ML and Image Analyses for Livestock Data

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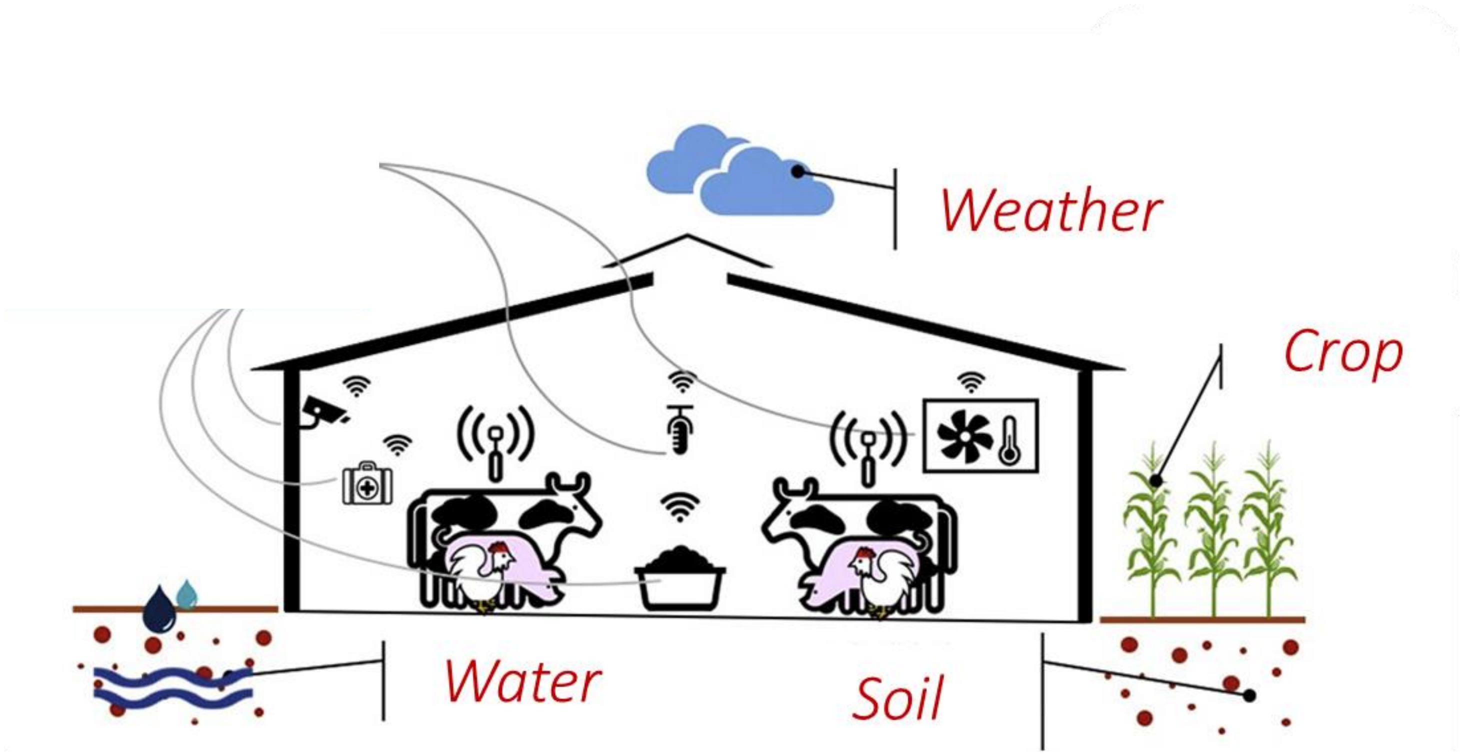
High-Throughput Phenotyping: animal-level

- **Animal-level information for optimized decision and genetic selection**

Sensors:
Wearable
Cameras
IR Spec.
RFID
Sound
Housing

Animal Identification
Animal Behavior
Body Weight
BCS/Composition
Milk Components
Milk Yield
Estrus Event
Feed Intake
Feed Efficiency
GGE

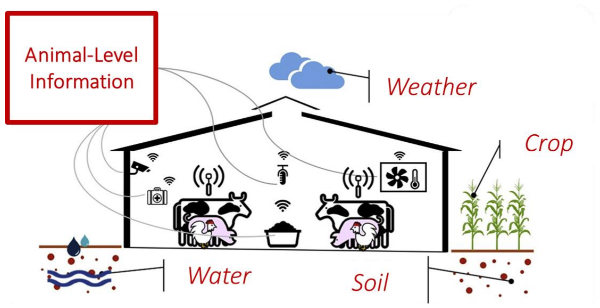


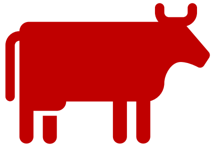
➢ **Cheap + Precise + Real-Time**

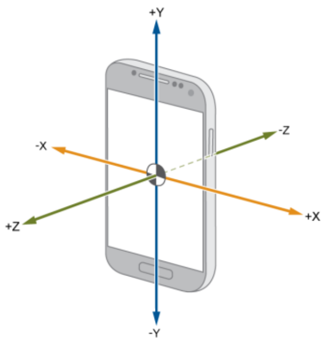
Tullo et al., 2019

Why Computer Vision Systems?

Can I use other sensing technologies?





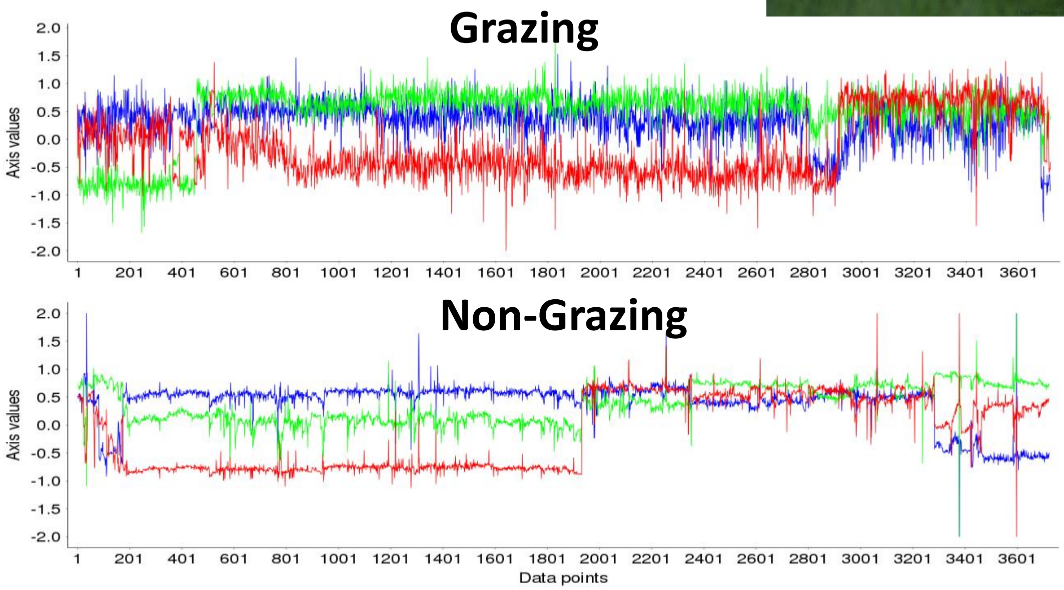


Grazing

Non-Grazing

A single image can be extremely informative!

...it can go beyond your primary interest!



Ribeiro et al., 2021 (submitted) - JAS

Computer Vision Systems: Image Analyses

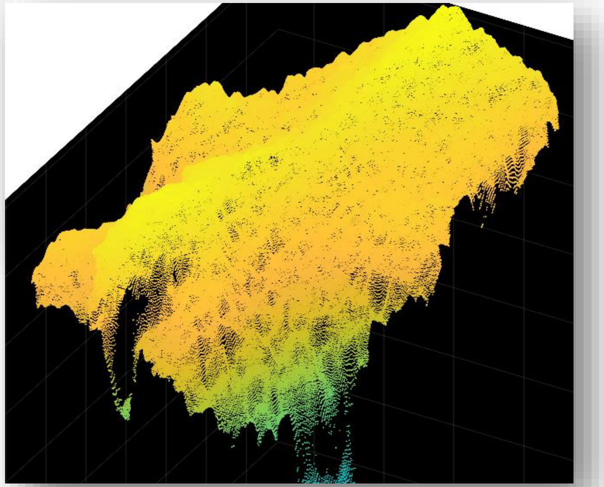
- **Complex dataset to analyze**
- **Variety of tasks: Deep Learning context**

2D Image Classification

- No calf
- Calf

Semantic Segmentation

3D Image Classification



Object Detection

Instance Segmentation

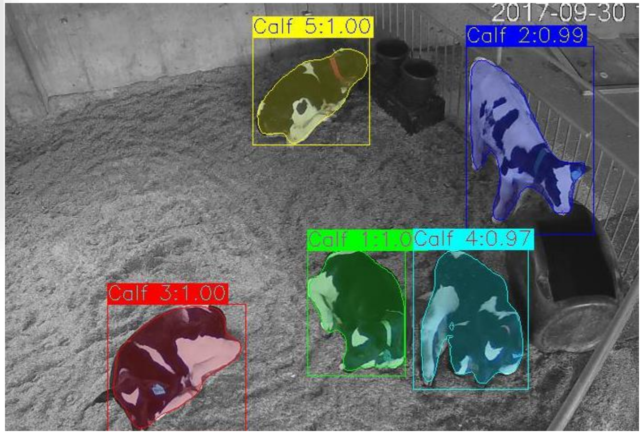
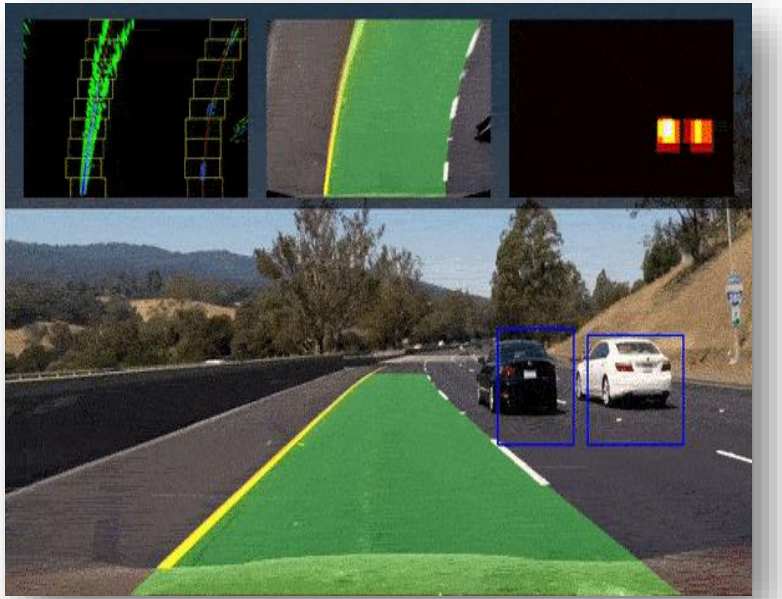


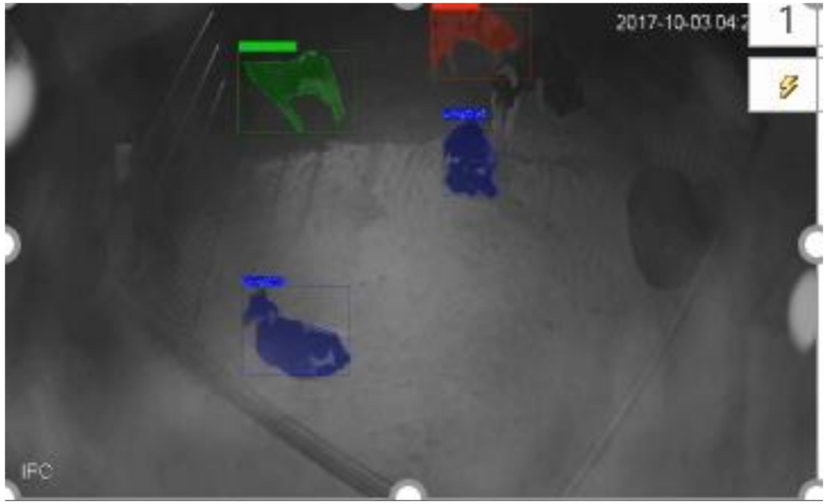
Image Synthesis

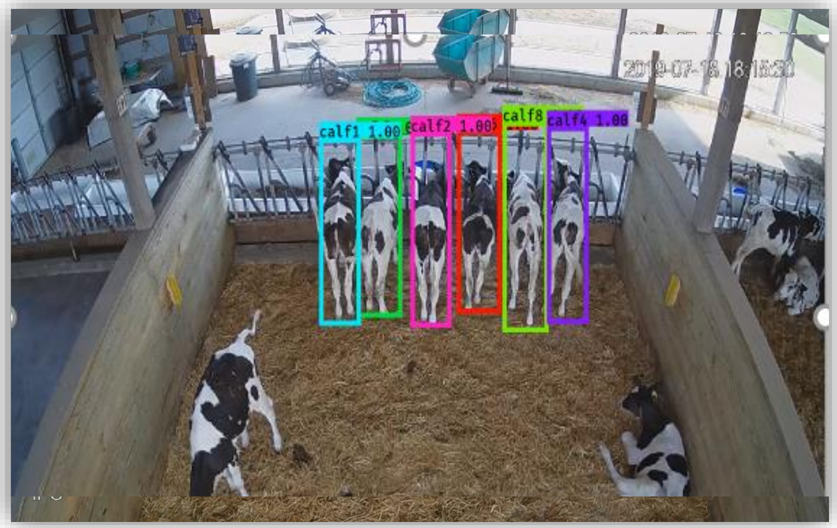
Monitoring Animal Behavior



Early detection of diseases, social interaction, welfare, feed efficiency, estrus, locomotion, etc.

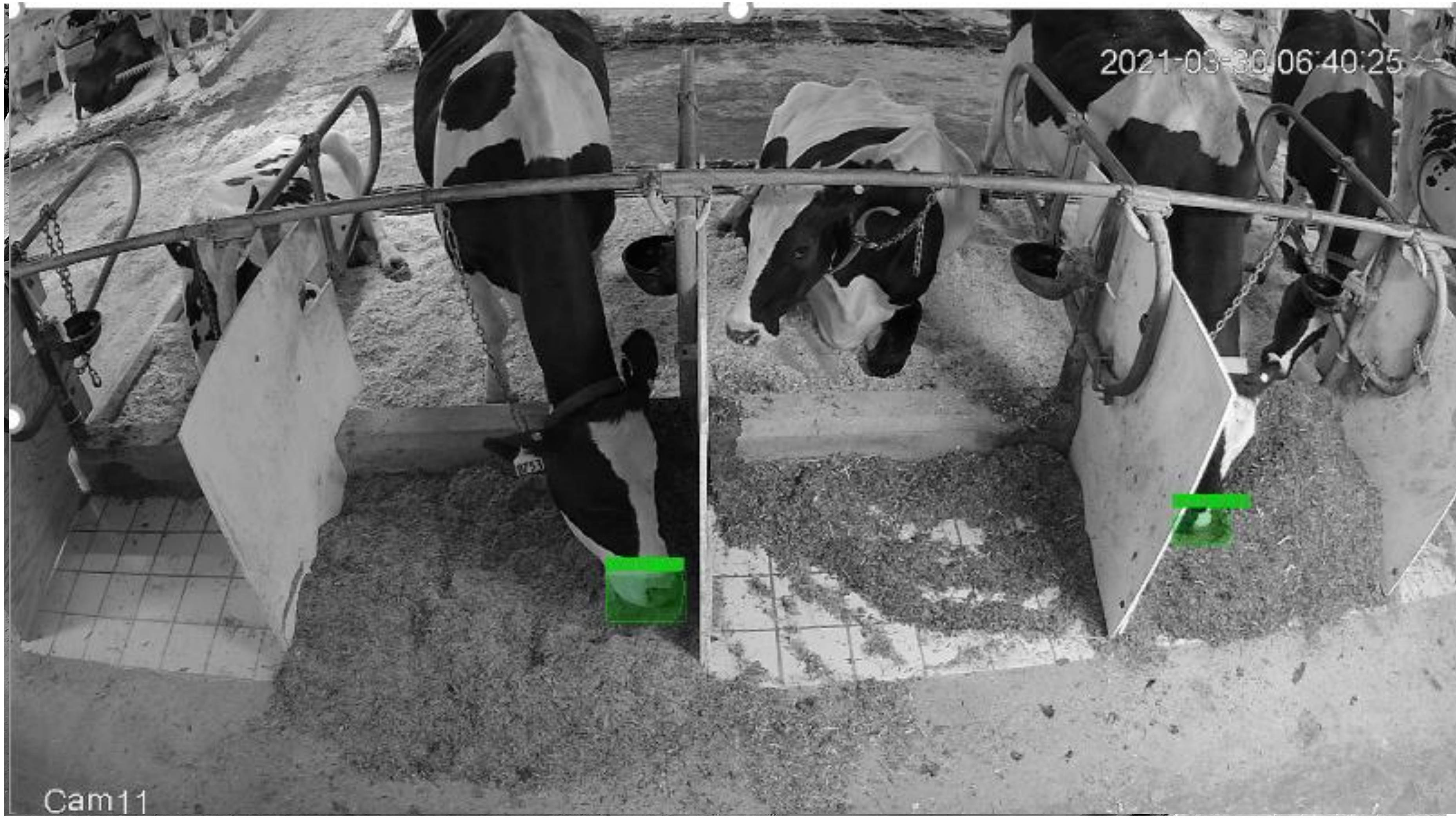
Monitoring Animal Behavior



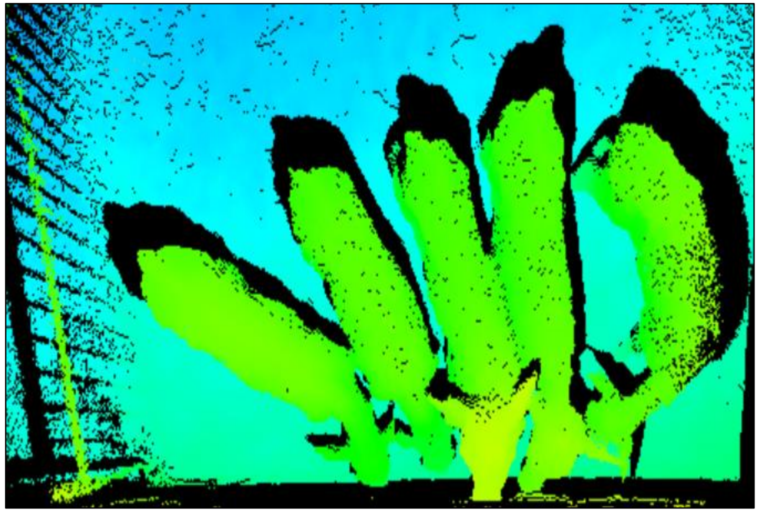


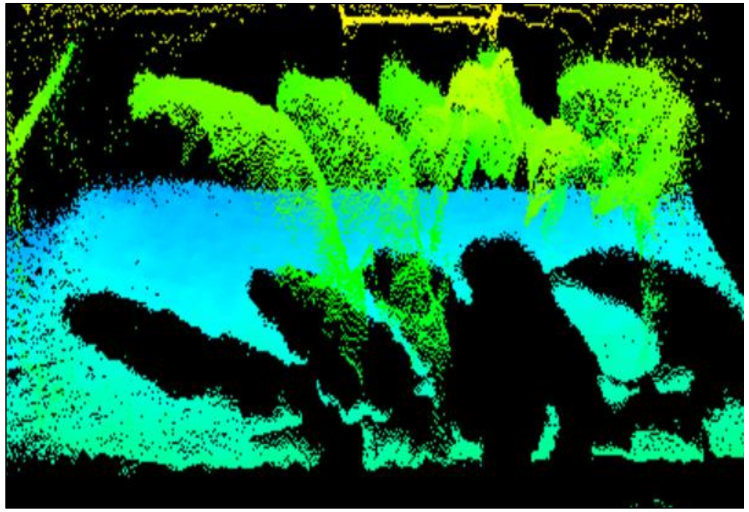
Monitoring Feeding Behavior

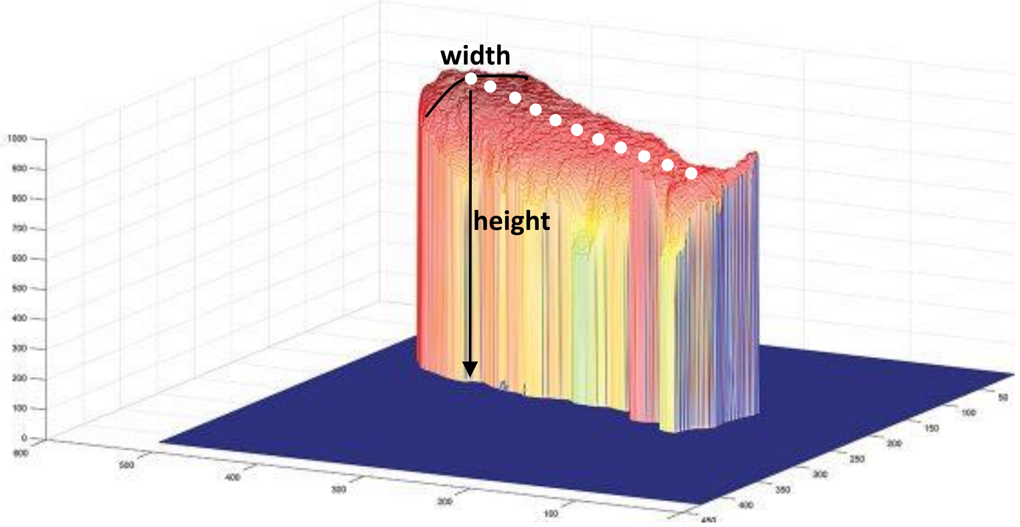
Hand Motion

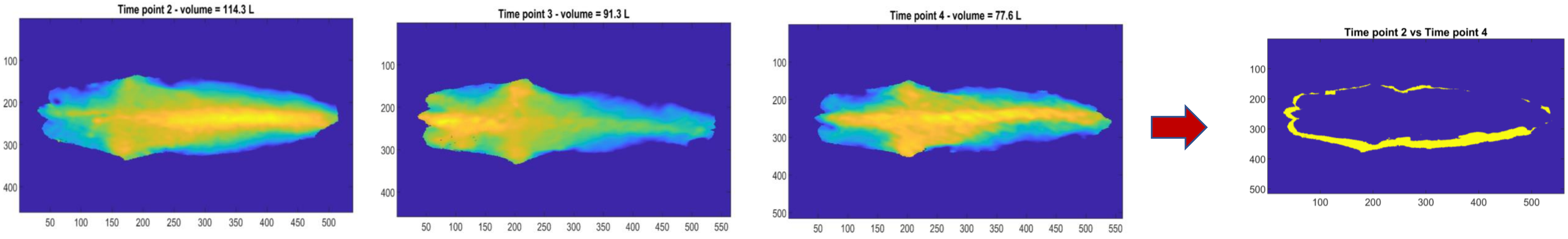


Predicting body weight in dairy calves through 3D images





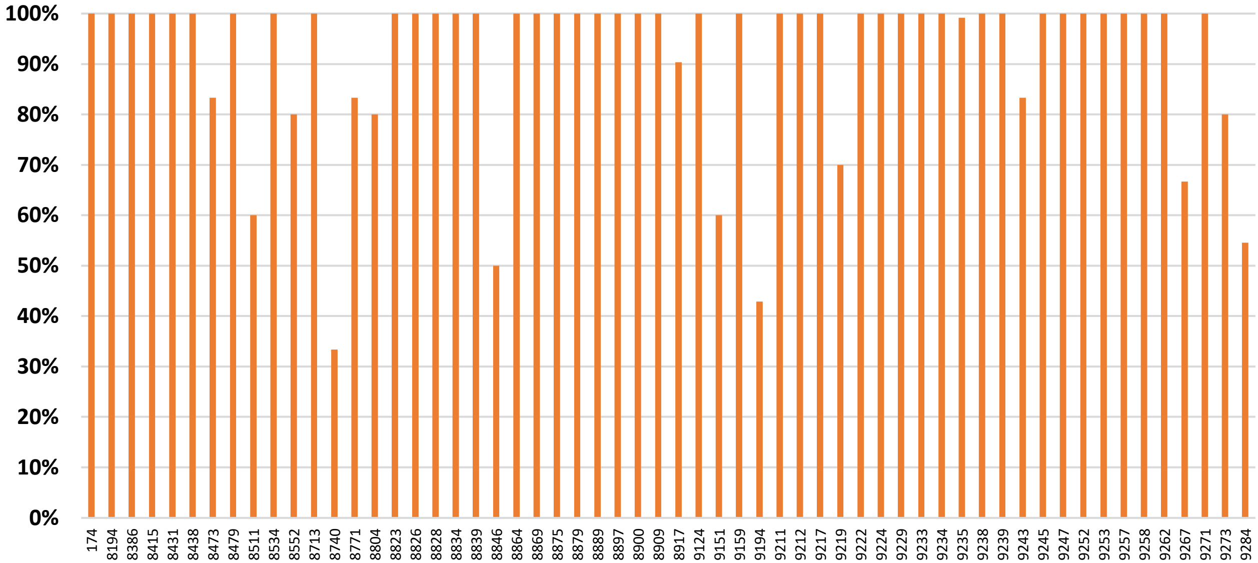


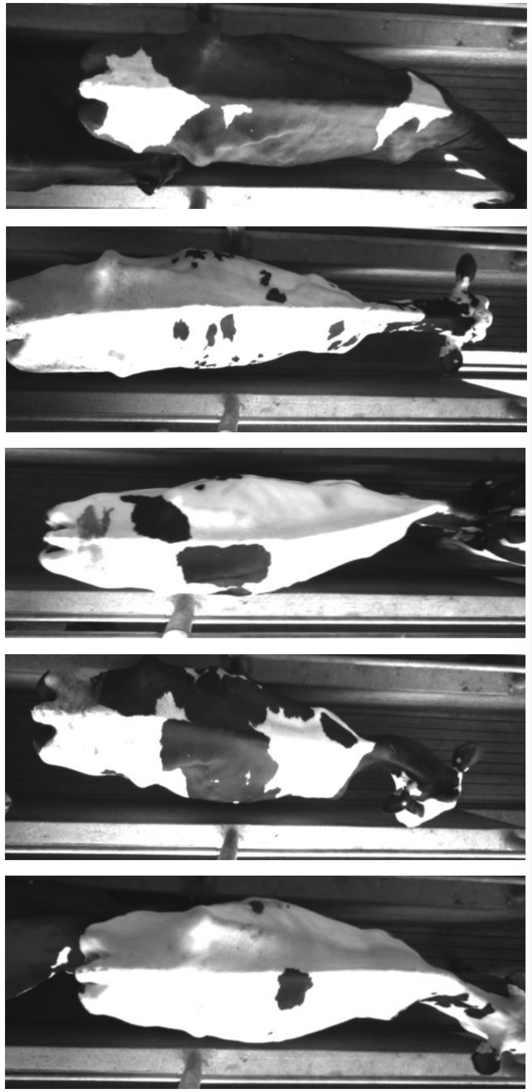


Cominote et al., 2020   *Dorea et al., 2019*   *Fernandes et al., 2019*

First Step: Animal identification using 2D images

- *59 lactating dairy cows*
- *Training set: 13,222 images automatically acquired at UW-Madison*
- *Testing set: 617 images test*
- *Avg accuracy: ~**94%** to identify individual animals*

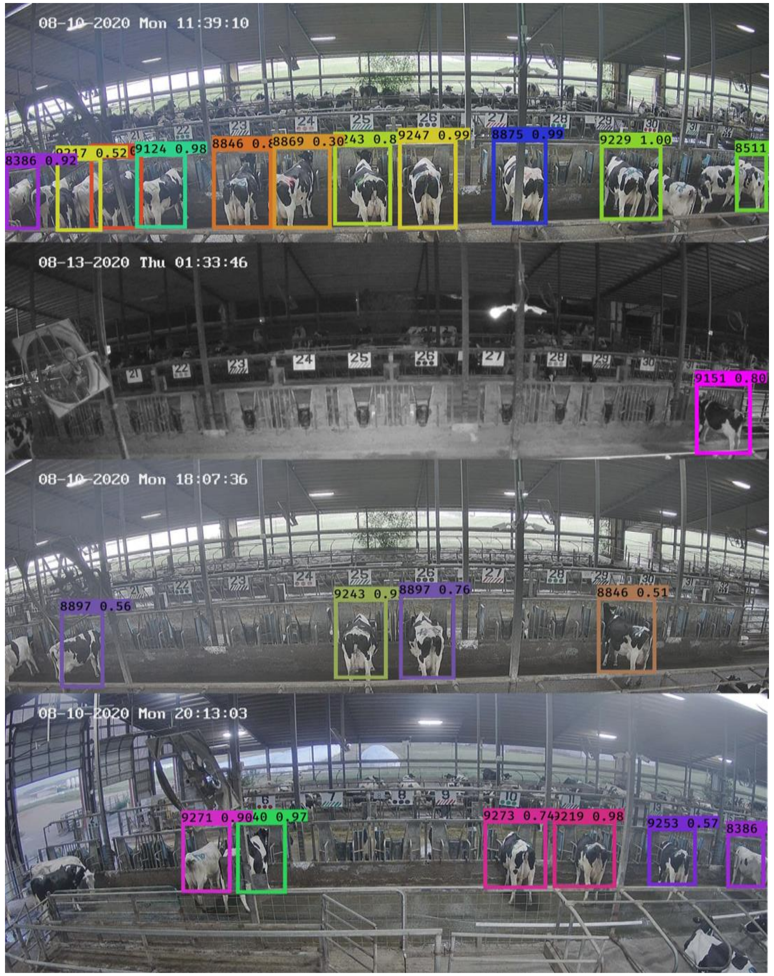


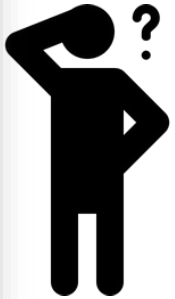


Ferreira et al., 2021 - ADSA

Animal identification using 2D images

- **It will not work for similar color patterns**

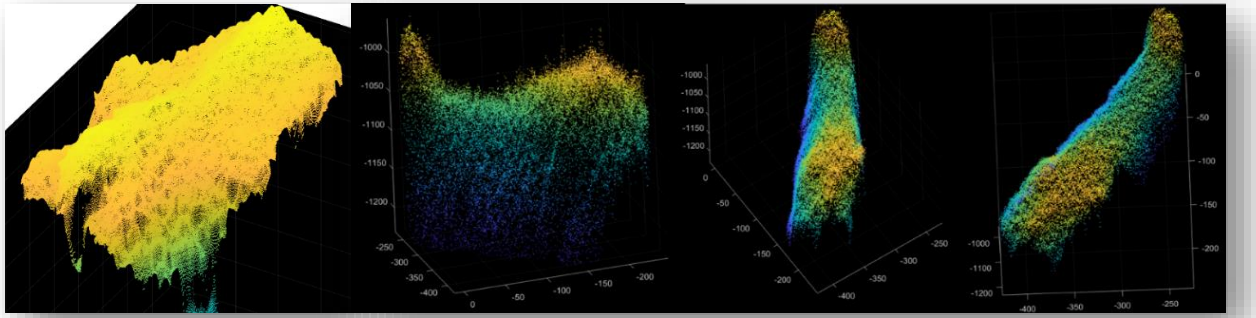




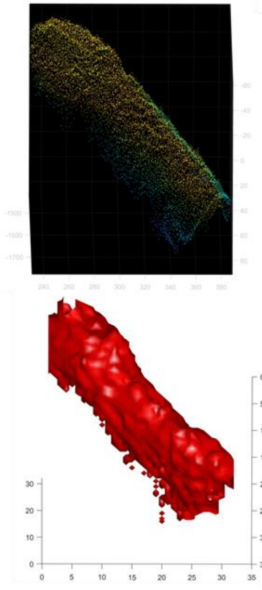
Ferreira et al., 2020 - ADSA

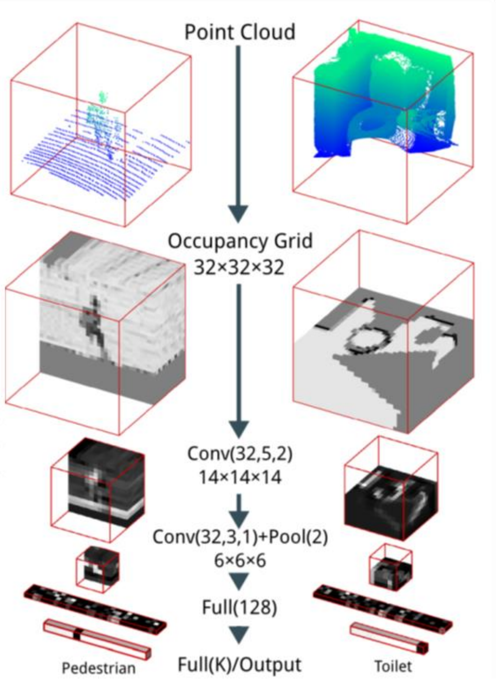
Animal identification using 3D images

Using 3D:
Voxels
Point Cloud

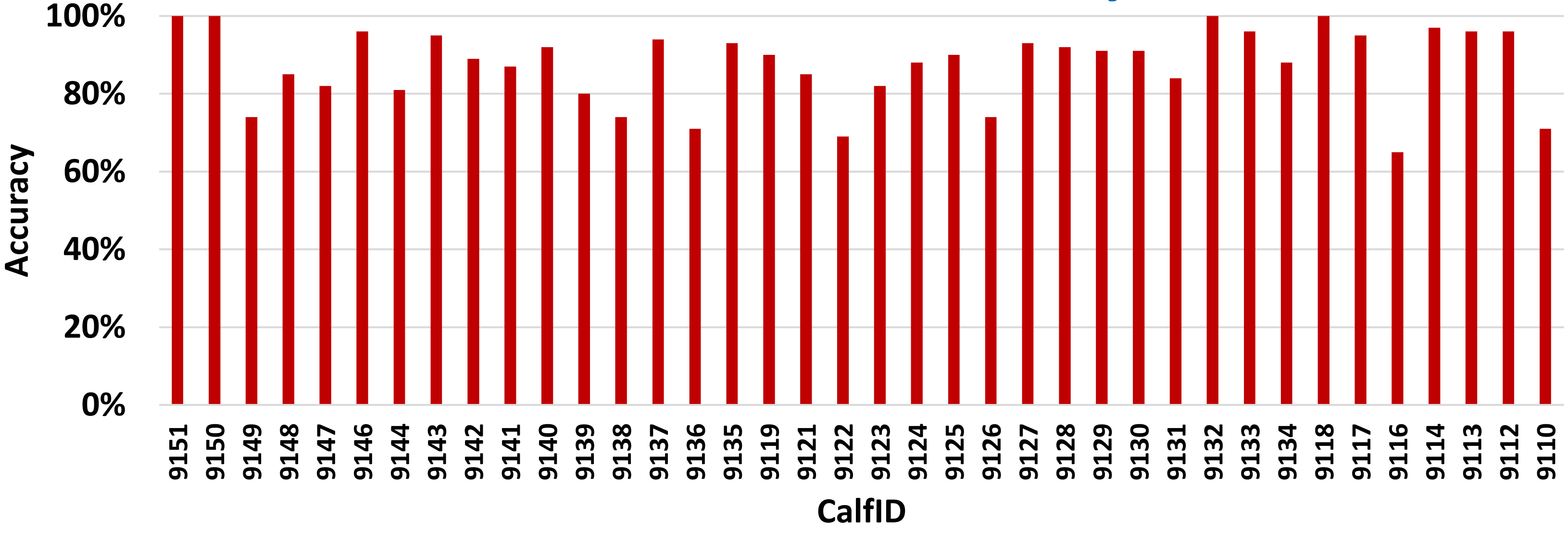


3D CNN
VoxNet/PointNet





38 animals - Overall Accuracy = 87%



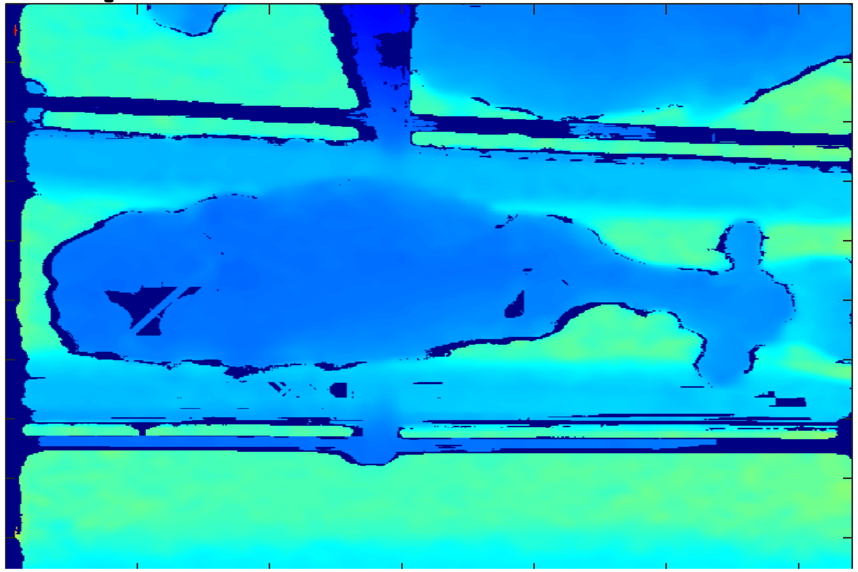
Ferreira et al., 2020 - ADSA

Using HTCondor: Animal Identification + Body Condition Score

Rafael Ferreira
(PhD Student)

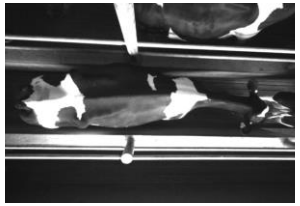
Infrared

Depth

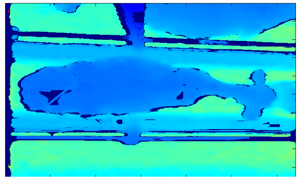


Using HTCondor: Animal Identification + Body Condition Score

Infrared

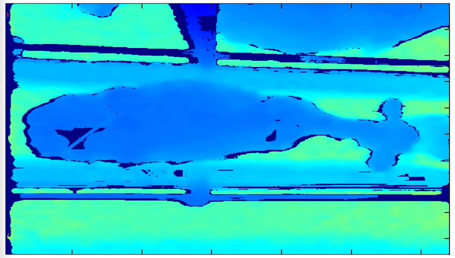


Depth

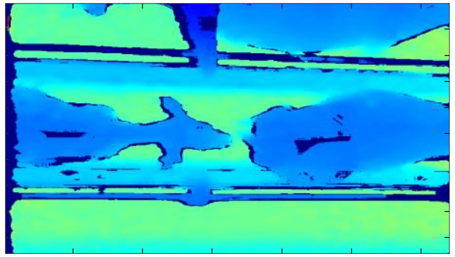


1st Step: Image Classification

Good



Bad

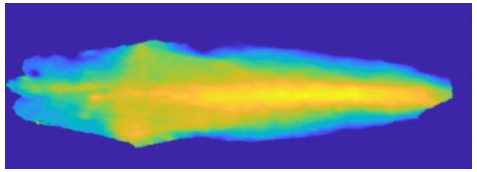


Xception
2D CNN
23M params

If good: ***2nd Step: Image Segmentation (Mask)***

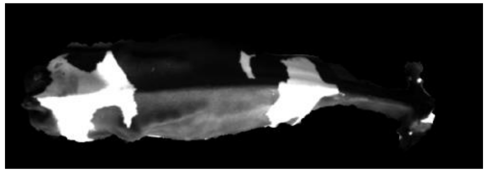
U-Net
2D CNN
31M params

3rd Step: Image Classification (Body Condition Score: 1-5)

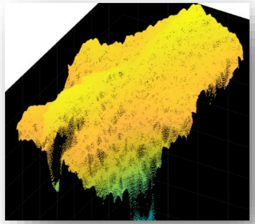


Xception
2D CNN
23M params

4th Step: Image Identification (Animal Identification)



Xception
2D CNN
23M params



PointNet
3D CNN
3.5M params

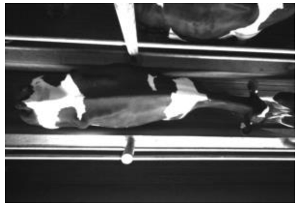
Rafael Ferreira
(PhD Student)

1 student
60 cows
4 Cameras
2 phenotypes
Training only

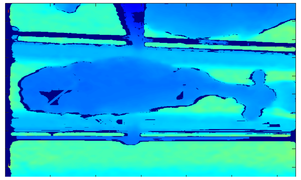
Jobs	127
Number of images/Job	218,355
Training time	1,872 hours
Disk usage	1072 GB
GPU	1
GPU Memory used	754 GB
RAM	739 GB

Using HTCondor: Animal Identification + Body Condition Score

Infrared



Depth



What about inference? – Azure

- Total processed images: 104,494 (52,247 png, 52,247 tiff)
- Good images (segmented, identified, BCS calculated): 19,163
- Total execution time: 6,441 hours (total time: from image upload to final SQL insert, not only inference!):
  - *Several tasks (transfer time, SQL insert, image storage: masks, cropped, ident, BCS);*
- Azure logs shows memory allocated but not memory used and the max memory allocated per instance is 1.5GB
- Max parallel instances count: 200

We would love to use HTCondor for automated inference (real-time?)

Using HTCondor: Animal Identification + Body Condition Score

1st Step: Image Classification

Good

Bad

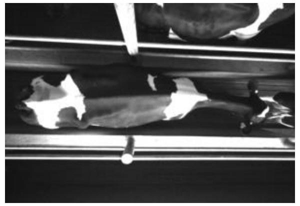
Xception
2D CNN
23M params

DONE!

Deep Neural Networks are trained!

U-Net
2D CNN
38M params

Infrared



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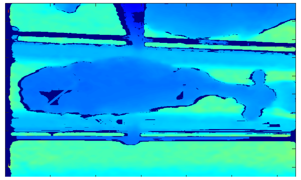


3rd Step: Image Classification
(Body Condition Score: 1-5)

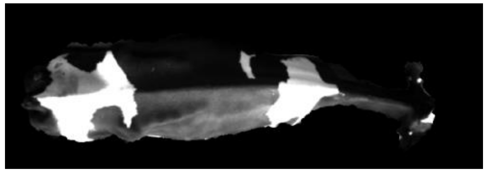
Xception
2D CNN
23M params

Need to retrain daily (weekly?)

Open-Set problem!
New cows every day

Not Here!

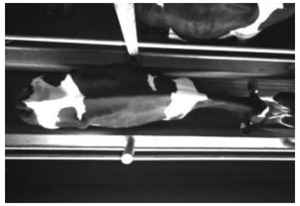
4th Step: Image Identification
(Animal Identification)



Xception
2D CNN
23M params

Using HTCondor: Animal Identification + Body Condition Score

Infrared



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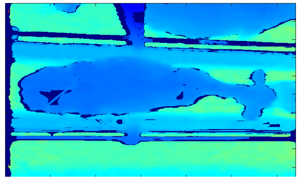


We would need to retrain daily (60 cows only):

Number of images	~13,000
Training time	10 hours
Disk usage	10.7 GB
GPU	1
GPU Memory used	38 GB
RAM	5.7 GB

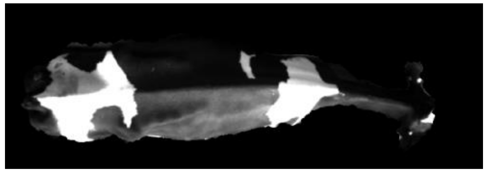
A farm with 6,000 cows would require significant computational resources!

Need to retrain daily (weekly?)

Open-Set problem!
New cows every day

Not Here!

4th Step: Image Identification (Animal Identification)



Xception
2D CNN
23M params

Our Camera System at UW-Madison

We have:

- *40 RGB Cameras collecting data every 5 seconds;*
- *Depth cameras collecting 3D images and infrared twice a day of every single cow;*

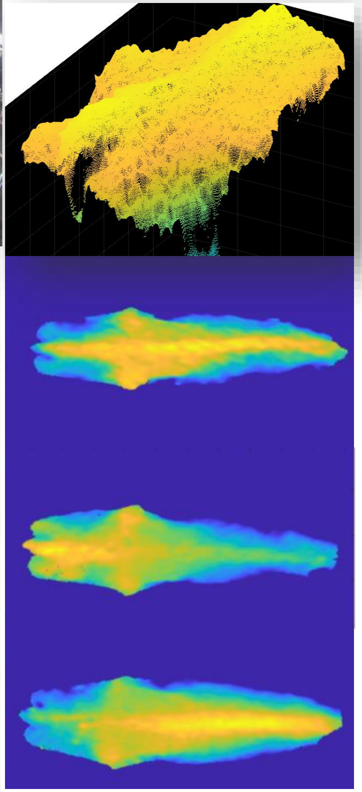
We generate:

- 1.38 TB of RGB per day
- 10 GB of 3D and Infrared images

(500 cows)

Our Vision:

Create state-of-the-art computer vision systems and the largest public database for livestock (image, audio, sensor)



Using HTCondor

Our Challenges:

- Frequent transfer of large databases for each new training process;
- Number of GPUs for concurrent jobs;
- User-Friendly interface for general public usage (e.g. Animal Science, Agronomy, BSE, Vet students) – Graphical Interface (commands), teaching?
- Example: Azure Lab Services (Deployment of VMs for each student with Linux or Windows interface – GPU labs);

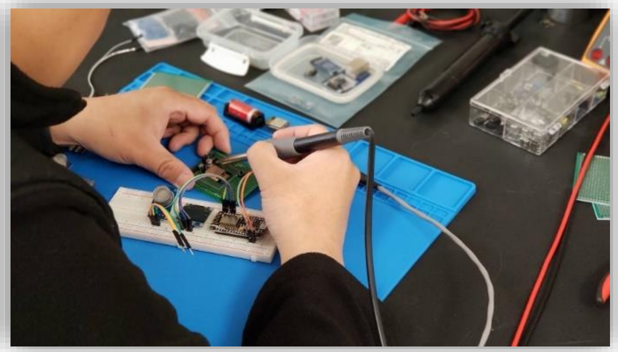
Using HTCondor

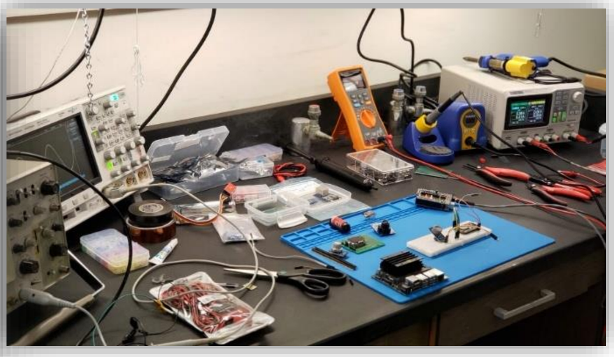
Opportunities:

- Development of state-of-the-art computer vision systems for livestock operations;
- Training and implementation of complex deep learning algorithms for image analyses;
- Analyses of large imaging datasets (100+ concurrent jobs);
- Collaborations to develop automated training and inference strategies using HTCondor infrastructure;
- Publications of high-impact (realistic research) research in the field of Digital Agriculture

Our Research Group

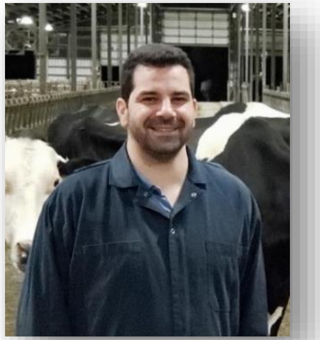
Digital Livestock Lab



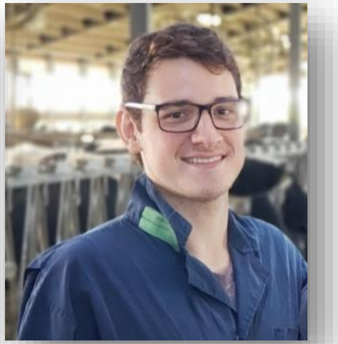
Research Group:

Dr. Luiz Gustavo Pereira
(Visiting Scientist)



Dr. Tiago Bresolin
(Research Associate)

Dr. Dario Oliveira
(Research Associate)



Rafael Ferreira
(PhD Student)

Ariana Negreiro
(PhD Student)

Caleb LaCount
(Undergraduate Student)

Acknowledgments

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Lauren Michael
Brian Bockelman
Miron Livny

PURINA®

DAIRY INNOVATION HUB

Microsoft

DSM

Thank you!

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