Final Report

AUSTRALIAN MEAT PROCESSOR CORPORATION

Collaborative Robots

Collaborative Robots Evaluation and Deployment Strategy Development – Stage 2

Project Code
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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.

The collaborative robot is an innovative technology that has been broadly adapted to the manufacturing industry. Typical examples include assembly, dispensing, finishing, machine tending, material handling, welding, material removal, quality inspections, etc. Comparing with traditional industrial robots, collaborative robots have significant advantages in safety, cost, and flexibility.

AMPC is partnered with the University of Adelaide (UoA) to investigate how current, and pending, collaborative robots may be deployed within the Australian red meat processing sector. In general, UoA has provided suggestions on where collaborative robots can be deployed today, including a conceptual example of using collaborative robots for sharpening knives. UoA has provided the design of how the suggested use of collaborative robots can be implemented to the processing site directly without major upgrades, and what are the potential technical risks. UoA has also suggested some future implementations which require some additional developments to current meat processing practices.

Suggestions:

1. Sorting, packing and palletising of vacuum-packed meat parts
2. Picking, cutting and weighing lamb shanks
3. Meat quality inspection and processing performance monitoring
4. Human-robot collaborative beef fat trimming

Throughout the project, work health safety and ergonomics are considered for designing a safe-to-work environment for human-robot collaborative meat processing. The project, however, does not consider the financial aspects of the collaborative robots for specific meat processing applications. While this limitation allows the project to focus on the functionality and feasibility of proposed implementations, the limitation also inherently creates a gap in the project for future work on the financial applicability and sustainability of the design.

2.0 Introduction

Collaborative robots are robots designed to work alongside humans. They can therefore combine the benefits of robotic precision and speed with the higher-order decision-making and adaptability of humans [1]. Their implementations enhance the speed and efficiency of production processes, as well as reduce repetitive tasks that lead to musculoskeletal disorders in human workers [1]. Another significant benefit of them compared to traditional industrial robots is that they can be easily integrated into existing facilities, rather than requiring complete factory reorganisation with new robot cells.

This project investigates applications of using collaborative robots in the meat processing industry to design a human-robot collaborative workspace. Many meat processing tasks still require human operations, which induce a high injury rate for human labours. While full automation using the industrialised robot is difficult due to high input material variability, collaborative robots have the potential to solve this problem by performing dangerous and repetitive tasks while outclassing industrialised robots in processing material variability.

This section provides a brief introduction to collaborative robots and their characteristics. It reviews some existing applications across different industries to give an overview of how have collaborative robots been used.

2.1 Collaborative robots

First introduced in 1996 [2], collaborative robots are general purpose manipulators designed to have direct, safe and reliable physical interaction with humans in a shared workspace. With innovations in edge computation and other technologies, collaborative robots are rapidly growing in the robotic industry and expanding to other industries with a wide range of practical applications. Unlike industrial robots, which work primarily alone and without supervision, collaborative robots do not need to be isolated from fences and barriers and are designed to respond directly to human instructions and actions. They are more flexible and scalable to be used in dynamic situations; safe for human-robot interaction; and easy to be set up and programmed.

Based on safety measurements and levels of human-robot collaboration, there are four types of collaborative robots, including power and force limiting, speed and separation monitoring, hand guiding, and safety monitored stopping.

2.1.1 Power and force limiting

Power and force limiting collaborative robots are the most popular and common types that directly reduce collision damage. They are designed with non-sharp edges and corners, and they are integrated with a series of collision sensors that will detect contact with humans and other equipment and quickly cease operation. These collaborative robots are usually featured with force limitations to reduce the chance of getting injured/damaged by collision. This type is the most suitable collaborative robot for applications in limited space where humans are unavoidably working within the footprint of the robots. While the three other types can be any industrial robots that are integrated with safety devices and features, power and force limiting collaborative robots are commercially available under a special category in the robotic industry. Popular products include the Universal Robot e-series, AUBO robotic i-series, Fanuc' CR-series, and ABB's YuMi.

2.1.2 Speed and separation monitoring

This type of collaborative robot is usually implemented with laser or vision sensors to detect any humans entering the robot's workspace. They work at high speed while no humans are on the paths of their motions. Once humans approach to the interaction zone, these robots will significantly slow down their movements. If any humans enter the restricted zone, the robots will stop immediately. When the humans leave the motion paths of the robots, they will automatically resume their average operating speed. These robots are usually called "fenceless" robots, and they are set up based on existing industrial robots using/integrating human motion detection systems to replace fences and barriers. This type is feasible for applications that only require limited human interactions and human operations are part of system processes (in-the-loop). This type has been broadly adapted to the industries to improve safety and efficiency. Typical examples include car manufacturing and electronic device assembling, in which operations are standardised, and industrial robots have already been widely adapted. Companies, such as SICK Sensor Intelligence, are providing system solutions for upgrading existing industrial robots with speed and separation monitoring features.

2.1.3 Hand guiding

Robots with the hand guiding function allow operators to directly control the robots' motions by manually guiding and moving them. This function allows human operators to quickly and easily program robots with paths and waypoints. For example, human operators can "teach" the robot a task by manually guiding it through the training stage, then the "learnt" robot can repeat the task without human guidance. This function has a significant advantage in applications, whereas robots need to be frequently reprogramed based on dynamic tasks and changing environments. It is also

Figure 1 Packing and picking

easy for non-professional operators to set up robots easily to accomplish different tasks. Nowadays, most commercial collaborative robots are built in with this function.

2.1.4 Safety monitored stopping

The safety monitoring stopping function of collaborative robots is similar to speed and separation monitoring yet can only trigger the emergency stopping function while humans enter the robots' operation zone. Once humans finish their operation and leave the zone, the robots will resume the task automatically/semi-automatically. It is used for applications that are designed to have minimal/no human-robot interactions in a human-robot shared workspace. This function is designed to allow humans to work safely alongside robots and eliminates the efforts of restarting the process after an emergency stop is triggered. Conventional practices usually integrate an external safety system to provide this function to allow humans to interrupt robots' operations without terminating and restarting the entire system.

2.2 Examples of applications

Since 2017, collaborative robots have started to take over the market in the manufacturing industry. By emerging with other technological innovations, such as computer vision, 3D sensing and scanning, and Artificial Intelligence, collaborative robots are rapidly occupying work that was previously only done by humans. The following sections provide typical examples of using collaborative robots across different industries.

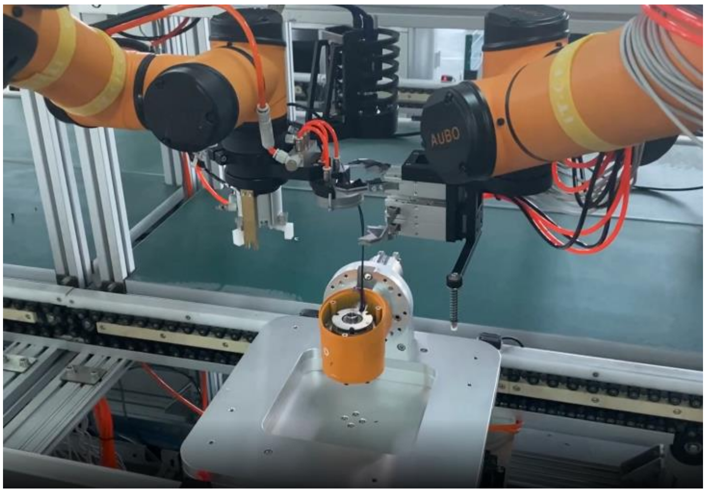

Figure 2 Automate assembling

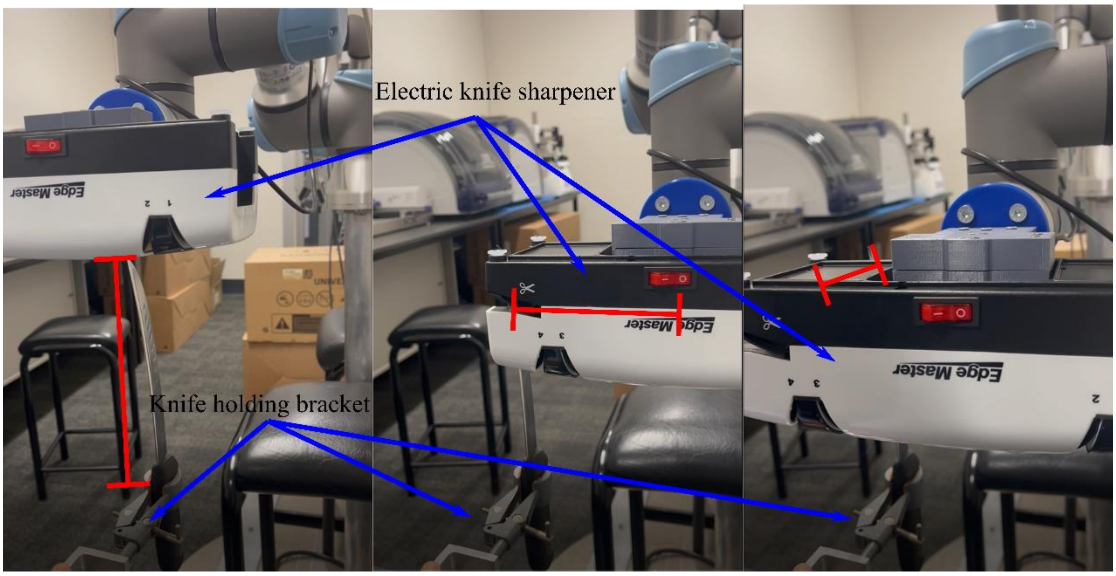

Figure 3 Knife sharpening example

2.2.1 Picking, packing, and palletising

Picking, packing, and palletising are the most common applications that collaborative robots are used in the manufacturing industry. Manual operations are time-consuming and labour-intensive, and they are repetitive and mundane. In many situations, traditional industrial robots are not suitable because of the limitation of spaces, shared workspaces with humans, and variability and uncertainty of handling products and their packages. Therefore, collaborative robots are the most suitable equipment that can effectively and efficiently perform these operations.

2.2.2 Automate assembling

Another typical example of using collaborative robots is the manufacturing assembly process. While products are increasingly complex, assembly processes are getting more sophisticated. Designing and building fully autonomous assembly lines with industrial robots requires an immense investment of engineering efforts and cash contributions, and they can not handle the mass customisation demands of value-added productions. Therefore, many assembly processes still require human involvement. Using collaborative robots is an optimal solution that not only takes advantage of precise and efficient machine operations but also frees humans from repetitive and mundane tasks. Human workers can concentrate on more creative tasks and add more value to the products.

2.2.2 Medical and healthcare

Medical and healthcare are other industries whereas collaborative robots have been broadly adapted in recent years. Applications, such as medicine dispensing, remote surgeries and human support systems, have improved our healthcare system considerably. For example, doctors can drive collaborative robots and provide medical treatment to patients from isolated zone. Multiple experts can work collaboratively from different locations via network controlled collaborative robots. Features of collaborative robots can ensure the safety of the patients and other participants alongside.

3.0 Project Objectives

This stage of the project aims at encouraging, via reducing the risk, collaborative robot manufacturers and integrators (and the Australian red meat processing sector) to ascertain:

- An understanding as to where collaborative robots could be deployed today within a meat processing business.
- An understanding as to where collaborative robots may be utilised in the future in the industry, and what is preventing this from occurring today. For example payload, washdown, speed, end-effectors, guarding, process changes. Outcomes from this step will feed into Stage 5.
- Engagement with possible meat processing customers who by seeing the potential of the deployment of collaborative robots engage with AMPC and providers/integrators to then deploy demonstration solutions at a range of Australian red meat processing facilities against the range of identified ‘today’ opportunities.
- Development and submission of Stage 3 deployment projects for funding consideration by AMPC.

4.0 Methodology

4.1 Example application of knife sharpening

To demonstrate the concept of using collaborative robots in the Australian meat processing industry, we developed an example of using them for sharpening knives. An electric wheel knife sharpener is attached to the end of the robot. It will approach the knives held by a bracket. The main issue of this task is how to allocate the knife precisely and safely and what is the human involvement in this task. The human operation is to change and replace the knife in the holding bracket. However, we used two different approaches to let the robot locate the tip of the knife each time.

4.1.1 Manual positioning

While the human operators are replacing knives in the holding bracket, they are expected to place the knives in the same position each and every time. The collaborative robot will go through the same path each time, and it will stop and let the human operator confirm that the position matches.

4.1.2 Automatic locating

Another approach we developed for our example is that the collaborative robot automatically measures the position of the knife each time by reaching and lightly colliding each side of the knife in the holding bracket. After locating the knife, the robot will take the sharpener to go through a related path to sharpen the knife. The example is shown in Figure 3.

5.0 Project Outcomes

This project aims to find and suggest the use of collaborative robots within the red meat processing industry. Through investigation, the project finds the following examples that collaborative robots can be used.

5.1 Sorting, packing and palletising of vacuum-packed meat parts

Sorting, packing and palletising are typical examples of using collaborative robots in the industry [2]. For the meat processing industry, collaborative robots can also be used for these functions. Collaborative robots can be deployed to the packaging stations and installed by the side of the conveyer belt which delivers vacuum-packed meat parts. Using collaborative robots will not eliminate humans from the workspace yet shift their roles from doing the packing work to supervising/coordinating multiple collaborative robots for the tasks.

Traditionally, human workers pick up different parts from the belt and place them into boxes based on the packing requirements of different orders. Collaborative robots can achieve the same function yet relieve humans from heavy lifting and repetitive tasks. Collaborative robots also perform faster than humans, and they can receive instructions and commands directly from a central task allocation system to reduce errors caused by human mistakes.

In order to effectively and efficiently use collaborative robots for sorting, packing and palletising, some other technologies are required to be integrated into the collaborative robots.

5.1.1 Detection and scanning for classification and localisation

On the conveyer belt, different vacuum-packed meat parts are all mixed up. Therefore, the most important function for picking up the right parts to put into the allocated boxes is to identify different parts on the conveyer belt. There are two methods that can be used to achieve this function.

1) An overview camera can be placed on top of the belt, and it will be used to detect and classify different parts based on their shapes and patterns of them and the labels and barcode on the packages. Combining with data from the conveyer belt and collaborative robots, the detection system will be able to identify all parts with their precise position on the belt relative to the coordinates of the robot. The detection system can be developed by machine learning algorithm.
2) Another approach is to use a depth camera only to detect the edge of different parts. Then, collaborative robots will pick up each detected part and scan its barcode on a code scanner to identify the part. The development of this approach is simpler than the other approach. However, in the scenario of the contact points covering the barcode, the scanning may not be successful, and the packing task for the part may need to be repeated.

5.1.2 Universal gripper design for picking and placing all parts

On the conveyer belt, different vacuum-packed meat parts vary in shapes and sizes, and collaborative robots for picking and placing meat parts need to use suitable grippers. In order to reduce the effort of setting up, a universal gripper needs to be designed and selected for picking up all different parts from the conveyer belt. There are two types of grippers that can be suitable for picking up meat parts.

1) Vacuum grippers are flexible in gripping objects in different shapes and sizes. It generally requires smooth surfaces to provide contact points for the suction pads/cups. The air pump can be installed externally from the collaborative robots, so the payload to weight ratio is relatively high. In addition, the suction pads/cups can be reconfigured easily with different sizes and patterns, so the vacuum grippers are usually flexible and feasible in picking up large, heavy and uncertainly shaped parts.
2) Another option is the most commonly used finger grippers. Finger grippers use gears and servos to grip the parts by holding their sides. They are suitable for picking up different parts with different shapes, yet they require a precise detection of the edges.

5.1.3 Systems communication and integration

To use collaborative robots more effectively in the meat parts packaging scenarios, the robotic system needs to communicate with the conveyer belt and the central task allocation system. The conveyer will provide feedback on the speed to help detect and locate meat parts, and the central task allocation system will assign different tasks to different

Figure 4 Lamb shank

robotic arms based on the orders and packaging standards. The robotic system will also provide tracking records of parts been packed.

5.1.4 Human operation standards

The main benefit of using collaborative robots is that they will work collaboratively with humans in a shared workspace. In the scenarios of packing meat parts using collaborative robots, human's roles are set-up, coordination and supervision. We will need to standardise human operations and train workers to perform in the roles.

1) Each collaborative robot will need to be set up by human operators. The operators will need to ensure that the collaborative robot is in the correct position and set into the correct pre-programmed program. In the case of failure, the human operators will need to reset the robots.
2) Another work for the human operators is to coordinate the packing operations. For example, human operators may need to manual instruct the robots to pick and pack some specific parts in some situations.
3) Human operators will also be on the side to supervise the packing operations. They will need to regularly check if all collaborative robots function normally and correctly towards their assigned tasks. If the meat parts are jammed/blocked on the conveyer belt, human operators will need to sort them out manually.

5.2 Picking, cutting and weighing lamb shanks

There are many tasks in meat processing that require picking, cutting and weighing parts with similar sizes and shapes. These tasks are usually repetitive and are conducted by non-experienced/under-trained human operators. Tasks, such as packing mince and cutting and sorting lamb shanks, are typical examples work that can be replaced by collaborative robots. We use picking, cutting and weighing lamb shanks as an example to explain how can collaborative robots effective fit into human roles in these repetitive tasks without modifications to the processing site.

Traditionally, human operators pick up shanks from the main belt and place them on a side conveyer belt with individual slots. Each shank will take a slot. As the belt will take the shanks through a bandsaw and cuts off the condyles of them (Figure 4). After that, each shank will be weighed and sorted into different containers based on their sizes. This task usually requires 2-3 human operators, in which one is required to pick and place shanks from the main belt to the slotted belt, and another 1-2 workers to weigh and sort trimmed shanks into different containers. While using collaborative robots for this task, only one robot is needed.

The collaborative robots will also pick up shanks from the main belt and place them in the slots of the belt. However, in order to identify shanks, a vision camera with a recognition model is required to attach to the end of the robot. Collaborative robots are able to measure and calculate their payload with joint forces, so they will weigh the part while

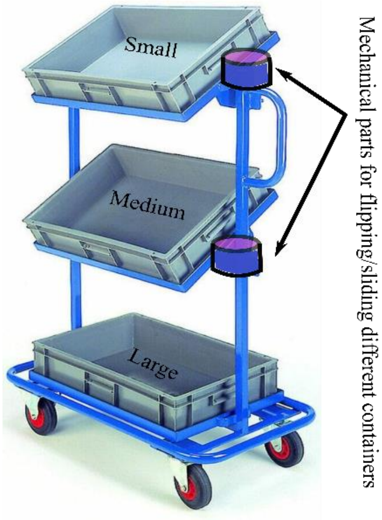

Figure 5 Trolley with containers

picking them up. Therefore, the main technical challenges for this implementation are 1) detection and localisation of the shanks and 2) the processing logic.

5.2.1 Detection and localisation of the shanks

Similar to the packaging task, detecting and localising the shanks from the conveyer belt is the main challenge. A dedicated machine learnt model needs to be developed to recognise shanks as well as locating them based on their position detected from the image frame. Then, the frame coordinates will be transformed into the robot coordinates and picked from the belt.

5.2.2 Picking and weighing

After a shank been detected with its coordinates, the collaborative robot will reach it and pick it up. For this task, the robot is only required to pick up a single part, in which the shapes and sizes are similar. Therefore, a two-finger gripper can be used for picking up shanks.

1) The robot will weigh the part by calculating based on the forces of each joint. Then, the robot will place the shank on the belt with slots and track the order of each weighed shank. After trimming the condyle, the shank will fall into different containers based on their sizes. A trolley with different containers (Figure 5) will be placed by the slotted conveyer belt and the bandsaw, and a special mechanical part will be designed and attached for flipping/sliding containers based on the different sizes of the shanks.
2) If the task requires a more precise weighing of each shank, the robotic system will replicate the exact human operations, which will weigh the trimmed shanks on a digital scale and then sort them into different containers. The system may require an additional collaborative robot to speed up the process with this additional process.

5.2.3 Human involvement

In addition to standardised set-up procedures, humans will still involve in this example task. Human workers will supervise the operations and terminate/pause the robots if something goes wrong. Human workers will also monitor and replace the containers/trolleys if they are full.

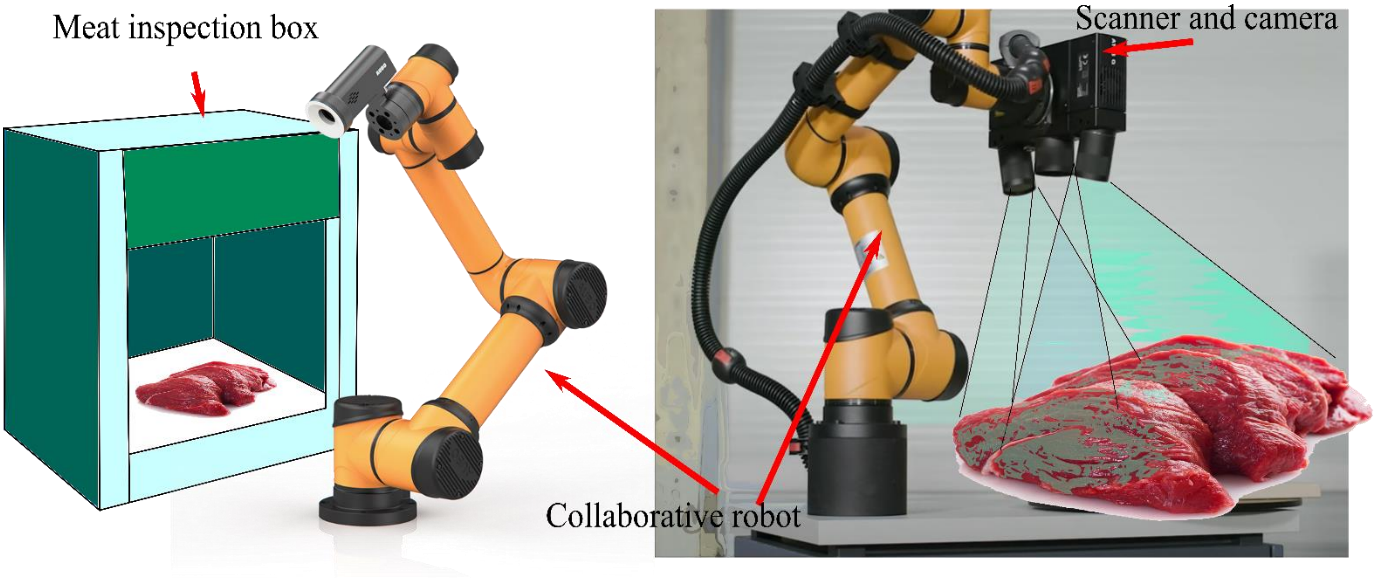

Figure 6 Meat quality and processing performance inspection

5.3 Meat quality inspection and processing performance monitoring

Supervising and monitoring are critical issues in the meat processing industry. It requires both inspecting the quality of the meat and checking the processing performance. Traditionally, this work is conducted by supervisors, production managers and inspectors, and getting senior staffs to monitor processing quality all time is not cost-effective. Therefore, collaborative robots can be used for this task. We can 1) place them at different locations by the side of the main conveyer belt, 2) randomly pick different processed parts and check their qualities, and 3) record data for further analysis.

The collaborative robots will pick up random or selected parts from the belt. In order to fully and effectively assess the meat quality and processing performance, collaborative robots can be attached with vision and depth cameras and 3D scanners, and, in some scenarios, an X-ray machine can be used to assess the meat quality.

5.3.1 Picking up parts

The details and critical issues while using collaborative robots to pick up meat parts have already been introduced in the examples of 4.1.1 and 4.1.2. In addition to that, the parts picked for inspection are uncertain and unpackaged. Therefore, this task will be using fingered grippers with large payloads.

5.3.2 Scanning parts

We will attach cameras (vision and depth cameras) and 3D scanners to the robot to generally scan through the surface of picked parts. In order to get more detailed assessments, we will develop a 3D scanning station with multiple sensors and scanners in a box (with an optional X-ray scanner). Both example set-ups are shown in Figure 6.

5.3.3 Assessing and analysing

By using collaborative robots for inspections, meat parts will be randomly picked from the main conveyer belt, and parts will be put back onto the belt without affecting further processes. The system will record all related data and information of inspected parts and stamped with the time and locations that they were picked.

The system will be developed with standards of the inspection procedures, and the parts will be automatically assessed by comparing captured data and standard data. If issues with any inspected parts are detected, the system will notify

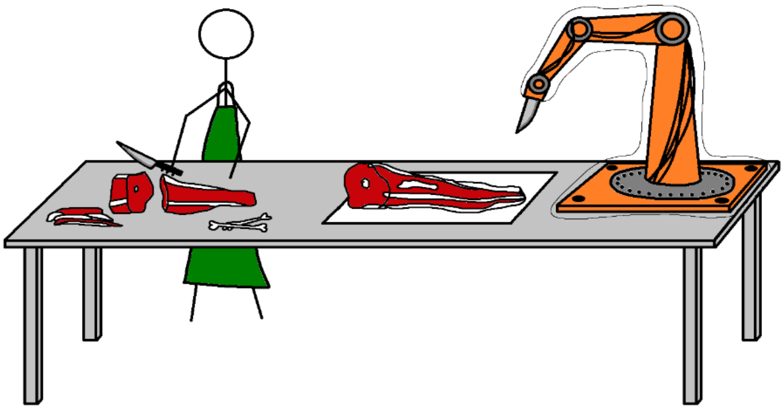

Figure 7 Concept of beef fat trimming

the human supervision team for further evaluations. Supervisors and production managers can also check any historical data to assess long term productivity.

5.4 Human-robot collaborative beef fat trimming

Beef fat trimming is another potential application that can be used in the meat processing industry, as it utilises their precision and adaptability without requiring much physical force and much human cognition. Robots can work collaboratively with humans, in the trimming area, who would first cut the meat, and perform the higher-order decision of what should be removed. The human would instruct the collaborative robot, for example, to mark sections of fat with their knives/markers with sensors and pass the meat to a collaborative robot for trimming. This will allow human operators to continue butchering and increase their efficiency. This idea capitalises on the ability for collaborative robots to be integrated into existing boning rooms and production lines, without major changes to factory layouts or processes. Offloading this high-risk task to collaborative robots would also increase safety, as it reduces the amount of knife work being performed by humans. A rough depiction of this idea can be seen in Figure 7.

In order to perform this task, the robots need to identify and differentiate tissue types in 3D space and accurately interpret human instructions as marked on the target. Recognition and 3D modelling methods are similar to the previous sections' examples. Finally, the robot generates paths and safely trims the fat off to a near-human standard while minimising waste.

This example application can also be extended to other applications such as the human-guided deboning, in which human operators mark the cutting points for the robots to trim the meat off, and peeling the skin processes, in which humans can place the robot tip at the starting position, and it then completes the pre-programmed peeling motions.

6.0 Discussion

Based on the four suggested example applications, there are no major technical barriers that prevent us from using collaborative robots in the red meat processing industry, yet some additional developments need to be conducted in order to allow conventional collaborative robots to be adapted to existing processing sites. We recognise them in three categories.

1) Recognition and localisation: Recognising the handling object and segmenting its edge from the background are the most essential and critical tasks that need to be addressed for all suggested applications. Collaborative robots have typical advantages in handling materials in a human-robot shared workspace. Before conducting

any further functions/tasks, the robot needs to know what (types and shapes) and where (positions) to take actions on. Based on different requirements of applications, methods, such as laser/infrared scanning and RGB recognition (introduced in the project outcomes), can be integrated into the robotic system and achieve the function.

2) System control and logic: In order to allow sub-systems/modules to be integrated and work together harmoniously, an automated overall system needs to be built. This system will monitor data and information and coordinate system operations based on them.
3) Human involvement: The main characteristics of using collaborative robots are a) allowing the robots to work with humans in the existing human-robot shared workspace and b) optimising productivities by enforcing human-robot collaboration. Therefore, designing standardised human operations to coordinate and collaborate with robots effectively are important.

7.0 Conclusions / Recommendations

Based on the suggested example of further application, we propose four projects of building prototype systems for the next stage of development.

7.1 Vacuum-packed meat packaging

This project aims to develop a prototype system that can be installed in the packaging stations at the meat processing plant. The system will be able to pick vacuum-packed meat parts from the conveyer belt and sort and place them into different boxes. The project will achieve the objectives of,

- Demonstrate feasibilities of using collaborative robots for picking, sorting and packing vacuum-packed meat parts,
- Develop recognition models for different meat parts,
- Implement real-time localisation methods for supporting picking up parts, and
- Design processing logic for the packaging processes.

To ensure the steps of achieving each objectives of the project, the following milestones will be accomplished,

- Deposit on signing the contract to enable:
    - High-level system and project plan design
    - Consultation with AMPC
    - Conducting site visit
- Site visit for data collection and labelling
- Recognition model training and development
- Real-time position methods implementation
- System integration
- Testing and evaluation
- Demonstration to AMPC, submit Final report and SnapShots and submit a plan for the next stage

The proposed project will take ten months to complete, and it will cost $178,000 professional fee and $50,000 estimated operation cost.

7.2 Lamb shanks trimming and sorting

This project is proposed to use collaborative robots to pick lamb shanks from the conveyer belt and trim the condyles with a bandsaw. Then, it will sort them into different containers based on their sizes and weight. The project aims to build a prototype system that can achieve the following objectives,

- Demonstrate feasibilities of using collaborative robots for replacing the manual operations of lamb shanks trimming and classifying,
- Develop recognition and localisation models for lamb shanks,
- Develop an effective weighting and classifying mechanism, and
- Design a processing tracking logic.

To achieve these objectives, we set the following milestones to be accomplished,

- Deposit on signing the contract to enable:
    - High-level system and project plan design
    - Consultation with AMPC
    - Conducting site visit
- Site visit for data collection and labelling for unpacked and untrimmed lamb shanks
- Recognition and real-time localisation development
- Weighting and sorting mechanism design
- System implementation
- Testing and evaluation
- Demonstration to AMPC, submit Final report and SnapShots and submit a plan for the next stage

We propose that the project will take seven months to complete, and it will cost $130,000 professional fee and $50,000 estimated operation cost.

7.3 Meat processing inspections

This project is similar to the proposed project in 7.1, yet it requires a better mechanism for picking up unpack meat parts and more advanced 3D scanning and modelling algorithms to get detailed situations for validating the processing performance and meat qualities. The project aims to develop a prototype system that will pick a random part from the conveyer belt and then scan and 3D model the part. In order to achieve that aim, we propose the following objectives,

- Demonstrate feasibilities of using collaborative robots for inspecting meat parts,
- Develop a mechanism for locating and picking up unpacked meat parts from the conveyer belt,
- Develop methods for 3D scanning and modelling the picked parts, and
- Design assessing criteria for the scanned data.

In order to achieve these objectives, we set the following milestones to be accomplished,

- Deposit on signing the contract to enable:

  - High-level system and project plan design
  - Consultation with AMPC
  - Conducting site visit
- Site visit for the data collection on unpacked meat parts
- Picking mechanism design
- 3D scanning and modelling methods design
- System implementation
- Testing and evaluation
- Demonstration to AMPC, submit Final report and SnapShots and submit a plan for the next stage

This proposed project will cost $150,000 professional fee and $50,000 estimated operation cost, and it will take seven months to complete all objectives of the project.

7.4 Human-robot collaborative fat trimming

Based on the suggested innovation introduced in section 5.4, we propose a project to design a conceptual system, in which humans and robots will work collaboratively to trim fat from beef parts. The project will demonstrate more interactive collaborations (compared with the other three proposed projects) between humans and robots. The project will have the following objectives,

- Demonstrate harmonious human-robot interactions and effective collaborations between humans and robots in the red meat processing industry, and
- Design and develop a conceptual system with humans and robots collaboratively trim fat from a beef part.

To achieve these two objectives, we set the following milestones in this project,

- Deposit on signing the contract to enable:
  - High-level system and project plan design
  - Consultation with AMPC
  - Conducting site visit
- Site visit for understanding the fat trimming process
- Human-robot interaction design
- System implementation
- Testing and evaluation
- Demonstration to AMPC, submit Final report and SnapShots and submit a plan for the next stage

The proposed project will cost $78,000 professional fee and $50,000 estimated operation cost, and it will take five months to complete the project.

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9.0 Appendices

N/A