The Tenth International Conference on Advances in Sensors, Actuators, Metering and Sensing

ALLSENSORS 2025

STSA: Sensors, Actuators, and Metering for Agriculture and Knowledge in Engineering

Evaluation of an IoT System Used with Sensors for the Recognition of Invasive Plants in Groundnut Crops

Bruno M. Moreno
bruno.moreno@estudante.ufscar.br

Paulo E. Cruvinel
paulo.cruvinel@embrapa.br

Augusto G. F. Costa
augusto.costa@embrapa.br

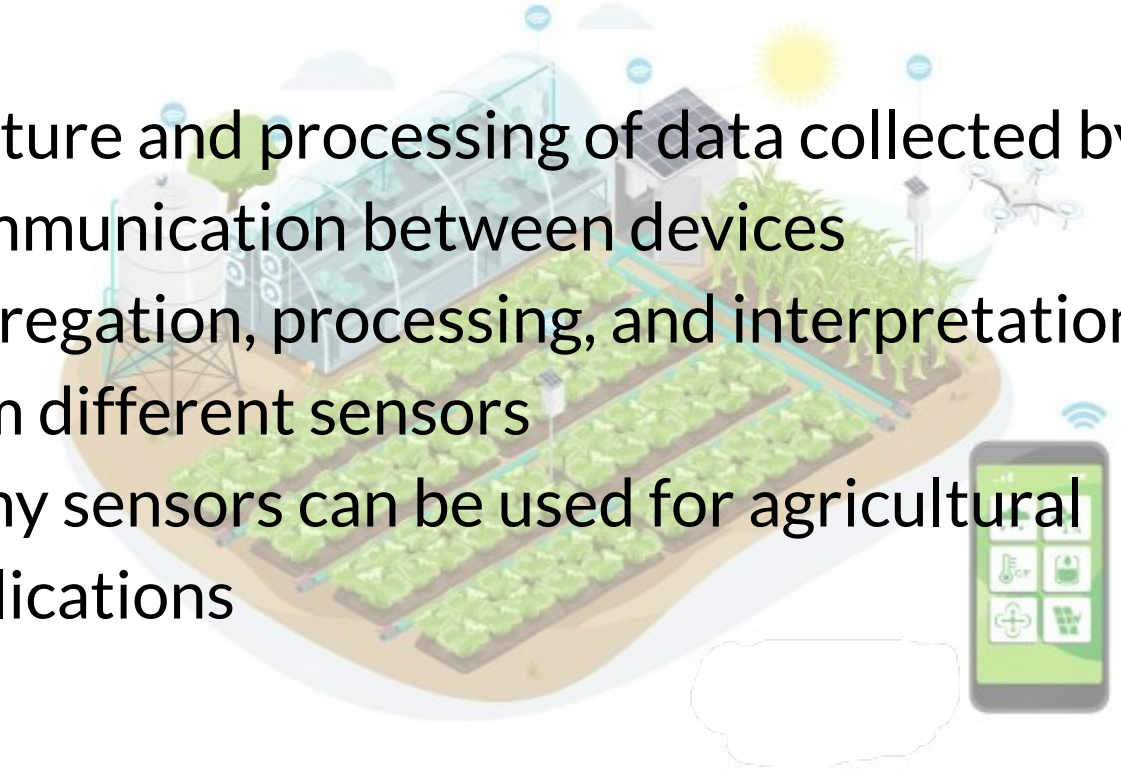
2025

Introduction

INTRODUCTION

Internet of Things (IoT) systems

- Capture and processing of data collected by sensors
- Communication between devices
- Aggregation, processing, and interpretation of data from different sensors
- Many sensors can be used for agricultural applications



INTRODUCTION

Precision agriculture and weed management - Groundnut

- Unwanted outcomes of invasive plant interference
- Use of optical and position sensors to aid Computer Vision
- Studies in the Literature worked with pre-existing image databases, without real field tests and consideration of IoT specifications and limitations

INTRODUCTION

Objective

- Evaluation of an IoT system able to:
  - Acquire stereo images in a real-field operation from wireless commands
  - Recognize more than one invasive plant species in groundnut crops
- Consideration of limitations regarding handling data obtained by IoT sensors

Material and Methods

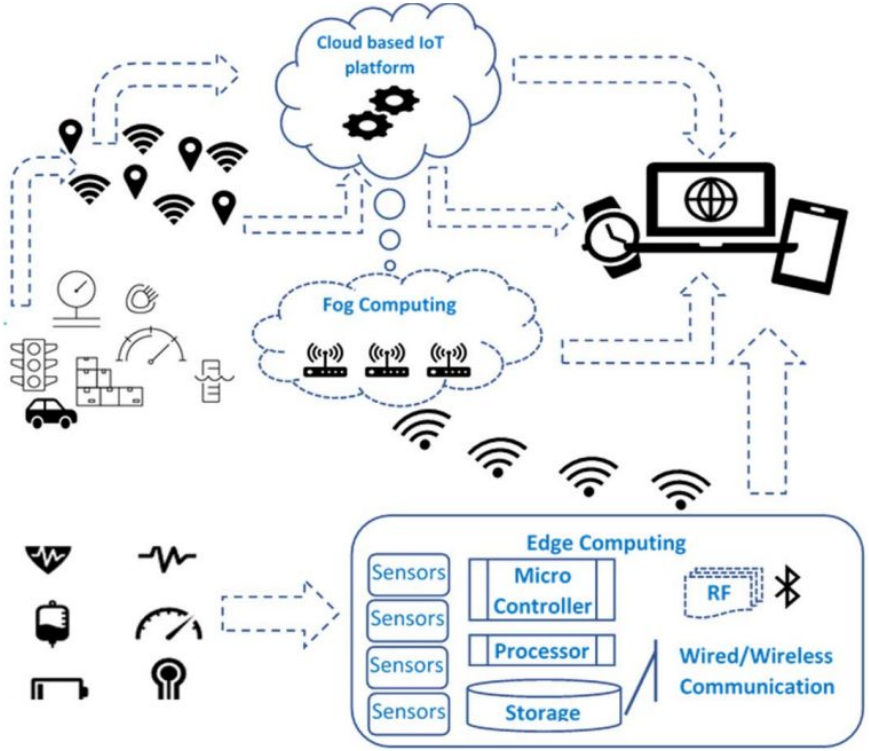
IoT Sensor Data Insights

- Security:
  - private, authentic and uncorrupted data
- Scalability:
  - growth of devices and data handling
- Bandwidth availability:
  - ensure transmission

IoT Sensor Data Insights

- Battery life:
  - energy efficiency
- Data volume:
  - data filtering and storage capacity
- Exposure Risk:
  - protection from environment

IoT Communication Protocols



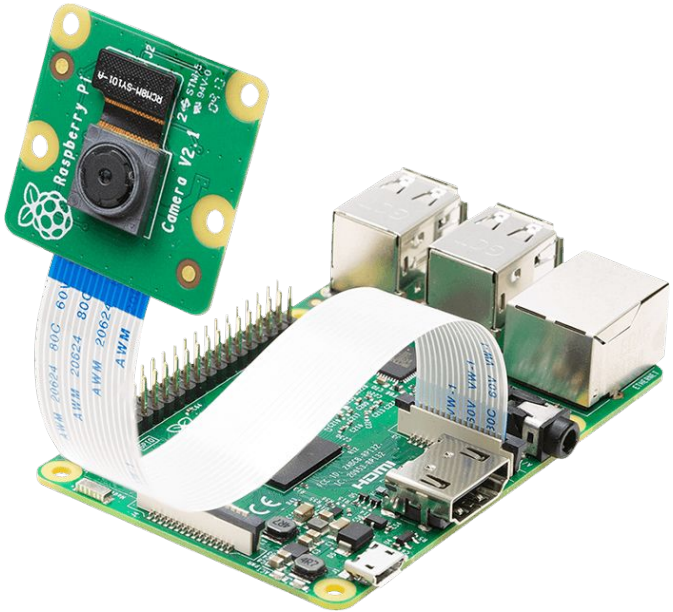
Bluetooth:

- max transfer rate: 1 Mbps
- range: 10 - 50 m

Camera Sensor Specifications

CAMERA HARDWARE SPECIFICATIONS

Size	25 x 24 x 9 mm
Still resolution	5 MP
Video modes	1080p30, 720p60, 640x480p60/90
Sensor	OmniVision OV5647
Sensor resolution	2592 x 1944 pixels
Sensor image area (W_s x H_s)	3.76 x 2.74 mm
Pixel size	1.4 μm x 1.4 μm
Optical size	1/4”
Full-frame SLR lens equivalent	35 mm
S/N ratio	36 dB
Dynamic range	67 dB @ (times of gain equal to 8)
Fixed focus	1 m - ∞
Focal length	3.60 ± 0.01 mm
Horizontal field of view (HFOV)	53,50° ± 0,13°
Vertical field of view (VFOV)	41.41° ± 0.11°
Focal ratio (F-stop)	2.9



Recognition of Invasive Plant

- Experimental Setup
  - total area of 72 m²
  - weeds: velvet bean (*Mucuna aterrima*) and signal grass (*Urochloa decumbens*)
- Feature Extraction: Local Binary Patterns (LBP) on the edge and Haralick moments of the texture
- Pattern Recognition: Support Vector Machine (SVM)

Results and Discussions

IoT System Evaluation

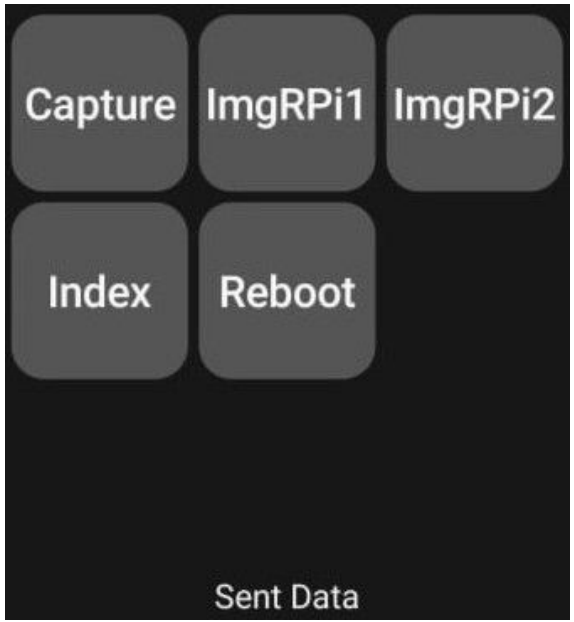
- Security: connected only to trusted equipment using MAC address and specific ports
- Battery life: 12 V 60 Ah battery → 15 h operation
- Data volume: 32 GB micro SD card for each sensor → total of 6,000 images (1280 x 960)
- Exposure Risk: structure and protective case to house the sensors

IoT System Evaluation

```
function IMAGE CAPTURE ON THE MASTER RPI(comd, resol, dir)
begin function
    while True do
        if comd == 'captr' then
            send(comd, Slave)                    ▷ sync trigger
            img ← capture_image(resol)
            save_image(img, dir)
            img2 ← receive_data(Slave)
            wait_operation()
            save_image(img2, dir)
        else if comd == 'send1' then
            send(img, cell_phone)
            wait_operation()
        else if comd == 'send2' then
            send(img2, cell_phone)
            wait_operation()
        else if comd == 'slres' then
            send(lower_resolution(img), cell_phone)
            wait_operation()
        else if comd == 'shutd' then
            send(comd, Slave)
            wait_operation()
            shutdown_system()
        end if
    end while
end function
```

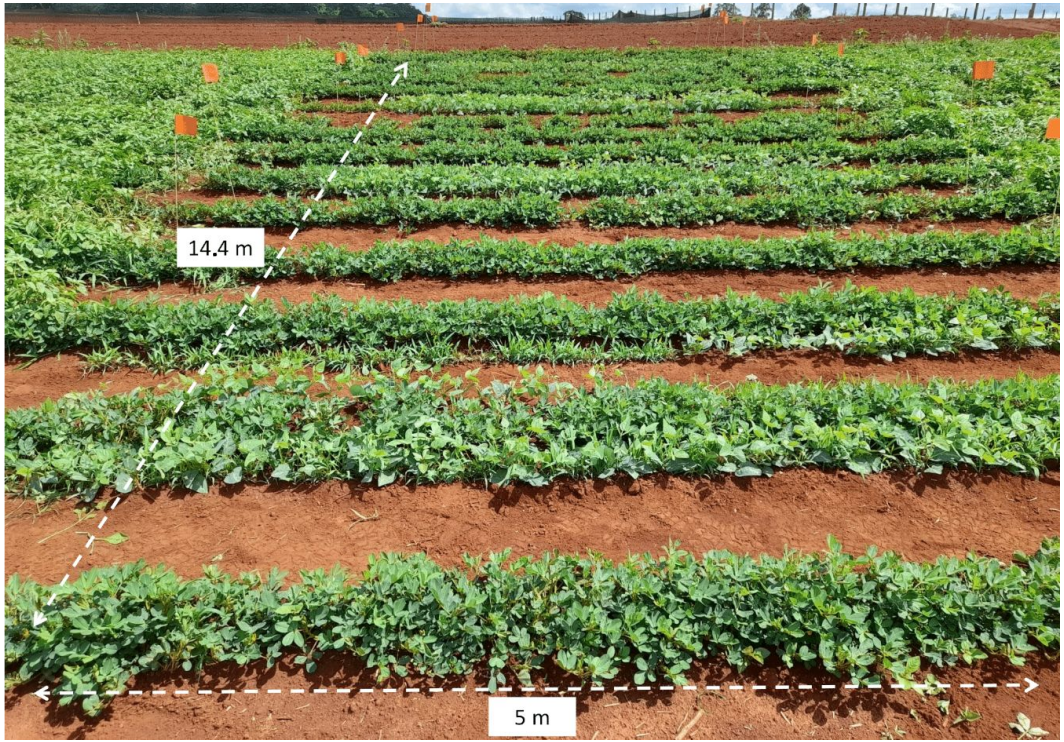
```
function IMAGE CAPTURE ON THE SLAVE RPI(resol, dir)
begin function
    while True do
        comd = receive_data(Master)
        if comd == 'captr' then
            img2 ← capture_image(resol)
            save_image(img2, dir)                ▷ optional
            send(img2, Master) ▷ via OBEXFTP protocol
            wait_operation()
        else if comd == 'shutd' then
            shutdown_system()
        end if
    end while
end function
```

IoT System Evaluation



Android app interface

Experimental Field



RESULTS AND DISCUSSIONS

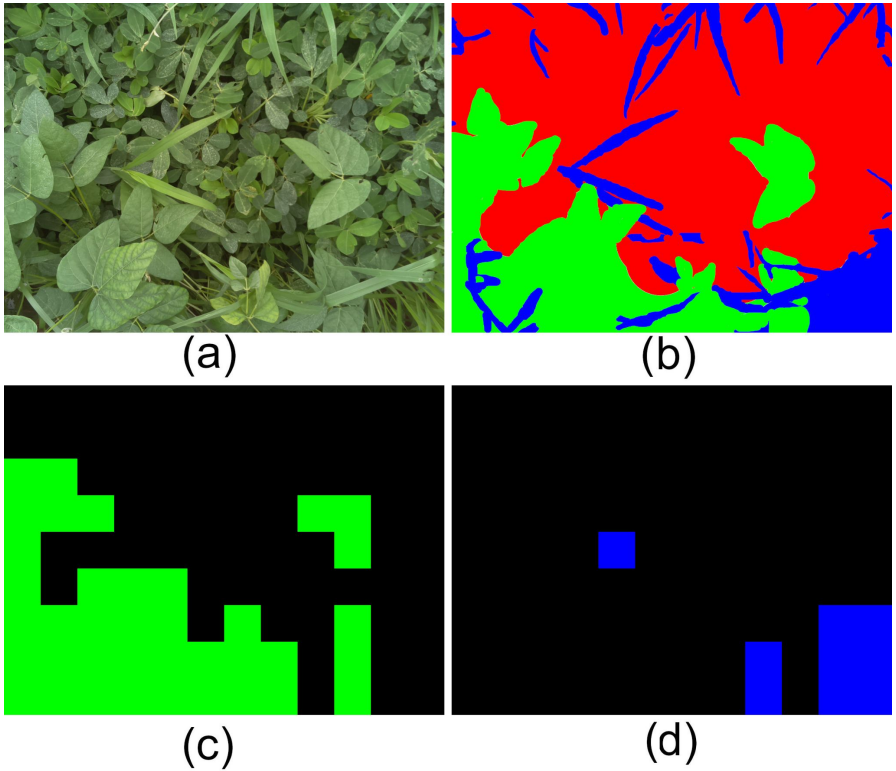
Classifier Results

SVM
- RBF kernel
- C = 1000
- γ = 0.01

Classifier		Precision	Sensitivity	F-score	Samples	Accuracy
SVM velvet bean					1383	81.1%
$\mathcal{H}_1$	sample has weed	0.80	0.41	0.54	349	80.2%
$\mathcal{H}_0$	don't have weed	0.83	0.97	0.89	1034	82.8%
SVM signal grass					1383	79.2%
$\mathcal{H}_1$	sample has weed	0.72	0.14	0.23	313	71.7%
$\mathcal{H}_0$	don't have weed	0.80	0.98	0.88	1070	79.6%

RESULTS AND DISCUSSIONS

Classifier Results



Occupation area:

- velvet bean: 14.5 %
- signal grass: 4.12 %

Conclusion

CONCLUSION

- Aid of IoT sensors in the task of recognizing and distinguishing the presence of different invasive plants in groundnut crops
- Specific protocol and requirements in handling IoT sensor data and communication
- Invasive plants classifiers accuracy close to 80%
- Future work: FPGA integration to better processing

ACKNOWLEDGEMENT

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