Macrophotography of fern gametophytes using a DIY focus stacking system.

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Team

Jennifer Deegan, **jic24@cam.ac.uk**, as above

Growing and photographing the specimens, and planning and building the system.

Matthew Couchman, **matthew.couchman@jic.ac.uk,** Computer scientist, John Innes Centre.

Technical advisor in computer science and JI source of photographic specimens.

Tim Deegan, tjd@phlegethon.org, Computer scientist, CohoData

Computer programs and electronics driving the focus stacking system.

Richard Mortier, richard.mortier@cl.cam.ac.uk, Cambridge University Computer Laboratory.

Technical advisor in computer science and home robotics.

Summary

The aim is to take a series of photographs showing the development of the fern gametophyte from the very earliest feasible stage to the appearance of the first sporophyte leaf. To do this, we will build a focus stacking system for microphotography which is a very low-budget adaptation of the Bratcam system designed by Chris Slaybaugh (Fig 1).

Proposal

i) the problem

Fern gametophytes are beautiful and interesting developmentally, but currently only line drawings of them exist, as they are very small and difficult to photograph. (Fig 2).

We hope to take a series of photographs showing gametophyte development from the earliest feasible stage until the emergence of the first sporophyte leaf.

ii) the biological systems you are using,

We will use fern gametophytes as photographic subjects.

iii) the design goals for the hardware,

Jennifer Deegan has taken one good photo of a fern gametophyte (Fig 3, and Pteridologist Magazine 2017). This was taken using a Canon MP-E lens and a repurposed flatbed scanner as the focus stacking rail. The design goal of this project is to increase the magnification of the system from x5 to x10, to optimise lighting and automation of the system, and to make a more secure attachment for the camera and a more controllable base for the fern.

iiii) how you plan to implement the project,

We have already built part of the system (Fig 4). This is composed of a focus stacking rail made from part of an old Nikon microscope. It is driven by a stepper motor, controlled by a raspberry pi computer. With this grant we would optimise lighting using radio controlled flashes and diffusers, and possibly polarizing filters. The optics would be improved from the

made from part of an old Nikon microscope. It is driven by a stepper motor, controlled by a raspberry pi computer. With this grant we would optimise lighting using radio controlled flashes and diffusers, and possibly polarizing filters. The optics would be improved from the 5x MP-E Canon lens to a 10x microscope objective mounted on a 200mm prime Olympus Zuiko tube lens. We would attempt to maximise rigidity of the camera setup using 3D printed components to securely hold the camera and the fern. The raspberry pi computer would be replaced by an arduino, and we would use the sensors in the kit to maximise the automation of the whole setup.

v) the proposed outcomes and benefits.

The project, if successful, will provide a set of first class images showing the development of the gametophyte fern. We would anticipate the following uses:

- Submission to the RHS annual photography competition, which might win an RHS medal for the Cambridge Department of Plant Sciences and the John Innes Centre.
- The images could be made available for use in all school and undergraduate teaching, and for use in all plant science text books and online.
- We could extend the use of the system to photography of liverwort and other similarly small specimens provided by the Cambridge Botanic Gardens and the John Innes Centre. This would be a significant contribution to plant science research.
- The work is publishable as novel plant science research.
- A complete set of documentation will be released, to enable others to use the same design. This will include the code of all computer programs.

Components and budget

In the work previously carried out, the purchase of equipment has been funded entirely by Jennifer Deegan. In total, this constitutes matched funding of about £1500.

At a minimum, the remaining work could be completed with the purchase of one microscope objective which would cost around £700 or £800 depending on which one was chosen.

One or the other of these have been suggested:

10X Mitutoyo Plan Apo Infinity Corrected Long WD Objective (£752)
(Chris Slaybaugh)

N2183200 LMPLFLN10X OBJECTIVE (£880)
(Des Callaghan)

Ideally, we would like to use the remaining funds to create a secure, adjustable stand for the photographic subject (fern), and for the camera. These would made by 3D printing. Components included in the Biomaker Toolkit would be used for automation of the system.