UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

itee PhD
information technology
electrical engineering

DIETI UNINA

UNIONE EUROPEA
FSE REACT-EU

PhD Maria Teresa Verde

"Smart Farming on Dairy Buffalo Farms"

PON Dottorati di ricerca su tematiche dell'innovazione e green - Azione IV.5 (Green)

Tutor: Prof. Leopoldo Angrisani

co-Tutor: Prof. Francesco Bonavolontà

Cycle: XXXVII

Year: 2023

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My background

- **MSc** Degree in **Veterinary Medicine**
- Bachelor's Degree in **Technologies of Animal Production**
- **Qualified Zootechnical Veterinary Doctor**
- Attends the third year of **Specialisation School in Infectious Diseases**
- Research Grant at Department of Veterinary Medicine and Animal Production (Prof. Luigi Esposito, Scientific director)
- DIETI Group: **Electrical and Electronic Measurement Group (SSD ING-INF/07)**
- PhD start date – 01/01/2022

Research field of interest

The goal of my Ph.D. project, *funded by the National Operational Programme on Research and Innovation 2014-2020 of Italy*, entitled "***Smart farm in buffalo farm***", is to study and develop new measurement sensors, instruments, and equipment for Precision Livestock Farming (PLF) applications.

The final objective of PLF is achieve significant improvements in terms of:

(1) quantity and quality of animal production;
(2) animal welfare conditions;
(3) environmental sustainability (reduction of methane and ammonia emissions)

by means the use of new frontiers in livestock management and engineering technologies.

My research activity focused overall on the creation of the diagnostic tools that can help with early detect animal health issues, without animal manipulation (contactless and non-invasive data gathering).

The ability to recognize a disease outbreak days before other any traditional method, allow to limit economic negative impact of livestock disease and reduce animal stress.

Summary of Study Activities

In the following table, educational and research credits, acquired during the first and second year, are reported:

		BM1	BM2	BM3	BM4	BM5	BM6	TOT	TOT
Ad hoc course	**Yr1**			5				**5**	5
	Yr2								
Other course/Ph. D. Schools	**Yr1**		6	18	6			**30**	45
	Yr2			9			6	**15**	
Seminars	**Yr1**		2,6	2	3		1,1	**8,7**	17,5
	Yr2	0,4			3,4	3	1,5	**8,3**	
Research	**Yr1**	3	3	3	3	6	6	**24**	69
	Yr2	6	9	9	9	9	3	**45**	

The minimum number required for each item and year is reached

Summary of Study Activities

Courses:

Activity	Credits
Corso di dottorato in Ingegneria Industriale "Federico II": Piattaforme di misura e monitoraggio basate su Internet of Things. Prof. Schiano Lo Moriello.28/04/2022	6
Big Data Architecture and Analytics. Prof. Sperlì. 29/06/2022	5
Sensori e Trasduttori di Misura. LM Ing. Elettronica. Prof. D. Grillo.29/06/2022	9
Sensori e Smart Metering. LM Ing. Elettrica. Prof. F. Bonavolontà. 20/06/2022	9
Intelligenza Artificiale. Prof. Flora Amato 7/7/2022.	6
Misure su Sistemi Wireless. Prof. Angrisani, 9 cfu, A2, 3/7/2023	9
Incertezza dei Dati. Prof. Angrisani, 9 cfu, A2, 3/7/2023	6
	50

Seminars:

"La termografia come strumento di precisione nell'allevamento degli animali da reddito." Leonardo Nanni Costa, Università di Bologna, Veronica Redaelli, Università di Milano Fabio Luzi Università di Milano. 02/03/2022.	"Running towards Car Electrification, ST MICROELETRONICS", S. Cannavacciuolo, V. D'Angelo, F. Bonavolontà, 16/05/2022.	"Corso formazione specialistico Classyfarm per veterinari aziendali: Modulo specialistico bufala da latte." Piattaforma per la rilevazione, la raccolta e la elaborazione dei dati relativi alle seguenti aree di valutazione: biosicurezza; benessere animale; parametri sanitari e produttivi; alimentazione animale; consumo di farmaci antimicrobici; Istituto Zooprofilattico Sperimentale del Mezzogiorno (IZS) dal 5/9/2023 al 7/9/2023.
"Transdairy Living Lab's Open Day ICT & Bio Nanotechnology", Prof. L. Zeni, A. Mandolini, A. Anastasio, A. Minardo, F. Bonavolontà, N. Cennamo, A.Varriale, S. Sarkis, 31/03/2022.	"Artificial Intelligence @ The Deep Edge" 2/06/2022.	
	Smart clothes and wearable technology. 30/1/2023	
"Picariello Lectures on Data Science – II Cycle Ethics and Politics of A.I, Prof Mark Coekelbergh", 11/04/2022.	"Augmented reality for remote use of measurement Instrumentation" Prof. Liccardo. 24/05/2022.	Nuove opportunità per progetti di ricerca industriale: l'intervento "Scoperta imprenditoriale" del MIMIT. Seminar date 7/11/2023
"Picariello Lectures on Data Science – II Cycle Can a Text-to-Speech Engine Generate Human Sentiments?", Prof. Vijay K. Gurbani. 28/02/2022	Powe Electronics: control and architecture. A mini Campus. 4/5 Luglio 2022 presso STMicroeletronics.	Kick-off meeting della Task 5.3.8 (Living Labs) - Spoke 5 AGRITECH, in modalità telematica (via piattaforma ZOOM).
"Protozoi Intestinali come ospiti sgraditi: Giardiasi e Trichmoniasi nella pratica clinic", Prof. Tommaso Furlanello. 2/03/2022	Seminar title Il futuro della medicina alla luce dell'applicazione dell'intelligenza artificiale e della robotica Seminar date 15/11/2022 Lecturer Bruno Siciliano , Agostino Sibillo	"Elementi di Automazione e Introduzione al concetto di domotica. Smart Building e vantaggi del sistema nelle strutture ricettive. I sistemi di comunicazione e la connessione tra i dispositivi. Il concetto di attuatore e di cavo bus." Prof. Francesco Bonavolontà. 7/03/2022
Power and Analog electronics: Design, Control and Architecture, MINI CAMPUS DI STMICROELETRONICS DEL 4-5-6 LUGLIO 2023		

Research activity: Overview

One of the most prevalent problems on dairy buffalo farms (70% of Livestock diseases) is mastits, a severe inflammation of the mammary gland.

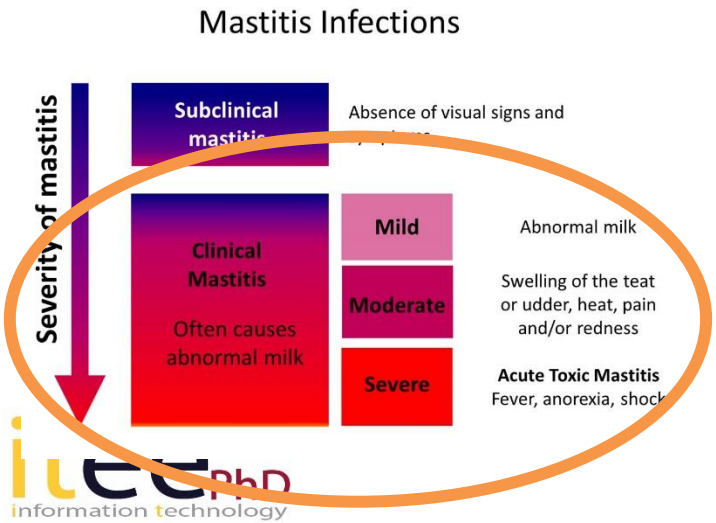
Mastits reduces the number and activity of milk producing epithelial cells, reduces quality milk, and increases cost for treatment.

Current tools for diagnosing mastitis are mainly based on tests performed directly on milk:

(1) Somatic cell counts (significant relationship between somatic cell count in collected milk samples and severity of Mastits);

(2) Bacteriological culture.

They are slow and expensive. Moreover, they are effective in diagnosing clinical mastits, detected too late, when milk is abnormal and animal health is already compromised.



Mastitis

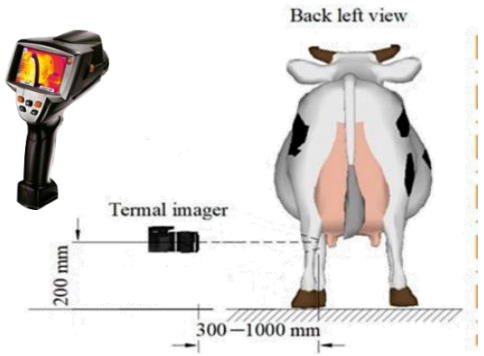
Abnormal milk

Bacteriological culture

Research activity: Overview

To reduce their negative impact, it is important to detect mastitis early, even in the absence of visual signs and symptoms.

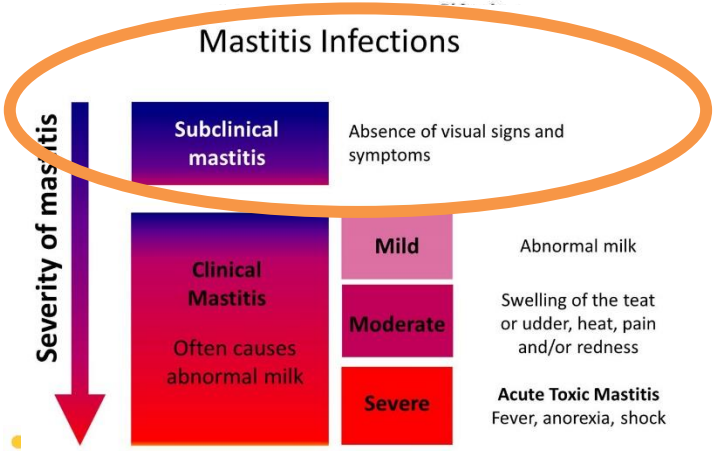
To this aim, by considering that udder skin surface temperature increases at the onset of inflammation, during the first year, the use of ***Infrared (IR) imaging technology*** for ***Early Detection of Mastitis*** (Subclinical Mastits), has been studied and evaluated.

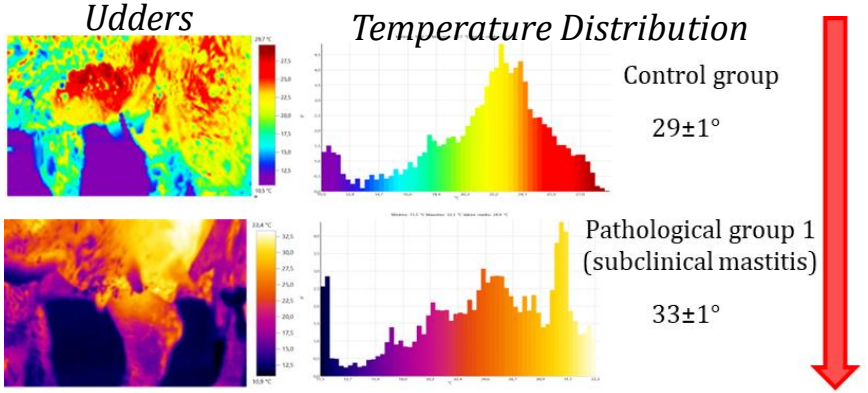


Two group were considered:

- Control group (when the level of SCC is less than 400,000 cells/mL, threshold to classify a subclinical mastitis: *healthy cases*)
- Pathological group 1 (when the level of SCC is greater than 400,000 cells/mL, but visual sign and symptoms of mastits are absence)

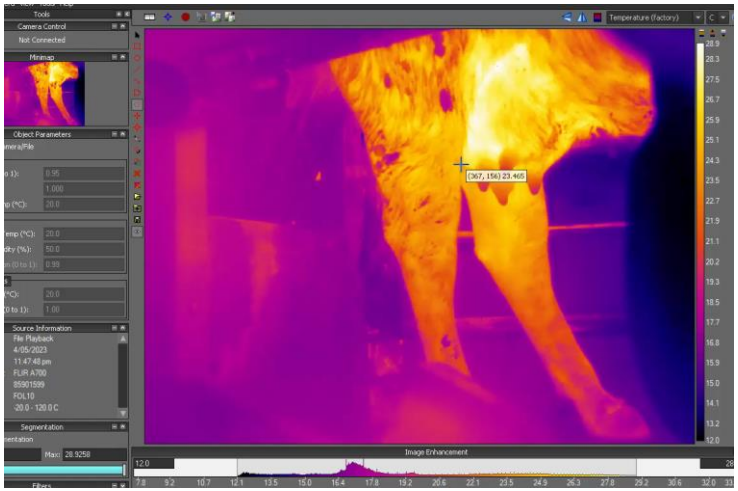
We demonstrated that the use of infrared technology is effective



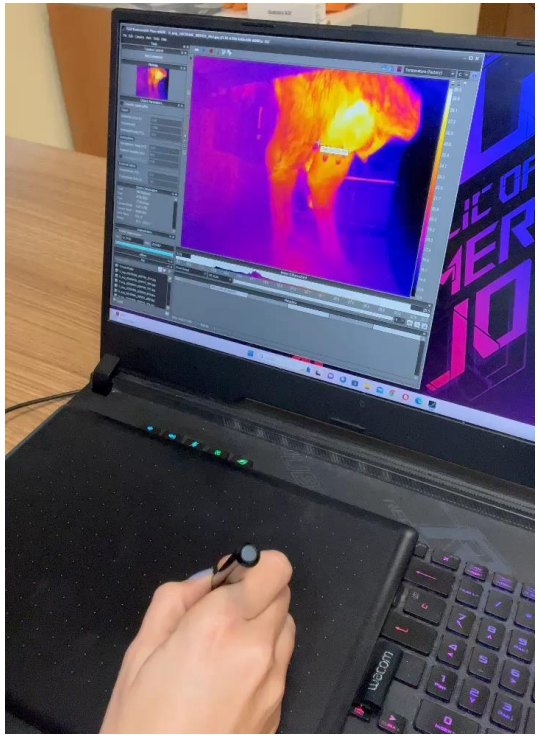


Research activity: Overview

However, some areas near udder of dairy buffalo may lead to inaccurate target detection, resulting in errors in temperature extraction and affecting the accuracy of dairy buffalo mastitis detection. Therefore, for each thermal image, a Region of Interest (ROI) coincident with the udder, must be set up.



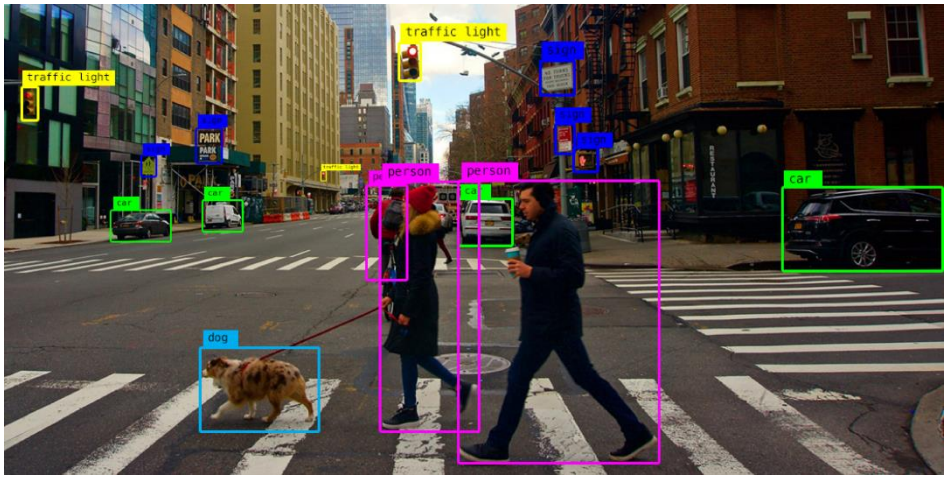
This operation, since no predefined ROI is available for the udder, must be drawn freehand (as example by means a graphics tablet, and is therefore time-consuming.



The limited automation of these methods make its unsuitable for the large-scale practical needs of detecting mastitis in dairy buffalo.

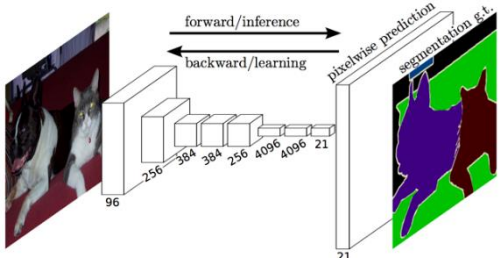
Research activity: Overview

In recent years, with the rapid development of deep learning in computer vision, neural networks have achieved significant success in target detection scenarios with complex backgrounds.

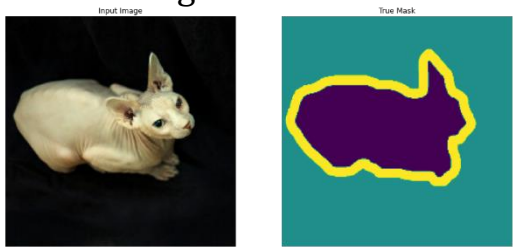


We proposed a UNet model to achieve the accurate automatic segmentation of buffalo udder to solve the above problems and further promote the detection accuracy of buffalo mastitis.

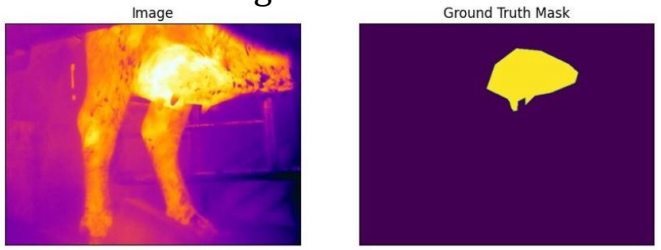
UNet



segmentation



segmentation



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Research activity: Overview

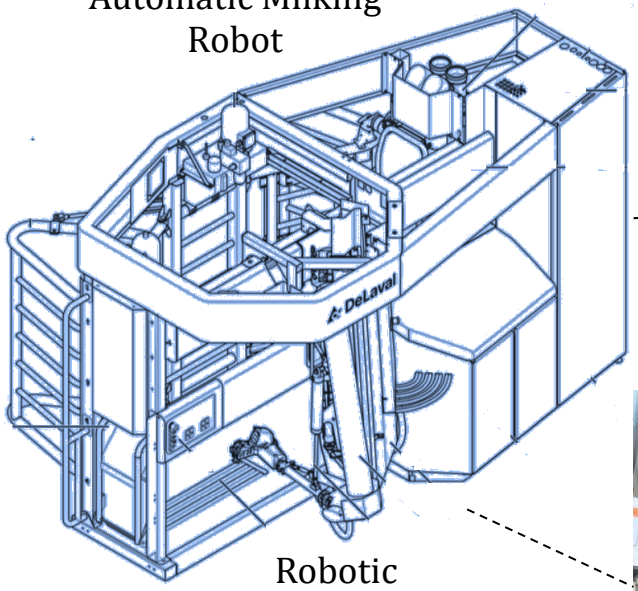
The overall process is shown in the following.

Firstly, a dataset of udders thermal images was constructed, thanks to an **Automated Data Acquisition System** consist of:

1. ***Fixed Infrared Cameras (FLIR A700),*** *located on the rear side of the milking robot;*

Automatic Milking Robot

Automatic Milking Robot



Robotic Arm

Infrared Camera FLIR A700

FLIR A700

Research activity: Overview

Firstly, a dataset of udders thermal images was constructed, thanks to an **Automated Data Acquisition System** consist of:

1. *Fixed Infrared Cameras (FLIR A700), located on the rear side of the milking robot;*

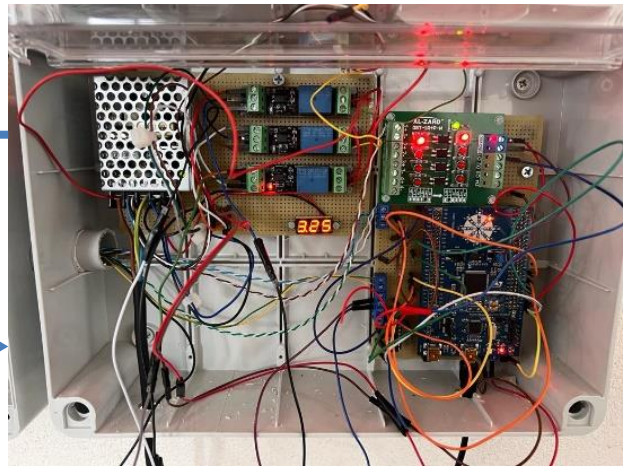
2. *A* **Logic Control Unit**, *that is responsible for detecting when buffalo enter the robot, and triggering Infrared Camera, just before the start of milking, to obtain reliable udders thermal images.*

Flir A700

trigger

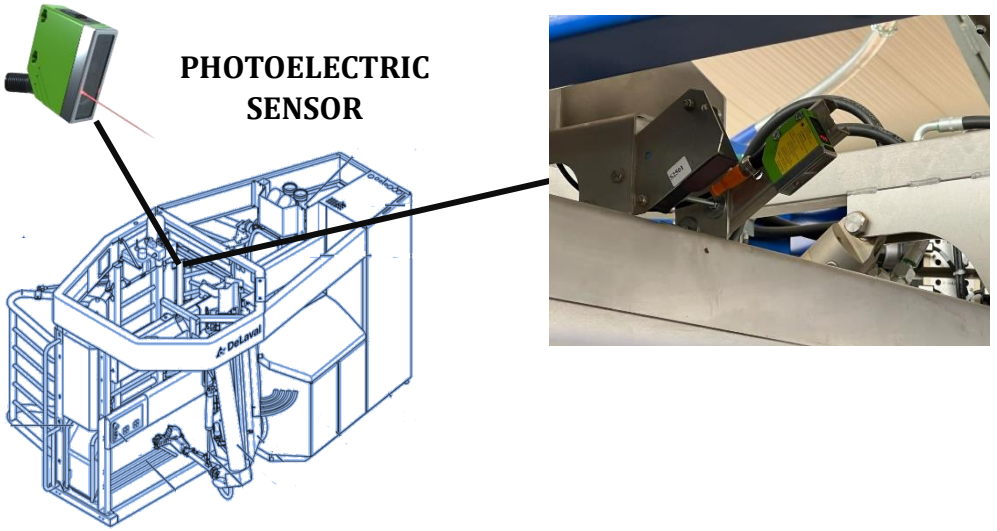
Thermal Image

Logic Control Unit



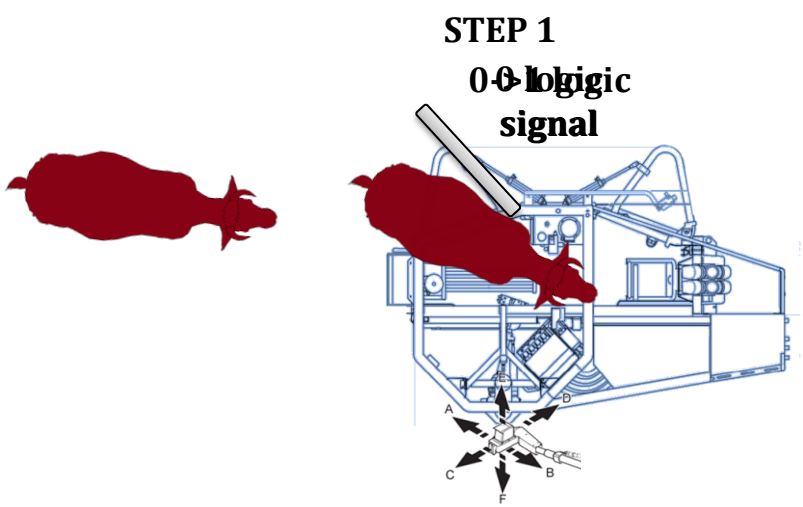
Research activity: Overview

Thanks to a **Photoelectric Sensors**, installed on the top of the milking robot, the **Control Unit** can detect when a new Buffalo enters or leaves the robot (after milking).



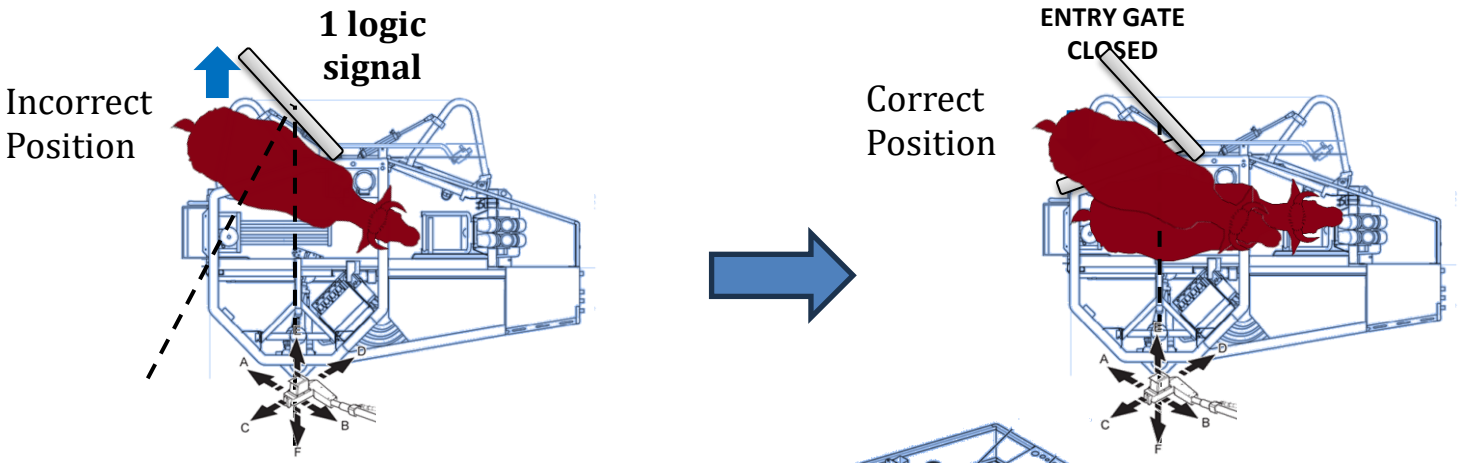
When a Buffalo enters the robot, the **Photoelectric sensors output** switch from:
LOW-SIGNAL (0 logic)

to HIGH-SIGNAL (1 logic)

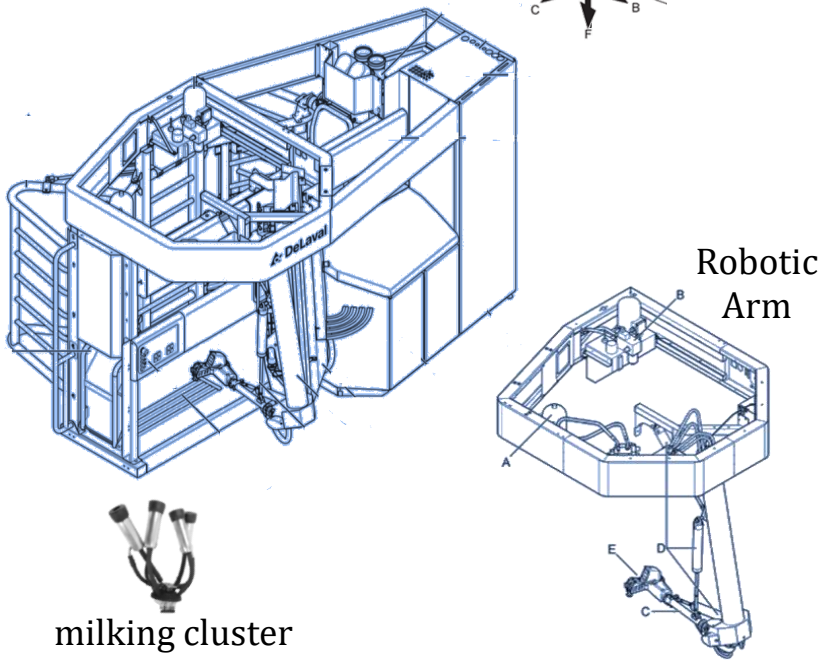


Research activity: Overview

However, the milking can start only if the Buffalo completely enters in the box, assuming a correct position, and the entry gate close.



Then, after a few seconds the closing of the entry gate, the robotic arm moves towards Buffalo udder, to attach the milking cluster and began milking routine.



Research activity: Overview

In the following video, an initial activity of an automatic milking routine is shown

The buffalo, before assuming a correct position and allowing the entry gate to close, can take several time, even minutes.

Research activity: Overview

It is then during this short interval of few seconds (≅ 2 sec), between **the closing of the entry gate** and the **robotic arm moving**, that a **trigger signal for Infrared Camera** must be generated to take a reliable and useful thermal image just before milking

In the next video, an example at the **correct** and incorrect **point** of trigger is shown

Infrared Camera View

Reliable udder thermal image

to be discarded

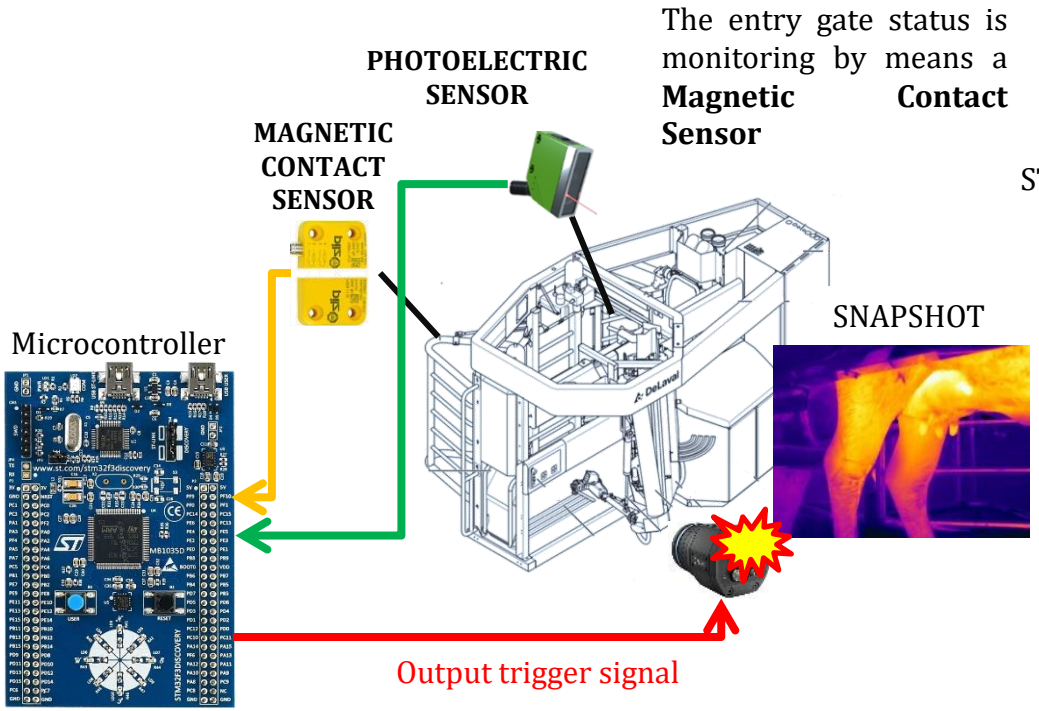
Research activity: Overview

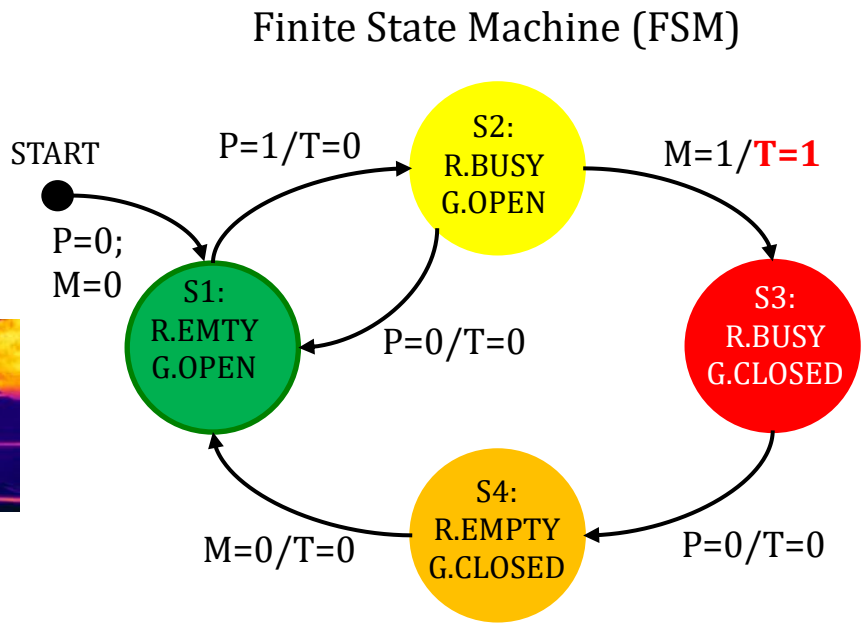
Thermal camera has digital inputs in the back panel.
It is capable of taking a thermal snapshot at an external trigger signal.

back panel

FLIR A700

The heart of the **Automatic Data Acquisition System (ADAS)** is the **Control Unit**, consists of a **Microcontroller.**





The Firmware running on Microcontroller is based on a Finite State Machine (FSM) that takes two inputs, Photoelectric Sensor (P) and Magnetic Contact Sensors (M) and generate a single output, i.e., the suitable trigger signal (T) for the Infrared Camera, which captures a thermal snapshot of the udder.

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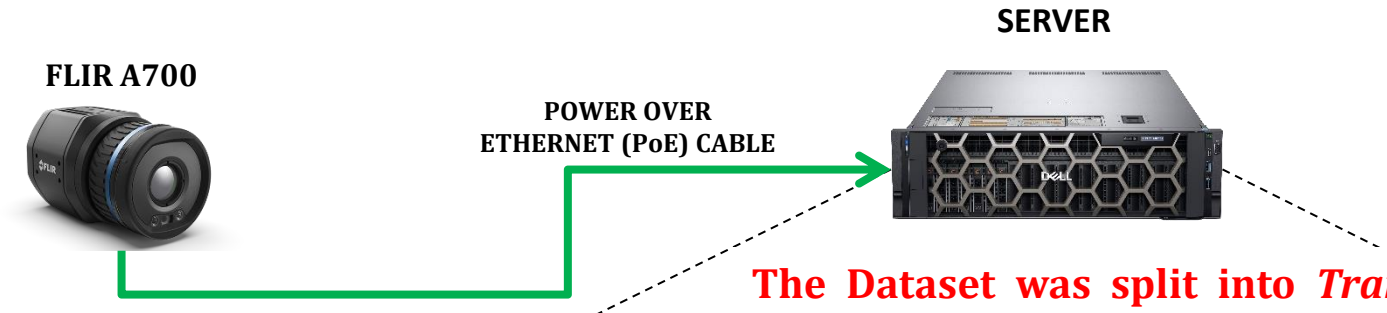
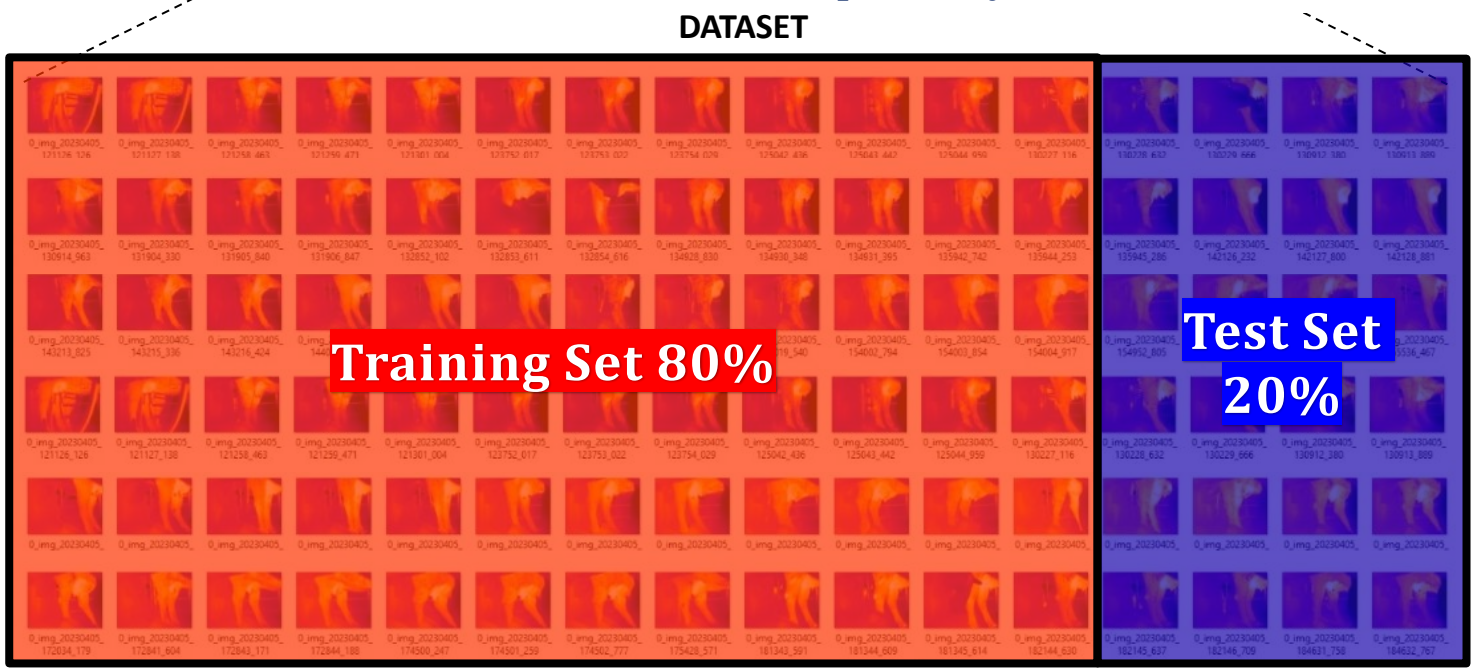
Research activity: Overview

The thermal cameras is powered via a power over ethernet and are configured to send the image taken each time to the local server with File Transfer Protocol (FTP) protocol where they are historicized and processed.



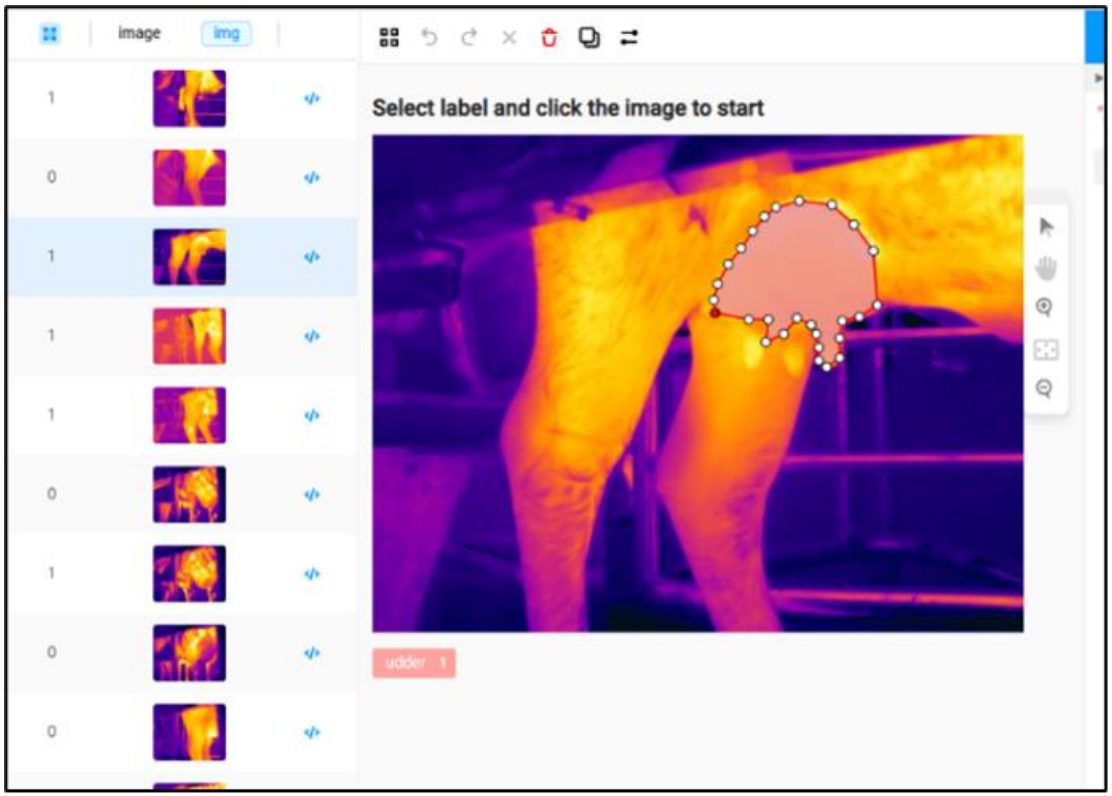
The Dataset was split into *Training* and *Test* sets: 80 and 20% respectively.



Each image is distinguished by the date and time of the shot. An appropriate algorithm allows the image to be associated in the platform with the Buffalo ID and weather data.

Research activity: Overview

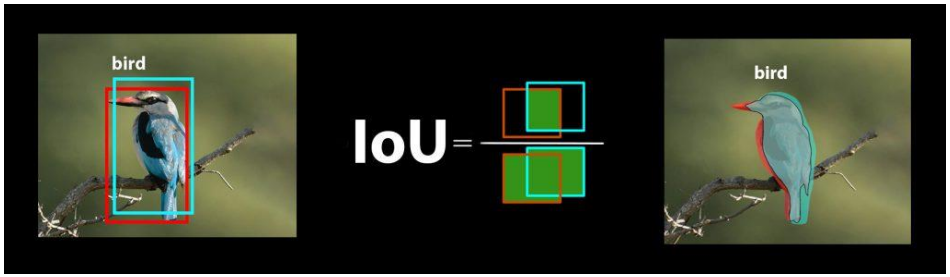
Using open-source software "*LabelStudio*", annotator experts in veterinary medicine performed segmentation of udders with polygonal masks.



Thus, the model was trained and used for udder segmentation.

Research activity: Overview

The first checkpoint for evaluating the accuracy of the developed model was the **Intersection Over Union (IoU),** a number that quantifies the degree of overlap between two boxes. In the case of object detection and segmentation, **IoU** evaluates the overlap of the **Ground Truth*** and **Prediction** region.



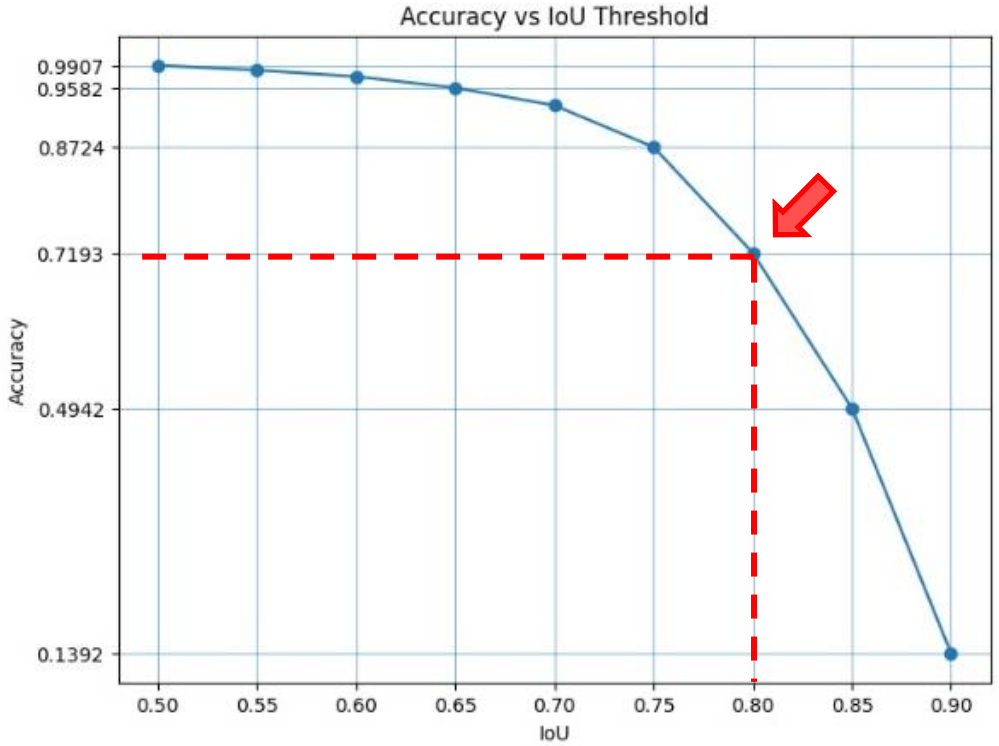
In the case of Image Segmentation, the area is not necessarily rectangular. It can have any regular or irregular shape. That means the predictions are segmentation masks and not bounding boxes.

*where the Ground Truth (GT) Masks are those annotated by experts in veterinary medicine, while Predicted Masks are results by UNet model.

Research activity: Overview

The IoU of two areas can have any values between 0 (no overlapping) and 1 (perfect match). The greater the region of overlap, the greater the IoU.

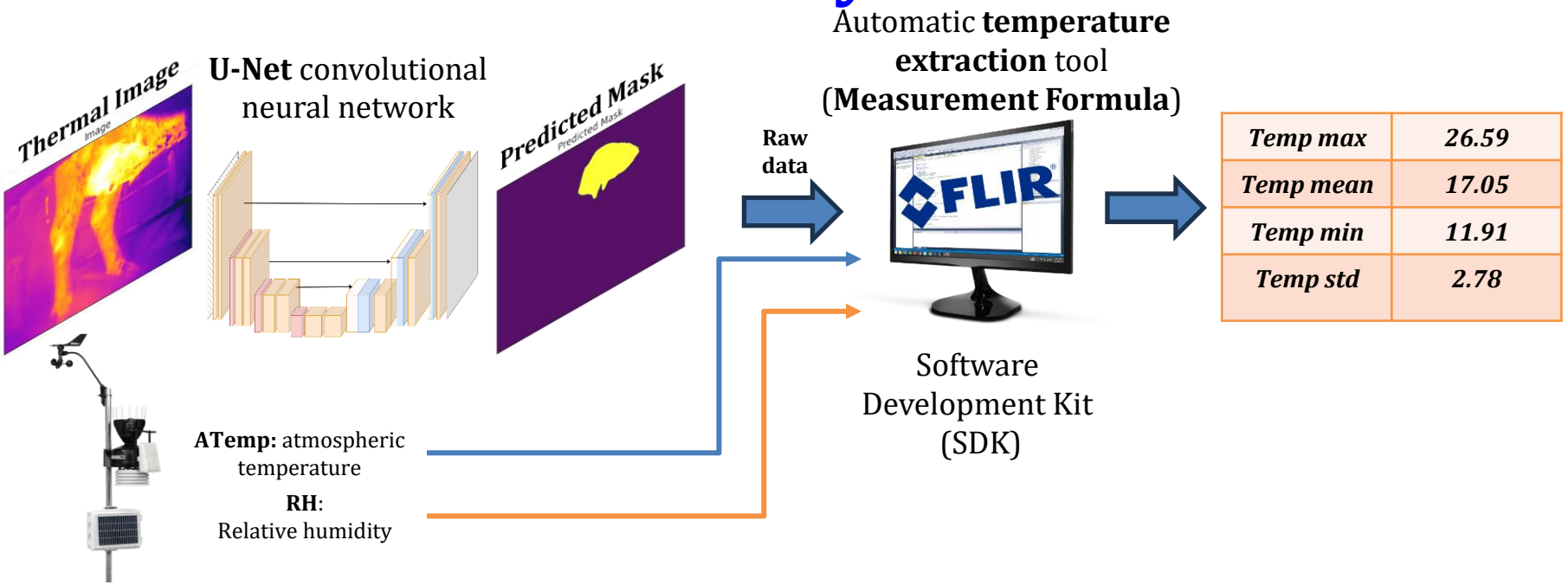
The Graph below shows Accuracy Vs. IoU Threshold.



Model's performance was evaluated using different IoU thresholds.

As an example, fixed a **IoU threshold** of **0.8,** for the trained model, 72 % of predicted box have an IoU greater than **0.8**, which can be considered a **Good** result.

Research activity: Overview



Once the neural model has predicted the mask, raw data are converted to temperature using a **Measurement Formula**, which takes also Atmospheric Temperature (**ATemp**) and Relative Humidity (**RH**) as input parameters, to provide more accurate and precise values.

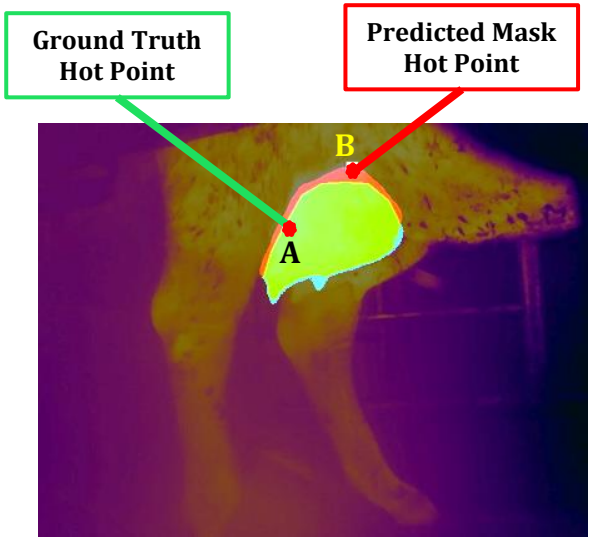
Then, temperatures of interest, such as maximum, average, minimum temperatures of the predicted mask, are extracted and compared with other parameters related to animal health, (Somatic Cell Count (SCC), Electrical Conductivity (EC), Milk Production) to study and develop an ***Early Warning System*** model to predict ***"subclinical mastits"***.

Research activity: Discussion and Conclusions

In conclusion, results obtained with automatic segmentation of udders can be considered very good, especially from a computer vision and object detection point of view.

However, remembering that the final goal of the application is not simply segmentation, but the extraction temperatures from it, particular cases may arise.

As shown in the image, even with **high IoU** values, **Ground Truth** and **Predicted Mask** can determine different **hot points,** which can lead to an incorrect assessment of subclinical mastitis. There is therefore an uncertainty in the application of the method which must be appropriately evaluated.

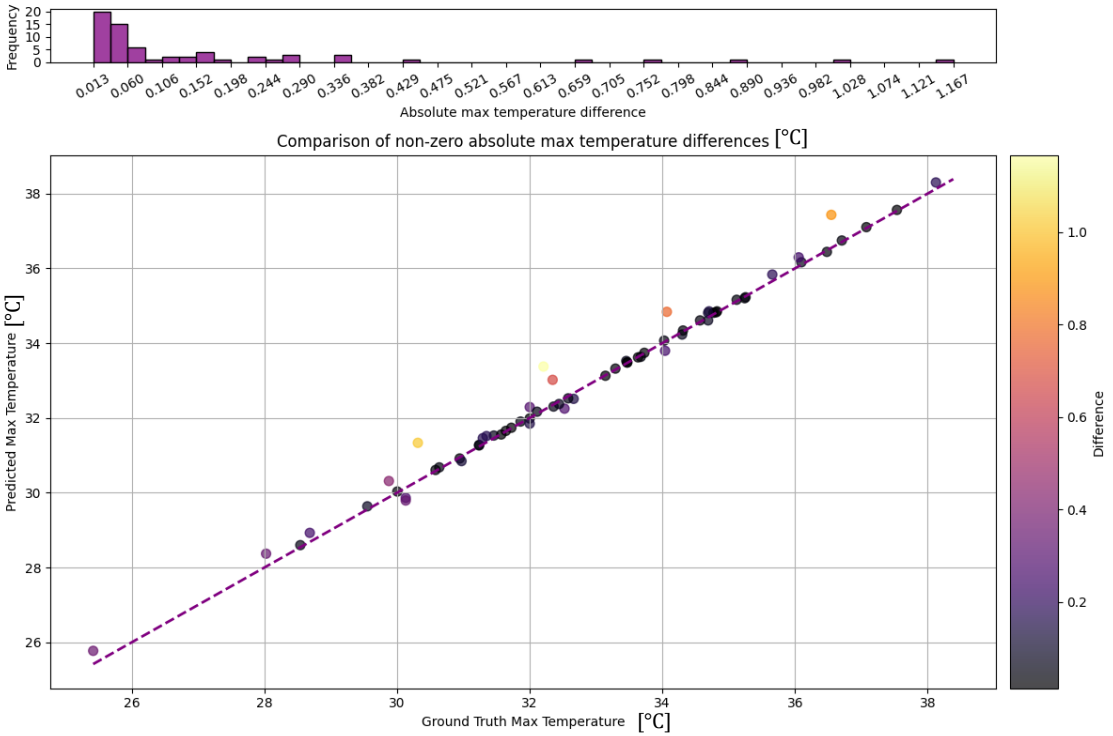


Three different areas can be distinguished

- (Green area). **True Positive**: The area of intersection between Ground Truth**(GT)** and segmentation mask(**S**)
- (Red area). **False Positive**: The predicted area outside the **Ground Truth(GT)**
- (Blue area). **False Negative**: Number of pixels in the **Ground Truth(GT)** area that the model failed to predict

Research activity: Discussion and Conclusions

A preliminary analysis carried out comparing the maximum temperatures of **Ground Truth** and **Predicted Masks** shows that the corresponding measurement results are highly correlated, with most of residuals with a value lower than 0.5 °C.



Future Steps

Obtained results highlighted the feasibility of the proposed method, thus taking the first step towards the development of a ***New Generation of Measurement Sensors and Instruments for PLF based on Artificial Intelligence Technology***.

Next goal will be to determine and evaluate the Sensitivity and Specificity of infrared thermography in detection of subclinical mastitis

Producs

[P1]	*Alessio Cotticelli, **Maria Teresa Verde**, Roberta Matera, Isabella Pividori, Alberto Prandi, Gianluca Neglia & Tanja Peric (2022) **Validation of a radioimmunoassay method for cortisol in buffalo milk whey. A preparatory step for future sensor technology**, Italian Journal of Animal Science, 21:1, 1622-1631, DOI: 10.1080/1828051X.2022.2147868*
[P2]	*Nadia Piscopo, Oscar Tamburis, Francesco Bonavolontà, **Maria Teresa Verde**, Maria Manno, Marianna Mancusi, Luigi Esposito, **"Assessing wild boar presence and activity in a monitoring specific area of Campania region using camera traps",** ACTA IMEKO, ISSN: 2221-870X, December 2023, Volume 12, Number 4, 1 – 5, DOI: https://doi.org/10.21014/actaimeko.v12i4.1617*
[P3]	***Maria Teresa Verde**, Pierluigi Guerriero, Francesco Bonavolonta, Leopoldo Angrisani, Francesco Lamonaca, Ioan Tudosa, Oscar Tamburis, Gianluca Neglia, **"A measurement system for enteric CH4 emissions monitoring from ruminants in livestock farming",** ACTA IMEKO, ISSN: 2221-870X, December 2023, Volume 12, Number 4, 1 – 6, DOI: https://doi.org/10.21014/actaimeko.v12i4.1618*
[P4]	*Alessio Cotticelli, **Maria Teresa Verde**, Annalisa Liccardo, Giorgio de Alteriis, Francesco Lamonaca, Roberta Matera, Gianluca Neglia, Tanja Peric, Alberto Prandi, Francesco Bonavolontà **"On the use of 3D camera to accurately measure volume and weight of dairy cow feed",** ACTA IMEKO, ISSN: 2221-870X, December 2023, Volume 12, Number 4, 1 – 6, DOI: https://doi.org/10.21014/actaimeko.v12i4.1633*
[P5]	***Maria Teresa Verde**, Francesco Bonavolontà, Annalisa Liccardo, Francesco Lamonaca, Emilio Di Stasio, Giampaolo Raimondi, "**A smart combination of IoT and blockchain enabling technologies to measure and improve workplace safety in dairy farm",** ACTA IMEKO, ISSN: 2221-870X, December 2023, Volume 12, Number 4, 1 – 7, DOI: https://doi.org/10.21014/actaimeko.v12i4.1634*

Producs

[P6]	***Maria Teresa Verde***, *Roberta Matera, Francesco Bonavolonta, Francesco Lamonaca, Leopoldo Angrisani, Concettina Fezza, Luca Borzacchiello, Alessio Cotticelli, Gianluca Neglia,* ***"Comparative performance analysis between two different generations of an automatic milking system",*** *ACTA IMEKO, ISSN: 2221-870X, December 2023, Volume 12, Number 4, 1 – 6, DOI: https://doi.org/10.21014/actaimeko.v12i4.1646*
[P7]	*Leopoldo Angrisani, Angela Salzano, Roberta Matera, Francesco Bonavolontà,* ***Maria Teresa Verde****, Nadia Piscopo, Domenico Vistocco, Oscar Tamburis,* ***"Reliable Use of Smart Cameras for Monitoring Biometric Parameters in Buffalo Precision Livestock Farming" ,*** *Accepted for pubblication and in Proofreding on Acta IMEKO.*

Conferences and seminars attended

I attended the **2023 IEEE International Workshop on Measurement and Applications in Veterinary and Animal Sciences,** where:

- I held tutorial **Innovative Technologies for a Buffalo Smart Farm**
- I was chair of the **Special Session #6:** *IOT-BASED INNOVATIVE TECHNOLOGIES FOR PRECISION LIVESTOCK FARMING*

Scientific Research interactions/relations with other Research Center, Institutions, and companies established

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National Center for Technology in Agriculture

Dipartimento Medicina Veterinaria Produzioni Animali

Finanziato dall'Unione europea
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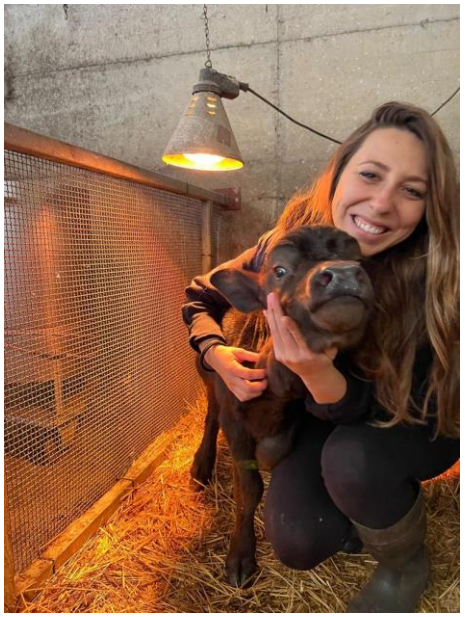

Research activity: Overview

Cortisol concentration

The assessment of cortisol concentration in biological samples is one of the main tools to evaluate the stress in animals.

The study on cortisol concentration has allowed to validate a reliable radioimmunoassay method to assess cortisol concentration in buffalo milk in order to provide a preliminary data for the calibration of future biosensing technologies for non-invasive assessment of cortisol to be integrated in milking parlour systems.

The results of the research are detailed in the following paper:

Validation of a radioimmunoassay method for cortisol in buffalo milk whey. A preparatory step for future sensor technology

Alessio Cotticelli, Maria Teresa Verde, Roberta Matera, **Isabella Pividori**, Alberto Prandi, Gianluca Neglia & Tanja Peric

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