Final Report

Beef striploin fat removal - Stage 2A)

Twin-head laser and ultrasonic 3D fat-lean boundary profiling sub-system

Project Code
2021-1077

Prepared by
Koorosh Khodabandehloo

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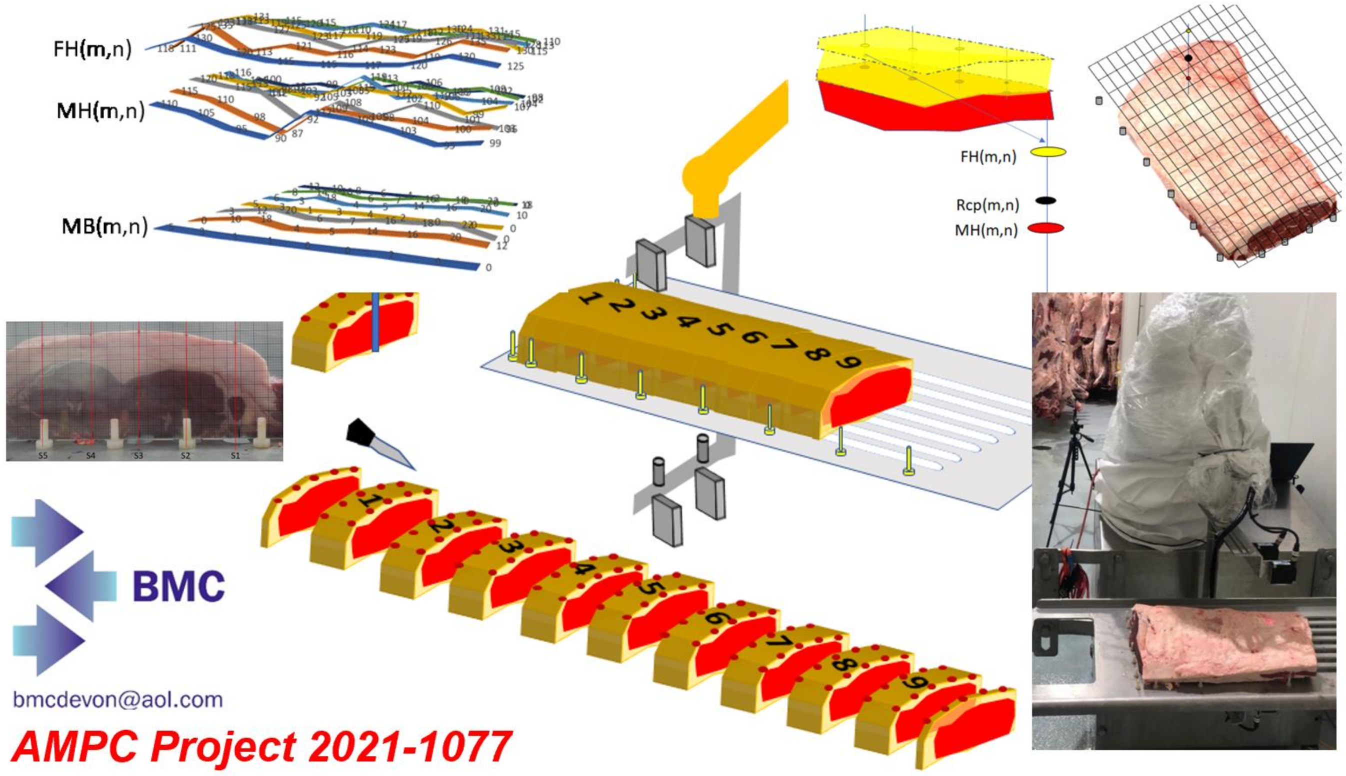

FH(m,n)
MH(m,n)
MB(m,n)
Rcp(m,n)
BMC
bmcdevon@aol.com
AMPC Project 2021-1077

1.0 Executive Summary

Stage 2A project has been considering the specific validation of the ultrasonic and laser profiling of beef striploin primal pieces in discrete 3D measurements of meat height and fat thickness, appropriately referenced in a robot geometric workspace. A twin-head solutions demonstrates the first step to improving measurement cycle over the whole volume of small and large striploin primal pieces.

The work expands on the previous R&D supported by AMPC including:

- Stage 1 of the research feasibility, AMPC Project 2016-1032
- Stage 2 of R&D, AMPC Project 2019-1045

Stage 2A was proposed and has refined the understanding of the sensing process to show the capability of the ultrasonic and laser measurements of fat and meat dimensions for the controlled separation of fat to leave a uniform layer on the primal to specific user defined thickness. The limiting factor in the validation process has been the inaccuracies of manual process used to compare with the measurements by the robot using electronic sensors.

The use of a ruler, as a best approach, had been the specified alternative method; but this has revealed to be constraining in the validation process. Nevertheless, the results table below provides the best outcome, which indicates the robotic measurement process to be appropriately capable of providing the necessary sensory date for the control of fat trimming.

The project has reached its objective to assess the capability and the application process of the robotic 3D profiling of the striploin with measurements as presented in this report.

Special thanks are due to AMPC for funding this project and the input and support for JBS Beef City and University of Southern Queensland are gratefully acknowledged.

2.0 Introduction

Trimming to achieve a specific fat thickness on a beef striploin primal is a highly manual process requiring significant human skill and judgement. The sensory processes that allow determination of the fat thickness and the positioning of the striploin in the geometric space relative to a work datum are essential to automation developments. With the use of ultrasonic measurements in a manner that determines profile data in the robot frame of reference, the process of cutting automation may be realised without the need for laborious referencing. It is important to state, that once the capability is reached, the level of control to archive target fat cover specification on a beef striploin will be beyond what is achievable manually as human sensors could not have the possibility to gauge fat thickness, except in a notional manner by feeling the top of the fat over the profile of the striploin. Moreover, the control over the trimming process removing fat is limited to the accuracies that may be achieved by the manual manipulation of a knife or a cutting tool being driven through the fat along the path that removes variable fat thickness to leave a known specific thickness of fat behind on the lean meat.

The work of two specific AMPC projects, Stage 1 (Project 2016-1032) and Stage 2 (Project 2019-1045) have been reported over the development period prior to the start of this project to validate the sensory sub-system by implementing a twin-head ultrasonic and laser profiling unit for integration with a robot that can perform measurements to determine fat cover profile facilitating controlled trimming. Figure 1 and 2 provides the approach for Stage 2A.

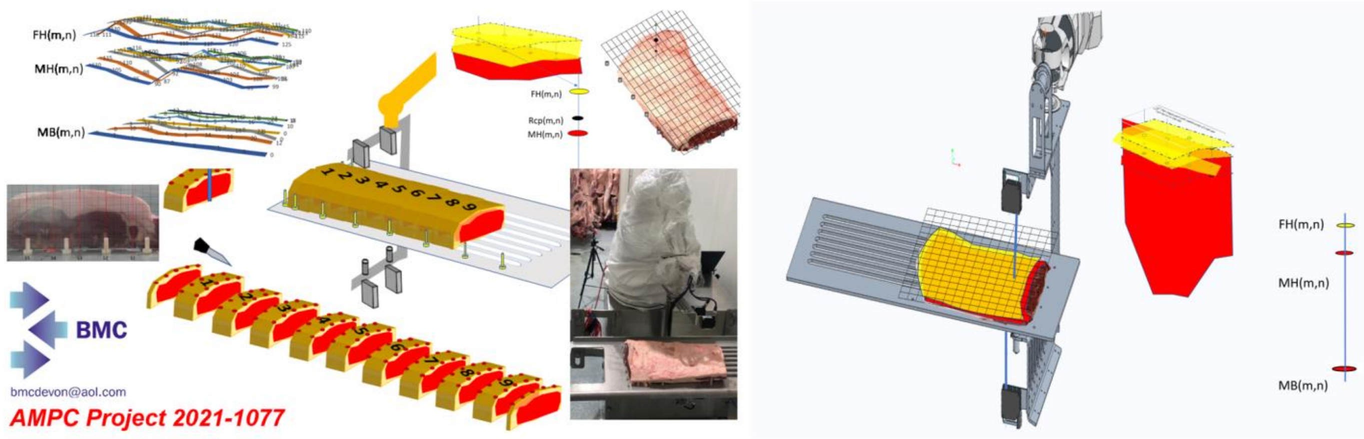

Figure 1: Stage 2A - Robotic profile measurement of meat and fat heights in a robot workspace.

Under Stage 2A, the outcome also provides the necessary development pathway to reach a much-desired industry solution for a solution that proves the separation of a variable thickness of fat in a controlled manner as a fundamental step to demonstrate fat trimming automation comparable to what is currently performed by people on beef striploins.

3.0 Project Objectives

The objective is to reach the implementation and testing of a twin-head laser and ultrasonic 3D fat-lean boundary profiling subsystem. This is to support controlled thickness fat trimming post project end. The specific goals are:

- Consolidation of sensory subsystem and process developed in Stage 2 with the international team.
- Implementation of single head sensor unit (based on ultrasonic and laser devices of Stage 2.
- Implementation of scanning unit extending existing BMC equipment with two sensor heads, each head including one ultrasonic and one laser sensor.
- Testing adjacent to the line, measuring no less than 20 range representative striploin primal pieces, with the new twin head sensing unit and current equipment. Dissentions and manual measurements to show capability with resolution at ±2mm for 85% and ±4mm for remaining 15%.

4.0 Methodology

The approaches adopted in previous Stages have been carried through in the execution of Stage 2A.

Developed technology that are of appropriate cost will be used, filling gaps in know-how and technology integration to achieve the target solution at the operating speed considered acceptable. Solution that are simple and capable of being maintained by existing staff in meat plants will be applied.

System definition will be modular for trouble shooting and with the appropriate technical specification that can be understood readily by any qualified engineer. System interfaces are to have simple configuration for operators, avoiding complicated arrangements to secure safety and operability, meeting all standards and regulation.

5.0 Project Outcomes

Figure 2 presents the physical set ups for the single, twin, and more (up to 7), sensor arrangements respectively.

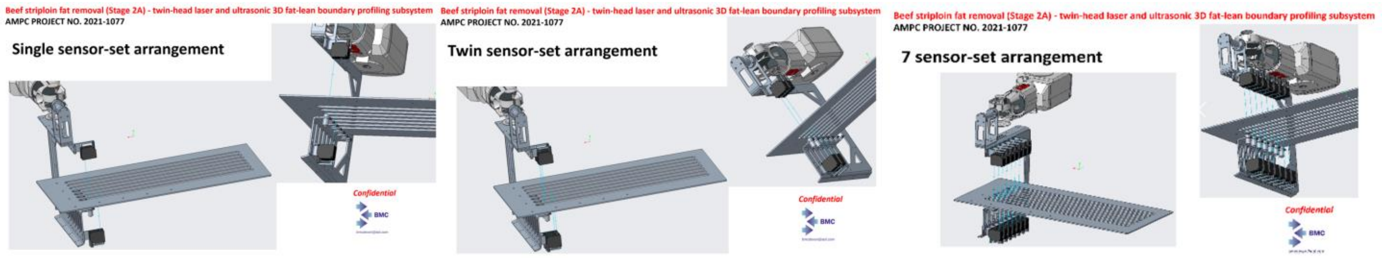

Figure 2: Single, Twin and 7 sensor arrangements.

Figure 3 presents the modular arrangements for the instrumentation, which is for acquisition of the measurements, transfer ready format for use in the robot programs guiding the trimming paths and the interfacing for presentation of the fat-meat profile within the striploin (see Figure 4 bottom right).

The integration of the sensors with a robot programme providing a structured sequence at specific measurement nodes provides for the determination of meat and fat heights above the reference plate on which the beef striploin sits (see Figure 4).

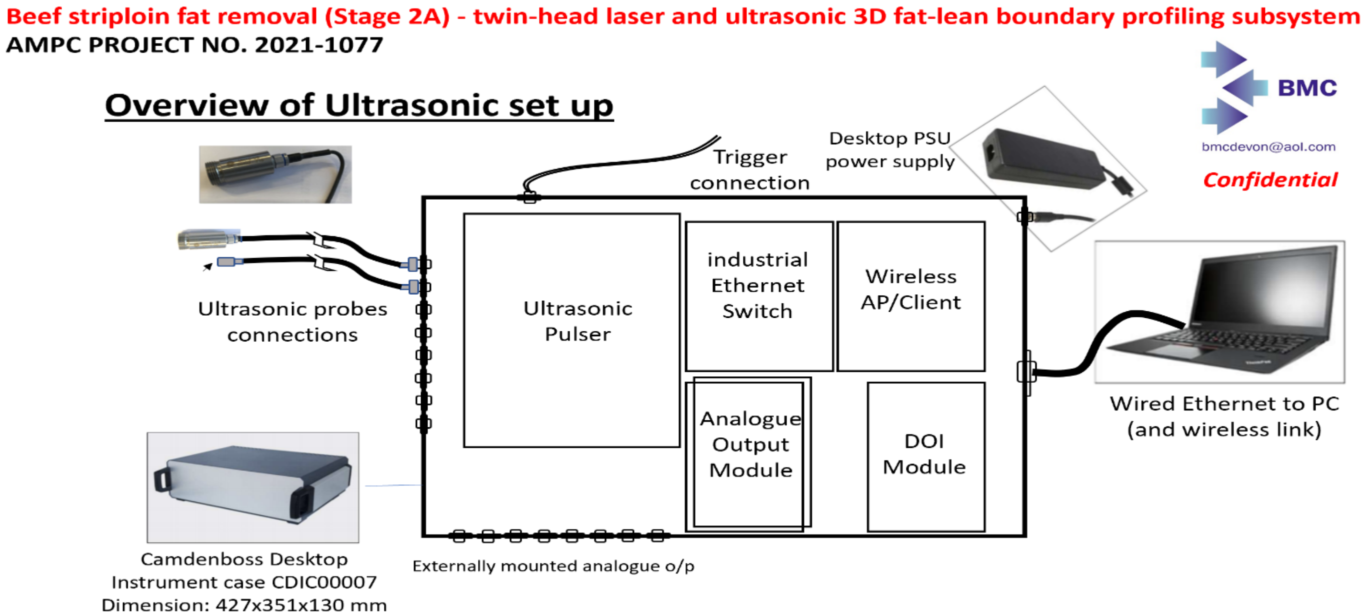

Figure 3: Multi-head ultrasonic and laser sensor arrangements.

Figure 4 shows schematics of the set up and the planned process for measuring the striploin profile.

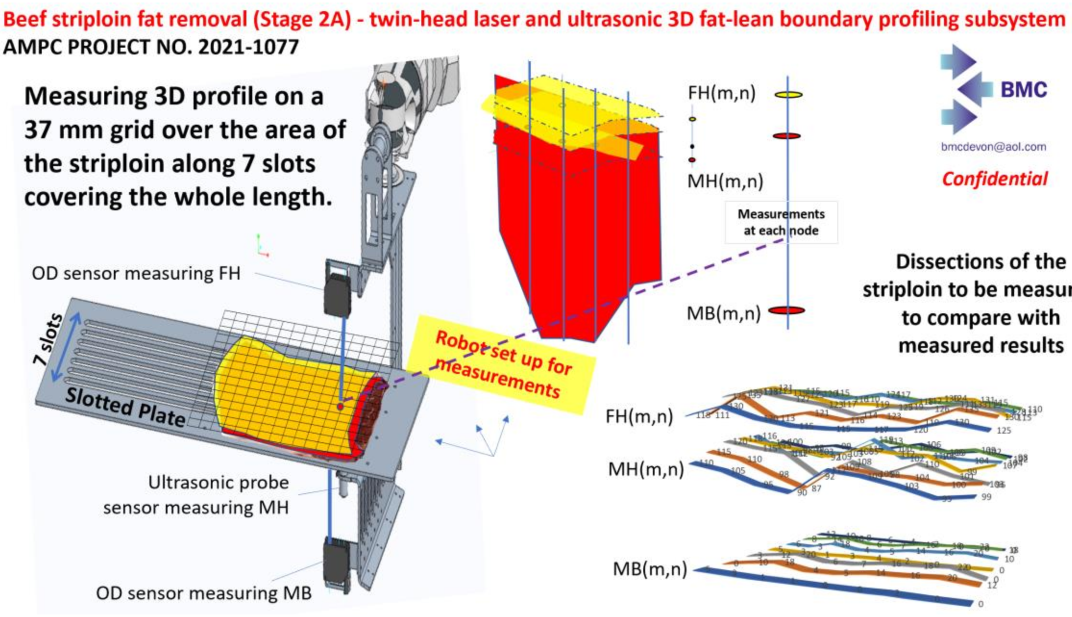

Figure 4: 3D striploin profile measurement.

Robot programming has provided for the sensor positioning at each node, measuring:

- fat height (FH) above the slotted plate,
- meat height (MH),
- meat base (MB) relative to the top surface of the slotted plate.

The measurements, digitally stored within the robot controller may be referenced for trimming; however, for the purposes of validation, the data is transferred using an ethernet link to an external computer to access the measurements data file in raw format, which in turn are manually transferred to an excel spreadsheet.

Figure 5 presents the end-effector brackets for the single, twin, and 7 sensor set arrangements as may be required by future Milestones or Stages of the project. The modular design provides for the addition of sensor heads as the project progresses.

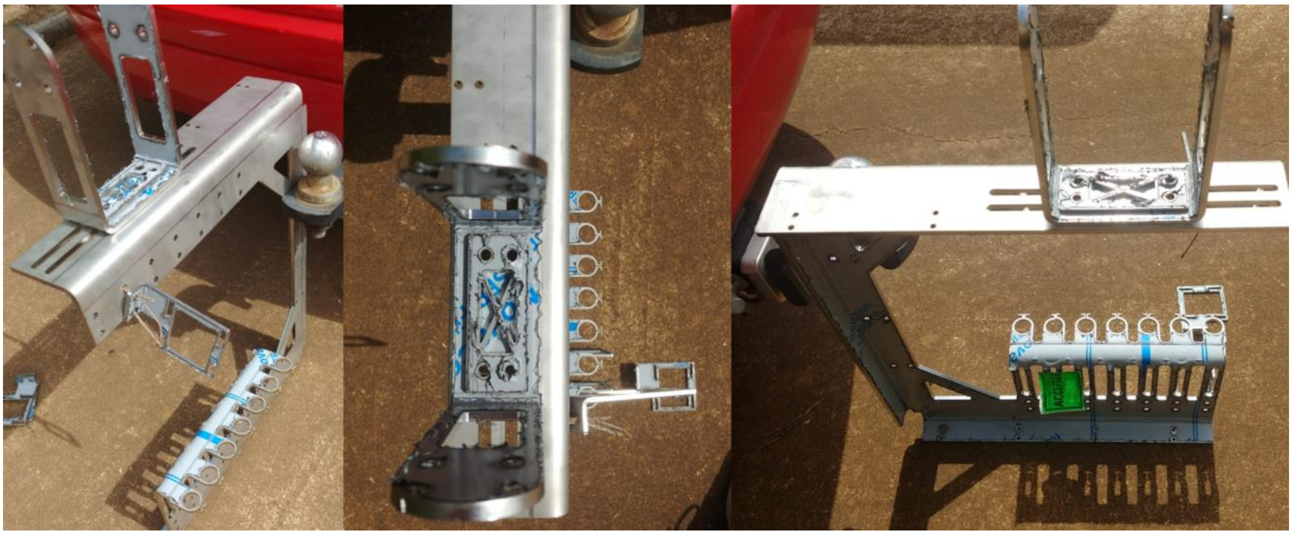

Figure 5: End effector brackets.

Figure 6 presents the end-effector module as assembled on the ABB 140 in the BMC integrated cell.

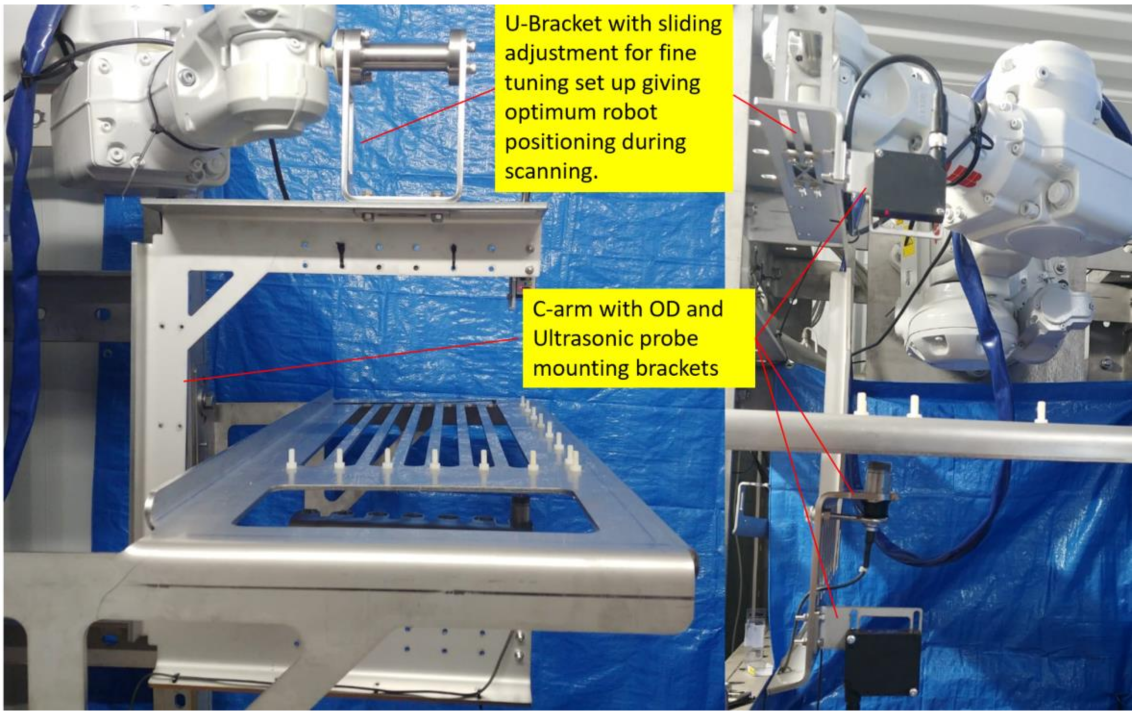

Figure 6: Striploin primal piece overall variability.

The design allows addition of second and subsequent sensor units with the alignment of the sensors easily achieved as may be seen in Figure 7.

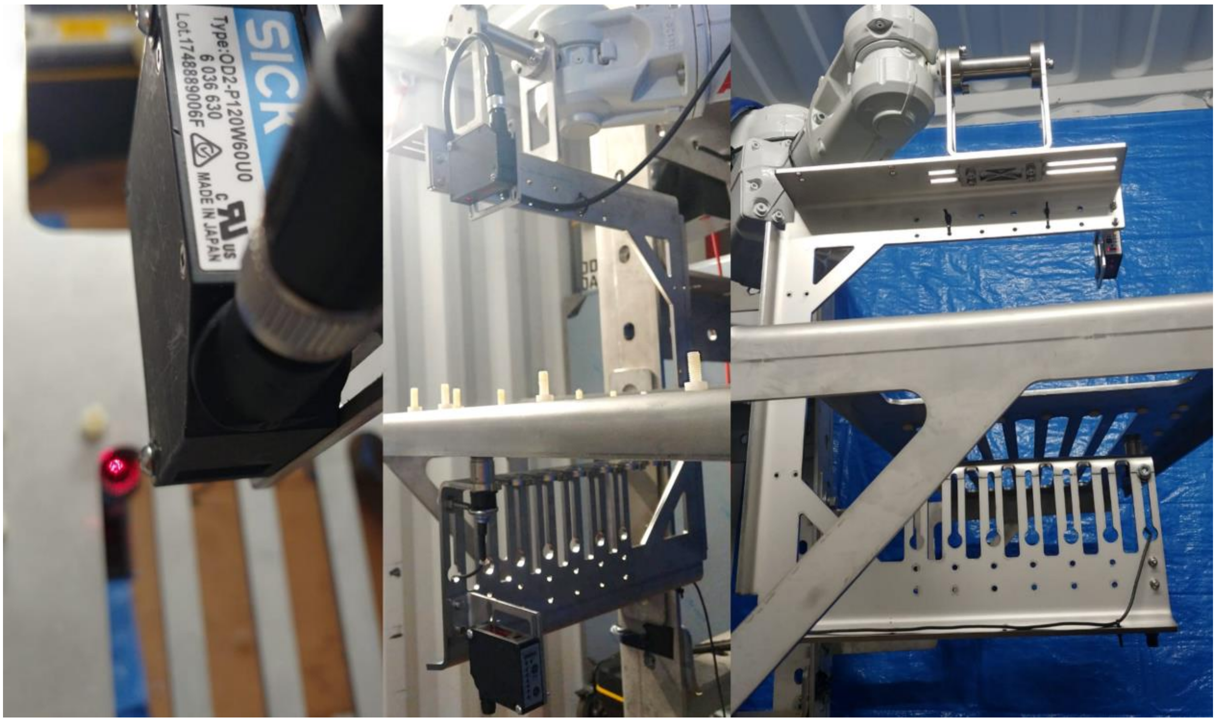

Figure 7: Set up for addition of sensor units.

Figure 8 shows the setup of the single sensor unit assembles and tested for function.

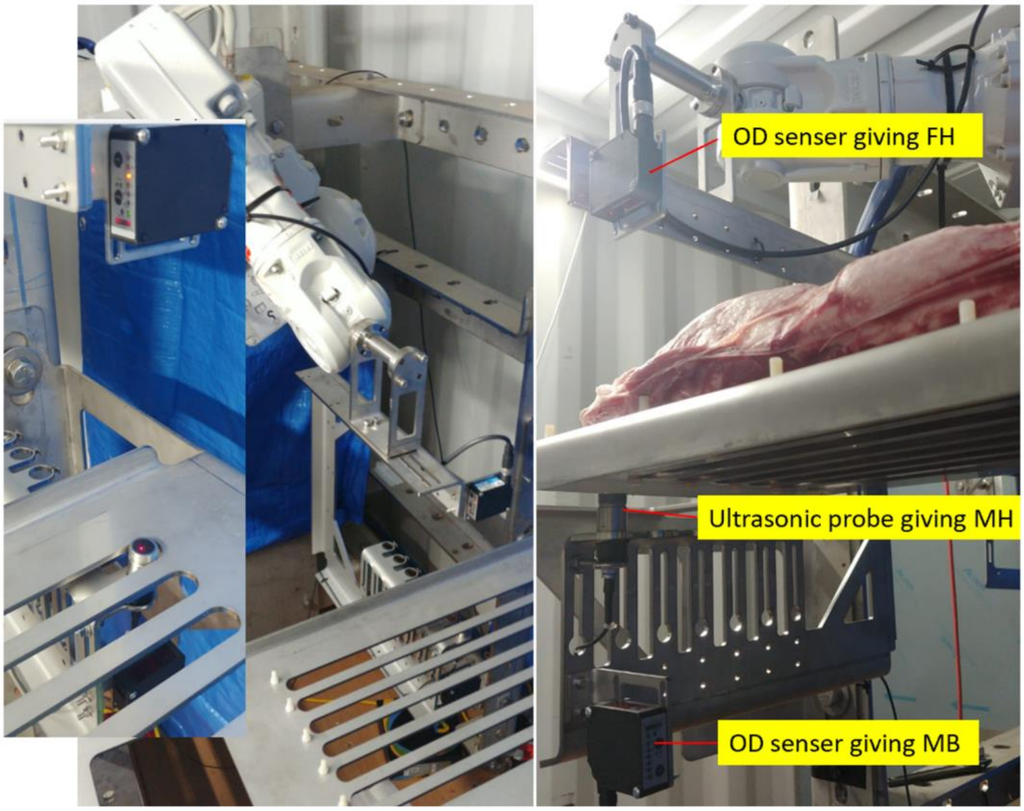

Figure 8: 3D striploin profile measurement.

With the addition of the second sensor set the robot programming has provided the sensor positioning for measuring the profile giving the following measurements at each measurement position or node:

- fat height (FH) above the slotted plate,
- meat height (MH),
- meat base (MB) relative to the top surface of the slotted plate.

An Excel sheet with measurements of FH and MH provides the 3D measurements. Cross checking the sensor profiling data with physical measurements, corresponding to dissected striploin sections at each node, allows the validation to be possible by discretion. This requires physical marking of the striploin at each measurement node, which is visible by the laser dot of the Sick OD sensor, measuring the height of the fat above the striploin plate.

The set up to be arranged is shown schematically in Figure 9. The single-head unit as set up uses analogue connection of the Stage 2 project; however, the new set up will use the new architecture with the same OD sensors, all connecting via the Analogue Module of the IRB controller to the robot program.

The measurements, as recorded in a matrix array at each node, are taken using a trigger signal once the robot has positioned the sensor head(s) correctly at each node along the designated slots in the plate on which the striploin sits.

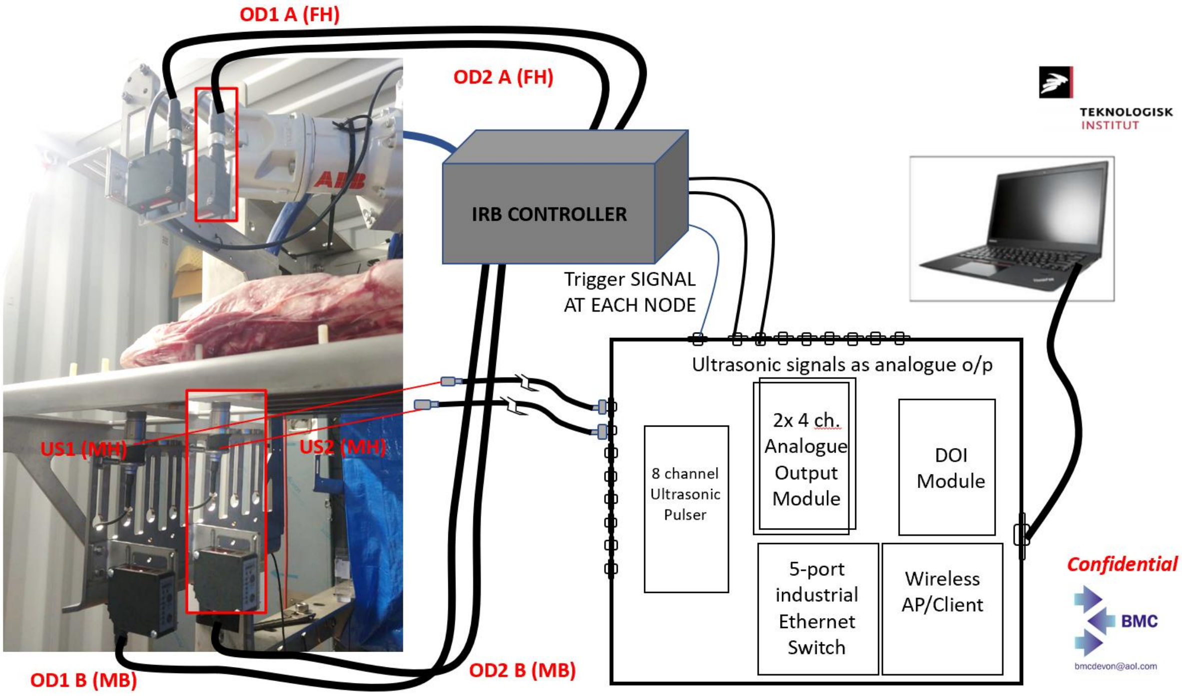

Figure 9: Schematic of the interconnections within the test rig.

Figure 10 and 11 present the set-up with Twin-head arrangement initially arranged under M3 with the associated developments in instrumentation, robot programming and procedures to capture a 3D striploin profile at designated nodes referenced to the physical geometry of the striploin.

Dissection and cross matching to the same measured manually by a ruler were initially performed outside a meat processing environment**.**

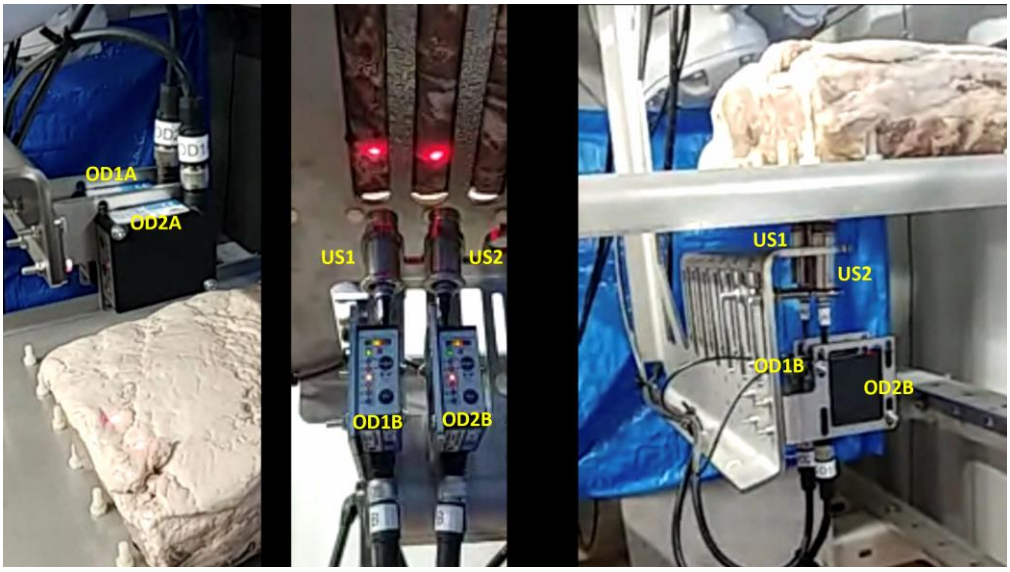

Figure 10: End-effector carrying two sets of OD sensors above and two sets of OD sensors below the striploin plate and two ultrasonic sensors US1 and US2 as shown.

The robot programs and the procedure to scan a striploin were undated to accommodate the signals from the second set of sensors.

The robot scans performed in two passes, allowed the data from slots 1, 3,5 to be captured, followed by the same, but for slots 2, 4 and 6. A repeat scan in slot 6 provided the data for slot 7; however, trials suggested that for the purposes of validation, slot 7 scan would not be necessary given the width of the many of primal pieces falls withing slots 1-6.

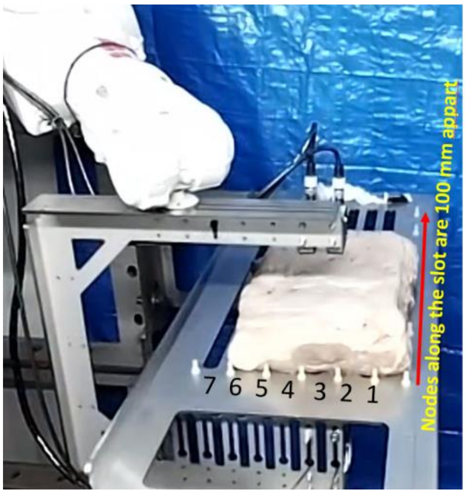

Figure 11: Scans along each slot at nodes 50 mm apart after the first node.

The first node in each slot is at the front edge of the striploin with the second node approximately 37 mm along the slot. The subsequent nodes are 50mm apart moving along the striploin. The scan is adjusted for the length and width of the primal piece. This is achieved by using an initial scan using one OD sensor from above.

The adjustment of the scans long the length and width provide time saving when measuring striploins.

It is estimated that the process will take 10-15 minutes from placement of one striploin on the slotted plate in front of the robot, to the measurements being available for evaluation against dissections. The overall task per striploin is estimated around 60 minutes based on the initial testing, with manual dissection taking most of the time, especially as measurements using a ruler need careful attention.

Figure 12 shows the set up for the measurements of a first striploin after completion of programming.

The scans are adjusted for the measurements along 5 slots as slot 6 is not in range and several points on slot 5 fall outside the points that may be measured with achievable ultrasonic contact. It is important to highlight that the striploin needs to be free of surface fat on the underside, normally trimmed. The top fat also extends to the edge, where there is no meat present on the underside. The results are presented in Figure 13.

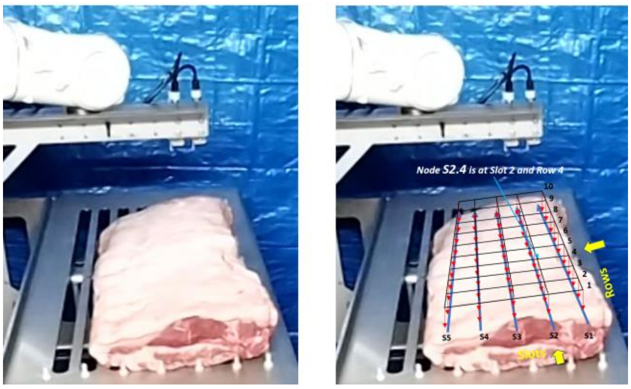

Figure 12: Initial test set-up.

OD MEASURED						RULER MEASURED						DIFFERENCE								
ODA	SLOT 1	SLOT 2	SLOT3	SLOT4	SLOT 5	FH	SLOT 1	SLOT 2	SLOT3	SLOT4	SLOT 5	SLOT 1	SLOT 2	SLOT3	SLOT4	SLOT 5			hits	
ROW 1	88	89	84	77	59	ROW 1	88	88	84	78	58	0	1	- 0	- 1	1	Fat Height	total=	50	
ROW 2	86	86	84	75	57	ROW 2	86	86	84	77	57	- 0	- 0	- 0	- 2	0		NM=	0	
ROW 3	85	85	84	71	62	ROW 3	85	87	84	71	61	0	- 2	- 0	- 0	1		>=2mm=	50	100%
ROW 4	85	84	79	76	67	ROW 4	84	83	80	77	65	1	1	- 1	- 1	2		>=4mm=	0	0%
ROW 5	86	87	83	78	66	ROW 5	85	85	82	77	65	1	2	1	1	1		Total measured	50	
ROW 6	87	90	84	77	64	ROW 6	87	89	85	77	65	-	1	- 2	- 1	- 1				
ROW 7	92	91	84	69	67	ROW 7	92	90	85	70	70	- 1	1	- 1	- 1	- 4				
ROW 8	96	92	84	75	69	ROW 8	95	90	85	73	70	1	2	- 1	2	- 1				
ROW 9	96	92	82	70	61	ROW 9	94	91	81	72	59	2	1	1	- 2	2				
ROW 10	96	91	82	68	54	ROW 10	94	90	81	68	55	2	1	1	- 0	- 2				

US MEASURED						RULER MEASURED						DIFFERENCE								
US	SLOT 1	SLOT 2	SLOT3	SLOT4	SLOT 5	mh	SLOT 1	SLOT 2	SLOT3	SLOT4	SLOT 5								hits	
ROW 1	62	79	69	33	26	ROW 1	62	77	70	31	27	-	- 2	1	- 2	1	Meat Thickness	total=	50	
ROW 2	62	NM	65	35	32	ROW 2	63	77	66	35	33	1	NM	1	-	1		NM=	12	
ROW 3	62	60	34	34	NM	ROW 3	61	62	35	35	35	- 1	2	1	1	NM		>=2mm=	35	92%
ROW 4	62	60	44	44	NM	ROW 4	60	58	44	44	35	- 2	- 2	- 0	- 0	NM		>=4mm=	3	8%
ROW 5	62	60	46	52	NM	ROW 5	63	58	46	52	38	1	- 2	- 0	-	NM		Total measured	38	
ROW 6	62	50	50	56	NM	ROW 6	61	50	50	54	34	- 1	0	0	- 2	NM				
ROW 7	62	64	45	63	NM	ROW 7	61	62	44	62	NM	- 1	- 2	- 1	- 1	NM				
ROW 8	72	64	58	NM	NM	ROW 8	71	63	59	50	NM	- 1	- 1	1	NM	NM				
ROW 9	72	65	56	NM	NM	ROW 9	70	63	59	49	36	- 2	- 2	4	NM	NM				
ROW 10	61	65	53	NM	NM	ROW 10	55	61	55	51	NM	- 6	- 4	2	NM	NM				

Observations

- Measurements are affected by surface fat layer not removed from the meat side of striploin as required for conforming primal pieces.
- Ultrasonic measurements may be missed close to the edges of the primal or if the underside of the striploin resting on the plate are raised (image A).
- OD measurements may also be missed close to the edges where the alignment does not fall withing the slots at the edge or the end faces of the striploin (image B).
- NM denotes No Measurements or No Meat given that there are regions within the body of the striploin where only fat resides (see image C).
- Manual measurements could have inaccuracies that exceed 2mm unless care is applied.

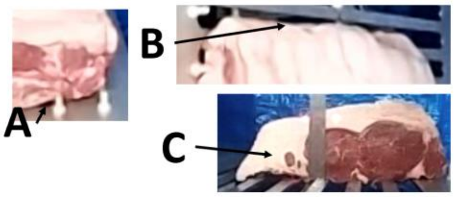

Figure 13: First testing of twin-head implementation with dissection results.

The dissection was made across the striploin with the manual measurements as shown in Figure 13 in close range of the 3D profile data measured using the OD and Ultrasonic units in the twin-head robot cell, with the programmes providing for the transfer of the data to an excel sheet for cross checking. Figure 13 shows that at the nodes the measurements could be made in this initial test 100% of the measurements reflating to the fat height above the meat plate fall within ±2 mm and 92% of the ultrasonic meat thickness measurements fall within the same ± 2mm. The observations were at the conclusion of M3:

1. Measurements are affected by surface fat layer not removed from the meat side of striploin as required for conforming primal pieces.
2. Ultrasonic measurements may be missed close to the edges of the primal or if the underside of the striploin resting on the plate are raised (image A, Figure 13).
3. OD measurements may also be missed close to the edges where the alignment does not fall withing the slots at the edge or the end faces of the striploin (image B, Figure 13).
4. NM denotes in the table of Figure 13 both for manual and measured data indicated No Measurements; or No Meat given that there are regions within the body of the striploin where only fat resides (image C, Figure 13).
5. Manual measurements could have inaccuracies that exceed 2mm.

Stage 2 has had the target to use the twin-head striploin profiling robot to perform trials at JBS Beef City. The trial rig was subsequently upgraded and transported to site and the trials planned and executed.

Striploin beef primal pieces have been measured and each striploin has been sliced into strips that allow direct manual measurements of the same measurements taken by the robot, but using a ruler.

20 tests have been conducted using striploin pieces in 2 separate trials using the OD sensors and Ultrasonic probes integrated within a robotic cell. Each robot measurement run has been followed by dissection of the same Striploin primal. The 20 specific tests have compared manual and robotic measurements at specific nodes to quantify the difference and the measurements of FH (fat height) and MH (meat height) as each node, which is essentially

intended for the determination of Rcp (the robot cutter tip heigh), which is the point the separation tool would need to pass for the gap between Rcp and MH to be the thickness of the fat to be left behind at that node (Figure 14).

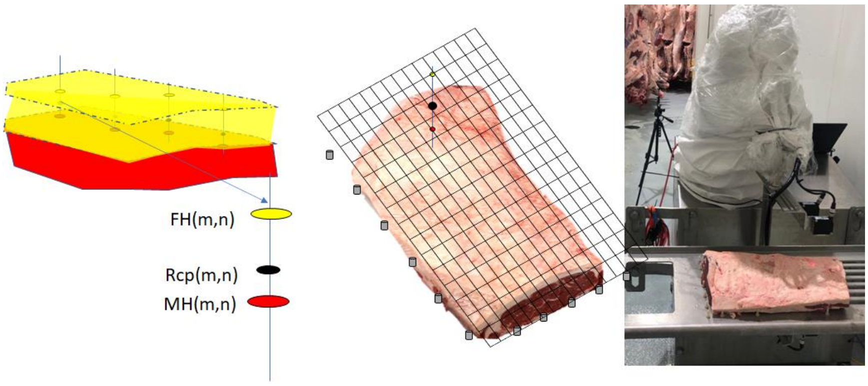

Figure 14: Robotic set up for measurements.

The measurements by the robot provide FH and MH (meat height and fat height) relative to plate with slots that allow access for the ultrasonic probe to make contact with the underside of the striploin piece as illustrated in Figure 14.

Figure 15 illustrate the approach to slicing each striploin primal piece.

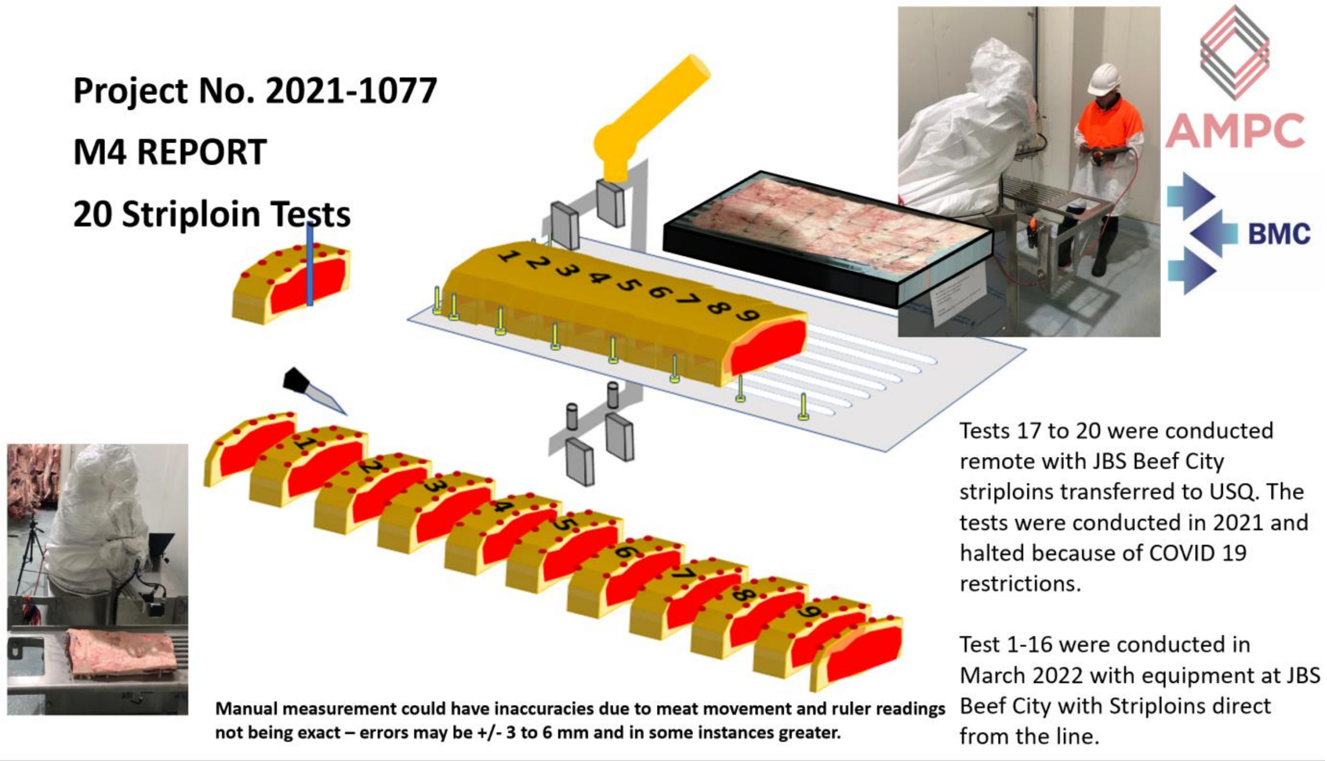

Figure 15: Slicing for manual measurements.

A ruler has been used to measure MH and FH at the sliced face of the striploin with the dot markings on the top of the fat giving the approximate node positions of the robot measurement points (identified and physically marked using a food grade marker pen) during the robot cycle (Figure 15).

In summary, for the nodes at which valid measurements were taken, 62% of the meat height (MH) measurements were within 2 mm of the same taken manually after dissection for each node, 29% within 4 mm, and 9% outside this rage. The figures for FH (fat height) were 69% within 2 mm, 22% within 4 mm and the remaining 9% outside this band. See Table 1.

It should be noted that the errors due to manual measurement impact the findings. On the whole, the results are considered accurate and consistent when using the robotic 3D profiling process, especially with the variability in surface profile of the fat and presence of intermuscular fat. Contact between the ultrasonic probe and the meat is also impacted by the shape and the inconsistency of the meat surface of the striploin underside.

With all considerations it is reasonable to conclude that the measurement system would provide the necessary number of data points to the expected accuracy for the profiling of the fat lean interface to be mapped for the calculation of Rcp, the points though which a cutter tool path can be fitted for guiding a robot for fat trimming.

AMPC PROJECT No. 2021-1077									
M4 - Robot sensor measurements and Manual measurements comparison									
		MH	**Ultrasonic - Meat thickness**			**FH**	**OD sensor Fat height**		
No		**Valid nodes**	**Within 2mm**	**Within 4mm**	**Outside 4mm**	**Valid nodes**	**Within 2mm**	**Within 4mm**	**Outside 4mm**
1	Striploin 1 - JBS	17	10	5	2	31	29	2	0
2	Striploin 2 - JBS	20	13	6	1	36	28	8	0
3	Striploin 3 -JBS	9	8	1	0	32	22	5	5
4	Striploin 4 -JBS	10	7	3	0	32	26	5	1
5	Striploin 5 - JBS	11	9	1	1	28	14	8	6
6	Striploin 6 - JBS	5	3	2	0	28	11	5	12
7	Striploin 7 - JBS	13	8	5	0	36	24	10	2
8	Striploin 8 - JBS	21	14	6	1	36	22	12	2
9	Striploin 9 - JBS	15	9	3	3	26	14	8	4
10	Striploin 10 - JBS	13	10	3	0	25	17	4	4
11	Striploin 11 - JBS	12	8	3	1	32	24	7	1
12	Striploin 12 - JBS	9	5	1	3	30	15	8	7
13	Striploin 13 - JBS	9	8	1	0	32	22	9	1
14	Striploin 14 - JBS	12	5	7	0	28	17	10	1
15	Striploin 15 - JBS	15	5	8	2	36	20	12	4
16	Striploin 16 - JBS	21	14	6	1	32	27	5	0
17	Test 17 SLP 01	17	8	5	4	2	1	1	0
18	Test 18 SLP 02	11	6	4	1	19	18	1	0
19	Test 19 SLP 03	18	10	5	3	19	15	2	2
20	Test 20 SLP 04	36	22	11	3	39	36	3	0
	Total	294	182	86	26	579	402	125	52
			62%	29%	9%		69%	22%	9%

Table 1: comparing robotic measurements and manual readings for MH and FH

There is a shortfall in respect of reaching 85% of the measurements being with 2 mm: the figures calculated being 62% within 2 mm for meat height (ultrasonic) measurements at each node, and 69% within 2 mm for OD laser sensor measuring fat height at the same point of the striploin. The contributory factors to the errors are attributable to manual measurements being at error by +/- 5 mm when using a ruler, whilst there is also significant shape and profile variation in the striploin, contributing to the process of measurement. These are causes by the preceding processing stages such as de-boning or de-hiding leaving the fat cover broken or the meat surfaces not fully trimmed

It is important to highlight that with the robot in a measuring position and sensors giving continual readings, the readings of MH and FH are within 1 to 2 mm when using an accurate manual measurement of the exposed face of the striploin with the sensors at the node being observed.

6.0 Discussion

Stage 2A has met with the objectives to verify, to within the constraints of the manual measurements that confirm or otherwise the fat and meat heights (FH and MH) using a ruler.

There is limited capability in the manual process (but the best available) for the verification of the robotic measurement technology developed under this project.

The ultrasonic (US) probes, as used in the twin-set setup, provides a measurement from the meat side of the striploin primal piece as shown in the set up and illustrations of Figure 15. In its simplicity, the ability of the sensor to return a valid measurement is achieved only when there contact between the head of the probe and the meat, with the transmission of ultrasound signal being possible. The signal reflection and time of travel is used to calculate the thickness of the meat. The reflection of the ultrasound signal corresponds to the boundary changes between different tissues along the path of the signal to the point of the meat fat interface at the top fat below the surface of the top at the lean meat interface. MH (meat height) measured from below using the ultrasonic probe and FH (Fat heights) using the OD laser sensor from above may be used to fit a cut path for a robotic cutter, with Rcp being a certain distance above MH or below FH in order to remove a desire thickness of fat. It is practical, as one of the outcomes from Stage 2A (for the set of 20 striploin tests), to have a number of such measurements of MH and FH at nodes over the area of the striploin primal piece, where an appropriate cut path may be fitted for a robotically driven cutter blade.

MH (meat height) measurement relative to face of the probe may have a false value in certain circumstances (see Figure 16), which include:

- The probe active sensing area is not in contact with meat even if the body of the sensor has made contact.
- The probe head is in in contact with sinew over the surface of the meat that may have needed to be trimmed.
- The probe head is in contact with surface fat over the bottom face of the striploin that should have been trimmed
- The probe head is in contact with the regions that may have residues of bone or cartilage left behind from the previous steps of boning (button bone and flat bone separation).
- The probe head misses the striploin along the line measurement because the edges of the striploin are curved and not on the slots along which measurements are taken from below through the slots on which the striploin is sitting.
- The zone of measurement has thick fat immediately within the muscle structure at the point of probing.

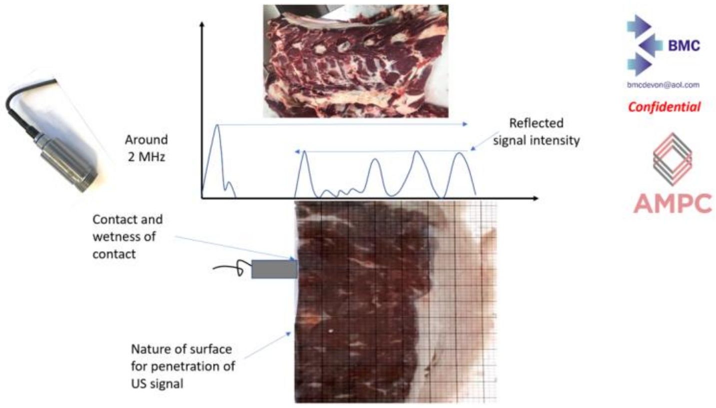

Figure 16: Slicing for manual measurements.

Given the constraints, there has been no anticipation that under these circumstances a reading is achievable at every node. Indeed, the expectation is the by taking measurements at multiple nodes cut paths may be determined using only a limited number of valid readings. The method for determining which readings are valid and should not be used requires a filtering process with corresponding software to eliminate measurements. The remaining measurements may be used for robot path generation.

Stage 2A has reach a better understanding of the performance of the sensing approach and emphases the necessity for this filtering software before path determination for robot separation is applied.

The measurements that are achieved and valid as presented in this report, are within target range for such path generation process to be considered practical when applying filtering. This an important next step, requiring further R&D to be demonstrate practically.

The comparison process using manually measured values by a ruler, corresponding to points measured by the ultrasonic and laser probes, is prone to errors and not necessarily a reflection of the capability of these devices used.

The dissection process as illustrated in Figure 17, provided the possibility for cross verification of the measurements at each node, both at the ultrasonic probe positions and at OD laser positions, marked during projected OD sensor laser dot during the robotic measurement cycle.

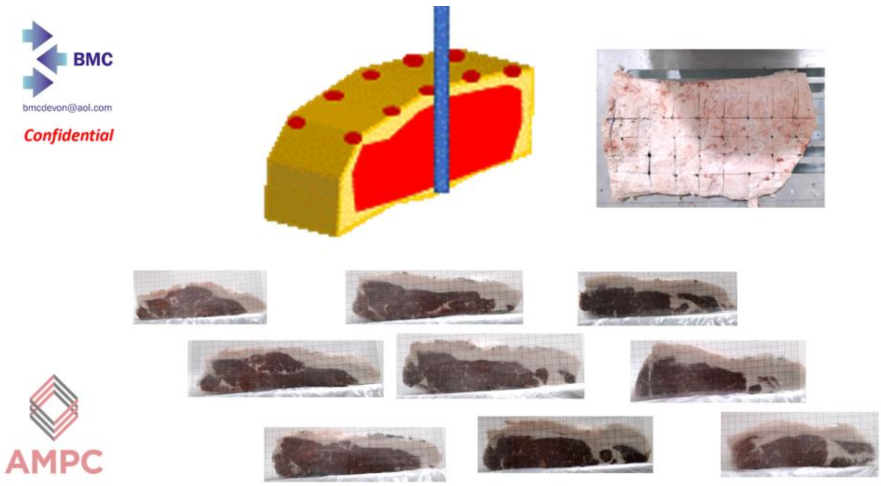

Figure 17: Slicing for manual measurements using a ruler.

The inaccuracy of measurement by a ruler can be in excess of 5 mm. Even with careful positioning of the ruler, the deformation of the striploin during slicing could give a 3-5mm vertical movement at the points of interest when placing a ruler to line up the marker showing the reading. This somewhat distorts the percentage estimations that are to reveal the performance of the robot measuring devices, which are in fact more accurate than using the ruler, especially in the case of the laser measurements, where there is less uncertainty because of the profile and nature of the tissues and the composition of the striploin.

Using the probes in a static and clearly visible face of the striploin cross section, capturing MH and FH, and visually viewing the markers of the ruler, manual placed against the face of the meat, shows the ultrasonic and laser measurement devices have higher resolution than may be seen on the ruler.

The process of slicing and measurement by a ruler, as applied, does not provide an accurate comparison, though useful as a guide. The physical distortion of the striploin combined with the error in measurement by a ruler have a greater band of inaccuracy than the resolution of the probe measurements. Hence the bands of data in Table 1 could well fall to higher percentages of the readings being within the anticipated range for calculating separation paths.

To this end, and with the most careful steps in manual measurements, the comparison shows the performance to be generally applicable for fat trimming despite the limitations of verification by a ruler. Table 1 is a reasonable, if not the best, expected outcome that may be reached in such a trial.

The task of striploin fat trimming by hand requires human sensing and judgement as well as degrees of control to using a cutting tool to separate fat from the top surface of a striploin primal.

The results, as presented, demonstrate that there is capability to measure the striploin primal pieces with the degree of accuracy for the determination of path generation for robotic trimming. This was reported in Stage 2 for a small example set and was proposed for further R&D. Stage 2A was introduced to increase the extent of confidence in the measurements. Table 1 provides this to the extent that the process of measurements is in the range of expectation given the nature of striploins and their variability.

7.0 Conclusions / Recommendations

Stage 2A has refined the understanding of the sensing process to show the capability of the ultrasonic and laser measurements of fat and meat dimensions for the controlled separation of fat to leave a uniform layer on the primal to specific user defined thickness. The limiting factor in the validation process has been the inaccuracies of manual process used to compare with the measurements by the robot using electronic sensors. The use of a ruler, as a best approach, had been the specified alternative method; but this has revealed to be constraining in the validation process. Nevertheless, the results table (Table 1 above) provides the best outcome, which indicates the robotic measurement process to be appropriately capable of providing the necessary sensory date for the control of fat trimming.

The project has reached its objective to assess the capability and the application process of the robotic 3D profiling of the striploin with measurements.

A first automatic solution for trimming striploin primal pieces may be based on ultrasonic and laser measurement of meat thickness and fat as integrated with robotics. This is targeting a project proposal, which is to develop a World first robotic trimming solution for striploin beef.