PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Maria Teresa Verde

Cycle: XXXVII

Training and Research Activities Report

Academic year: 2022-23 - PhD Year: Second

Tutor: prof. Leopoldo Angrisani

Co-Tutor: Francesco Bonavolontà

Date: December 9, 2023

1. Information:

- **PhD student: Maria Teresa Verde**
- **DR number:**
- **Date of birth: 21th May 1991**
- **Master Science degree: Veterinary Medicine** **University: UNINA Federico II**
- **Doctoral Cycle: XXXVII**
- **Scholarship type:** ***PON Dottorati di ricerca su tematiche dell'innovazione e green - Azione IV.5 (Green)***
  - ***Period abroad goes from 1 October 2023 to 31 March 2024 (6 months), at the comany Castelluccia (CE) under supervisor Giuliano Cacciapuoti.***
  - ***number of months spent abroad in the current year: 3 months***
  - ***number of months to be spent abroad in the next year: 3 months***
- **Tutor: Leopoldo Angrisani**
- **Co-tutor: Francesco Bonavolonta'**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
"La termografia come strumento di precisione nell'allevamento degli animali da reddito."	Seminar	1	0.2	02/03/2022	ASPA, Commission e Precision Livestock Farming Dr. Fabio Abeni	Y
"Transdairy Living Lab's Open Day ICT & Bio Nanotechnology"	Seminar	7.5	1.5		Prof. Luigi Zeni	Y
Picariello Lectures on Data Science – II Cycle Ethics and Politics of A.I, Prof Mark Coekelbergh	Seminar	2	0.4	11/04/2022	Picariello Lectures on Data Science – II Cycle	Y
Picariello Lectures on Data Science – II Cycle Can a Text-to-Speech Engine Generate Human Sentiments?	Seminar	1	0.2	28/02/2022	Picariello Lectures on Data Science – II Cycle	Y
Protozoi Intestinali come ospiti sgraditi: Giardiasi e Trichmoniasi nella pratica clinic	Seminar	0.5	0.1	02/03/2022	INNOVET ITALIA Srl Tommaso Furlanello	Y
Elementi di Automazione e Introduzione al concetto di domotica. Smart Building e vantaggi del sistema nelle strutture ricettive. I sistemi di	Seminar	1	0.2	07/03/2022	Prof. Francesco Bonavolontà	Y

comunicazione e la connessione tra i dispositivi. Il concetto di attuatore e di cavo bus.						
Running towards Car Electrification, ST MICROELETRONICS	Seminar	2.5	0.5	16/05/2022	Salvatore Cannavacciuolo	Y
Artificial Intelligence @ The Deep Edge	Seminar	6	1.2	01/06/2022	UNINA, DIETI	Y
Augmented reality for remote use of measurement Instrumentation	Seminar	1.5	0.3	24/05/2022	5G ACADEMY	Y
Powe Electronics: control and architecture. A mini Campus.	Seminar	15	3	8/07/2022	STMICROELETRONICS	Y
Il futuro della medicina alla luce dell'applicazione dell'intelligenza artificiale e della robotica	Seminar	2.5	0.5	15/11/2022	Il Sabato delle idee	Y
Focus on di Ginecologia	Seminar	3	0.6	4/11/2022	SIVAR	Y
Piattaforme di misura e monitoraggio basate su Internet of Things.	Courses	30	6	28/04/2022	Corso di dottorato in Ingegneria Industriale "Federico II":	Y
Big Data Architecture and Analytics	Courses	16	5	29/06/2022	Proff. Giancarlo Sperlì, Giovanni Improta, Jari Haukka, Peter van Ooijen	Y
Sensori e Trasduttori di Misura	Courses	72	9	29/06/2022	MsD Electronic engineering	Y
Sensori e Smart Metering	Courses	72	9	20/06/2022	MsD Electronical engineering	Y
Intelligenza Artificiale	Courses	48	6	07/07/2022	MsD	Y
Smart clothes and wearable technology.	Seminar	2	0.4	30/1/2023	UNINA-ACCADEMIA DELLE BELLE ARTI DI NAPOLI	Y
Power and Analog electronics: Design, Control and Architecture	Seminar	15	3	4-5-6 LUGLIO 2023	STMICROELETRONICS, F.Pirozzi	Y

"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;.	Seminar	15	3	5/9/2023 al 7/9/2023	Istituto Zooprofilattico Sperimentale del Mezzogiorno (IZS)	Y
Kick-off meeting della Task 5.3.8 (Living Labs) - Spoke 5 AGRITECH, in modalità telematica (via piattaforma ZOOM).	Seminar	2	0.4	25/7/2023	Prof. Enrico Sturaro UNIPD Prof. Francesco Bonavolontà	Y
Misure su Sistemi Wireless	Courses	72	9	3/7/2023	Prof. Angrisani, A2	Y
Data Uncertainty	Courses	48	6	5/12/2023	Prof. Angrisani, A2	Y

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

Yr1	Courses	Seminars	Research	Tutorship	Total
Bimonth 1			**3**		**3**
Bimonth 2	**6**	**2.6**	**3**		**11.6**
Bimonth 3	**23**	**2**	**3**		**28**
Bimonth 4	**6**	**3**	**3**		**12**
Bimonth 5			**6**		**6**
Bimonth 6		**1.1**	**6**		**7.1**
Total	**35**	**8.7**	**24**		**67.7**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

Yr2	Courses	Seminars	Research	Tutorship	Total
Bimonth 1		**0,4**	**6**		**6.4**
Bimonth 2			**9**		**9**
Bimonth 3	**9**		**9**		**18**
Bimonth 4		**3.4**	**9**		**12.4**
Bimonth 5	**6**	**3**	**9**		**18**

Bimonth 6		**1.5**	**3**		**4.5**
Total	**15**	**8.3**	**45**		**68.3**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

Total Yr1	**35**	**8.7**	**24**		**67.7**
Total Yr2	**15**	**8.3**	**45**		**68.3**
Total	**50**	**17**	**69**		**136**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

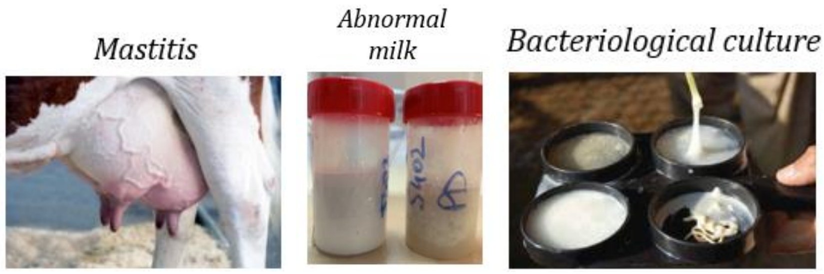
Describe the topic, methodology and results of the research carried out in the current year

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:

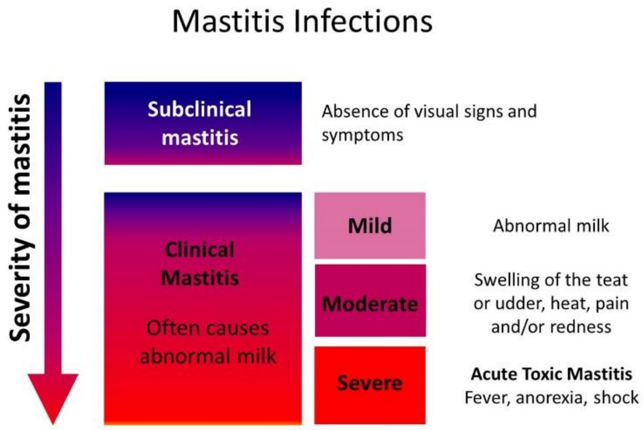
- quantity and quality of animal production;
- animal welfare conditions;
- environmental sustainability (reduction of methane and ammonia emissions)

by means the use of new frontiers in livestock management and engineering technologies.
My research activity focused overall on the creation diagnostic tools that can 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.
One of the most frequent problems affecting 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:

- Somatic cell counts (significant relationship between somatic cell count in collected milk samples and severity of Mastits);
- Bacteriological culture.



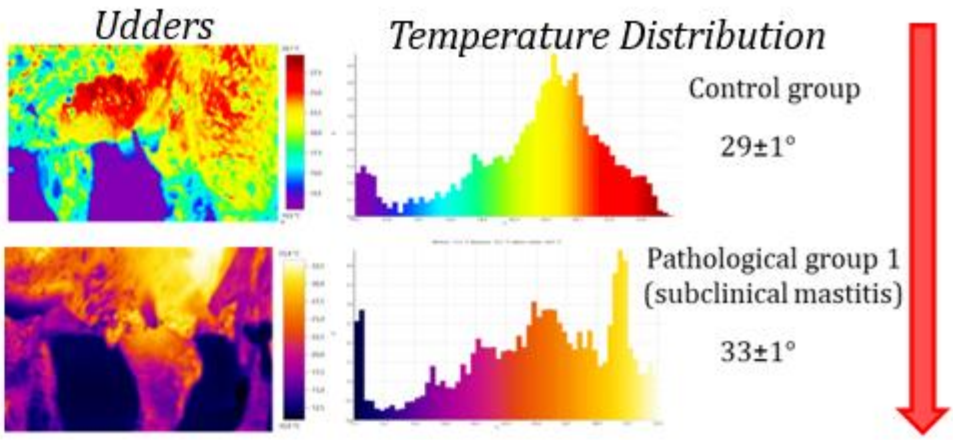
They are slow and expensive. Moreover, they are effective in diagnosing clinical mastits, detected too late, when milk is abnormal and animal health compromised.
To reduce their negative impact, it is important to detect mastitis early, even in the absence of visual signs and symptoms.



To this aim, by considering that udder skin surface temperature increases at the onset of inflammation, 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)

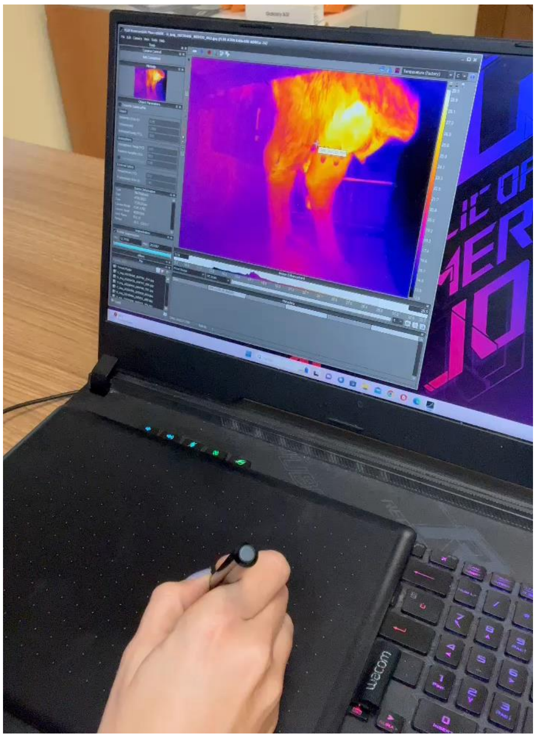
As well as for somatic cell count in collected milk samples, the udder surface temperature increases with the severity of inflammation.



However, some areas near udder of dairy buffalo, such as the high-temperature areas of the buffalo's abdomen, cleavage, and inner thigh, may lead to inaccurate target detection, resulting in errors in temperature extraction and affecting the accuracy of dairy buffalo mastitis detection.

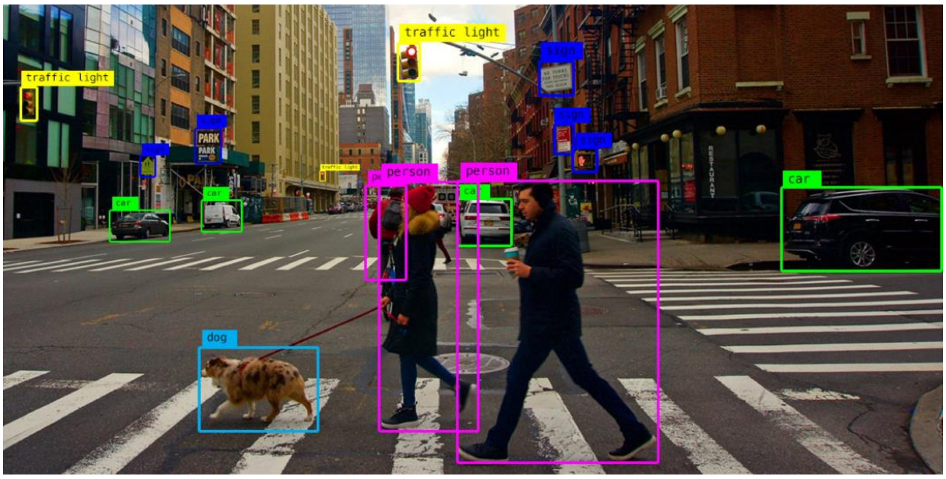
Therefore, for each thermal image to be analyzed, a Region of Interest (ROI) coincident with the udder, from which to carry out extract temperatures, must be set up.

This operation, since no predefined ROI is available for the udder, must be performed freehand (as example by means a graphics tablet, as shown in the videos below) and is therefore time-consuming. Moreover, its accuracy depends heavily on the operator ability.

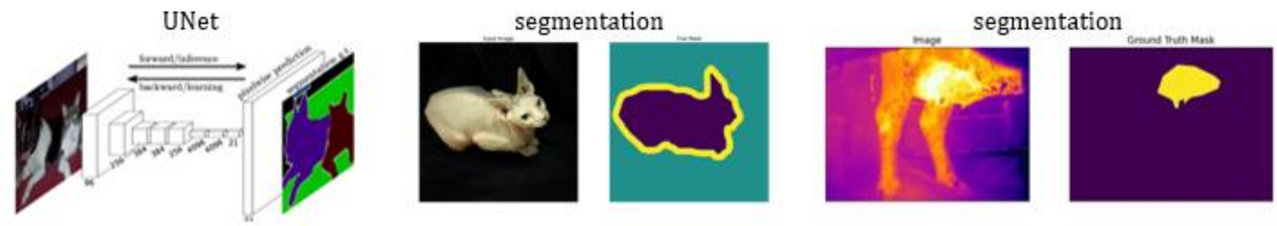


The limited automation of these method makes its unsuitable for the large-scale practical needs of detecting mastitis in dairy buffalo.

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.

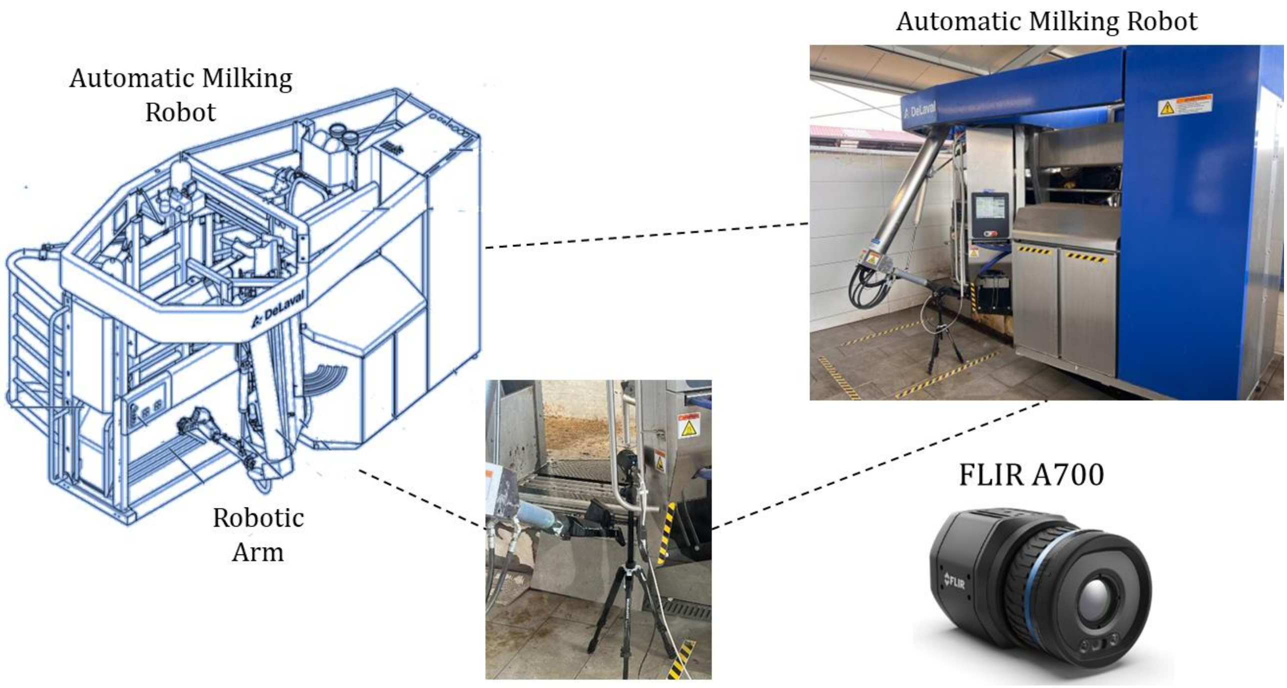


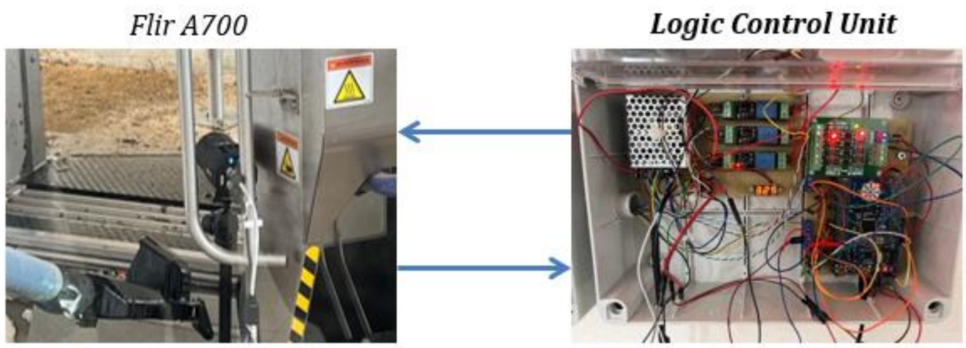
We proposed a UNet model to achieve the accurate automatic segmentation of buffalo udder to solve the above problems and further promote the detection accuracy of buffalo mastitis.



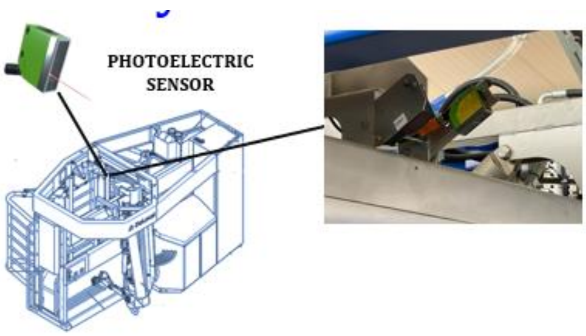
Firstly, a dataset of udders thermal images was constructed, thanks to an Automated Data Acquisition System consist of:

1. ***Fixed Infrared Cameras (FLIR A700),*** *located on the rear side of the milking robot;*
2. *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.*

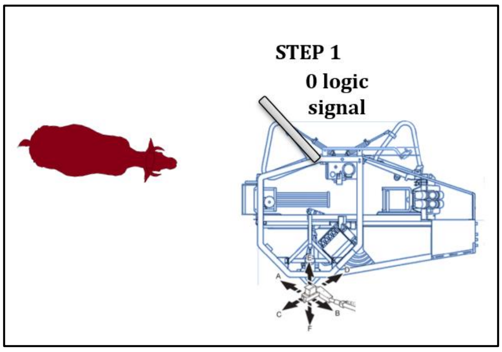


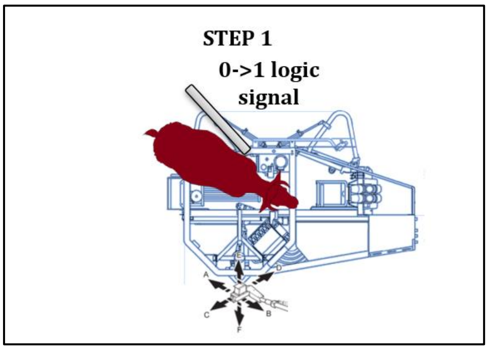


First, to take a picture we have to know when the Buffalo is in the robot. Thanks to a **Photoelectric Sensors**, installed on the top of the milking robot, the **Control Unit** can detect when a new Buffalo enters or leaves the robot (after milking).

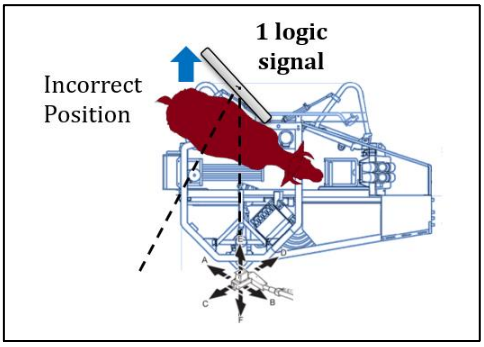


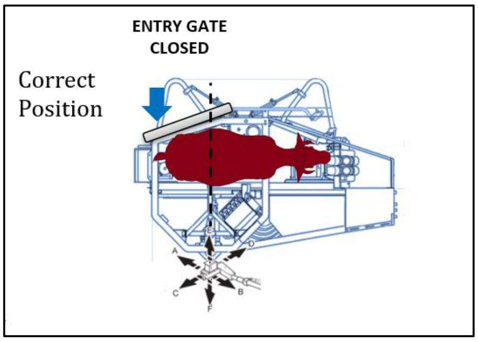
When a Buffalo enters the robot, the **Photoelectric sensors output** switch from: **LOW-SIGNAL** (0 logic) to **HIGH-SIGNAL (1 logic)**





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 attack the milking cluster and began milking routine.

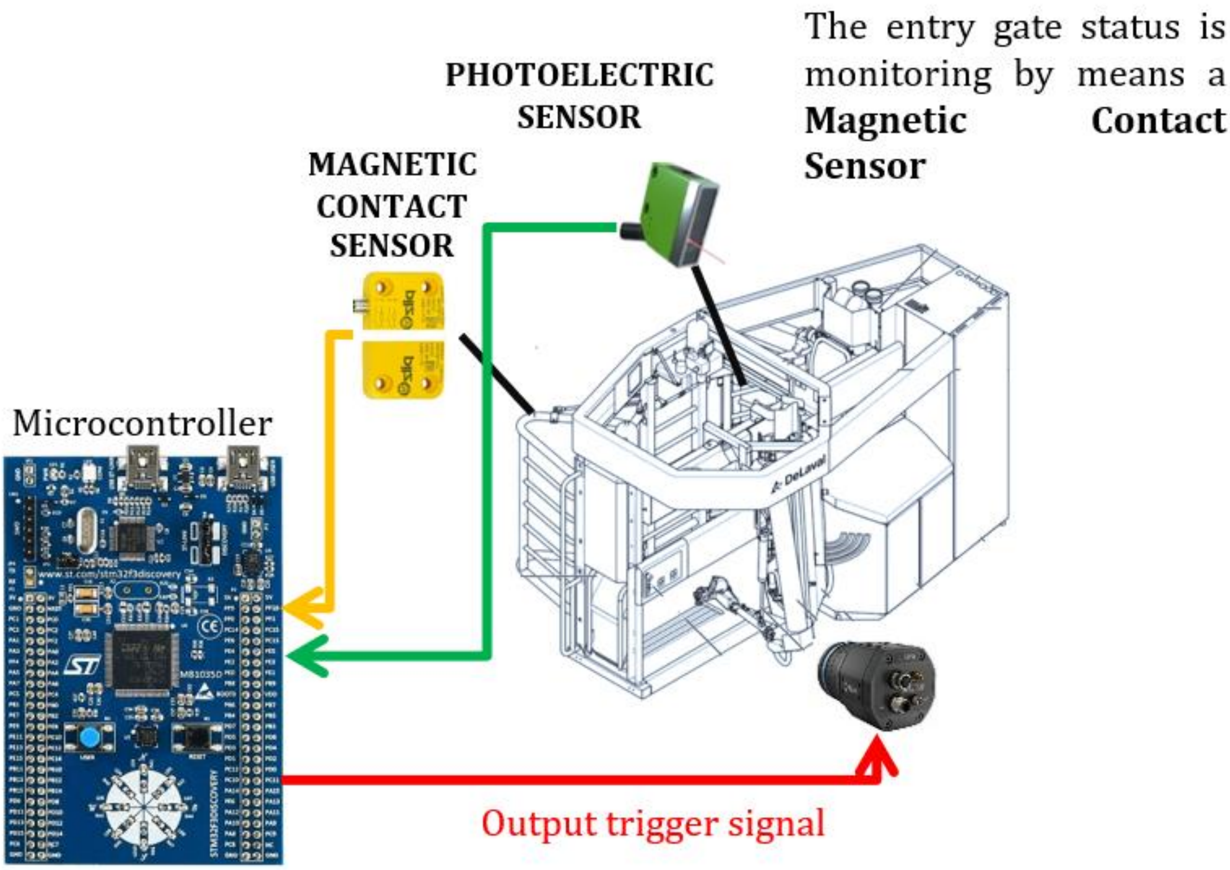
The buffalo, before assuming a correct position and allowing the entry gate to close, can take several time, even minutes.

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.

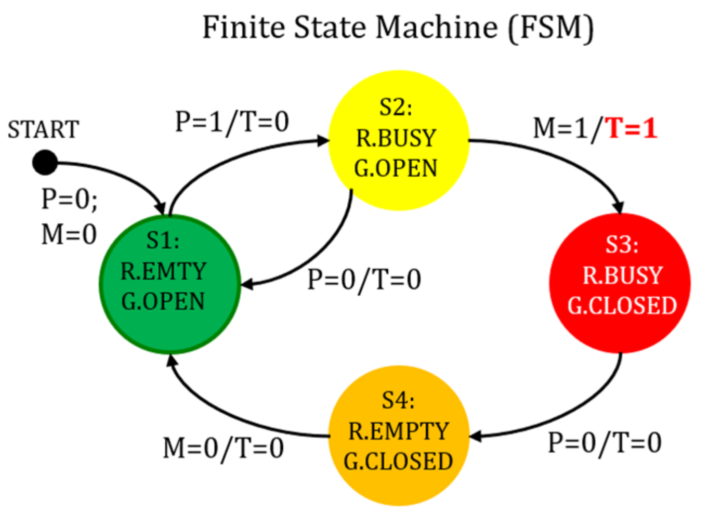
In the next photos, an example at the **correct** and incorrect **point** of trigger is shown.

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

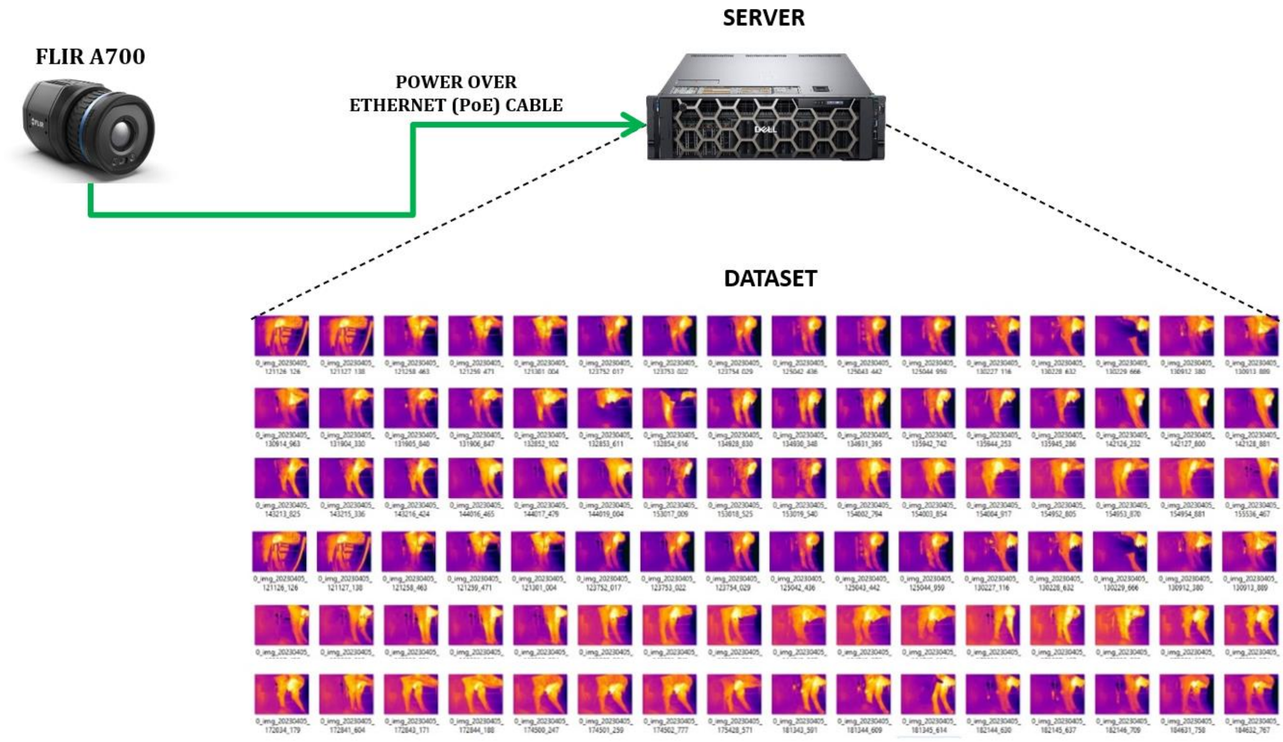
The heart of the Automatic Data Acquisition System (ADAS) is the Control Unit, consists of a Microcontroller.



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.



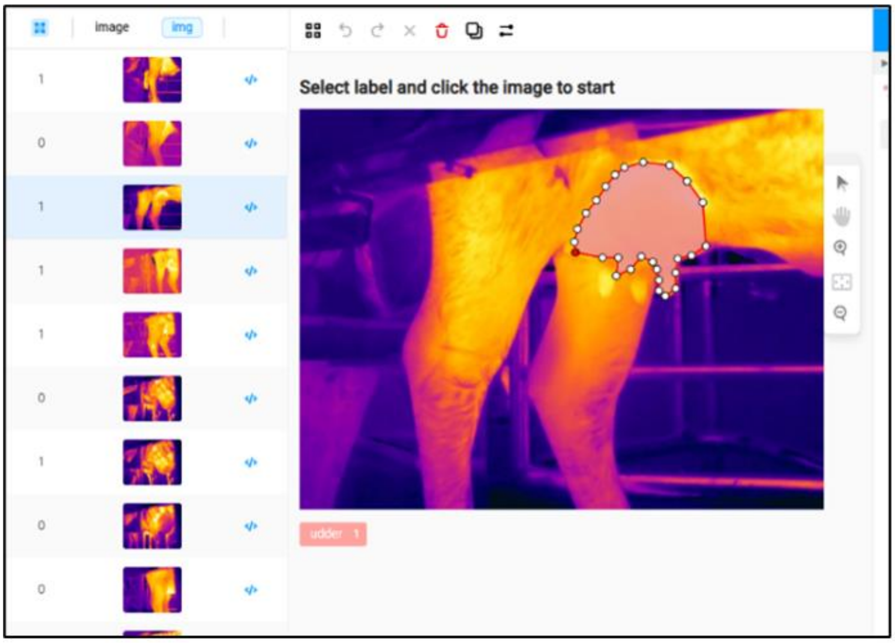
The thermal cameras is powered via a power over ethernet and are configured to send the image taken each time to the local server with File Transfer Protocol (FTP) protocol where they are historicized and processed.



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.

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

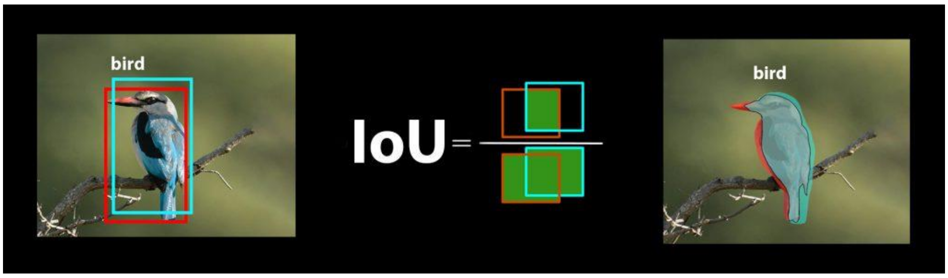
Using open-source software "*LabelStudio*", annotator experts in veterinary medicine performed segmentation of udders with polygonal masks.



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

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.

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

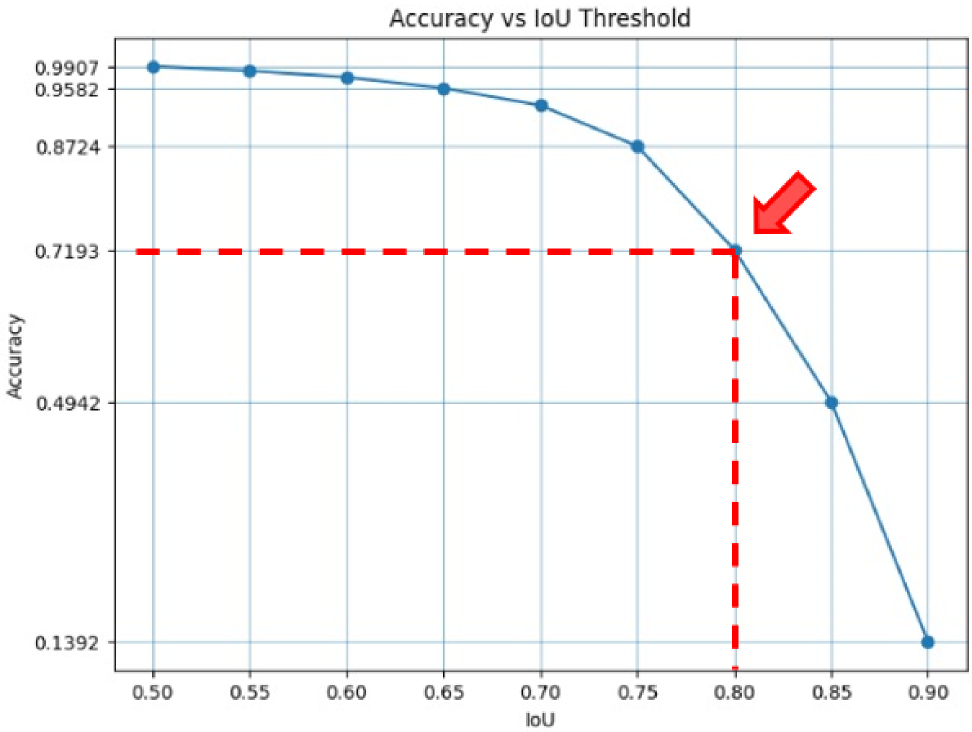


In the case of Image Segmentation, the area is not necessarily rectangular. It can have any regular or irregular shape. That means the predictions are segmentation masks and not bounding boxes.

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.

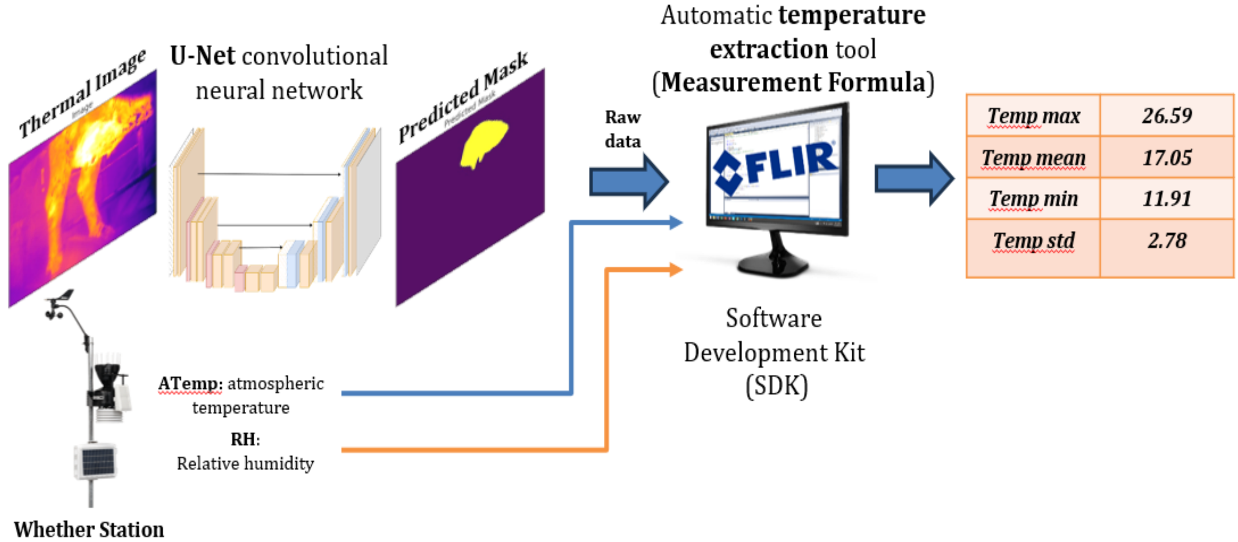
Model's performance was evaluated using different IoU thresholds. The Graph below shows Accuracy Vs. IoU Threshold.

Fixed a certain IoU threshold **X**, a predicted box must have an IoU of at least **X** with a ground truth box to be considered a true positive detection.



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.

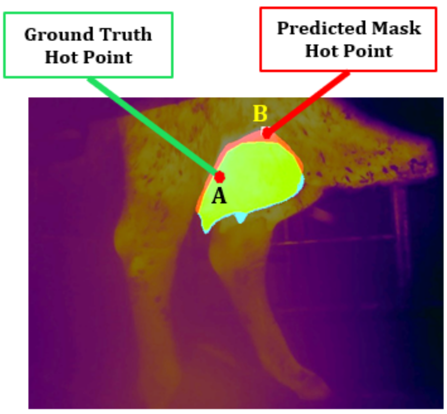
Once the neural model has predicted the mask, raw data are converted to temperature using a **Measurement Formula**, which takes also Atmospheric Temperature (**ATemp**) and Relative Humidity (**RH**) as input parameters, to provide more accurate and precise values.



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"***.

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.

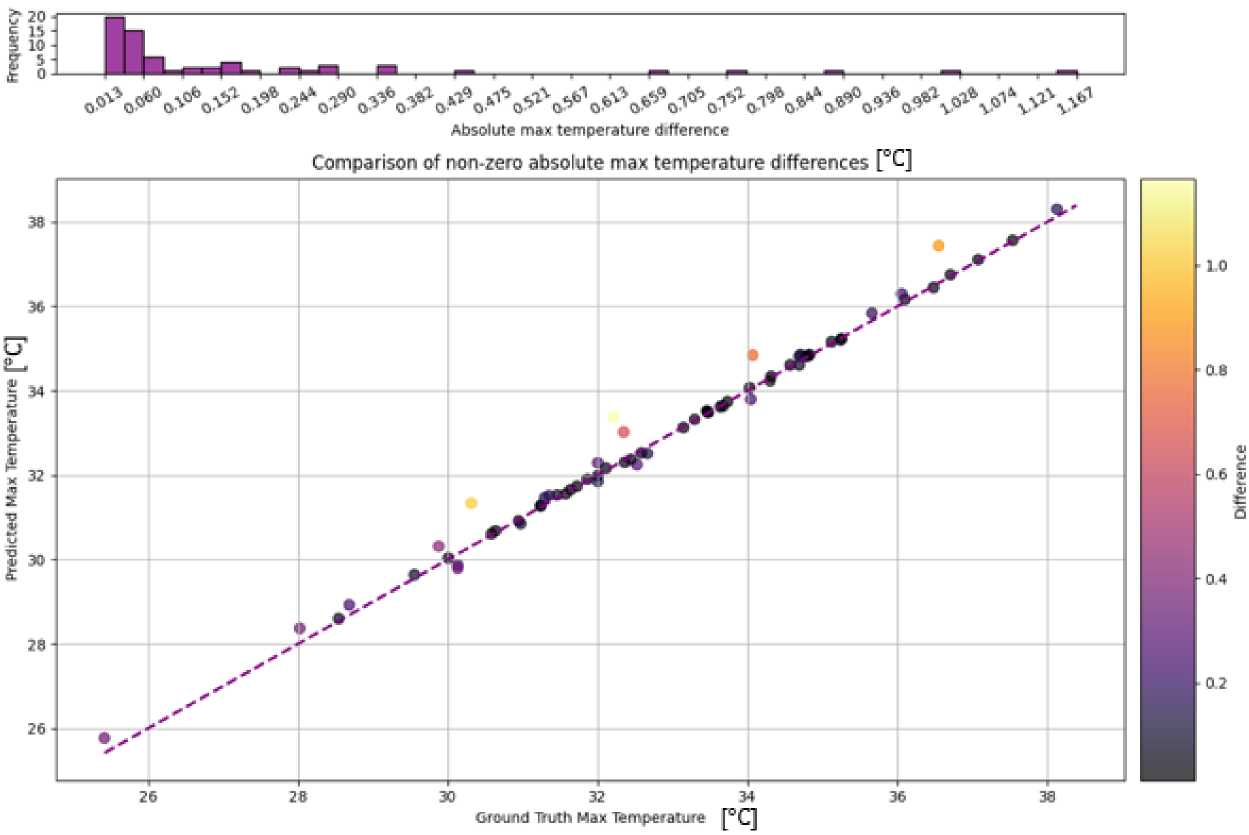
As shown in the image, even with **high IoU** values, **Ground Truth** and **Predicted Mask** can determine different **hot points,** which can lead to an incorrect assessment of subclinical mastitis. There is therefore an uncertainty in the application of the method which must be appropriately evaluated.



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

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.



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.

4. Research products:

List the products of your research in the current year (e.g., scientific papers, prototypes, etc.)
For papers, list: author(s), journal or conference full name, acronym, current status (submitted, accepted, published), year of publication. Specify if the publication venue is indexed in Scopus and/or ISI Web of Science.
List also awards, such as best paper awards, best presentations awards, best student paper awards, best tool prizes, student contests prizes, etc. (if any).
List here also participations to tool fairs, student contests, etc. (if any).

1. *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

2. ***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*

3. *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*

4. ***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*

5. ***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*

6. *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"*** *in proofreding on Acta IMEKO.*

5. Conferences and seminars attended

List the conferences/workshops/tutorials you attended, providing their details (full conference name, acronym, place, dates); specify if you presented a paper

I attended the 2023 IEEE International Workshop on Measurement and Applications in Veterinary and Animal Sciences, APRIL 26 - 28, 2023, NAPLES, ITALYwhere:
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

6. Periods abroad and/or in international research institutions

Describe the study and research periods (exact dates), the hosting institution(s) and supervisor(s), and the activities carried out abroad, and the framework of the scientific co-operation with the hosting institution

Construction of the "ultimate" model of an innovative system for monitoring animal welfare and precision livestock farming by exploiting data processing of the field trial. Validation on field of the infrared thermography in detection of subclinical mastitis. ***Period abroad goes from 1 October 2023 to 31 March 2024 (6 months), at the comany Castelluccia (CE) under supervisor Giuliano Cacciapuoti.***

At the end, provide the number of months spent abroad in the current year: 3 months

7. Tutorship

List the tutorship activities (including nr of hours) for undergraduate or graduate (ONLY activities authorized by the ITEE Board and by the related BSc or Msc Program Committee)

8. Plan for year three

Describe the activities planned for the third PhD year, including (but not limited to):

- *Research activities (research topics, national and/or international collaborations, projects, experiments, case studies,* ***…) Collaboration with AGRITECH, National Center for Technology in Agriculture***
- *Research periods abroad :* ***Azienda Agricola Castelluccia from 1 Oct. 2023 to 31 March 2024 (6 months)***
- *Courses for tutorship activities*
- *Draft topic or title of the thesis :* ***New Generation of Measurement Sensors and Instruments for Precision Livestock Farming based on Artificial Intelligence Technology***
- *…*