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**ICAR & INTERBULL  
MAY 19-24, 2024  
SLOVENIA**



**Advancements in combining electronic  
animal identification and augmented reality  
technologies in digital livestock farming**

**Giuseppe Todde**

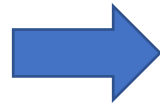
*Department of Agricultural Sciences, University of Sassari, Italy*

**ICAR Session 4: Value Adding to Electronic Identification**

# Realities at a Glance

## AUGMENTED REALITY (AR)

Real world with digital information overlay

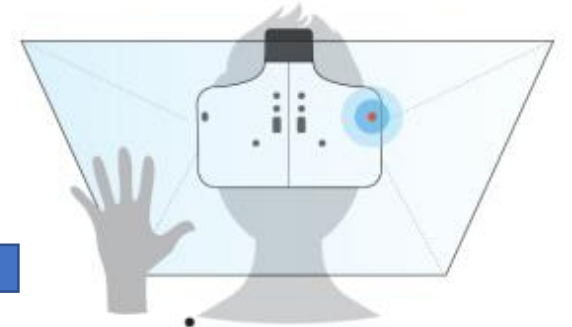
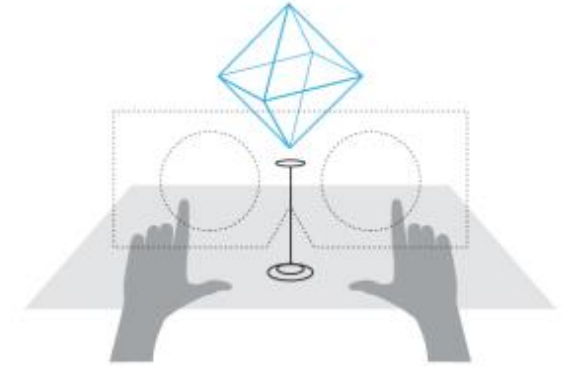


Real world remains central to the experience, enhanced by virtual details.

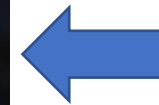


## MERGED REALITY (MR)

Real and the virtual are intertwined



Interaction with and manipulation of both the physical and virtual environment.



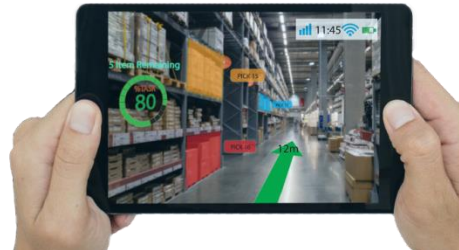
# Augmented Reality Devices

Hand-held

Smartphone



Tablet



Wearable

Smart Glasses



# The Rise and Challenges of Augmented Reality Glasses

The first Smart Glasses marketed on the general public was the Google Glass in May 2014

## Consumer Application

Google Glass V1



## Professional Application



# Augmented and Mixed Reality Devices

## Augmented Reality

Epson Moverio Bt-300



ODG-R9



Optical  
See-through

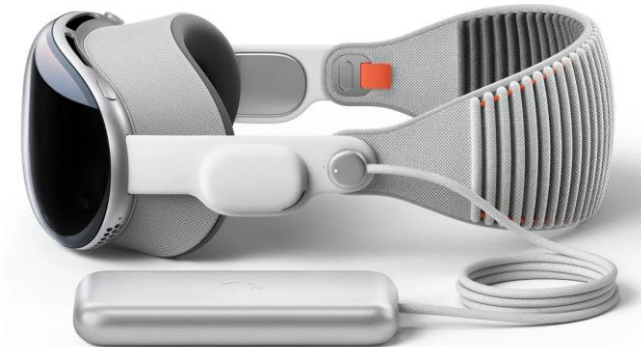
Video  
See-through

## Merged Reality

Microsoft HoloLens 2



Apple Vision Pro



# How Augmented Reality Works

## Tracking and registration

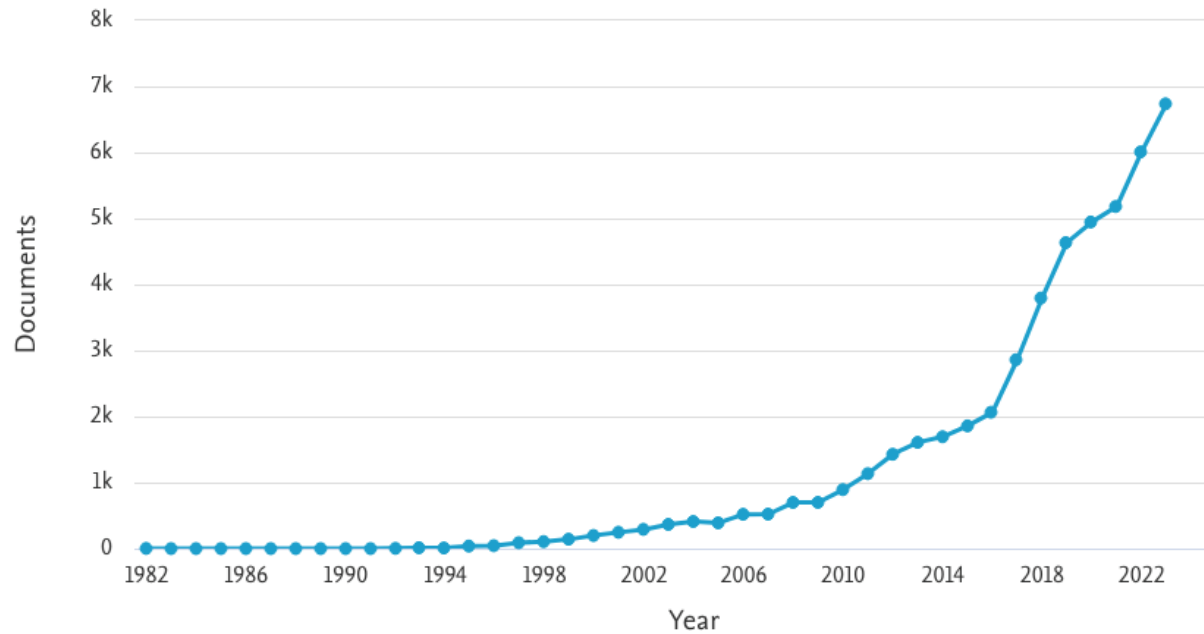
**Marker-based**  
(Video-based)

**Marker-less**  
(Sensor-Based)

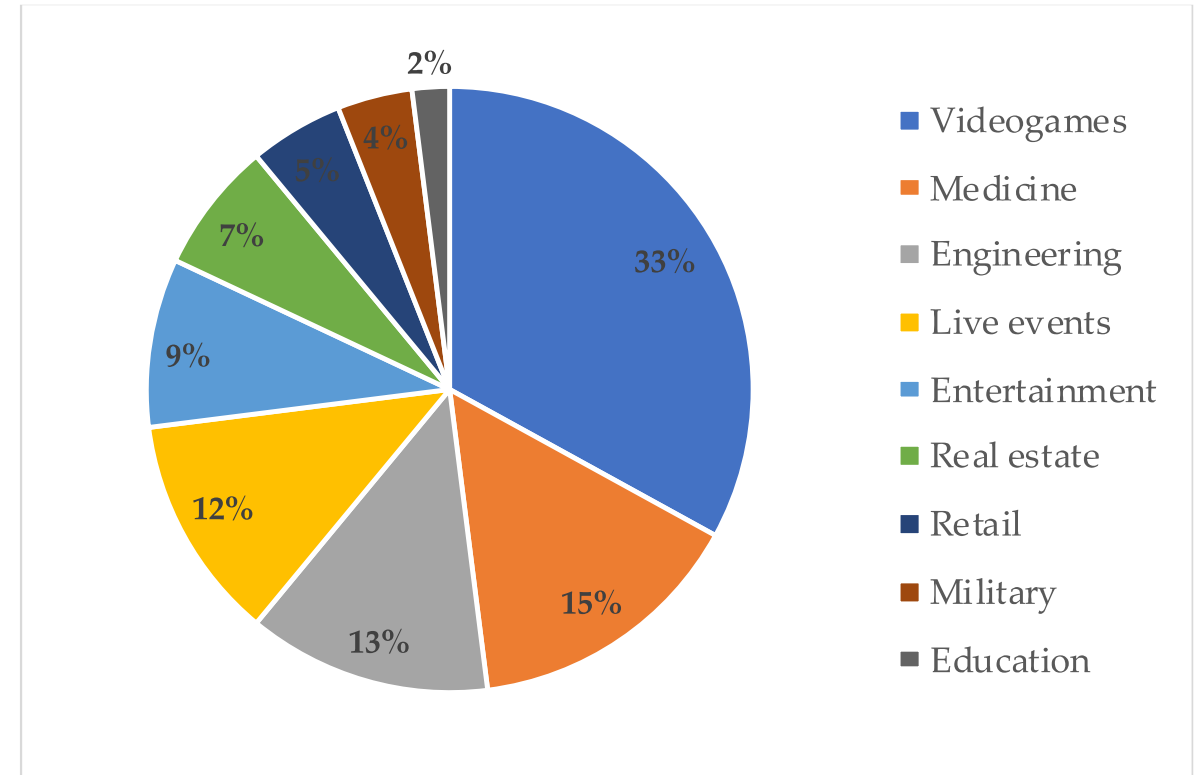


# Interest and Application of Augmented Reality

Documents by year



Growing interest in “Augmented Reality” documents from 2000 (195) to 2023 (6737)



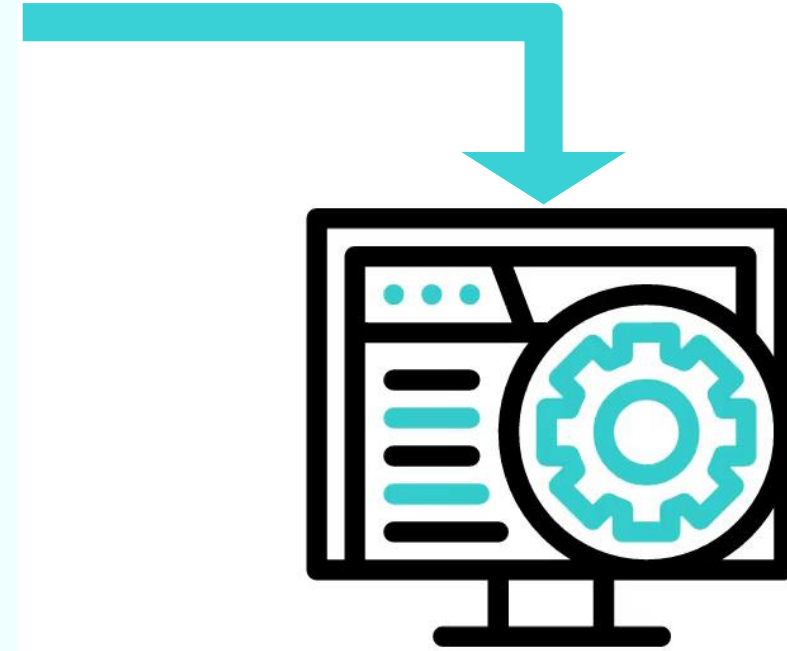
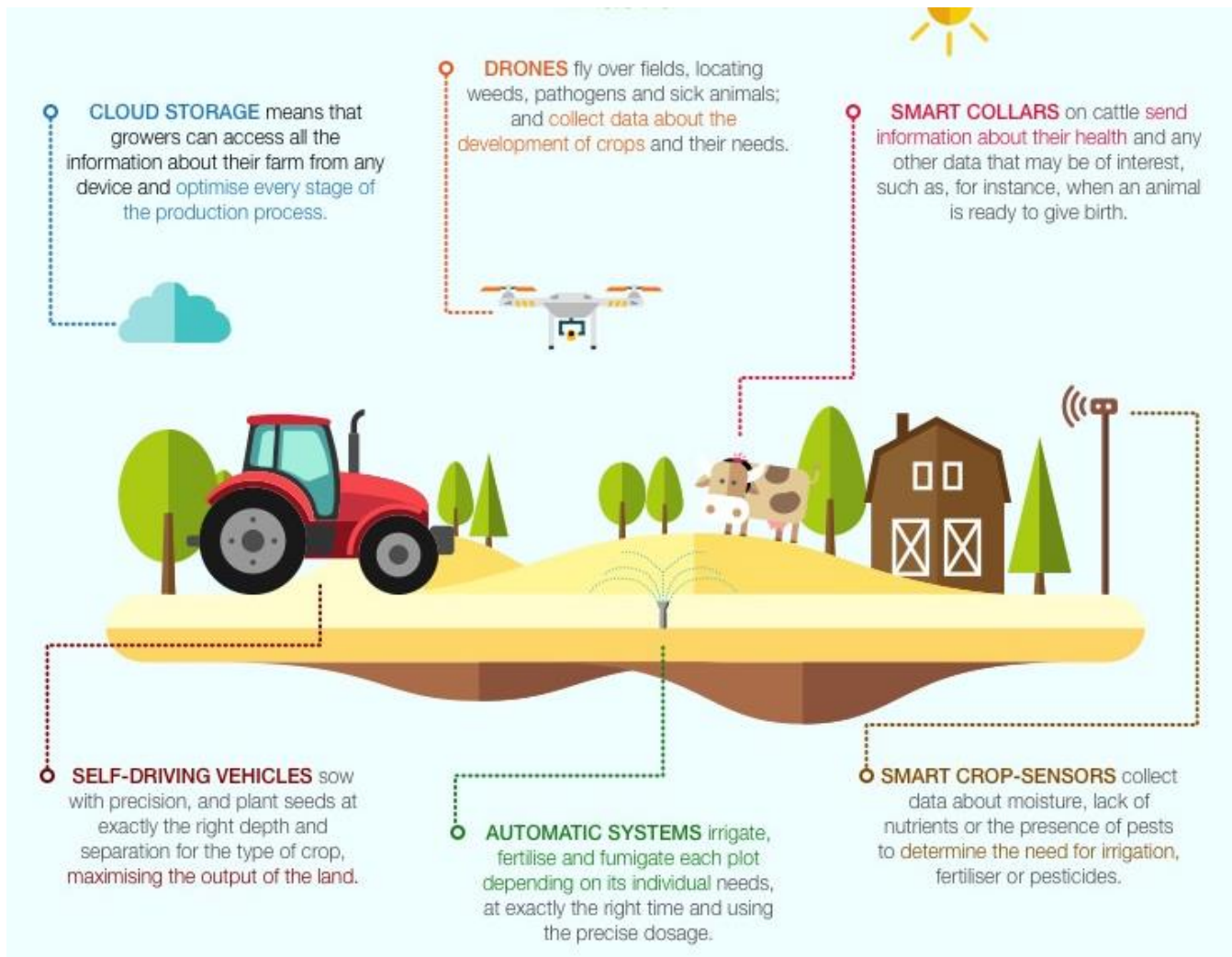
**Main fields:** Gaming, Healthcare, Engineering

What about applications in agriculture and livestock farming?



# Precision Livestock Farming Technologies and Data

Modern livestock farms are increasingly equipped with digital technologies



Large amount of farm data



# Consultation and Access to Data



**Data consultation is a time-consuming activity for farmers**



**Most of this information is not available in the field**

# Research Questions



Can mixed and augmented reality be profitably implemented in livestock farming?



Which could be the smart glasses utility in farm management considering the available functions?



What type of smart glasses is best suited to be integrated into the activities of a farm?



How can we effectively integrate individual animal data with augmented reality devices?



# Challenges in the Livestock Farming



Problems with **available space, dimensions** and QR code holder

Problems of dirt, **damage** and **loss** of the QR code

QR Codes are **not officially recognized** as a system for the identification of animals

# Livestock Electronic Identification

In the European Union, electronic identification of sheep, goats and cattle has been mandatory

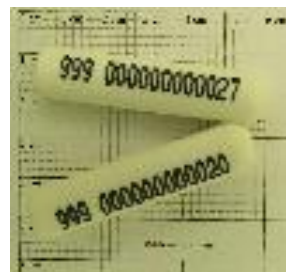
Ear tags



Collars



Rumen bolus



Pedometers





# From Dream to Reality

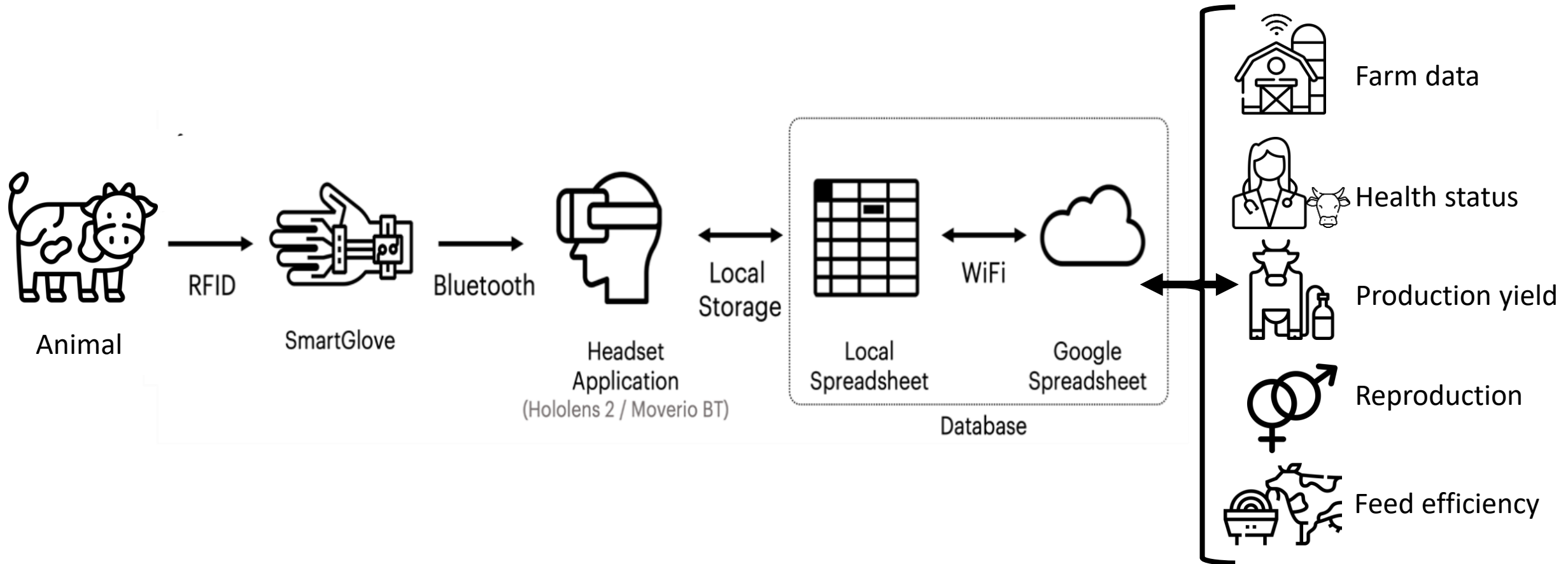


# The Research Goals

Develop and evaluate a wearable RFID reader to display, in real time, individual animal information on Smart Glasses for Augmented and Mixed Reality



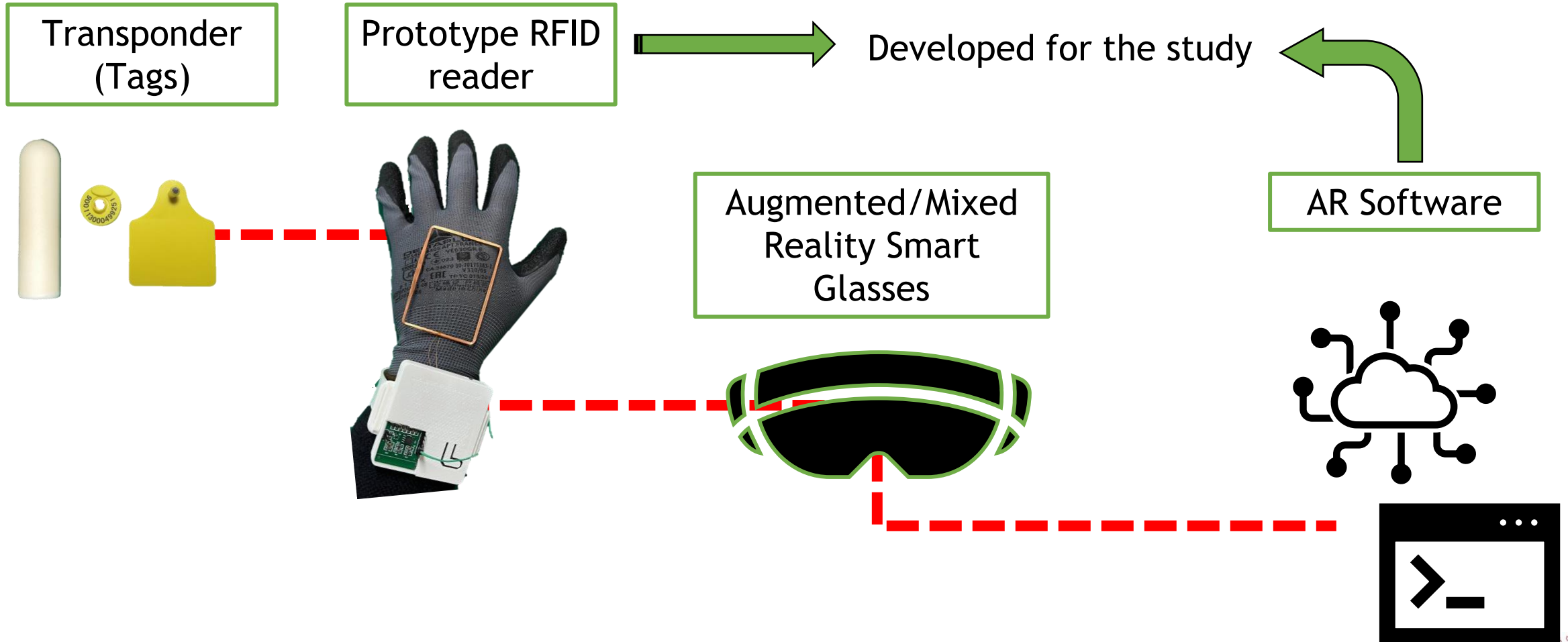
# The SmartGlove Idea





# The SmartGlove Development

The Architecture of the SmartGlove system





# The Smart Glasses Tested

## Epson Moverio BT-300

GPS, WiFi,  
Bluetooth

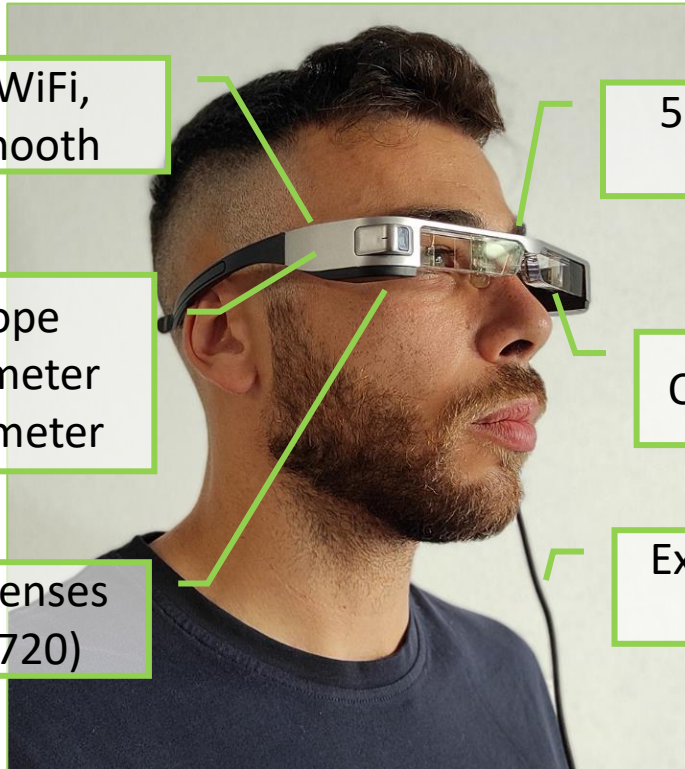
Gyroscope  
Accelerometer  
Magnetometer

Si-Oled lenses  
(1280x720)

5 Megapixels  
camera

OS: Android 5.1

External touch-  
pad



Optical Binocular **Augmented Reality**

## Microsoft HoloLens2

Head and eye  
tracking

GPS, WiFi,  
Bluetooth

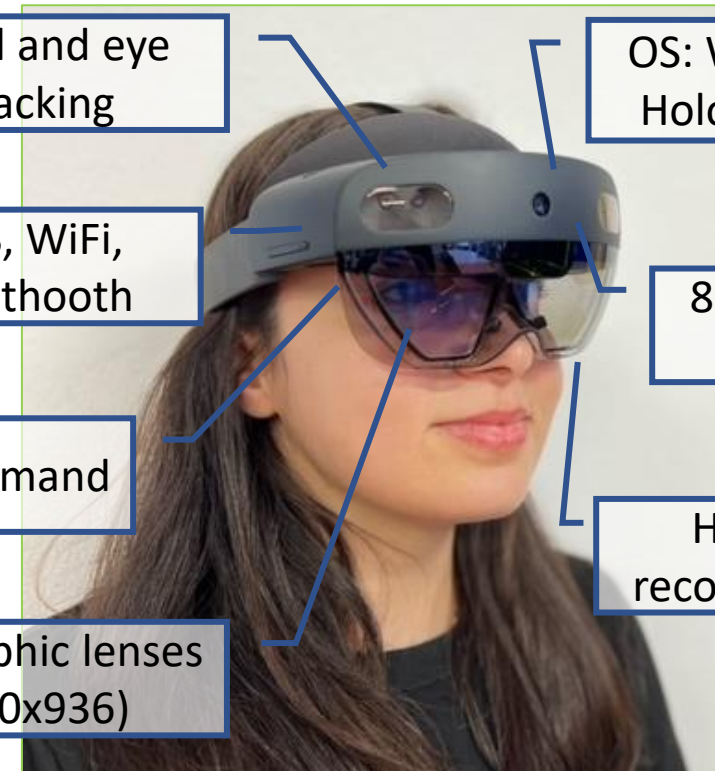
Voice command

Holographic lenses  
(1440x936)

OS: Windows  
Holographic

8 Megapixel  
camera

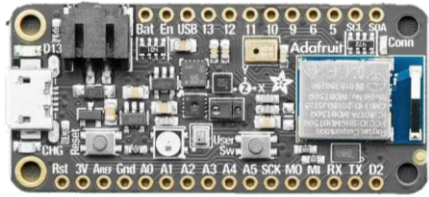
Hand  
recognition



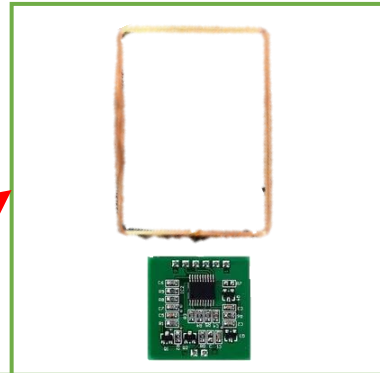
Optical Binocular **Mixed Reality**

# Hardware development

(TECHNOLOGY READINESS LEVEL 3)



Microcontroller



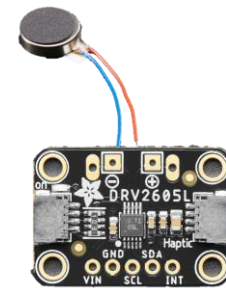
Antenna - Reader FDX-B



Li-Ion Battery - 3.7V 2000mAh



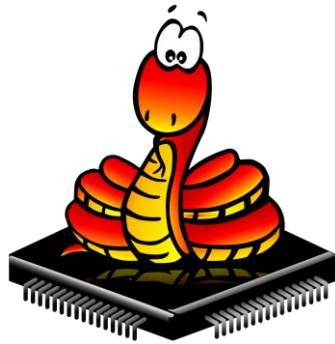
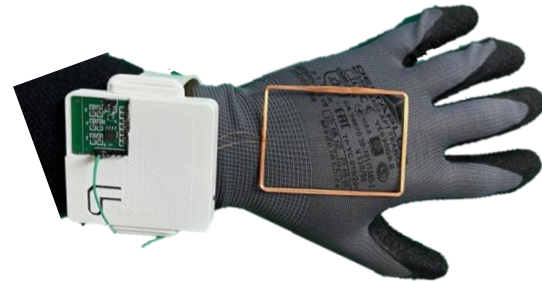
3D printed case



Haptic Motor Controller -  
Vibrating Mini Motor Disc

# Software development

Smart Glove  
Software

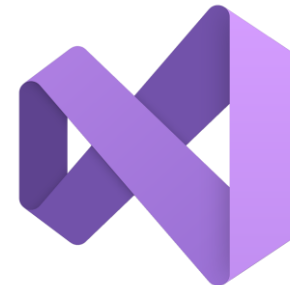


MicroPython

Android Software



Microsoft Software



Visual Studio 2022

Animals  
information

	A	B	C	D	E	F	G	H	I	J
1	CodiceAnimale	Tag	Gruppo	Nome	UltimoParto	Anni	Prodlett	ProdSetScore	NumeroPart	Mastit
2	46412400281	B			14/07/2021	5	1.5	10.5	3	N
3	46412400282	A			21/07/2021	3	1.2	8.4	1	N
4	46412400283	B			13/07/2021	3	1.4	9.8	3	P
5	46412400284	A			15/07/2021	4	1.2	8.4	2	N
6	46412400285	B			29/07/2021	5	1.6	11.2	3	N
7	46412400286	A			18/07/2021	3	1.4	9.8	1	N
8	46412400287	B			14/07/2021	3	2.28	16.15	1	N
9	46412400288	A			09/07/2021	4	1.96	11.25	2	N
10	46412400289	B			22/07/2021	4	1.15	8.05	2	N
11	46412400290	A			19/07/2021	4	1.5	10.8	2	N
12	90002333850	A			14/07/2021	3	1.5	10.5	3	N
13	90002333851	B			21/07/2021	4	1.5	10.5	1	N
14	90002333852	A			13/07/2021	5	1.2	8.4	1	N
15	90002333853	B			15/07/2021	3	1.4	9.8	2	N
16	90002333854	A			29/07/2021	3	1.2	8.4	3	N
17	90002333855	A			18/07/2021	4	1.6	11.2	1	N
18	90002333856	B			14/07/2021	5	1.4	9.8	1	N
19	90002333857	A			09/07/2021	3	2.28	16.15	2	N
20	90002333858	B			22/07/2021	3	1.96	11.25	2	N
21	90002333859	A			19/07/2021	4	1.15	8.05	2	P
22	90002333860	A			14/07/2021	4	1.5	10.8	3	N
23	90002333861	B			21/07/2021	4	1.5	10.5	1	P
24	90002333862	A			13/07/2021	3	1.5	10.5	1	N
25	90002333863	B			15/07/2021	4	1.2	8.4	2	N
26	90002333864	A			29/07/2021	5	1.4	9.8	3	N
27	90002333865	A			18/07/2021	3	1.2	8.4	1	N
28	90002333866	B			14/07/2021	3	1.6	11.2	1	N
29	90002333867	A			09/07/2021	4	1.4	9.8	2	N
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31	90002333869	A			19/07/2021	3	1.56	11.25	2	N
32	90002333870	A			14/07/2021	3	1.15	8.05	3	N
33	90002333871	B			21/07/2021	4	1.5	10.8	1	N
34	90002333872	A			13/07/2021	4	1.5	10.5	1	N



Google Sheets

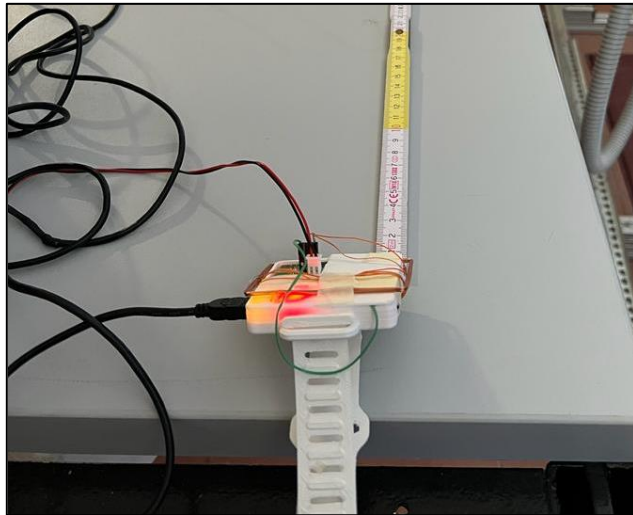


# Electronic Animal Identification and Augmented Reality Trials



Laboratory tests

Smart Glove reading performances



Rumen Bolus

Ear Tag

- Activation distance
- Reading time



In vivo trials

Augmented VS Mixed reality system



- Reading RFID + sheep grouping information (A or B)
- Task completion time, identification error



# Mixed Reality Glasses



# SmartGlove MR output

Animal ID

Connesso a CIRCUITPY9485

Connettiti

Aggiorna Database

CodiceAnimale	Gruppo	UltimoParto	Anni	Prodleri	ProdSettScorsa	NumeroParti
46412400282	A	21/07/2021	3	1.2	8.4	1

Parametri

Database update

Connection status

Animal data

Parameters setting

The operator can visualize information of a specific animal in real-time while working hands-free

# SmartGlove On-Field Tests



In vivo trials (dairy sheep) **Augmented** VS **Mixed** reality system





# Laboratory Operating Tests



Distance (cm)	Ear Tag (%)	Rumen bolus (%)
50	0	0
20	0	0
10	0	0
5	5	25
4	10	15
3	70	60
2	100	75
1	100	100



# On-Field Trials

In vivo trials **Augmented** VS **Mixed** Reality systems

Reading process

	BT300	HoloLens2
Overall Mean (s)	79.5	84.0
Standard Deviation	32.7	35.8
For one sheep (s)	16.2	17.3
User Error (%)	0	5.6



# Take-~~home~~<sup>farm</sup> message



The study focused on developing the **SmartGlove**, an integration of wearable **RFID** reader technology with **Smart Glasses** for **augmented/mixed reality**



The **SmartGlove** aimed to enhance electronic identification of livestock animals through **RFID tags** and provide **real-time** access to **individual information**



Lab and on-field tests demonstrated **promising performances**. This advancement showed the potential of the **SmartGlove** for practical use in livestock farms



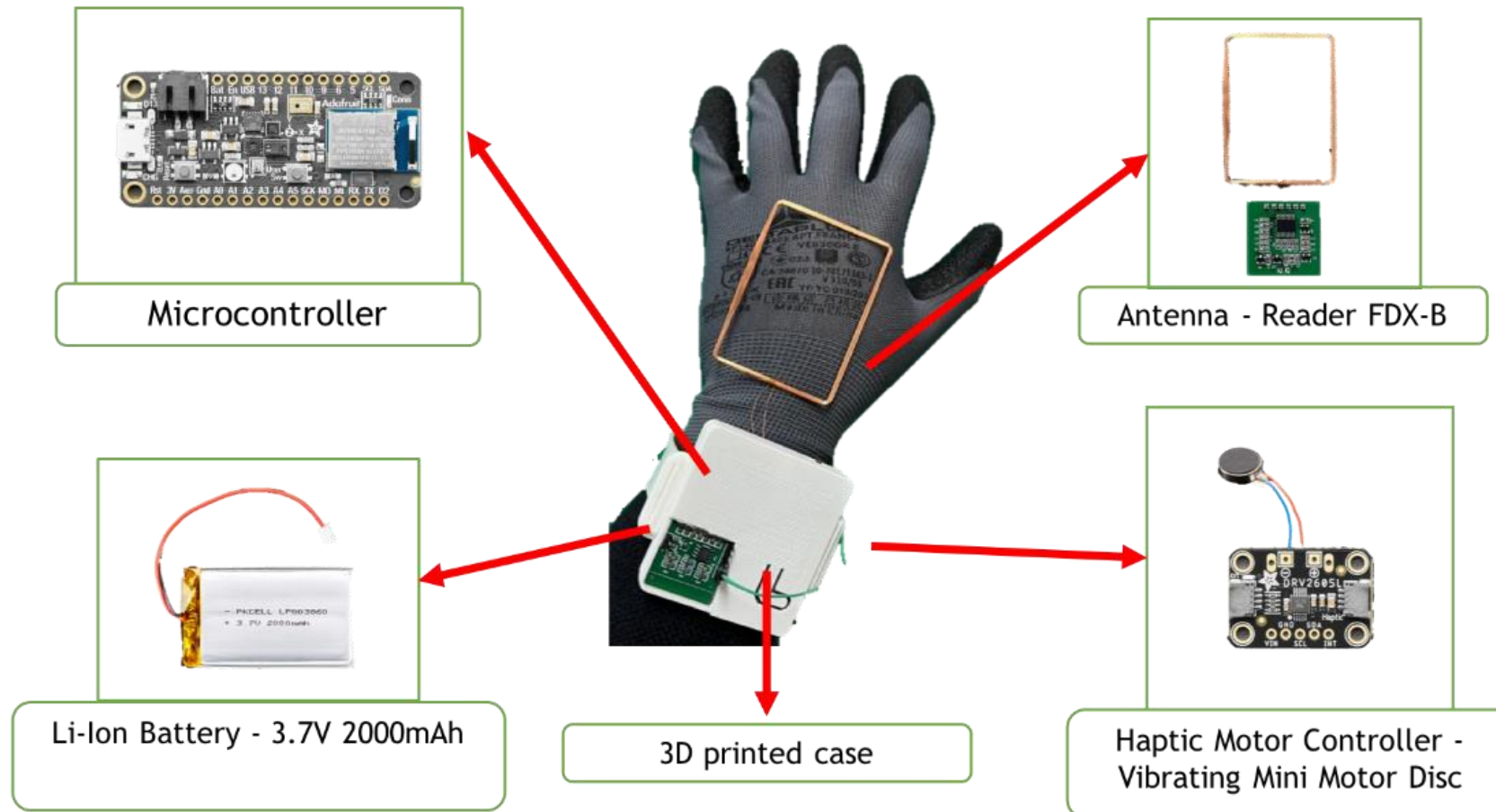
The **SmartGlove** system shows promise but requires further enhancements to move beyond the **prototype phase**. Future works are needed



To **boost the adoption** of this technology in the **agricultural and livestock domain**, **internet access in rural areas** must be strongly improved

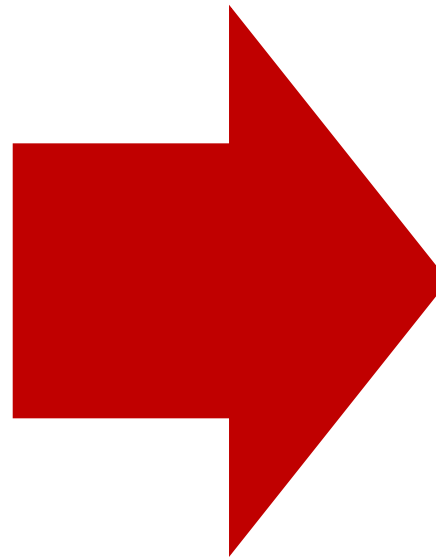
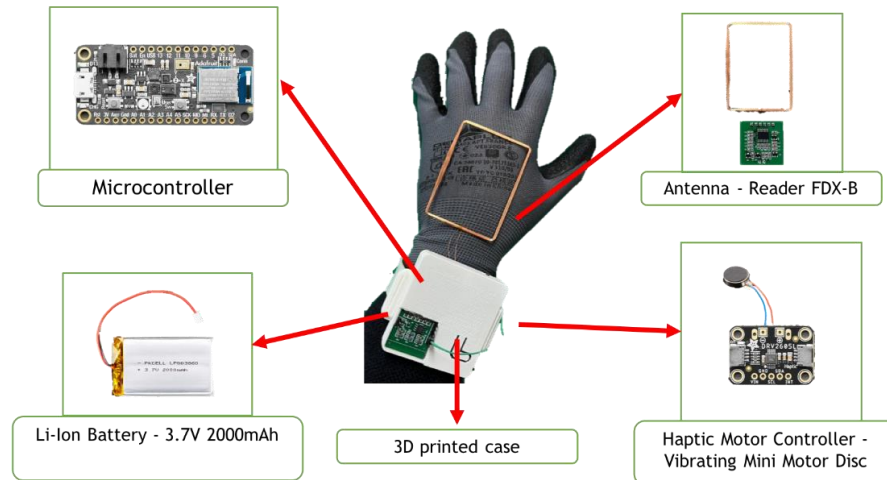
# Work in Progress

Miniaturizing the RFID reader (TRL 3 → 5)



# Work in Progress

Miniaturizing the RFID reader (TRL 3 → 5/6)



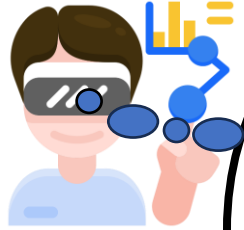


# Work in Progress

Collecting Farmers needs and feedback



# Work in Progress



## Herd management

### Milking

Milking time

Cows not milked

SCC

Milk yields

### Breeding

Days after calving

Insemination vocal note

Insemination optimum time

### Cow identification & Localization

### Feeding

Feeding history

Rumination Data

Ingestion

### Health

Treatments

Lameness

Instant Temp.

## Machines and Systems

AMS remote assistance



# Work in Progress

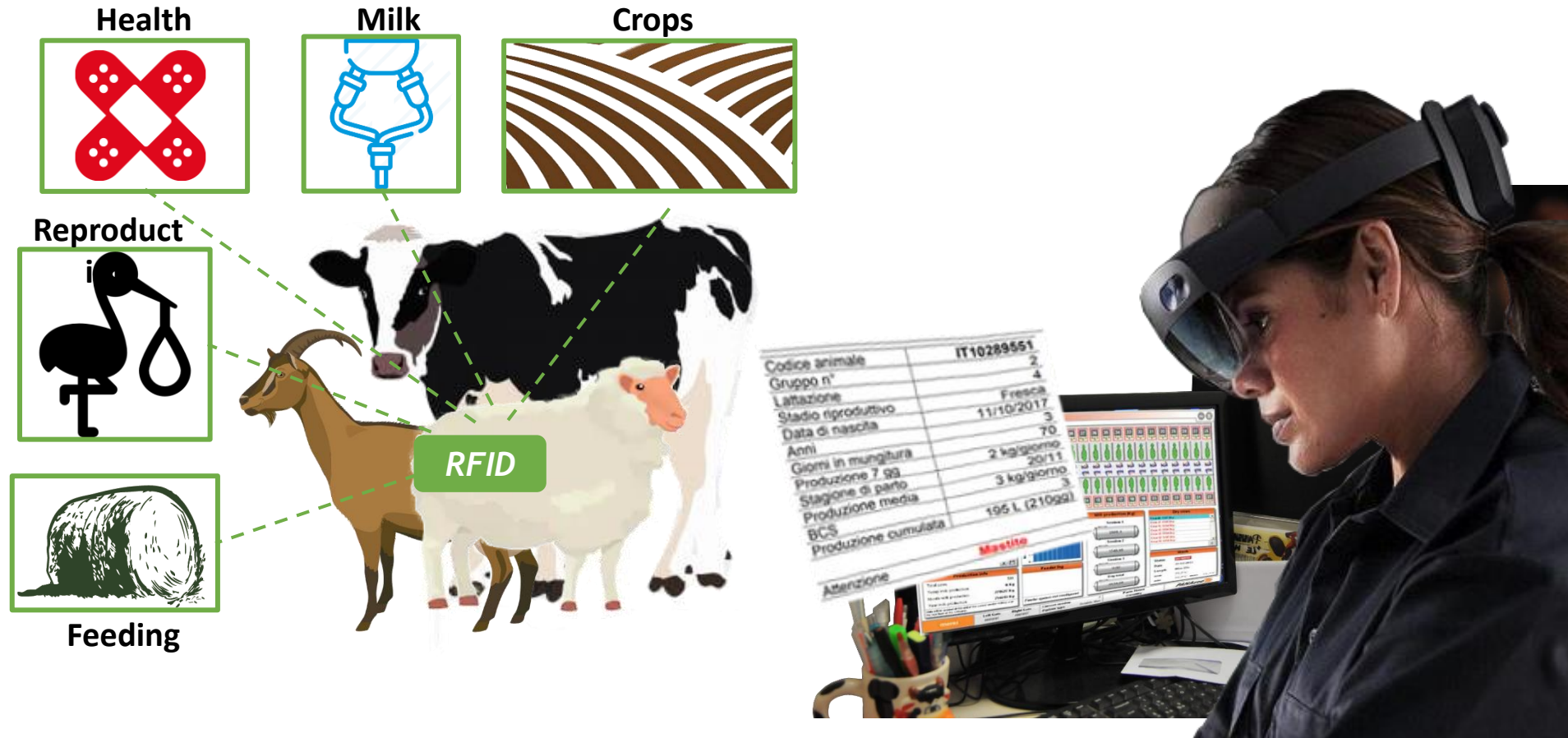
Developing a DSS for Mixed and Augmented Reality





# Work in Progress

Developing a DSS for MR and AR



# Work in Progress

## Indoor Positioning Systems





# Work in Progress

## Indoor Positioning Systems





# Work in Progress

## Indoor Positioning Systems



# Contributions in scientific journals and international conferences

## Full studies available here:

- Daniele Pinna, Gabriele Sara, **Giuseppe Todde**, Alberto Atzori, Valentino Artizzu, Davide Spano, Maria Caria. 2023. Advancements in combining electronic animal identification and augmented reality technologies in digital livestock farming. *Scientific Reports*, 18282
- Gabriele Sara, **Giuseppe Todde**, Daniele Pinna, Maria Caria. 2023. Combining Smart Glasses and Thermal Imaging as a Tool for Water Stress Detection in Greenhouses: A Preliminary Study. *Lecture Notes in Civil Engineering*, Springer LNCE, 337. 909-916
- **Giuseppe Todde**, Gabriele Sara, Daniele Pinna, Maria Caria. 2023. Smart Glove: Development and Testing of a Wearable RFID Reader Connected to Mixed Reality Smart Glasses. *Lecture Notes in Civil Engineering*, Springer LNCE, 337. 949-956
- Gabriele Sara, **Giuseppe Todde**, Maria Caria. 2022. Assessment of video see-through smart glasses for augmented reality to support technicians during milking machine maintenance. *Scientific Reports*, 12(1), 15729
- Gabriele Sara, **Giuseppe Todde**, Daniele Pinna, Maria Caria. 2021. Smart Glasses' Acceptance by Agricultural Stakeholders Using the Technology Acceptance Model (TAM). VI RAGUSA SHWA International Conference - Safety, Health and Welfare in Agriculture and Agrosystems. September 15-16, 2021. Ragusa, Italy.
- Gabriele Sara, **Giuseppe Todde**, Marco Polese, Maria Caria. 2021. Evaluation of smart glasses for augmented reality: technical advantages on their integration in agricultural systems. EurAgEng 2021 Conference. New Challenges for Agricultural Engineering Towards a Digital World. July 5 – 8, 2021, Évora, Portugal
- Maria Caria, **Giuseppe Todde**, Gabriele Sara, Marco Piras, Antonio Pazzona. 2020. Performance and Usability of Smartglasses for Augmented Reality in Precision Livestock Farming Operations. *Applied Sciences*. 10 (7).pp 1-11. doi:10.3390/app10072318
- Maria Caria, Gabriele Sara, **Giuseppe Todde**, Marco Polese, Antonio Pazzona. 2019. Exploring Smart Glasses for Augmented Reality: A Valuable and Integrative Tool in Precision Livestock Farming. *Animals*. 9(903). Pp 2-17. doi:10.3390/ani9110903



# Funding



Innovative  
Agriculture



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PAS-AGRO-PAS - The Making of Fragile Agro-ecosystems Productive, Adaptive and Sustainable: Multifunctional Agro-pastoralism

SMARTGLOVE - Prototype development of a wearable RFID reader system for augmented reality in the livestock

BOVARIA - Knowledge and sustainable management of agricultural and forestry systems with sustainable improvement of primary productions: the case of cattle breeding in Sardinia

ATLANTIDE - Advanced Technologies for LANDs management and Tools for Innovative Development of an EcoSustainable agriculture – WP06, Development and implementation of an augmented reality system in agriculture

Agritech National Research Center and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1032 17/06/2022, CN00000022).



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# Thanks for your attention



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DI SASSARI

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