DEVELOPING A LOW-COST DIGITAL IMAGING SYSTEM FOR PLANT PHENOTYPING USING RASPBERRY PI COMPUTERS

Agriculture and Agri-Food Canada
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INTRODUCTION

- In recent years advancements in digital electronics, and sensor technologies in agriculture have aided in the development of innovative methods for measuring plant phenotypic characteristics.
- In this study the Raspberry Pi (RPi) based automation system was integrated with a imaging sensor (Sony IMX219 PQ CMOS 8MP camera) in growth chamber to timely monitor the crop growth parameters in wheat breeding trial for plant phenotyping.
- The RPi system was programmed using open-source Python scripting to capture high-resolution multiple images in user defined time interval (~4 hrs) throughout the experimental cycle.
- These images allow us to study about the morphometric phenology (structure, plant height, plant density/volume, canopy cover, leaf area index, anthesis timing, maturity and digital biomass) and other physiological parameters which represents overall plant growth and health.

MATERIALS AND METHODS

Hardware and software;

The Raspberry Pi module with the accessories are shown in the **Fig. 1.**

- Raspberry Pi microprocessor (Pi 3 B+ / 4 Model B Quad Core 64 Bit)
- Raspberry Pi camera (IMX219 Sony 8MP)
- Solar power bank (5V, 3A)
- Display Monitor (7"), clock (D3231) and cables (HDMI and USB C type)
- Shelving unit and light source (growth chamber)
- Python programming software

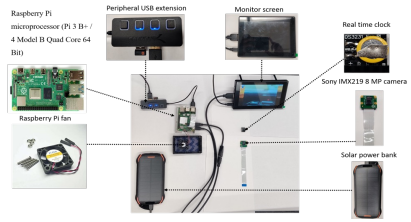

Figure 1. Raspberry Pi module and accessories

The flowchart **(Fig. 2)** for time-lapse digital image capturing script is shown below

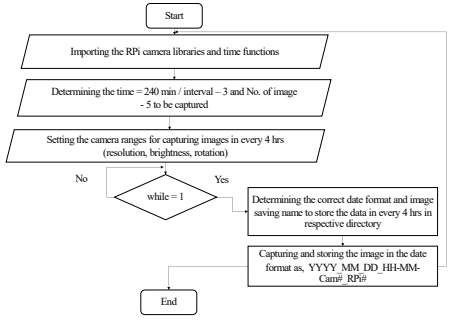

Figure 2. Flowchart for digital image capturing time-lapse script

EXPERIMENTAL SETUP

- The experimental setup for plant phenotyping (Wheat crop) was carried out in growth chamber at the Lethbridge research and development centre (LeRDC), AB (**Fig. 3**).
- The growth chamber has two sides where five shelves were installed with Raspberry Pi module to capture digital images. **Fig. 4** represent the one side of the growth chamber and **Fig. 5** shows the mounting view of the Raspberry Pi module.

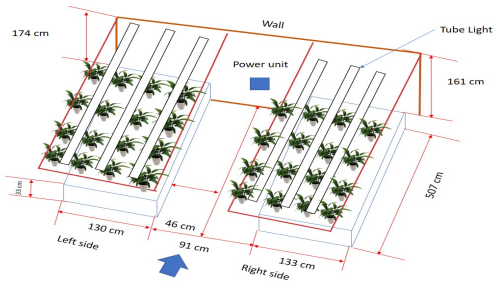

Figure 3. The Schematic diagram of the growth chamber at the LeRDC, AB

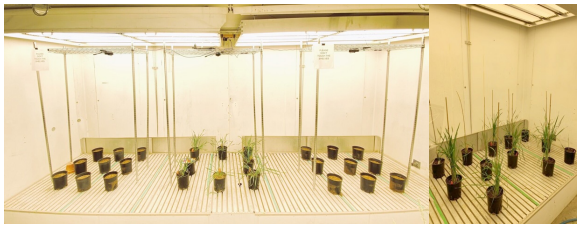

Figure 4. The experimental setup of plant phenotyping system in growth chamber

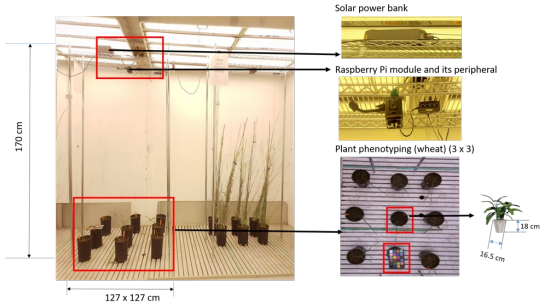

Figure 5. The closed mounting setup of Raspberry Pi module in growth chamber

ACKNOWLEDGEMENT

The authors would like to thank the Agriculture and Agri-Food Canada (AAFC) for supporting this Abase and WGRF project. We acknowledge the Lethbridge Research Centre's winter cereal group members for their support in setting up experiments to conduct this study. Funding from the following institutions are greatly appreciated:

Western Grains Research Foundation
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

RESULTS AND DISCUSSIONS

The proposed experimental setup is able to captured 30 images in a day. The Wi-Fi hotspot was used for data transfer from RPi to Laptop. The image processing software and python scripts were used to analyze the digital images captured by Raspberry Pi camera with the following three steps (**Fig. 6**).

- ***Object segmentation*** - Segmenting the plant region in the image captured.
- ***Plant extraction*** - Extracting the plant leaves in the image captured.
- ***Morphology*** - Analyzing and processing the extracted plant pixels based on the shape which helps to determine the plant structure and growth.

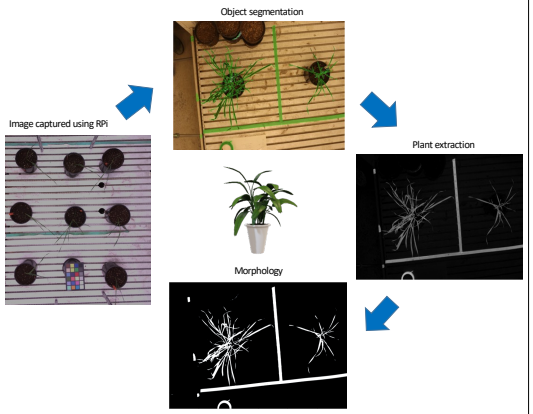

Figure 6. The plant morphology retrieval process from the digital image collected using Raspberry Pi module in the growth chamber

CONCLUSION

- The Raspberry Pi system found promising to automatically capture spatiotemporal images to identify plant growth and structure.
- The images has been timely analyzed to extract morphological features and physiological characteristics of plants (phenology).
- This study suggests that the developed low cost digital imaging system can be integrated with internet to facilitate Internet-of-Things (IoT) based sensor system which helps plant breeders to make timely decisions and monitor crops health in real-time.

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