**Title:**

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Date (2022-02-27)

Modifications: (1: YYYY-MM-DD [First-name Surname]; 2: YYYY-MM-DD [First-name Surname]; etc)

**Abstract**

This protocol present a pipeline to use multi-view back projection for analyzing thermal images that were taken with a drone. Compared to analyzing thermal images on orthomosaics directly, this approach allows to include effects of measurement time and viewing geometry in the analysis as well as to improve spatial correction of the measurements. Same as for the orthomosaic analysis, an orthomodel has to be created but the analysis is done on single images instead of orthomosaics by means back projection. The orthomosaic serves only as a reference to orient the single images in space for analysis.

The approach can be used to analyze thermal images that were taken during a drone mapping campaign of an agricultural plot experiments.

On one hand, this protocol improves the measurement precision of relative temperature differences of plant canopies, particularly when an uncalibrated thermal camera was used. On the other hand, it includes several additional steps compared to the simple analysis of thermal orthomosaics which makes it more time consuming.

**Keywords**

*thermal imaging, multi-view, single image analysis, spatial correction, drift correction, drone, viewing geometry,*

**Materials**

To use this protocol, the following software is needed:

* Qgis software version 3.22.6 or higher (<https://www.qgis.org/de/site/>)
* Agisoft software version 1.7.2, (https://www.agisoft.com/)
* Python coding environment (e.g. Anaconda), ideally with an IDE (e.g. PyCharm). Python versions and packages used are indicated in the individual scripts.
* ExifTool must be installed on the computer (https://exiftool.org)

**Knowledge**

To use this protocol, the following knowledge is prerequisite:

* Basic knowledge of Python
* Be familiar with the concept of virtual environments an knowing how to set them up in Python
* Basic knowledge of the Agisoft workflow
* Basic knowledge on spatial data treatment and Qgis (or similar GIS software)

**Procedure**

As this pipeline includes many individual steps, this documents I not a complete protocol but a guide through the individual steps. Those steps are described in individual protocols.

First, have a look at the document “ThermalMultiviewPipeline.pdf”. It shows a flow diagram of all the steps of the pipeline.

*Describe the procedure step-by-step. It must take the form of a continuously numbered set of steps (use 1, 2, 3, 4; not 1.1, 1.2 etc.), with numbering continuing from step to step. There can only be one level of subheading. If there are options of how to proceed at a particular step, options A, B, C etc. can be used within that step, and within these options, different steps should be numbered using roman numerals. Please indicate if any steps are optional.*

*Write with active voice and verbs in the present tense (e.g., write "Prepare stock solutions and reaction mixtures under anaerobic conditions” instead of “Stock solutions and reaction mixtures were prepared under anaerobic conditions"). If possible, please add information about the time that it takes to perform the task and the number of persons needed to complete the task successfully.*

*The protocol should provide enough information for a first-year student to perform it and be successful.*

*Provide information data processing and analyses if applied: make sure to include statistical tests, and criteria for data inclusion/exclusion. When detailed information of data analyses already appear in research article or protocols, cite the reference. Please, indicate clearly where the analysis can be found (e.g., Supplemental information or Figure X).*

*Please add !Trouble in the step of the procedure for which you will give a troubleshooting guidance in the Troubleshooting section (e.g. !Trouble). The detailed description of the issue, possible reason, and possible solution should be described in the troubleshooting section and not here.*

*Flowcharts summarizing the procedure are highly welcomed and recommended.*

*Flowcharts/Figures/Tables/Boxes must be cited in the main text, should be numbered in a continuous order, and should have a legend that explains the object. Please avoid the use of colored backgrounds.*

1. **X**
2. **Y**

**Units, symbols, abbreviations**

*Describe and spell out all units, symbols, abbreviations used.*

**Troubleshooting**

*All Troubleshooting information should be removed from the procedure and combined here to form an independent Troubleshooting section.*

*Each issue should ideally include four parts entitled ‘Step’, ‘Problem’, ‘Possible reason’ and ‘Possible solution’. ‘Step’ is the step number of the procedure section where this trouble can be encountered.*

* *XXXX*
  + *Step:*
  + *Problem:*
  + *Possible reason:*
  + *Possible solution:*

**Safety**

*Please add a CAUTION note to any potentially harmful items and explain the danger and precautions that should be taken when handling them.*

**Waste Management**

**References**

**Examples of use in own work**

**Notes**

*When possible please include information to explain how long the protocol takes to complete.*