FINAL REPORT

Robotic Removal of Button Bone and Flat Bone after Striploin Chine Bone Removal – Stage 1 Practical Feasibility

FINAL REPORT (M4) - Open

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TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

The research has examined the feasibility of automating the manual task of button bone and flat bone removal from a beef striploin primal piece. The boning practices under consideration involve the use of a powered rotary wizard cutter for button bone removal and a standard butcher's knife to separate the flat bones. The task is highly skilled.

Video recordings of the task have been analysed and the variability of the striploins have been assessed. The approach to automation has considered methods of fixation and sensing to identify the profile of the bones of interest. The feasibility for sensing using low cost imaging and laser range sensing for robot guidance to perform separation of the button and flat bones has been reached and practically demonstrated using a unique robotic system. Sensory data, including force, imaging and range, as well as physical integration of all components with a cutting a tool has been achieved and practically tested on an experimental basis to assess feasibility, which has been reached.

The feasibility effort and the project as a whole have reached positive outcomes, establishing the automation of the boning processors under consideration to become practical. Figure 1 presents the integrated set up for a first experimental system developed by BMC UK (bmcdevon@aol.com) under this AMPC funded project, which is a first of its kind.

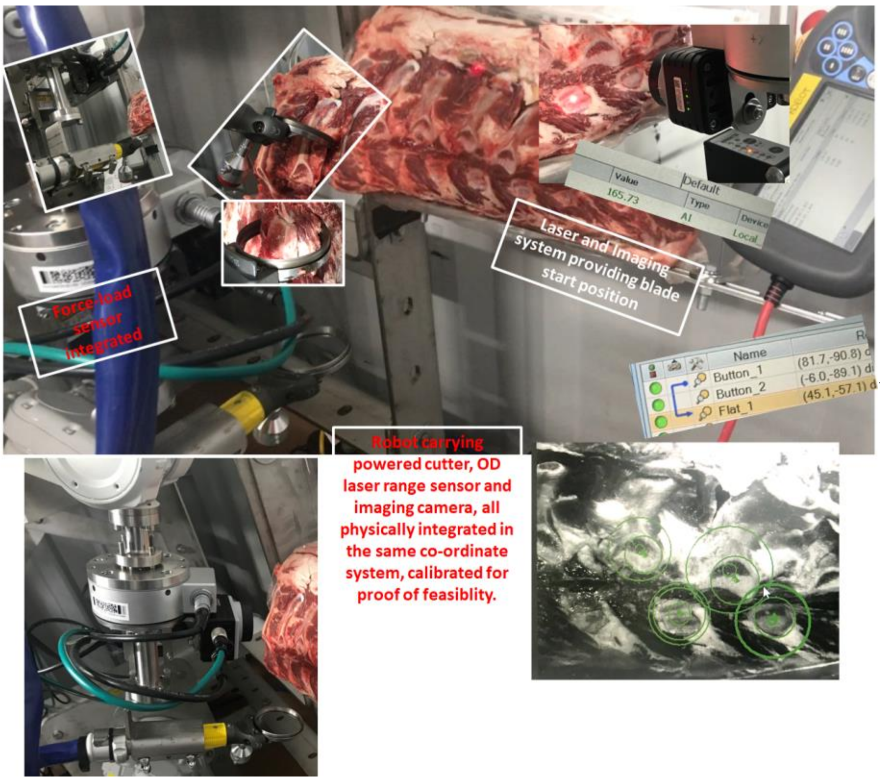


Figure 1: Stage 1 outcome for striploin button bone and flat bone removal as a first integration.

It is proposed that Stage 2 follow up project aims to reach an integrated system for use adjacent to a processing line in the fourth quarter of 2020.

2.0 INTRODUCTION

The current practice of removal of cutting out button and flat bones from a striploin beef primal piece requires manual effort and separation using a powered cutter as well as sharp knives. For the usual reasons of safety, efficiency and potential yield improvement, automating the practice is desired. A low-cost solution would provide an important contribution to the Australian beef sector. An important requirement by the industry.

Figure 2 provides an overview of the task that have been under consideration as performed manually using a rotary trimming tool for the removal of the button bones and a normal butchers knife for the separation of the flat bones. The feasibility of automating the specific tasks of Figure 2, meeting the requirements of Australian beef sector, has been the focus.

Figure 2: Current practice: removing button bones (left) and flat bones (right).

This project as a Stage 1 feasibility has examined the possibilities in a structured and practical manner, using the knowledge of past projects, experience of the service providers and the support of experienced organisations. Methods of simple fixation and handling when integrated with vision sensing for robot guidance provide practical solutions. Integration of the data relying on a fast calibration and the reduced reliance of co-ordinate transformation reduces the cost of implementation as the project progresses to future Stages to the point of wide-spread adoption possibilities.

3.0 PROJECT OBJECTIVES

The objective has been to evaluate the feasibility of automatic removal of button bones and flat bones in beef striploin primal pieces investigating and delivering the following:

- Fixation solution and sensing options,
- Cutting tool options and their design for effective integration,
- First integrated experimental system,
- First stage feasibility documentation in a final report.

4.0 METHODOLOGY

The project is to follow a methodical approach as follows:

- Measure and quantity variabilities in the primal pieces and features of relevance to the process of button bone and flat bone removal.
- Evaluate skills and effectiveness of current process
- Identify, examine and evaluate robotic tooling, handling and fixation technologies that may be integrated for the task of button and flat bone removal.
- Perform practical evaluations using a robotic system to establish extent of feasibility, with respect to expectations.

5.0 PROJECT OUTCOMES

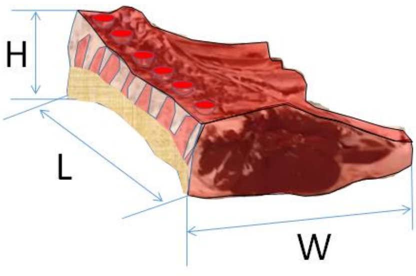
This Stage 1 project has shown the capabilities of cutting options, sensing and robotics, establishing the feasibility of automatic striploin button and flat bone removal in and integrated experimental arrangement. The following sections provide the project progress and outcome in this final report.

5.1 Variability, fixation and sensing

Based on trials, the striploin presentation would not require specific handling or fixation, if it were conveyed and presented as shown in Figure 3.

Figure 3: Positioning of striploin

Figure 4 provides the variability in the overall dimensions of striploin beef primal pieces. It is important to note that the button bone is approximately a half hemisphere with diameter of 35-40 mm in diameter as a maximum.



mm	Min.	Max.
L	350	700
W	180	350
H	70	150

Figure 4: Striploin primal piece overall variability.

It is important to note that the chine bone cutting influences the process under consideration. The button bone and flat bone separation can be performed most effectively, only if the chine bone cutting process prior to this step has been achieved correctly and to quality as illustrated in Figure 5. Observations suggest that unpredictable outcomes are possible where button bones may not be fully separable from the primal piece if chine boning removal results in anomalies, Such may be detected by the automation intended based on force sensing providing a means for recovery and in certain instances, intelligent execution of the steps that reach the end product specification.

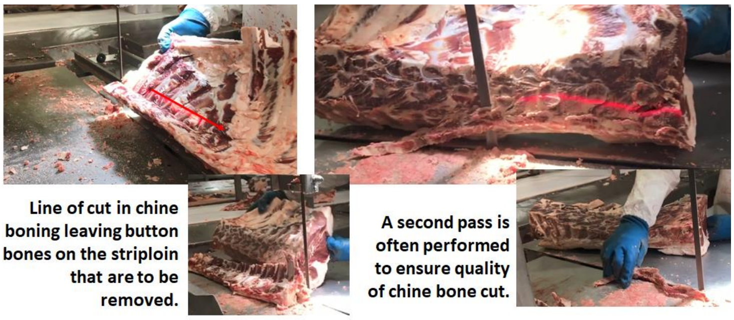


Figure 5: Influence of chine bone cut on button bone and flat bone removal.

The separation process of the button bone would use a robotic approach and the automatic execution of the task is to follow the same method as the manual process. The handling and fixation require the control of the striploin primal piece and each button bone as the wizard cutter penetrates the meat under the button bone 'scooping' the button bone out. It is envisaged that the separated bones would fall under gravity with the striploin located as in Figure 3.

Sensing capabilities based on proven solutions have been assessed. These include touch or contact, vision and laser distance sensing as well as force or load sensing in the specific context as may be applicable.

Vision capabilities have been in use in the meat grading, classification, recognition, inspection and robot guidance over several decades. The specific process of interest has been examined using solutions that provide for easy integration at low cost, both in relation to the hardware and programming.

Figure 6 illustrates the schematic options both for button bones and flats. It is necessary to guide a cutting tool when separating button bones in a manner that lifts the button bone, whilst separating the button bone from the striploin muscle, with the load or force control keeping the cutting edge of the blade in close contact with the bone at the meat-bone boundary (Figure 7).

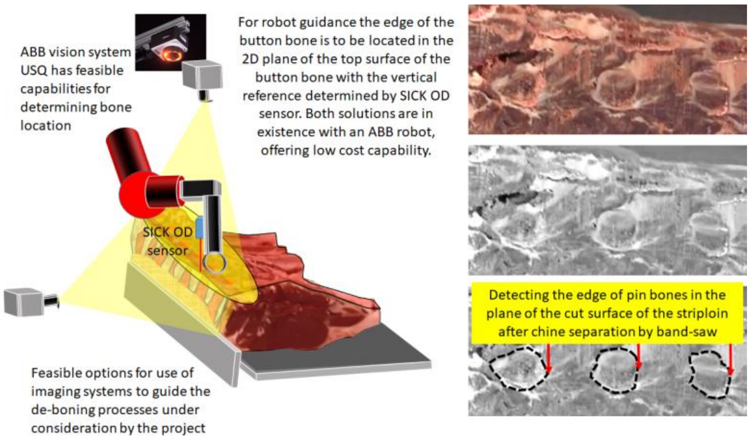


Figure 6: Vision sensing enhanced by OD and touch sensing keeping solution costs low, using proven and feasible capabilities.

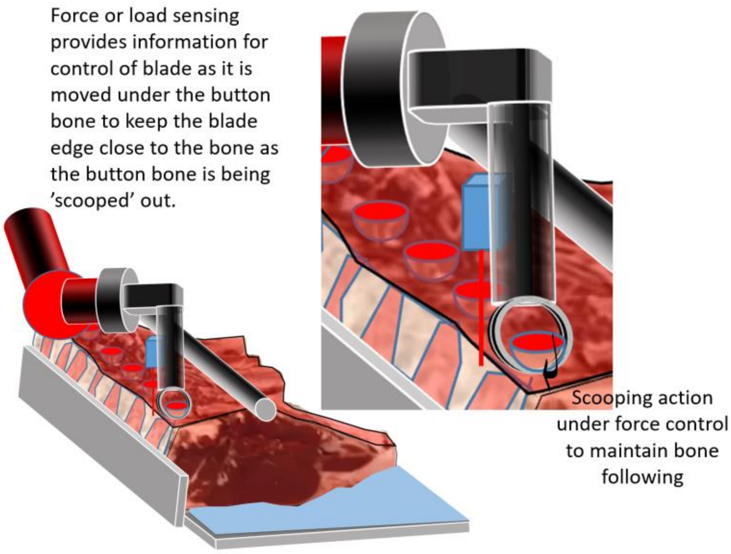


Figure 7: Scooping action would use force-load sensing capability as a feasible option.

5.2 Cutting tool options

Figure 8 provides an overview of the setup of the sensing equipment and the cutter in a robotic cell in the first evaluation of the cutting tool. The setup, using a slicing machine as a rig is also shown for the evaluations relating to side bones as a third group of bones additional to the scope of the feasibility, focusing on button and flat bones as in Figure 1.

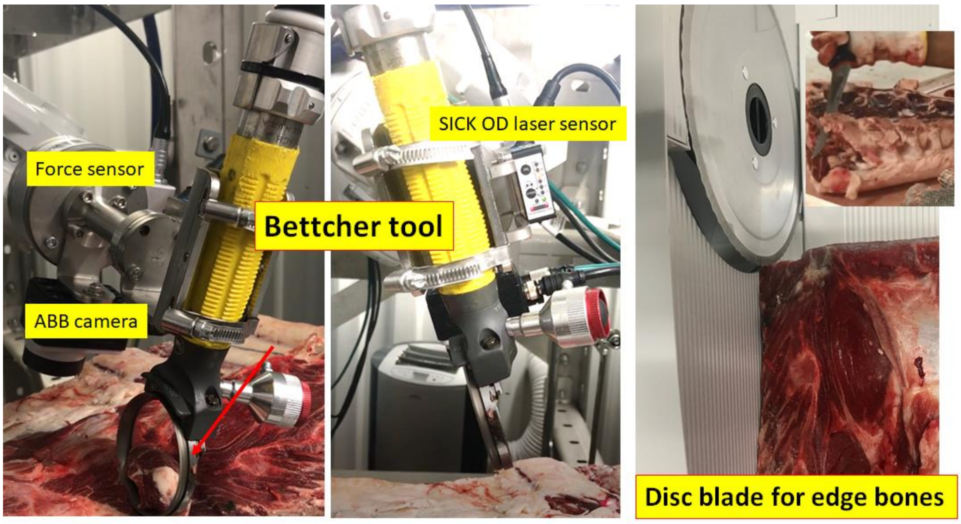


Figure 8: Cutter tool trials in first cutting attempts (trials in specific rigs).

The Cutter tool as shown in Figure 8 with a blade of 50 mm diameter is considered appropriate. Figure 9 shows the attempts of the Cutter tool being used with a robotic action separating the button bone and flats. The critical aspects of the process are the placement of the tip of the cutter blade close to the edge of the face of each bone and controlling the cutting action with the blade following the bottom surface of each bone keeping the cutting edge on the bone-meat interface using force sensing. The trails reveal that a larger dimeter (120mm) blade will be required for flat bones in future developments.

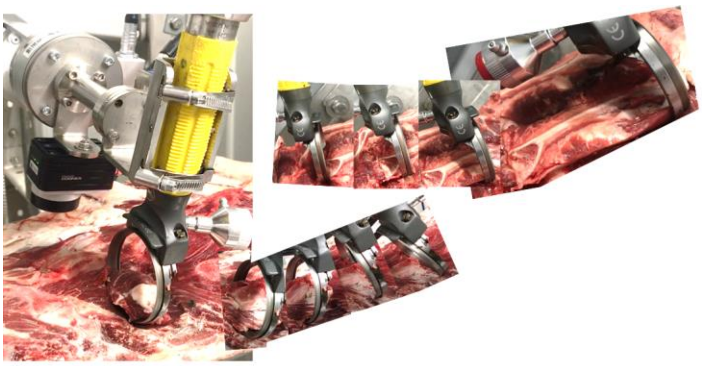


Figure 9: Scooping action to remove button bone tested using a robotic rig set up.

It is important to note that the chine bone cutting influences the process. The button bones need to be separated from the back bones with the chine boning meeting specification.

5.3 Integrated experimental system

Figure 10 presents the tool in its physical set up with the capability to perform bone separation, as experimentally integrated (see Figures 1 and 8).

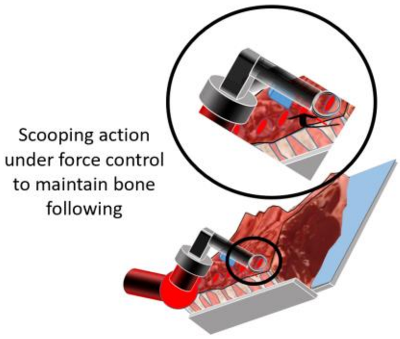


Figure 10: Approach to handling and integration.

The project has defined low-cost and functional sensing solutions, which have been integrated with the IRB 140 robot, as a suitable manipulation unit for the task in hand. In experimental form, and on a practical basis, the sensory solutions including laser range sensing, vision system and 6 axis force sensing, all of which have been successfully integrated with the IRB 140 robot (see Figure 11). ABB and SICK solutions have been used with input from ABB supporting the software integration with the physical robotic system and tooling implemented at USQ. The team have tested the function of the integrated hardware and software using the set up illustrated in Figure 11.

Figure 11: Sensor integration considered feasible based on practical implementation.

Figure 12, gives the vision data transfer capability as an integral part of the control software, demonstrated for the first time in Australia for such an application. Although the integration solution has been available for at least a decade, its practical use in such application has now been practically achieved by this project as a low-cost platform for further development in the future stages of this project.

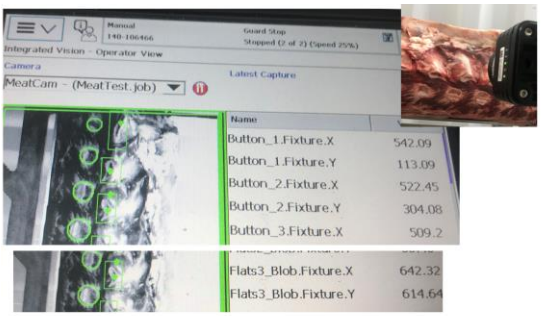


Figure 11: Vision integration with the IRB 140 achieved in this application for the first time in Australia as low-cost platform for future implementation.

6.0 CONCLUSIONS/RECOMMENDATIONS

Examination of the processes of button bone and fat bone removal has been performed for automation.

Mechanisms for locating and holding the primal pieces as well as sensing capabilities already applied in other applications, requiring minimum integration effort, have been considered for integrated solution in the long term.

The approach to the solution for removal of button bones and flats in striploin beef has been considered and all milestone objectives have been met, establishing the feasibility based on practical implantation of integrated solution on an experimental bases and deboning trials.

Testing has shown the functionality of the integrated elements of the system. The practical experimental integration of all the elements of a solution for removal of button bone and flats from a striploin primal piece has been reached.

7.0 ACKNOWLEDGEMENTS

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- JBS Australia, Beef City,
- ABB Robotics Australia,
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