Tutorial:

Fully automated workflow for Minirhizotron-based *in situ* root phenotyping: from image acquisition to analysis

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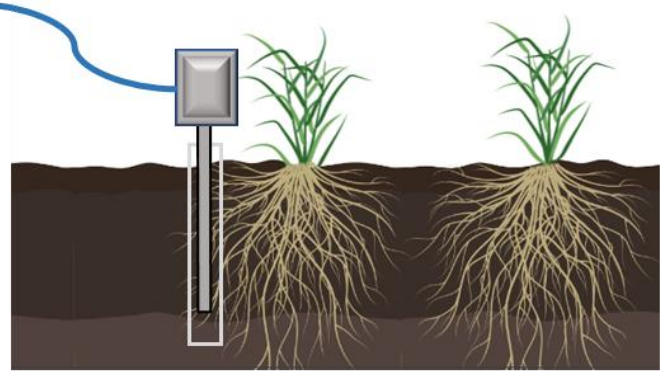
Before

Automatic Minirhizotron camera



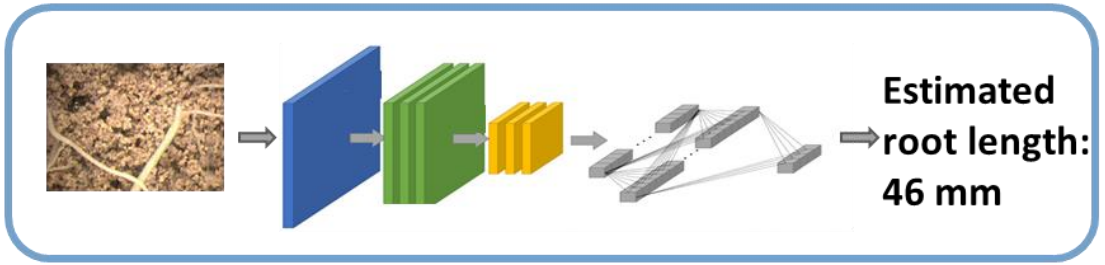
Field

Decision making

Download image remotely

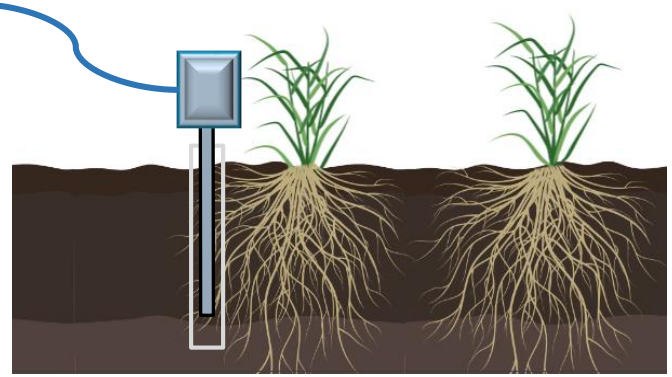
Challenge:
data transfer

Image analysis with Convolutional Neural Networks



Now

Automatic Minirhizotron camera



Field

Decision making

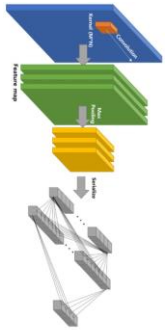
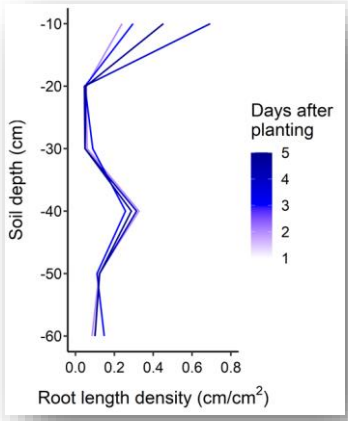


Image processing & analysis with Convolutional Neural Networks in the cloud

Stitched images

Time series analysis of RLD



Part 1: Automated image acquisition

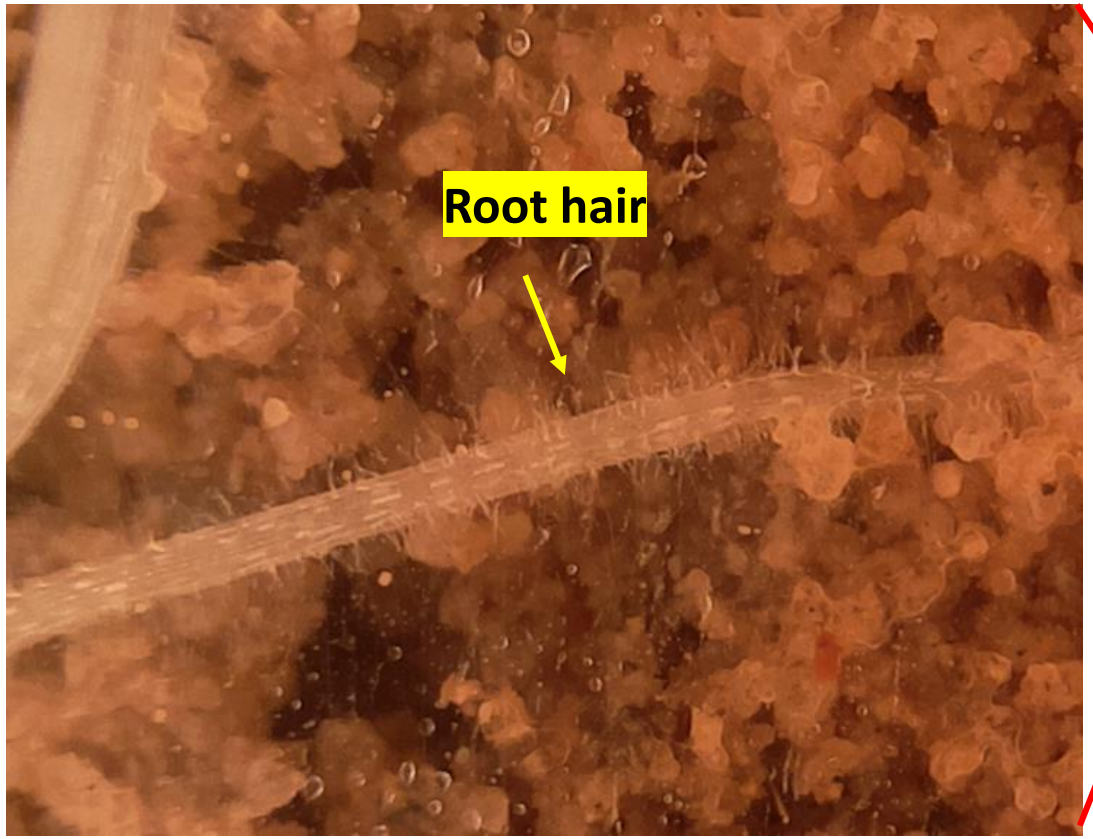
RootCam© system manufactured by crystalvision
Cutting-Edge Field Lab Solutions

Technical details:

- Processor: Raspberry Pi 4B
- Camera: 2592 x 1944 pixels
- LED light
- Power supply: 12 VDC
- Interface: Virtual Network Computing (VNC)

RootCam© in the field

Part 1: Automated image acquisition



High resolution:
2592 x 1944 pixels/image

Big observation area:
25 x 19 mm^2/image

Part 1: Automated image acquisition

Challenges:

- Occasional internet disconnection
- Adjacent images don’t connect exactly at the same spot in the new camera no.8
- Unequal amount of images taken by the same camera day from the day

Part 2: Automated data transfer

Traditionally, there are two ways to transfer image data.
However, both of them have drawbacks that hinder access to real-time data.

1. Raspberry Pi embedded in the automated MR camera → Transfer to the local computer through AnyDesk → Users download data remotely through AnyDesk

Drawback:
Images are so big that it's time-consuming to download

2. Raspberry Pi embedded in the automated MR camera → Transfer to the local computer through AnyDesk → Users copy data with a hard disk in the field and bring it back

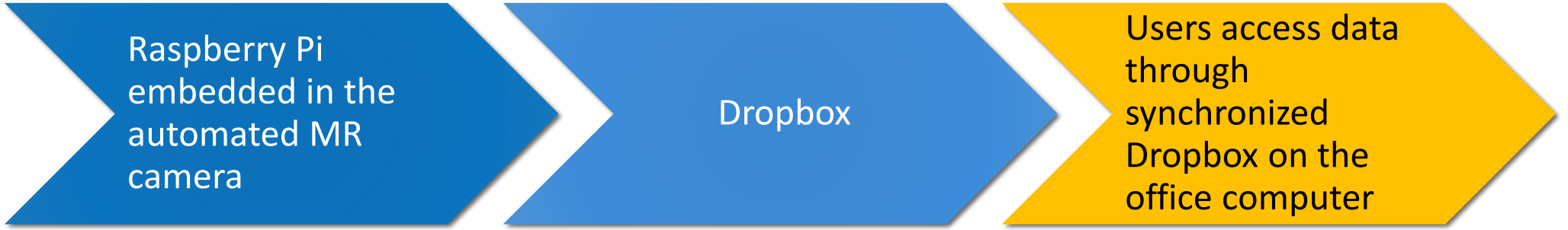
Drawback:
Users need to be in the field to download data each time

Note: AnyDesk is a remote desktop application that offers remote control, file transfer, and VPN functionality.

Part 2: Automated data transfer

Now, Dropbox was employed to address the limitations and achieve real-time data transfer.

Current workflow:

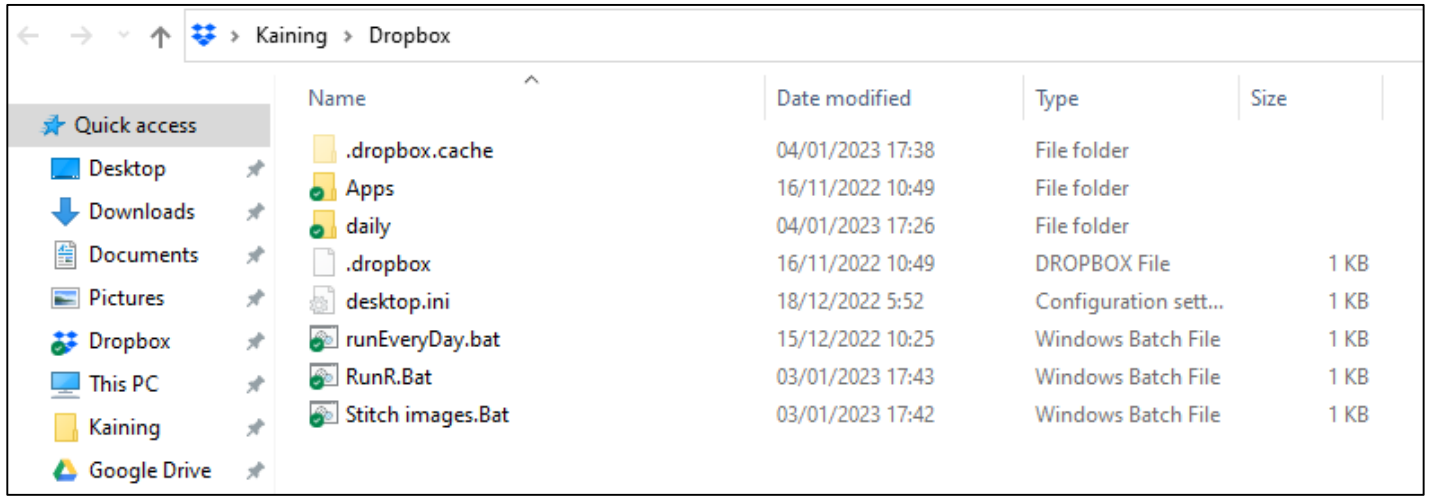


Note: MR is the abbreviation of Minirhizotron.

Part 2: Automated data transfer

Step-by-step protocol:

1. Download Dropbox to the office computer and sync it with this account: crystalrootcam@gmail.com



2. Make sure images are sent from the automated MR camera to Dropbox every day (plz consult Ofer)

3. Set task schedulers on the office computer to automatically conduct analysis inside the local Dropbox

Part 3: Automated data analysis

Preparation work:

1. Use Adam's model to estimate the root length of each day's images and export the data to a single data file (TRL.csv). Data from the next day will be added to the data from previous days.
2. Write an R script (Estimated RLD plot.R) for analyzing time series data from TRL.csv and make an RLD plot.
3. Write another R script (Stitch images.R) for stitching images taken from the current day. The stitched image provides a visual demonstration of the soil profile and root distribution.
4. Write an R Markdown (Root data report.Rmd) for generating a report to publish on the Rpubs website.

Note: RLD is the abbreviation of root length density.

Part 3: Automated data analysis

Use batch files to automate routine tasks.

What is the batch file?

A batch file is a script file that stores commands to be executed in a serial order.

It helps automate routine tasks without requiring user input or intervention.

Part 3: Automated data analysis

Step-by-step protocol

1. Create batch files

1.1 runEveryDay.bat: (a) estimate root length from images of the day and (b) move these images to a local folder

1.2 RunR.Bat: make RLD plot with time series data from TRL.csv

1.3 Stitch images.Bat: (a) stitch images of the day and (b) add annotation of soil depth on the stitched image

1.4 Root report.Bat: generate root growth report with RLD plots and the stitched image

Part 3: Automated data analysis

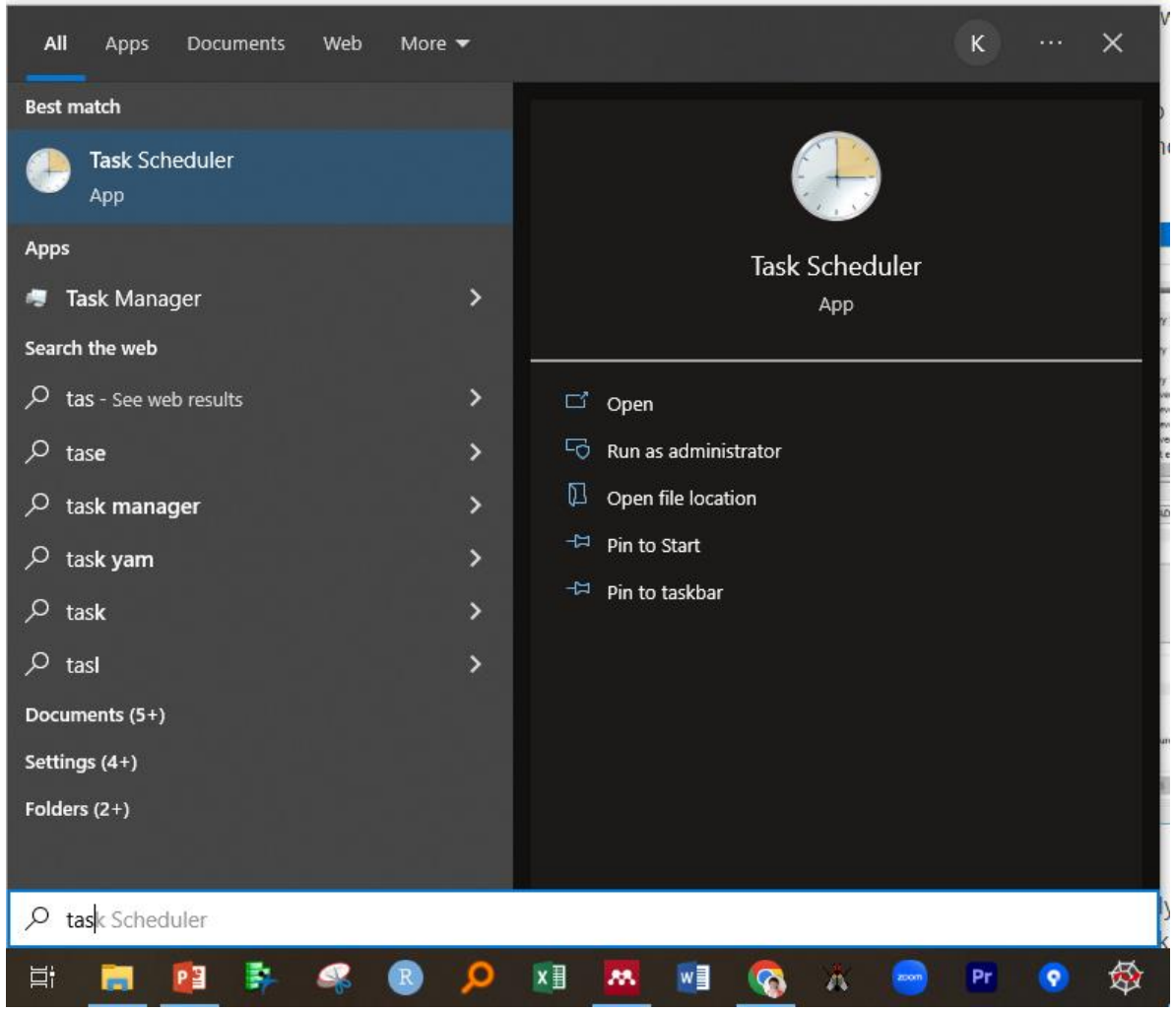
Step-by-step protocol

2. Set task scheduler

2.1 Open Start. Search for Task Scheduler, and click the top result to open the app.

2.2 Follow this instruction to create a new task:

https://www.windowscentral.com/how-create-automated-task-using-task-scheduler-windows-10

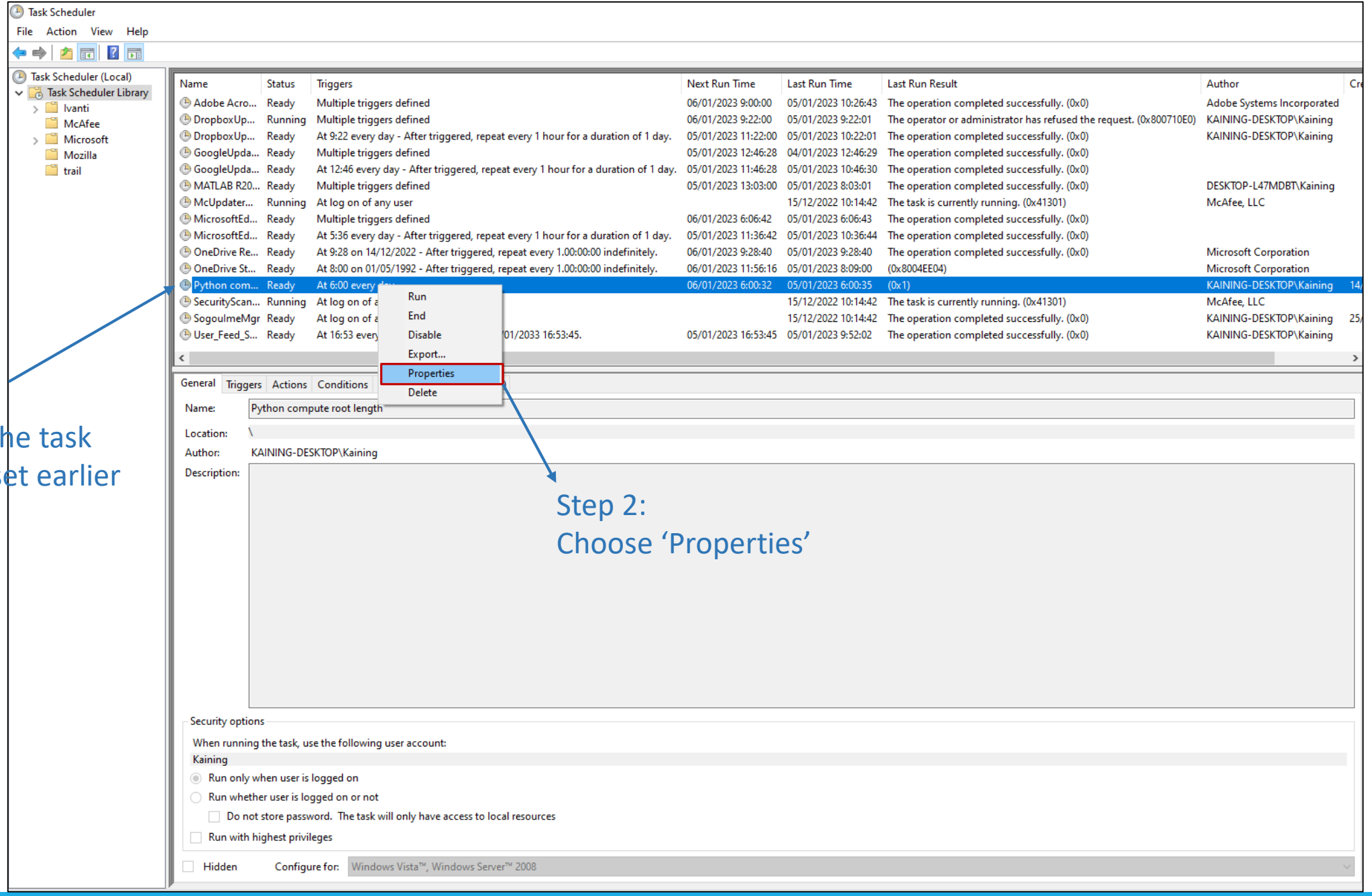


Part 3: Automated data analysis

Step-by-step protocol

2. Set task scheduler

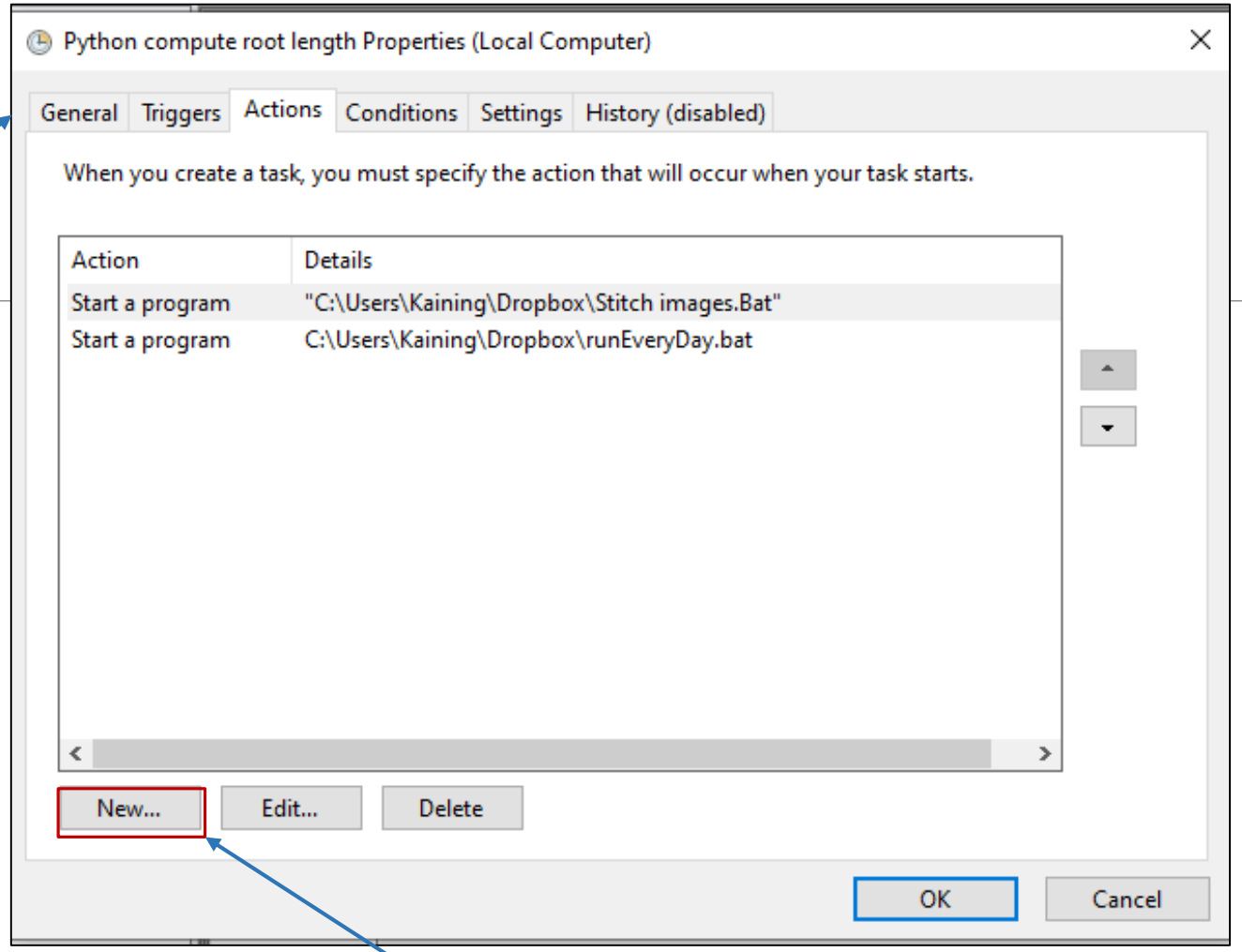
2.3 Once the basic task is set, add multiple actions under this task in a preferred order. Please see the instruction in the following slides.



Step 1:
Right-click the task which was set earlier

Step 2:
Choose ‘Properties’

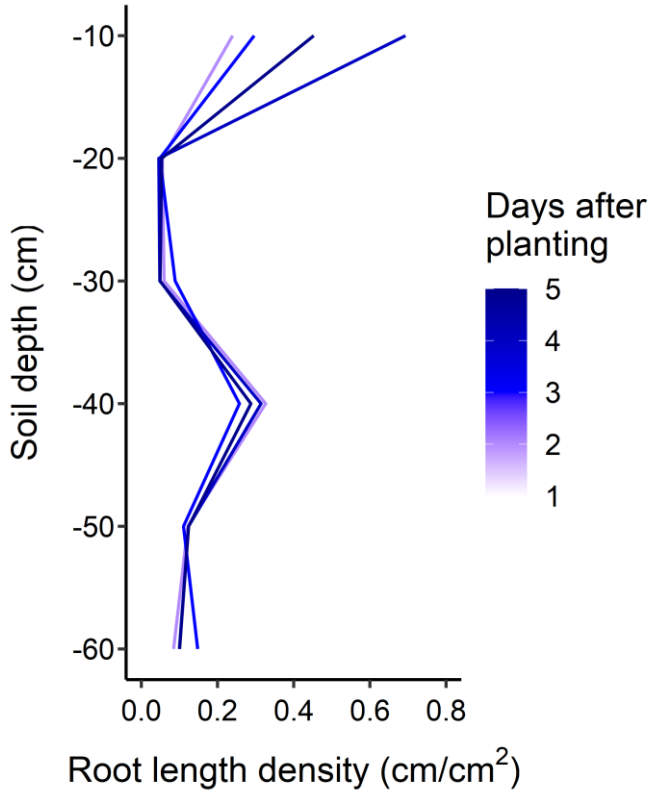
Step 3:
This panel is for changing various propertities of the task



Step 4:
Click ‘New’ if new action needs to be added
Note: new actions should be in the batch file format

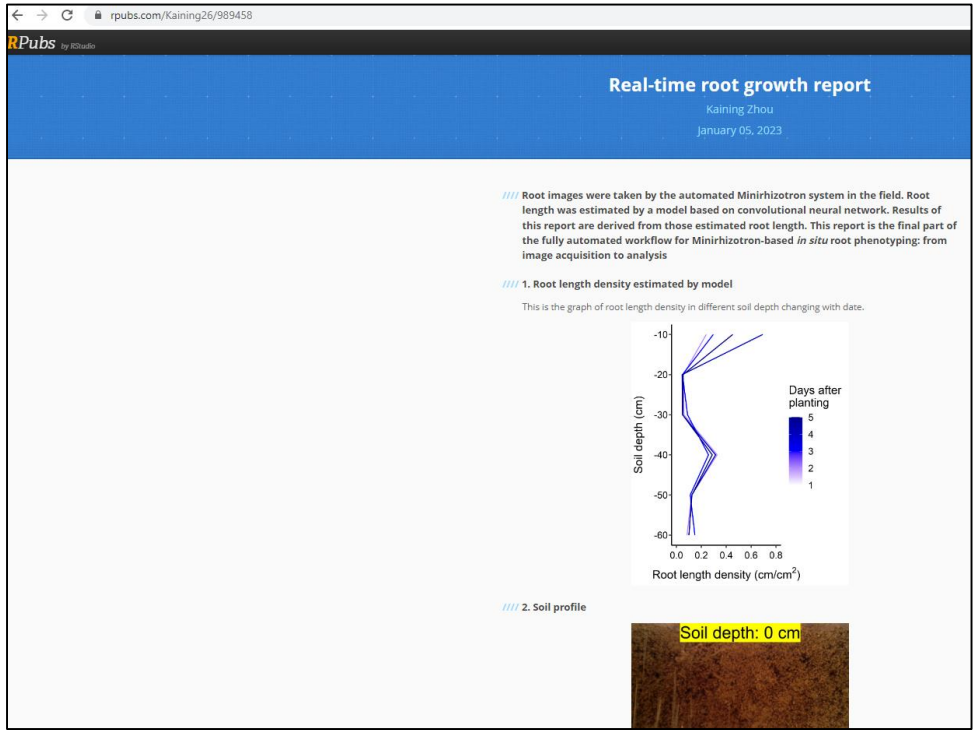
Result demonstrations:

Time-series RLD plot



Stitched image

Online root growth report



Online tutorial

1. About batch file:

https://www.techtarget.com/searchwindowsserver/definition/batch-file

2. How to create an automated task using Task Scheduler on Windows 10

https://www.windowscentral.com/how-create-automated-task-using-task-scheduler-windows-10

3. Scheduling Rmarkdown files on Windows

https://www.r-bloggers.com/2021/10/scheduling-rmarkdown-files-on-windows-your-foolproof-guide/