

Handling

Scanning & Reconstruction

Publishing

Towards high-throughput 3D insect capture for species discovery and diagnostics

Chuong Nguyen¹, Matt Adcock¹, Stuart Anderson¹, David Lovell², Nicole Fisher³ and John La Salle⁴

eScience 2017, BigDig 24 Oct - High Throughput Digitization for Natural History Collections

CSIRO Data61 - Quantitative Imaging
www.csiro.au



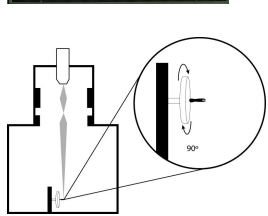
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 - a. Digitisation and 3D photogrammetry
 - b. Pros and cons of 3D photogrammetry, and common issues
2. Proposed solutions for high-throughput 3D capture
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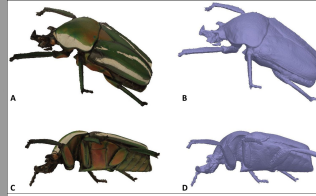
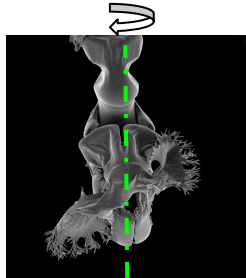
Digitisation of natural collections



2D Mosaicing,
Mantle et al
(2012)



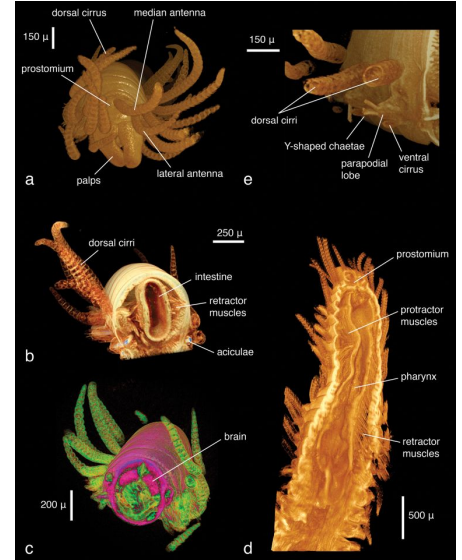
Rotational SEM,
Cheung et al (2013)



Macro & 3D
photogrammetry,
Brecko et al (2014)

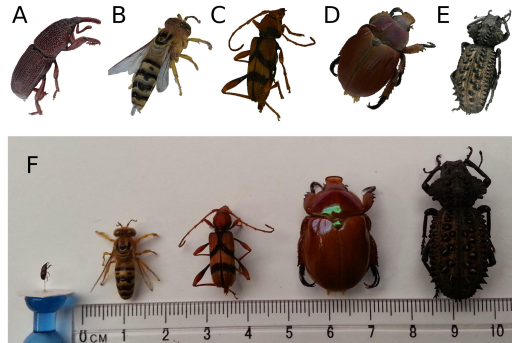
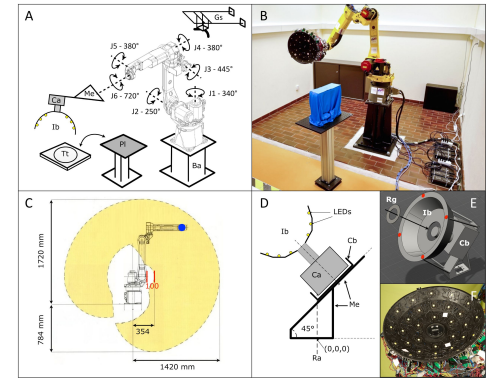
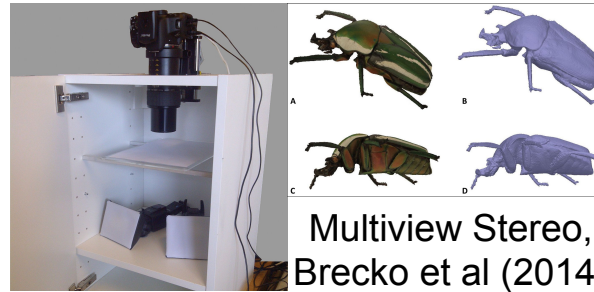
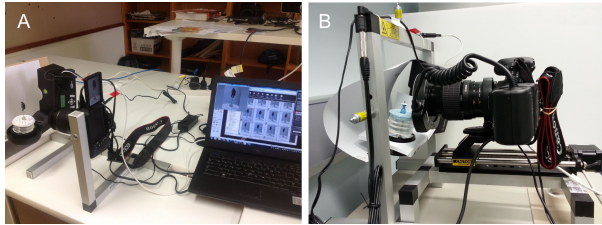
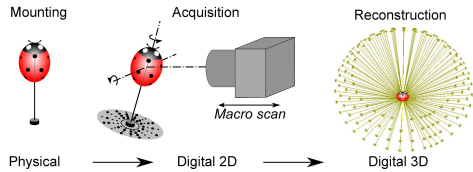


Large scale CT,
Stanley &
Blackburn (2017)



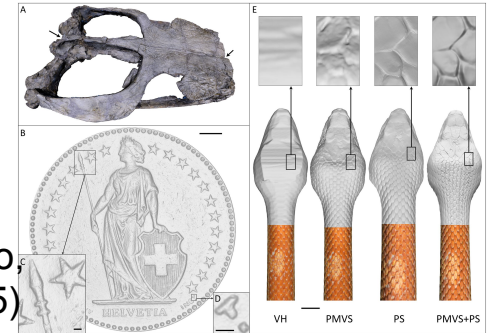
MicroCT,
Faulwetter et al (2013)

3D photogrammetry



Macro & Visual Hull,
Nguyen et al (2014)

Multiview &
Photometric Stereo,
Martins et al (2015)



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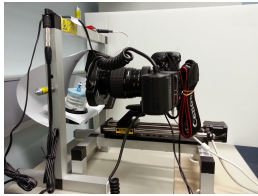
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Pros of 3D photogrammetry

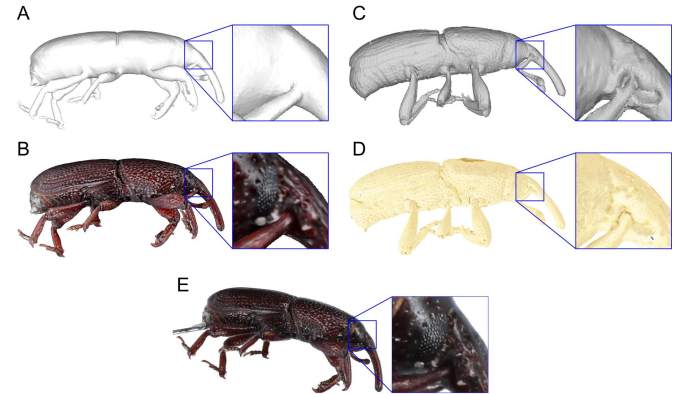
- Low cost (\$10K vs \$1000K) and DIY
- Fast (2.4hrs vs 24hrs) and safe (no radiation)
- True color



InsectScan^{3D}



Skyscan 1172 Micro CT



3D photogrammetry vs Micro CT

Cons of 3D photogrammetry

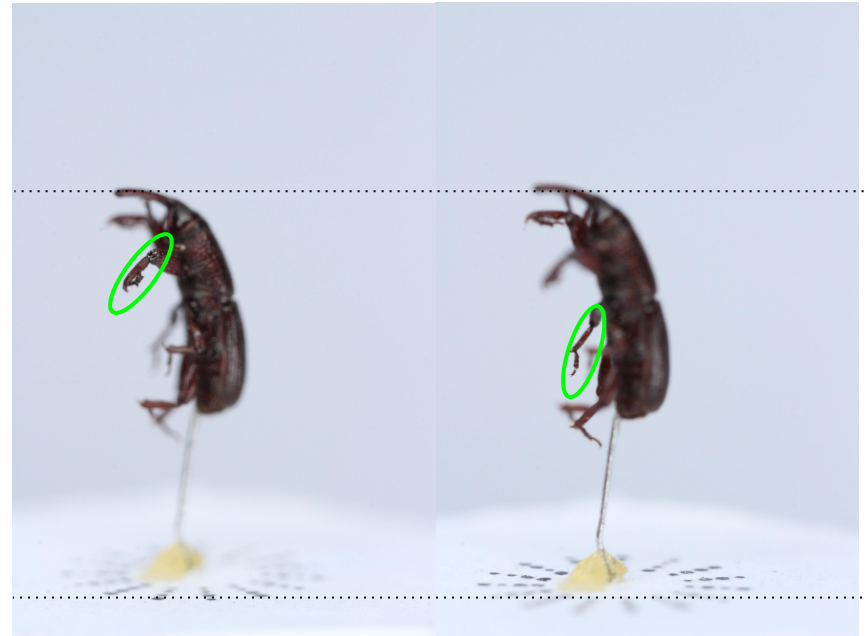
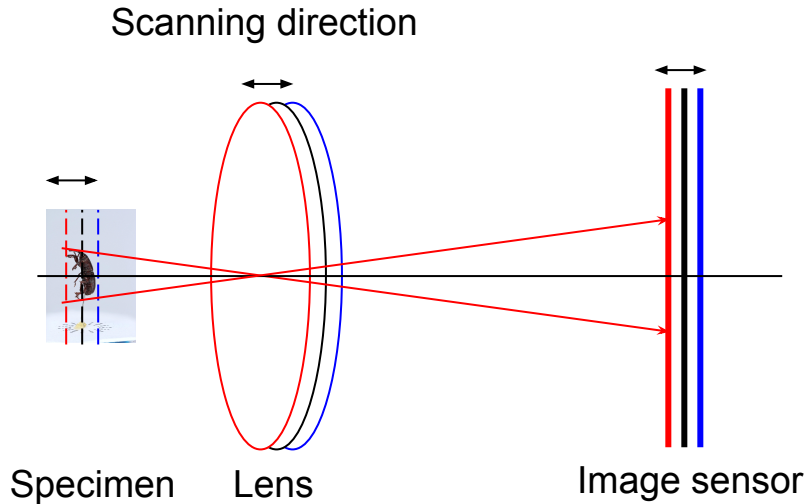
- Trouble with thin/transparent/hairy/reflective/texturedless parts
- No internal structure



Micro CT, J.Alba-Tercedor et al (2016)

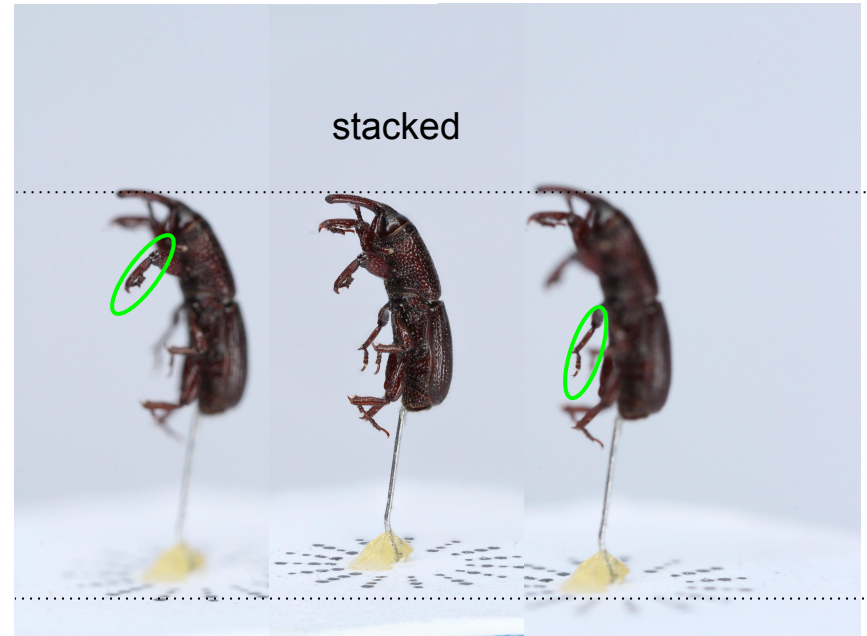
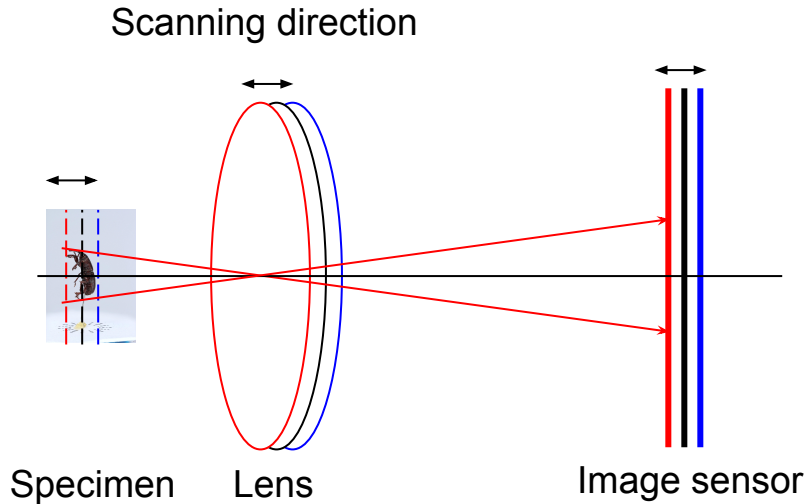
Cons of 3D photogrammetry (continue)

- Macro focal stacking slow and erroneous*
- 3D reconstruction unreliable*



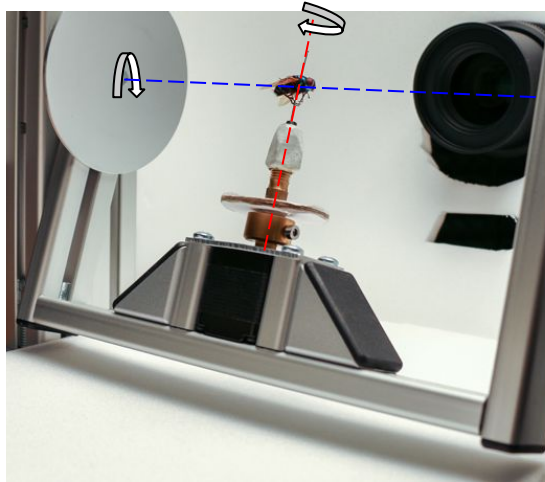
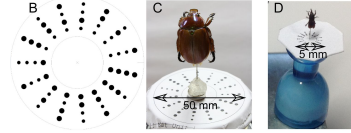
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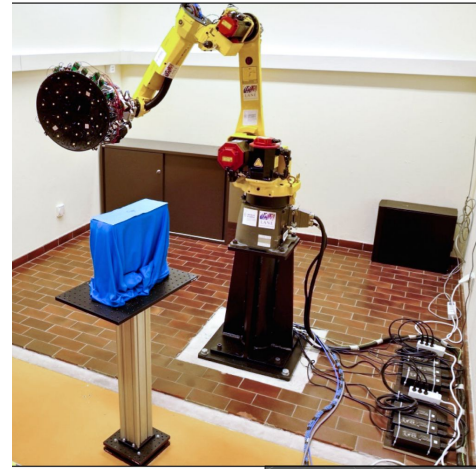


Cons of 3D photogrammetry (continue)

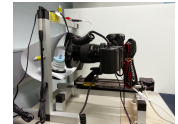
- Camera parameters and poses missing/inaccurate*
- Robotic system potentially expensive & unsafe*



ZooSphere's pan-tilt rig



Martins 2015's R2obbie-3D

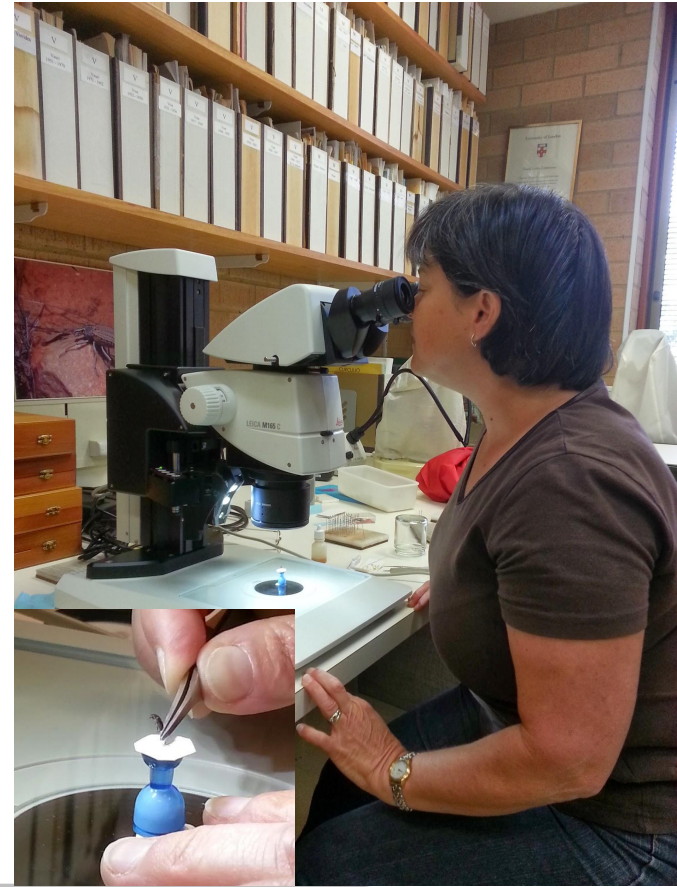


InsectScan^{3D}

Other common issues

Specimen handling:

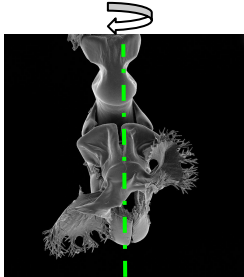
- Manual and labor intensive handling*
- Large scale (~12M) collections, “w/o accidents”*
- Dealing with labels



Other common issues

Data curation and publication:

- 3D editing and annotation
- Non-standard embedding in scientific publications
- Emerging visualisation platforms ([Web3D - Sketchfab](#), Virtual Reality - Oculus, Augmented Reality - HoloLens)
- 2D & 3D catalogue and search



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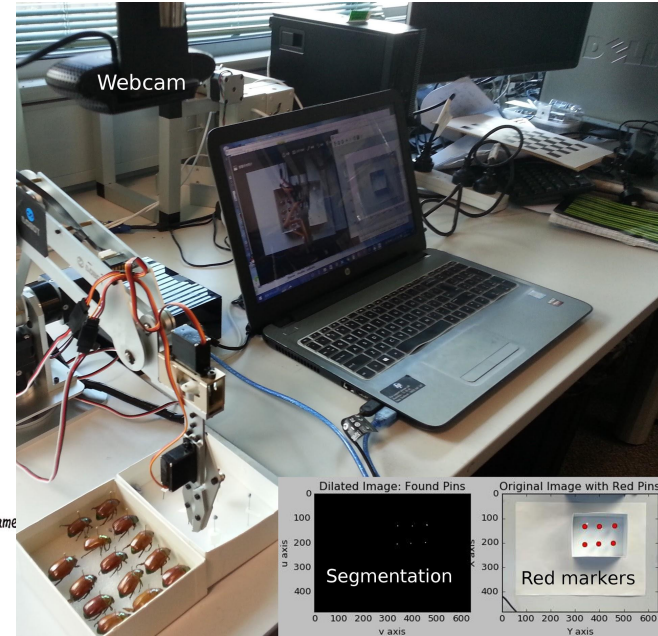
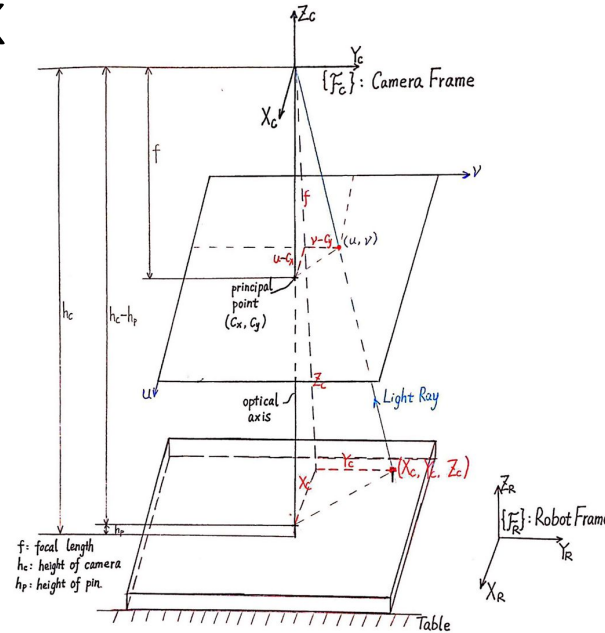
Automatic specimen handling

- Affordable desktop robots from \$1.5K



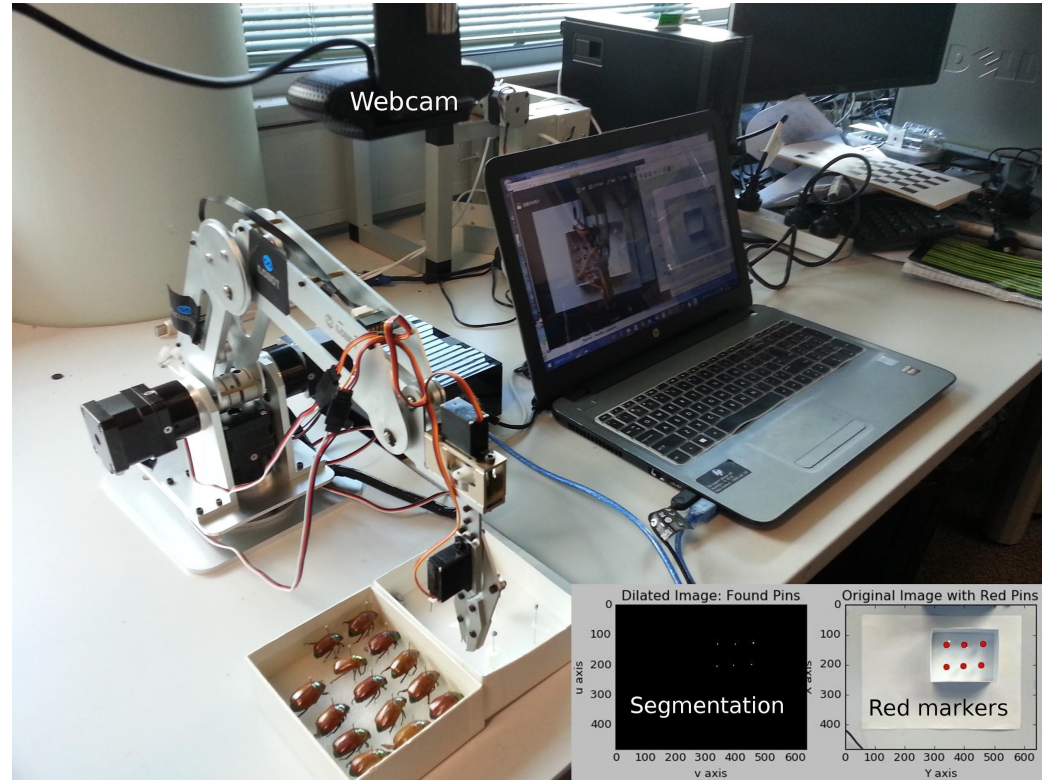
Automatic specimen handling

- Affordable desktop robots from \$1.5K
- 2D & 3D camera
- Computer vision
- Control logic



Automatic specimen handling

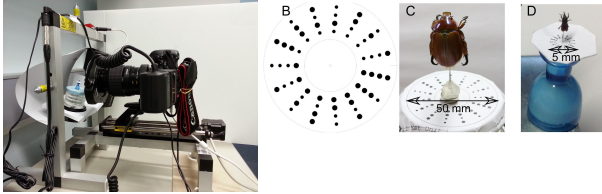
- Affordable desktop robots from \$1.5K
- 2D & 3D camera
- Computer vision
- Control logic
- *Lots of engineering*



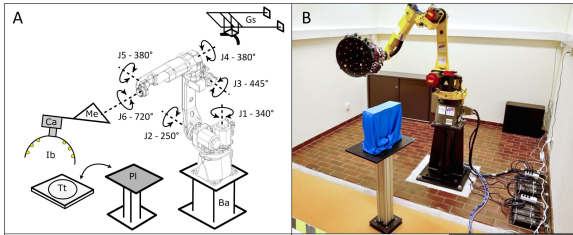
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Target-less 3D reconstruction



Nguyen et al (2014)



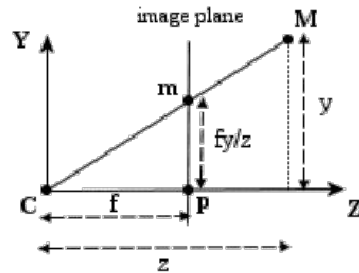
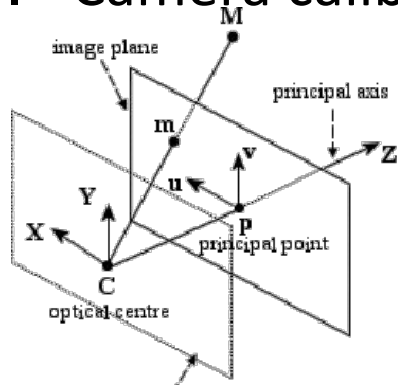
Martins et al (2015)

InsectScan V2



Target-less 3D reconstruction (cont.)

1. Camera calibration: focal length (f), distortion coef., initial pose



$$s \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix} \begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

$[R_0, t_0]$: initial pose

2. Pose generation

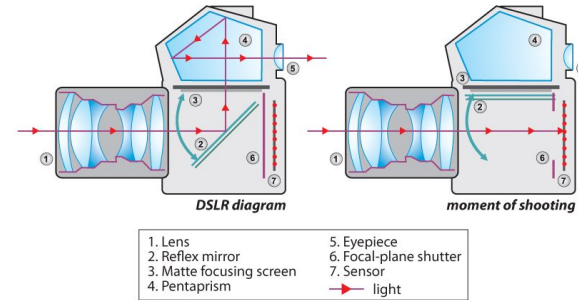
$[R_y(\alpha)R_x(\beta)R_0, t_0+dt]$: new pose and pan (x) tilt (y) angles α, β and movement dt

High speed & resolution image acquisition

- DSLR camera versus lab camera (\$3K)
- Mechanical/electronic/rolling/global shutters



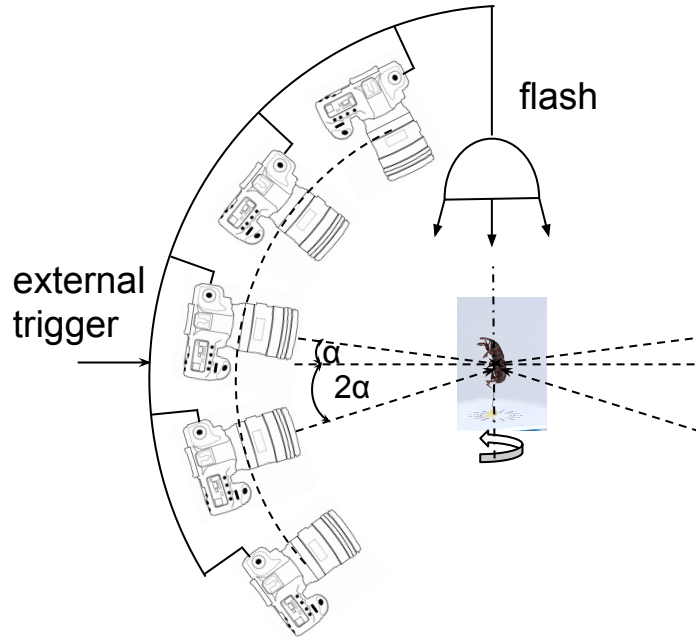
30MP/7fps vs 12MP/30fps



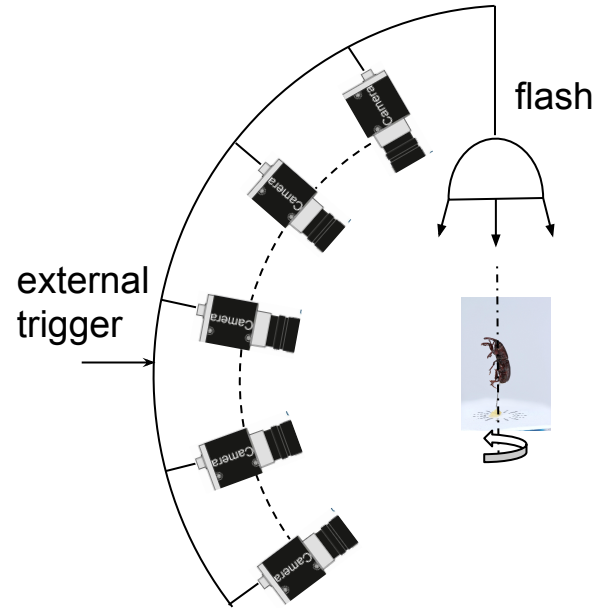
photodrugs.wordpress.com

teledynedaisa.com

Multi-camera consideration

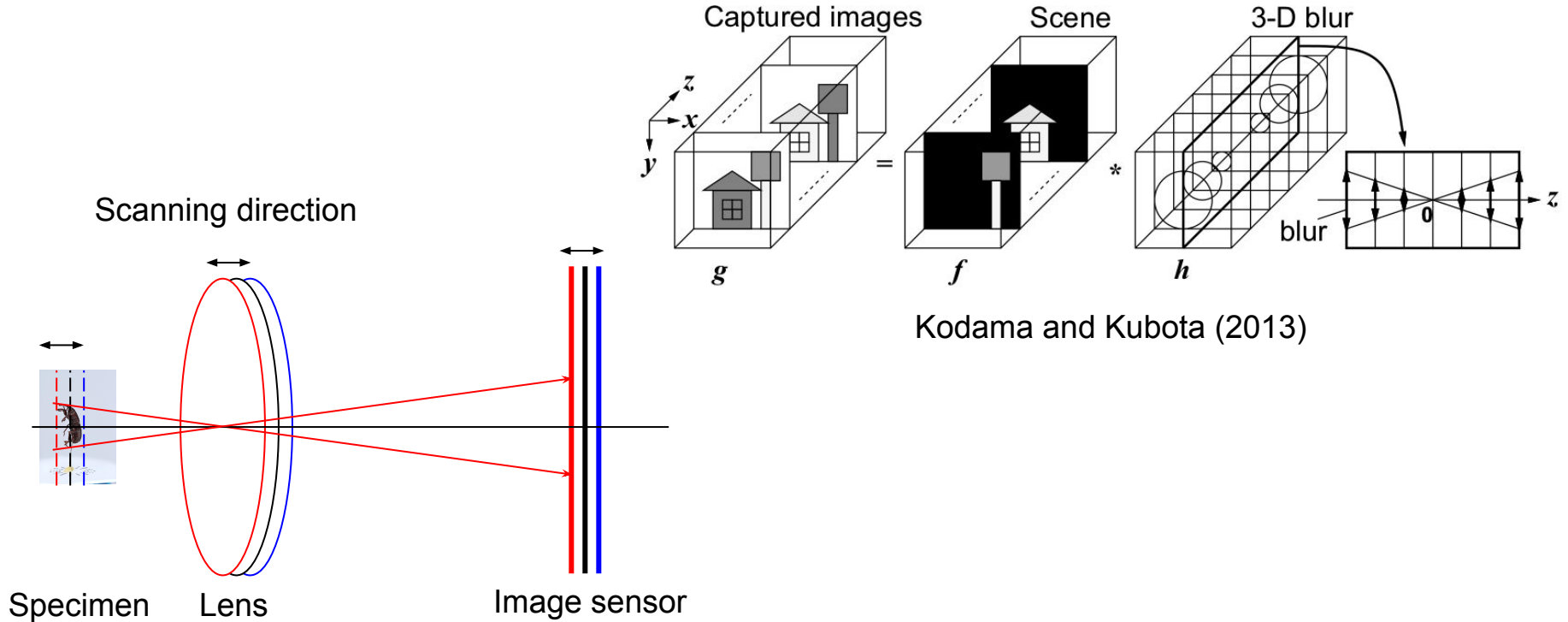


DSLR cameras
sync. uncertainty ~100ms
slow continuous run



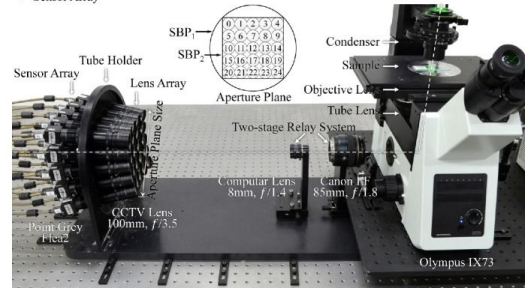
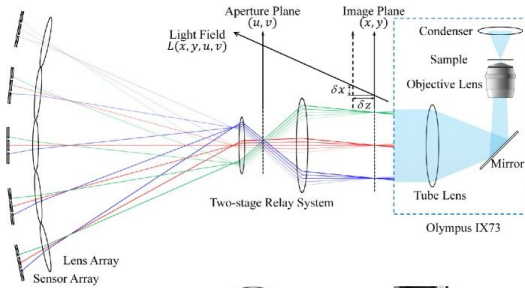
Lab cameras
sync. uncertainty <1ms
fast continuous run

Multi-focus stacking using light field

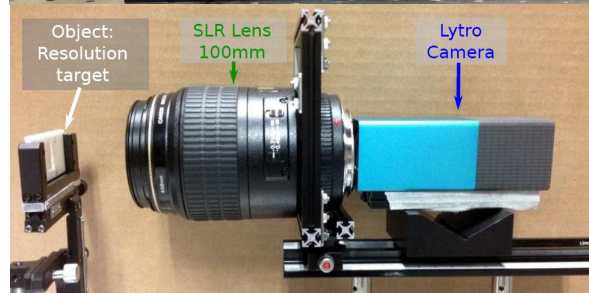
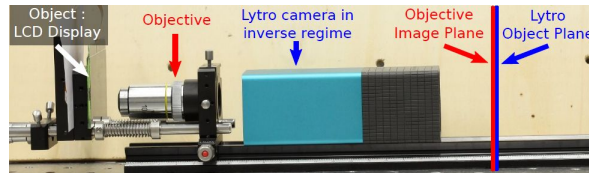


Macro focal stack versus light field imaging

- Resolution versus depth of focus



5x5 multi camera light field microscopy (19MP), Lin et al (2015)



1st Lytro camera (11MP), Mignard-Debise & Ihrke (2015)

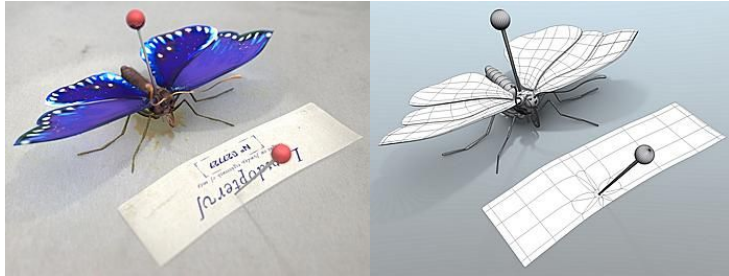


Our Lytro Illum (40MP) & macro lens

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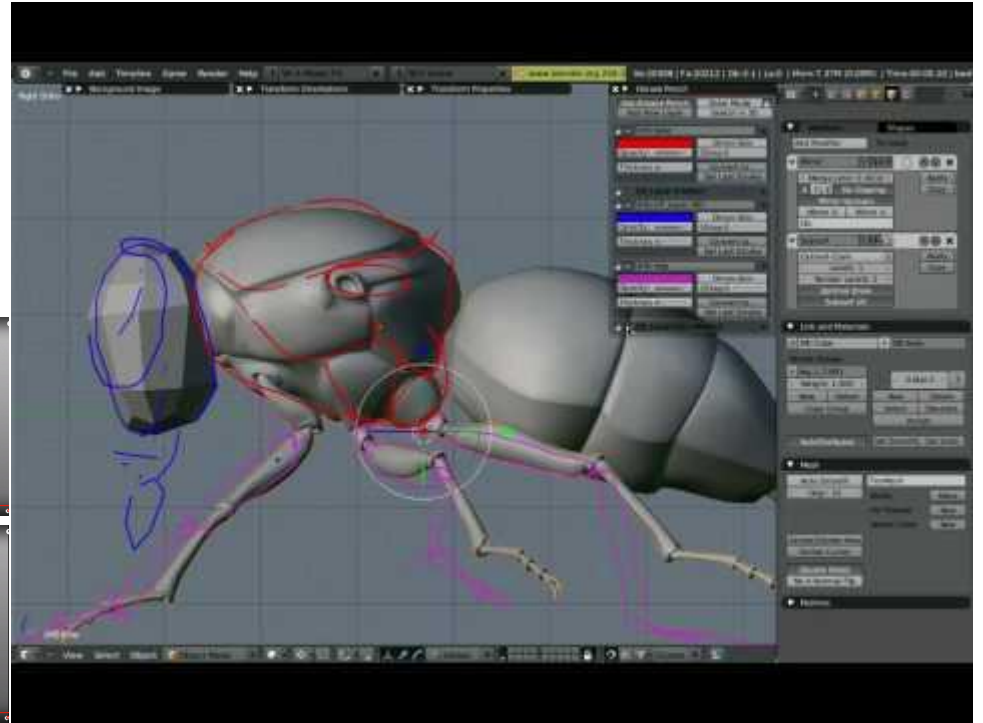
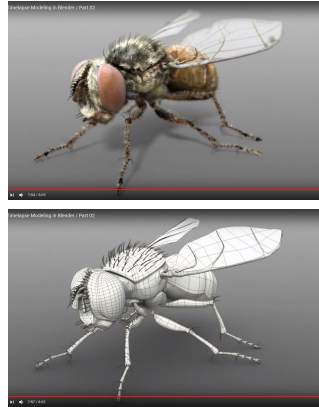
Artistic modeling



A butterfly in blender,
Sebastian König (2008)

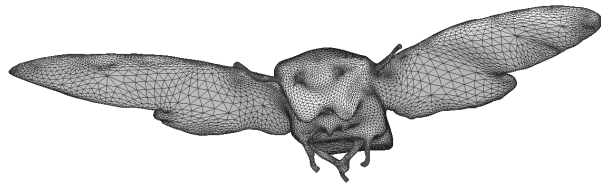


Insects Collection V6,
3d_molier (2011)

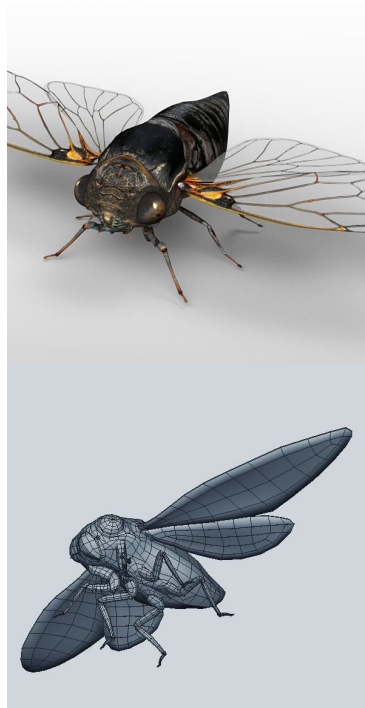


"Fly" Modeling in Blender, Sebastian König (2009)

Scanned model versus artistic model



3D scanned cicada



3D hand-modelled cicada

Interactive reconstruction
with part library?

“Human in the loop” reconstruction

Human => Deep Learning

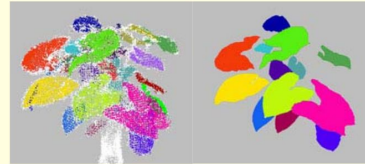
Automatic refinement



Structure from Motion



Leaf Segmentation



3D

2D

Leaf Reconstruction



Plant Model



Quan et al (2006)

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3D annotation

- WebGL technology to represent and link in all metadata
- Our annotation platform <https://ie.csiro.au/apps/p3d-legacy/>
- No ISO standard archival format for this kind of data
- Live demo?

Augmented Reality Showcase

Scope Tv: 3D Insect Scan



Live demo with Hololens

During the next break

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Conclusions

- High throughput 3D digitisation needs 3D photogrammetry
- Possible solutions for
 - Specimen handling with robotic arms
 - High speed image capture
 - Light field capture/reconstruction of in-focus images
 - “Human in the loop” reconstruction
 - 3D web and augmented reality for publication and catalogue
- Cross discipline developments require more efforts...

Thank you

CSIRO Data61 - Quantitative Imaging

Chuong Nguyen

Experimental Scientist

t +61 2 6216 7025

e Chuong.Nguyen@data61.csiro.au

w <http://people.csiro.au/N/C/Chuong-Nguyen>