Final Report

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

# Remote Operations (Gamification) – Stage 1

## Semi-Automated Beef Scribing User Interface


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# 1.0 Executive Summary

AMPC (and the industry) have an innovation vision, and support R&D program, to eliminate all WHS incidents from processing operations. Where possible dangerous tasks will be fully automated. Where automation is not currently viable (either due to technology limitations or ROI), semi-automated/remote solutions will be developed that will remove the operator from dangerous tools and implements. Where semi-automated solutions are not viable then the remaining hands-on tools will be made as safe as possible (i.e. BladeStop and Guardian).

This project focuses on further developing solutions, and approaches, for semi-automated / remote solutions, with the first task being evaluated that of beef scribing. An Innovation Theme on a Page (ToaP) has been developed for this program of work (depicted within the Project Description) and shows both the proposed development stages of the area as well as implementing an innovation competition where more than one provider may be supported in the early stages to evaluate different approaches to the primary goal and secondary goals of Remote Operations via Gamification.

Although not a deal breaker for Stage 1, considerations must be made for ability to place accurate cut locations in a short amount of time. This is with the view of the system being able to be adopted within industry. Based on requirements and current industry operations, the target KPI's are:

1) Accuracy to +/- 10mm accuracy
2) Place 4 cut lines on a beef side within 20 seconds

Looking further into the future, the system is to be developed with the final solution involving a robotic solution that performs the cuts for the operations staff to remove people from the processing line.

This project successfully saw the design and prototype implementation of a gamified semi-automated scribing web user interface by Intelligent Robotics. The intent behind IR's approach was focused heavily on utilising the interface in the context of driving an automated system. The user interface concept consists of a number of modes: instruction mode, which teaches the operator about the interface and how to use the program; practice mode, which guides the operator on how to place and adjust markers and gives assistance when incorrect placements are given; test mode, which runs through a mock production situation, taking the operator through a series of carcase images and then grading them on accuracy and placement time; and production mode, which uses live images from production to drive a robotic cutting system.

The concept developed over a number of iterations through the course of the project, taking into account feedback from AMPC and processors, and also factoring in learnings from other projects occurring in parallel. The end result is an interface which received positive feedback and would be commercially feasible for driving a semi-automated beef scribing system.

While the use-case presented focused on the particular application of beef scribing, the concept can be extended to other vision-guided red meat automation tasks. For example, the interface could be modified to ask the operator to identify the dew claw for automated hock cutting, or the spinal cord channel for spinal cord removal.

In the context of scribing, it is felt that the next step for the technology is likely to implement it within a commercial project with a processor for a semi-automated scribing system. The user interface was presented to two Australian red meat processors who both delivered positive feedback to the concept. Work with both these processors is continuing to proceed to next steps.

# 2.0 Introduction

AMPC (and the industry) have an innovation vision, and support R&D program, to eliminate all WHS incidents from processing operations. Where possible dangerous tasks will be fully automated. Where automation is not currently viable (either due to technology limitations or ROI), semi-automated/remote solutions will be developed that will remove the operator from dangerous tools and implements. Where semi-automated solutions are not viable then the remaining hands-on tools will be made as safe as possible (i.e. BladeStop and Guardian).

This project focuses on further developing solutions, and approaches, for semi-automated / remote solutions, with the first task being evaluated that of beef scribing. An Innovation Theme on a Page (ToaP) has been developed for this program of work (depicted within the Project Description) and shows both the proposed development stages of the area as well as implementing an innovation competition where more than one provider may be supported in the early stages to evaluate different approaches to the primary goal and secondary goals of Remote Operations via Gamification.

Note: It is anticipated that by the time that Stage 3 is being supported the number of providers being supported will have significantly reduced, and eventually one selected for Stage 4 developments onwards.

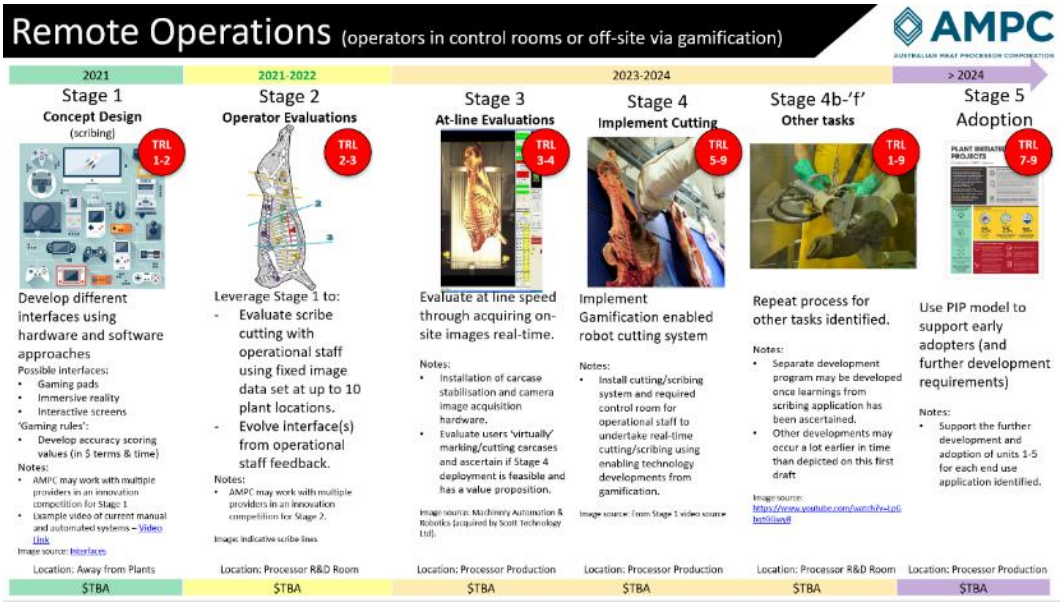
**Primary Goal**

At the conclusion of all development stages Australian beef processing facilities have operational staff undertaking scribing activities without being adjacent to the carcase and holding onto the scribe cutting saw. Ideally operators are based in a control room.

**Secondary Goals**

Other focus areas for desired achievement include: (1) develop an on-line training tool for current and pending processor operational staff, (2) develop a public (end of Stage 2) offering that enable future possible employees to obtain a different understanding of processing roles within beef plants, (3) provide an alternative way to renumerate staff based on cut line placement accuracy and speed, (4) provide a wider pool of staff suitable for the task, and/or, a role for light duty staff, and or, staff with less mobility and (5) evaluate if the task can be performed remote from site.

This project is focused on Stage 1 development scope only (refer ToaP below).



# 3.0 Project Objectives

There are a range of operations in meat plants that are dangerous, time consuming and hard to perform accurately. One such operation, is beef scribing. Beef scribing requires the holding of a saw and placing of a multitude of cuts on the beef carcase, and the primary objective of this project is to allow operational staff to undertake beef scribing without having to hold onto the saw. This reduces the risk of injury due to being removed from a powered saw.

A final ideal outcome is that the Stage 1 & 2 offerings morph into an engaging game that is compelling for industry and non-industry 'gamers' alike to immerse themselves in and remove themselves from the task and focus on beating their scores in terms of accuracy and time.

Although not a deal breaker for Stage 1, considerations must be made for ability to place accurate cut locations in a short amount of time. This is with the view of the system being able to be adopted within industry. Based on requirements and current industry operations, the target KPI's are:

1) Accuracy to +/- 10mm accuracy
2) Place 4 cut lines on a beef side within 20 seconds

Looking further into the future, the system is to be developed with the final solution involving a robotic solution that performs the cuts for the operations staff to remove people from the processing line.

The benefits behind this line up with AMPC's 2020-2025 strategic plan, including:

1) Removing staff from dangerous operations, via Hands-Off processing
2) Carcase Primal Profitability Optimisation, via accurate processing
3) Digitisation, via acquiring product information and leveraging data insights
4) Attraction, via demonstration and developing a wide range of operations
5) Retention, via improving working conditions and making tasks exciting
6) Development, via developing tasks that require higher skills and intellect
7) Safety and Wellbeing, via reducing the high-risk nature of processing operations

This will result in the project output, of a Successful demonstration of an AMPC evaluated beef scribing gaming interface.

## 3.1 Project Methodology

The project methodology is as follows:

1) Concept design for program including prototype UI and UX theme, interaction and program flow
2) Program a basic proof of concept gaming/semi-automated platform for beef scribing cut placement. This will include a means for displaying images to an operator for marking of key points of interest which define the cuts.
3) Continue development of platform with UI/UX kept simple and basic, but demonstrating the concept and interaction mechanisms. Implement concept 'gamer' options for interface.
4) Recommendations on Stage 2 developments, timeframe, budget, third party inputs, expected interface using resulting accuracy and carcase marking cycle times.
5) Perform site trials of the software for processor feedback.

# 4.0 Methodology and Discussion

## 4.1 Initial UI/UX Design

Previous work done in the red meat industry on semi-automated beef scribing has involved an operator drawing scribe lines on an image of a carcase using a stylus and a large touch screen monitor (Inglis, 2011). This setup allowed a highly trained operator to place scribe lines in approximately 26 seconds by drawing them on an image of the carcase displayed on the screen. A number of factors however aren't reported upon, including: accuracy of placement, number of scribe lines placed, and variation in placement times over an entire shift.

For this project, Intelligent Robotics has proposed taking a different approach. When programming automated cutting systems, vision algorithms analyse sensing data to identify key points of interest, which are then used to generate the cut profiles. One of the barriers to entry for fully automated scribing for small to medium-sized plants is the cost and footprint required for the x-ray sensing needed to automatically identify certain key points accurately. Intelligent Robotics hypothesise that focusing the user on selecting key points rather than drawing actual scribe lines will result in faster, more consistent, and more accurate scribe line placement for a semi-automated system. Such a system would consist of a colour camera and a 3D camera/scanner for sensing, as well as a robot for performing the cuts.

For this work, the placement of the following scribe lines was considered:

1) Horizontal spine scribe across the lumbosacral junction (separating the loin and rump)
2) Horizontal spine scribe separating the forequarter and hindquarter
3) Horizontal spine scribe separating the chuck from the ribset
4) Two vertical rib scribes isolating the short ribs and/or chuck short ribs

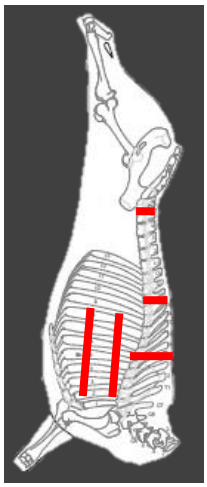


*Figure 1 - Scribing Lines*

The operator would then select specific points of interest required to define these cuts given the processor's specific cut specifications. In the future, variations to the cut specification can be linked with carcase RFID and plant cut specifications to be dynamically updated for that particular carcase. Cuts can also be enabled / disabled as per the site's requirement.

The design requirements supplied for the UX/UI design include:

- High degree of usability

  - Clean, easy-to-use, intuitive design
  - Delivers strong positive user experience
  - Enhance usability, operability, and manufacturability
- Future-proof in design and aesthetic
  - Interface to be flexible enough to include room for future expansion of features
  - Aesthetic will remain appealing over a long lifecycle

## 4.2 Cycle time and Accuracy Considerations

A critical success factor for the semi-automated scribing concept is the ability to place the cut markers quickly *and* accurately, over an extended period of time.

Placement of points rather than drawing of lines is thought to be able to facilitate this most effectively. It keeps the operator selection down to the bare minimum in terms of input data for the vision system. The vision system then uses this data to compute the final scribe lines, as well as assisting the operator by performing tasks better suited to the vision processing, such as placement of cuts at certain widths or parallel to certain features.

These automatic operations will allow the system to obtain yield benefits over the current manual sawing operation.

Furthermore, the UX/UI design was completed with the following requirements:

- Overall number of clicks and mouse movements must be kept to a minimum
- Need for adjustments must be almost eliminated
- The user must be able to view the carcase image clearly so as to place markers accurately.
- The user must be able to view the platform with a high level of intensity for a prolonged period of time
- The user must be able to orient themselves quickly and easily so as to know what point on the carcase they are viewing at all times.
- The user must be guided through the steps to assist them in identifying features quickly.
- Consider the viability of using keyboard shortcuts to improve user speed when navigating cuts.
- Consider using keyboard shortcuts or mouse scroll to allow the user to zoom with speed where needed.
- The user should have an indication of how much time is remaining before 20s has elapsed per image.
- The user should have an indication of how many steps they have completed for the image they are currently processing.
- The user must be able to see what cuts are being processed as they progress.
- To ensure speed target is achievable, the interface automatically proceeds to the next step after each marker is placed. (There is no requirement for the user to confirm each click).
- Once all steps are completed for an image, the user must submit.

## 4.3 Development of Proof-of-Concept

A proof-of-concept UX/UI was built to demonstrate to AMPC to showcase the envisioned development pathway. This was presented via a clickable prototype to show the core features of the program and usability of the concept. The feedback given was positive and a Go decision was given by AMPC to continue development in the next milestone of the project.

In terms of the presented design, the feedback received was positive with the direction shown. Some items of feedback were given which were implemented into the design of the software:

- Display of AMPC logo


*Figure 2 - AMPC logo placed on screen*

- Incorporate a means to widen/narrow the rib cuts – "+" and "-" symbols has now been integrated into the design on the relevant page for placement of the rib lines.

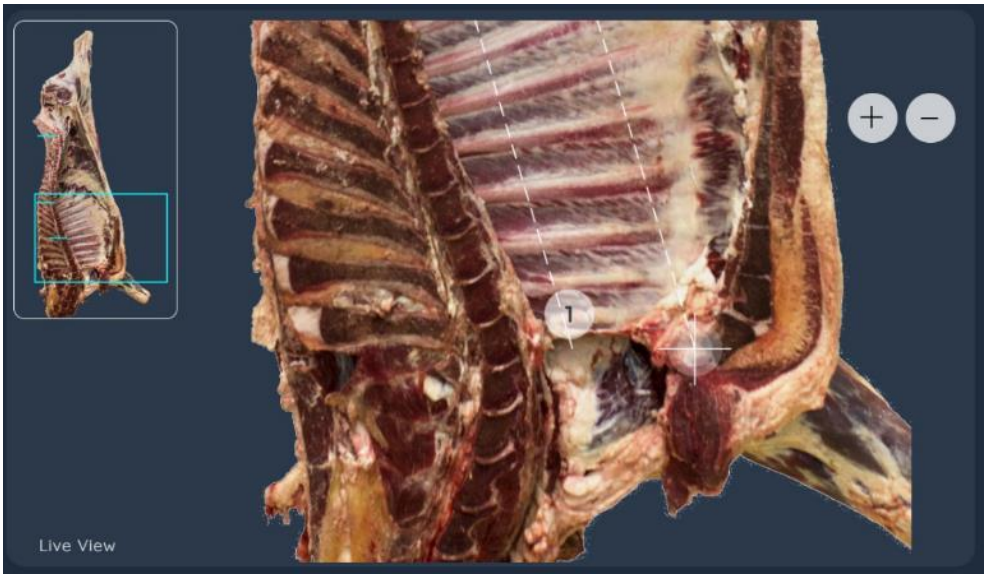



*Figure 3 - Means added to change width of rib scribes*

## 4.4 Web development design

The front-end development of the webpage was then performed in the project. It was coded in a way which enables the page to be updated dynamically based on the production requirements of the given site.

It was envisioned that this will be expanded depending on what pre-processing of the carcase image can be done to assist the operator with quick and accurate placement of cut markers. The manner in which the front-end has been coded as well as its communication with the back-end server facilitates this level of flexibility and upgradeability.

Similarly, information regarding the cut positions selected by the operator, as well as timing information for each step can be sent back to the back-end server. The timing information will be gathered to enable analysis to be performed on how the operators are using the interface, and to identify areas of improvement for optimising cycle time.

## 4.5 User-interfacing

The webpage was coded to facilitate both mouse interaction and stylus interaction. As testing with the website has progressed however, it appears that using a mouse and keyboard will be the most likely means of interaction. Using a stylus presents the issue of not being see very well exactly where the point is being placed (due to the stylus being in the way). The use of a mouse and the feedback of its motion appears to orient the user better for quick and accurate placement after the initial learning curve. There are also significant concerns regarding ergonomics for stylus placement over long periods of time. Pairing mouse interaction with a keyboard is also more straightforward than with a stylus. It is envisioned that operators may find using the keyboard easier for things like adjusting the width of the scribe lines, and moving to the next step.

## 4.6 'Gamer' Option for Interface

Some elements have been integrated into the UX/UI design for 'gamer' type experiences, but the focus is still on its useability for long-periods of time as per a production environment. A timer bar at the bottom of the screen progresses based on the throughput of the system to give the user constant feedback on how they are tracking for time, as well as a subconsciously providing stimulus and positive-reinforcement for fast operation without overwhelming them and distracting from the content.

The main utilisation of 'gaming' features will occur during the "Test" mode of the software, rather than "Production" mode. In this mode, a set of images of carcases from a library will be shown to the operator in a manner that replicates the "Production" interface. This library will have a 'ground-truth' for cut placement associated with each carcase to enable the operator to be scored based on time as well as accuracy across the set of carcases displayed to them during their "Test" run. This feedback is presented to the operator after finishing "Test" mode, and historical data may also be shown to indicate how they've improved and areas that need more focus.

Supervisors will have access to the latest results for a given operator to approve them for use in production.

## 4.7 Review of Concept Design Intent

Revisiting the design intent of the user interface, the ability to ***quickly*** and ***accurately*** place cuts has always been the greatest priority. This has been addressed by:

- Breaking the interface up into stages for selection of 'key points' (rather than drawing of actual cut lines)
- Zooming into regions of interest to allow key points to be placed as accurately as possible
- Incorporating features to keep the user 'oriented' while progressing through the screen (e.g. by labelling relevant ribs in a given screen to prevent the need to re-counting)
- Allowing progress between screens and to the next carcase with minimal clicks
- Minimising the chance of an operator needing to make amendments (which will significantly impact cycle time)

## 4.8 Modifications to User Interface

While performing testing with the interface, a number of key modifications were made to improve its usability, speed, and accuracy.

**Pre-filled Rib Identification**

The first screen on the interface requires the operator to label ribs 1 to 12. This is simply to provide them fixtures for the following screens to remain oriented when the image is zoomed in, and to ensure they only need to count the ribs on a carcase once.

While performing initial profiling of cycle times, it was found that this step took ~30-35% of the complete cycle time to perform this step.

The interface was modified to integrate predictive labelling of rib numbers. This was seen as something that would occur with future versions of the software but with this finding on the rib counting it was deemed that it would be necessary for the first commercial release for this step to have automation behind it to reduce the time spent on this screen and minimise overall cycle time.

The operator still has the ability to adjust any rib markers which may have been misplaced slightly. If a rib is missed (e.g. rib 1) the operator can click and drag an existing marker and the labels will reshuffle accordingly. They also have the ability to clear markers and place them manually.

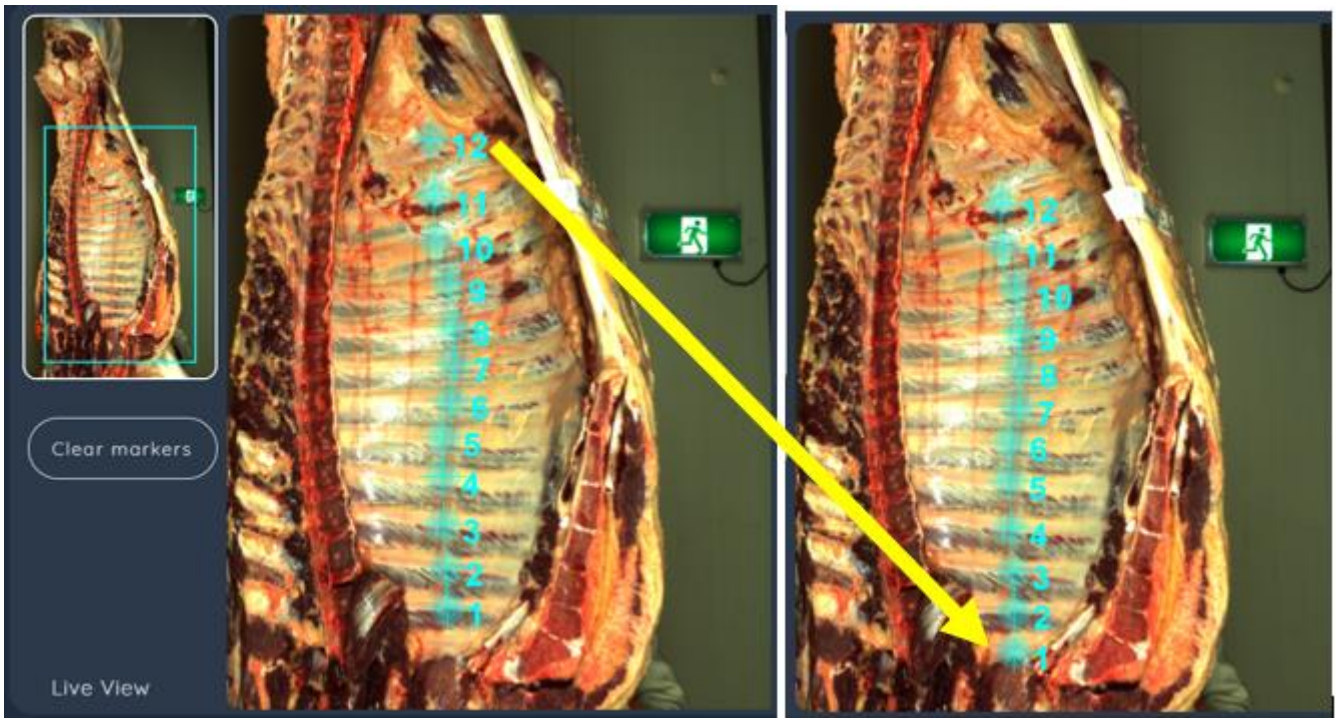



*Figure 4 - Example where the AI has missed rib 1 (left), and the result after dragging the old rib 12 marker down to rib 1 (right)*

**Rib Scribe Marking**

As aforementioned, the original concept involved zooming into areas to allow the operator to position key points which define where the cuts should go. For the spine cuts, this is very straight-forward – the interface shows a zoomed in image of the rib of interest (e.g. rib 5 for performing the 5/6 spine scribe), indicating which rib #5 is (to quickly orient the operator and prevent them from having to count ribs again), and asking the operator to click the top

of rib 5 close to the spine. This results in a quick placement which is as accurate as possible due to the zoomed in window.

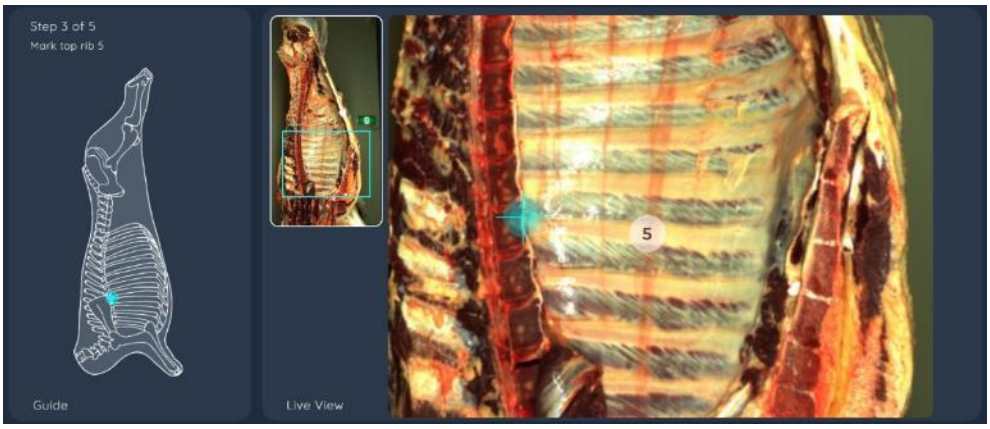



*Figure 5 - Spine cut placement example - 5/6 spine scribe*

For placement of the rib scribes, the brisket cutting line is first placed between two key points of interest according the AUSMEAT specification:

1) The junction of the 1st rib and 1st sternal segment (i.e. the rib 1 junction)
2) The reflection of the diaphragm at rib 11

These points are difficult for the operator to assess in isolation. With the point #2, this is a highly subjective position which is also influenced by how the diaphragm has been trimmed. Some sites also use alternative targets and any point can be used as per customer preference.

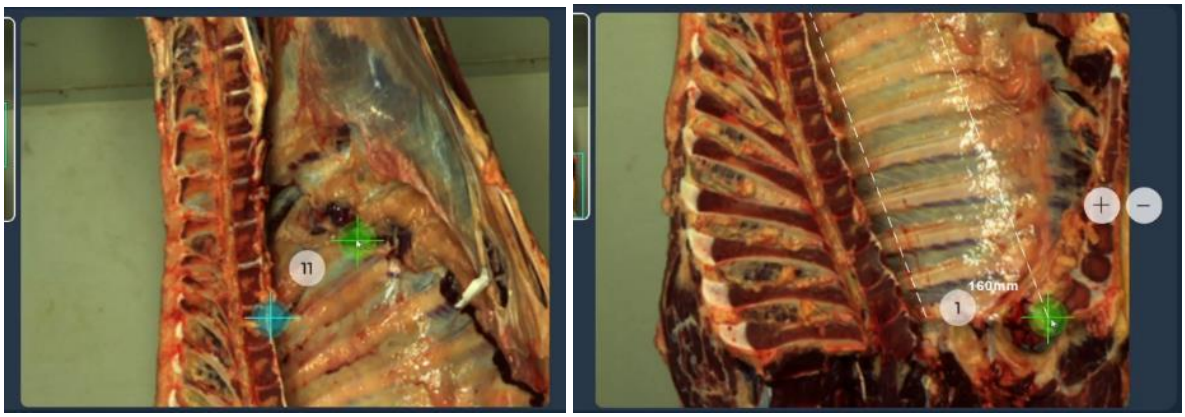



*Figure 6 - Original concept with the placement of the Diaphragm Reflection at Rib 11 (left) and Rib 1 Junction (right) placed on separate screens*

During initial runs with the software, we found that after placing these two points, adjustment was often required once the screen zoomed out to show how the brisket cutting line angle 'looked' across the whole rib cage. This caused a time inefficiency.

It is also known from previous cost-benefit analysis work that "the main benefit is the reduced angulation and variation in the width of the rack produced for the automated system" (Bryan, Webb, & Green, 2016). I.e. the key value drivers for these cuts are ensuring the brisket and dorsal cutting lines are parallel and to the correct width, rather than the absolute positioning of the cut lines themselves.

With this in mind, the following change was implemented into the interface:

- The marking of the two brisket cutting line end points, and the end of the dorsal cutting line have merged into one screen
- The start of the dorsal cutting line is placed on the next screen

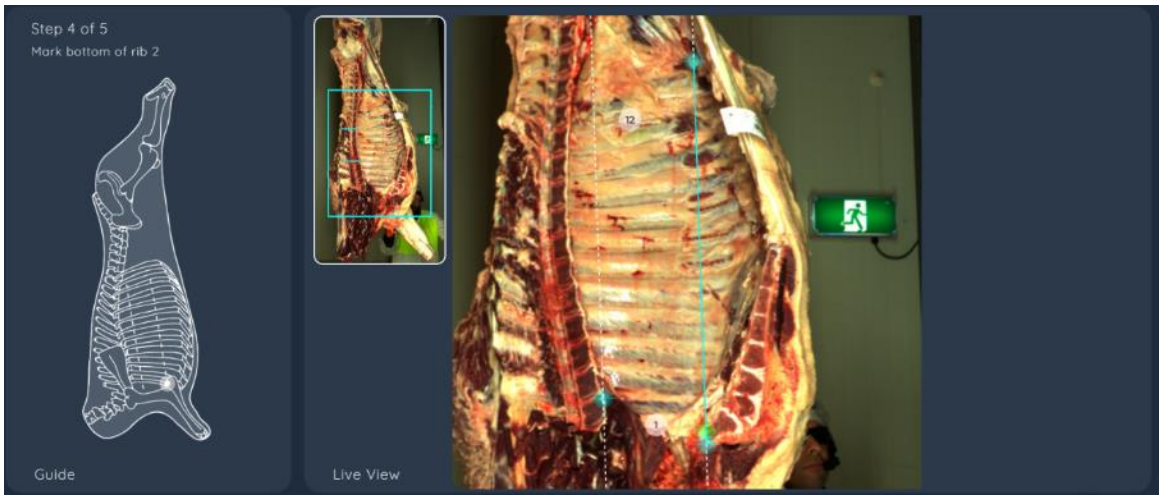



*Figure 7 - Modified concept with all markers for the Brisket Cutting Line placed on one screen*

The image is zoomed out to show the entire rib cage so that the angle of the lines are visible across the entire rib cage. The angle of the cut can be adjusted if needed before proceeding by clicking and dragging either of the anchor points.

As a result of this change, the interface will be modified in the future into a portrait orientation. It would be paired with a suitably sized monitor arranged in a portrait orientation in a commercial system. The aspect will be kept as landscape for now during demonstrations however, for compatibility purposes.

## 4.9 Overview of Concept Workflow

The workflow of the designed interface is outlined below. The workflow is to define two rib cuts (rib 2-8), a chuck-ribset separation spine cut, and a grading spine cut for a 3-rib hindquarter (below rib 11).

1) When the operator accesses the web interface, they are presented with a screen to select “Training Mode” or “Production Mode”

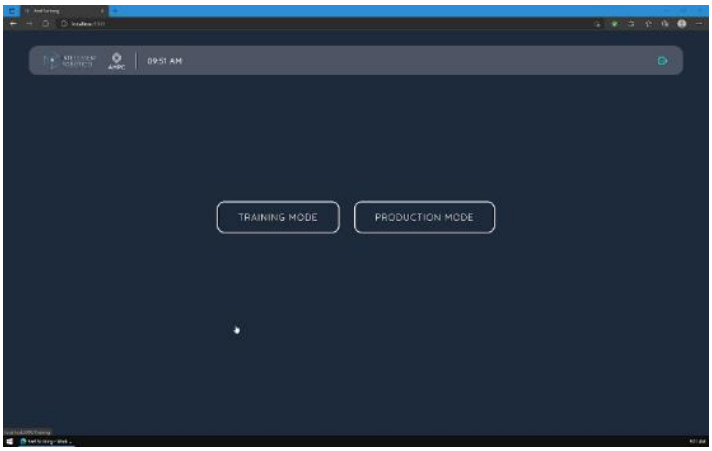



*Figure 8 - Home screen*

2) *In Production Mode:* Carcase images come up as carcases pass the camera during production

a. Once a carcase passes the camera, the rib counts are predicted and presented on the screen. The operator adjusts any rib numbers if necessary.

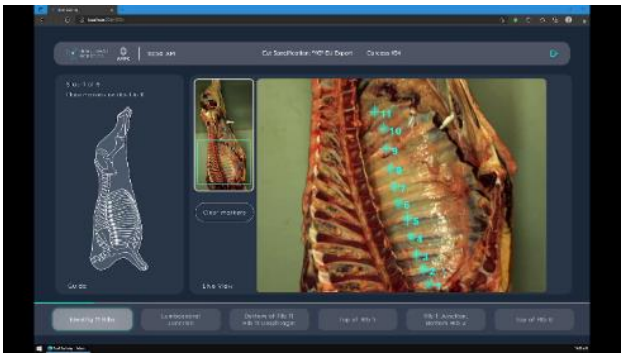


*Figure 9 - Rib count selection*

b. A zoomed image of the rib 11 area is shown. Rib 11 is numbered to allow the operator to quickly orient themselves. The grading spine cut point is selected but clicking the bottom of rib 11 next to the spine, followed by the intersection of the diaphragm with rib 11 for the brisket cutting line.

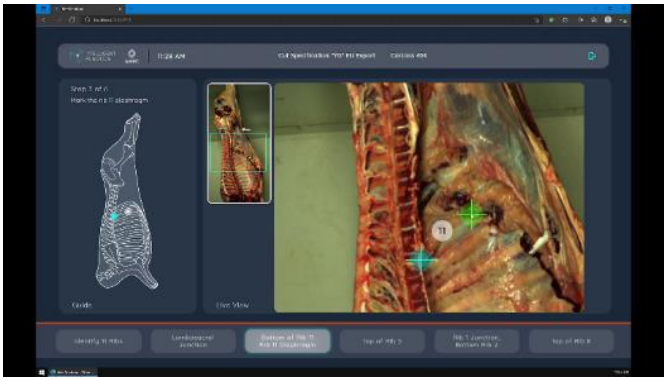


*Figure 10 - Grading spine cut point and rib 11 diaphragm point (for brisket cutting line) selection*

c. A zoomed in image of the rib 5 area is then shown with rib 5 numbered. The chuck-ribset separation spine cut point is selected by clicking the top of rib 5 next to the spine.

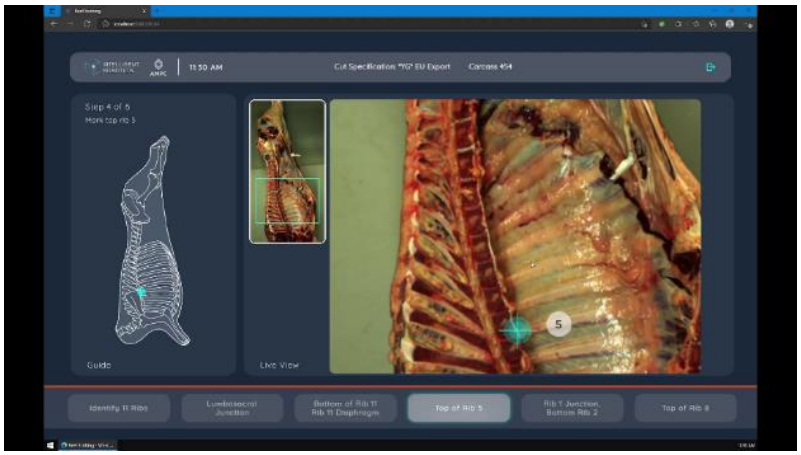


*Figure 11 - Chuck-ribset separation spine cut point selection*

d. A zoomed in image of the rib 1 area is then shown with rib 1 numbered. The operator first places the end of rib 1. The dashed lines indicating the two rib cutting lines are then shown at the designated width. The width of the cut can be adjusted using the “+” and “-“ buttons. The bottom of rib 2 for each cut is then selected.

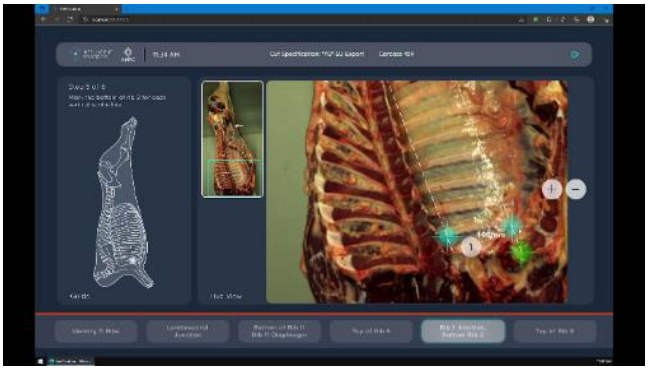


*Figure 12 - Cranial end of rib cut selection*

e. A zoomed in image of rib 8 is then shown with rib 8 numbered. The top of rib 8 for each cut is then selected.

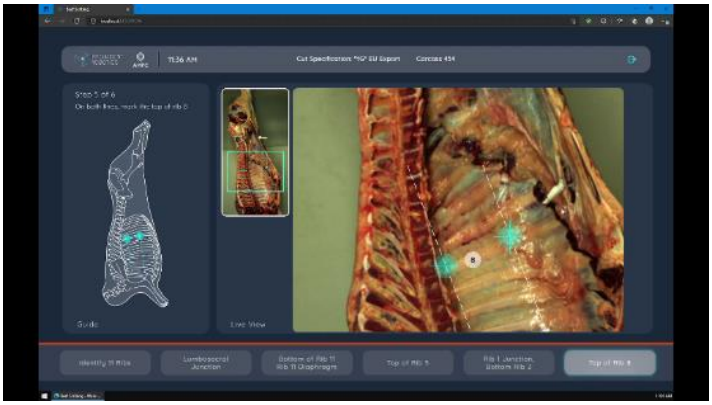
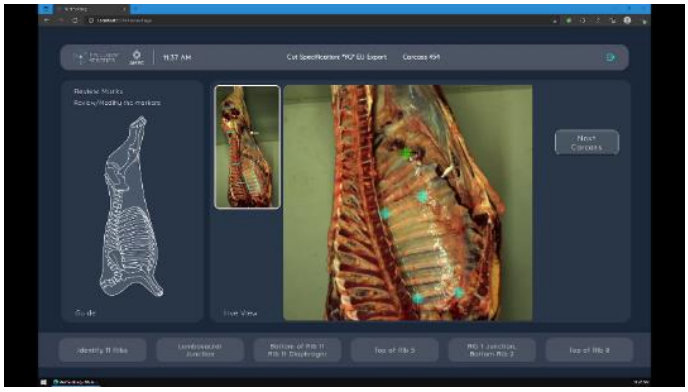


*Figure 13 - Caudal end of rib cut selection*

f. A summary screen of the rib cuts is then shown. The operator can adjust the angle of the lines by moving the green rib 11-diaphragm marker, and the start and end points of the cuts by adjusting the blue cut markers (which are bound to the dashed rib cutting lines)



g. The operator then selects the “Next Carcase” button to bring up the next carcase. They can go back to any step to make an adjustment if needed using the bottom navigation bar.

3) *In Training Mode:* A selection screen comes up for the different training modes for the system.

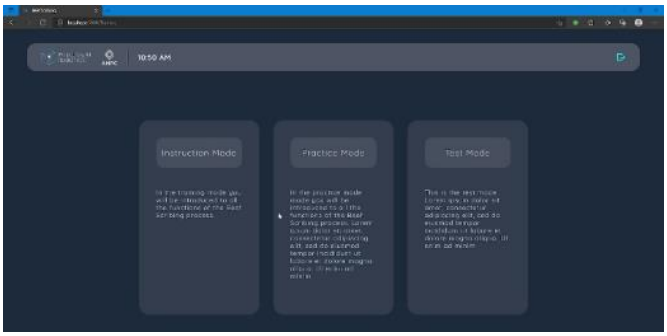



*Figure 14 - Training Mode Selection Screen*

a. *Instruction Mode:* This guides the operator through the process for an example carcase, giving instructions at each step

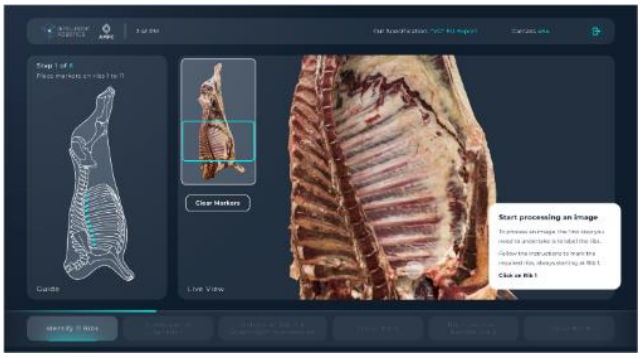



*Figure 15 - Instruction Mode*

b. *Practice Mode:* This takes the operator through a library of carcase images to allow them to practice marking. Any mistakes are flagged to allow them to get feedback and improve their skill.

c. *Test Mode:* The operator is taken through a batch of carcase images for which the ideal cut positions are known. The operator is then graded at the end of the batch based on time and accuracy.

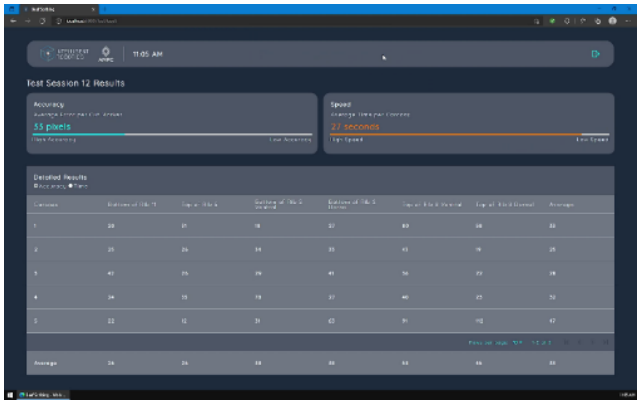



*Figure 16 - Test Mode Feedback*

## 4.10 AMPC Demonstration Feedback

In order to demonstrate the concept to AMPC, a server was setup at Intelligent Robotics to host the web application. A weblink was created to enable the website to be accessed by AMPC staff from their local computers. It should be noted that this is a temporary measure to facilitate the demonstration. In a commercial system, the server would be hosted on a PC on the plant's local network, or via a distributed web service provider. The application has not yet been optimised for multiple users, but this functionality would also be developed and tested.

A brief walkthrough of the interface was given during a weekly meeting. A brief instruction document was also drafted up to explain how to access the webpage, and how to progress through the process.

It should be noted that, in a commercial installation, there would be proper training associated with the system conducted by Intelligent Robotics, to operators of the system, as well as potential trainers for future operators (i.e. 'train the trainer'). Furthermore, the following modes will also be further developed for the software, once the core functionality and design has been 'locked' in.

**AMPC Feedback**

Some key points of feedback from AMPC included:

> *Initially I couldn't go back a screen if I needed to make correction on previous action but eventually found the buttons on the bottom that were hidden on my screen when I got to step 9. Should have followed step 3 in the instructions. That said it would be easier to click on the left of the image to go backwards and right of the image to go forwards?*

This suggestion has been noted and we plan to explore that implementation of navigating backwards. We've also thought about implementing keyboard shortcuts for going forward and backwards on screens.

There was also an issue where for some computers, the automatic zoom level in the browser meant the bottom navigation buttons weren't visible unless the webpage was manually zoomed out. This will be addressed in the coding of the web application.

> *Consider (for those of us that don't know what we are doing):*
> *- On screen instructions*
> *- And or (future) video tutorial / instruction*

These suggestions have been noted and functionality around training is in the roadmap for development work.

> *Technical issues were encountered when trying to run the interface. However from what was seen the concept looks positive and appreciated the balance between 'training tool', 'industry exposure tool', and 'production tool'.*

These issues will be addressed in further development. We believe they stem from the server not being yet setup to handle multiple users properly, as well as the site being hosted on an IR PC (rather than a proper web service or dedicated server PC). Such access issues would be tested extensively in the production build however.

> *Liked the interface – found it very clean. Quite easy to use after following instructional video (this was a lot more helpful than the instruction document). Some suggestions include:*
> *- Present all cuts on the final cut screen before moving onto next carcase*

The suggestion of showing all cuts on the final cut screen before moving onto the next carcase has been noted.

## 4.11 Initial Recommendations for Stage 2 Development

While there is a bit of a learning curve associated with using and getting comfortable with the interface, we believe the design facilitates the ability to meet the key design targets. Outlined below is a summary based on the design intent and from internal testing.

**Accuracy to +/- 10mm accuracy**

*Spine Cuts*

By zooming into the areas of interest, particularly with respect to the spine cuts, the operator is able to mark the point of interest to within a pixel or so. When paired with the appropriate camera, the target resolution of each pixel on the original carcase image will be less than 1.5mm per pixel, which, when coupled with the zooming functionality of the interface, should allow the operator to select points well within the ±10mm accuracy target. An even higher resolution camera can also be used if it is thought it will cause a significant improvement.

*Rib Cuts*

For the rib cuts, while this approach was initially explored, it was found to be sub-optimal. This is because the placement of this cut, and particularly the angle of the cut, is not so strictly defined. A lot of 'look and feel' is used when observing the angle of the cut sitting along the entire rib cage of the animal to adjust the angle accordingly, rather than needing to draw a line between two succinct and well-defined spots. As aforementioned however, the shortcomings of this are addressed in yield benefit analyses which show the primary driver for value in these cuts is that they are parallel and to the correct width, rather than millimetre-perfectly placed (Bryan, Webb, & Green, 2016).

With this in mind, the updated layout allows the operator to accurately locate the vertical rib cuts and ensure the angle looks desirable for the brisket cutting line. The dorsal cutting line is then generated automatically ensuring that it is parallel. The interface assists the operator to place the correct width cut via two methods, depending on what the processor cut specifications are. This approach ensures maximum value through keeping the cuts parallel and at the desired width.

**Place 4 cut lines on a beef side within 20 seconds**

During the initial testing on the concept, it took approximately 21 seconds to identify the ribs and place 4 scribe lines. This was while trying to go as fast as possible.

It was noticed that the rib placement screen took the longest amount of time (due to the high number of clicks) and added the smallest amount of direct value as none of these clicks were defining actual cuts. The plan to have this functionality optimised through pre-processing algorithms was therefore shifted from a "future development" functionality to a critical functionality for product viability.

After this functionality was developed, the average time to place all four cuts was reduced to 14 seconds, placing it within the target processing time range.

It is also expected that a trained operator who gains familiarity with the system, as well as with scribing, would be able to drive the system faster than the engineers at Intelligent Robotics.

## 4.12 AMPC Webinar

Intelligent Robotics was invited to present the Semi-Auto Scribing interface online as part of a webinar hosted by AMPC on the innovation theme. The scribing interface was demonstrated in terms of functionality as well as design intent in the context of facilitating quick and accurate marking of scribing cuts to power automation.

A video of the webinar presentation can be found at the following link (accessed 26/09/2022):
https://www.youtube.com/watch?v=FdHnZwqm3sg&t=515s

The feedback from AMPC was positive regarding the content of the presentation. There were no questions or comments from any of the attendees with respect to the IR concept.

## 4.13 Review of Concept

Intelligent Robotics continued to review and modify the semi-auto scribing user interface concept, particularly in the context of how it may be used most effectively to drive automation and with respect to other related R&D work being performed.

Considering these factors, the pre-processing algorithms for the interface were bolstered. This would allow the operator to adjust them as needed. This is in contrast to placing the markers from scratch and would enable significantly faster throughputs to be achieved as the number of operator interactions required is minimised. This was therefore thought to be a more commercially-relevant direction for the technology and allow greater uptake.

With this pivot in mind, the interface was modified to reflect the new design intent. The concept was simplified and consolidated into a single screen. This screen would show all the relevant guide and cut markers as estimated. In order to allow sufficient resolution in the display, the interface was switched to portrait orientation. A timer bar at the top and a label at the top-right of the screen would indicate how much time the operator had before the next side will be displayed. This would be based on the throughput of the plant, and the number of operators being used for the mark-up activities.

After a number of design iterations, refining the interactivity of the interface and the design, the final version of the updated scribing interface was built.

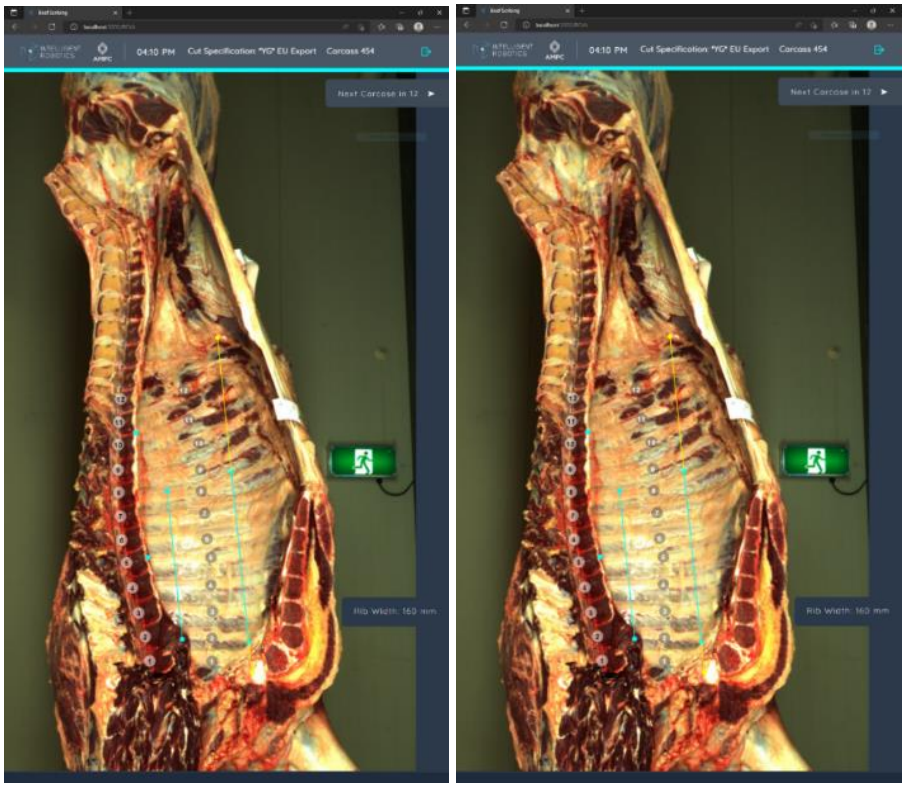


*Figure 17 - Revised semi-auto scribing user interface design*

This version of the interface was demonstrated to AMPC with positive feedback being received on the change in direction.

## 4.14 Demonstration to Processor #1

With the new version of the interface compiled, it was demonstrated to a beef processor. A laptop was taken to their site and a desk was setup with a 24-inch monitor setup in a portrait orientation.

The feedback from the operator was positive in terms of usability and thought that the concept was fit-for-purpose and could be used for the task of driving semi-automated beef scribing for their plant. A number of small items of feedback were given:

- *a line should extend across the spine to indicate where the spine cuts would be placed*
    - This is something that can and will be implemented in future versions of the interface
- *ability to keep the dorsal rib cut cranial point fixed while adjusting the brisket cutting line points. This would result in pivoting the brisket cutting line while keeping the dorsal rib cutting line as close as possible to the spine*
    - This is certainly a functionality that can be implemented in future versions
- *the 24-inch monitor looks like a good size for the format*
    - Originally the interface was intended to be operated on a 27-inch monitor as it was thought this size would be required to accurately place the cuts. However, based on the feedback from this processor, it appears as though a 24-inch monitor may also be suitable, or even preferable.

## 4.15 Demonstration to Processor #2

The user interface was also demonstrated to a second processor, where a laptop was setup on a desk with a 27-inch monitor in portrait orientation. A number of staff members were involved in the demonstration, including their innovation manager, production and operations managers, and safety managers.

In terms of the user interface itself, the site was positive about its functionality and fit-for-purpose nature. Some key points of feedback they provided included:

- *Consideration for displaying and changing cut specification*
    - Their main concern was how an operator would know what cut specification they are currently operating to, and how to change specification when needed.
    - Some feedback on the interface was suggested, for example radio button selection down the side.
    - Moving forward, RFID could be used to define the cut specification for a given carcase, although there were no plans in the short term to implement RFID hooks at this particular plant.
    - One other potential option is the ability to upload the production run sheet for each day into the system. The cut specification could then change automatically based on this. The ability to manually change the specification would still be enacted.
- *Provisions to ensure an operator is paying attention*
    - One potential issue which may arise is whether the operator is maintaining attention.

- One mechanism for coping with this would be to insert intentionally poor results randomly during production. If the operator doesn't pick up this mistake then their lack of concentration can be flagged.

The site was extremely positive in terms of the overall concept of using a semi-automatic interface to drive robotics. This was particularly in the use-case of scribing, but they could also understand how it could be used to drive other robotic automation. The key benefits they saw were in improved yield and safety. On the latter point, they mentioned that while they haven't had a serious incident involving scribe saws at their particular plant in the past, the historical instances of bad incidents occurring across the industry in general spoke to the dangers of the task. The site was interested in continuing conversations to progress the opportunity to put the technology into their plant.

# 5.0 Conclusions / Recommendations

This project successfully saw the design and prototype implementation of a gamified semi-automated scribing web user interface. The intent behind IR's approach was focused heavily on utilising the interface in the context of driving an automated system. The user interface concept consists of a number of modes: instruction mode, which teaches the operator about the interface and how to use the program; practice mode, which guides the operator on how to place and adjust markers and gives assistance when incorrect placements are given; test mode, which runs through a mock production situation, taking the operator through a series of carcase images and then grading them on accuracy and placement time; and production mode, which uses live images from production to drive a robotic cutting system.

The concept developed over a number of iterations through the course of the project, taking into account feedback from AMPC and processors, and also factoring in learnings from other projects occurring in parallel. The end result is an interface which received positive feedback and would be commercially feasible for driving a semi-automated beef scribing system.

While the use-case presented focused on the particular application of beef scribing, the concept can be extended to other vision-guided red meat automation tasks. For example, the interface could be modified to ask the operator to identify the dew claw for automated hock cutting, or the spinal cord channel for spinal cord removal.

In the context of scribing, it is felt that the next step for the technology is likely to implement it within a commercial project with a processor for a semi-automated scribing system. The user interface was presented to two Australian red meat processors who both delivered positive feedback to the concept. Work with both these processors is continuing to proceed to next steps.

# 6.0 Bibliography

Bryan, K., Webb, L., & Green, P. (2016). *P.PIP.0288 & P.PSH.0633 - Ex-Post Cost Benefit Analysis of Automated X-ray Beef Rib Cutter with Ex-Ante estimation of additional objective measure benefits from DEXA data.* AMPC.

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