The Abdus Salam International Centre for Theoretical Physics

Workshop on TinyML for Sustainable Development

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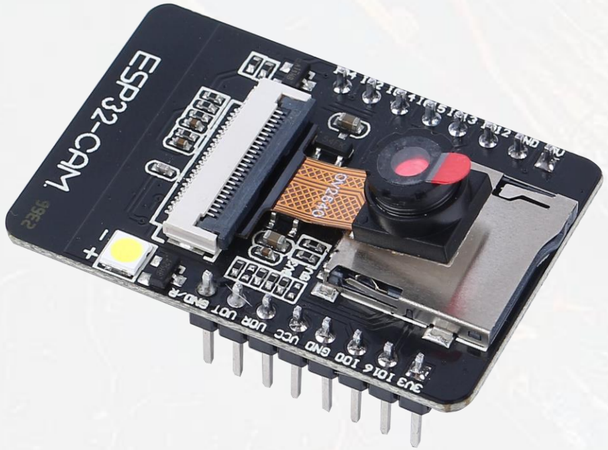

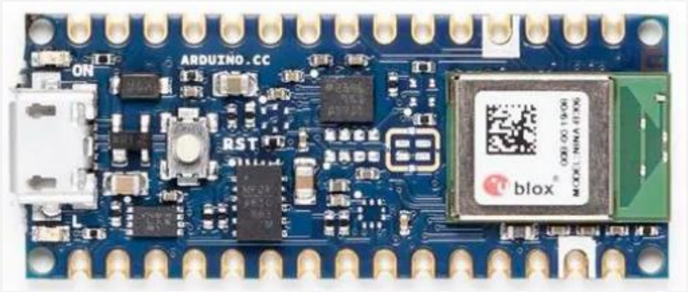

Intelligent System for Identification on Leaf Diseases in Soybean Crops

Dr. Walter Augusto Varella

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The Abdus Salam International Centre for Theoretical Physics

Workshop on TinyML for Sustainable Development

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Walter Augusto Varella holds a PhD in Production Engineering from Universidade Nove de Julho (UNINOVE - 2022). He earned his master's degree in Electrical Engineering from the Escola Politécnica da Universidade de São Paulo (POLI USP - 2003) and an MBA in Public Management from Universidade Dom Bosco (2017). He also has a bachelor's degree in Electrical Engineering from FEI (1982). He has authored several books on cloud technologies published by Editora SENAC. He is a retired full professor at the Federal Institute of Education, Science, and Technology of São Paulo (IFSP), where he continues to conduct research as a volunteer research professor. He is one of the founders and co-leaders of EAILab - Embedded Artificial Intelligence Laboratory and a member of the Labmax research groups at IFSP. Currently, he is developing research involving embedded systems technologies, IoT, TinyML, machine learning (ML), and artificial intelligence (AI), applied in agriculture and health, promoting the Circular Economy and sustainability.

Harvard John A. Paulson School of Engineering and Applied Sciences

IBM

UNIFEI

TINY ML FOUNDATION

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Context for implementing sustainability in Smart Agriculture

Key words

TinyML

Edge Impulse

Smart Agriculture

Soy Crops

Circular Economy

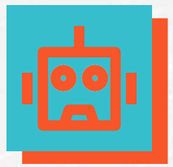
Artificial Intelligence

Machine Learning

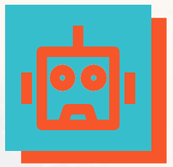
Sustainability

TinyML, What is it?

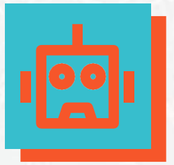
TinyML is a branch of machine learning and embedded systems research that looks into the types of models that can be run on small, low-power devices like microcontrollers



Small devices



Low-power devices



Resource constrained devices

TinyML

Embedded Systems

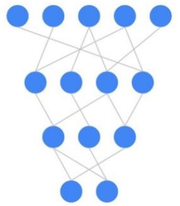
TinyML

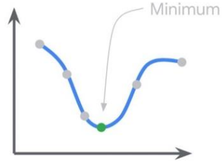
Machine Learning

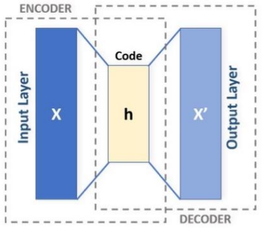
Part 1
Fundamentals of TinyML

Part 2
Applications of TinyML

Part 3
Deploying TinyML







TensorFlow | TensorFlow Lite | TensorFlow LiteMicro

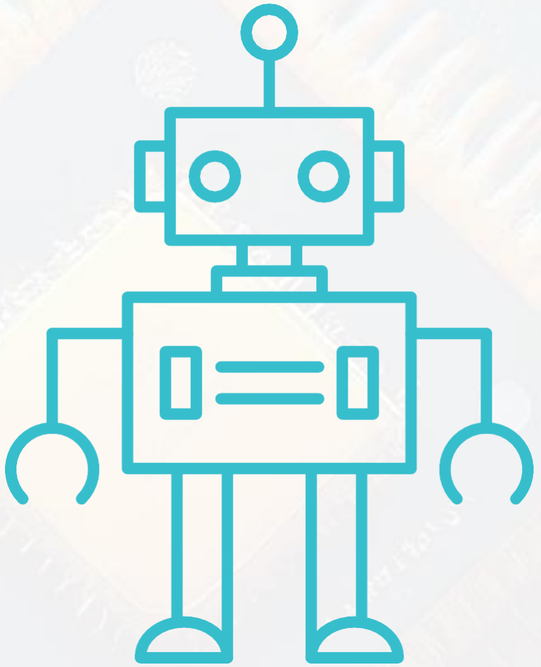
Train a model → Convert model → Optimize model → Deploy model at Edge → Make inferences at Edge

Applications of TinyML

Personal assistant like Siri, Alexa ...

Industrial predictive maintenance

Wildlife tracking



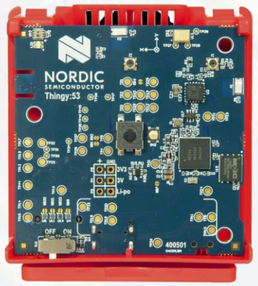
Detecting crop diseases

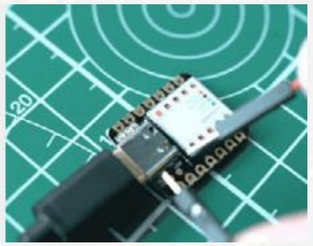
Healthcare

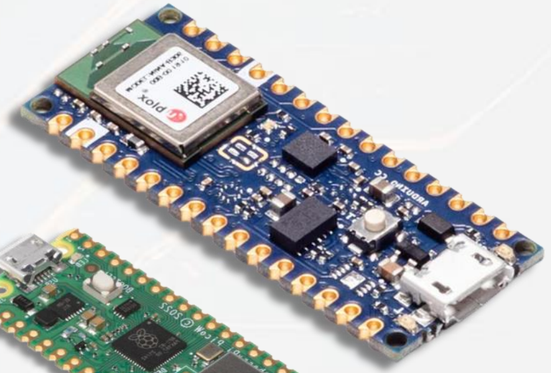
Ocean life conservation

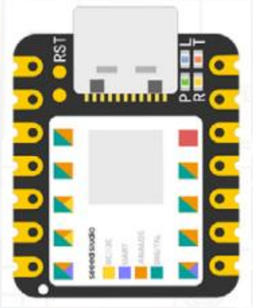
Some cool TinyML MCUs

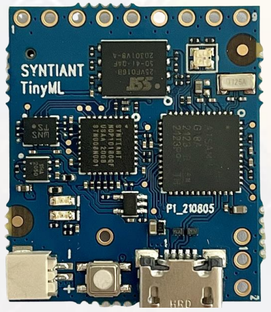
- Arduino Nano 33 BLE Sense
- Arduino Nicla Vision
- Arduino Nicla Sense ME
- Arduino Portenta H7 + Vision
- XIAO Seed
- Espressif ESP32
- Espressif ESP-EYE
- Himax WE-I Plus
- Open MV Cam H7 Plus
- SiLabs xG24 Dev Kit
- Seeed Grove - Vision AI Module
- Sony's Spresense
- Syntiant Tiny ML Board
- Raspberry Pi Pico
- .....

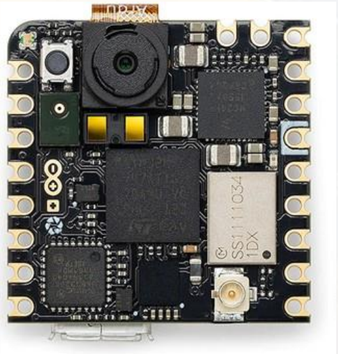


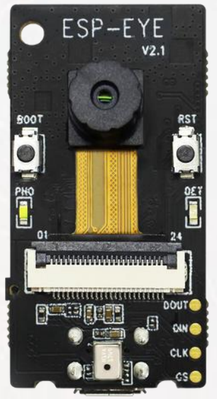


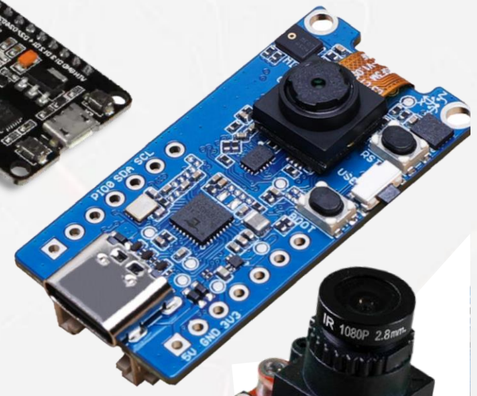




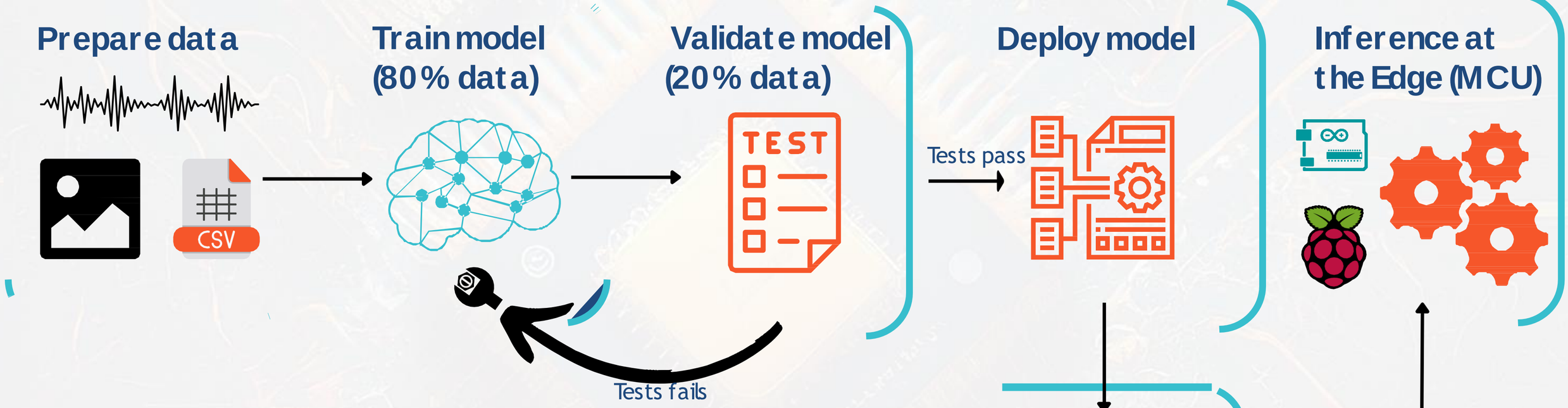








TinyML project flow



With AutoML tools, it can't get simpler

Edge Impulse

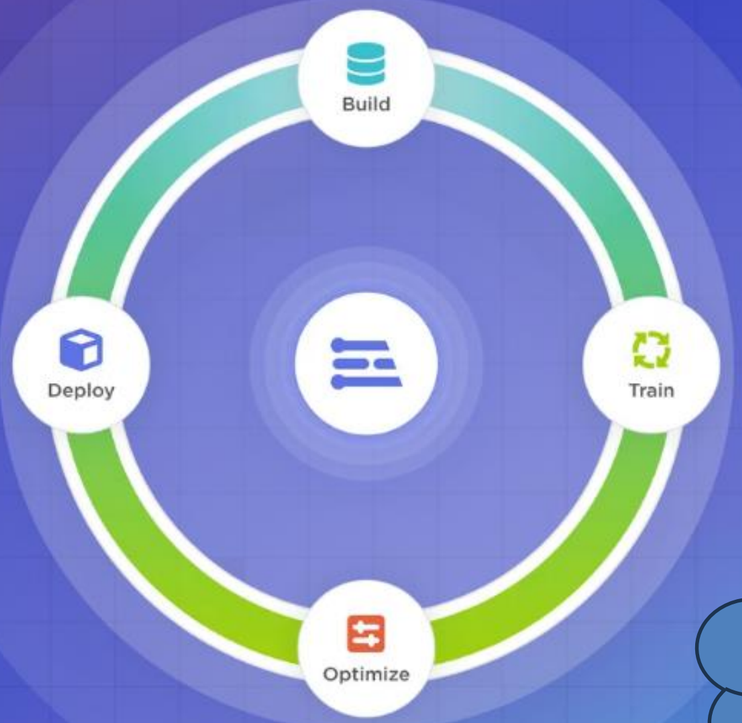
EDGE IMPULSE Product Solutions Developers Pricing Company Blog Login Get started

AI for Any Edge Device

MCUs, NPUs, CPUs, GPUs

Build datasets, train models, and optimize libraries to run directly on device; from the smallest microcontrollers to gateways with the latest neural accelerators (and anything in between).

Get Started Schedule a Demo



Use No Code ease of development

Application with TinyML in Soybeans

The key to a more efficient, sustainable, and profitable agriculture.

Diseases in soybean crops and that appear on the leaves

- **Asian Soybean Rust;**
- **Target spot;**
- **Potassium deficiency;**
- **Frog eye leaf spot;**

Development team

This project was developed by students Carolina Barusso and Leonardo Knoeller, in a course completion work for the Control and Automation Engineering course at the Federal Institute of São Paulo - Cubatão Campus and presented in June.

He was guided by me and professor Dr. Arnaldo de Carvalho Junior

Dataset for Neural Network

DRYAD

Pictures of diseased soybean leaves by category captured in field and with controlled backgrounds: Auburn soybean disease image dataset (ASDID)

Bevers, Noah, Auburn University, https://orcid.org/0000-0002-0683-3658

Sikora, Edward J., Auburn University

Hardy, Nate B., Auburn University

nzb0054@auburn.edu, sikorej@auburn.edu, nbh0006@auburn.edu

Published Nov 08, 2022 on Dryad. https://doi.org/10.5061/dryad.41ns1rnj3

https://datadryad.org/stash/dataset/doi:10.5061/dryad.41ns1rnj3

Article by the Authors About the Database

ELSEVIER

Computers and Electronics in Agriculture

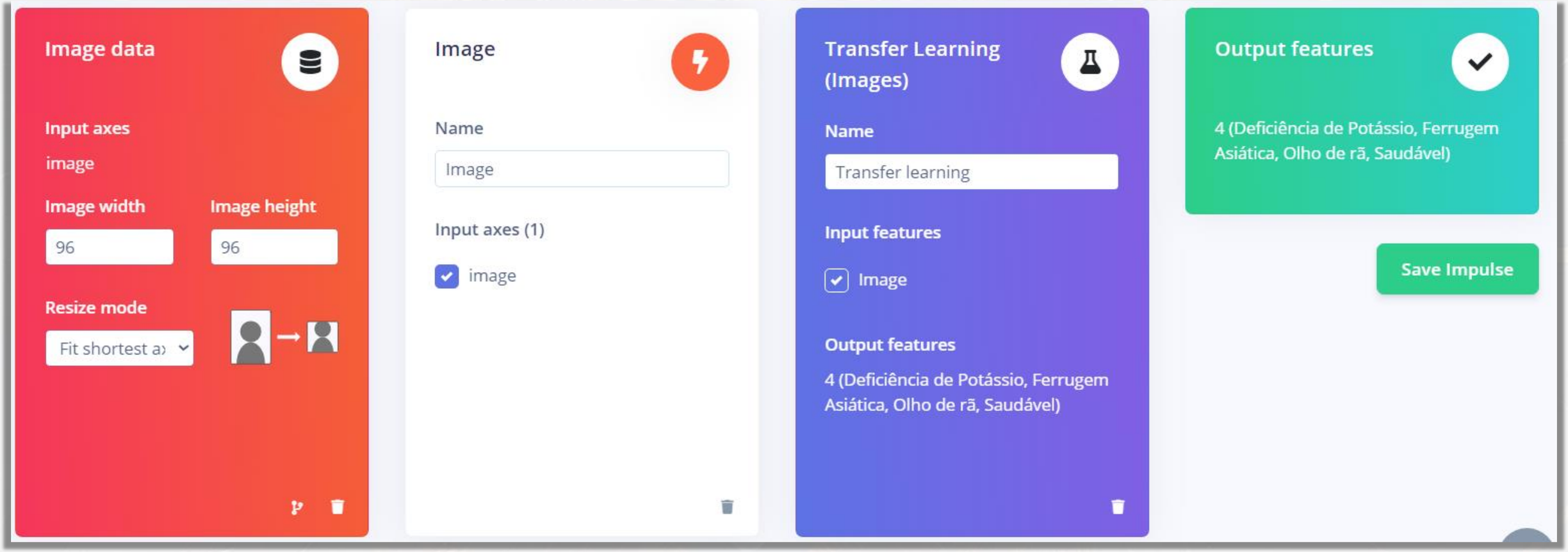
Volume 203, December 2022, 107449

Soybean disease identification using original field images and transfer learning with convolutional neural networks

Noah Bevers, Edward J. Sikora, Nate B. Hardy

https://www.sciencedirect.com/science/article/abs/pii/S0168169922007578?via%3Dihub

Projetc with Edge Impulse



Results of the first Neural Network training

PRECISÃO
71.1%

PERDA
2,18

Matriz de confusão (conjunto de validação)

	DEFICIÊNCIA DE P	FERRUGEM ASIÁT	OLHO DE RÃ	SAUDÁVEL
DEFICIÊNCIA DE	72.1%	27.9%	0%	0%
FERRUGEM ASIÁT	2.0%	98.0%	0%	0%
OLHO DE RÃ	9.3%	51.2%	25.6%	14.0%
SAUDÁVEL	5.3%	14.0%	0%	80.7%
F1 SCORE	0.76	0.70	0.41	0.84

Problems with frog eye (olho de rã) and potassium deficiency classes

Proposed adjustments to improve the accuracy of the Neural Network

In order to improve the network, some modifications were made as:

- Increasing the number of images for training, from 1221 to 2003
- Also increasing the number of training cycles.

Results after proposed changes

Último desempenho de treinamento (conjunto de validação)

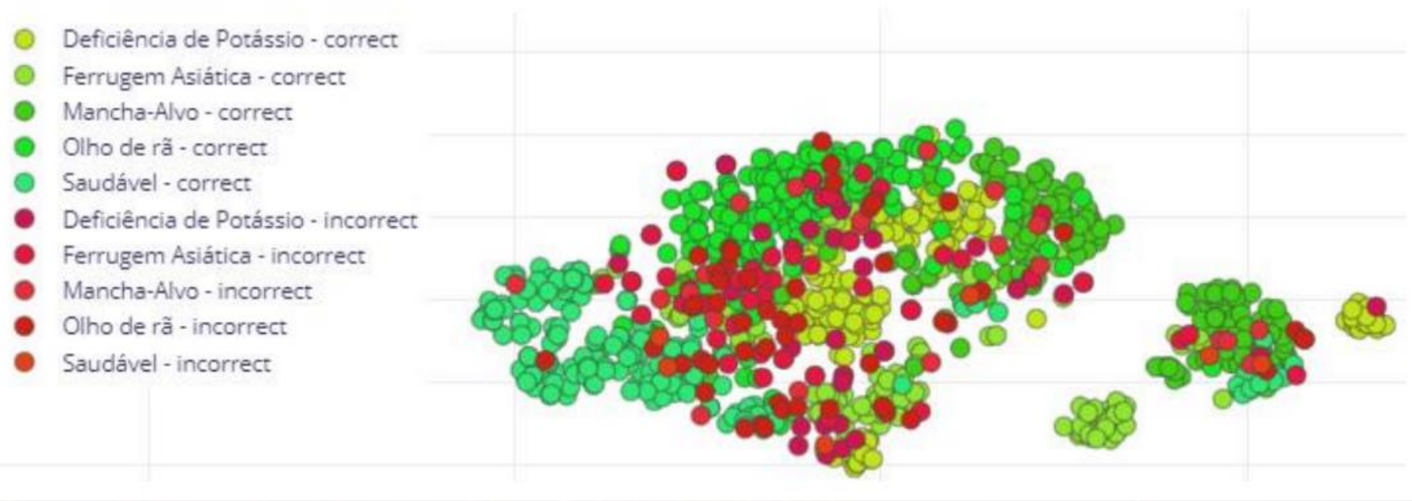
PRECISÃO
87,7%

PERDA
0,36

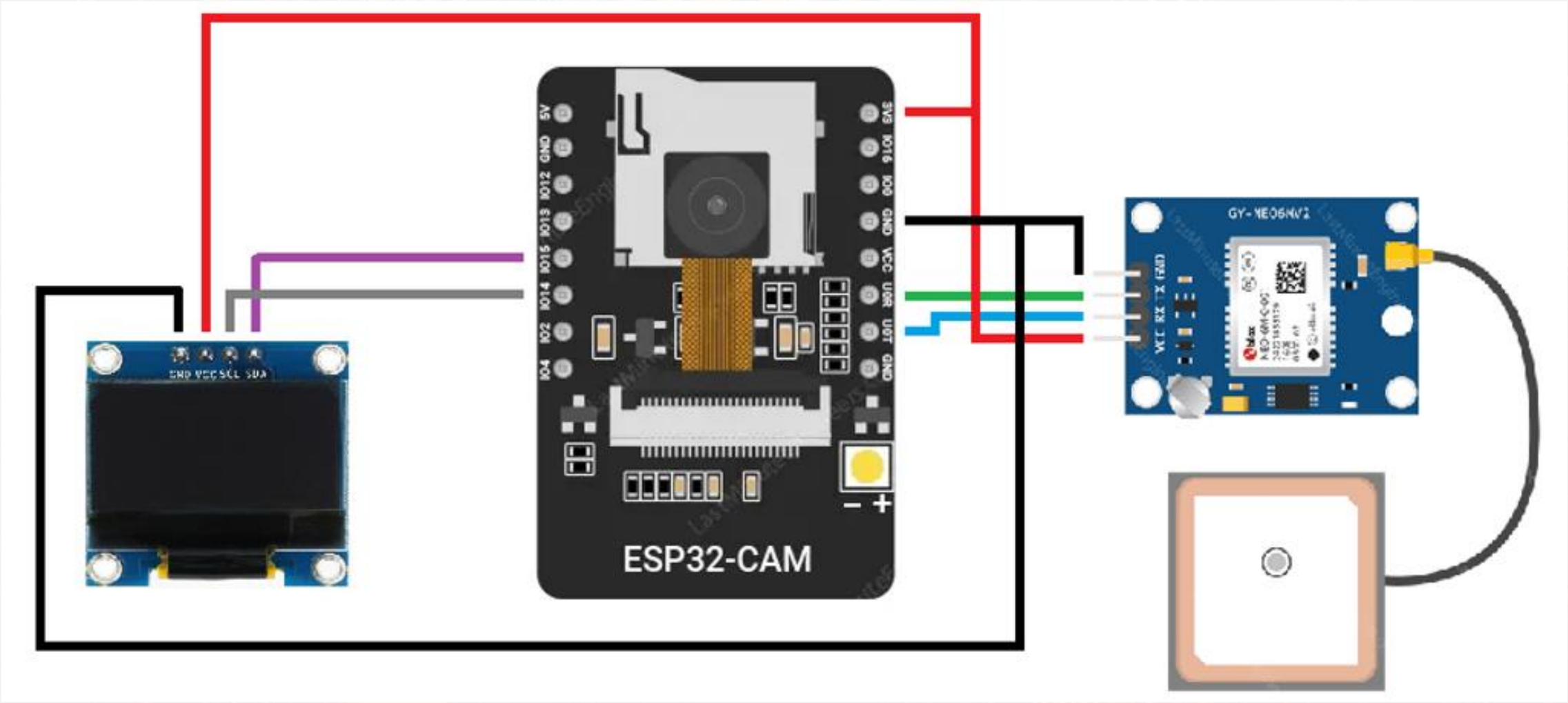
Matriz de confusão (conjunto de validação)

	DEFICIÊNCIA	FERRUGEM A	MANCHA-AL	OLHO DE RÃ	SAUDÁVEL
DEFICIÊNCIA DI	**88,1%**	6,0%	3,0%	3,0%	0%
FERRUGEM ASI	8,2%	**80,3%**	4,9%	4,9%	1,6%
MANCHA-ALVO	1,6%	1,6%	**92,2%**	4,7%	0%
OLHO DE RÃ	11,3%	3,8%	1,9%	**75,5%**	7,5%
SAUDÁVEL	0%	0%	0%	1,4%	**98,6%**
PONTUAÇÃO F1	0,86	0,84	0,91	0,78	0,96

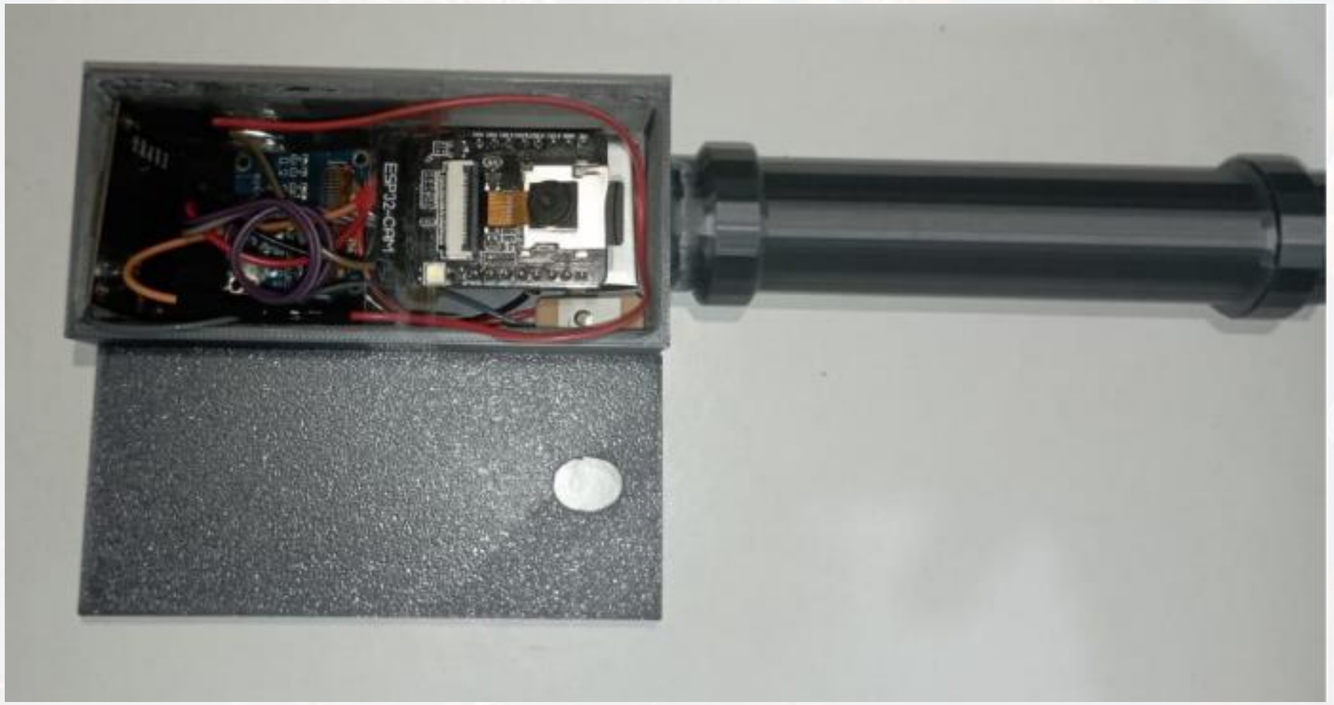
Explorador de dados (conjunto de treinamento completo)



Prototype Hardware



Prototype Hardware



https://www.youtube.com/watch?v=znPjoXWZ0eM

How to use the prototype

- The farmer collects data from multiple locations on the farm
- As the proposed project was for small properties, this collection will be manual
- This data is recorded on a local SD Card, with GPS coordinates, date and time and the image of the leaf and status (healthy or sick, in which case the onboard AI already informs the disease)
- The collected data is "downloaded" onto a computer at the farm's headquarters and analyzed by management software developed in Power BI.

AGRO VISION

Sistema inteligente para identificação de doenças foliares na cultura de soja

DASHBOARD

CARTILHAS

RELATÓRIO

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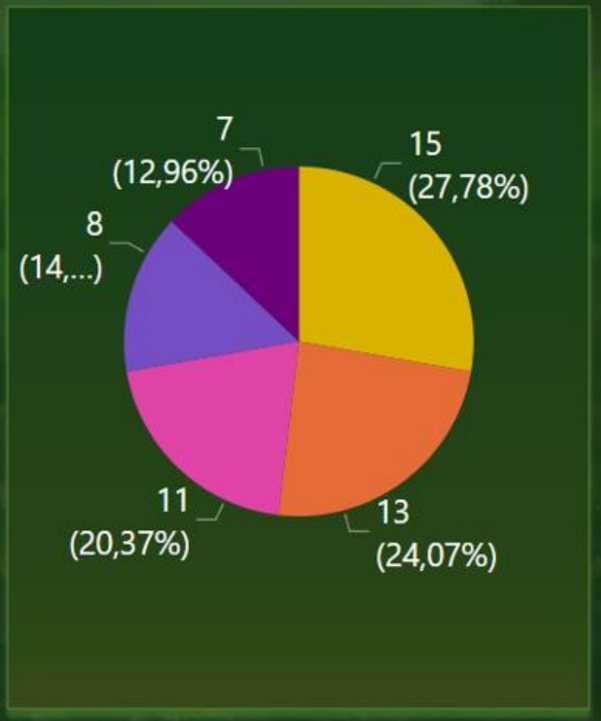
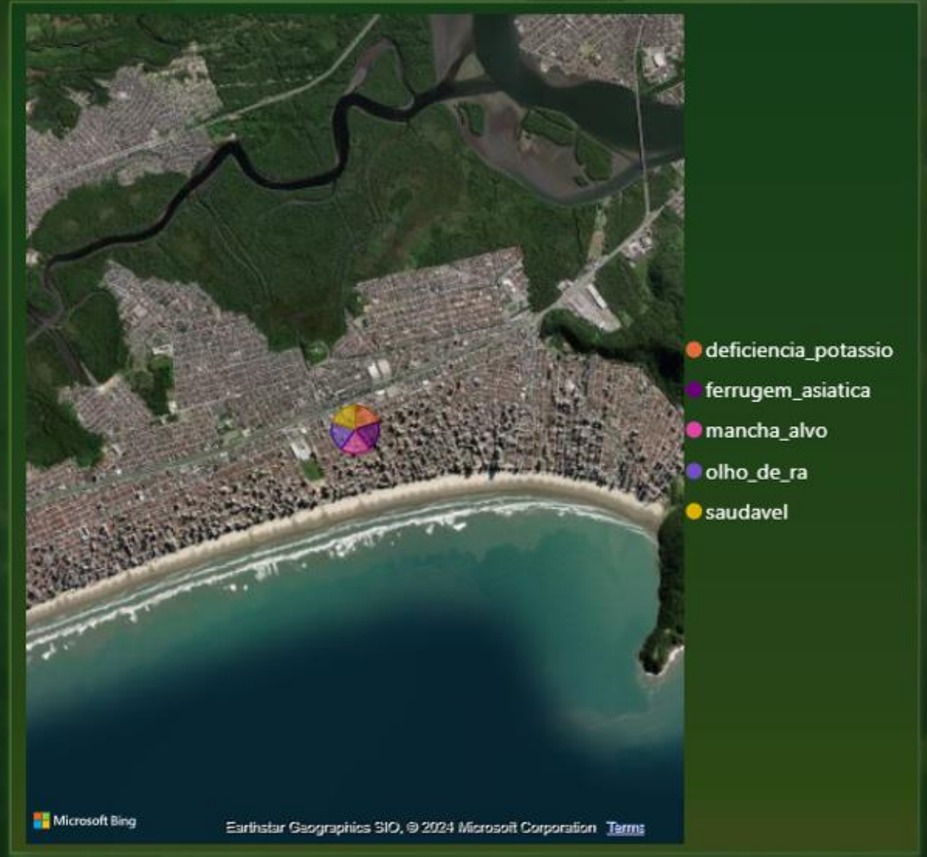
INSTITUTO FEDERAL
São Paulo
Câmpus Cubatão

DASHBOARD





- 09/06/2024 17:42:00
- 09/06/2024 17:43:00
- 09/06/2024 17:44:00
- 09/06/2024 17:45:00
- 09/06/2024 17:46:00
- 09/06/2024 17:47:00
- 09/06/2024 17:48:00
- 09/06/2024 17:49:00
- 09/06/2024 17:50:00
- 09/06/2024 18:04:00
- 09/06/2024 18:05:00
- 09/06/2024 18:06:00

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CARTILHAS

As cartilhas oferecem uma visão geral de cada doença listada de forma simplificada, incluindo informações fundamentais, tais como:

- Condições propícias para o surgimento da doença.
- Medidas de controle / insumos para sua gestão.
- Sintomas característicos que auxiliam na identificação e diagnóstico.

MANCHA-ALVO

DEFICIÊNCIA DE POTÁSSIO

FERRUGEM ASIÁTICA

OLHO DE RÃ

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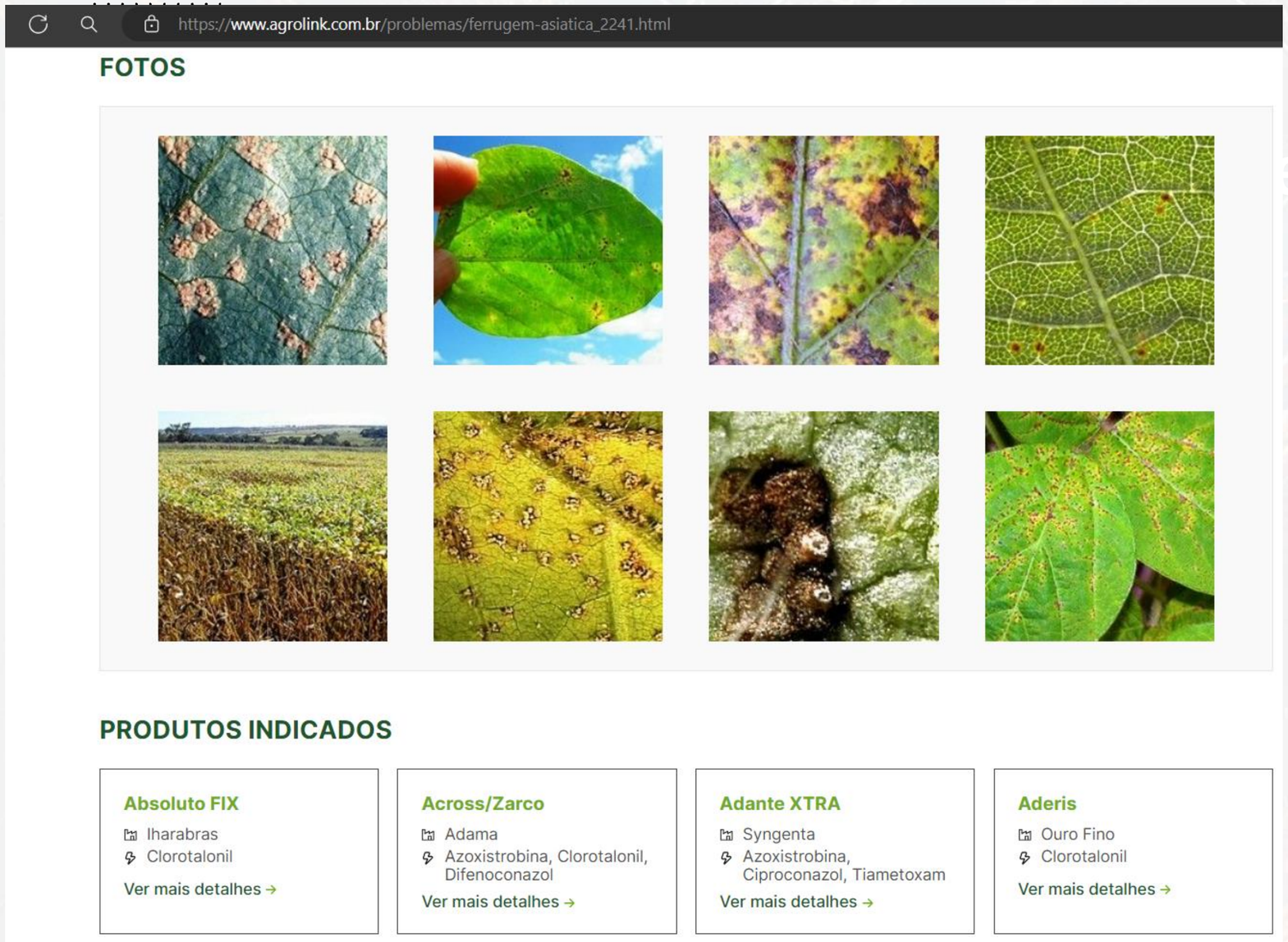
Fonte: Embrapa

INSTITUTO FEDERAL
São Paulo
Câmpus Caraguatatuba

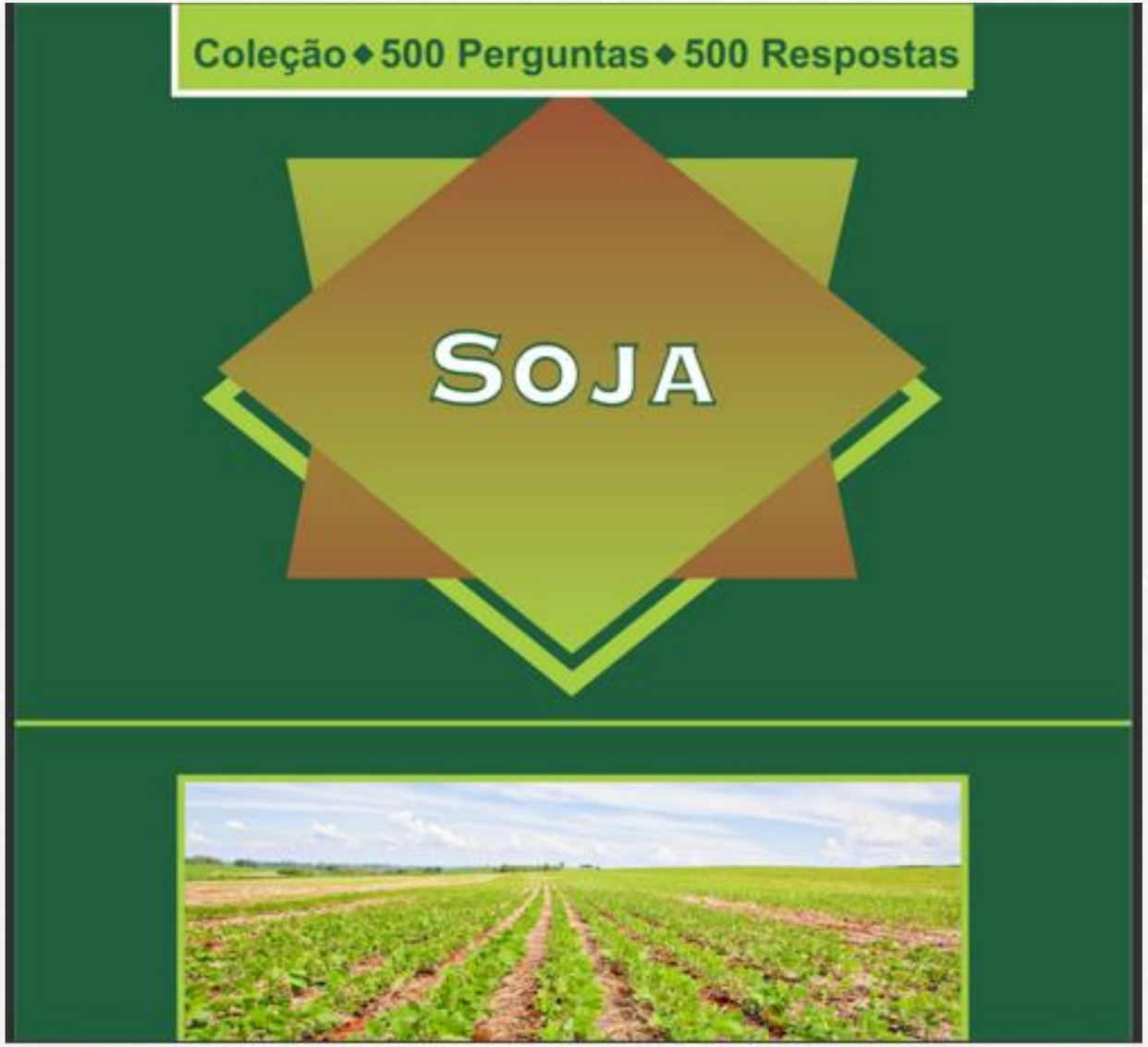
Booklet with information about diseases in soybean leaves



The website contains information such as:

- Description of the disease,
- Symptoms,
- Photos,
- Control methods,
- Recommended products with supplier contact details.

EMBRAPA booklet with information on diseases in soybean leaves



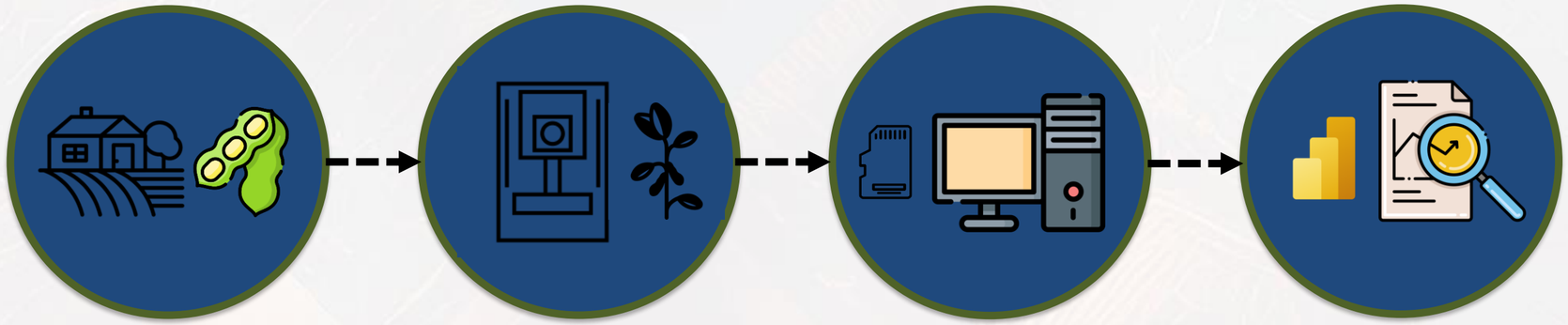
Embrapa's book of 500 questions and answers, which covers most diseases.

Results

- A network with 87.7% accuracy capable of classifying soybean leaf images among 4 diseases and classifying healthy ones;

- A prototype hardware that displays the current latitude and longitude of the person collecting the images, storing them on an SD card;

- A dashboard capable of aggregating all information and providing data for actions to be taken.

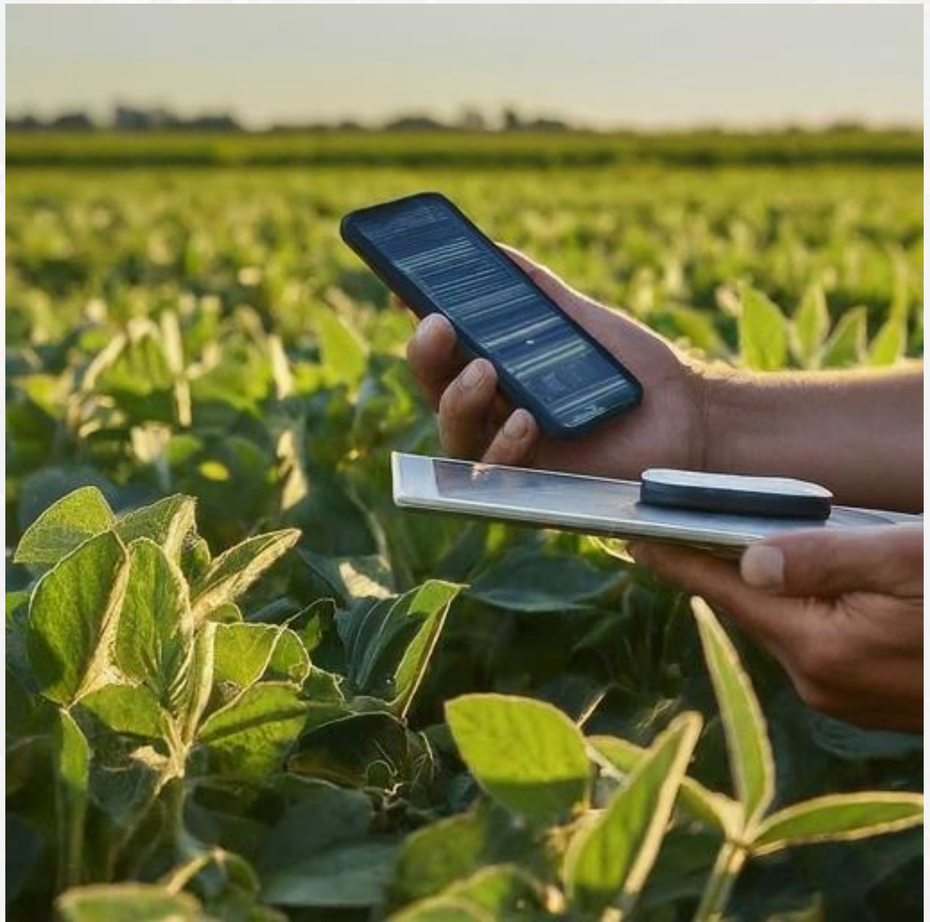


Future Projects

Field trials on a farm in the state of Paraná, Brazil

Use of drones with embedded AI for data collection and cloud storage.

Expansion to larger farms.



Intelligent System for Identification on Leaf Diseases

in Soybean Crops, using TinyML

Thanks!

Dr. Walter Augusto Varella

varella@ifsp.edu.br