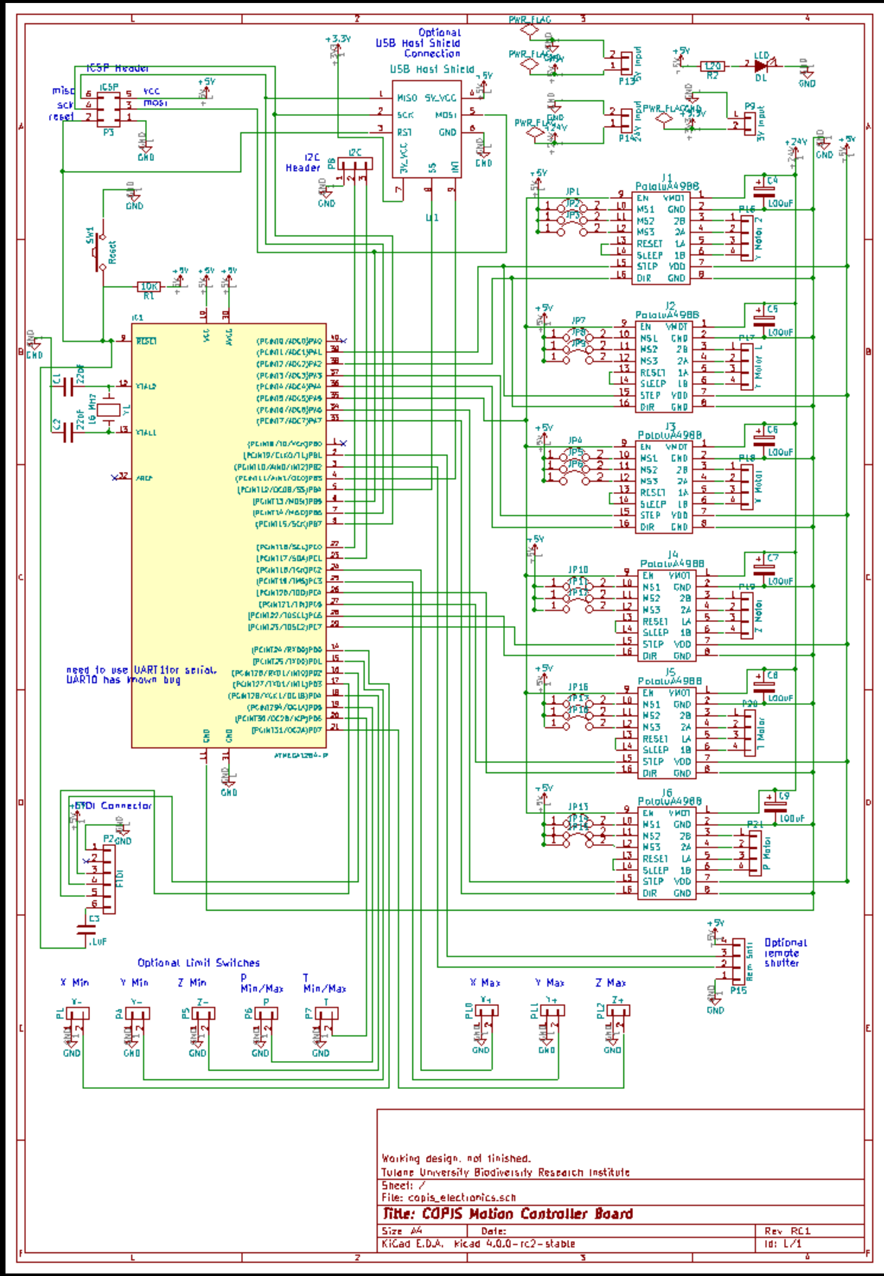
- Each axis driven by NEMA 17, 76.4 oz-in 1.8 degree/step stepper motors
- X & Y:
  - belt and pinion (.39um positional resolution at 1/16 stepping)
  - GT2 timing belt
  - 18 tooth pully
  - V-wheels on v-slotted aluminum extrusion
  - 1/8in Aluminum for linear carriage plates
  - paired motors on y-axis
- Z:
  - M8x1.25 threaded rod (6.25um positional resolution at full stepping)
  - V-wheels on v-slotted aluminum extrusion
  - 3D printed top and bottom plates
  - 1/8in Aluminum for linear carriage plates
- Pan & Tilt:
  - 3d printed Pan/Tilt
  - Modified from a design by Josh Sheldon (http://dcc.umd.edu/portfolio/jsheldon/)
  - 9:44 or 9:110 gear reductions (.023 or .0092 degree positional resolution at 1/16 stepping)
  - 1 inch hollow shaft for cabling to pass through

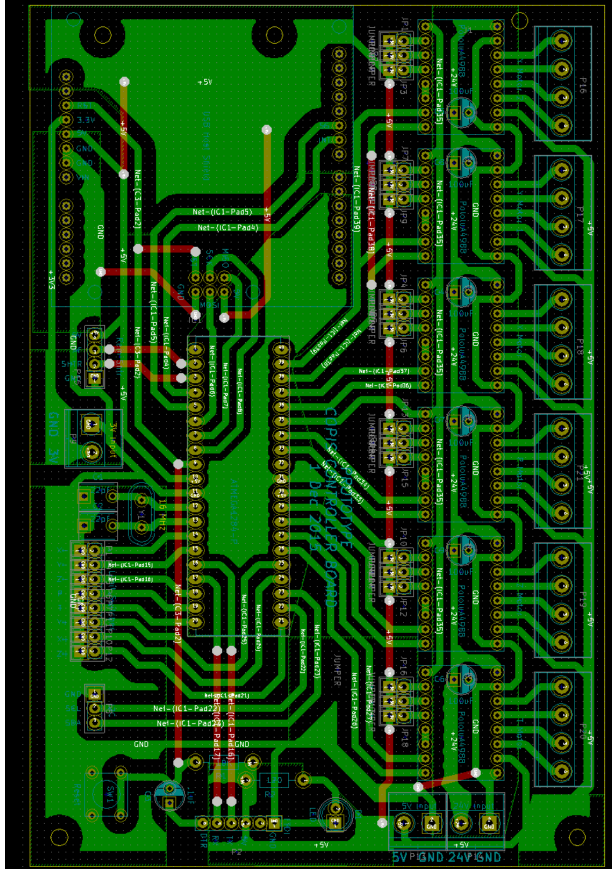
Pan and Tilt Camera Mount

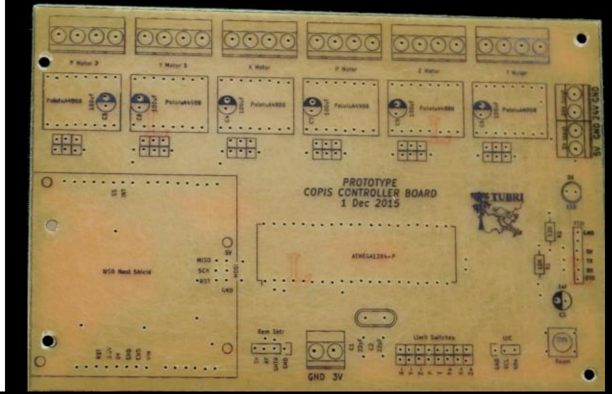


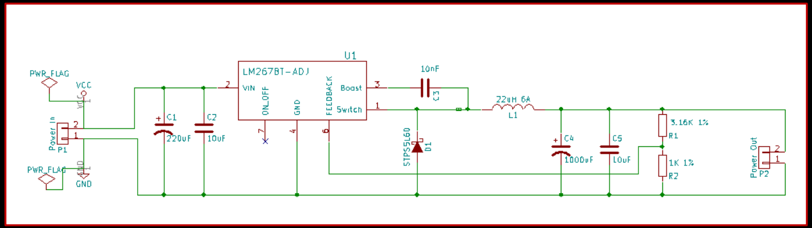
Electronics

- Designed for ease of production
  - DIY etching, milling or professional fabrication.
- ATMEGA 1284-P Microcontroller
- Allegro A4988 Motor Driver
  - Customizable Microstepping
    - Full, ½, ¼, 1/8 , 1/16 via jumpers
- Max 3421E USB Peripheral/Host Controller



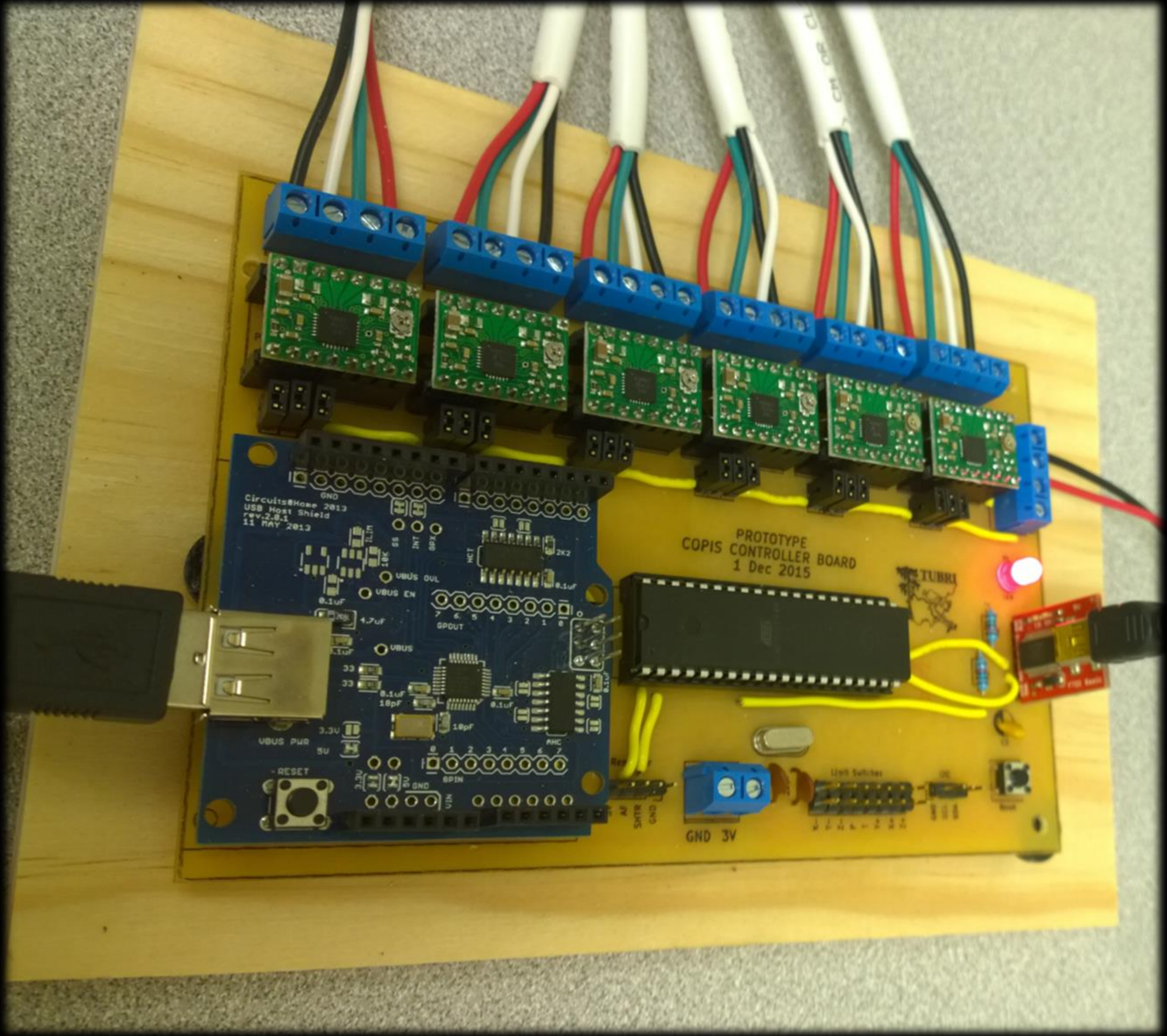






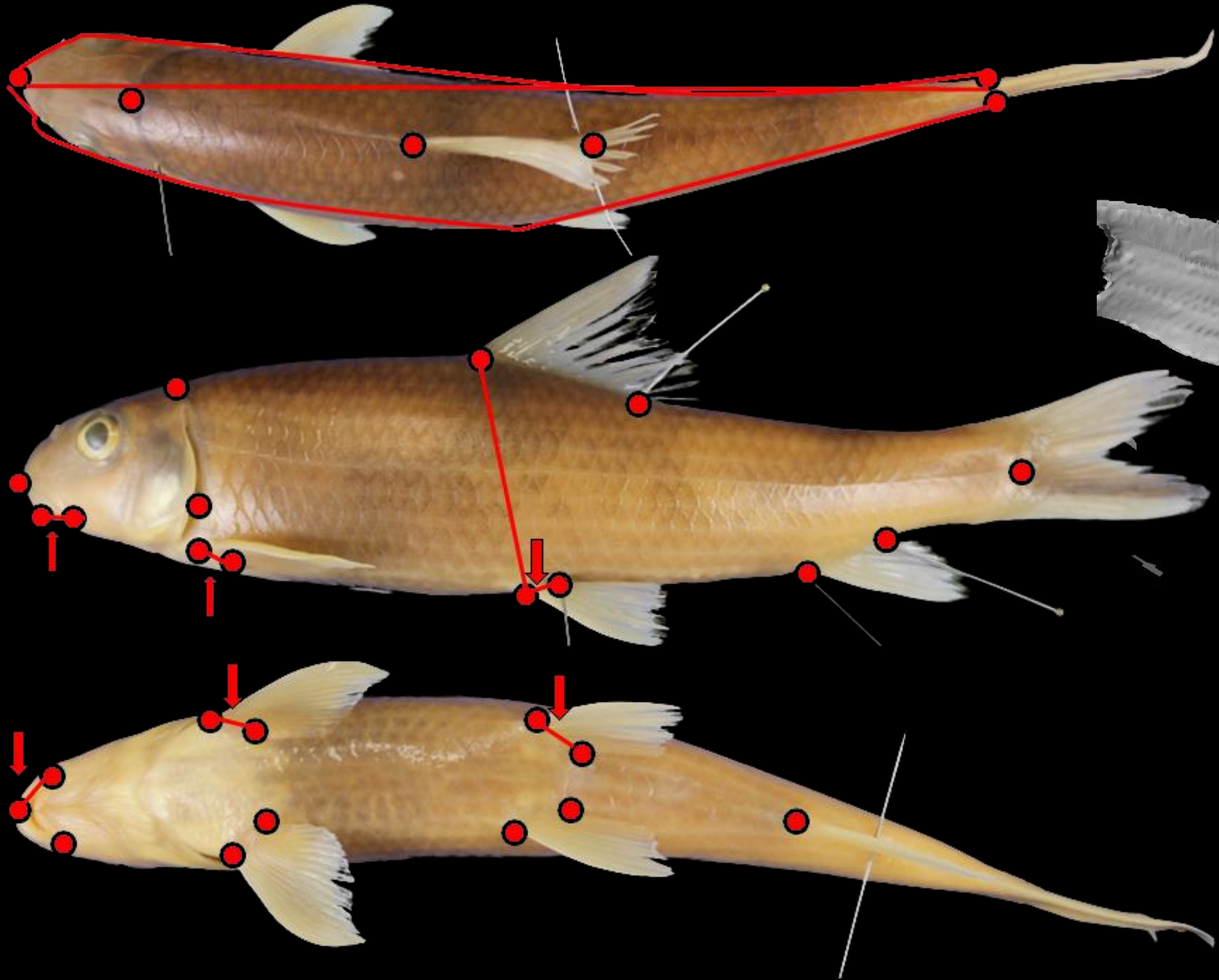
Firmware

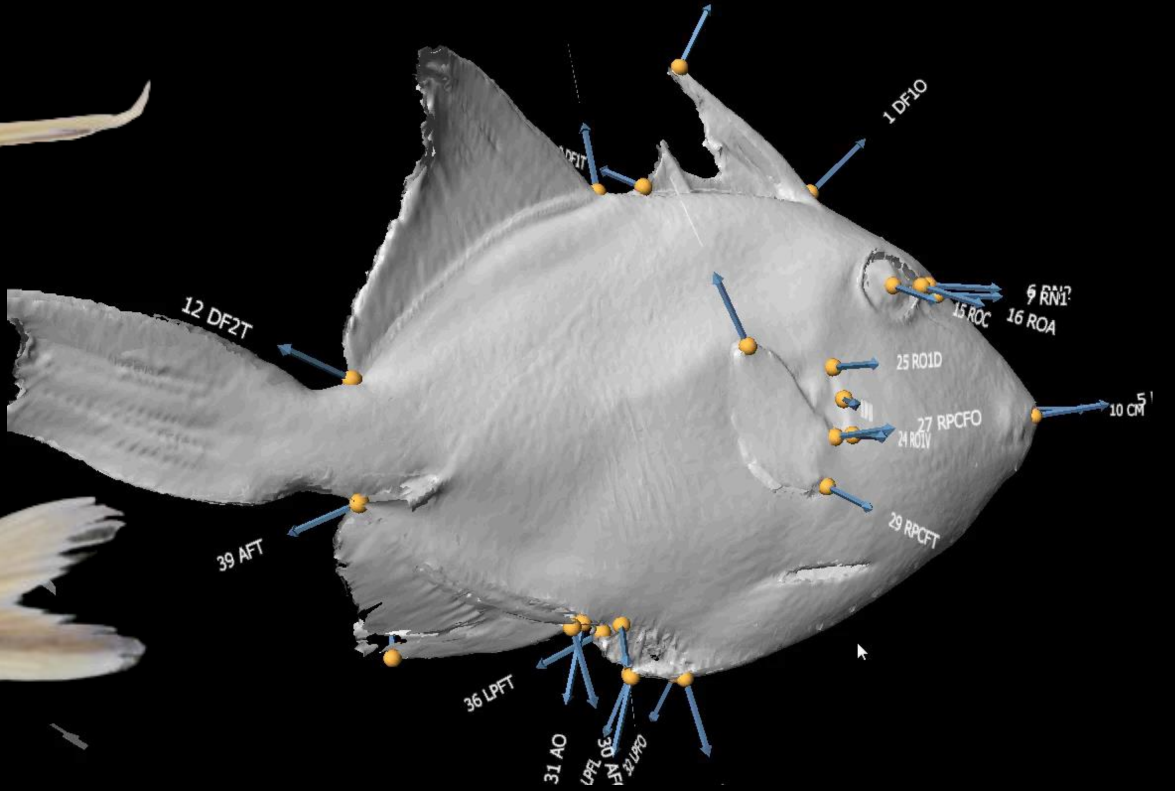
- Written in C++
- Camera Control via:
  - PTP – Picture Transfer Protocol
  - Remote Shutter & Autofocus
  - PC using manufacturer API’s
- X, Y, Z, Pan & Tilt min/max limit switches.
- Multi-board communication via I2C serial bus
- Motion control commands based on a variation of G-Code with extensions for Pan/Tilt and camera control.



Potential for 3D specimen surface

- 360 degree visualization and manipulation
- Accurate digital measurements
- Digitization of curved specimens
- Automated species recognition from images
- 3D geometric morphometrics
- Point cloud analysis
- Source material for 3D graphic artists
- Education & outreach

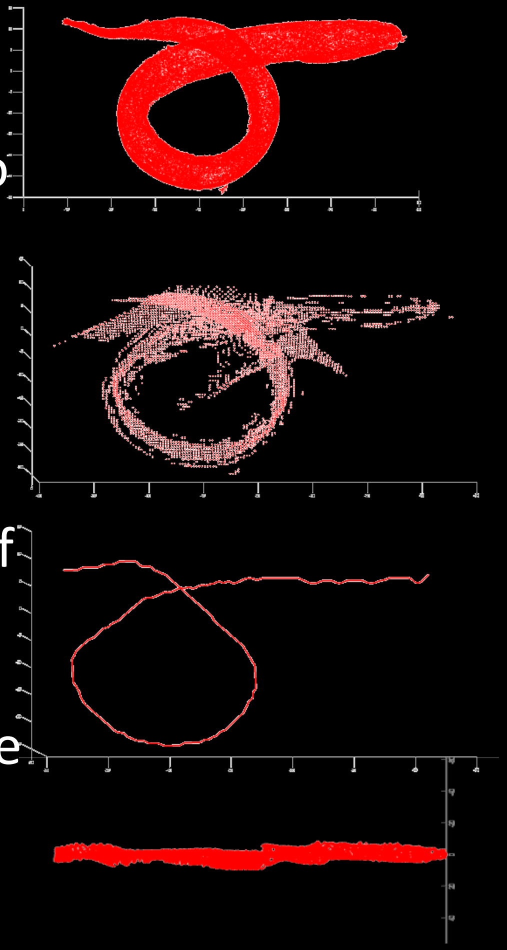




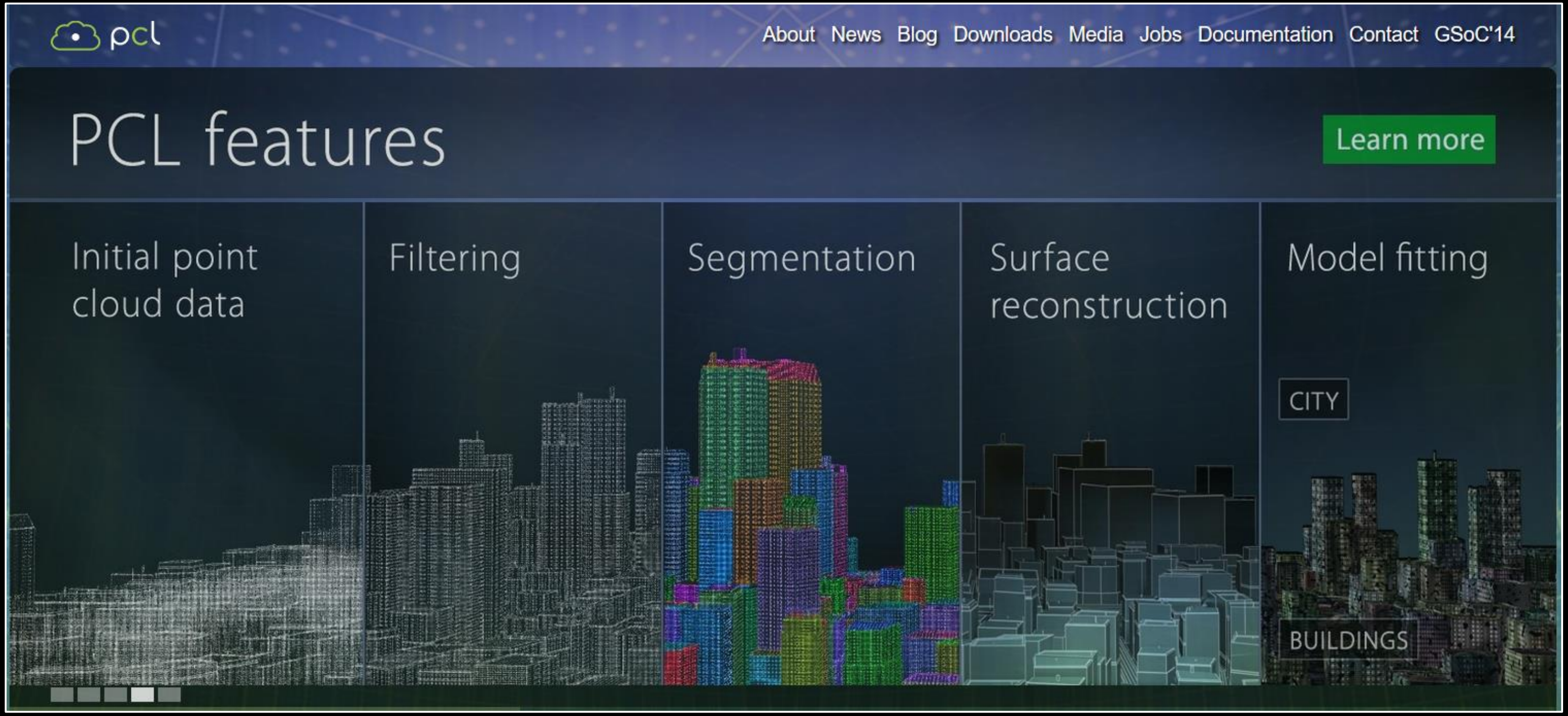
1 DF1O
9 RN1
15 ROC
16 ROA
12 DF2T
25 RO1D
27 RPCFO
24 RO1V
10 CM
39 AFT
29 RPCFT
36 LPFT
31 AO

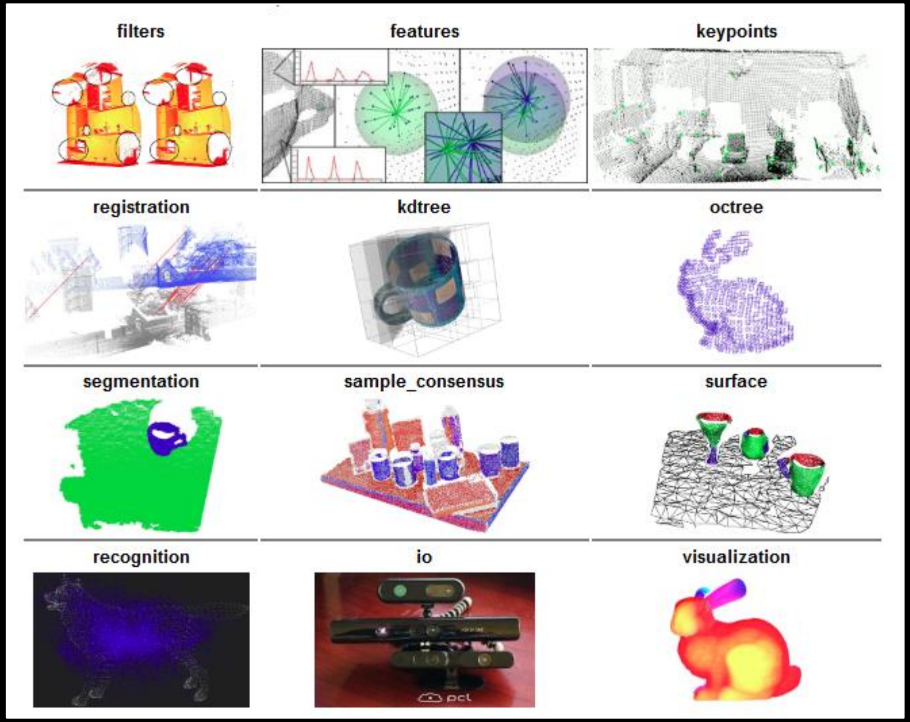
Uncurving 3D Scans of Curved Specimens

- Varying degrees of curvature is common in museum specimens.
- Doctoral student, James Church at Ole Miss, is experimenting with using Statistical Depth Function to uncurve 3D scans of curved specimens.
- Process involves sampling surface of 3D scan.
- Used statistical depth function to create a depth field of the entire scan in 3D.
- Used Dijkstra's Shortest Path algorithm to form a spine from head to tail along the path of the center of the depth field.
- Interpolated and smoothed the spine.
- Sliced the surface into sections and mapped each slice to its center spine.
- Uncurved the spine to decurve the scan.



Analysis and Processing of Point Clouds





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