MUSHNOMICS

Unlocking data-driven innovation for improving productivity and data sharing in mushroom value chain

Dr Dimitrios Argyropoulos
University College Dublin

2019 cofunded Call
End-term Project Seminar
30th January 2024

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grand agreement no 862665 ICT-AGRI-FOOD.

University College Dublin

UCD School of Biosystems & Food Engineering (SBFE) is the leading center for education and research in the application of engineering principles to agriculture, food and renewable resources in Ireland.

Led by Dr Dimitrios Argyropoulos, the **Digital Tech Lab** within the UCD School of Biosystems Engineering is focused on the application of "smart systems" to the agri-food and bio-resource sectors.

Areas of interest

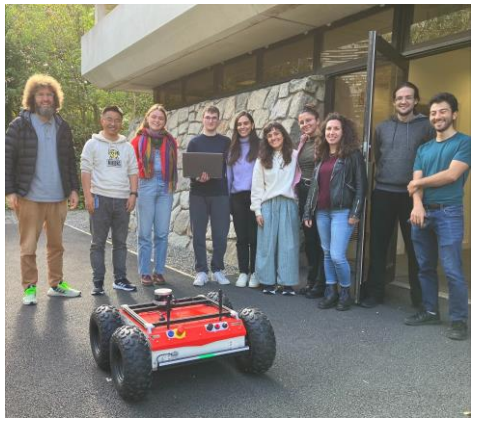
Technology-wise: sensor and sensing systems, multi-copters, agricultural robotics, agri-food electronics, computer controlled micro dryers, Internet-of-Things and machine learning.

Sustainable agri-food systems, automation and digitisation (€1 million research funding awarded annually)

A particular research interest in the application of IoT and sensor technology to enhance the operational efficiency of circular agri-food systems, from on-farm operations right through to food and biomaterial processing, including:

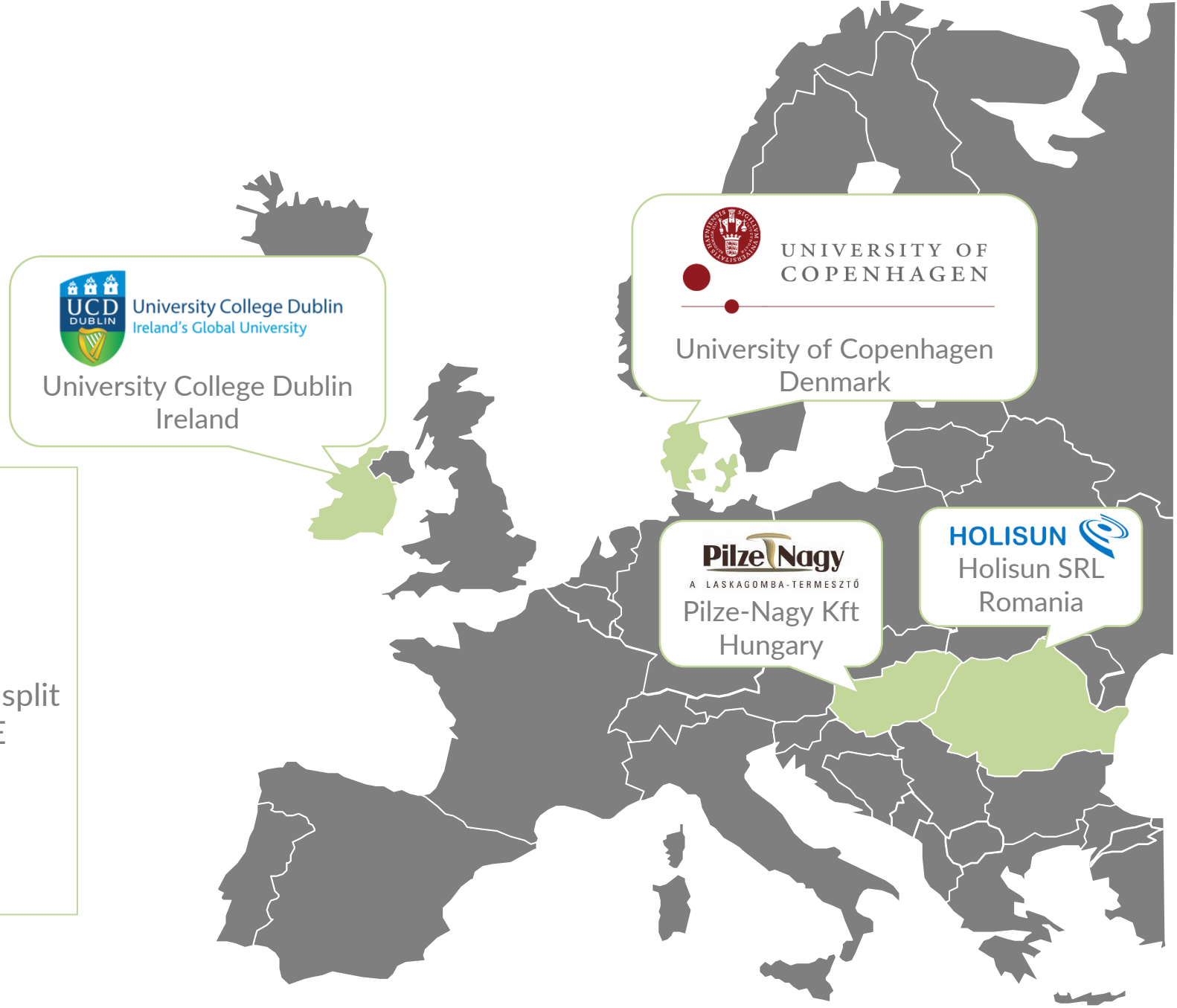
- Specialty crop agricultural mechanisation and automation
- Applications of artificial intelligence to agricultural systems management
- Implementation of a circular economy in agriculture

Digital Tech Group:
3 Postdocs; 5 PhD researchers;
2 research engineers;
2 project managers
3 visiting researchers
Contact:
dimitrios.argyropoulos@ucd.ie



MSc Digital Technology for Sustainable Agriculture (One Year Full Time / Sep start)

Consortium



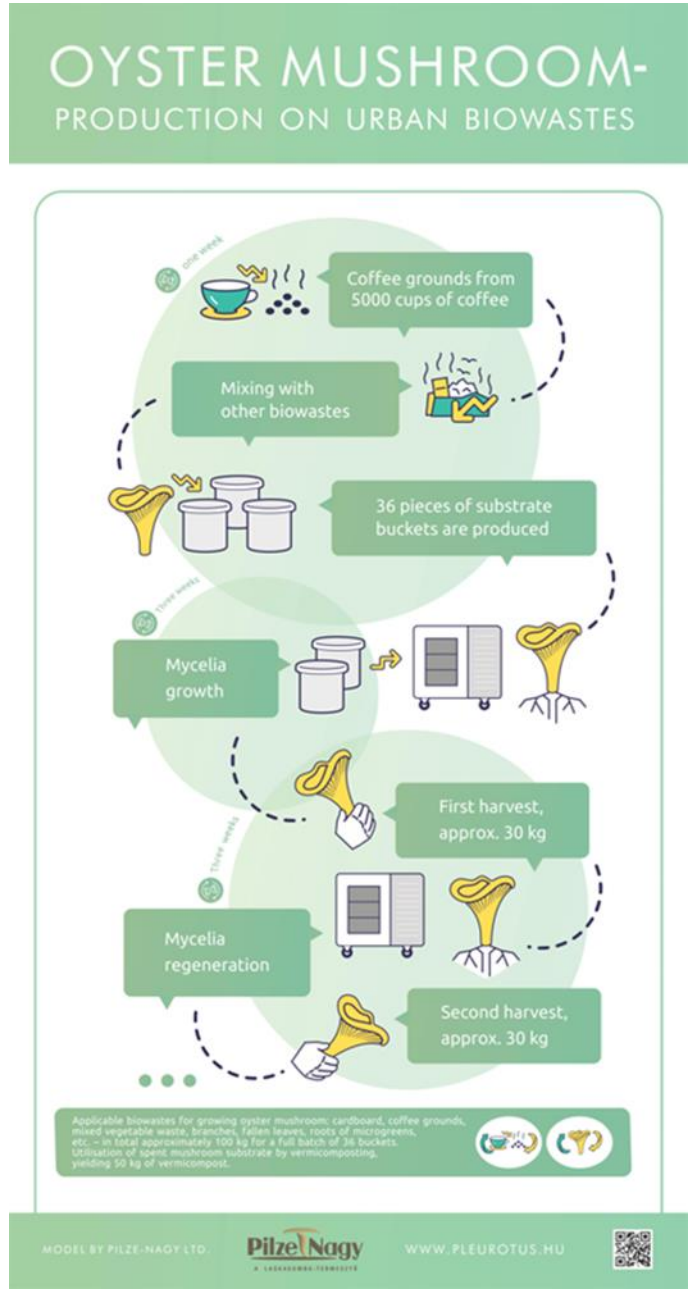
ICT-AGRI-FOOD ERA-NET
MUSHNOMICS

- Coordinator: HS Holisun SRL (RO)
- Partners: 50-50 research-business split
- Countries involved: RO, DK, HU, IE
- Project duration (months): 36
- March 2021 – February 2024
- Total project costs (k€): 982
- Total requested budget (k€): 816

Goal and context

- Commercial edible mushroom cultivation is a ‘big business’ world-wide with a total production exceeding 27 million tons.
- A 25-fold increase during the last 35 years, which is combined with a high increase in the respective per capita consumption.
- *Pleurotus* species are of particular interest because:
  i. their production amounts to ca. 30% of the total, corresponding to the fastest growing and most profitable section of the mushroom market.
  ii. they are commonly grown on pasteurized wheat straw, however, they can also be cultivated on a wide variety of agro-industrial residues and urban organic wastes.
- Substrate composition and environmental factors such as temperature, humidity, oxygen, carbon dioxide and light are anticipated to exert an effect on mushroom yield.

Data must be collected and analysed in a systematic manner over the production processes along the mushroom life cycle in order to quantify the effects of different environmental schedules on mushroom yield.



Aim and objectives

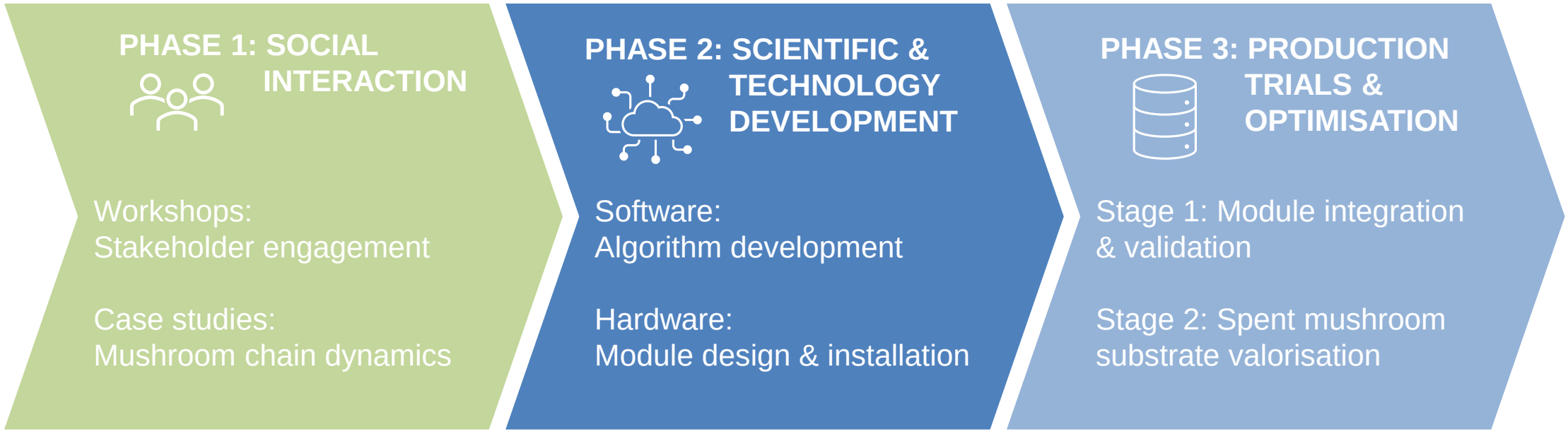
The aim of the **MUSHNOMICS project** is to demonstrate the feasibility of dynamic data-driven analytics for multi-domain mushroom production environments in order to optimize yield, lower costs and improve the economic viability of this agri-food sector.

Specific objectives:

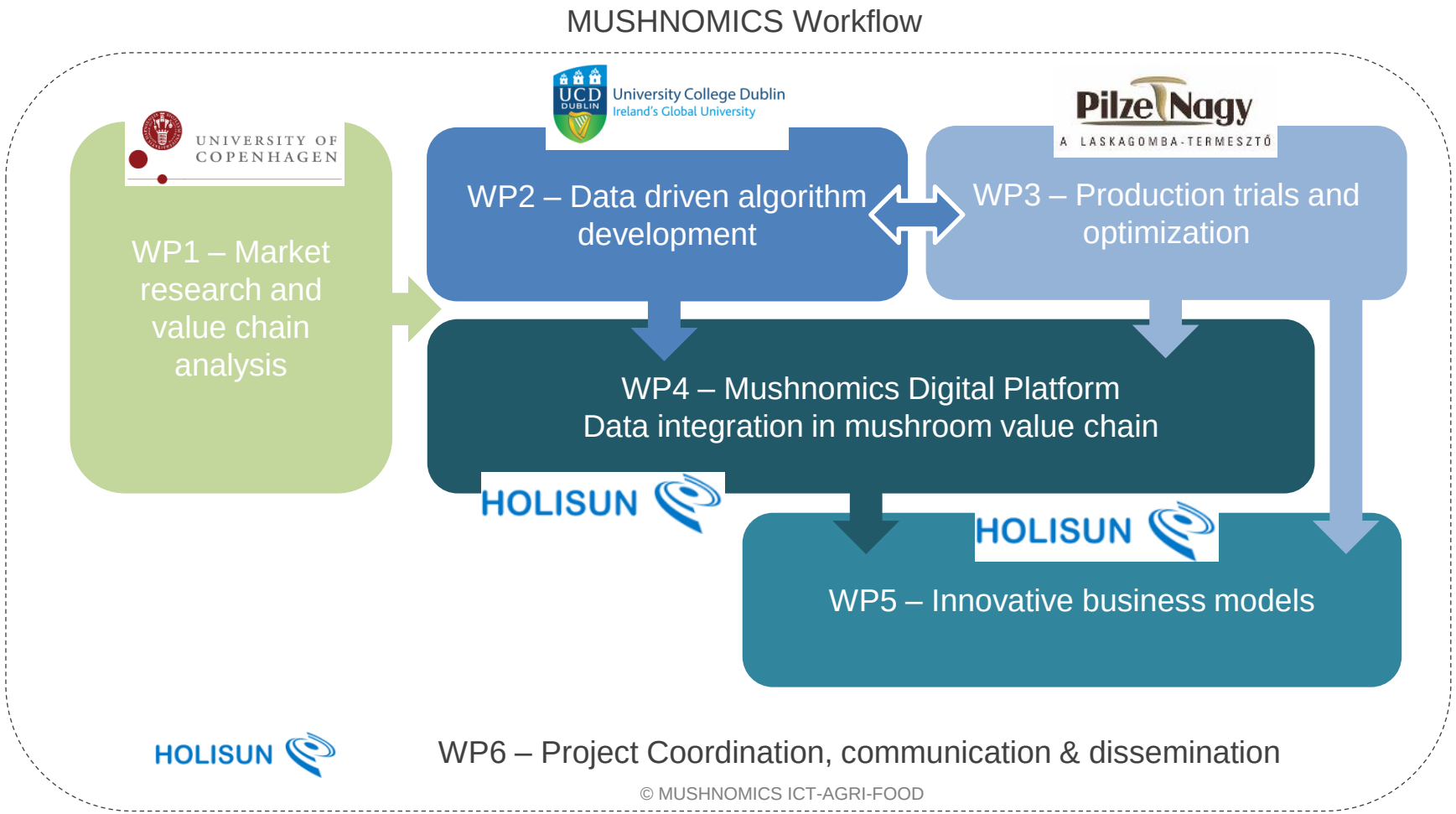
- **AI Integration:** Develop best-performing artificial intelligence (AI)-driven algorithms for yield prediction of mushrooms in a prototype MUSHNOMICS Module with IoT devices for real time production management and demonstration.
- **Data Exchange:** Develop the MUSHNOMICS Digital Platform to exchange data and information from production to points of sale along the mushroom value chain.
- **Innovative Business:** Develop innovative business models based on the IoT-enabled MUSHNOMICS Module for informed decision making by mushroom entrepreneurs.

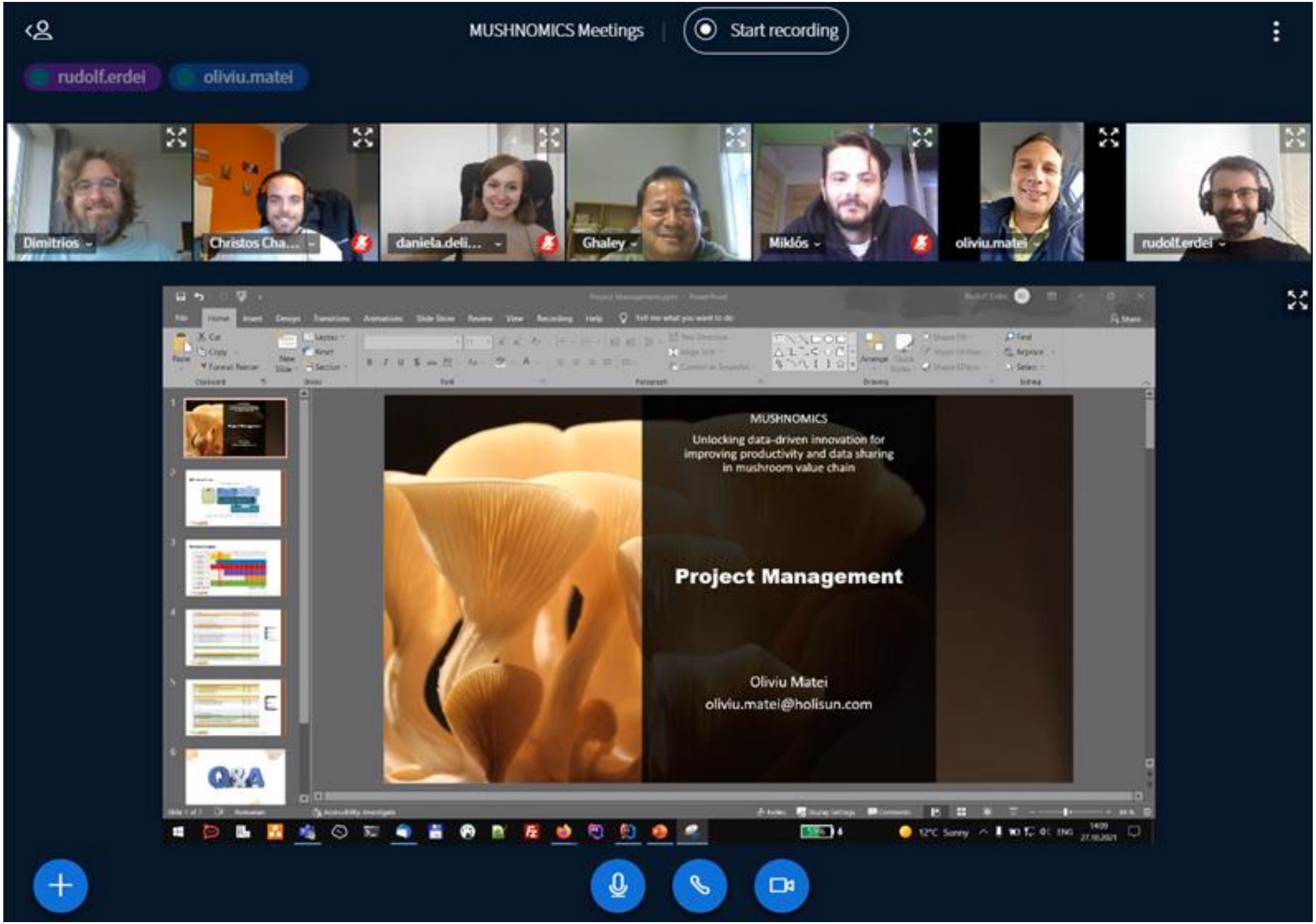
Research approach and activities

MUSHNOMICS was a 36-month project that implemented in three phases



Organisation of work



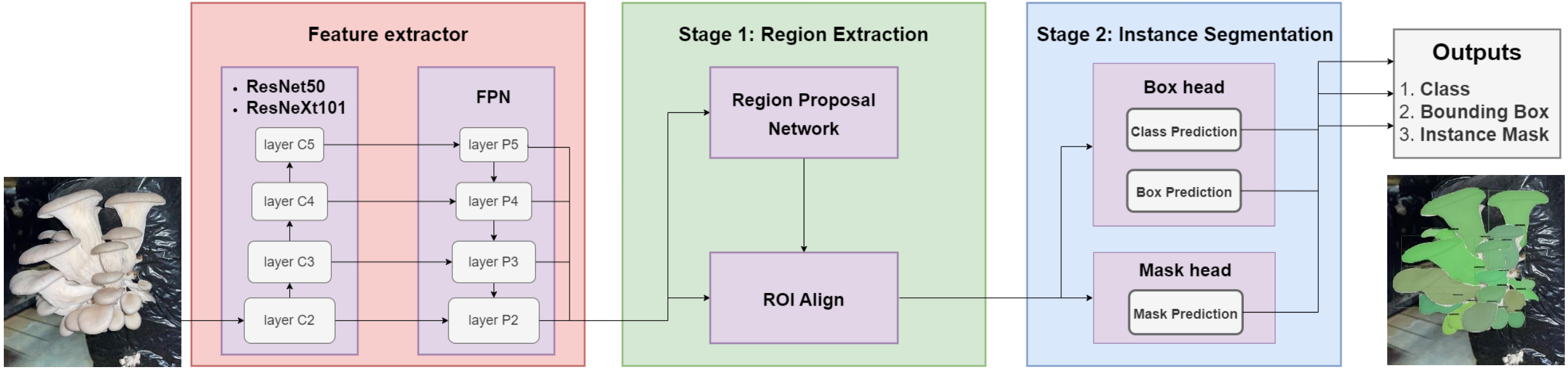

MUSHNOMICS Meetings
Start recording
rudolf.erdei
oliviu.matei
Dimitrios
Christos Cha...
daniela.deli...
Ghaley
Miklós
oliviu.matei
rudolf.erdei
MUSHNOMICS
Unlocking data-driven innovation for improving productivity and data sharing in mushroom value chain
Project Management
Oliviu Matei
oliviu.matei@holisun.com
Q&A

Major results

- Mushroom value chain analysis including biowaste mapping and assessment of potential raw materials
- MUSHNOMICS algorithms: A novel computer vision-based pipeline for automated mushroom growth monitoring
- MUSHNOMICS module system: tailor-made and modular technology offering a circular solution to turn urban biowastes into substrate for oyster mushroom cultivation
- Mushroom production trials and spent mushroom substrate valorisation through vermicomposting
- MUSHNOMICS Digital Platform, implemented as a Digital Companion App, that integrates the research results from all WPs into an easy to use and intuitive application for people who wish to enter this area and small-scale home growers
- MUSHNOMICS business model: Small-scale IoT-enabled production unit using urban biowastes
- MUSHNOMICS technology assessment and acceptance (stakeholder survey)

Novel computer vision pipeline

1. Acquisition of experimental image datasets using RGB cameras in a real-life production environment
2. Development of DL-based tool for the semi-automatic annotation of images
3. Examination of the data and application of pre-processing techniques to counter possible data defects
4. Selection and testing of suitable deep learning instance segmentation architectures
5. Evaluation of model performance through performance metrics
6. Validation of the MUSHNOMICS algorithms using new mushroom image datasets



MUSHNOMICS datasets

- Timelapse image acquisition at PILZE mushroom production facilities in Budapest over periods of ~6 weeks each
- Experiments in different seasons (Summer/Winter)
- Camera in a fixed position with a specific distance from the mushroom substrate block
- Oyster mushroom clusters at different growth stages
- Varying lighting conditions in a farm environment
- Homogenous dataset, similar shapes/texture/colour
- Image acquisition every 15 minutes (~4000 images)
- Recording environmental data (T, rH, CO_2) every 15 minutes

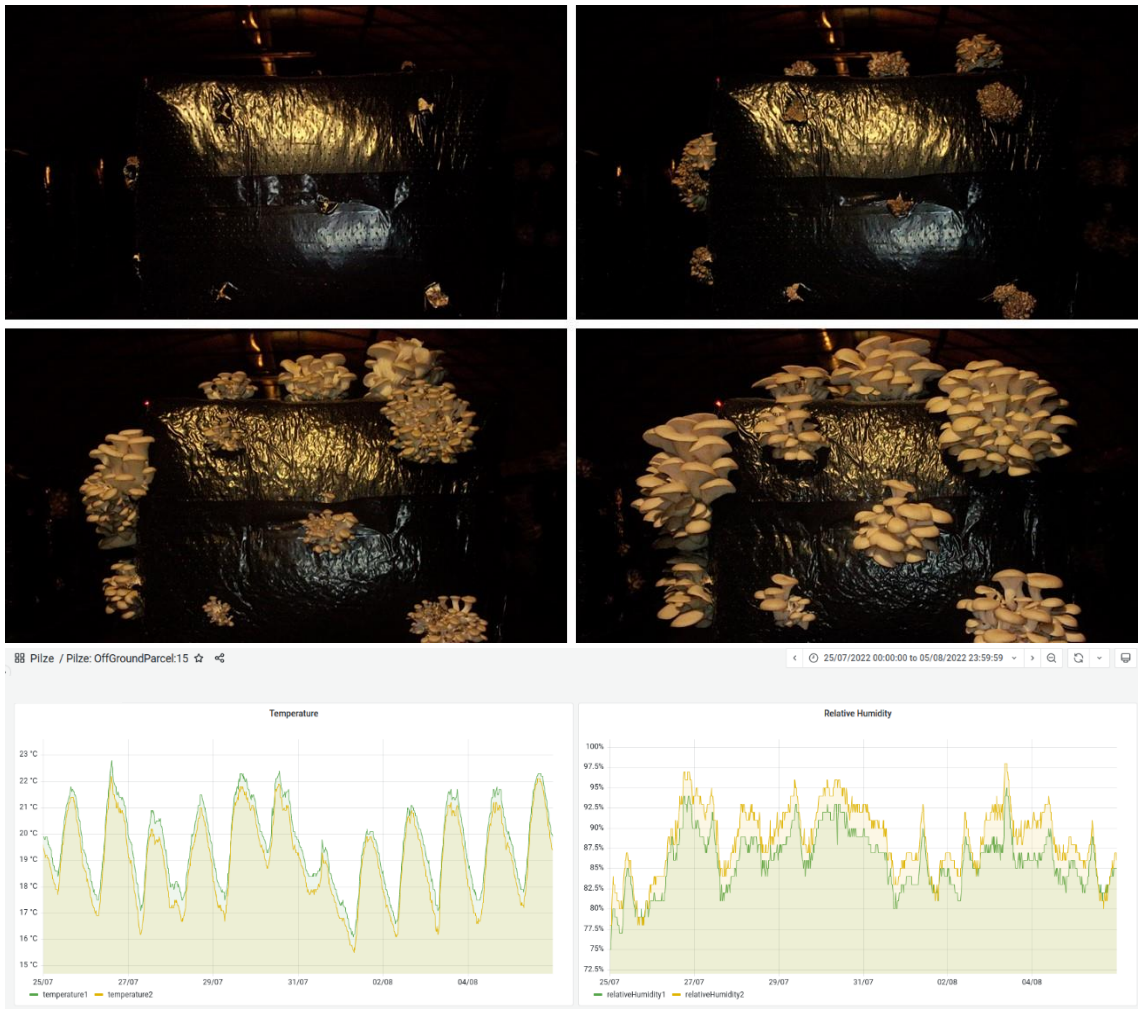
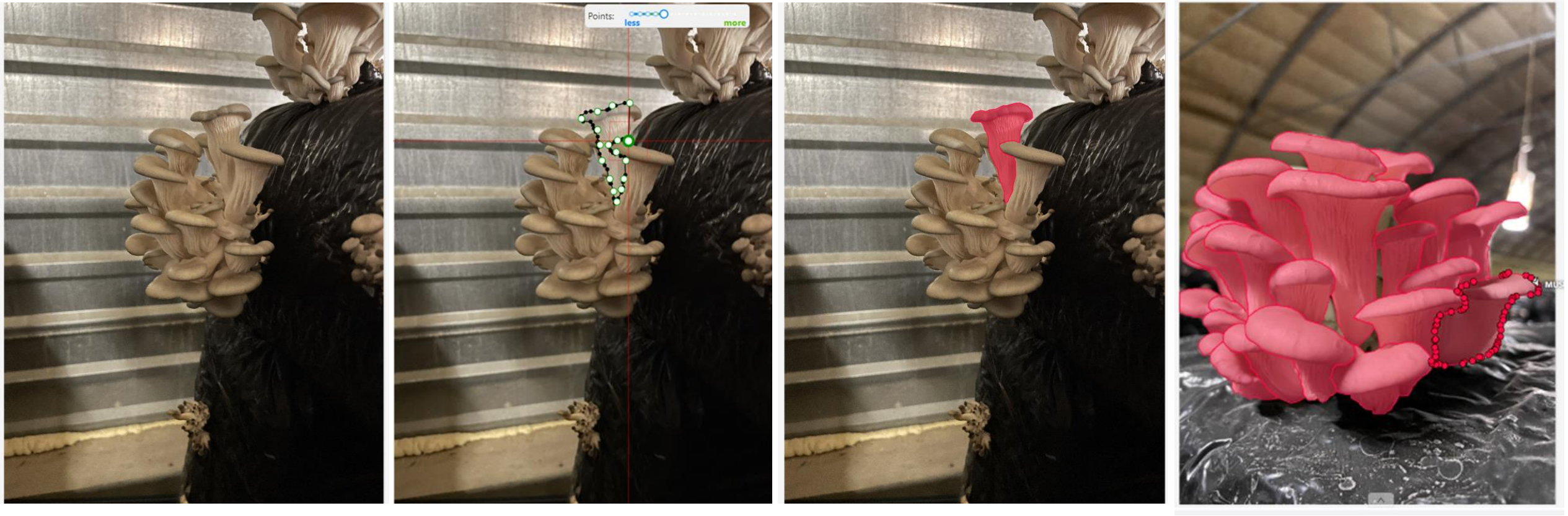
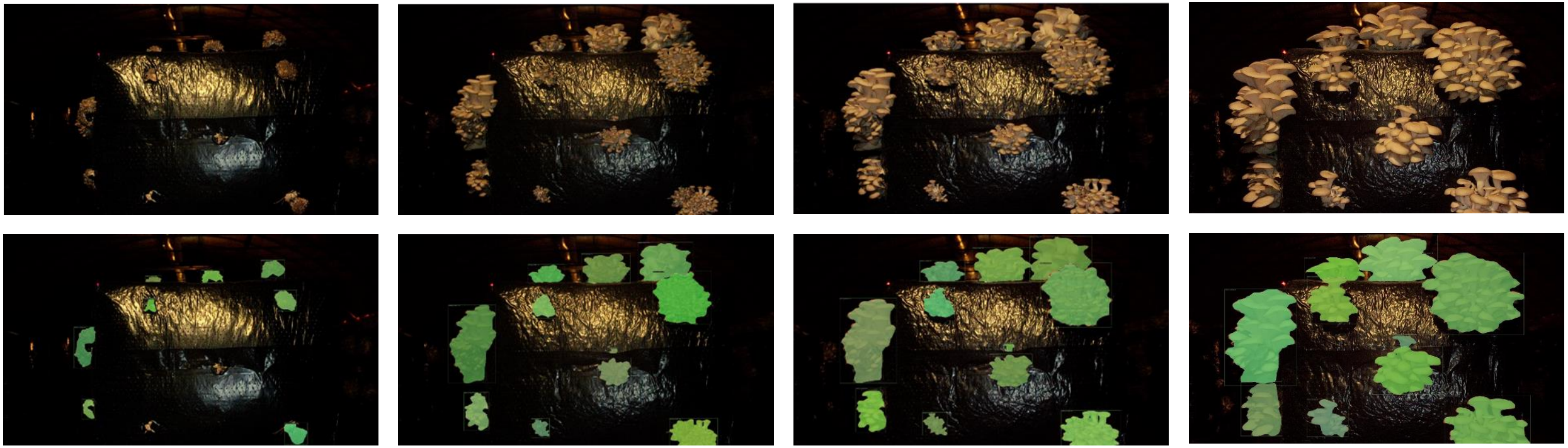


Image annotation process – mushroom labelling

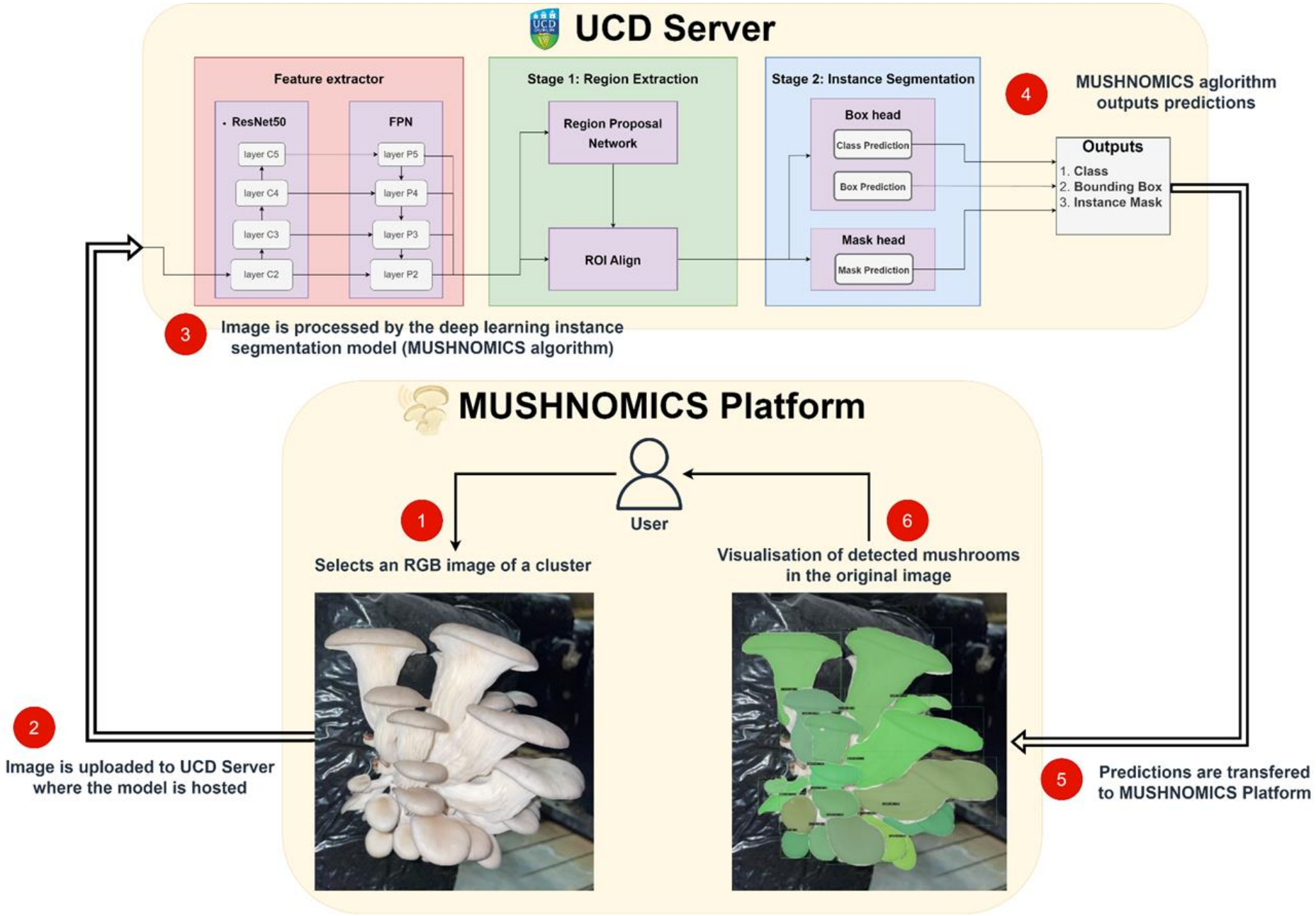


Computer Vision Annotation Tool (CVAT) [cite]

DL-based mushroom growth monitoring



Architecture	Backbone	Precision			Recall	F1 score
		AP_{50}	AP_{75}	mAP		
Mask R-CNN	SWIN	0.967	0.907	0.774	0.823	0.797


UCD Server
Feature extractor
ResNet50
FPN
layer C5
layer C4
layer C3
layer C2
layer P5
layer P4
layer P3
layer P2
Stage 1: Region Extraction
Region Proposal Network
ROI Align
Stage 2: Instance Segmentation
Box head
Class Prediction
Box Prediction
Mask head
Mask Prediction
4
MUSHNOMICS aglorithm outputs predictions
Outputs
1. Class
2. Bounding Box
3. Instance Mask
3
Image is processed by the deep learning instance segmentation model (MUSHNOMICS algorithm)
MUSHNOMICS Platform
User
1
Selects an RGB image of a cluster
6
Visualisation of detected mushrooms in the original image
2
Image is uploaded to UCD Server where the model is hosted
5
Predictions are transfered to MUSHNOMICS Platform

MUSHNOMICS module and production trials

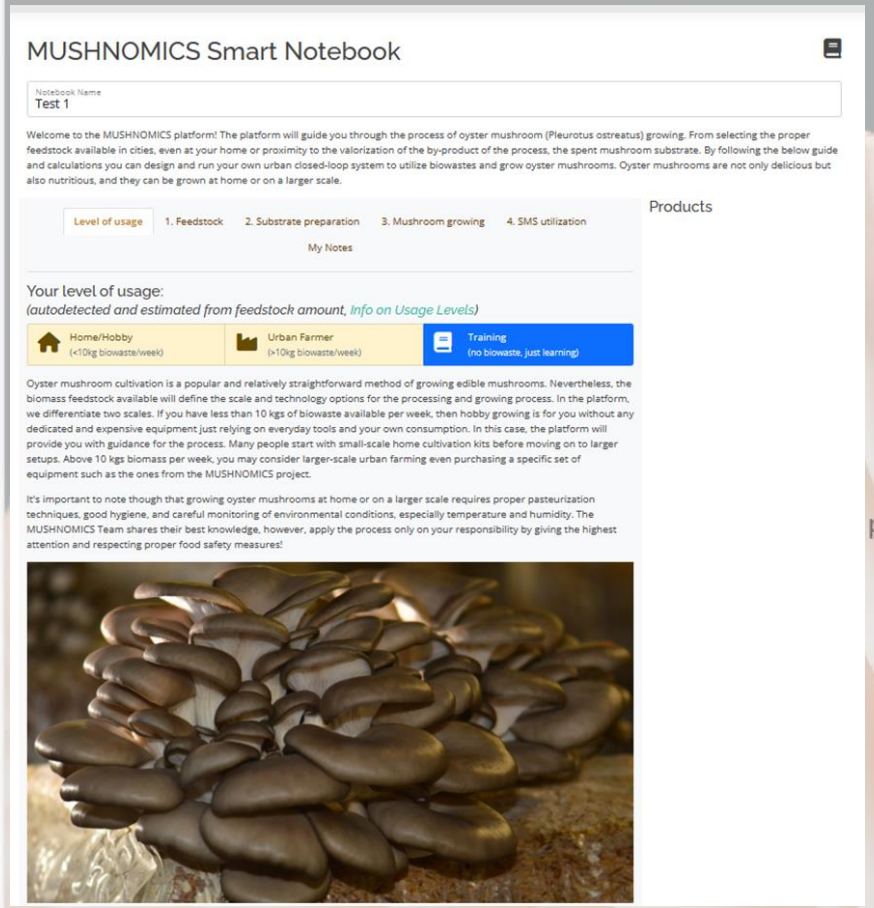
- Cabinet dimensions is 1.5x2.1 m in area and 2.7 m height
- The cabinet is insulated as its walls are sandwich panels
- A total of 9 shelves are there on 3 levels, each can hold 6-9 buckets.
- The cabinet is equipped with sensors to measure T, rH and CO_2
- Temperature and humidity sensors are placed both inside and outside of the cabinet, as the environmental control is not fully independent of the external conditions
- The software control algorithm that secures the optimal conditions for mushroom growing inside the cabinet operates based on the actual measured values of the sensors
- The measured and logged parameters are accessible and can be downloaded from an online surface and mobile app
- This dashboard also makes it possible to intervene remotely and to set the thresholds for the control parameters

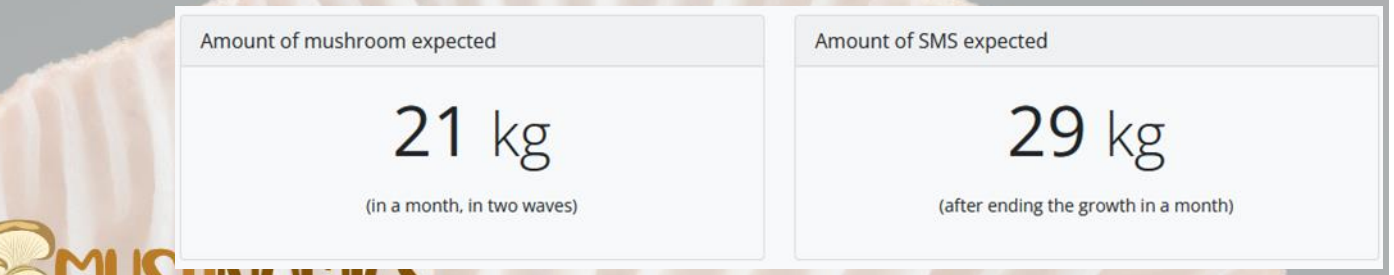
https://platform.mushnomics.org

MUSHNOMICS PLATFORM

Home App Knowledge Base

The App estimates the amount of mushrooms and the SMS expected for a given initial feedstock sources:

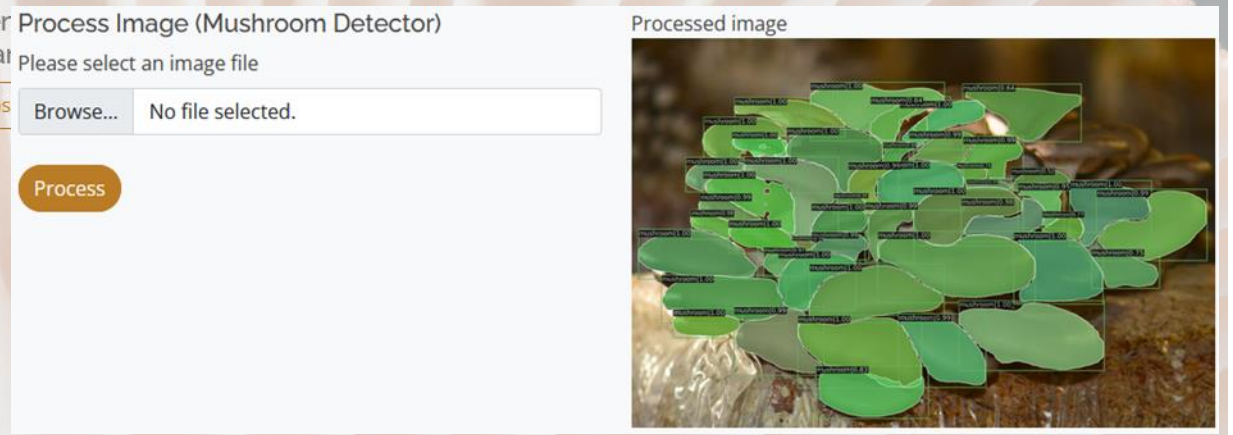




Resulting amounts of mushrooms and SMS

Digital Platform User Interface

Unlocking data-driver
productivity and data shar
Visit the project webs



The mushroom detector API integrated into the App

ictured are the members of the MUSHNOMICS team at their annual meeting in UCD.

ICT-enabled Agri-food Systems

JCD School of Biosystems and Food Engineering is participating in a €1 million EU project aiming to unlock data-driven innovation for improving productivity and data sharing in the mushroom value chain.

'MUSHNOMICS' is undertaken by a balanced and meaningful research-practice partnership (50-50 research-business split), including research-intensive academics with strong industry involvement from four European countries: (UCD, Ireland), (UCPH, Denmark), (PILZE, Hungary) and (HOLISUN, Romania).

Commercial edible mushroom cultivation is 'big business' worldwide with a total production exceeding 27 million tons, a 25-fold increase during the last 35 years, which is combined with a high increase in the respective per capita consumption. Among them, several species of the genus Pleurotus are of particular interest because: (a) their production amounts to ca. 30% of the total, corresponding to the fastest growing and most profitable section of the mushroom market during the last two decades; (b) they are commonly grown on pasteurised wheat straw, however, they can also be cultivated on a wide variety of agro-industrial residues whose disposal is otherwise problematic.

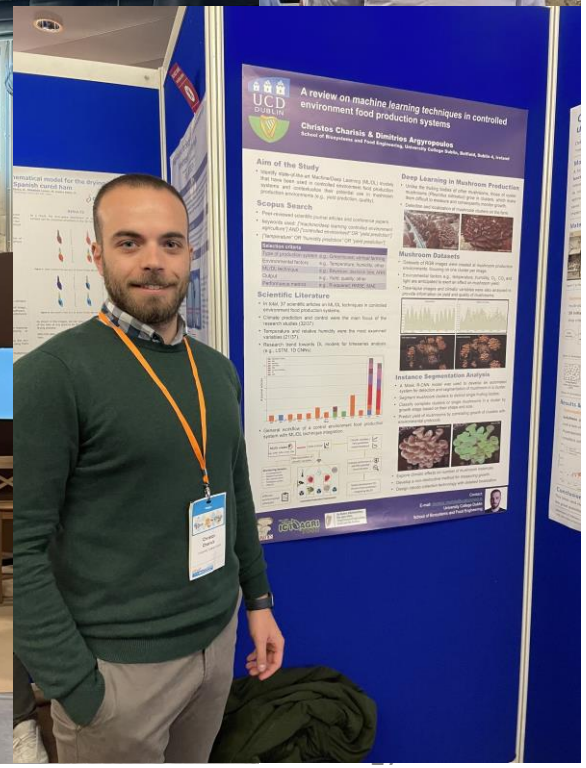
The aim of the MUSHNOMICS project is to demonstrate the feasibility of dynamic data-driven analytics for multi-domain mushroom production environments in order to optimise yield, lower costs and improve the economic viability of this agri-food sector. The specific objectives are to:

- Develop best-performing artificial intelligence (AI)-driven algorithms for yield prediction of mushrooms in a prototype MUSHNOMICS module with IoT (Internet of Things) devices for real time production management and demonstration in our end-user PILZE, Hungary by 2022.
- Develop an ICT platform to exchange data and information from production to points of sale along the entire value chain of mushrooms by 2023.
- Co-develop innovative business models based on container retrofitted MUSHNOMICS Module for informed decision making by mushroom growers/ entrepreneurs by 2024.

MUSHNOMICS will allow UCD to address technical challenges associated with the digitisation of mushroom production grown on various urban wastes using smart sensors and artificial intelligence. The project was one of just 19 projects funded under the ERA-NET 2019 call, out of 112 applications.

Dr Dimitrios Argyropoulos, PI, UCD School of Biosystems and Food Engineering said: "MUSHNOMICS brings together a multidisciplinary team of scientists with complementary skillsets: agronomists, biosystems engineers, data scientists, IT experts, biotechnologists and mushroom entrepreneurs, all working together to solve some of the key challenges in mushroom production. From an innovation perspective, the project will carry out mushroom production trials and optimise yields under real commercial settings using of smart sensors, Internet of Things (IoT) and artificial intelligence (AI)."

itros Argyropoulos at the Farmtopia kick-off meeting, September 2023 in Athens.



48. Detecting and locating mushroom clusters by a Mask R-CNN model in farm environment

C. Charisis, M. Gyalai-Korpos, A. Somosné Nagy, K. Karantzalos, D. Argyropoulos

Pages: 393 - 400

https://doi.org/10.3920/978-90-8686-947-3_48

Summary and conclusion takeaway and lessons learned

Please indicate the importance of the next key features of the technology!

Feature	Rather important (4)		Very important (5)	
The by-product of mushroom farming can be used as compost	76	30.52%	129	51.81%
The technology creates value from urban biowaste (coffee grounds, cardboard…)	56	22.49%	167	67.07%
The technology is energy efficient	35	14.06%	197	79.12%
It produces food locally from local feedstock	49	19.68%	180	72.29%
The technology guarantees that there are no risks associated to food safety	42	17.00%	182	73.68%
The technology is zero waste, there is no waste produced	49	19.84%	183	74.09%
The technology has high added value	65	26.32%	149	60.32%
The smart control helps to reach the proper conditions based on the measured variables	89	35.89%	120	48.39%

Number of answers: 246-250 depending on the feature
The table shows the answers to this question. For each feature the number and percentage of the relative importance is presented
Detailed results of the survey in Deliverable 5.3

Partners / funders

Partner	Logo	Country	Funding Agency
Holisun SRL https://www.holisun.com/ Dr Oliviu Matei	HOLISUN	Romania	UEFISCDI Executive Agency for Higher Education, Research, Development and Innovation Funding
Pilze Nagy http://pleurotus.hu/ Dr Adrien Nagy	Pilze Nagy A LASKAGOMBA-TERMESZTŐ	Hungary	National Research, Development and Innovation Office
University of Copenhagen https://www.ku.dk/ Dr Bhim Bahadur Ghaley	University of Copenhagen	Denmark	Ministry of Environment and Food of Denmark
University College Dublin https://www.ucd.ie/ Dr Dimitrios Argyropoulos	UCD Dublin University College Dublin Ireland's Global University	Ireland	An Roinn Talmhaíochta, Bia agus Mara Department of Agriculture, Food and the Marine

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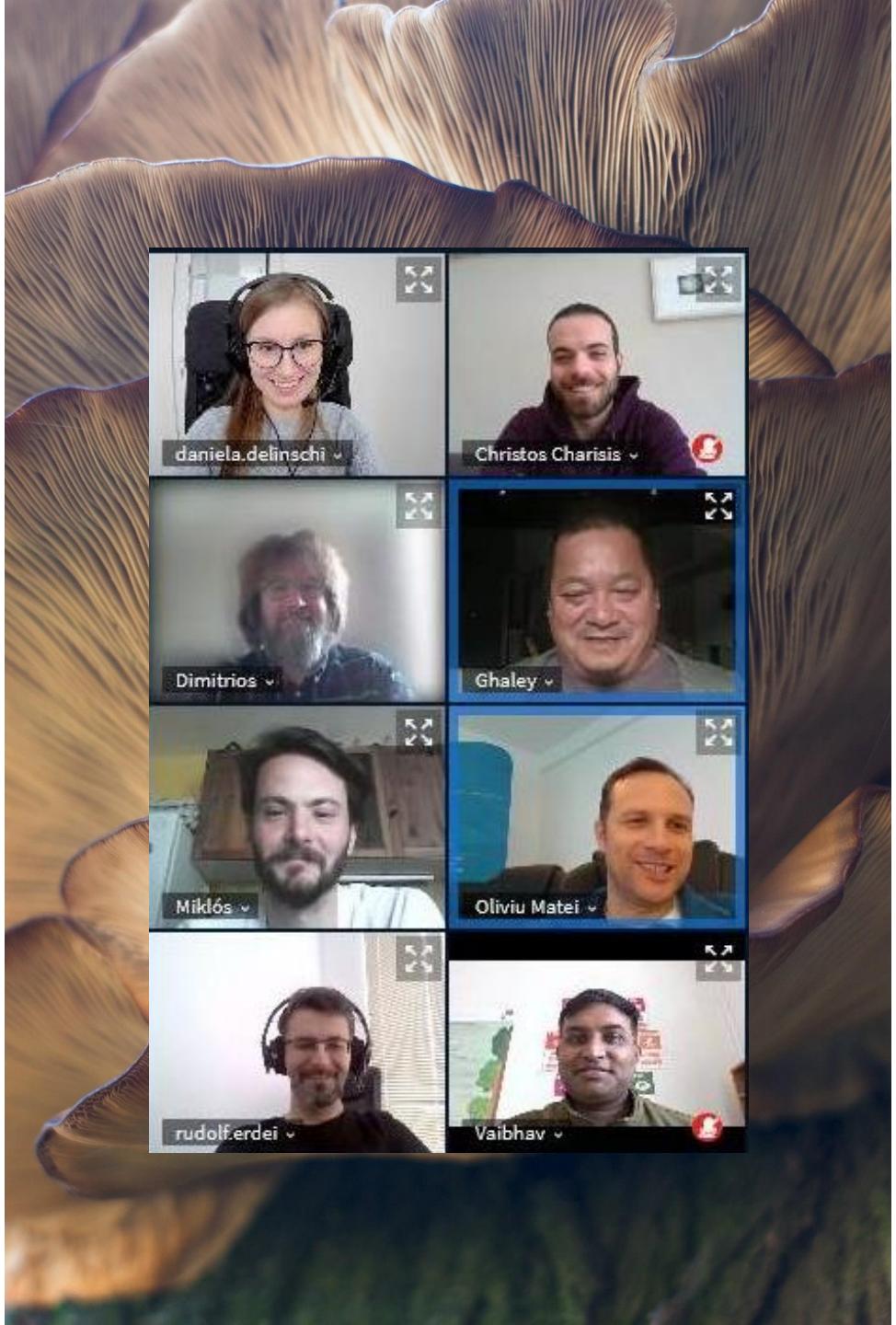

LET'S KEEP IN TOUCH!

Please feel always free to reach out to us.

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https://www.linkedin.com/in/mushnomics-project-645668206/

WEBSITE

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Thank you for your attention!

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