



# Vision-Guided Robotics for Blue Crabmeat Picking Automation



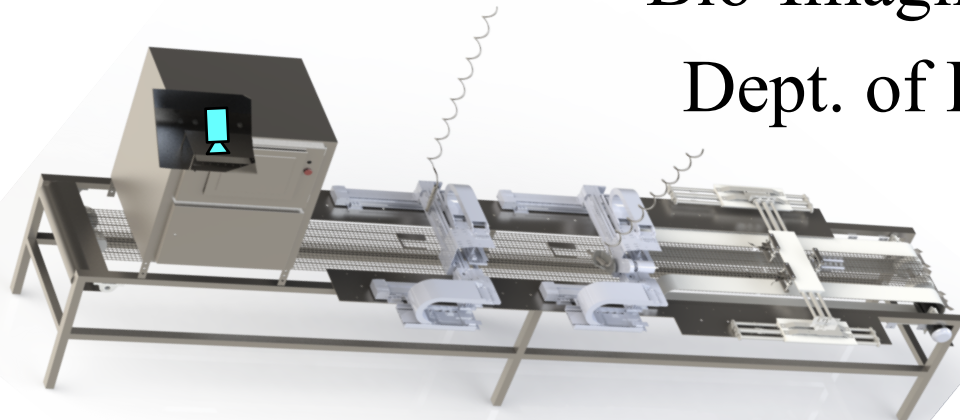
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Bio-Imaging & Machine Vision (BMV) Laboratory

Dept. of Bioengineering, University of Maryland

2020 NSF-NRI PI meeting

2/27/2020, Arlington





# Background & Significance



**Crab cake is delicious,  
very delicious, but ...**



**Professional crabmeat pickers are very hard to get...**



Videos captured at J M Clayton Co., 06/2019



# Background & Significance



## Seafood Market Values (NOAA 2017):



\$679.2 Million



\$678.7 Million - 2<sup>nd</sup> most valuable seafood in U.S



\$488 Million



Salmon : \$460 Million



\$3.99/lb



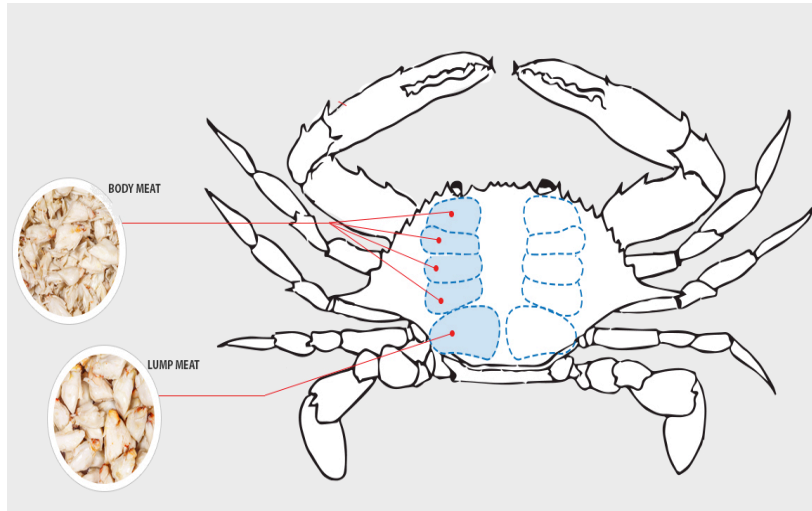
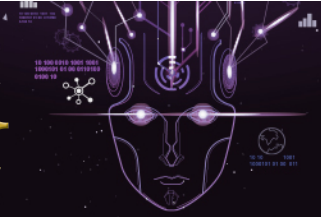
\$42.5/lb

Value-added even more in restaurants !!





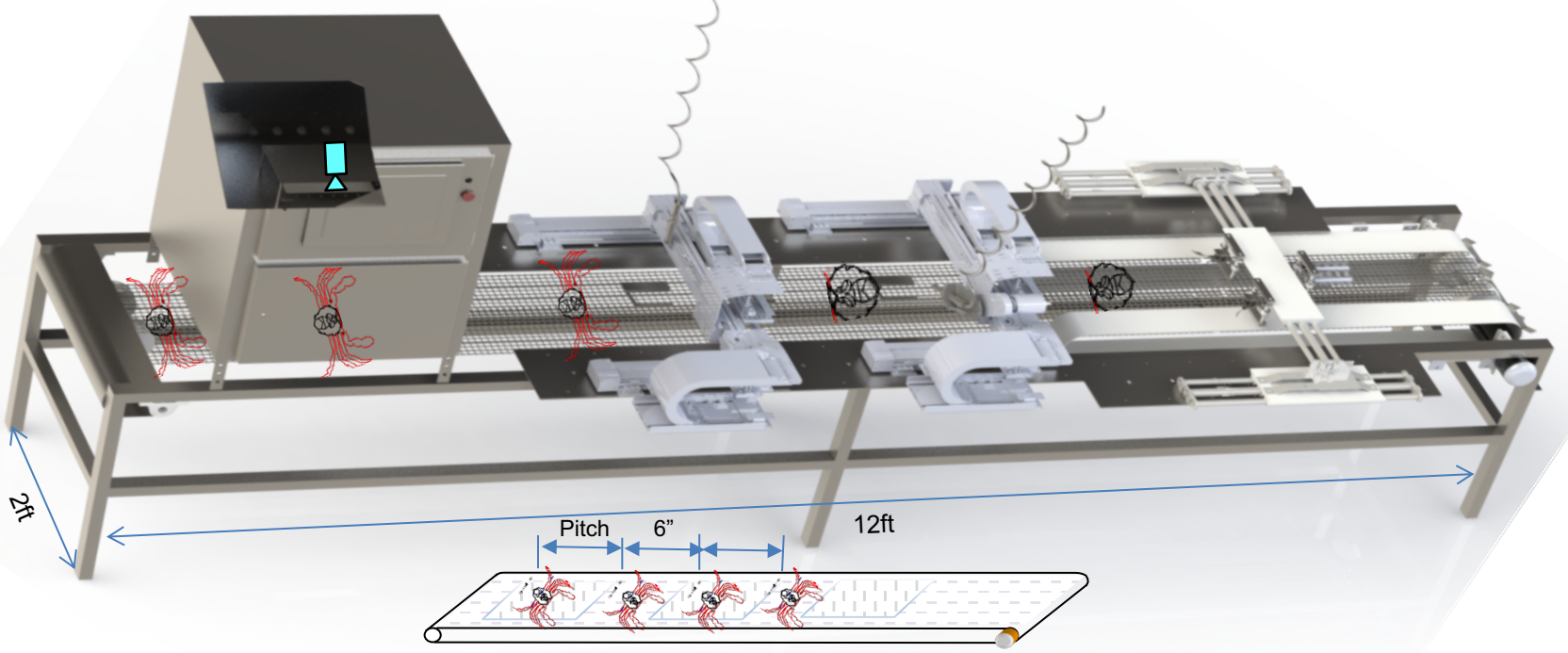
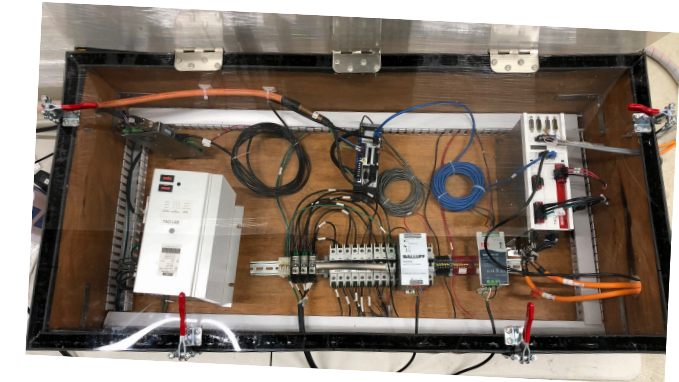
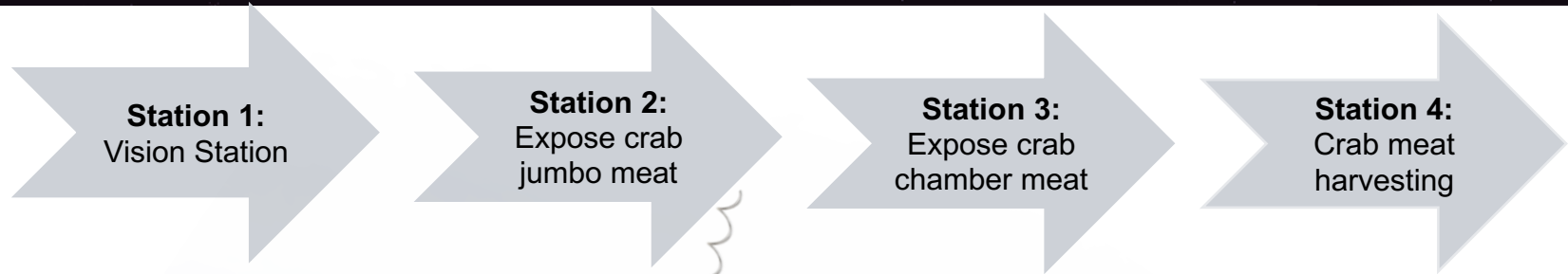
# Objectives



- ❖ **To design an automated vision-guided machine to harvest crab jumble lump meat and chamber meat**
- Target to Maryland iconic seafood
- Alleviate labor shortages
- Enhance food safety and productivity (~15 fold)
- Precision & smart food manufacturing



# System overview

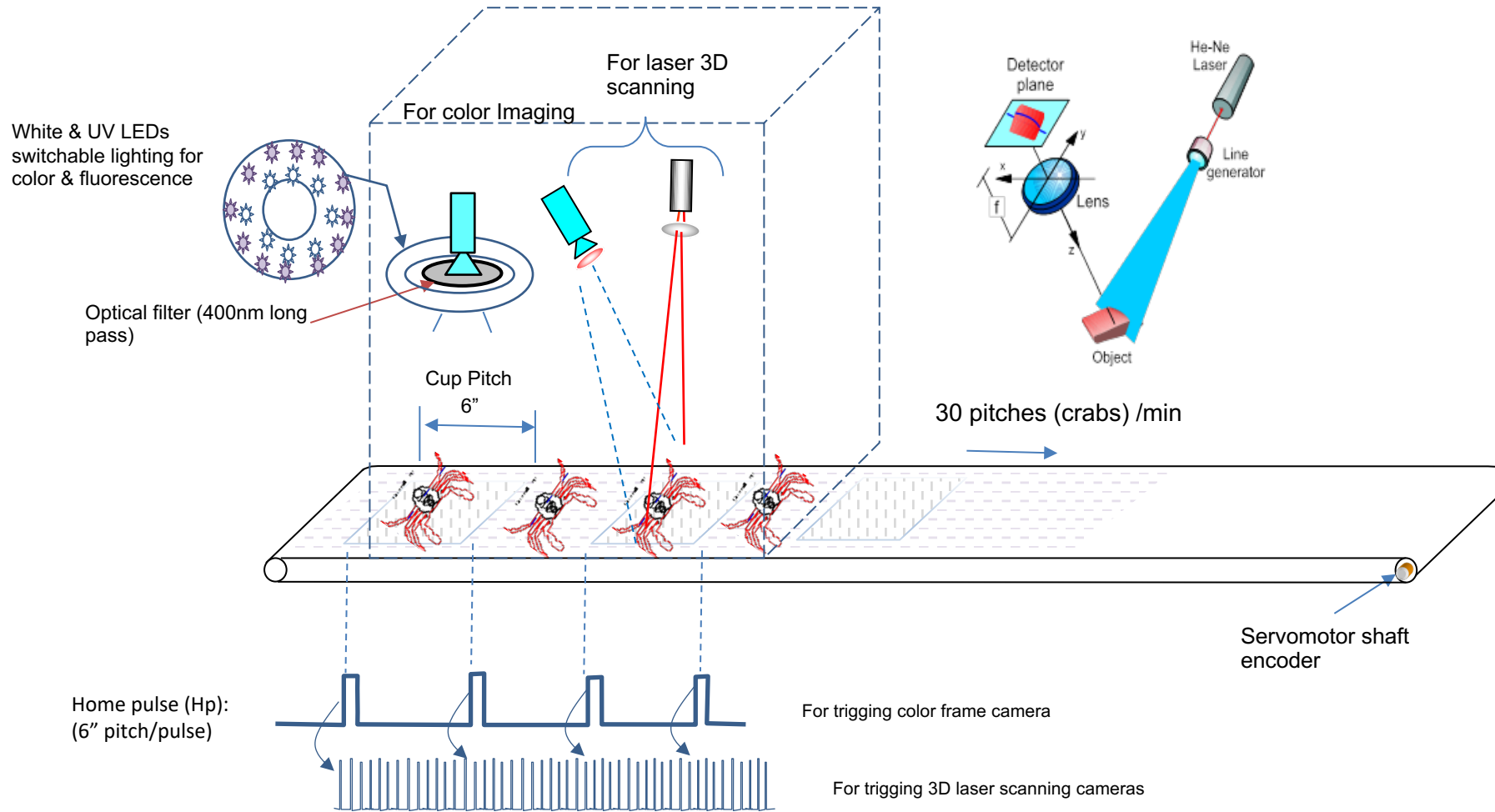


Encoder in servomotor for synchronization and tracking

Robotic crab disassembly line (Concept, under development)



# Vision Station Overview

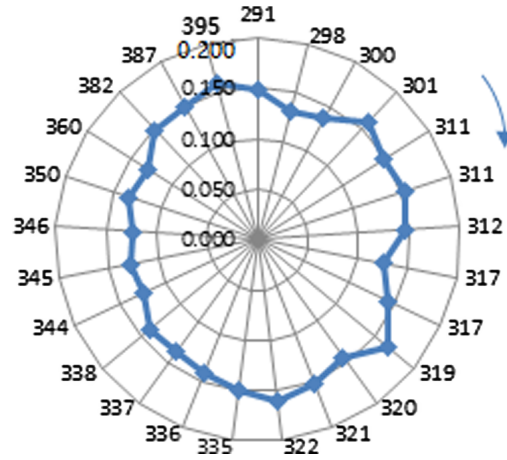
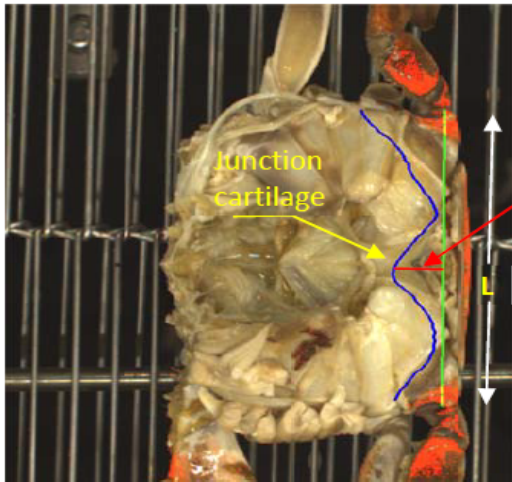




# RGB image guided crab leg removal



## Preliminary studies

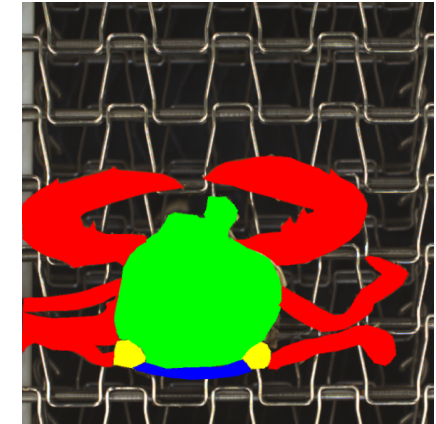


- The length between two backfin knuckles has linear relationship with the crab size and cartilage joint position

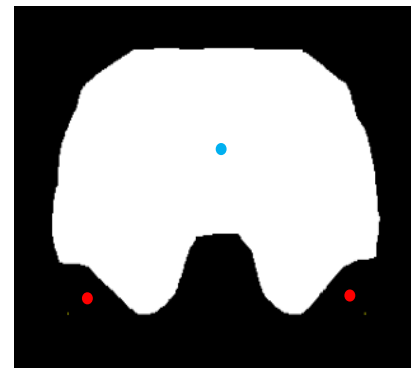
## Methodology



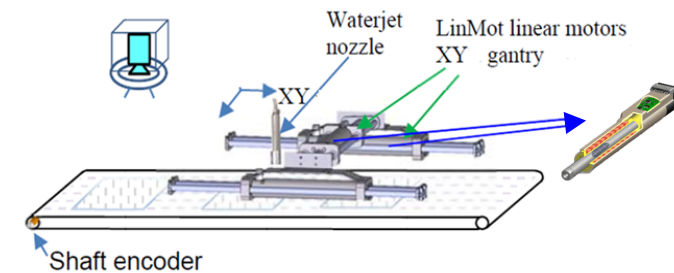
Step 1. raw color images



Step 2. image segmentation



Step 3. template matching



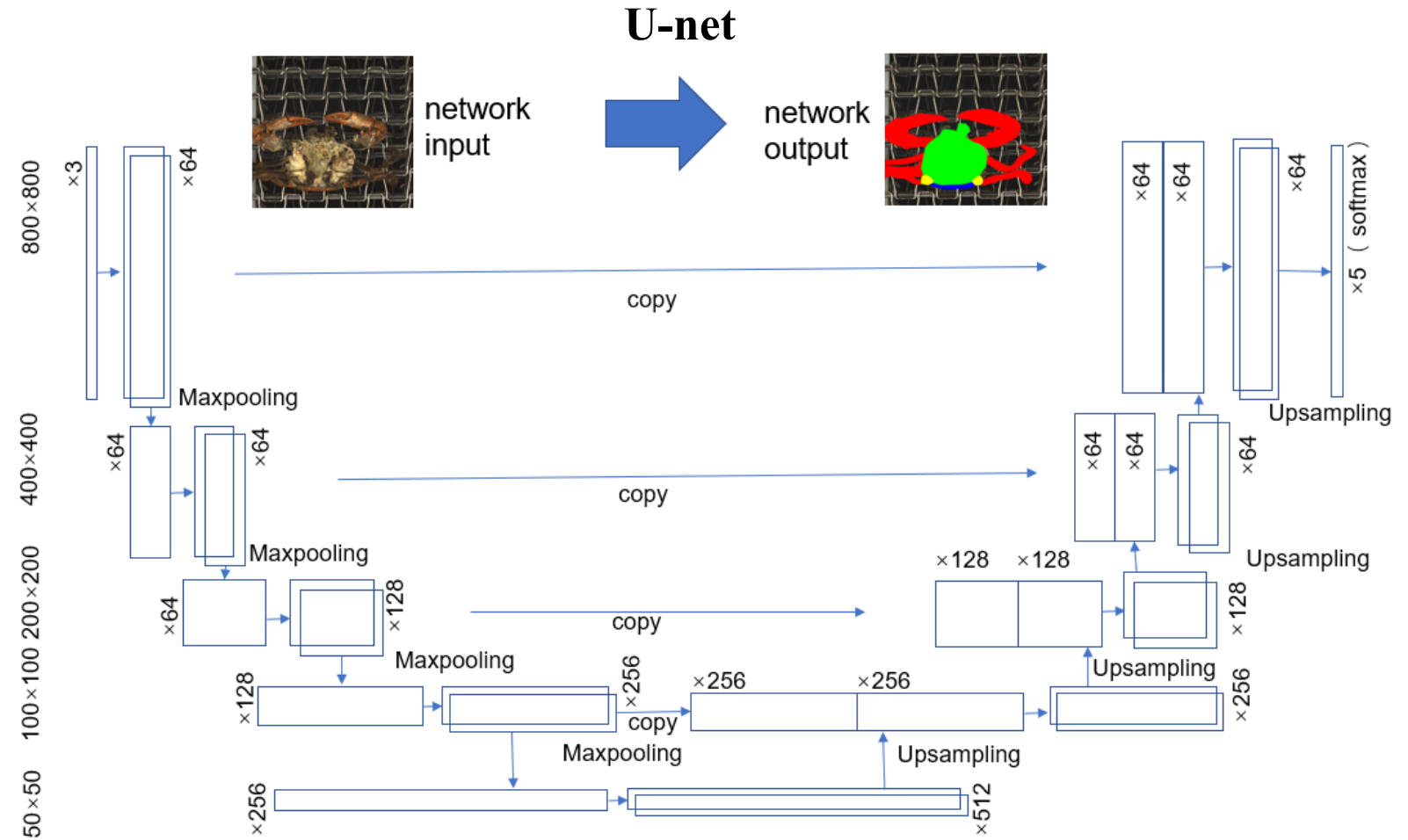
Step 4. customized XY gantry station and movements

**Label:**  
30 raw crab images

**Augmentation:**  
**Rotation:**  $\pm 25$  degree  
**Zoom in/out:**  $\pm 20\%$

**Training data:**  
9000 crab images

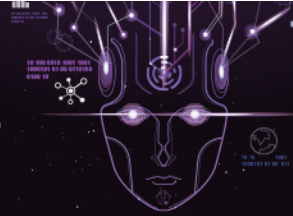
**Test data:**  
50 raw crab images







# Semantic segmentation



## Confusion Matrix

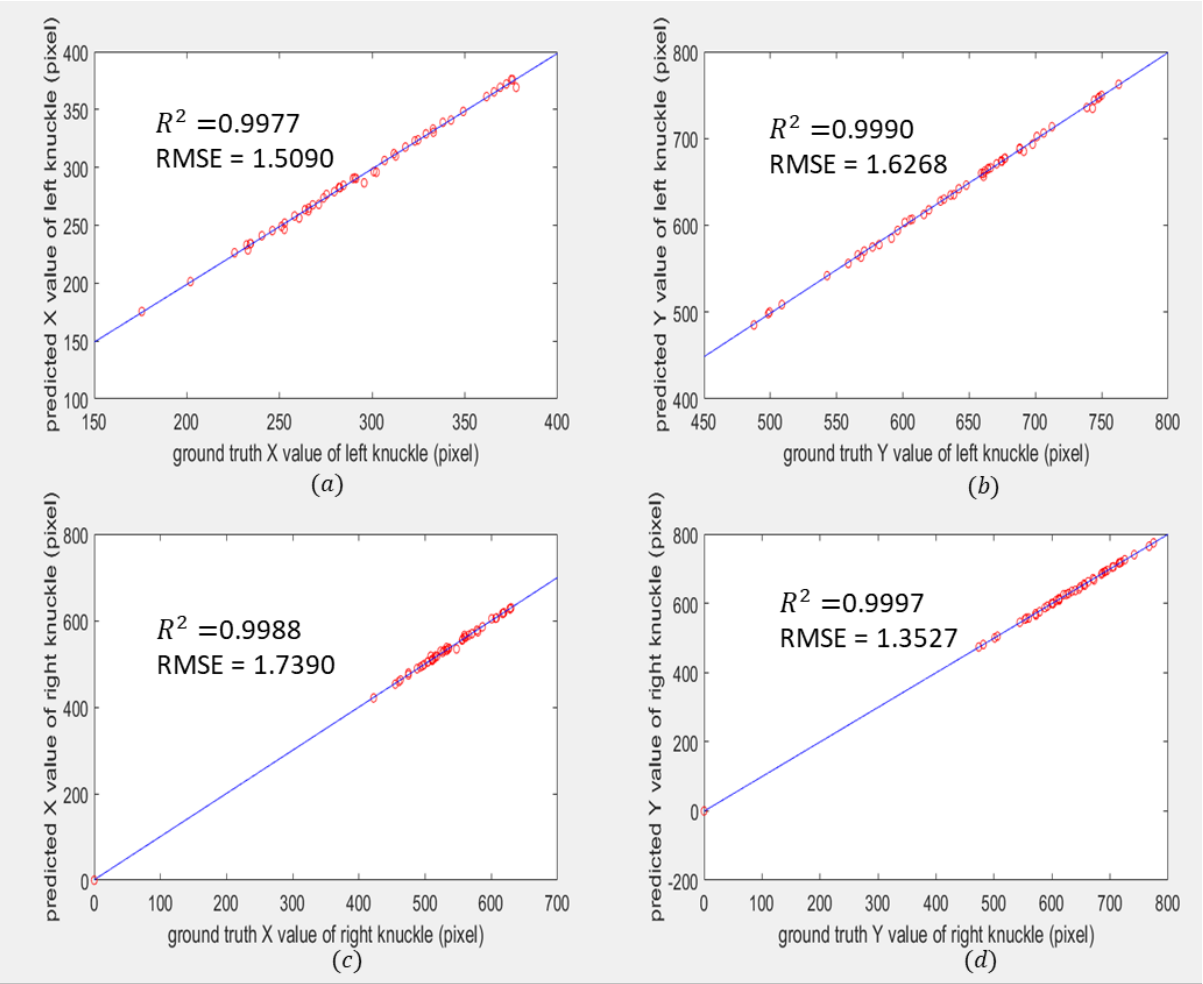
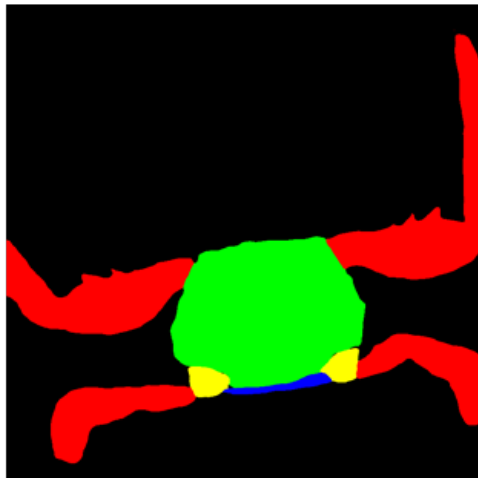
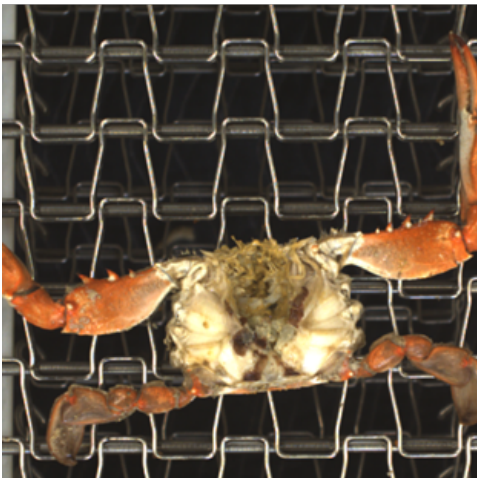
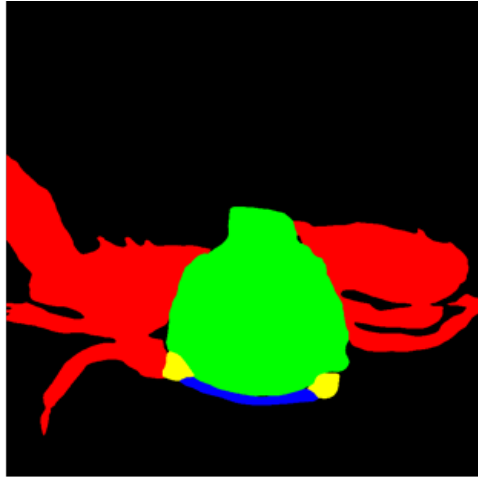
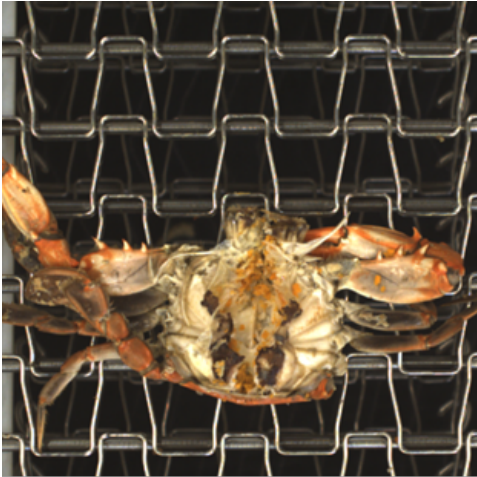
(50 raw crab images)

Average pixel level classification accuracy: **0.9843**

Prediction \ GT	Background	Legs	Crab Core	Backfin Knuckles	Back Bones
Background	<b>99.16%</b>	3.62%	1.15%	3.46%	8.05%
Legs	0.62%	<b>95.78%</b>	0.69%	1.42%	0
Crab Core	0.15%	0.53%	<b>97.61%</b>	3.54%	3.83%
Backfin Knuckles	0.03%	0.07%	0.27%	<b>89.29%</b>	0.72%
Back Bones	0.03%	0 %	0.29%	2.29%	<b>87.39%</b>

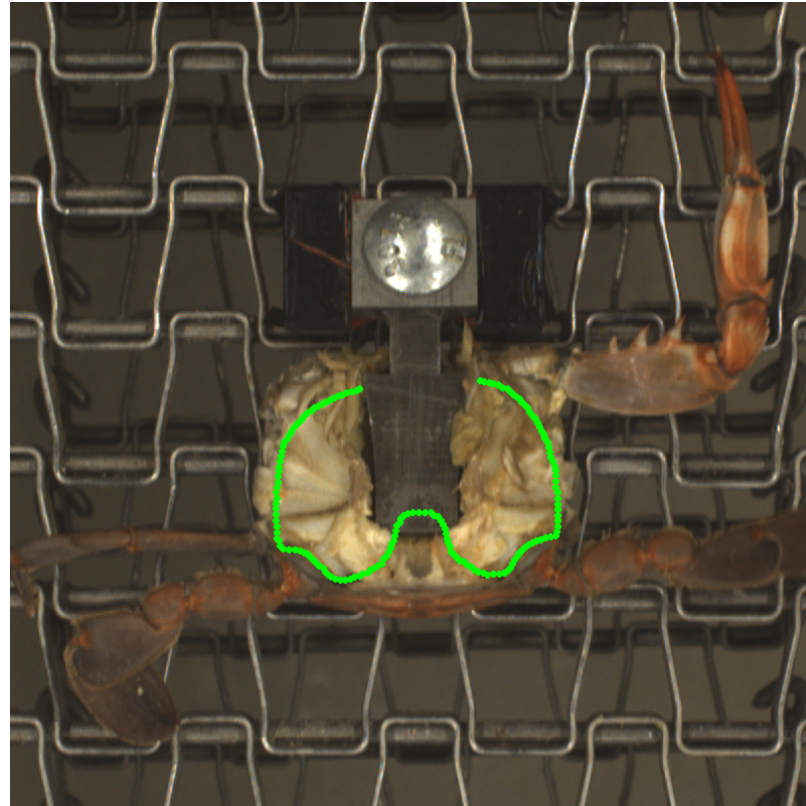
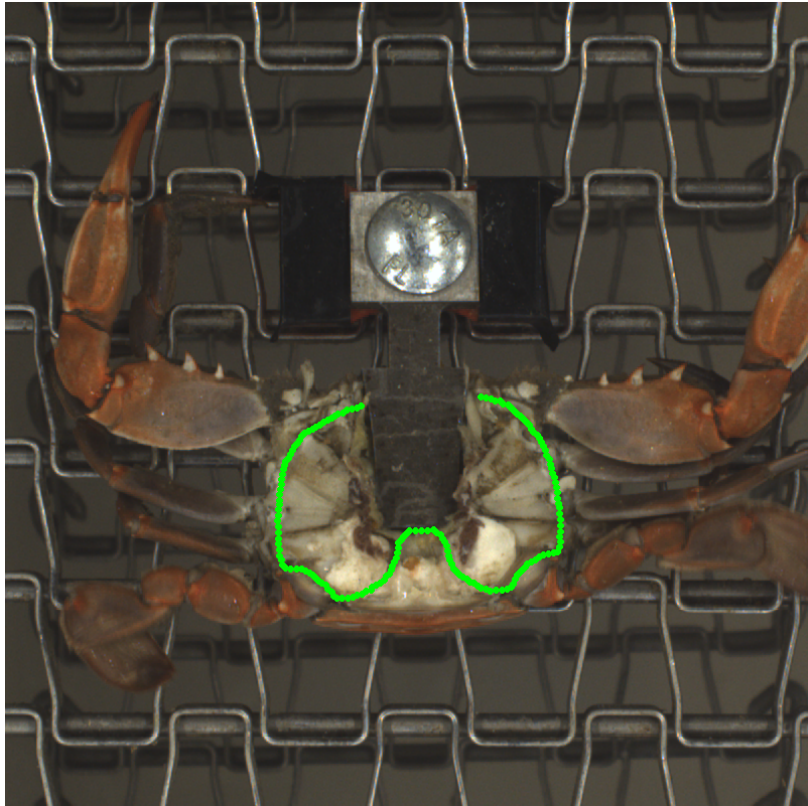


# Semantic segmentation



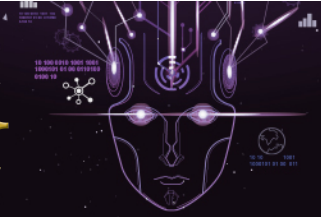


# Template matching

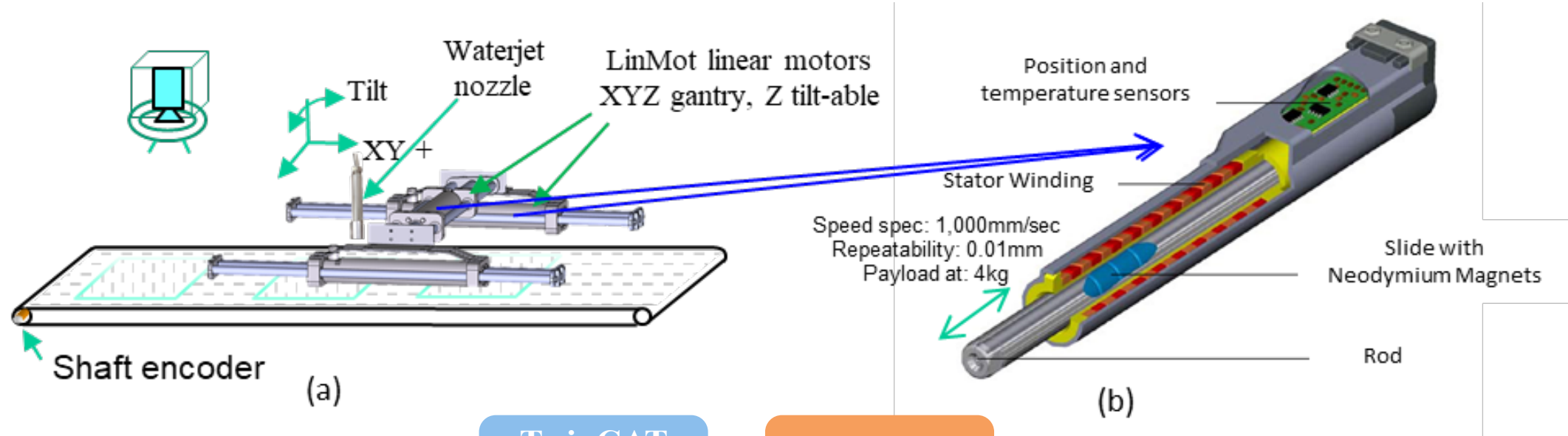




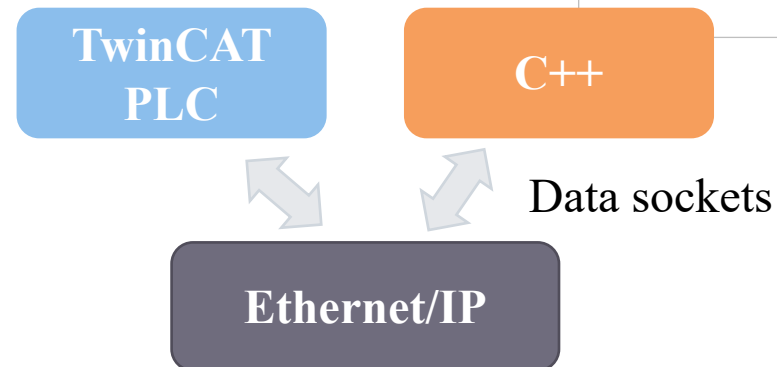
# Design of 1<sup>st</sup> gantry station



## Hardware design:



## Software implementation:

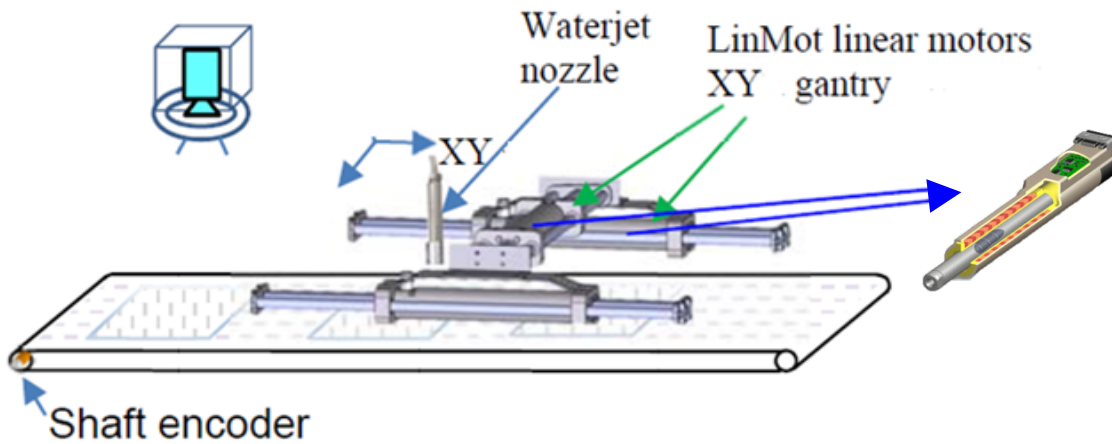




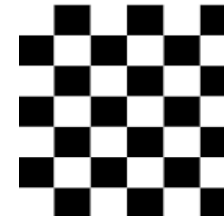
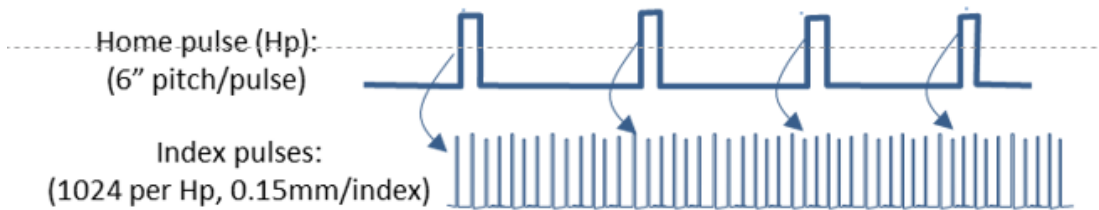
# Design of 1<sup>st</sup> gantry station



## Calibration between camera and 1<sup>st</sup> gantry station



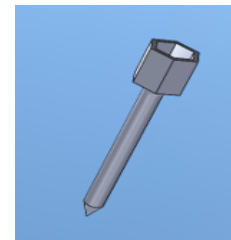
Special stainless steel crab mesh conveyer w/ shaft encoder for synchronization and pixel registration.



**Checkboard:** camera intrinsic and extrinsic parameters



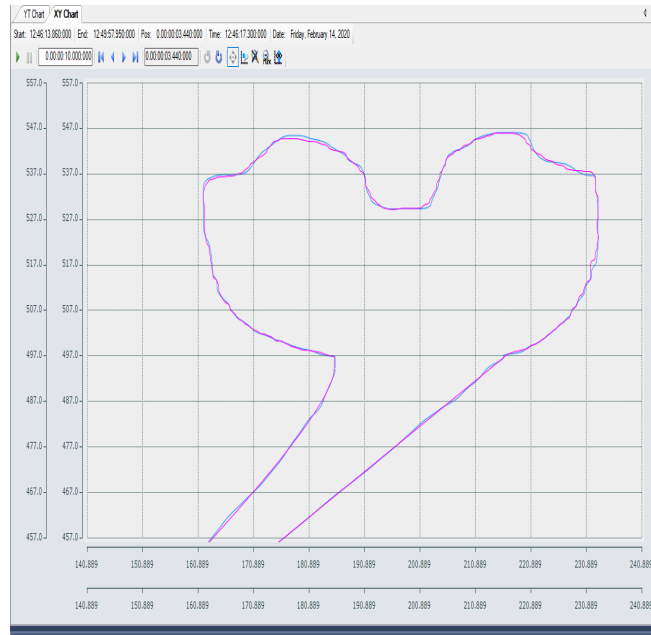
**Hold down system design:** keep crab in place during conveyor movement and cutting



**Gantry -> camera frame calibration**



# Design of 1<sup>st</sup> gantry station



1. 125 set points to represent the trajectory
2. Synchronize XY movements with PLC time stamps
3. Linear interpolation between the movement of two set points
4. Position and velocity level PID control fine tuning

- Red line represented set trajectory positions
- Blue line represents accurate trajectory positions



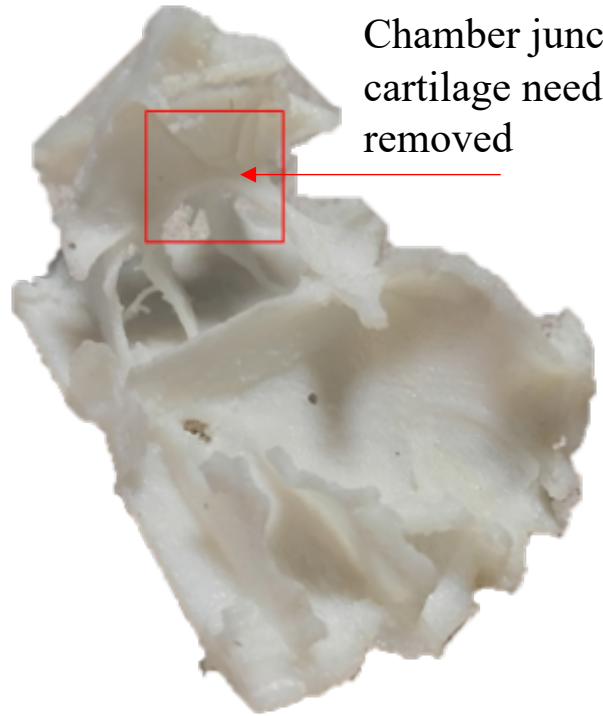
# Design of 1<sup>st</sup> gantry station



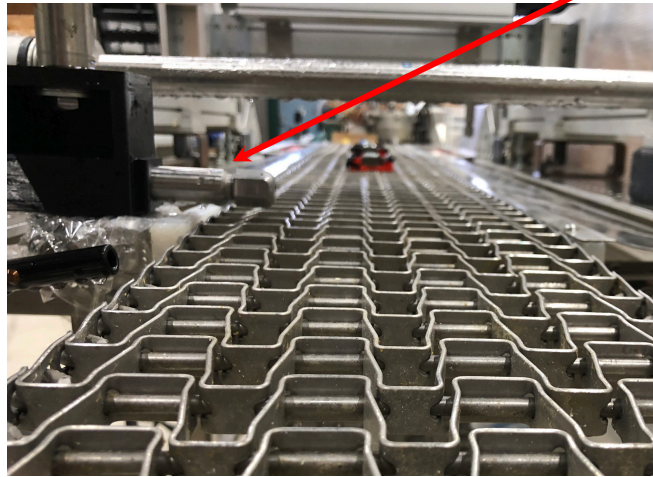
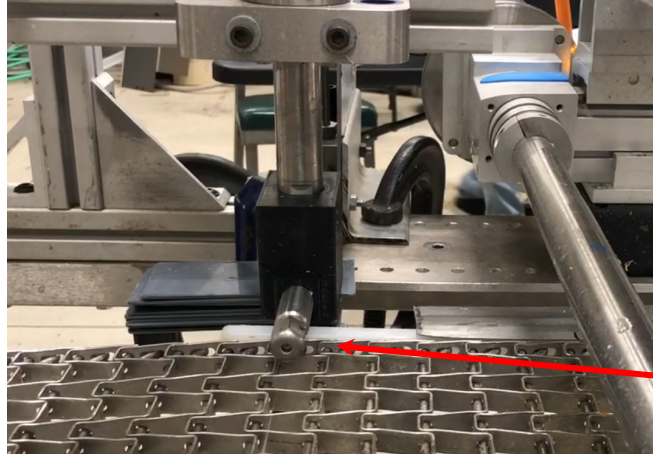
Video is shown in original speed



# 2<sup>nd</sup> station: z-cut for chamber cartilage removal



Chamber junction cartilage needs to be removed

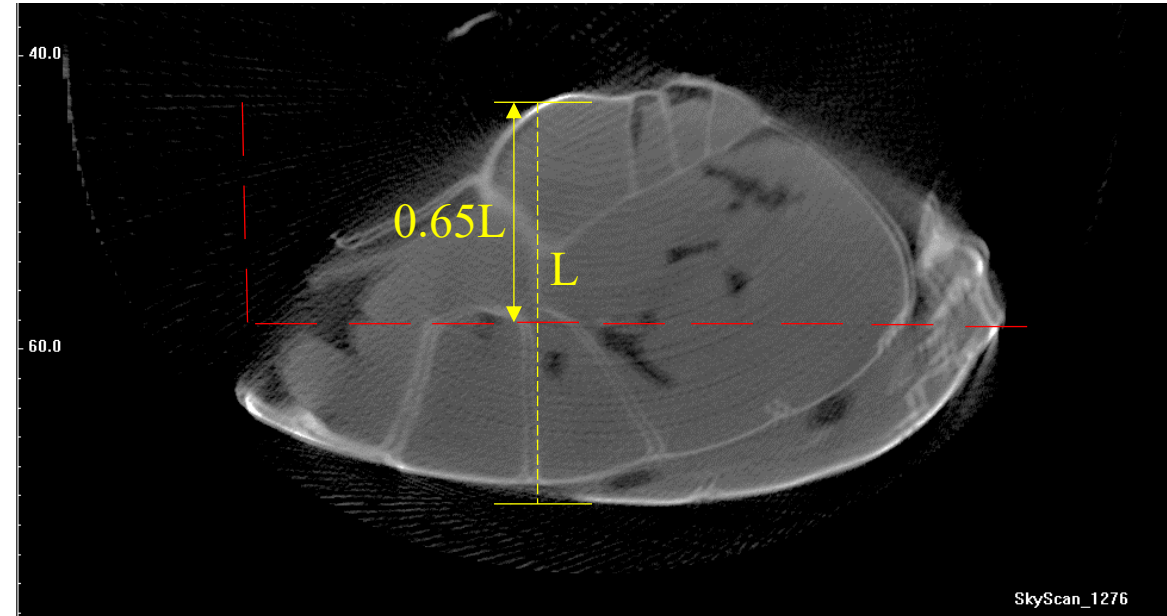
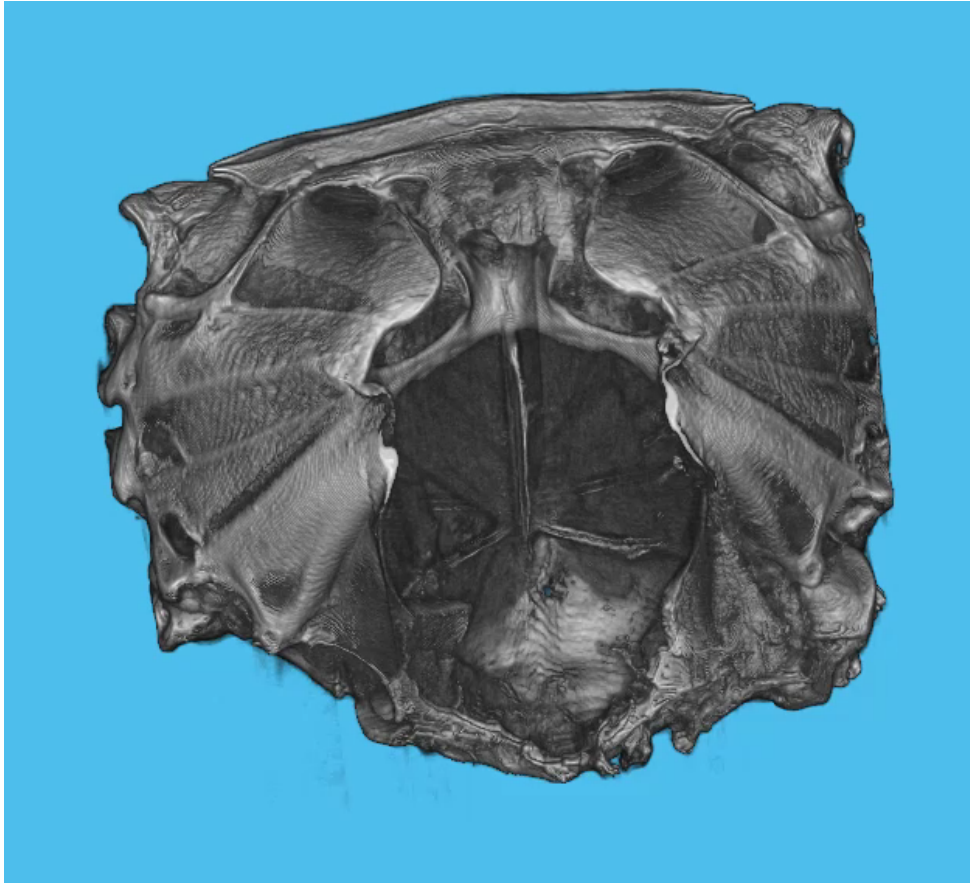


A Linmot motor holding a waterjet nozzle moving in z-direction to remove the joint cartilage.





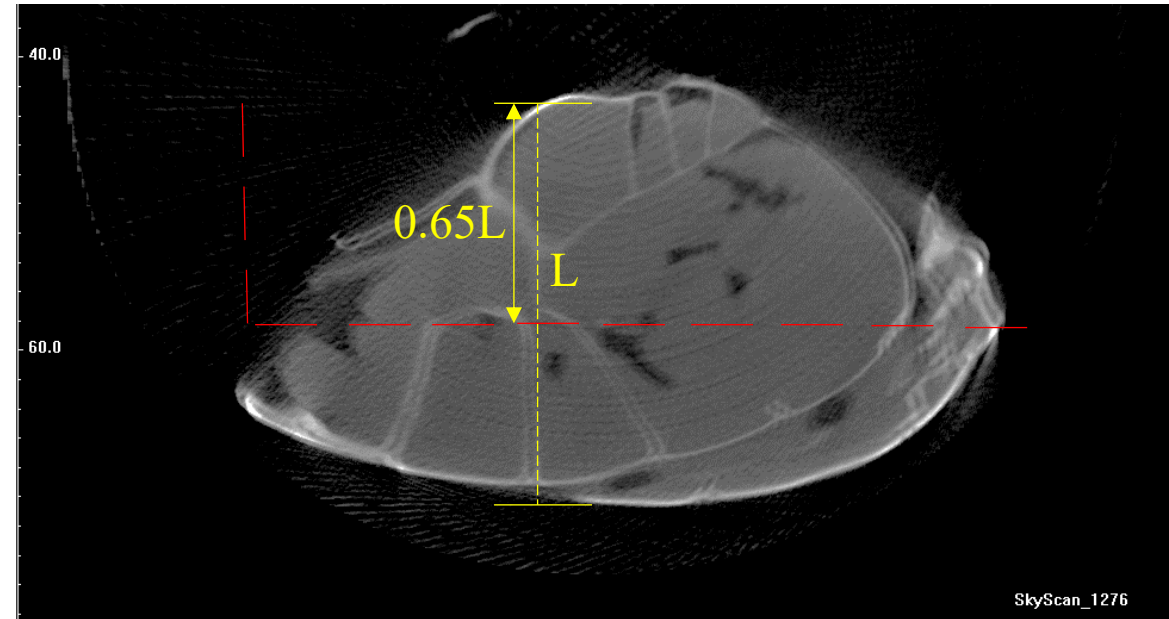
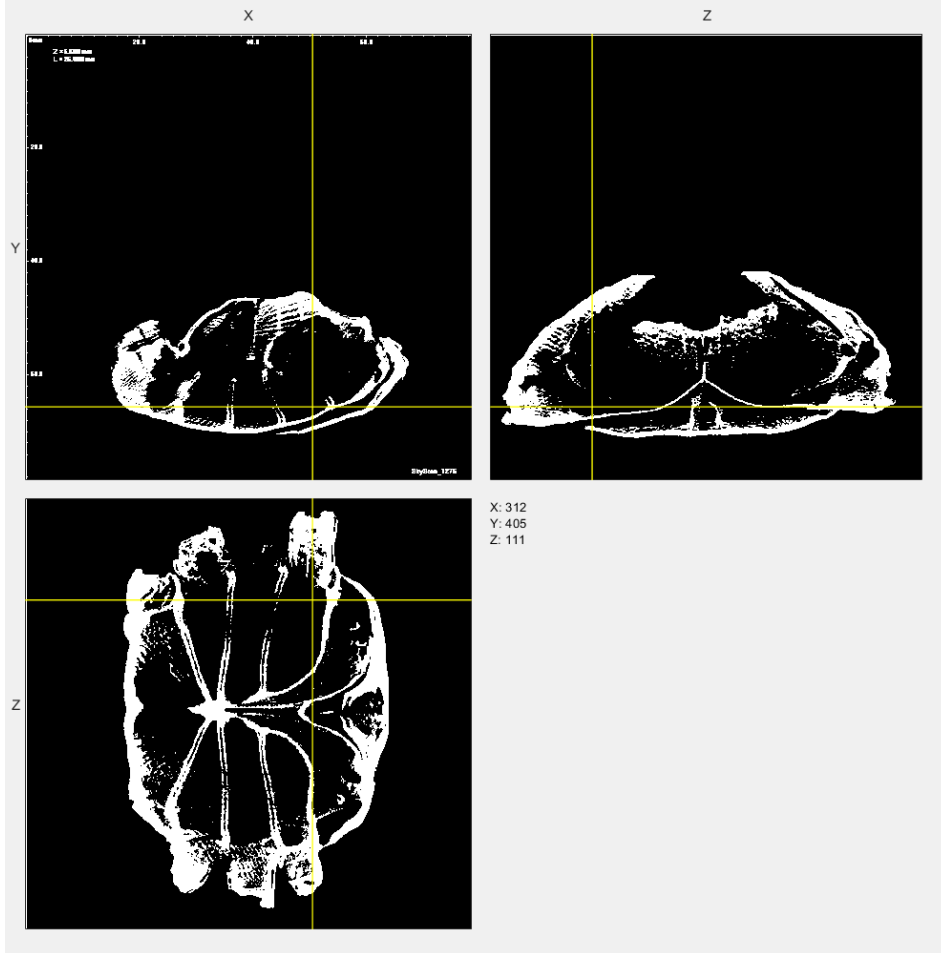
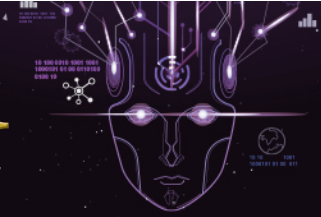
# Offline Micro-CT modelling



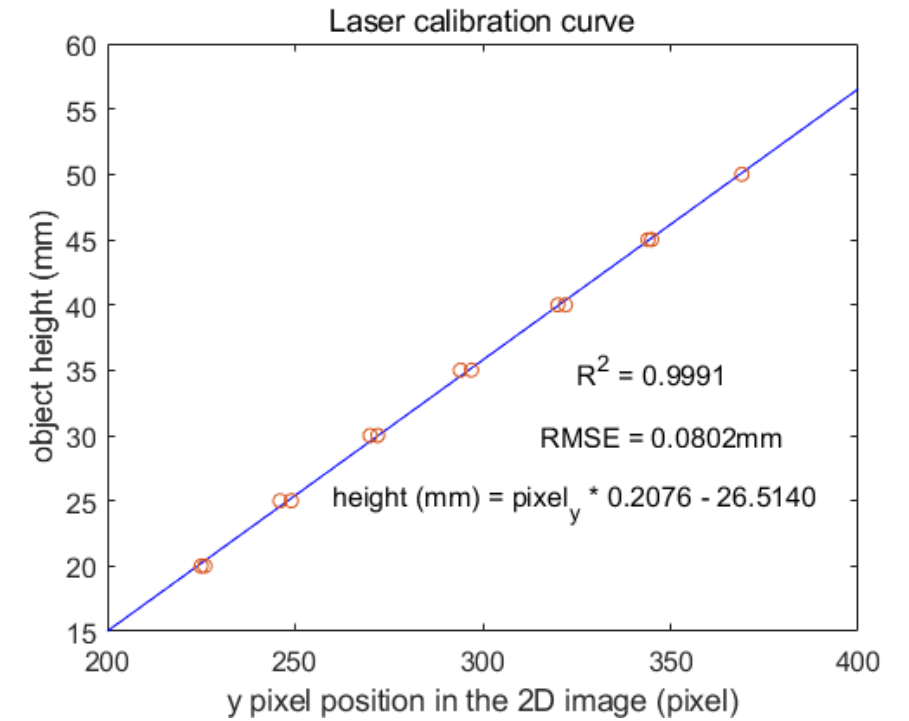
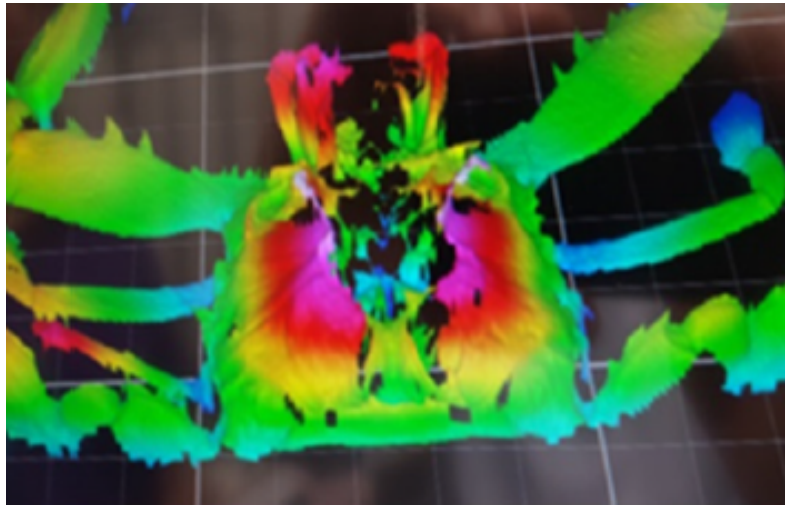
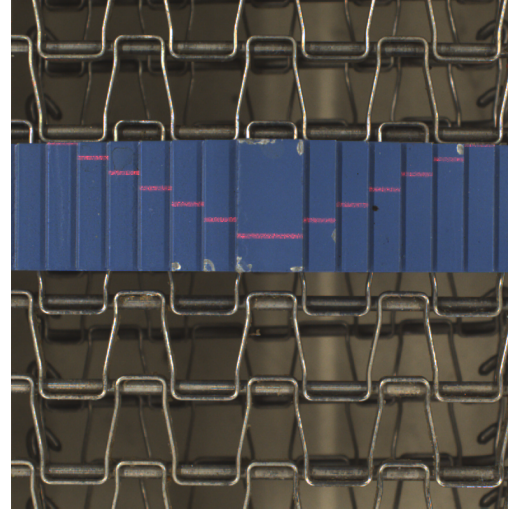
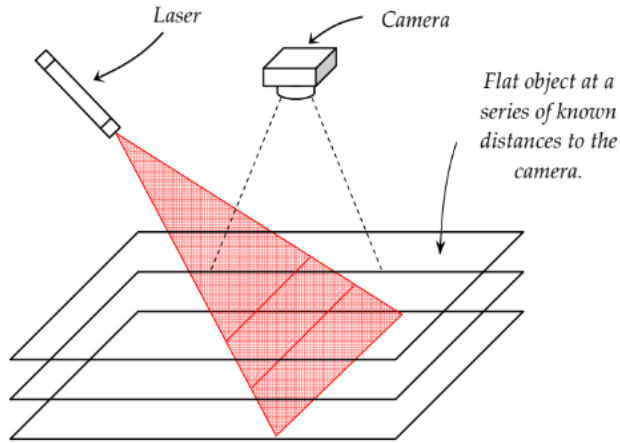
1. The intersection point is where we want to remove the crab junction cartilage
2. The position of the junction cartilage has linear relationship with crab heights
3. Crab heights depends on the season of crabs

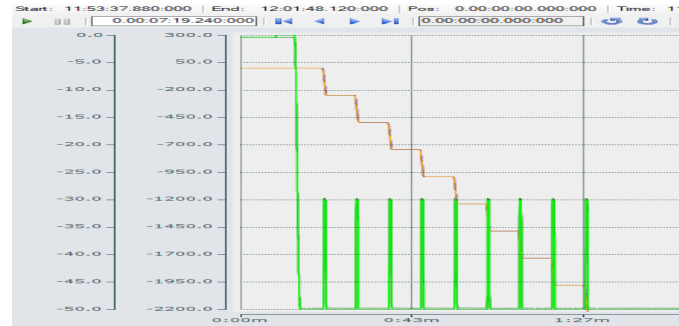
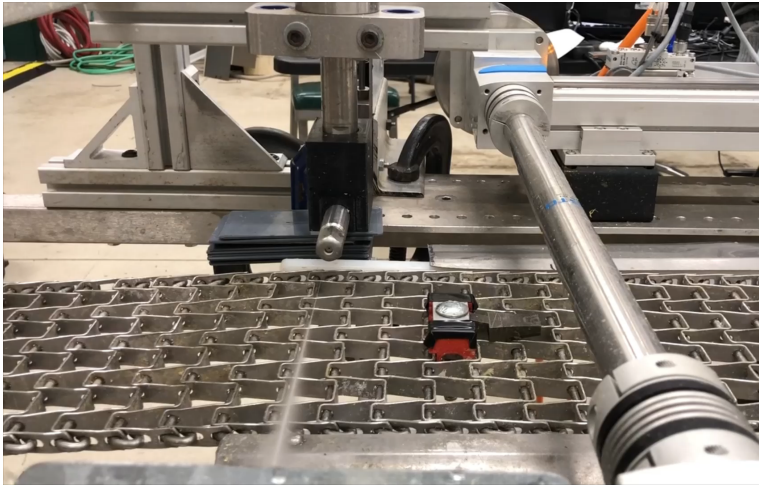


# Offline Micro-CT modelling

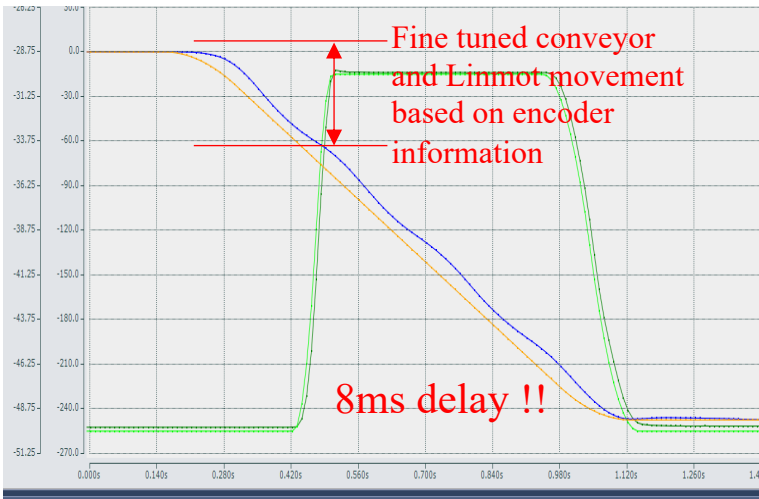


1. The intersection point is where we want to remove the crab junction cartilage
2. The position of the junction cartilage has linear relationship with crab heights
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In order to accomplish a dynamic z-cut, we adjusted the acceleration and deacceleration to match the movement between conveyor and z-cut linear motor



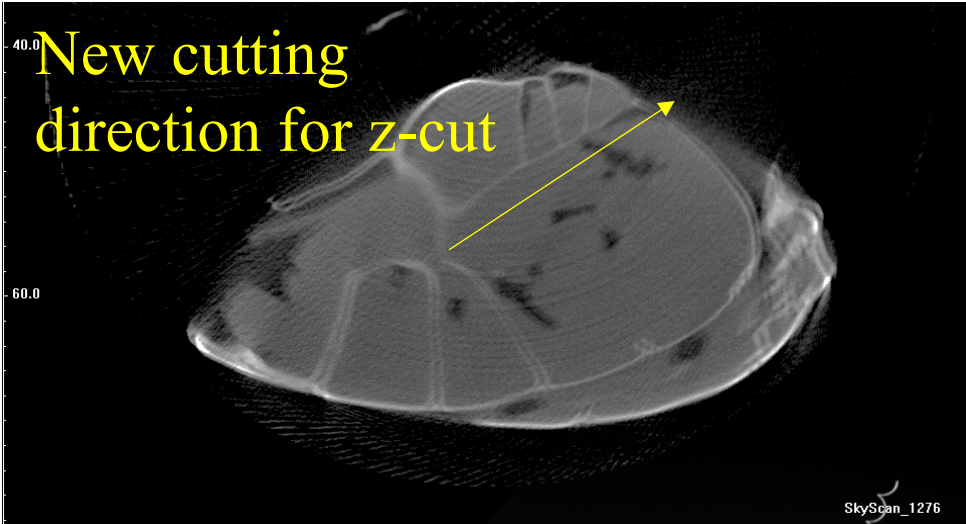


# Future designs

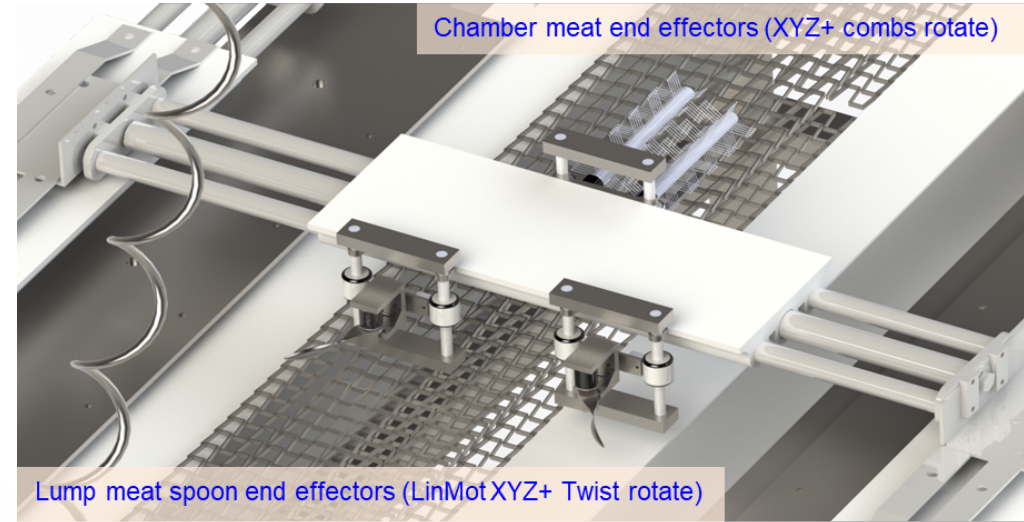


1.

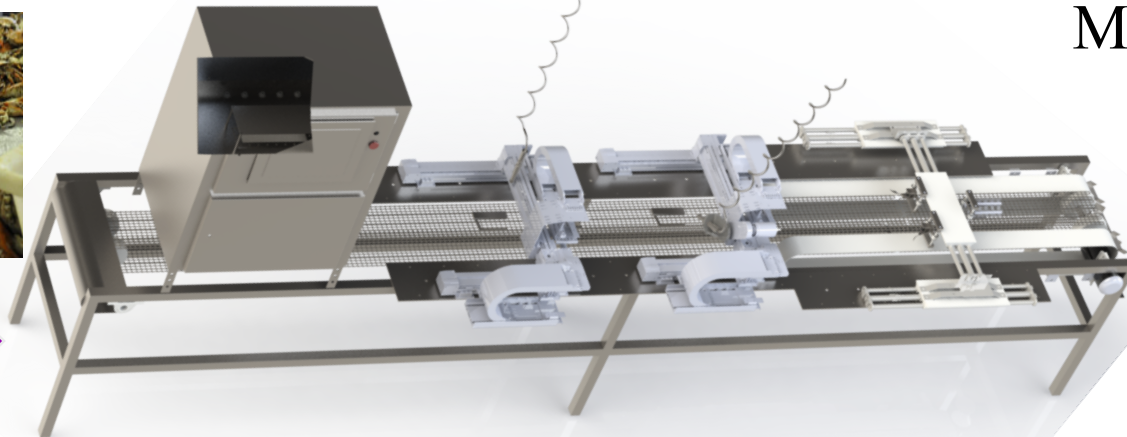
New cutting direction for z-cut



2.



3.



Meat final harvesting

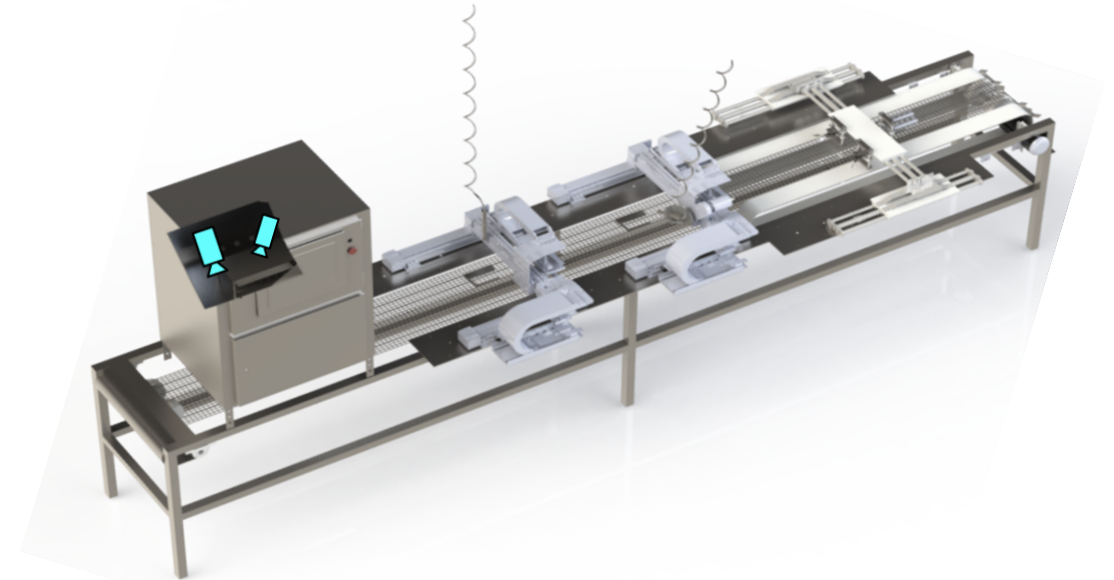
Material Loading



# Summary



## Engineering Future Foods through Vision Automation



Computer Vision

+

Robotics



**Labor Intensive**

**Automation**



Thank you



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