The Meat Factory Cell: Progress toward AI-driven robotic processing of entire pig carcasses

30.03.2023, RIBMINS WG4 (Impact of changes and alternatives to traditional meat inspection).
Presented by Alex Mason

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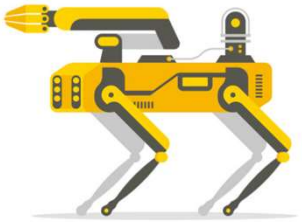
But first, by request…*Some* ***examples*** *and* ***trends***

- A video reel containing automation examples shown during live presentation are available here: https://youtu.be/kt4g3mXJFv0

Key trends in robotics

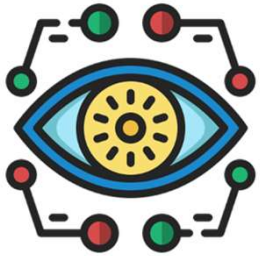


Advanced Robots

Artificial Intelligence

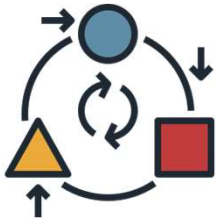
Digital Twins

Cobots

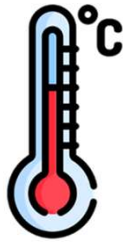


Machine Vision

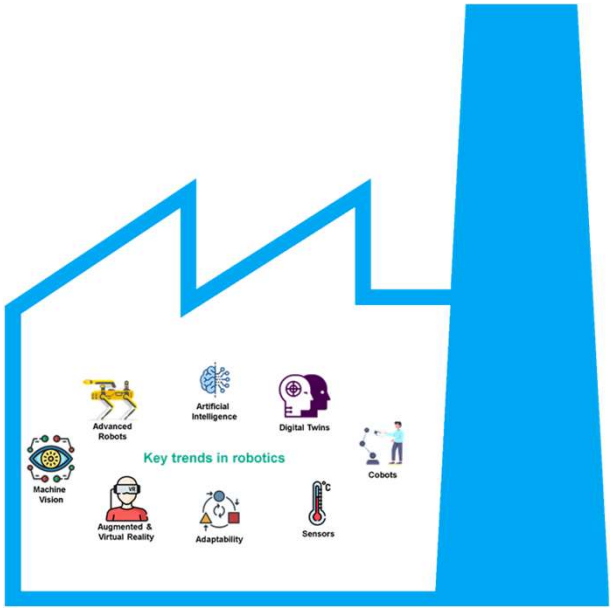
Augmented & Virtual Reality



Adaptability

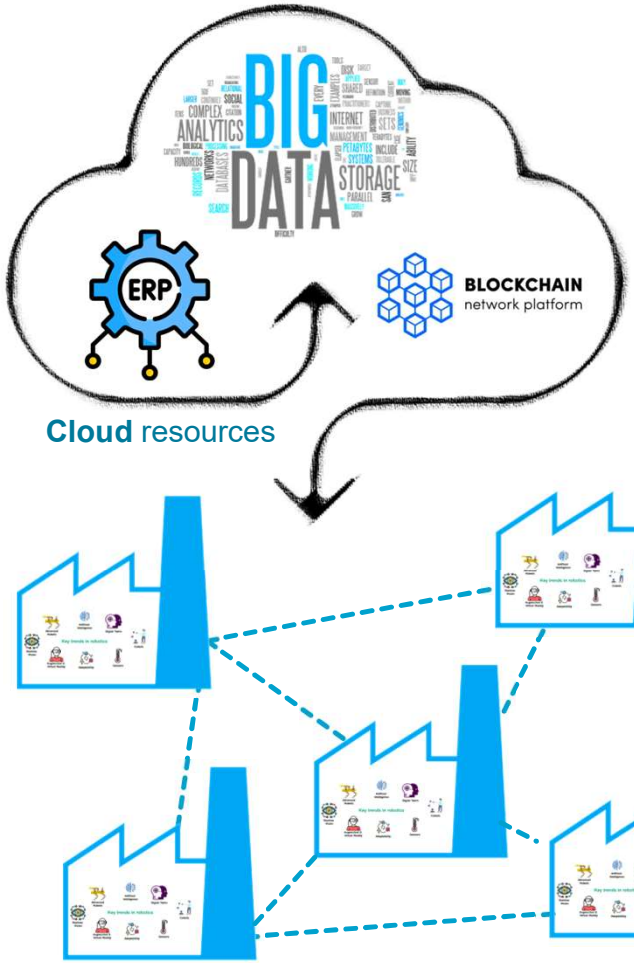


Sensors



Factories of the Future, with trending robotics technology integrated

Communication layers



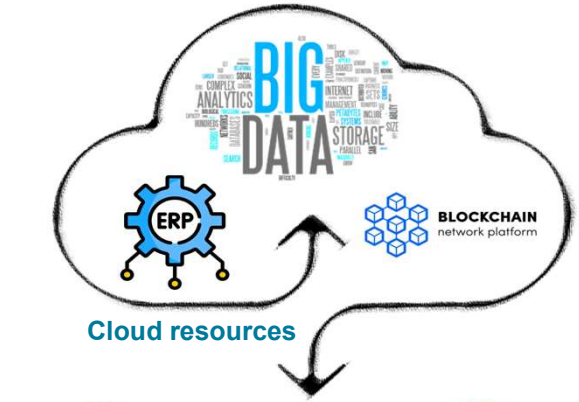
Cloud resources

Interconnected manufacturing resources; reconfigurable and responsive to changing needs or environment.

Big picture, **Industry 5.0**

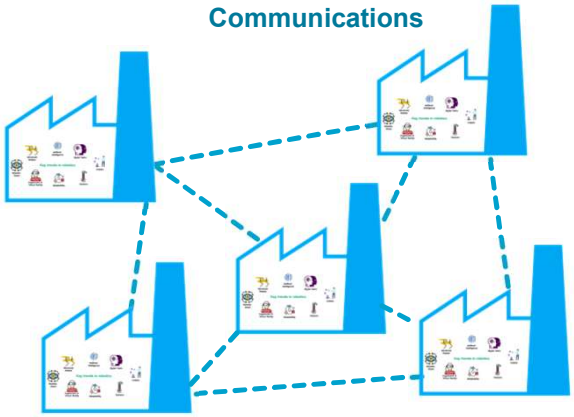
Bigger picture

Farms, raw material



Cloud resources

Communications



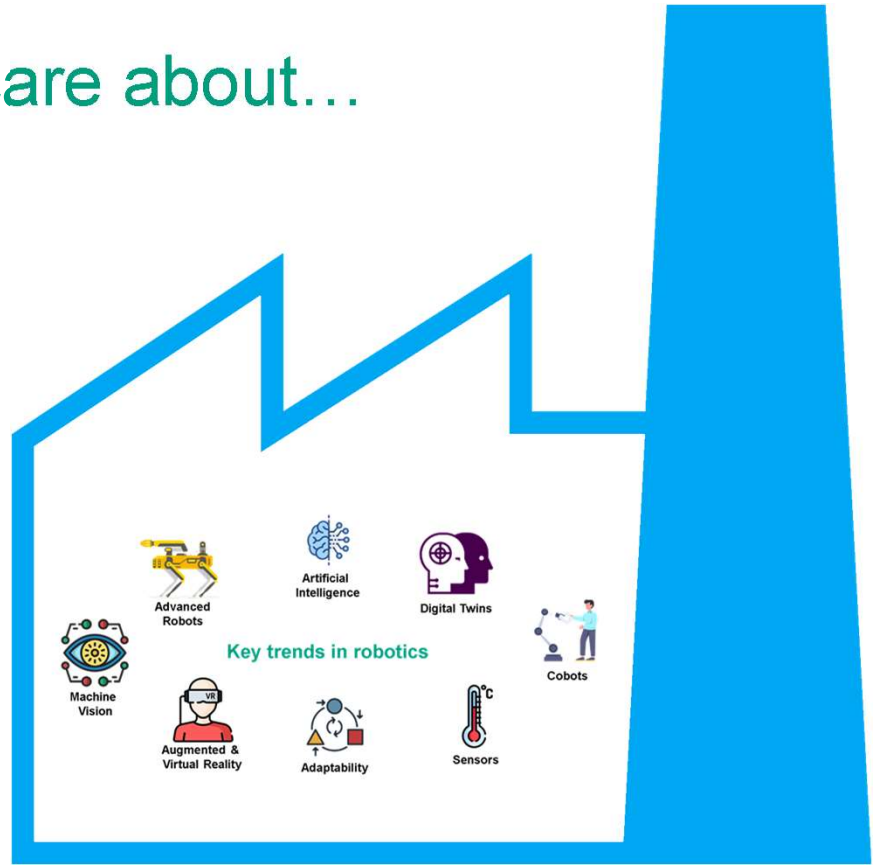
Manufacturing, processing

Consumers

Stores

Logistics, distribution

This is what I care about…

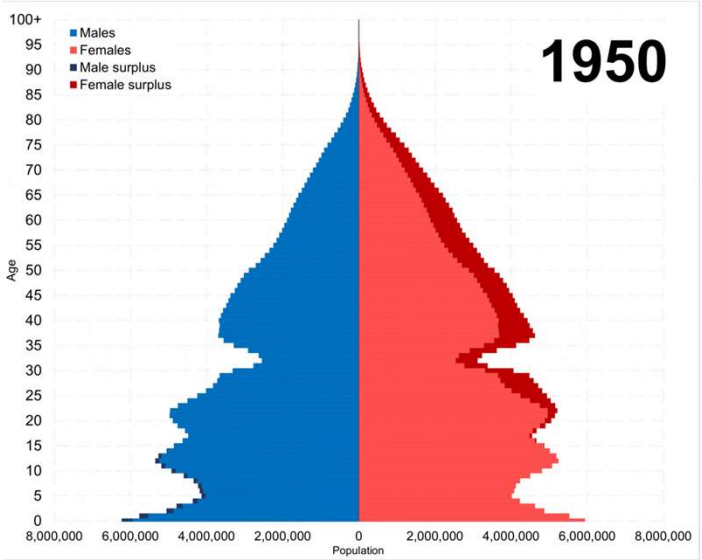


Factories of the Future

(… and bacon)

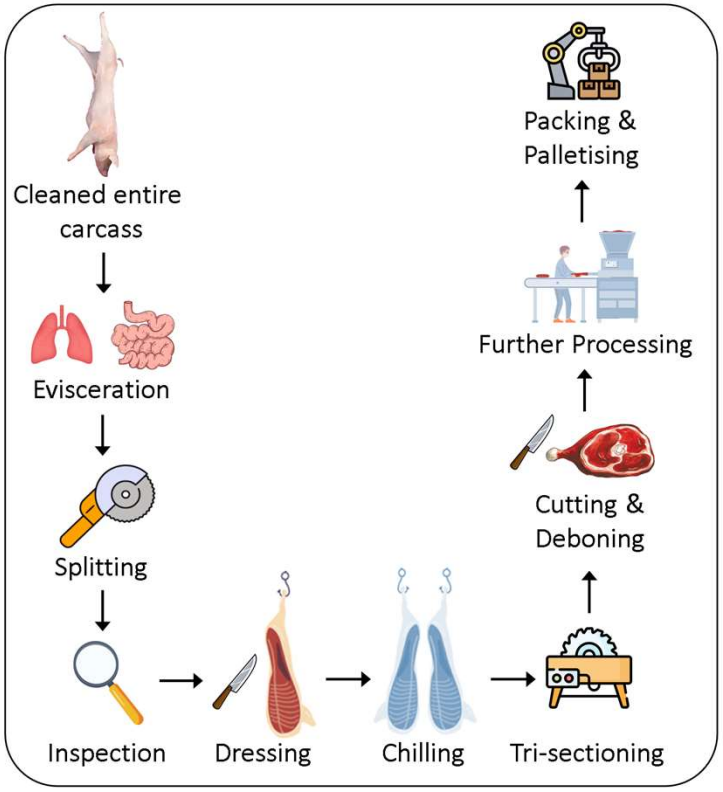
Why does it matter?

- *"Disruptive innovations are perceived necessary for accelerating sustainability transitions"*
  - Horizon Europe is the world's largest research and innovation program with a budget of €95.5 billion.
- Societal pressure in regard of SDGs. We must do better, but how without access to scalable and adaptable automation?
- Manufacturing labour crisis
  - A ticking bomb that will most impact those who cannot or will not automate. Age, disinterest in manufacturing, etc.

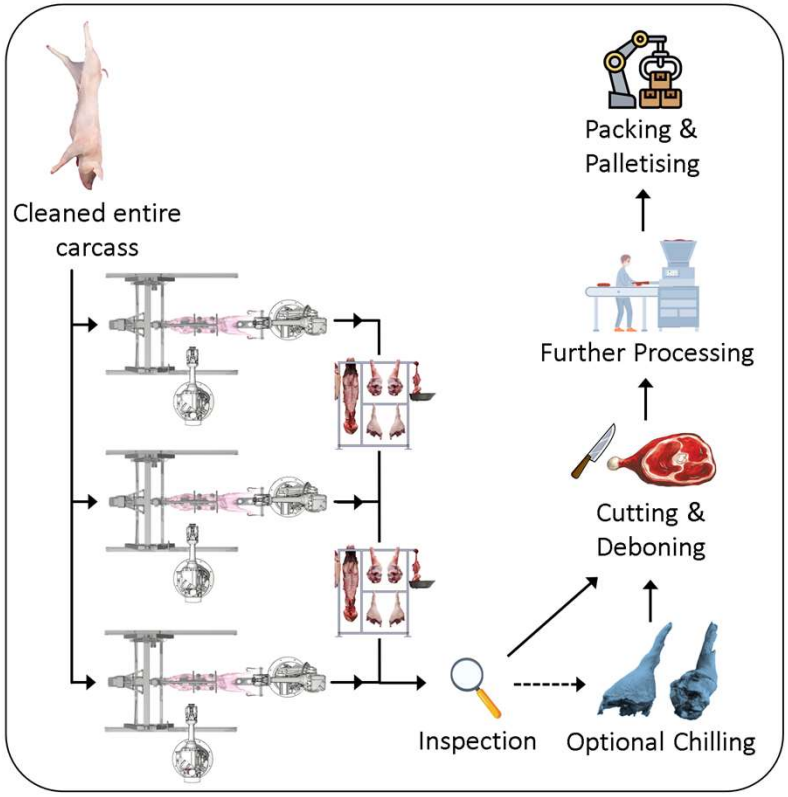


Europe's ageing population "pyramid", 1950 – 2023.

The “Meat Factory Cell” case



Conventional Processing

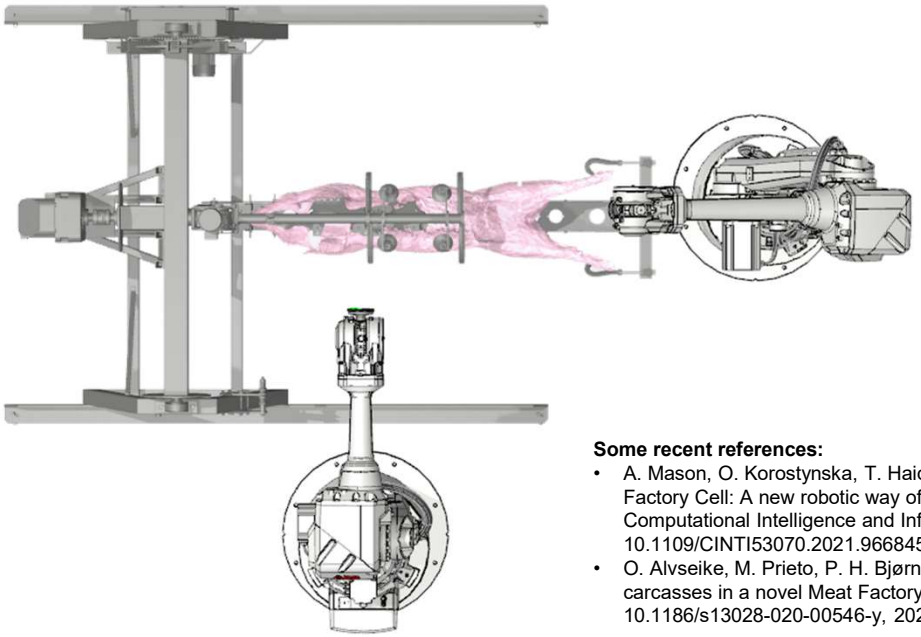


Meat Factory Cell Processing

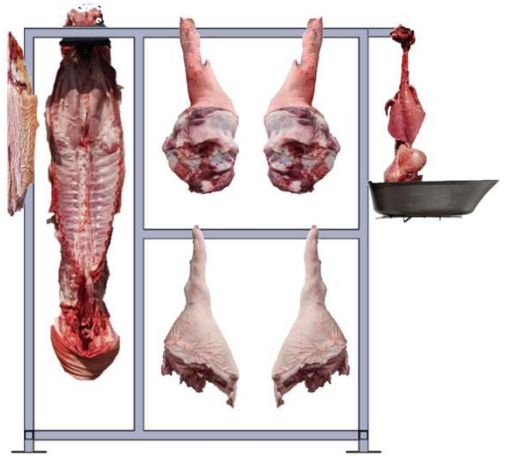
Key concepts

Cleaned entire carcass

Meat Factory Cell
(Two off industrial robots, plus one bespoke robot called the “carcass handling unit”)



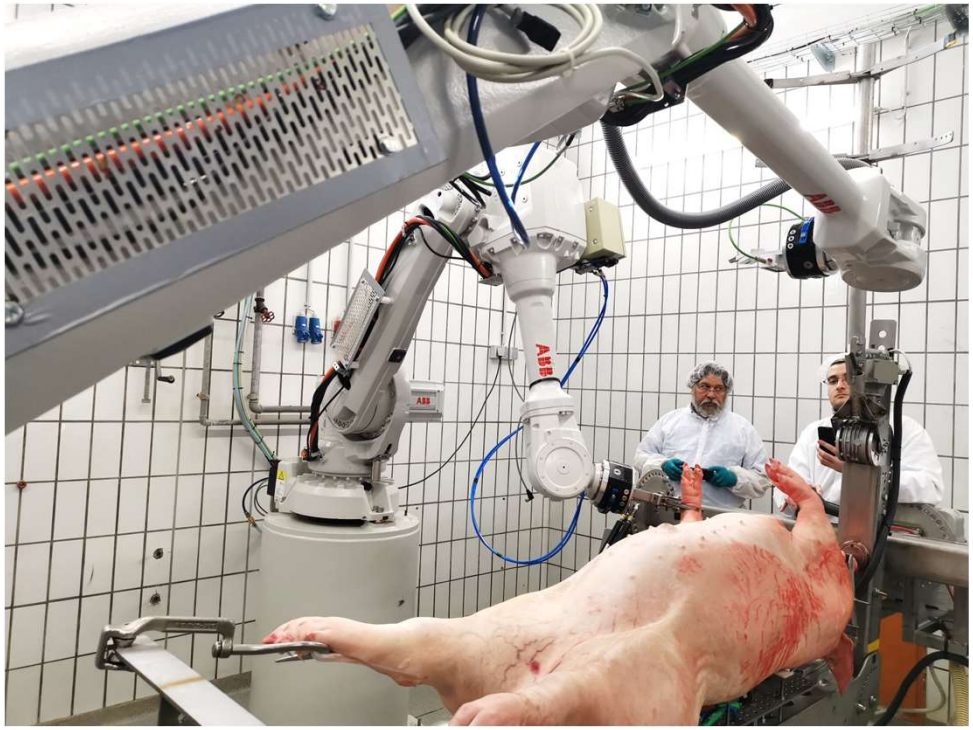
Output “rack”
(2x forelimbs, 2x hindlimbs, saddle, belly (with ribs) and entire organ set.



Some recent references:

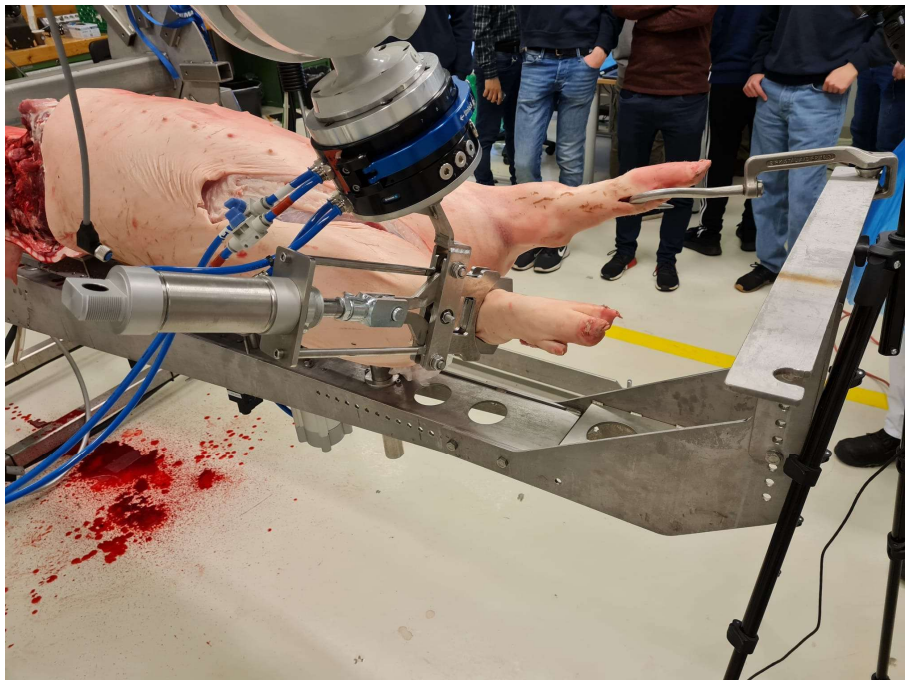
- A. Mason, O. Korostynska, T. Haiddegger, A. Popov, L. B. Christensen and O. Alvseike, "The Meat Factory Cell: A new robotic way of thinking for meat producers", IEEE 21st International Symposium on Computational Intelligence and Informatics (CINTI 2021), pp. 91-96, DOI: 10.1109/CINTI53070.2021.9668455, 2021.
- O. Alvseike, M. Prieto, P. H. Bjørnstad, A. Mason, "Intact gastro-intestinal tract removal from pig carcasses in a novel Meat Factory Cell approach", Acta Veterinaria Scandinavica, vol 62, an. 47, DOI: 10.1186/s13028-020-00546-y, 2020.

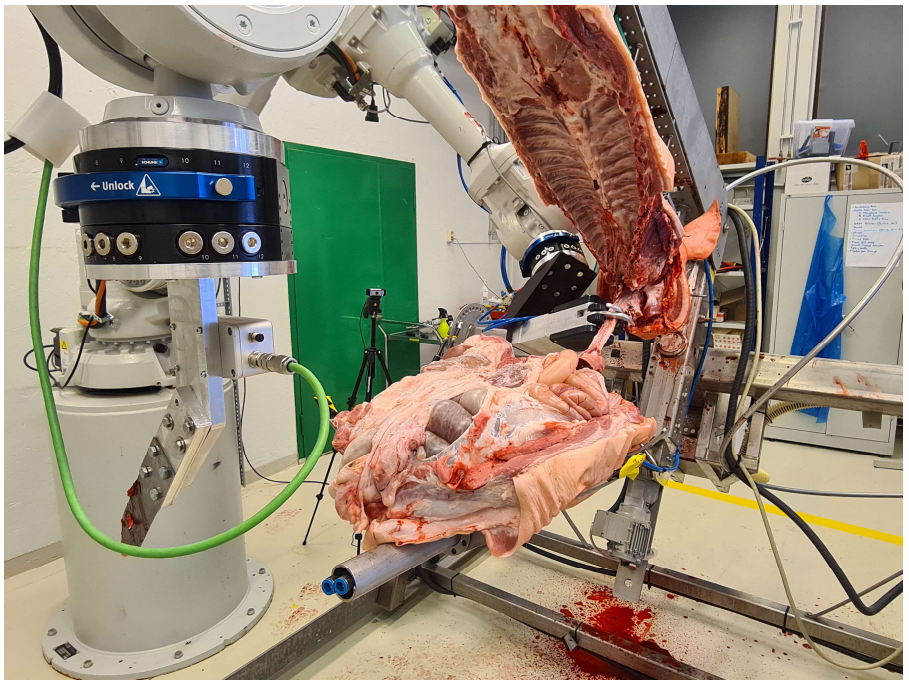
Meat Factory Cell, MRI, Germany



The MFC at MRI, January 2023. *Image source:* Tamas Haidegger, OBUDAUNI.

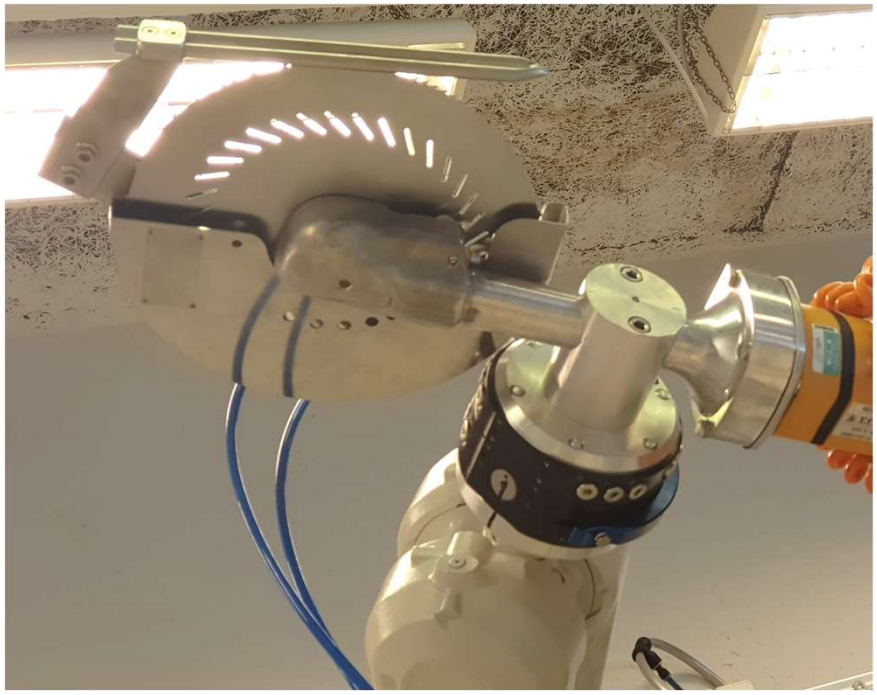
Tooling, gripping

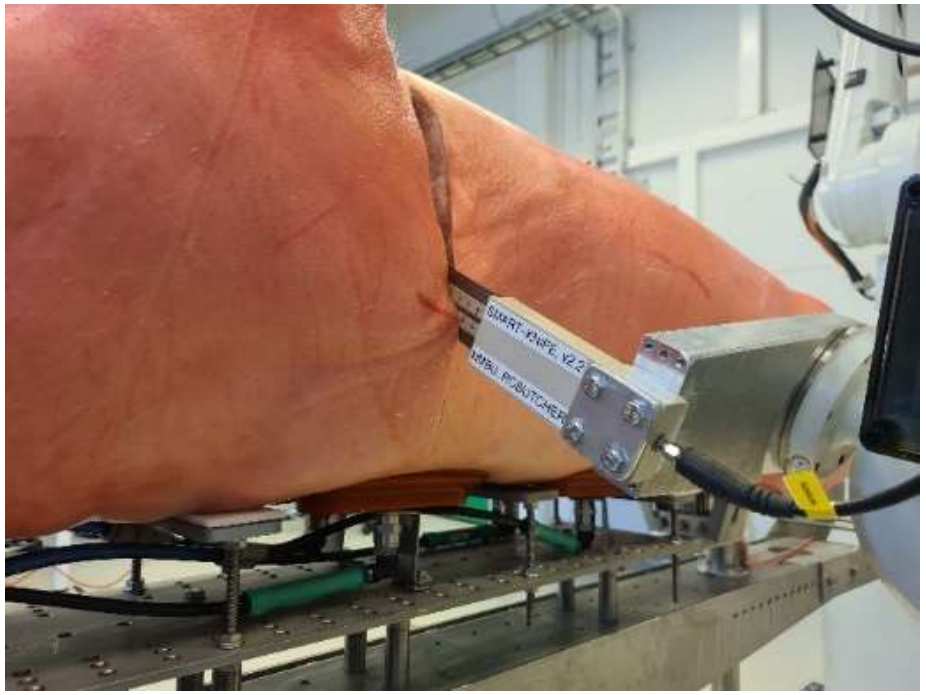




Grippers developed by DTI-DMRI and OBUDAUNI for external and internal gripping processes. *Image source:* Alex Mason, NMBU.

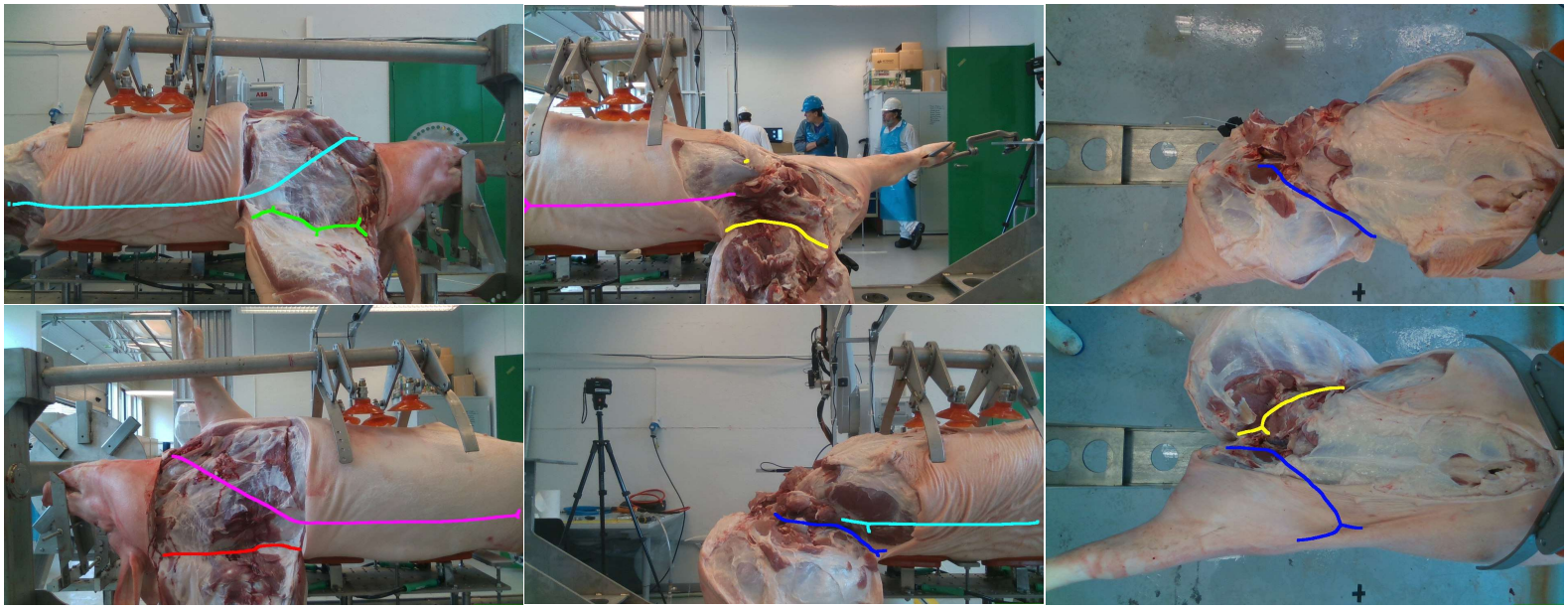
Tooling, cutting





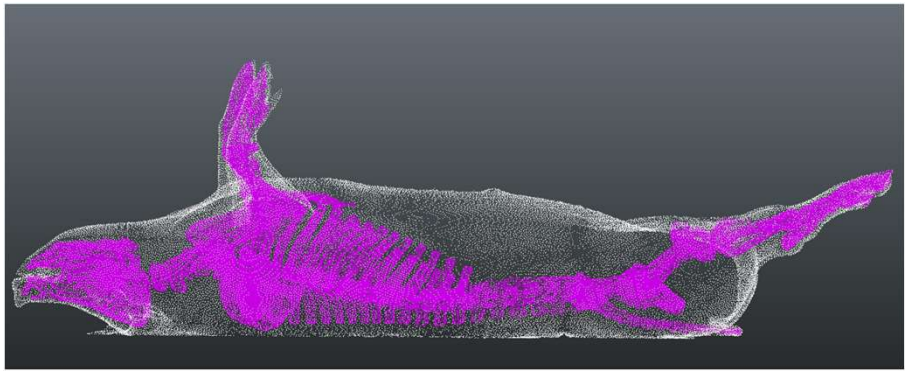
Saw and smart knife cutting tools used in the MFC. *Image source:* Alex Mason, NMBU.

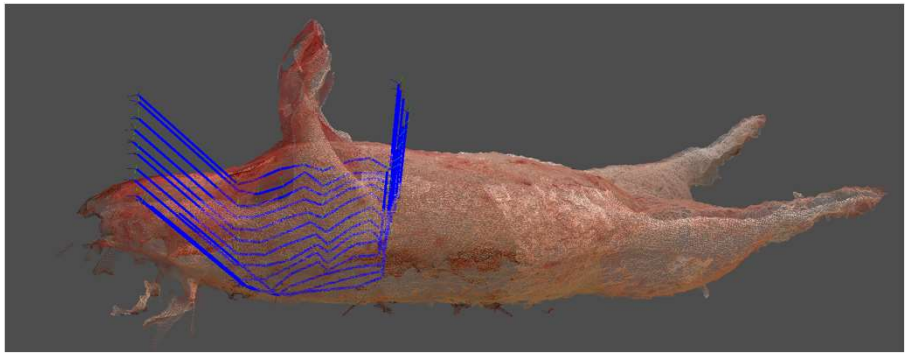
Imaging, conventional 2D labelling



Above are some examples, developed in RoBUTCHER by CIKLUM using more traditional approaches to machine vision, via human-labelling. This approach, while it can work, it lacks flexibility (e.g., difference species), customisation (i.e., new products), and requires significant resources. *Images:* Oleh Smolkin, CIKLUM-UKR.

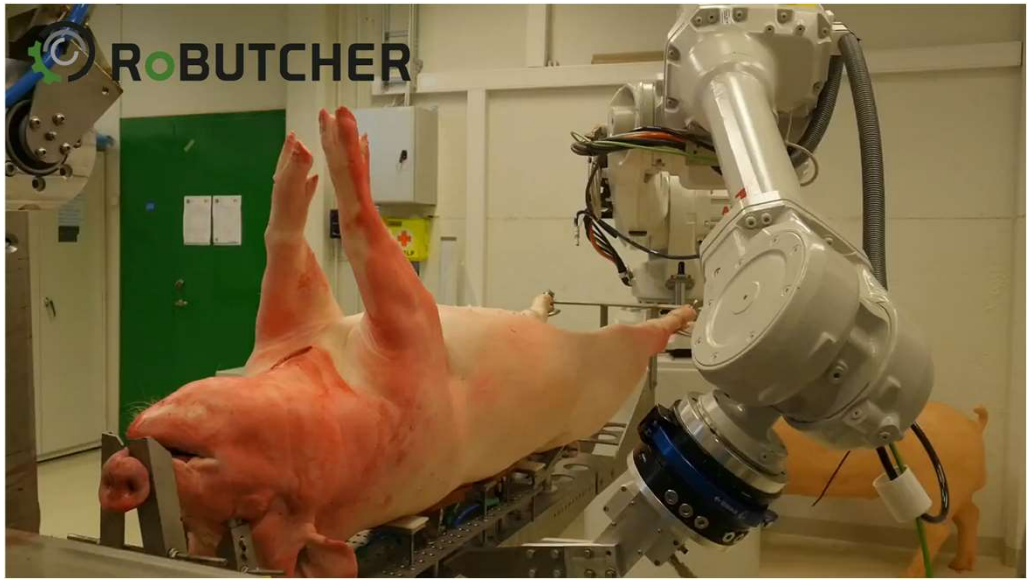
New approach, just do it all in 3D!





Currently we are working on an alternative to the conventional way of learning with AI, using anatomical information from CT data, matched to real-time 3D imagery. *Images:* Ian Esper and Alex Mason, NMBU.

Cutting examples



“Conventional” 2D labelling via expert butchers

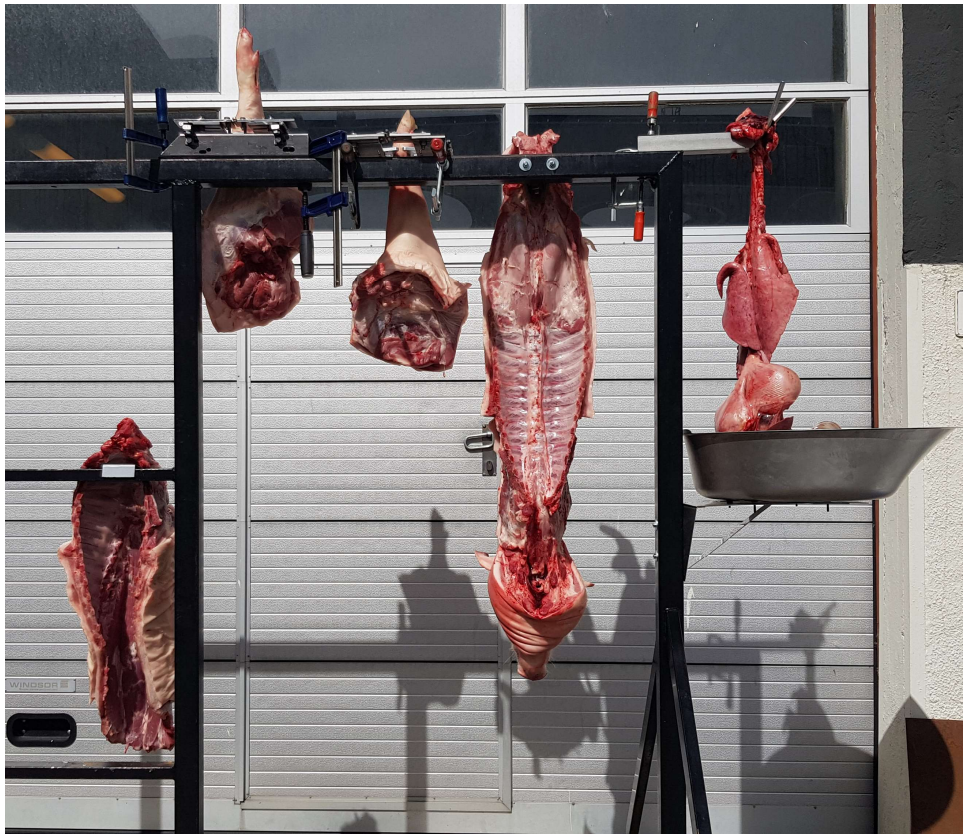
New 3D labelling via CT “Atlas”

Example of cutting, fully AI-driven, using two different methods. *Videos:* Ian Esper and Alex Mason, NMBU. Video footage from live presentation available here: https://youtu.be/8Fm5yWd2hxE and https://youtu.be/n9m2uOCVYk8

Cutting, robot vs. human butcher

Examples from trials in Germany (February 2023), comparing robot vs. human butcher shoulder *(left)* and ham *(right)* cuts. Can you tell which ones the robot has cut? *Image source:* Alex Mason, NMBU.

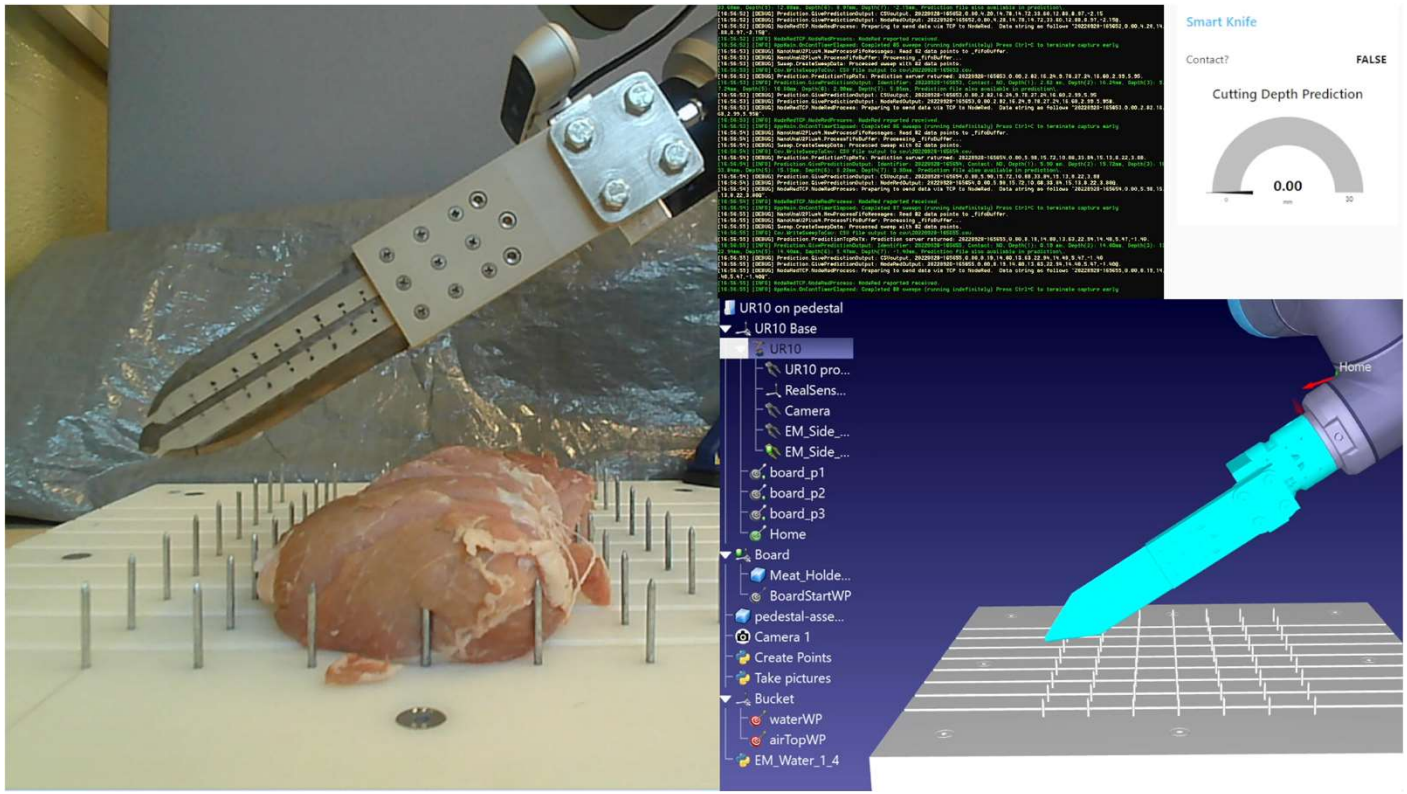
Transport and inspection, the “rack”



Development of several custom passive grippers for handling shoulder, ham, saddle, belly and gastrointestinal tract. Importantly, designed with robotic loading/access in mind.

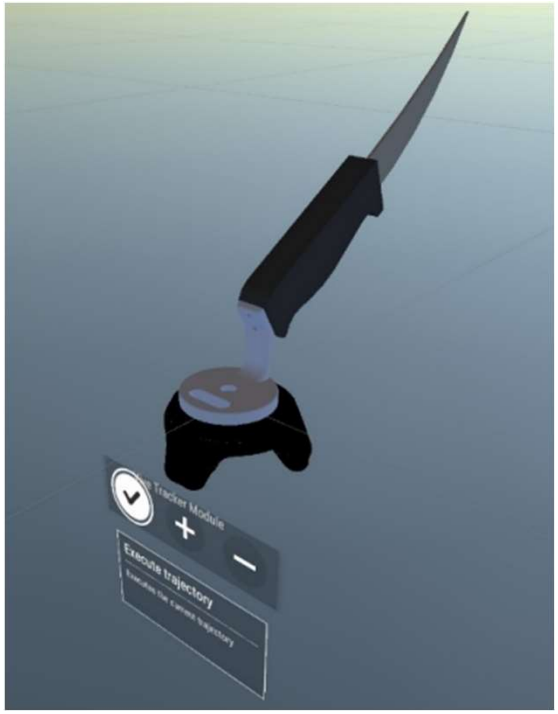
Image source: Luis Eduardo Cordova-Lopez, NMBU

Smart knife



A. Mason, O.Korostynska, L. E. Cordova-Lopez and D. Romanov, "Smart Knife: Integrated Intelligence for Robotic Meat Cutting", IEEE Sensors Journal, DOI: 10.1109/JSEN.2022.3208667, 2022. Video presented live available here: https://youtu.be/jWiFi50hz0s.

Virtual reality, human-robot interaction



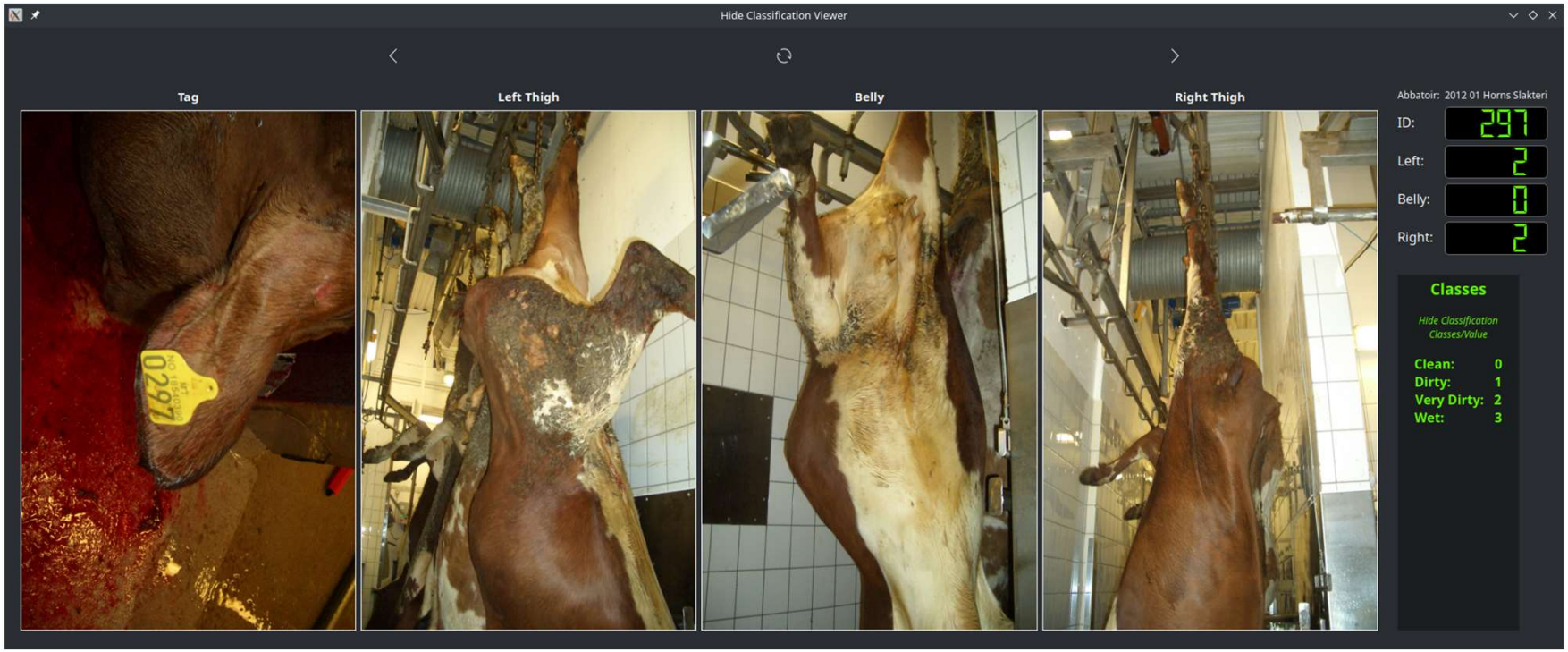
Left: Butcher using HTC VIVE headset and a bespoke trackable knife; Right: Live output from VR-world, where butcher is performing cutting in the MFC. *Images:* Haris Hadzic, BYTEMOTION. Video footage, shown during live presentation available here: https://youtu.be/AGHl4wbDQ7A.

Other initiatives we work on…

Sensor technologies

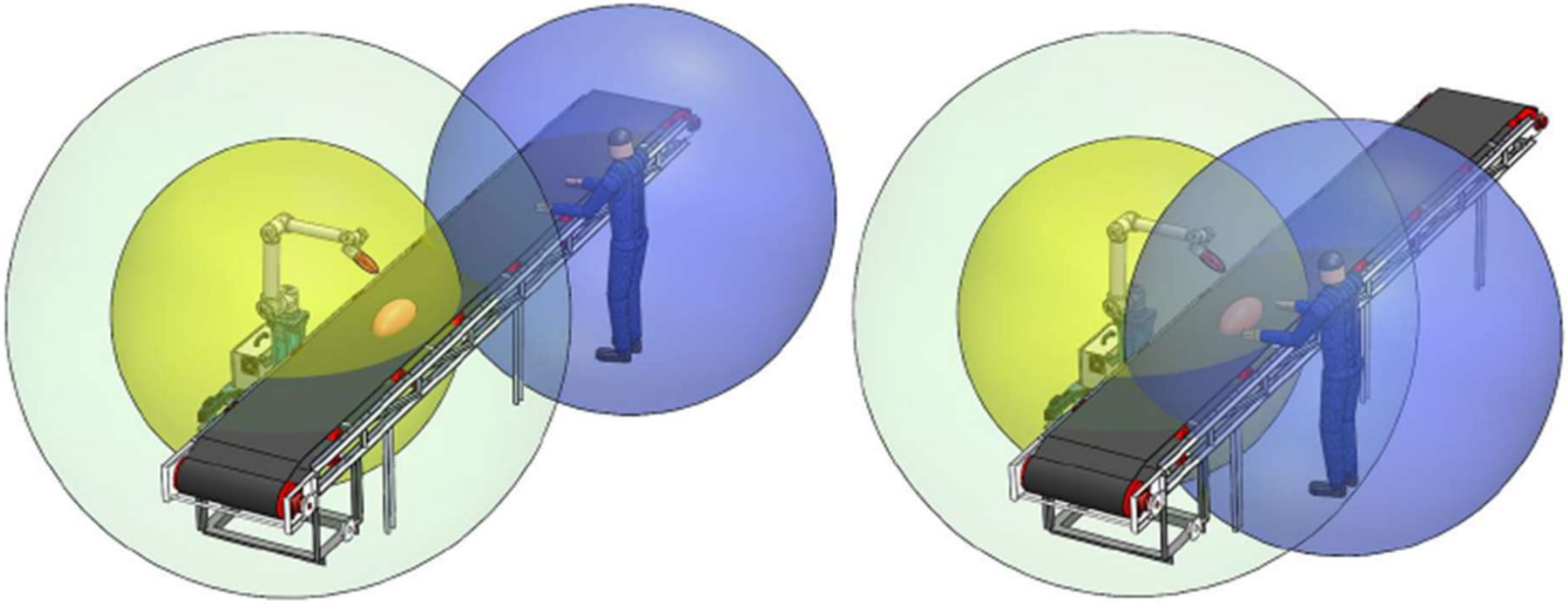
- Development of non-destructive sensors for:
  - Water activity
  - Carcass (fat) grading
  - Driploss
  - …
- Vision systems:
  - Welfare and identification

EyeAM!



EYEAM! project focuses at the moment is on hygiene, associated with automating assessment of hide cleanliness. Today, this is a manual process. *Images:* Ian Esper, NMBU.

Collaborative cutting



D. Romanov, O. Korostynska, O. I. Lekang and A. Mason, "Towards human-robot collaboration in meat processing: Challenges and possibilities", Journal of Food Engineering, vol. 331, pp. 111117, DOI: j.jfoodeng.2022.111117, 2022.

Acknowledgements

- **Meat 2.0,** and **MeaTable** have received funding from the Norwegian Research Council, grant ID 256266 and 281234 respectively.
- **RoBUTCHER** has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871631

An Invitation: If anyone should like to visit the MFC…

- The system is located in Kulmbach, Germany until mid-June 2023.
- We have “open days” to visit and see the system during development trials:
  - Thursday 27.04.2023
  - Thursday 11.05.2023
  - Thursday 25.05.2023
  - Thursday 01.06.2023
- Just drop me an email to get in touch (alex.mason@nmbu.no).
- Follow the project via its website: https://robutcher.eu/

Thanks for listening. Discussion, questions and follow-up?

Contact: alex.mason@nmbu.no

Follow RoBUTCHER: https://robutcher.eu/