Smart Multispectral Monitoring System of the Real-Time Estimation of Water Stress in the Crop and Automatic Irrigation (PLANTSENS)

Lukasz Rojek

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Beuth Hochschule für Technik in Berlin

Outline

Introduction

What are Project Goals and Objectives ?

Remote	sensing of water deficiency stress in crops.
Automatic	precise crop irrigation based multispectral imaging.
Targeted	resource-sensitive water supply.
Precise	geo-referenced monitoring system.

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DATA COLLECTION

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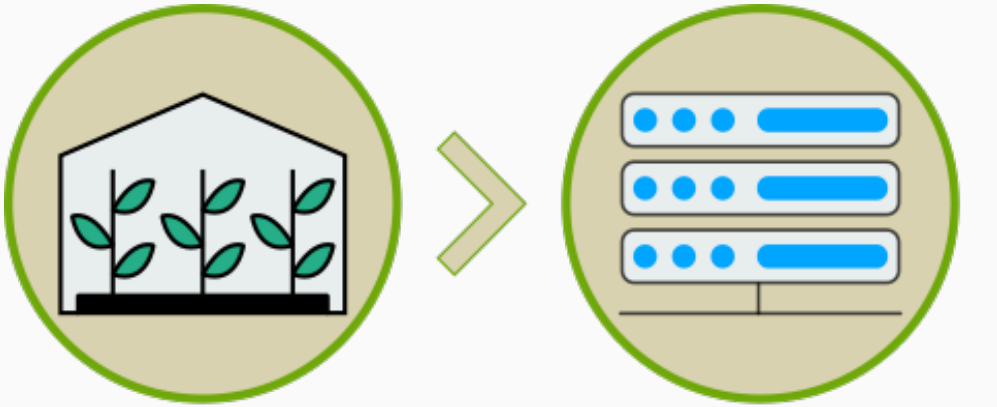
Precise	geo-referenced monitoring system.



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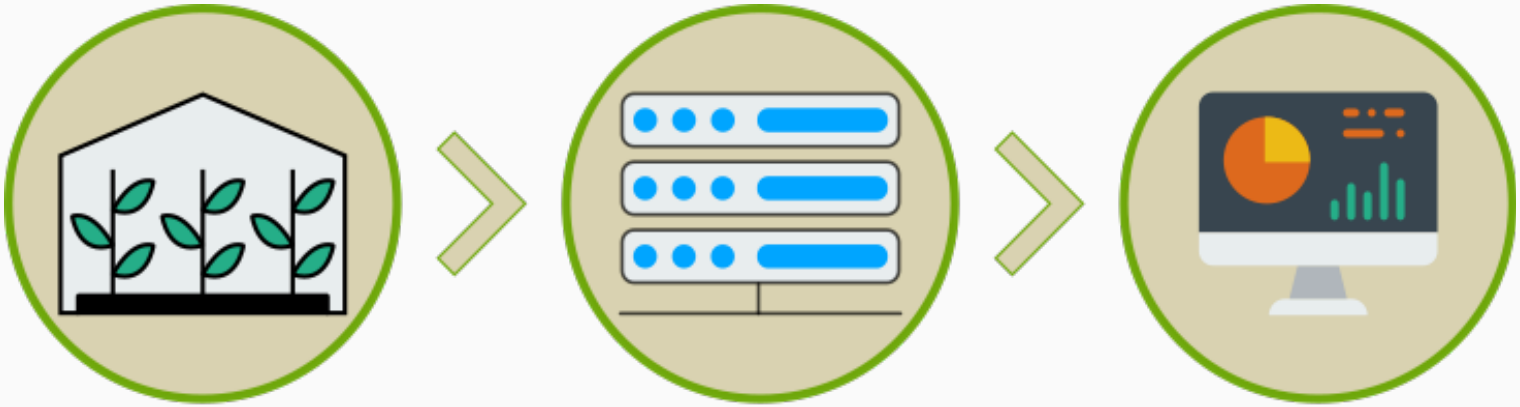

System Configuration

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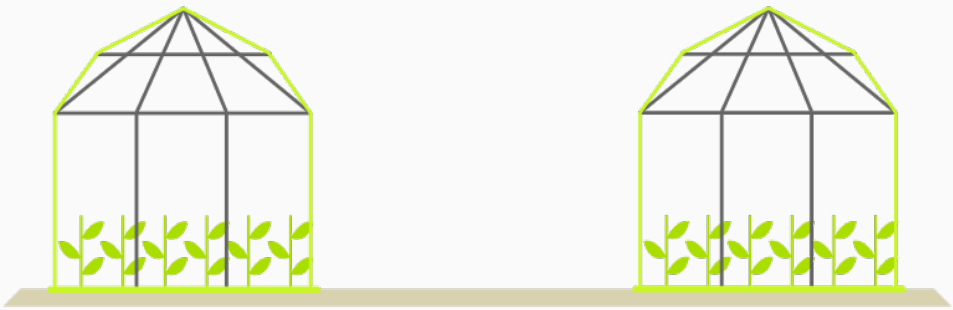

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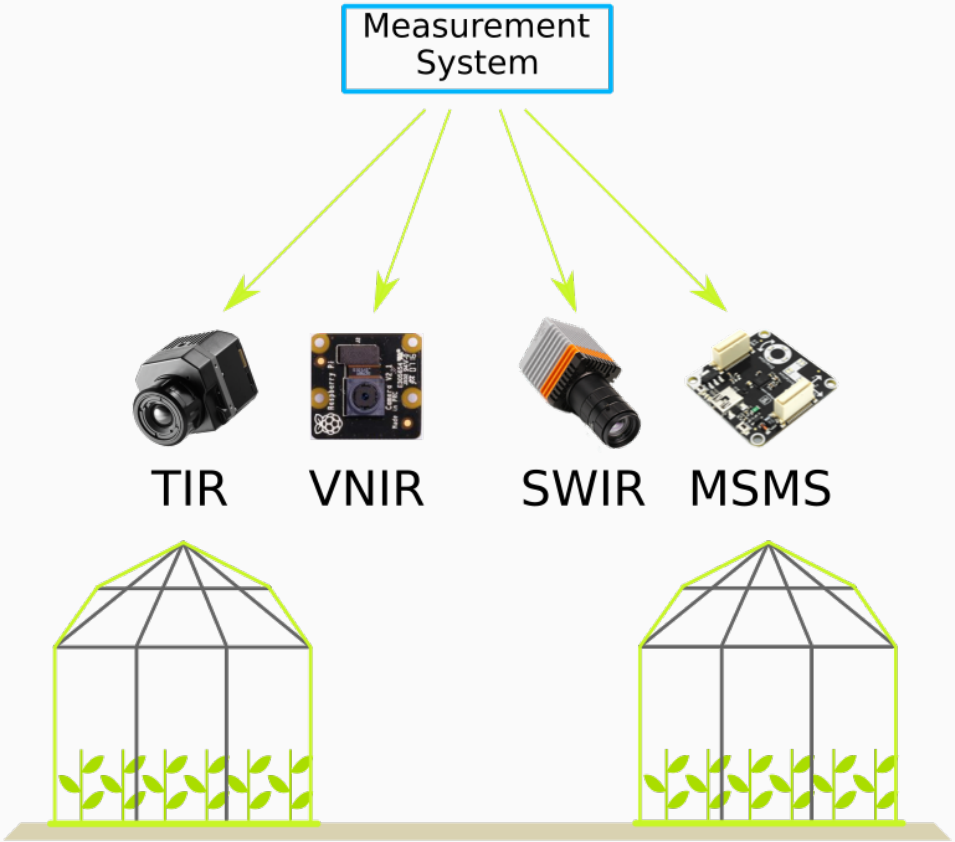

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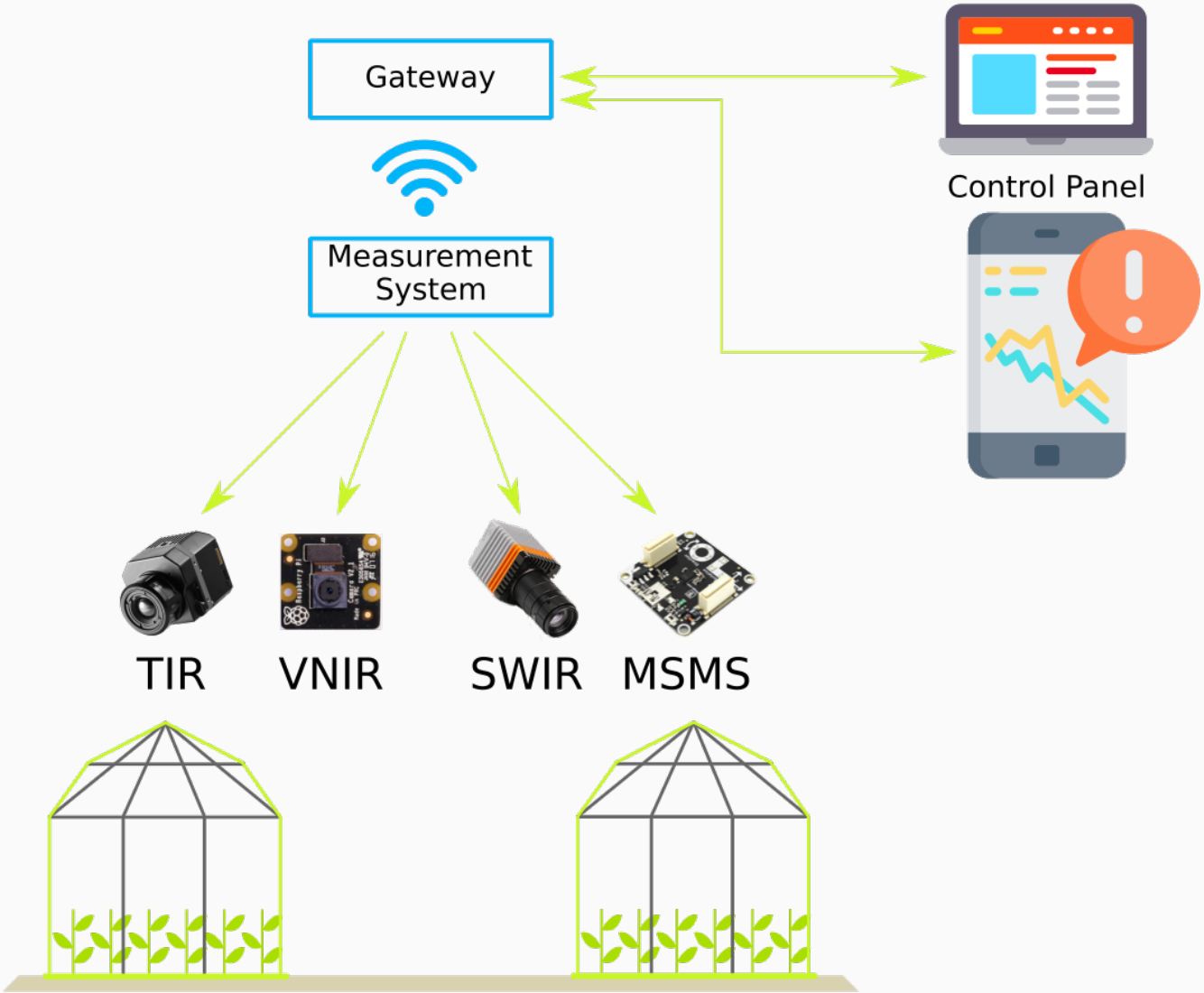

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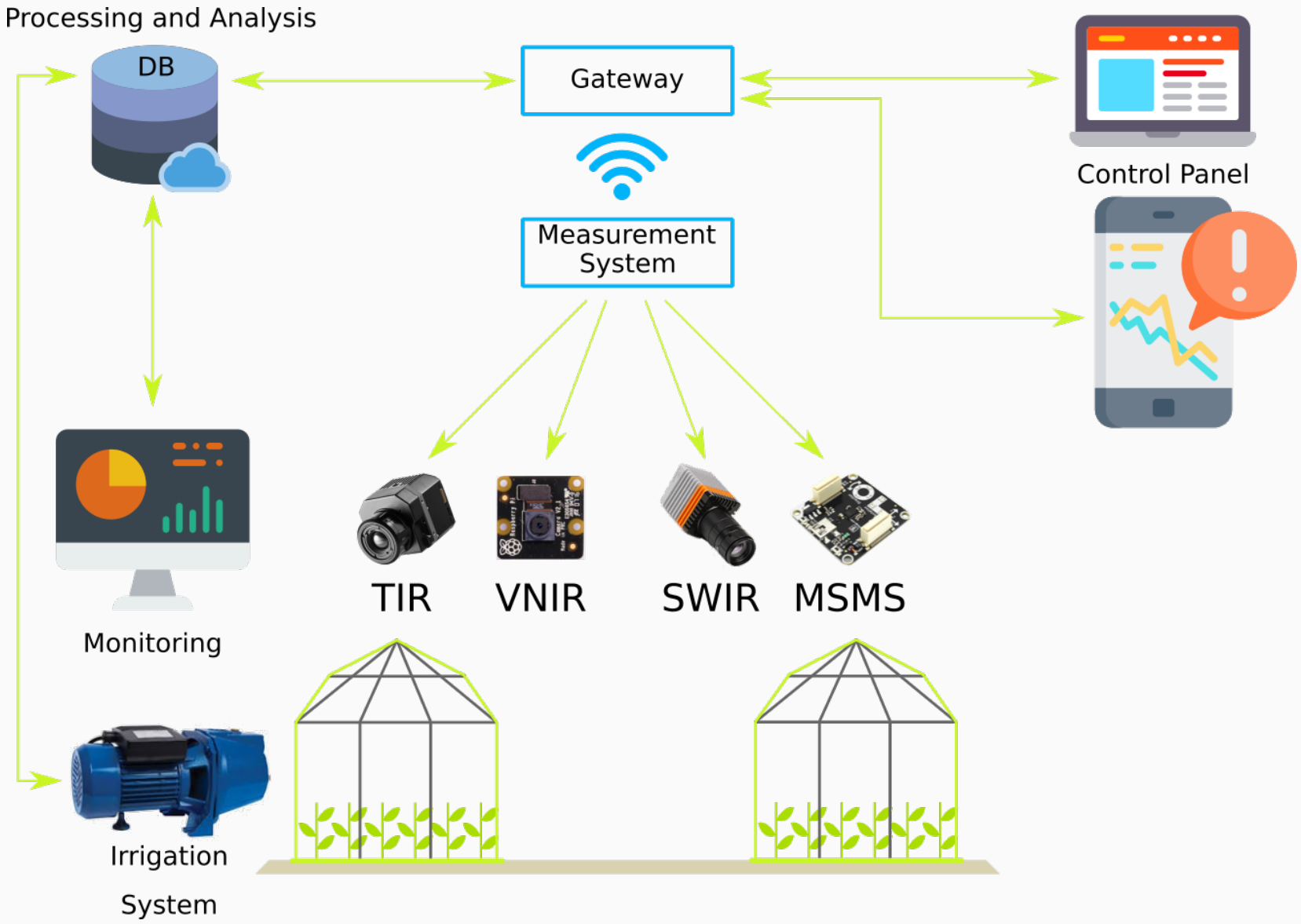
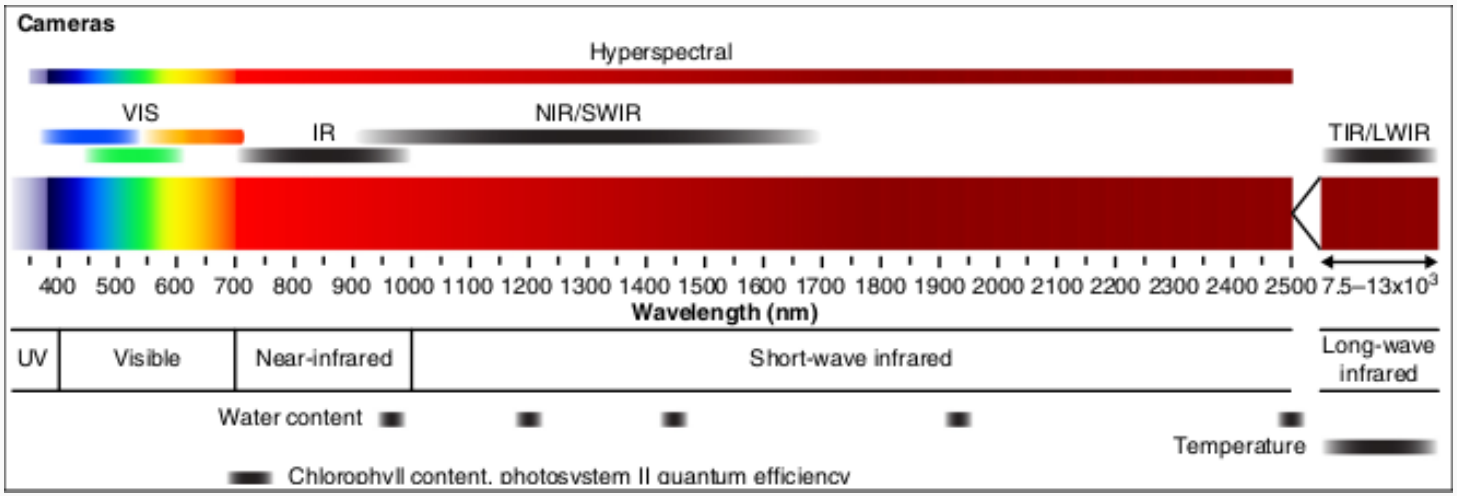


Materials and Methods

What are the Measurement Methods ?

Correlation	between temperature and water content of the crop.
Reflection	of the **s**hort-**w**ave **i**nfra**r**ed (swir) radiation (1450 nm) for estimating the water content.
Thermal imaging	for estimating the plant temperature.
Camera System	mounted on rails (indoor), i.e. greenhouse and UAV (outdoor).



Credit: *www.sciencedirect.com*

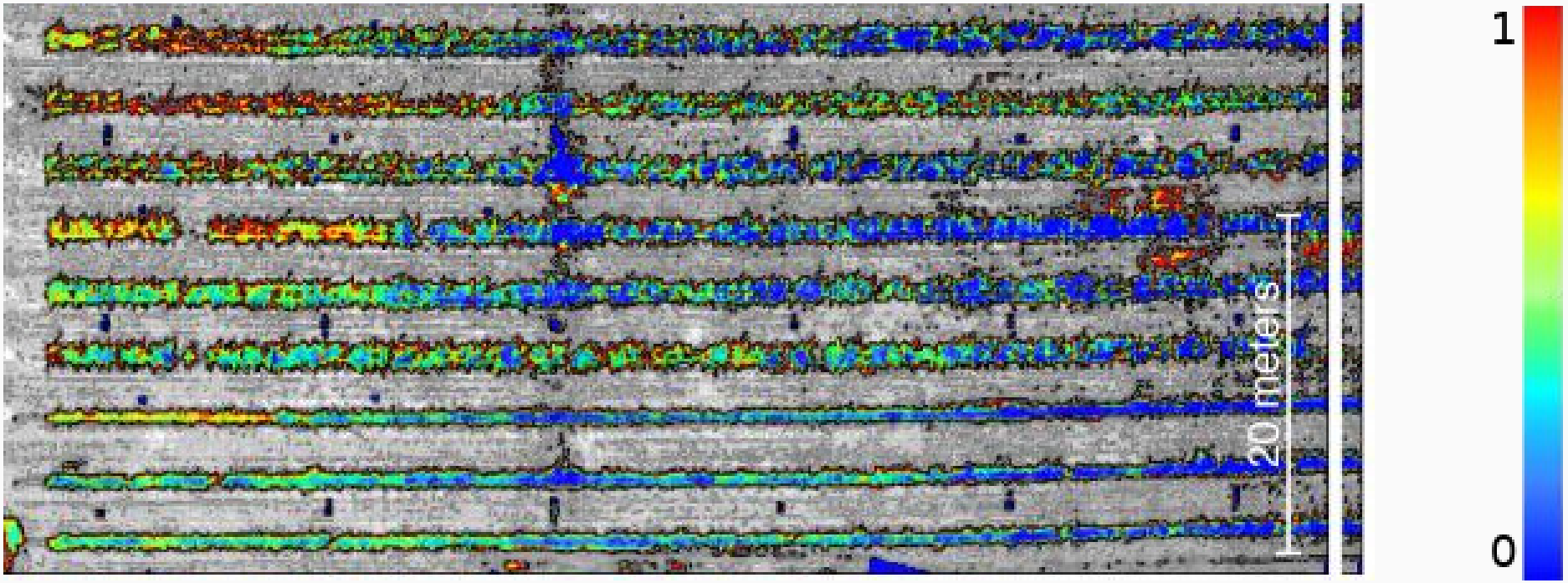
Crop Water Stress Index (CWSI)

The **C**rop **W**ater **S**tress **I**ndex can be used as an indicator of stomatal closure and water deficit stress as well as a means for targeted and precise irrigation.

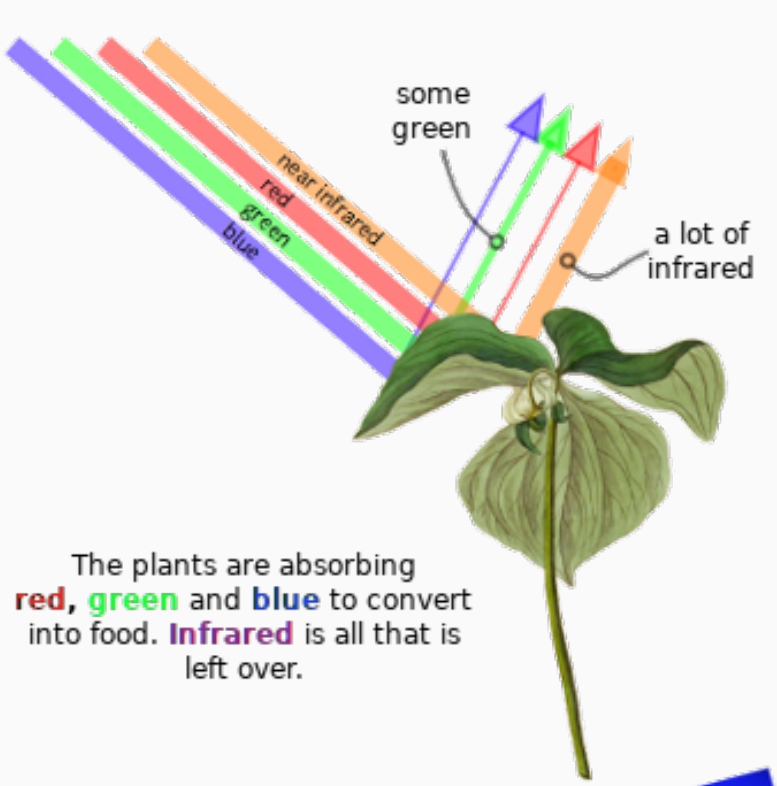
$$\mathrm{CWSI} = \frac{T_{\mathrm{leaf}} - T_{\mathrm{wet}}}{T_{\mathrm{dry}} - T_{\mathrm{wet}}}$$

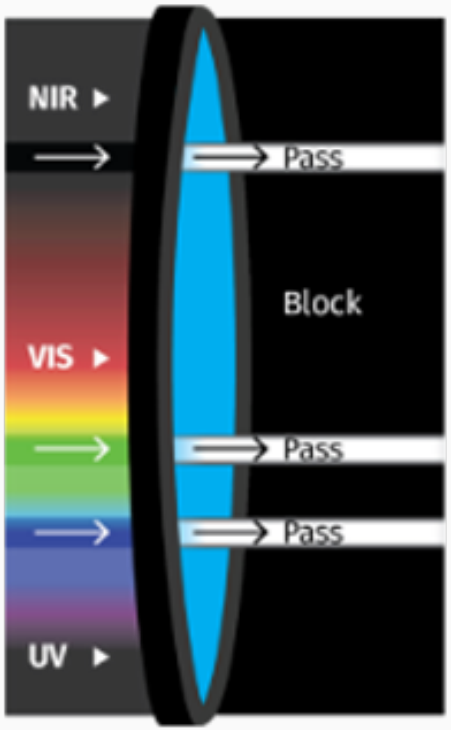
T_{leaf} ... is the current leaf temperature.
T_{wet} ... is the lower boundary for leaf temperature.
T_{dry} ... is the upper boundary for leaf temperature.

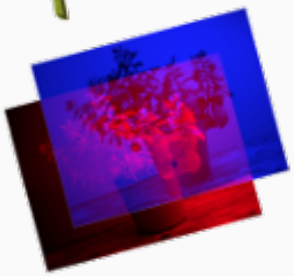
Crop Water Stress Index (CWSI)

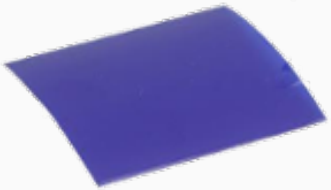


How does the Visible Near Infrared (VNIR) work ?





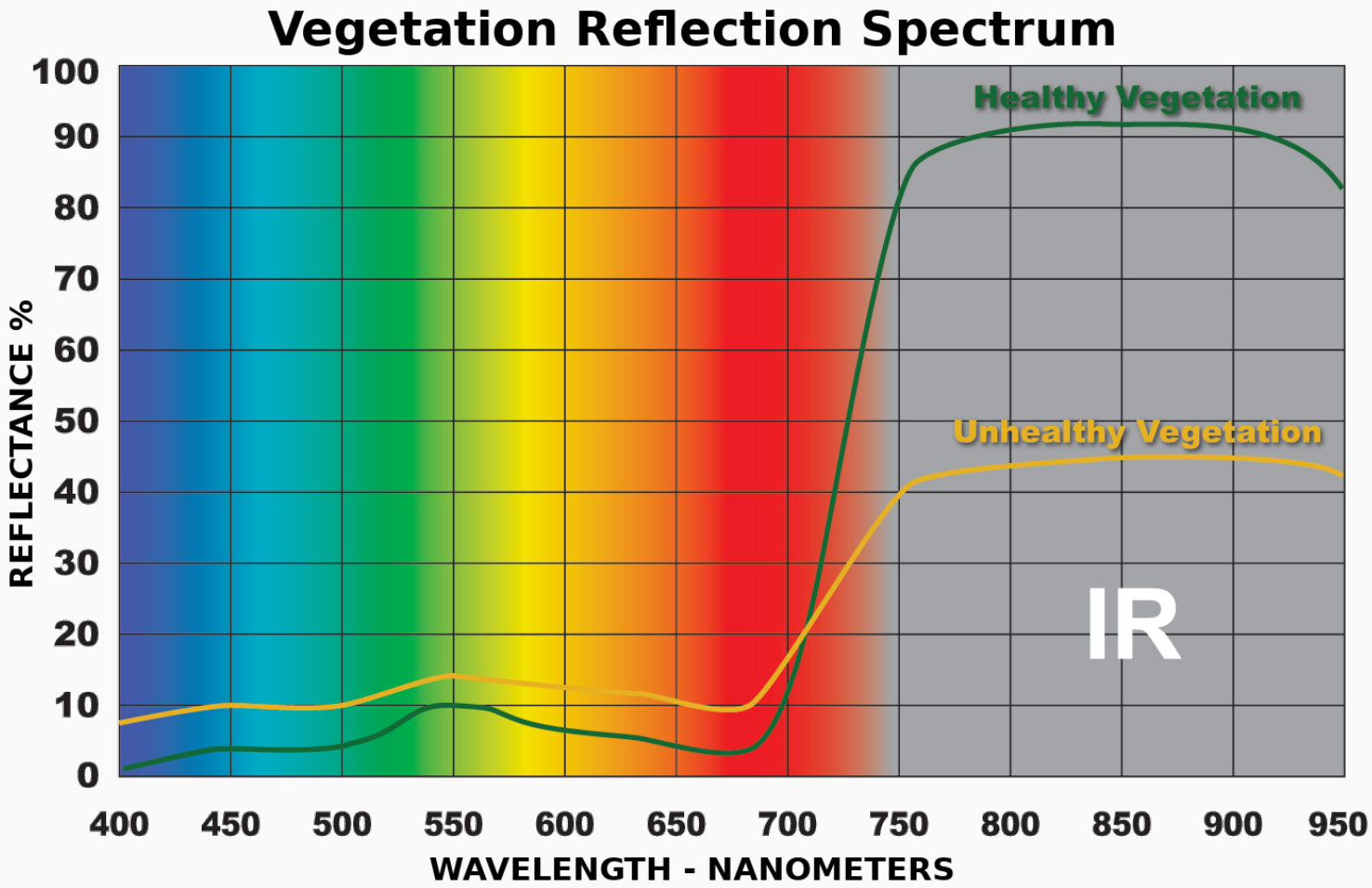




Two images are combined

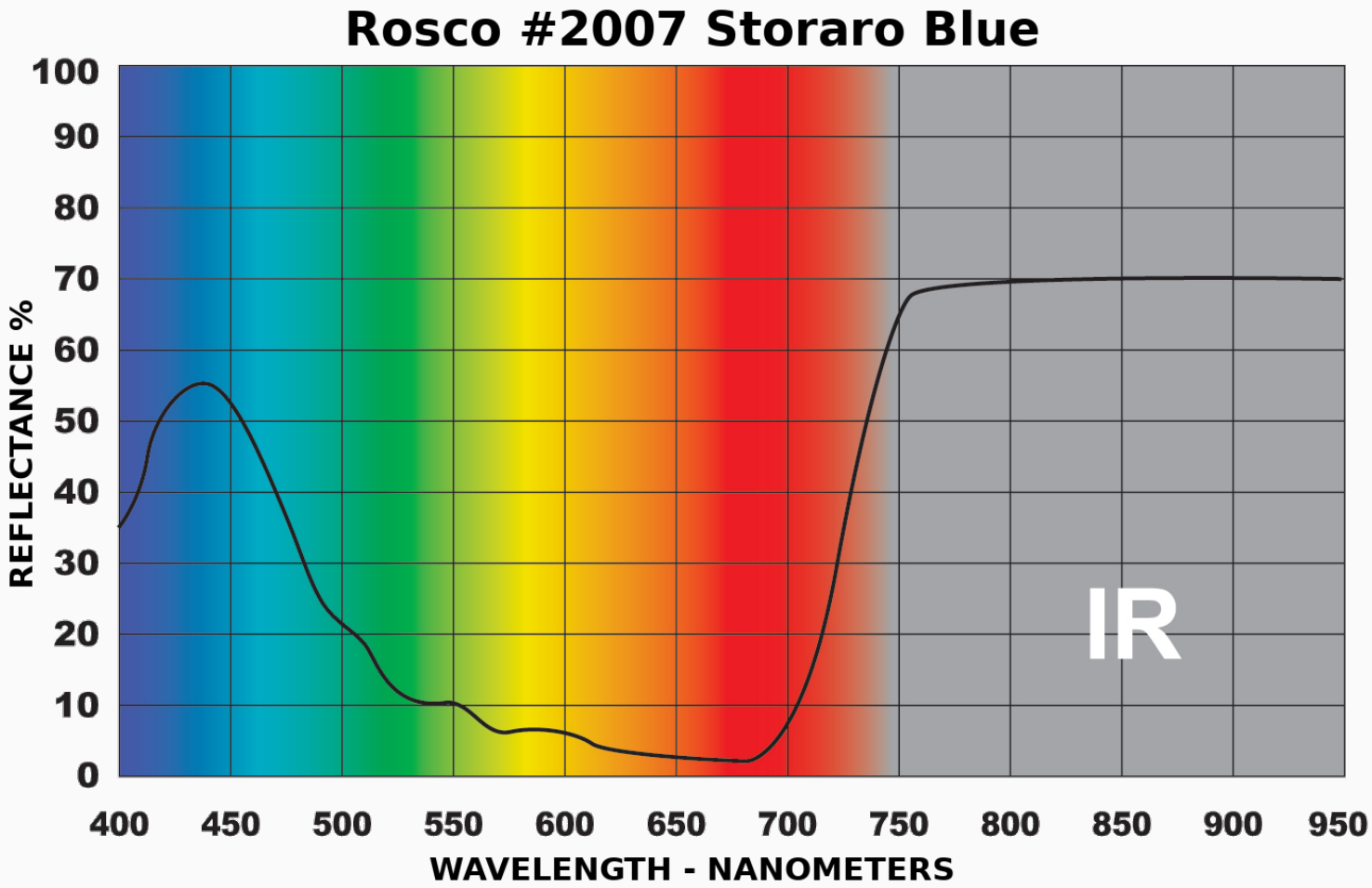
Credit: *www.raspberrypi.org & www.infragram.org*

Rosco Storaro Blue



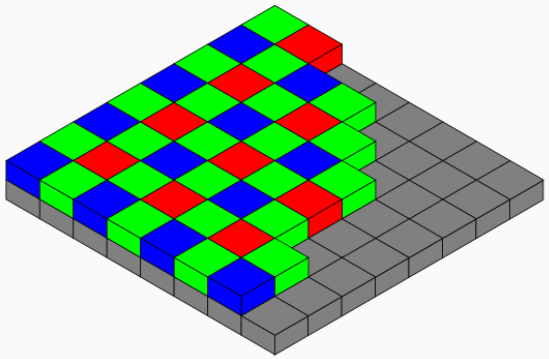
Credit: *www.rosco.com*

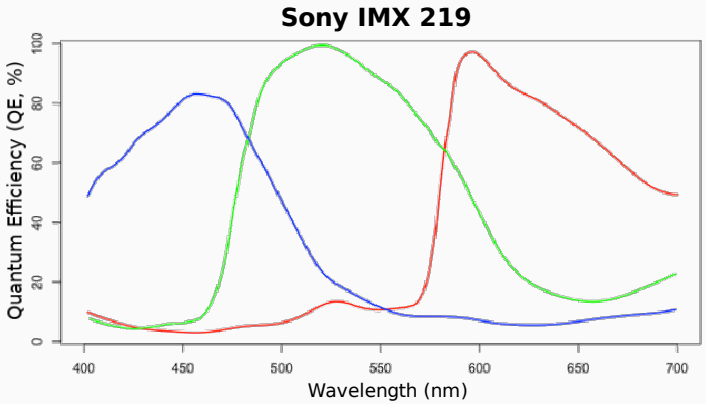
Rosco Storaro Blue

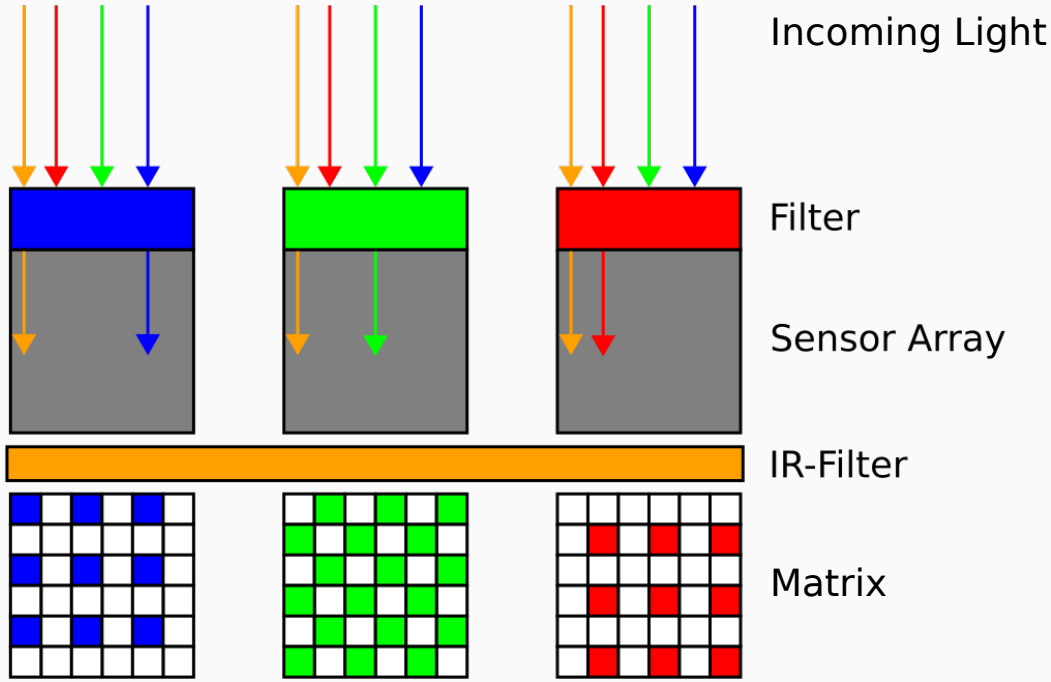


Credit: *www.rosco.com*

Bayer-Filter



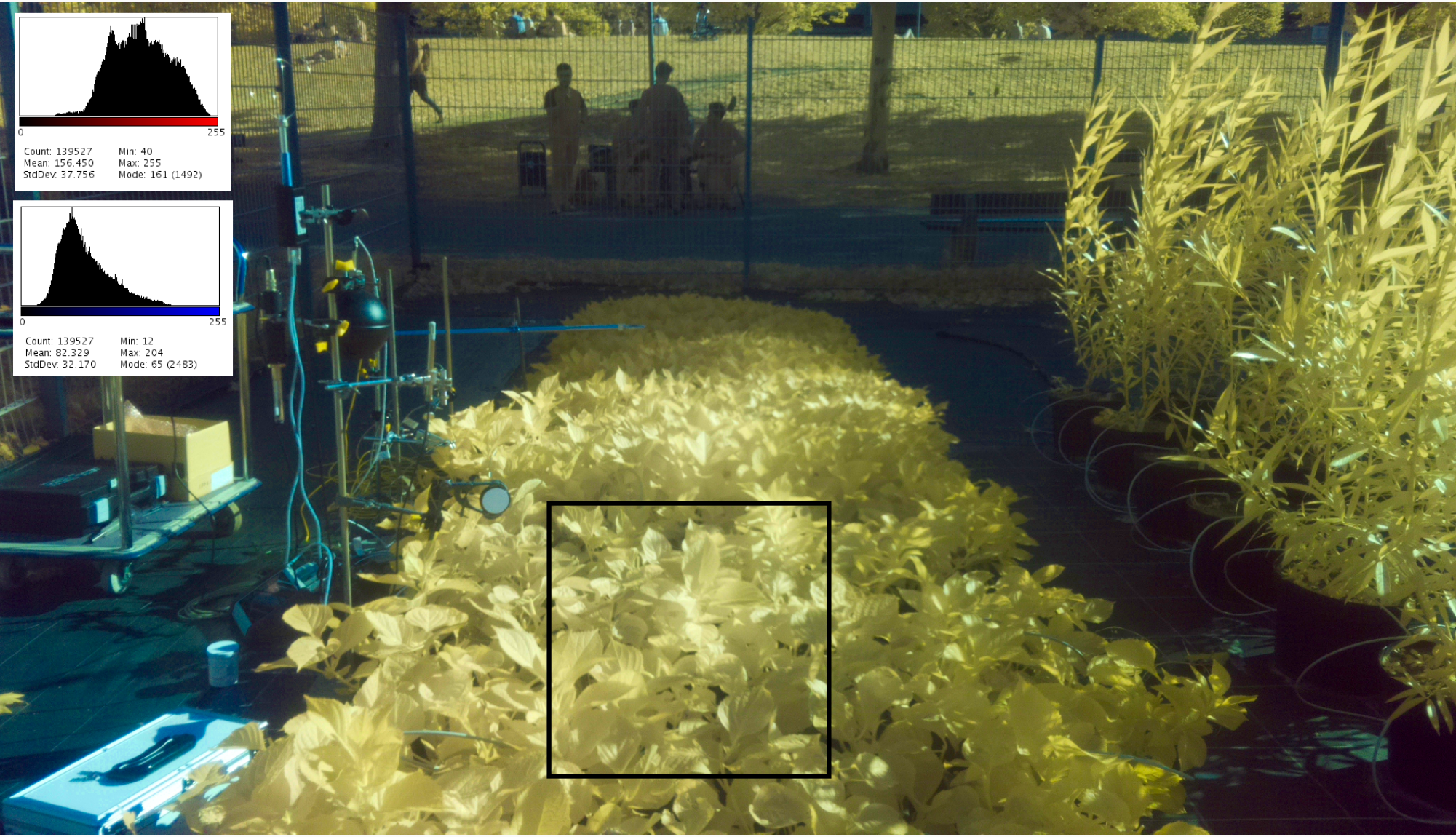




IMX219

The Sony IMX219 CMOS Sensor uses the Bayer filter in visible spectral range from 400 to 700 nm. The filter pattern has the BGGR channel order.

Normalized Difference Vegetation Index (NDVI)



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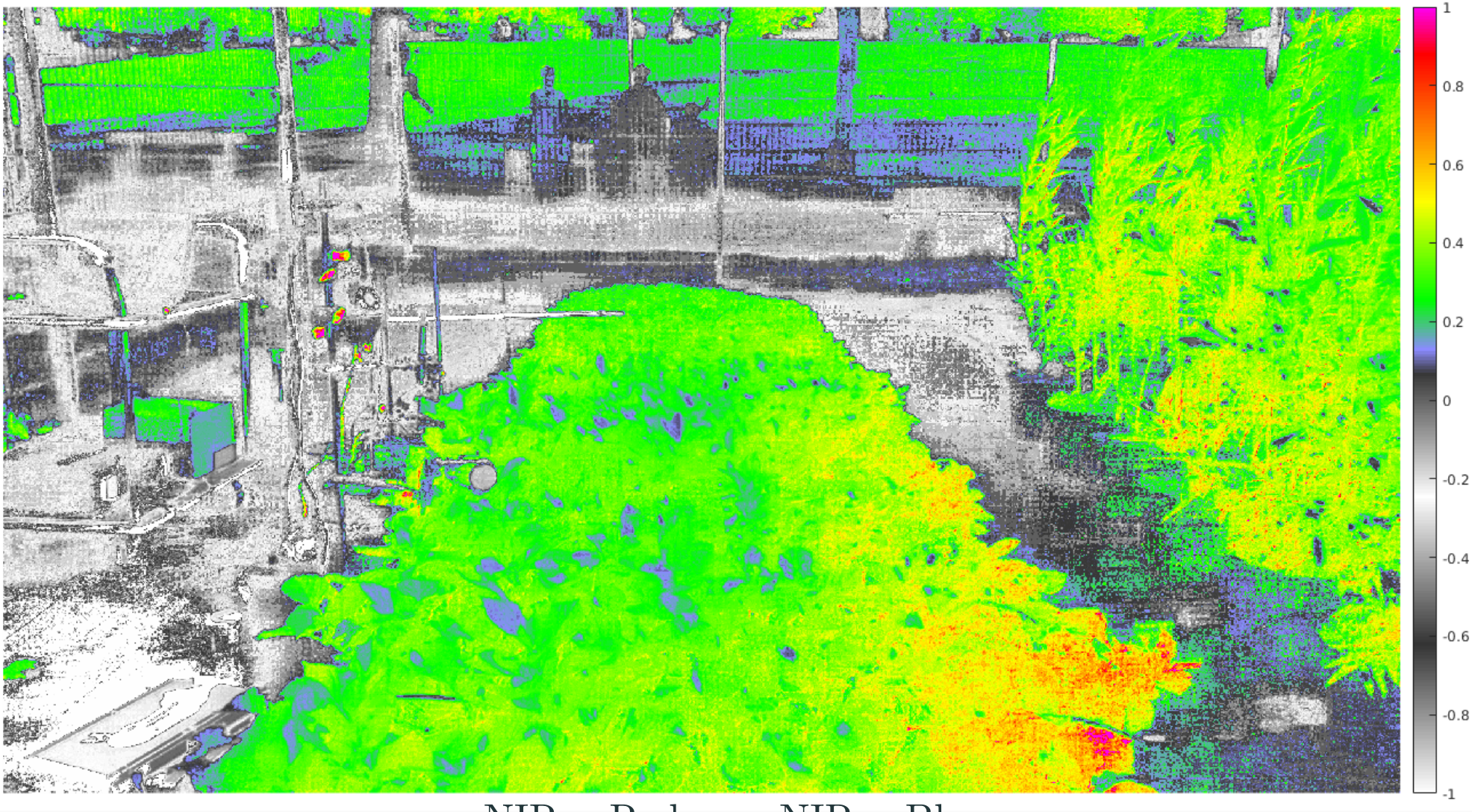
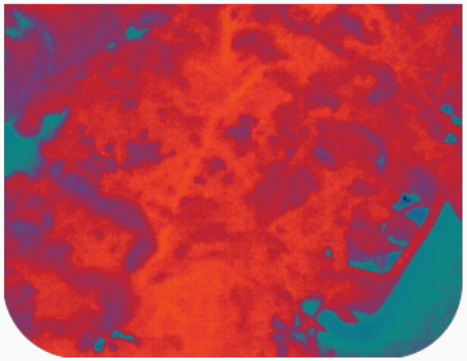


$$\frac{\mathrm{NIR} - \mathrm{Red}}{\mathrm{NIR} + \mathrm{Red}} \longrightarrow \frac{\mathrm{NIR} - \mathrm{Blue}}{\mathrm{NIR} + \mathrm{Blue}}$$

Normalized Difference Vegetation Index (NDVI)

Thermal Infrared (TIR)



Credit: *www.flir.com*

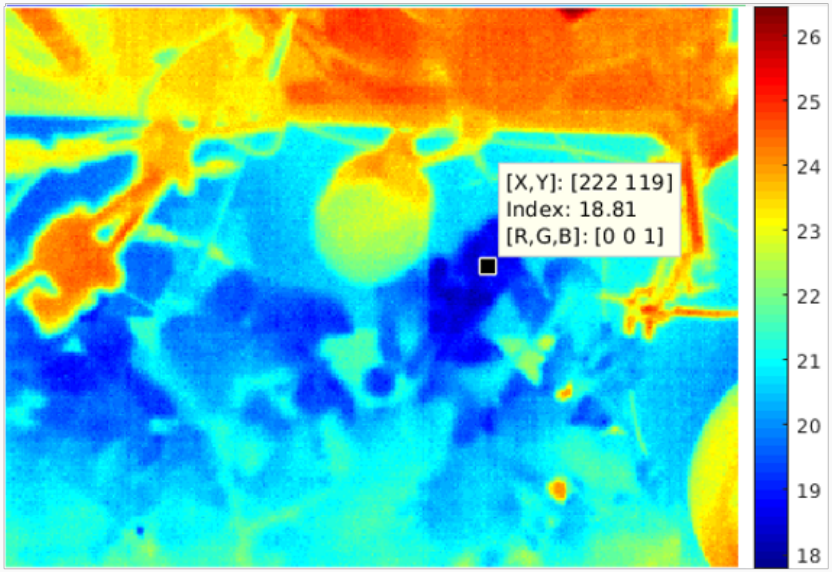
Resolution	336x256 px
Lens	13mm; 25° x 19°
Spectral Range	7.5 - 13.5 µm
File Formats	JPEG, RJPEG, TIFF
Interfaces	USB, PWM, MAVLink

Wet Leaf (lower boundary)

metadata

```
Emissivity                          : 0.94
Object Distance                     : 0.00 m
Reflected Apparent Temperature      : -30.0 C
Atmospheric Temperature             : 25.0 C
IR Window Temperature               : 22.0 C
IR Window Transmission              : 1.00
Relative Humidity                   : 45.0 %
Planck R1                           : 17096.453
Planck B                            : 1428
Planck F                            : 1
Atmospheric Trans Alpha 1           : 0.006569
Atmospheric Trans Alpha 2           : 0.012620
Atmospheric Trans Beta 1            : -0.002276
Atmospheric Trans Beta 2            : -0.006670
Atmospheric Trans X                 : 1.900000
```

wet leaf



14 bit raw data

	220	221	222	223
118	3112	3096	3096	3099
119	3099	3105	3109	3096
120	3085	3096	3107	3092
121	3099	3107	3106	3107
122	3102	3105	3097	3107
123	3098	3100	3107	3107
124	3097	3096	3113	3107
125	3102	3107	3116	3112

temperature (°C)

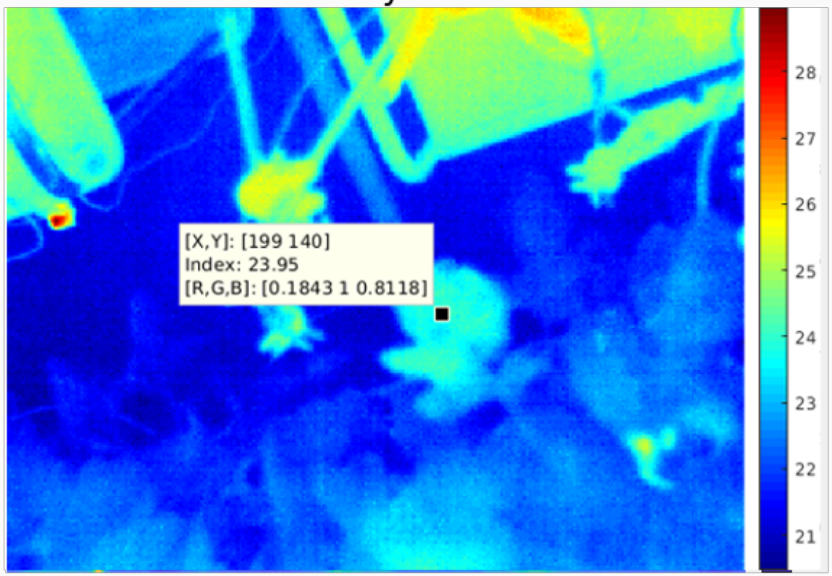
	220	221	222	223
118	18.8675	18.5386	18.5386	18.6004
119	18.6004	18.7238	18.8059	18.5386
120	18.3119	18.5386	18.7649	18.4562
121	18.6004	18.7649	18.7443	18.7649
122	18.6621	18.7238	18.5592	18.7649
123	18.5798	18.6210	18.7649	18.7649
124	18.5592	18.5386	18.8880	18.7649
125	18.6621	18.7649	18.9496	18.8675

Dry Leaf (upper boundary)

metadata

```
Emissivity                          : 0.94
Object Distance                     : 0.00 m
Reflected Apparent Temperature      : -30.0 C
Atmospheric Temperature             : 25.0 C
IR Window Temperature               : 22.0 C
IR Window Transmission              : 1.00
Relative Humidity                   : 45.0 %
Planck R1                           : 17096.453
Planck B                            : 1428
Planck F                            : 1
Atmospheric Trans Alpha 1           : 0.006569
Atmospheric Trans Alpha 2           : 0.012620
Atmospheric Trans Beta 1            : -0.002276
Atmospheric Trans Beta 2            : -0.006670
Atmospheric Trans X                 : 1.900000
```

dry leaf



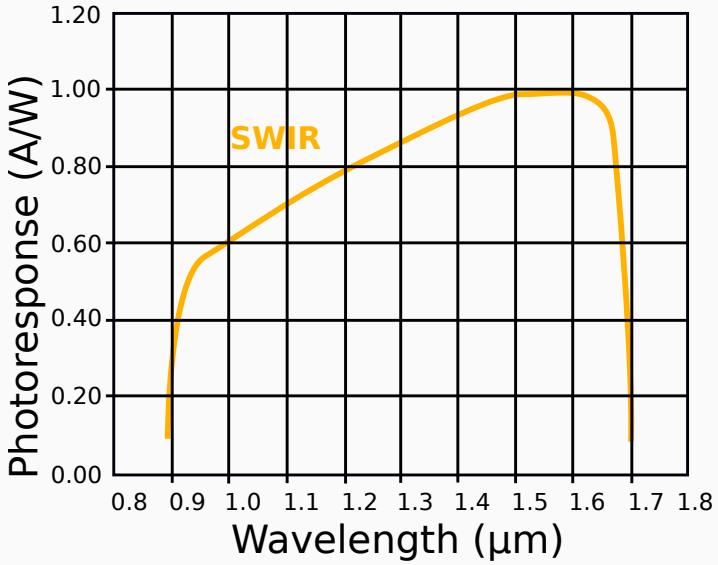
14 bit raw data

	197	198	199	200
139	3346	3356	3357	3356
140	3364	3351	3359	3356
141	3351	3335	3355	3350
142	3348	3341	3346	3346
143	3343	3343	3343	3351
144	3338	3347	3346	3343
145	3339	3335	3339	3336
146	3336	3334	3334	3339

temperature (°C)

	197	198	199	200
139	23.6947	23.8902	23.9097	23.8902
140	24.0462	23.7925	23.9487	23.8902
141	23.7925	23.4597	23.8706	23.7730
142	23.7339	23.5969	23.6947	23.6947
143	23.6360	23.6360	23.6360	23.7925
144	23.5185	23.7143	23.6947	23.6360
145	23.5381	23.4597	23.5381	23.4794
146	23.4794	23.4401	23.4401	23.5381

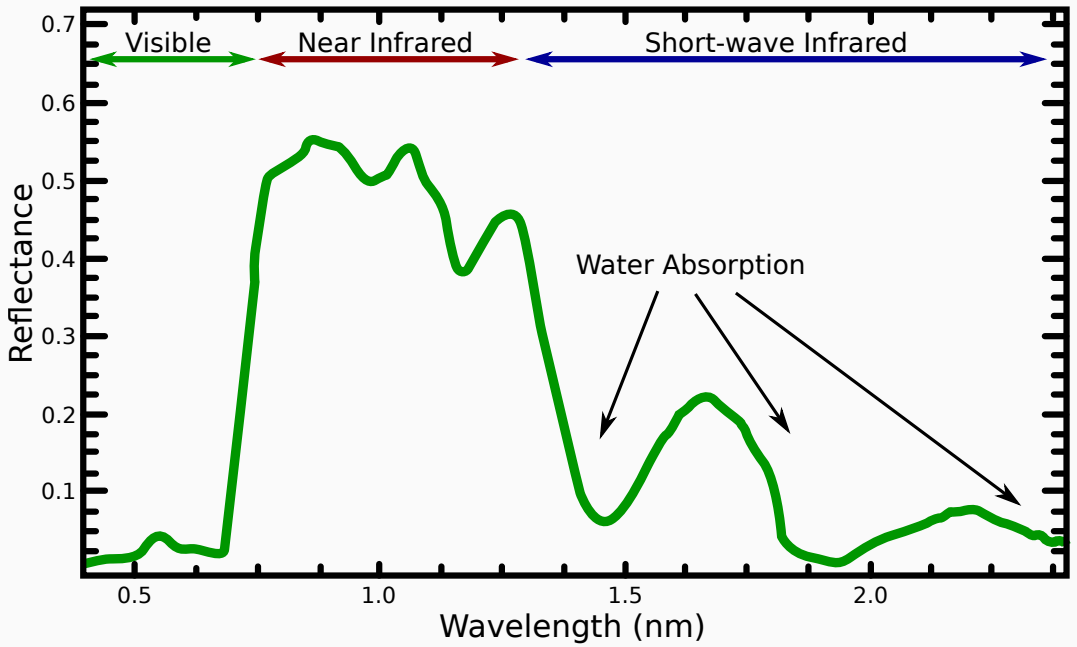
Short Wave Infrared (SWIR)



Credit: *www.xencis.com*

Resolution	336x256 px
Sensor Type	InGaAs
Spectral Range	0.9 - 1.7 µm
Depth	14-bit
Interface	GigE

Normalized Difference Water Index (NDWI)

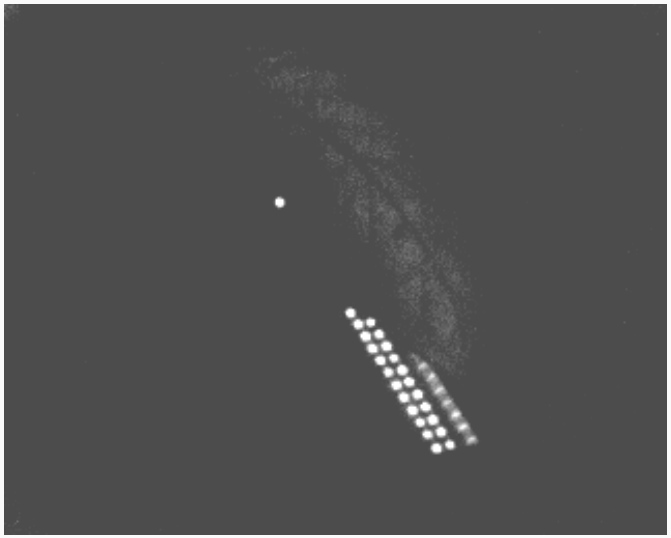


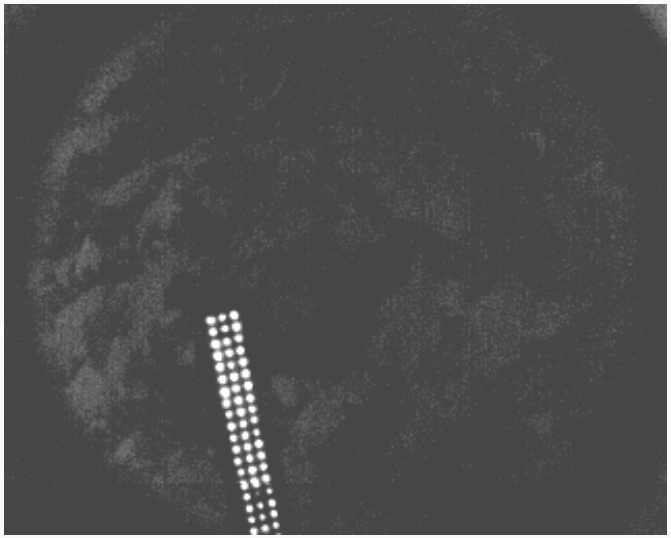
Credit: *www.thorlabs.com*

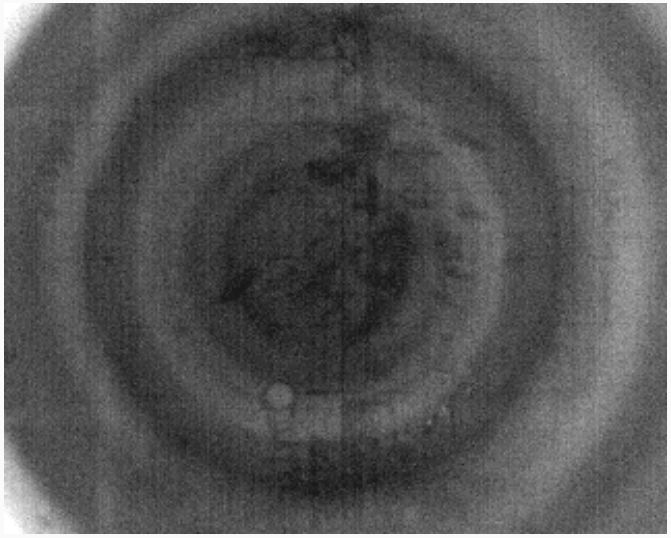
NDWI

$$\frac{\mathrm{SWIR}_{1450} - \mathrm{SWIR}_{1300}}{\mathrm{SWIR}_{1450} + \mathrm{SWIR}_{1300}}$$

1450nm vs 1300nm







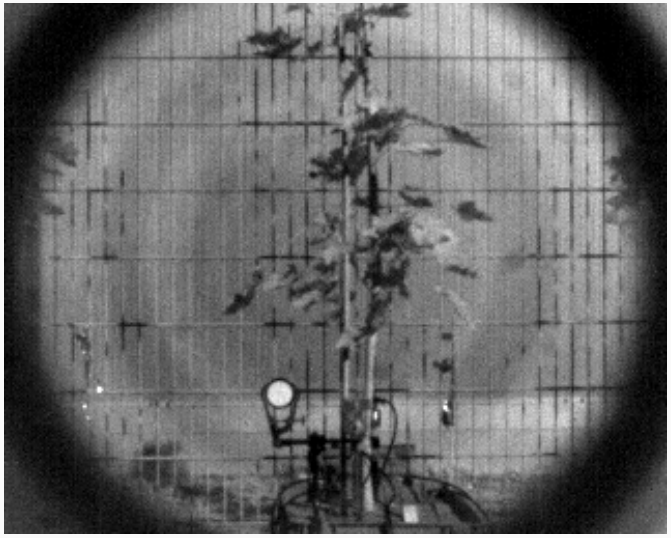


Image Overlap

Image Overlap

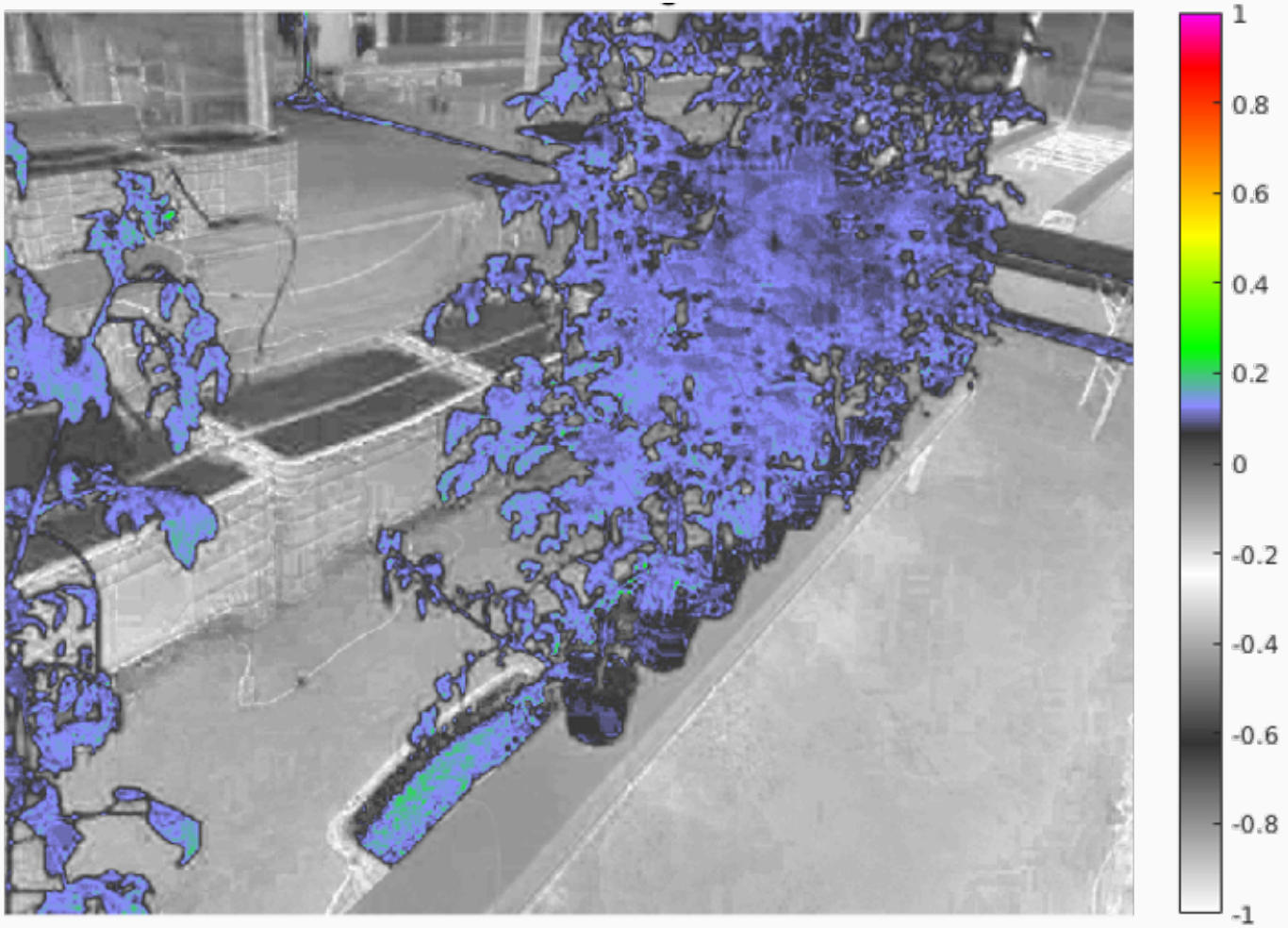


Image Overlap

Image Overlap

Image Overlap

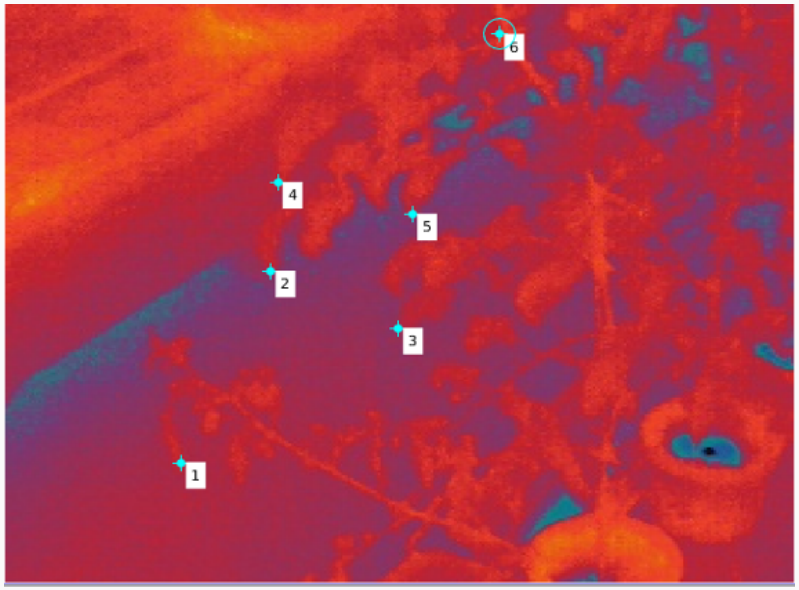
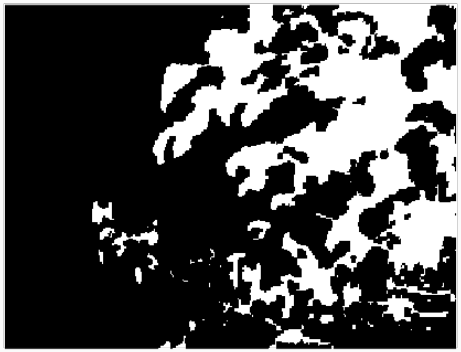


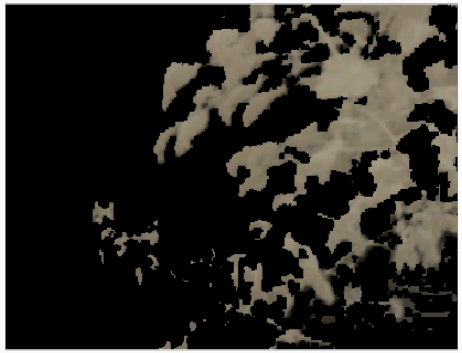
Image Overlap

NoIR

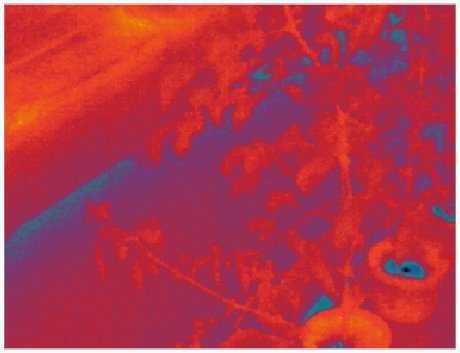
Threshold



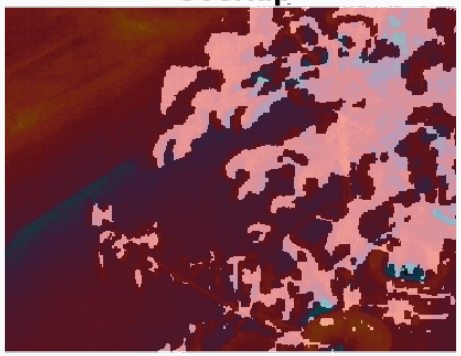
NoIR Mask



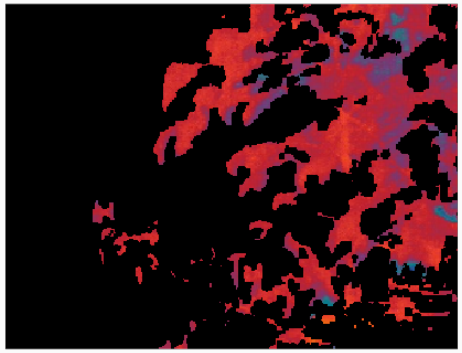
Thermal

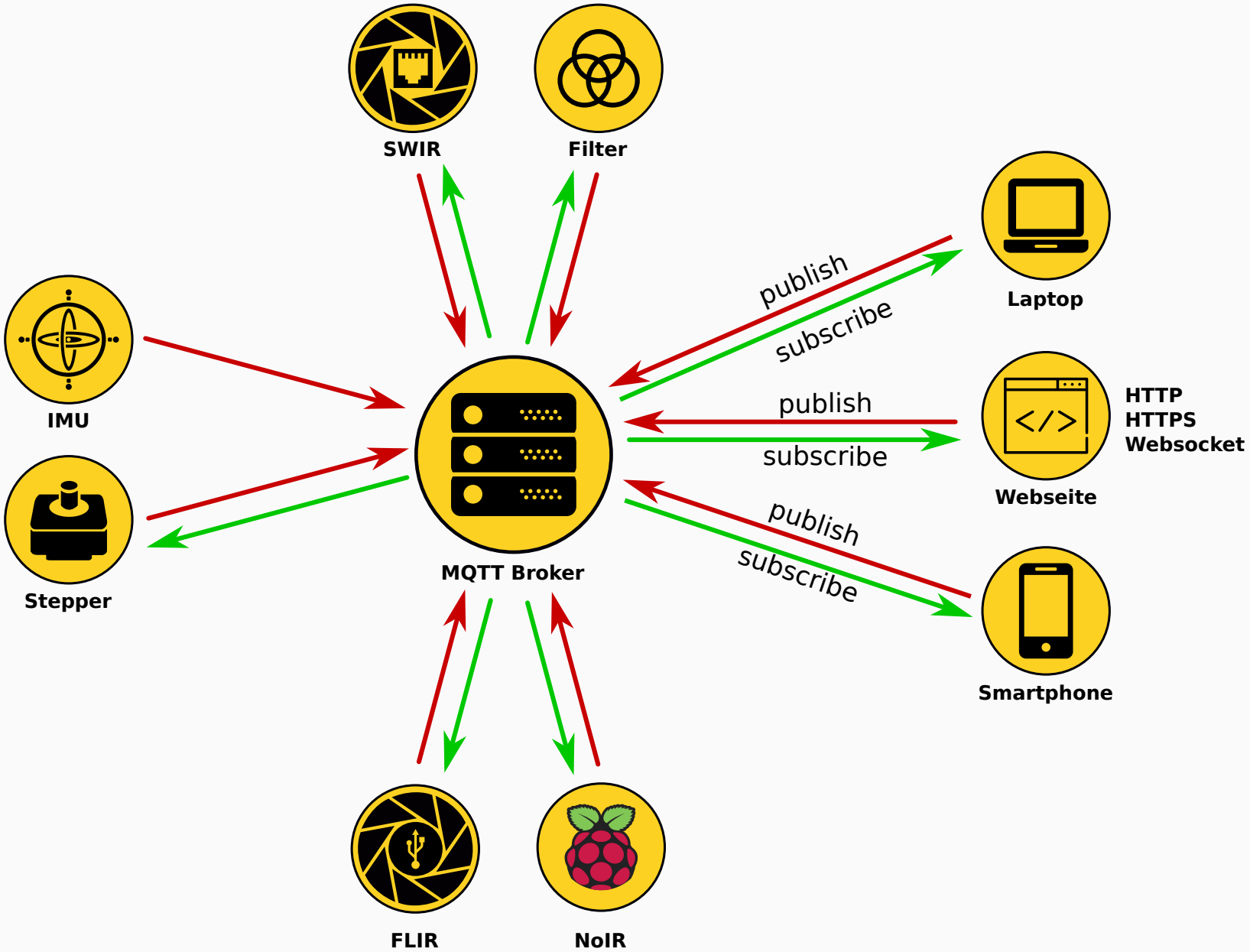


Overlap



Cut-Off

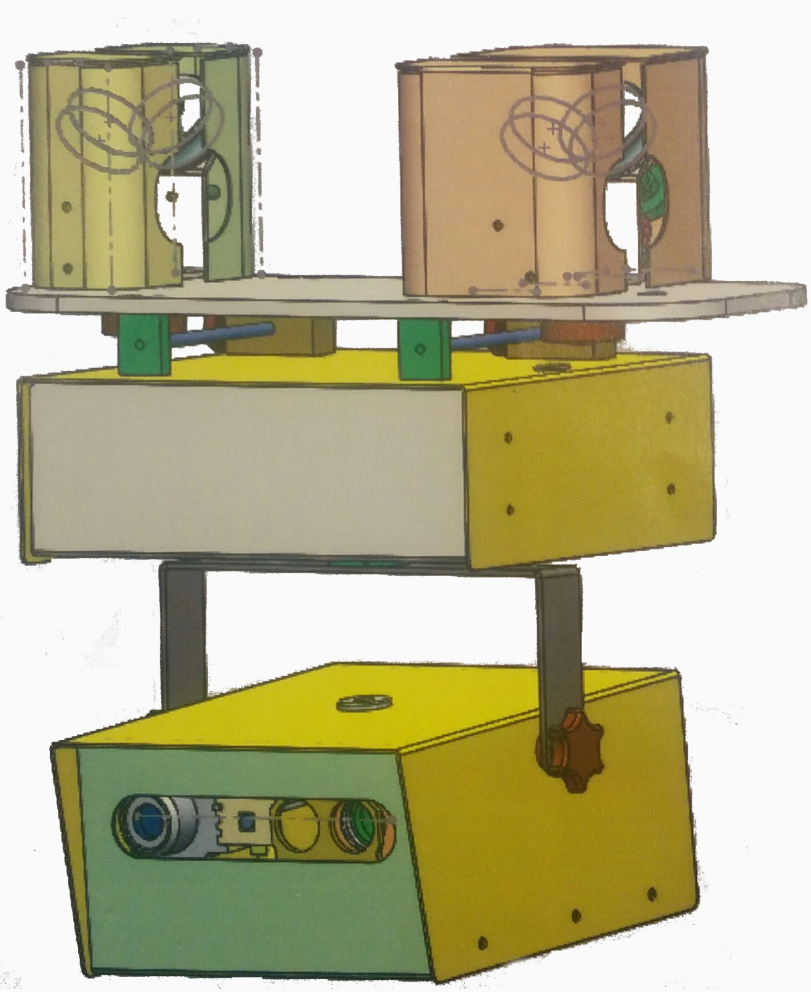


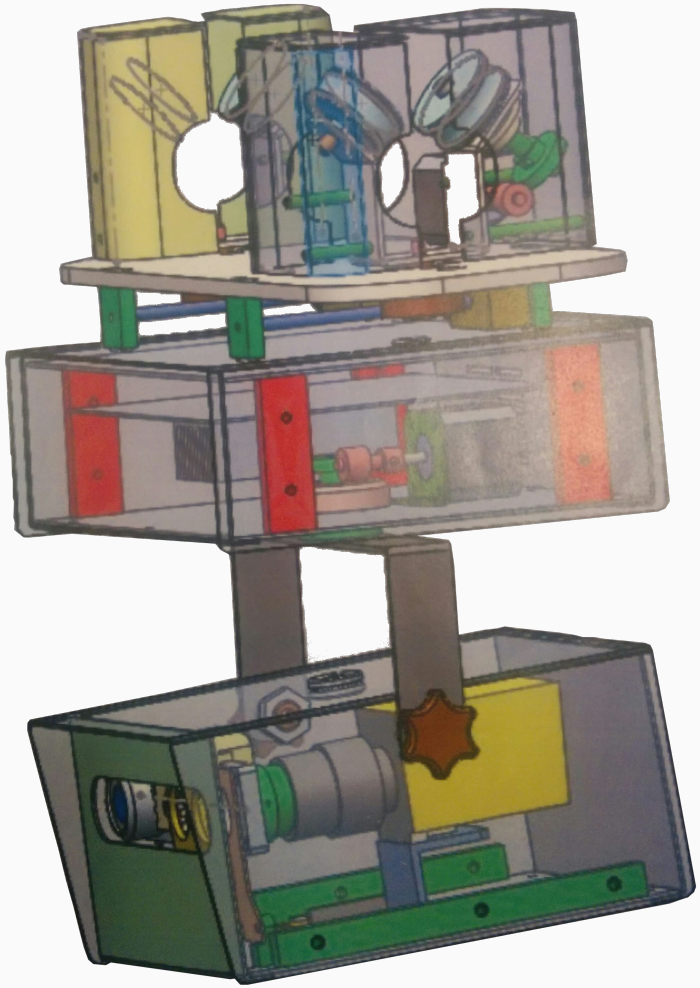

SWIR
Filter
IMU
Stepper
MQTT Broker
publish
subscribe
Laptop
publish
subscribe
HTTP
HTTPS
Websocket
Webseite
publish
subscribe
Smartphone
FLIR
NoIR

Test Field

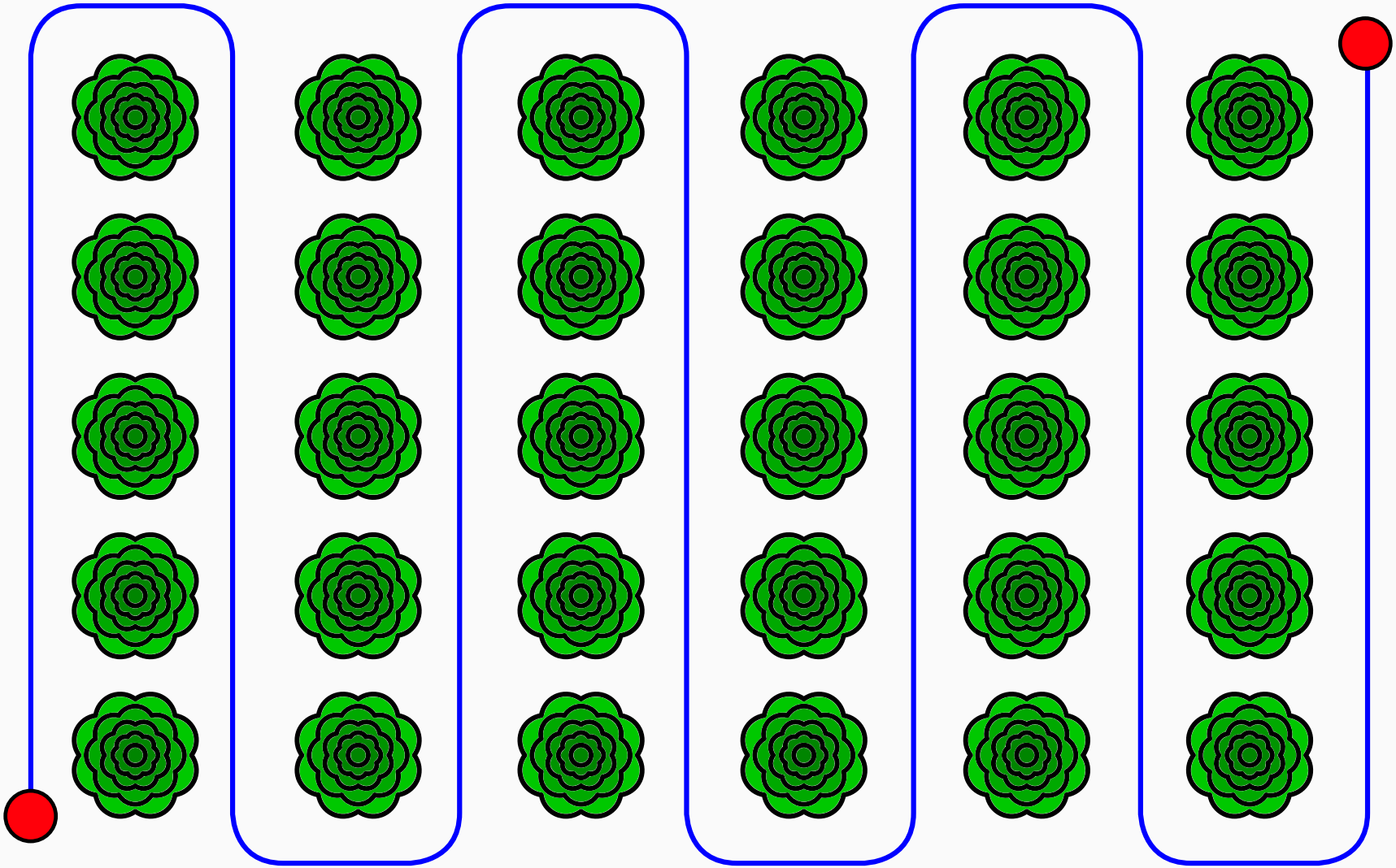
Rail System

Prototype





Route



Questions ?