Towards e-Entomology with Natural Colour 3D Insects

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INTRODUCTION

InsectScan3D (IS3D) is a system for capturing natural colour, high resolution 3D models of tiny specimens. It accelerates the rate at which we can acquire, access and analyse biological information. By bringing specimens into the digital domain, IS3D helps unlock the "big data" held in collections nationwide to advance biodiversity, biosecurity and natural history research.

3D CAPTURE

InsectScan3D is a system for acquiring natural-colour, high resolution 3D models of insect specimens 3–30mm long.
IS3D comprises several hardware and software components. The workflow has three main steps:
Mounting: the physical specimen is pinned onto a two-axis turntable that contains a printed marker used later by the reconstruction software to determine camera pose (viewing angle and position). Two laser pointers are used to help centre the specimen.
Acquisition: As the two axis turntable rotates, 2D images of the specimen are automatically acquired from different orientations by a macro-lens digital camera. To mitigate blur from shutter movement at high magnification, all photos are obtained by first opening the shutter with a tight aperture, then a ring flash is fired, and finally the shutter is closed. At each pose, photos are taken at multiple slightly different distances from the specimen using a macro rail.
Reconstruction: First, the multi-focus photo sets are combined in software to produce a single all-in-focus 2D image for each pose. These 2D images are processed into 3D reconstructions using software based on a visual hull algorithm – essentially 'carving out' a 3D model using silhouettes.

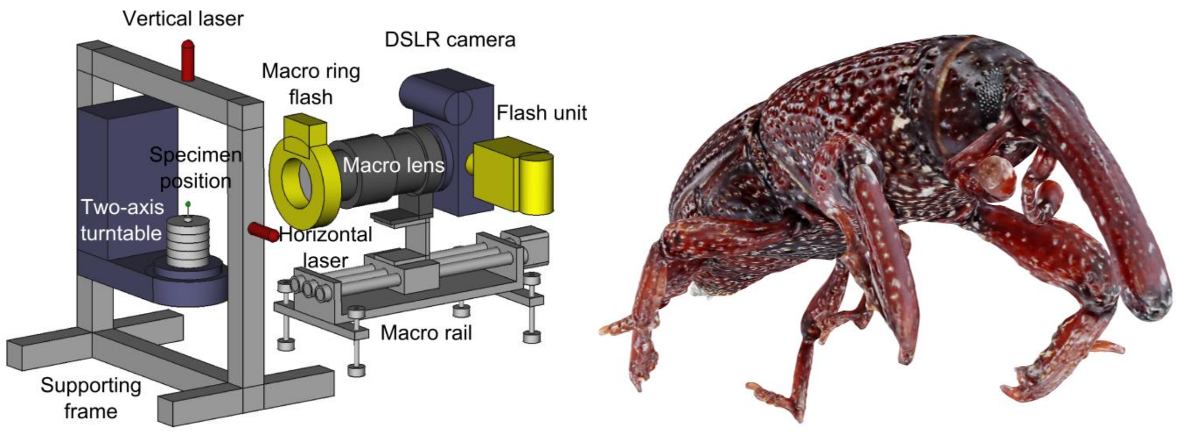

Figure 1: (Left) The InsectScan3D acquisition hardware (Right) Natural-colour 3D model of a 3mm long Granary Weevil [*Sitophilus granaries*] acquired with InsectScan 3D

FEATURES

The IS3D prototype fulfils key requirements of digitizing tiny insect specimens in 3D with natural colour and sufficiently high resolution to be of taxonomic value. Feedback from CSIRO Entomologists indicated that some IS3D models contain enough information for species-level identification and are more helpful than a Micro CT model (which does not capture surface colour or texture).
In comparison to alternative 3D digitization solutions, IS3D is a major advance with unique features:

- Minimal sample preparation is required (as compared to structured light or laser scanning which can require surfaces to be painted or powder coated to remove surface reflection).
- Scanning is non-destructive (unlike scanning electron microscopy).
- No pre-scan calibration is required beyond coarse positioning.
- IS3D needs no X-ray source or specialised computing for reconstruction (as Micro CT does).
- IS3D uses commodity hardware to reduce costs (below $10k). This also makes the system modular, serviceable and readily upgraded to take advantage of technological improvements.

In addition the models produced by IS3D

- are compact (~10 megabytes)
- can be exported in standard formats such as X3D, PLY or OBJ
- can be accessed in a standards-compliant web browser without additional plug-ins
- enable morphometry, the measurement and quantitative analysis of shape and structure
- have the potential to augment current practices in insect taxonomy which have traditionally used text, 2D diagrams and 2D images to describe and characterize species

IS3D is unique in the current market; as far as we know, no other commercial product or research system exists that can digitize 3-30mm specimens in natural colour and 3D. Industry press response [1] to our peer-reviewed publication [2] is consistent with IS3D representing an entirely new segment of the 3D scanning market. Unlike MicroCT which requires large, expensive X-Ray scanning equipment, and computationally-intensive reconstruction, IS3D is relatively portable, low-cost and safe, with reconstruction feasible on a standard PC, so there is potential for new business services in scanning small, detailed objects, especially in tandem with 3D printing.

We have made eight captured models publicly available [3] and the system, process and motivation are described on video [4].

TOWARDS E-ENTOMOLOGY

IS3D has been implemented in close collaboration with the Australian National Insect Collection (ANIC). IS3D stands to reduce the amount of handling for fragile and unique specimens; with the vast majority of the thousands of specimen loan requests received each year potentially facilitated digitally. However, before this can happen, a number of issues should be carefully considered. These include the appropriate licensing of the 3D models, methods of annotation, and ways to combine models with other documentation. Beyond reducing manual handling and increasing accessibility to collections, IS3D paves the way for computational analysis of biodiversity and, perhaps, one day soon, automated species discovery.

As with all its work, CSIRO's development of IS3D was motivated by its mission to deliver benefit from science. As well as helping to unlock scientific and educational value from Australia's national collections, we aim to see the system used in biosecurity [5]: protecting Australia's environment, its multi-billion dollar agricultural industries and the health of its population, all of which could be seriously damaged by invasive insects and the diseases they carry. Quarantine officers can intercept insects at ports. However, correctly identifying pests is difficult, time-consuming and often requires expert support—many invasive species can be very similar morphologically and difficult to distinguish even when using a high resolution 2D image. IS3D solves this issue by letting a quarantine officer quickly send a morphologically correct representation to an expert entomologist for identification.

REFERENCES

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ABOUT THE AUTHORS

Matt Adcock is a Research Engineer at CSIRO. His research interests include mixed reality interfaces, computer graphics and human computer interaction. He is a graduate of the Australian National University (ANU) and the Massachusetts Institute of Technology (MIT). He is also an adjunct lecturer at ANU.

Dr Chuong Nguyen graduated from a Bachelor of Engineering at Ho Chi Minh City University of Technology, Vietnam in 2001. He later completed a Master of Engineering at Ritsumeikan University, Japan (2003) and a PhD at Monash University, Australia (2010). Chuong's work at CSIRO, has included the development of imaging techniques for the creation of 3D plant and insect models using multiple 2D images.

Dr David Lovell began his scientific career with a Bachelor of Electrical Engineering, followed by a Doctor of Philosophy and a Postgraduate Diploma in Management. He joined CSIRO in 1998, where he researched and consulted on the analysis of large and complex datasets. From 2004, David led CSIRO's Mathematics, Informatics and Statistics' Statistical Bioinformatics – Agribusiness Group (2004-07), as well as its Bio Research Program (2007-08). In 2008, he was appointed Bioinformatics and Analytics Leader for CSIRO's Transformational Biology initiative, and in 2012 he became the Director of the Australian Bioinformatics Network.

Stuart Anderson is a Graduate Fellow at CSIRO. Stuart's research investigates virtual representations of reality and ways of interacting with these representations. He holds an Honours degree in Software Engineering from the University of Canberra.

Dr Beth Mantle is responsible for managing and developing the Australian National Insect Collection to ensure its current and future security and integrity as Australia's pre-eminent entomological collection. Dr Mantle's current activities include monitoring and prioritising the curation activities of the collection, supporting and leading technical staff in the maintenance and expansion of the collection, and providing input into the future development of the collection to align with the broader goals set out in the CSIRO Strategic Plan.

Dr Andrew Young is Director of the Director of the Australian National Research Collections at CSIRO. Dr Young's research centres in plant population genetics, population ecology and conservation biology. His specific research interests include: inbreeding and outbreeding depression, understanding of local adaptation, hybridisation and pollinator limitation. His research combines genetic and ecological approaches to understanding the viability of native plant populations in disturbed environments, specifically how Australia's native plant biodiversity can be conserved within farming landscapes.

Dr John La Salle is the Director of the Atlas of Living Australia. He is an entomologist with a particular interest in using new technology to generate knowledge about insects. He is interested in studying the importance of biological control and sustainable agriculture, and in the biology and evolution of parasitic Hymenoptera. John received his Doctorate in Entomology from the University of California Riverside (1984). From 2001 to 2012, he served as Director of the Australian National Insect Collection. In 2006, he was instrumental in the establishment of the Atlas of Living Australia (ALA), a project in which he is still involved.