Final Report

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Shadow Robotics

Remote Operations - Mimeo Shadow Robots (Stage 4)

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Contents

Contents 2

1.0 Executive Summary 3

2.0 Introduction 3

3.0 Project Objectives 4

4.0 Methodology 4

4.1 Approach and Scope 4

4.2 System and Interface Improvements 5

4.3 End-Effector Development 5

4.4 Operator-Informed Machine Vision 5

4.5 Robot Base and Dual-Robot Installation 6

4.6 Safety System Upgrade 6

4.7 Commissioning and Routine-Use Trials 6

5.0 Project Outcomes 7

5.1 Pick-and-Pack Performance 7

5.2 Remote Operation 7

5.3 Routine Use and Barriers Encountered 8

6.0 Discussion 8

6.1 Progress Against Objectives 8

6.2 Value Proposition and Use Case 8

6.3 Key System Features and Learnings **Error! Bookmark not defined.**

6.4 Future Pathway 9

7.0 Conclusions / Recommendations 10

8.0 Acknowledgement 10

9.0 Bibliography 10

1.0 Executive Summary

This project delivered a fully integrated, dual-robot shadow robot system operating remotely in a live meat-processing pick-and-pack application, confirming that the remote-operation concept is sound in a production environment. The trial application was the packing of lamb brisket (breast) pieces on the IW line at JBS Brooklyn, with the robots operated remotely by a trained operator from within the facility and from New Zealand.

The delivered system included:

- a wider field-of-view vision system and a refined operator interface with real-time system feedback;
- a redesigned, commercially manufactured washdown bag;
- a custom vacuum (suction-cup) end-effector delivering 90-92% grip success in trials;
- operator-informed machine vision (contour detection) to refine pick position and orientation; and
- a full safety upgrade comprising guarding and robot position/speed sensors installed on site.

The system was shown to work well under suitable conditions. The vacuum gripper achieved around 90-92% grip success in trials, and during the best production runs the integrated system reached approximately 90% pick success at a per-robot rate of about 17.5 picks per minute, operated remotely from within the JBS facility and from New Zealand.

The shadow robot platform performed to specification. The remaining barriers to unsupervised routine handover are environmental and application-specific — product surges and clustering on the conveyor, overflow of the downstream hungry bin, and the workspace resourcing required — rather than platform limitations. With the proof of concept now established, the route to a compelling value proposition is to extend the same platform to packing two or more product types per operator, and to automate peripheral tasks such as carton removal and changeover — reducing the in-room support requirement and translating the technical capability into commercial return.

A set of ten operator-experience sessions were completed, gathering structured user feedback on the remote selection and packing task; the next step is to use this feedback, together with detailing of the use case, hardware requirements and value proposition, to justify continued deployment.

The project confirmed that the remote-operation (shadow robot) concept works. In addition, the project showed how a shadow-robot system, when combined with machine learning can be a tool for increasing automation. It was shown that it was feasible to step from remote selection to automated selection. In this use case where packing requires in-room support, automating selection and increasing picking/packing to manufacturing line speed for both robots holds the key to realising the value proposition.

2.0 Introduction

The Australian Meat Processor Corporation (AMPC) put out a request for shadow robotic solutions for the meat industry in 2020. The primary motivation for implementing shadow robotics was to remove operational staff from potentially dangerous devices or tasks. The ultimate goal would be to have operational staff remote from the processing facility, thus creating a safer working environment. Additional benefits to using shadow robotic systems would be the added precision of industrial robots, the potential for yield increases due to sub-millimetre accuracy and machine learning integration, and the robot can be used to remove the physical demands of some tasks.

The purpose of the work presented here was to progress the previous development of a proof-of-concept shadow robot system (Mimeo Industrial Ltd., 2022a; Mimeo Industrial Ltd., 2022b; Mimeo Industrial Ltd., 2022c) through to a working production system trialled within a live meat-processing facility. The previous work on a shadow robot system had yielded a prototype system that would monitor the real time motion of an operator (using a tracked object held by

the operator) and “shadow” the operator’s motion using an industrial robot arm. In Stage 4 of the system development this was pursued through a single pick-and-pack application — the packing of lamb brisket pieces on the IW line at JBS Brooklyn — expanded to a two-robot, single-operator configuration to test the commercial value proposition. The development, trials and outcomes of this work — and the pathway it has opened toward routine, commercial use — are set out in the sections that follow.



Figure 1. The output from the last stage was a single robot, remote control robot in a pick and pack application.

3.0 Project Objectives

Leveraging the work from the previous stages of the Shadow Robot project (project numbers 2023-1039, 2022-1202, 2022-1118 and 2021-1158), the objectives of Stage 4 were to:

1. prove the application of shadow robotics for picking and box packing;
2. put a shadow robot into routine use in a meat-processing boning room for a picking and packing application; and
3. for this application, prove the business case.

Proving the business case was expected to require two robots controlled by a single operator. The project therefore included the build of a second shadow robot together with the supervisory and management systems. The intended project outcomes were:

- a reference-site demonstration of shadow robots being used routinely in a dedicated meat-processing application;
- a business case for shadow robots in pick-and-pack applications, with specific consideration of single- and multiple-robot operation; and
- a system that is proven and ready for full commercialisation.

4.0 Methodology

4.1 Approach and Scope

Work that continued picking and packing of lamb brisket pieces on the IW line at JBS Brooklyn was carried out through development at Mimeo's facilities in New Zealand, and on-site trials and progressive routine use at JBS Brooklyn with the assistance of JBS staff. A second packing robot was built and installed, together with the supervisory systems

needed to run two robots from a single operator. In addition, to achieve better pick performance the gripper was reviewed and changed out to a vacuum system and the safety system was upgraded.

4.2 System and Interface Improvements

A number of improvements were made to move the system toward routine use. The conveyor vision system was upgraded, robot motion was tuned for speed up to 24 picks per minute in the workshop, the washdown bag was designed for ease of use and cleaning, a supervisory and operator interface was developed to provide the platform that could be used to both operate and manage multiple shadow robots at a supervisory level.

4.3 End-Effector Development

A five-finger soft gripper plateaued at around 70% pick success so after a comprehensive review of alternatives, a vacuum gripper system was chosen and prototyped, with initial concepts showing up to 92% success. The vacuum gripper was progressed to a production prototype using a proprietary chain of vacuum components and filters to handle the product, with 2 different strategies implemented to accommodate parts of varying height.



Figure 2. Production vacuum (suction-cup) gripper picking a lamb brisket piece during on-site trials.

4.4 Operator-Informed Machine Vision

To improve pick accuracy, contour-detection software was developed to refine the operator's selection and determine the best picking orientation. Manual computer-vision techniques were used initially and tested in production, however clustered product on the belt prompted a change to Machine Learning based segmentation.

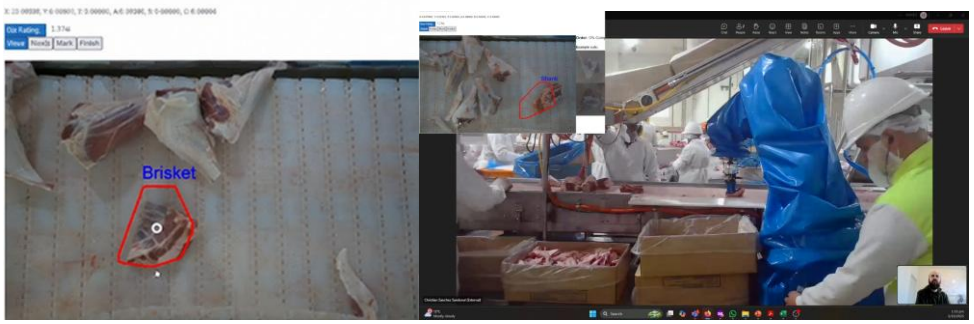


Figure 3. Contour-detection output used to refine pick position and orientation on the conveyor.

4.5 Robot Base and Dual-Robot Installation

The vacuum feet were removed to simplify the robot installation. Site changes during the September 2024 plant shutdown require the removal of the first robot and required the IW conveyor to be reconfigured before the equipment could be reinstated.

The first robot was reinstalled and upgraded in January 2025, and the second robot was installed in March 2025, together with code that distributes the picking workload between the two robots under a single operator's selections.

4.6 Safety System Upgrade

In April 2025 for routine use, additional guarding and robot safety systems were installed. All efforts were made to minimise the footprint of the guarding. Guarding panels were removable allowing full access when the robots were not is use. Carton-exchange drawers were installed to minimise downtime. Safety position sensors and robot hard stops were installed, giving a flexible, safety-rated system.



Figure 4. Installed safety guarding around the dual-robot cell.

4.7 Commissioning and Routine-Use Trials

With the gripper, vision and safety upgrades in place, the dual-robot system was recommissioned and progressively run during production. The focus of the final phase was increasing uptime and removing the remaining barriers to routine use, with the system operated remotely from a kiosk-style operator console set up at the JBS culture centre and from New Zealand. Hardware and software were upgraded in response to feedback from these sessions.



Figure 5. Recommissioned system showing the raised carton slot, new drawer fronts and added signage.

5.0 Project Outcomes

Key features confirmed in this work were:

- remote operation through a web interface on any internet-enabled device, demonstrated internationally;
- an installation that could be moved and suited to existing processing rooms;
- a core system adaptable across picking, packing and related tasks;
- operator-assisted selection with conveyor tracking;
- a high-performing vacuum end-effector suited to variable meat geometry; and
- safe operation around staff, complemented by compliant guarding and full washdown capability

5.1 Pick-and-Pack Performance

During the final production runs, the integrated system — two robots, vacuum grippers, contour detection and the new safety guarding — achieved approximately 90% pick success at a per-robot motion rate of about 17.5 picks per minute, when an experienced operator was selecting, product was roughly singulated, and the hungry bin was kept clear. Under these conditions very little product passed the robots unpacked.

5.2 Remote Operation

A central objective — and a key proof point — was remote operation. Throughout the stage the system was operated by multiple users, both from within the boning room and remotely, including from the operator console set up in the JBS innovation/culture centre and from New Zealand. The trials confirmed that an operator can effectively select and pack product from a location entirely removed from the processing line, including internationally.

Structured feedback was gathered from operators across these sessions via a post-session survey. Operators generally found the remote workstation comfortable, considered the conveyor pacing appropriate to the task, and did not identify video feed lag as a barrier to effective operation. The most consistently cited challenge was confidently identifying and selecting individual pieces of product on screen, particularly where product was clustered on the conveyor — consistent with the environmental and product-flow barriers discussed in Section 5.3. Several operators

noted that remote operation removed the physical demands of standing at the line and reduced pre-shift gowning time. This feedback will inform refinements to the operator interface and selection workflow.



Figure 6. JBS staff member marking up brisket pieces remotely from the operator console.

5.3 Routine Use and Barriers Encountered

While the system was shown to run continuously during production with suitable process management in place, routine handover to JBS operations was not achieved. The principal barriers were environmental and application-specific rather than failings of the shadow robot platform, including:

- surges and clustering of product on the conveyor, which the current single-product pick rate could not always absorb. Rough singulation upstream was shown to mitigate this aspect.
- overflow of the downstream hungry bin, which blocks the robot workspace unless tended regularly;
- the availability of trained staff to support the system in-room.

6.0 Discussion

6.1 Progress Against Objectives

The project demonstrated the application of shadow robotics for picking and packing and proved that the system can be operated remotely at high pick success. The technical building blocks — a high-performing gripper, operator-informed vision, dual-robot coordination and a compliant safety installation — were delivered and integrated.

The remaining gap, to meet the objective of routine use was limited by the need to supervise the system in-room, primarily changing cartons (as carton-exchange was not fully automated) and managing unexpected product back-ups.

6.2 Value Proposition and Use Case

Proof of concept has been established from this work: the remote-operation platform works at production performance levels. The use-case in which this was achieved was a remote operator selecting, two robots picking and packing one

part and an in-room person supervising carton exchange, preventing product back up from upstream missed packing etc. The value proposition for this set up is limited to:

- The remote operator having an improved work environment without the need for gowning up
- Reduction in repetitive tasks for both remote and in-room staff, reducing the likelihood of repetitive strain injuries, and
- Improved food safety, with only the robot end effector touching the product.

However, in the use-case here, an additional person was required above normal operations and staff supervision of a single dispersed team-member reduce the potential value. It is however a small step to have the two robots packing two products, with a single remote operator (selecting two parts) and in-room system supervision, strengthening the value proposition. Bigger wins come with:

- Scale: one operator selecting multiple products, and more remote-controlled robots picking more product,
- automation of in-room support tasks, and
- automation of the remote operator's tasks.

Regarding the latter point, by the end of the project and with the use of machine vision and machine learning, we demonstrated the feasibility of automated selection of brisket.

For the purposes of improving the value proposition (noting it was necessary to have an "in-room' support person) we see the next step for this application as automated selection and packing of brisket combined with automated selection and packing of a second part, where the second part is "taught' using a remote operator and the improved pick and pack speeds per robot achieved in this work are used. The end goal – two robots, picking two parts with in-room support, while using the remote operation platform as a tool to the end game. Achieving this objective will start to unlock the more impactful benefit of reduced labour. This was always a vision on the technology roadmap.

6.3 Future Pathway

Other industries such as the mining industry and ports use remote operations routinely to improve safety, ergonomics, and productivity as well as provide better working conditions and cost savings. In these industries a single remote operator controls multiple pieces of equipment from a central hub. The equipment is often semi-autonomous and able to partially complete a task, with the operator taking control to reach completion. This is a vision for the red-meat industry. To get there however, application-specific tasks need to be partially automated.

The work completed here contributes to automation that can take the meat industry down a similar path. The remote-operation (shadow robot) concept has been shown to work. As shown in this work however, implementing shadow robots for routine-operation requires dealing with application-specific considerations eg in room robot support in lieu of full-automation of tasks such as carton-exchange. For this use case, we see the next step as automated selection using progressively more robots.

To fully unlock the 'control-centre' model used by the likes of the mining industry and ports, more remote-controlled/semi-automated use-cases need to be developed for meat processing. Noting there are many repetitive and dangerous tasks in meat processing, the shadow robot system remains a promising platform for both increasing automation and managing semi-automation remotely.

7.0 Conclusions / Recommendations

This project advanced the shadow robot system from a pre-production prototype to a fully integrated, dual-robot, remotely operated picking and packing installation.

In its best production runs the system achieved around 90% pick success at approximately 17.5 picks per minute per robot, operated remotely both from within the facility and from overseas, confirming that the remote-operation concept is sound.

Handover to operations was not achieved due to factors that were predominantly environmental and application-specific — product surges/clustering and the availability of staff for in-room supervision.

It is recommended that the project now:

1. apply the findings from the ten operator-experience sessions to refine the operator interface and selection workflow;
2. detail the use case, hardware requirements and value proposition for a stronger application;
3. use the learnings from this stage to select the most suitable next deployment for the system.

The shadow robot system remains a promising platform on a clear pathway toward commercial application.

8.0 Acknowledgement

Mimeo Industrial gratefully acknowledges the Australian Meat Processor Corporation (AMPC) for its continued funding and support of the Shadow Robotics initiative, and for supporting additional activities such as the educational robotic picking system and the opportunities to present the work at industry events such as the AMPC Safety Spotlight, the JBS Producer of the Year, and the AMPC Innovation Showcase.

We also thank JBS Brooklyn and its Innovation team for hosting the system, for the substantial on-site assistance provided throughout the trials, and for the collaborative approach taken by the production and engineering teams in working alongside the shadow robots.

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