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Abstract

Applied Robotics was engaged to review and assess the state of manufacturing automation in the Australian Abattoir sector.

Ensuing field work allowed the positioning of the level of automation now attained in the Abattoir Sector vis-à-vis the general Australian Manufacturing Sector. Parallels drawn allowed the prediction of outcomes of various scenarios depending on the path taken.

Technology paths forward for the Abattoir Sector are discussed, in the context of existing automation technologies and near-future automation technologies.

Specifically, one automation solution was developed for the common requirement for Wrapped Primal Meat Cuts carton packing.

Executive Summary

Applied Robotics has over the last 2 years visited 7x beef abattoirs and 2x sheep abattoirs in a survey to assess the extent and the potential for robotic automation in the sector.

This report summarizes our assessment of the current level of automation in the sector, the automation technology that is seen to be needed, and the availability of this technology. We have drawn parallels between the abattoir sectors and other labour intensive sectors in Australian manufacturing, and have high-lighted the importance of automation to this industry sector.

Furthermore, Applied Robotics has identified an application area of good potential, a good match to its own experience, and that which has a commonplace need – the automatic sorting and nested packing of wrapped primal meat cuts into their shipping cartons. We have developed a machine concept in discussion with the sector along with a budget costing. This has been presented to the industry sector.

Unlike the ready response that our near 30 years of experience in the non-abattoir industry has led us to expect, we have received muted responses so far from the abattoirs to whom we have presented the concept.

In consequence, we have identified structural issues in the abattoir sector that has led to this dampened response. We believe that these structural issues are symptomatic of the current position of the sector in general in its evolution along the automation pathway, and that liken to other sectors, the sectors will progress through this phase as it “grows into” the automation stage.

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1 BACKGROUND: OPPORTUNITIES FOR AUTOMATION.

1.1 Background: Industry Needs

Materials handling (“picking and packing”) of post boned & sliced product, as well as half and whole carcasses and parts (primal cuts, sub-primal cuts & shelf ready portioned) is a significant cost to processors as well as a potential value add to the majority of businesses dealing with beef and small-stock processing.

Processing plants are very dynamic in specific product output with product mix changing dramatically on a daily basis. An industry wide problem is the congestion that exists at the end of the boning room given the multiple product mixes arriving and the excessive labour that is required in identifying the specific individual primal cuts and packing them in the respective product cartons. Australian red meat processing facilities are continually experiencing logistical congestion in both their sorting and packing area and cold storage areas. This situation is creating both a need for increased labour resources and is becoming an operational constraint and poses a potential OH&S risks to employees.

The opportunity exists to identify and integrate or develop a system that would automate some of the challenging tasks; primal type identification, collection and packing of primals into specific product carton, with the intention of removing a significant number of labour units, and then to commercially prove the equipment and evaluate the business case for the implementation of the system. Cost benefit of the commercial system would be applied to communicate the benefits of the system to the wider industry.

AMPC and MLA have reviewed options for future manual assist and automated options in picking and packing of trims, primal cuts and materials handling of cartons and carcasses. To build a portfolio for investment in this area, areas of industry need must be analysed and benchmarked, and the technological opportunities relevant to these needs, the likely developmental challenges and analysis of cost, benefit and possible technological or provider gaps determined.

This is being undertaken in the form of a review at present, where as part of this existing project, a priority list of tasks, analysis of solutions that processors either require or are undertaking, a review of existing technologies (including other industries), and the identification of technological (manual assist or automated) solutions, is being investigated.

1.2 Background: Investigator Qualifications.

Applied Robotics has over 28 years of experience in creating and installing automation and robotics solutions for Australian manufacturing and over this times has tallied over 500 successful installations. A particular niche occupied by Applied Robotics over this time is the creation of novel automation solutions, often preceded by an R&D stage, that gives the client a quantum jump ahead in competitiveness – a relevant statistic today is that some 40% of our Systems are preceded by an R&D stage to prove the novel elements of the System concept before implementation as a Production System. The areas in which we have worked span all the industry sectors from food packaging and textile products assembly & sewing, through building products packaging to automated assembly & welding cells, but not yet in the direct handling of food items.

It is in this context that Applied Robotics was invited to visit a number of abattoirs to explore what we may be able to do for the red meat abattoirs.

1.3 Preliminary General Industry Automation-Level Assessment

Applied Robotics has over a period of some 3 years and over a total some 10 site visits, investigated the potential opportunities for the application of both general, and specifically packaging, automation technologies in Australian abattoirs.

In general, like in the clothing industry sector with which we did a lot of work some 20 years ago, and in contrast to the bulk of Australian industry today, abattoirs are still very much at the bottom of the automation “S-curve”. As was the case with the clothing industry then, the emphasis is still on “mechanisation” where the efficient handling of product from one manual workstation to the next manual workstation is the focus – with the objectives of efficiency gains through better workflow and improved structuring of the manual tasks. History has shown that this in itself is not enough to counter rising labour/structural costs and labour shortages – the resultant disappearance of the Australian garment industry has been the result.

Despite keen interest by the Garment industry at the time, and despite valiant efforts by suppliers and government R&D organisations world-wide, back in the 1980s automation technology was not quite up to the task. Twenty years on, with the large technology advances since that time – in computing power, faster robots, vision systems, sensors and servos - we believe the technology is now up to the task*, but in the case of the Garment industry, that sector is no longer here.

* Four years ago Applied Robotics embarked on a new R&D Project for the Norwegian Government to create automated assembly and sewing technologies with the objective of retaining their Furniture Sector on shore. Although on hold for the GFC, in the first 18 months of development we were able to automatically assemble and sew for the first time in the world, representative items of “furniture clothing”.

For the Red Meat Abattoir sector our preliminary assessments is that there are very close parallels between the Garment Industry in the 1980s and the Red Meat Industry today:

1. We see in the Red Meat Industry there is the Primary task of a skilled knife-hand in removing meat from a carcass and there is the secondary support tasks of trimming, packaging, general handling, cartoning and palletising.
2. The Primary task is difficult to automate is still manually carried out – automation technology has not developed to the stage that there is a full and accepted match between the solution and the task, as there is for example for robots and welding, or for robots and carton palletising. We can say that automation for the Red Meat Industry's Primary task is still in the evolutionary or developmental stage when it is still not obvious what the full and accepted match solution when developed will would look like.
3. This "full and accepted match" notion is important as when such a solution is developed for a task genre it will become the dominant and mainstream technology for that genre of application. A full and accepted matched solution is hegemonic and in its prime will displace research efforts into non-competing applications. This gives rise to the "technology long-waves" that is evident in all industry sectors (1).
4. The primary task of a skilled knife-hand in removing meat from a carcass parallels closely to that of the skilled sewing machinist in that the person is the primary task effector (as opposed to a person operating a machine. Indeed, the sewing machinist is aided with more sophisticated technology than the simple knife wielded by the knife-hand).
5. As a result, the Industry's main emphasis is still on "mechanisation" where the efficient handling of product from one Primary task manual workstation to the next Primary task manual workstation is the focus – with the objectives of efficiency gains through better workflow and improved structuring of the manual tasks. This has good potential but also entails the risk of sub-optimisation (wherein a system that at once becomes highly efficient for one set of technologies most often becomes less suitable for any other technologies (unless that new "full and accepted" technology solution is a one-for-one replacement for a man).

1.4 Challenges for Automation for the Primary Task.

1. Automation of the knife-skilled processes has a very similar set of challenges that the Australian Wool Corporation’s Robotic Sheep Shearing Project presented us in the early 80s. In that apart from the obvious dexterous ability to guide a shearing handpiece (robot shearing handpiece manipulator and look ahead/contact sensing) and the manipulative skills to “condition and present” parts of the sheep sequentially for shearing (sheep manipulator “jigging”), also imbedded in the shearing process is the shearer’s knowledge of the sheep’s anatomy and in the ways that the sheep can be manipulated to best condition and present each part of the body surface for shearing (surface topology modelling of the specific sheep and how each surface presents under animal manipulation).
2. With this background, we believe that the raft of technologies required for de-boning are:

   a. Dextrous manipulator for the knife (maybe a 7 axes robot).

   b. Maybe a dextrous manipulator(s) for steadying, holding or conditioning/presenting the part(s) of the carcass to be cut.

   c. Real-time look ahead sensing (in your case x-rays; for sheep shearing we used forward looking limited-range ultrasonics to which the wool mass and clutter is transparent).

   d. Real-time contact sensing (when in contact with bone, or even better with contact on different meat textures. For shearing, the equivalent was simpler as it was skin contact sensing).

   e. Cut path predictor (in your case a whole body x-ray image providing the forward motion data for the robot will obviate the need for a predictor – for sheep shearing our ultrasonic look ahead sensor was like that for nap-of-the-earth flying, but for speed we needed a map of the terrain ahead of the sensor as well). If your x-ray is not in real-time but a once-only pre-scan, then this predictor may well be necessary to model how the x-rayed structure will change with the movement of the carcass.

1.5 Challenges for Automation for the secondary Support Tasks.

The secondary Support tasks in the abattoirs are far less technically challenging than that posed by the Primary task and can at present be largely be catered for by existing and newly existing automation technology categories already developed in other industry sectors. Although as mentioned in the above, the intense optimization of mechanization already in place here in the secondary Support task areas (that has flowed through from its principal application to the Primary tasks) are proving to be a disadvantage/hurdle for the easy adoption of the existing full and accepted automation solutions from other industry sectors.

Either, the factory layout of the secondary support task areas can be changed so that the existing full and accepted solutions from other industry sectors can be adopted with minor changes, or that the Red Meat sector will have to wait until a new genre of automation technology that can better interleave into the existing Support tasks factory layout, can be developed.

Nevertheless, we will pursue the discussion where existing full and accepted automation solutions from other industry sector can be applied.

Within this secondary Support task area, there are many obvious opportunities, many of which are simpler on-to-one replacement or an operator. The gains in automating these tasks are the same as for the non-abattoir sectors – labour cost savings, cycle time improvements, avoiding OH&S issues, side-step operator training requirements, functional consistency, and consistent availability.

We have picked out a few of the larger and obvious secondary Support task opportunities for discussion as follows:

1. Automation of the meat cut packaging/cartoning processes. This task set is simpler than the boning one, but still requires:
    a. Specific new sensing technologies to “read” the shape and sizes of the primal meat cuts to be handled. Ability to automatically recognize the meat cut type will be a bonus.
    b. For the accurate handling of floppy meat cuts repetitive or active scanning may be required.
    c. Specific new sensing technologies to “see” defects such as blood and contaminants, and defects in the vacuum bagging.
    d. A dextrous manipulator (robot).
    e. A universal work-piece gripper that is not only able to pick a wide range of meat cut shape and sizes, but is able to place the meat cut in an orientation different to that at the pick-up.

2. Automation of carton sorting & palletising. Here the basic technology is existing, proven and off-the-shelf. The economic configuration of a specific layout, however, may be a small challenge.

1.6 Applied Robotics’ Specific Focus.

It appeared to us that the automated boning application was already in the R&D process, with some commercial applications beginning to take place.

On the other hand, it also appeared to us that the task of automated packaging/cartoning of wrapped primal cuts, although smaller in scope, was “low hanging fruit” in that much of the basic technology can be derived from existing solutions in other industry sectors, and the small amount of additional R&D to fill the voids has not been initiated.

In every one of the 10 abattoir visited, whether a beef or a lamb plant, there is a universal need for this function –

a. mixed wrapped primal cuts from one or more Cryovac vacuum sealers,
b. sorted by types of cut and sometimes size.
c. loaded and nested into cartons (up to 3 sizes of cartons), by cumulative weight.

Accordingly, given Applied Robotics' extensive experience and technologies in novel solutions in handling, assembly and packaging of difficult-to-handle work-pieces, the wrapped primal meat cuts packaging/cartooning area became a natural and first point of focus for us.

2 SELECTED OPPORTUNITY: WRAPPED PRIMAL MEAT CUTS SORTIMG & CARTONING AUTOMATION.

2.1 Wrapped Meat Cuts Sorting & Cartoning Automation System.

With each of the abattoir site visits this potential area of automation became a special focus for us.

As a result of the data gathered and learning about the current manual process, and using traditional objectives and criteria normally employed in our non-abattoir concept formulations, we put together a System Concept and a preferred layout for this application.

The result is the Vacuum-Wrapped Meat Cuts Sorting & Cartoning Automation concept that is presented and detailed in the following.

In summary, the performance specifications of the preferred layout are:

a. Modular form that is readily expandable; we selected a 4x robot laser/vision module layout as one that will meet the typical user.
b. Handles 40 meat cuts per minute – output of 1x Cryovac.
c. Handles 24 different primal meats cuts into 3x carton sizes.
d. Replaces 3x packing operators, but retains a QC inspector who will also identify and "mark" the primal cut.
e. Weighs each primal cut and cumulates a carton weight.
f. Makes available real time production data.
g. System footprint: 15m x 6m
h. Costs $1M for the Production System.
i. Approximate payback between 1 & 2 years.

2.2 The Existing Manual Solution.

In all the abattoirs visited the solution format for the manual task of Vacuum-Wrapped Meat Cuts Sorting & Cartoning was the same (as shown in Figures 2.1 and 2.2), and comprised:

a. A primary "racetrack" conveyor sited at the operators' chest level, and of length and width dimensions that 3 to 4 operators can work comfortably inside. The enveloping dimension of this layout is compact and around 6m x 4m.
b. Wrapped meat cuts are fed onto this racetrack conveyor and continues to circulate until removed by the operators.
c. Positioned below the racetrack conveyor is a "U" shaped filled cartons takeaway conveyor, fronted by bench space where multiple empty cartons can be placed for filling. When each carton

is full the operator simply labels it and pushes it outwards on a takeaway conveyor.

d. Above the racetrack conveyor is another “U” shaped conveyor on which empty formed carton bottoms infeed. Cartons of up to 3x different sizes are queued on this conveyor in the predicted ratio that they will be used. The operators will simply reach up and take from this buffer whichever carton they require at the time.

e. If there is the average 24 types of primal cuts being wrapped at the time, each operator then is responsible for 6 types of cuts, and his or her job is to identify and take the incoming cuts that he/she is responsible to pack, off the racetrack conveyor and pack them into its carton by type, nesting each neatly to optimize its packing into the carton. Sometimes, one primal cut type is divided into separate cartons for large or small cuts, by weight. Cartons can be packed by overall weight, or by fit, or a combination of the two criteria.

f. The incoming rate from a typical Cryovac is 40 wrapped primal cuts per minute.

g. Obviously, the function of the recirculating racetrack is that primal cuts that are not picked off the first time around will recirculate and be available for picking again. This feature allows the orderly pick-off of an incoming cluster of the same primal cuts

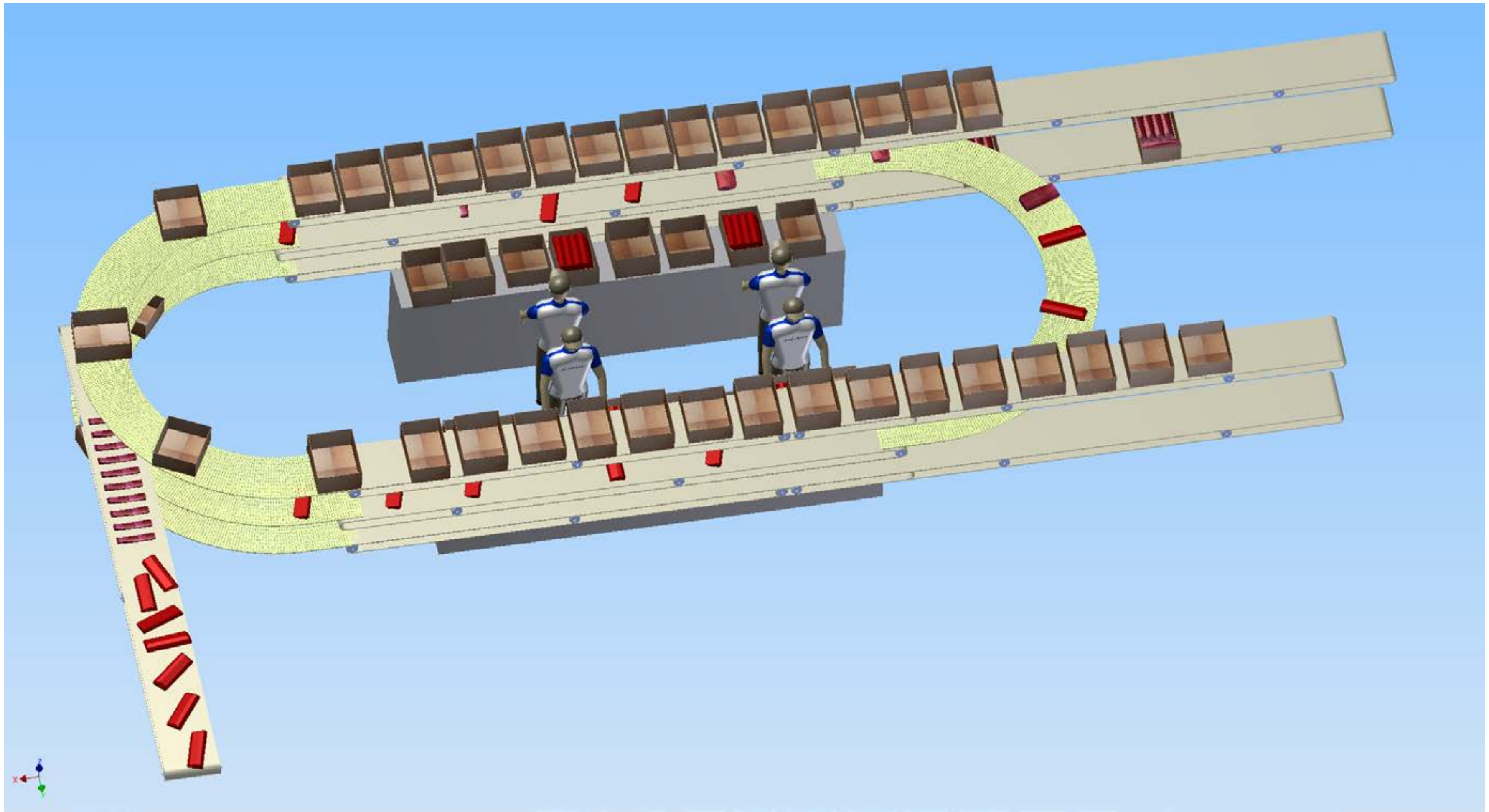


Figure 2.1 – Common layout of the existing manual solution.

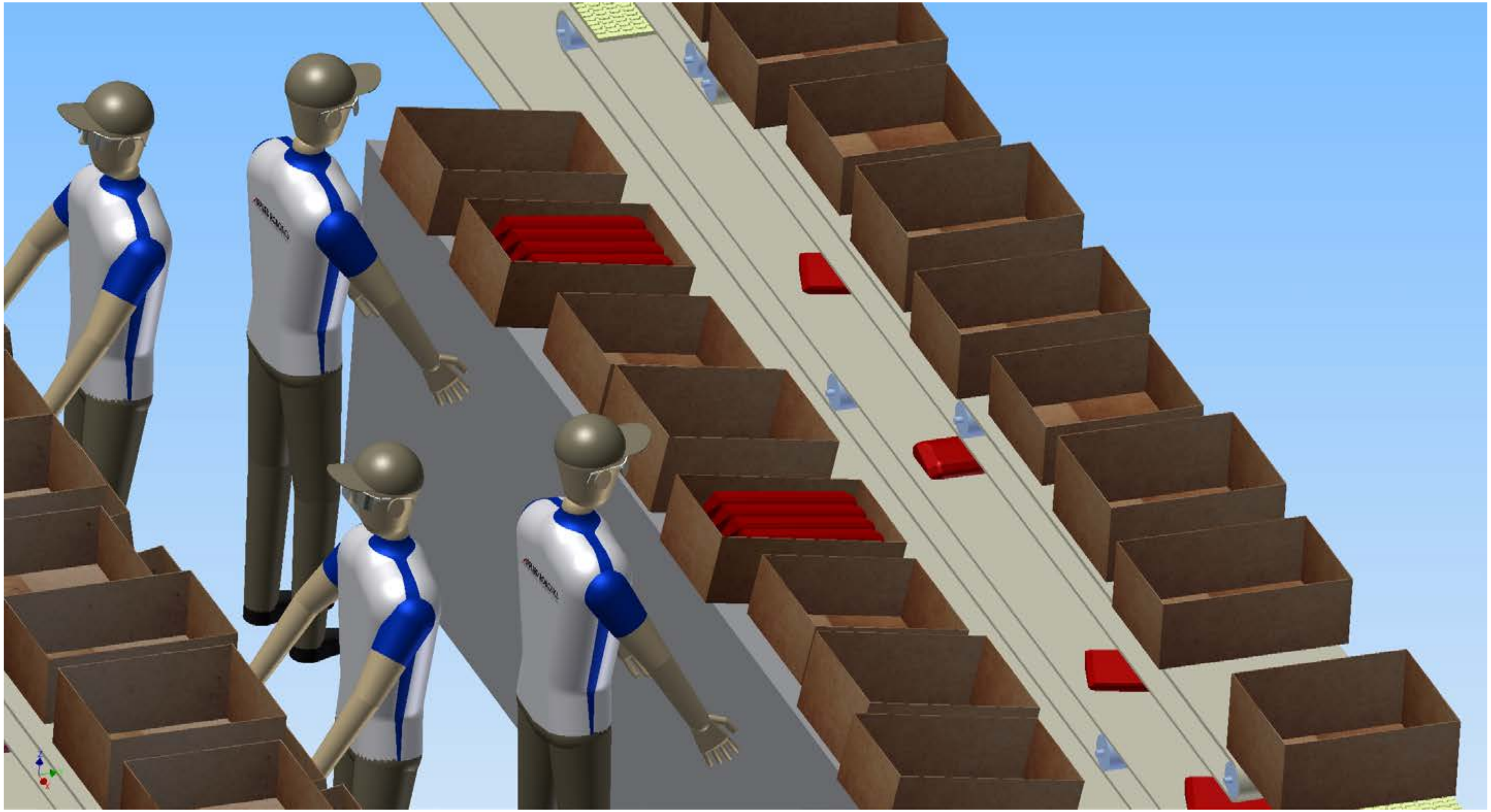


Figure 2.2 - Common layout of the existing manual solution

2.3 The Robotic Solution.

2.3.1 Concept Objectives.

The following is a list of the objectives which guided the formulation of the solution concept.

a. Create a modularly expandable System to handle the output of one or more Cryovac machines. This feature is necessary
    i. as the number of Cryovacs can vary between 1 to 4 units from the small to the larger users.
    ii. if the number of primal meat cuts vary due to a higher level of break-up of the carcass into more specialty cuts.
    iii. 3, 4, 5 or 6 Robot Packing Modules will be needed to match the combined primal cut infeed rate.
    iv. if space was available, it is possible to add an extra Module for production robustness.

b. Include a Quality Control & Meat Cut Identification (QC&ID) function, as well as an individual primal cut check weighing function, at the entry into the Robotic System. This feature is necessary because:
    i. this is the last time that the wrapped primal cut is exposed before packing into a carton.
    ii. the vacuum wrapped product may be imperfectly sealed, which if packed in this way will not prevent the meat from going off.
    iii. sometimes there is meat or blood debris in the wrapped pack that should not be present.
    iv. since a person is best able to carry out the above functions (as technically it will be a challenge to fully automate these tasks), we may as well use the human to ID the primal pack at the same time.

    v. In the long terms, however, it is envisaged that primal cut ID can be automated. Our R&D strategy here is that during the manual ID phase, we will carry out a data gathering process where numerous 3D images of each primal cut can be grouped by their ID, then when we have sufficient data this can be analysed by algorithms which will extract unique identifying features or groups of features that will enable a particular primal meat cut to be identified.

c. Buffer and infeed empty cartons of up to 3 sizes into our System. The allowance of up to 3x carton sizes is because for most of the abattoirs that we have visited, there are 3x carton sizes being used.

d. Each primal cut (sometime sub-classed by weight) to be nested packed into its assigned carton. Depending on the size and type of primal cut, the nominal nesting pattern i.e. “top and tail”, side-by-side along the carton length, or side-by-side across the carton length, will be specified fro that primal cut, however, the nesting program will over-ride this on a case-by-case basis to best utilize the empty space in each carton.

e. Nesting efficiency will be achieved for each incoming primal cut by the best match of its size and shape into the remaining empty volume in its destination carton. This will be done by 3D scanning both the incoming primal cut as well as the remaining empty 3D space in the carton; using this input, a best fit algorithm will determine the best place to stack the incoming primal cut, bearing in mind the stability of the placement and the good usage of the carton space that is still remains.

f. A primal cuts buffering function (for the last cut) will enable optimised carton packing. This functions means that we do not have to place the incoming primal cut straight away, therefore, if required we are able to select the next primal cut because it fits that carton more efficiently. The buffering function will be implemented in two ways

    i. an unsuitable primal cut can be left on its infeed chain conveyor for later use, but there is limited space here, or

    ii. an unsuitable primal cut is picked up but placed as the starting placement into a new carton. The 2x spare cartons in each robot Cell also will ensure that there is an available carton for immediate placement when a full carton is being replaced by an empty carton.

g. Cartons can be packed by count, by weight or by carton fit - or a combination of all these parameters. As each primal cut will be check-weighed upon entry into the System when it is QC-ed and ID-ed, the PLC will know its weigh as it tracks it to its destination Robot Module – after the robot has loaded it into a carton, the PLC will simply add its weight to the cumulating carton weight, thus tracking the weight of the carton as it build. As the PLC will know the top weight limit for that carton it will be able to select from a run of incoming primal cuts of that type, the best candidate cut to make up the carton weight.

h. Full cartons can be inkjet labelled upon exiting our System. This simple off-the-shelf labelling system will ensure that the correct ID and weight of each carton is correct, and this is carried out within the System boundaries before the carton have a chance to be mixed up. Inkjet printing is recommended as the identification is permanent and not easily detached in the cool-room environment.

i. Our System can give instant “real-time” production report and trending for individual primal cuts and filled cartons, and give performance comparisons to inputted targets at any time during the batch run. As the ID and the weight of each primal cut is ‘read” upon its entering out Robot System, it is easy for this information to be collated into useful summaries for production control purposes. As an example the following data can be read at any time:

i. cumulative weight of each primal cut type packed at any time.

ii. production weight distribution over time e.g. per hour, for each primal cut type. The difference between this distribution over different days, or any difference from an expected or a reference distribution, can be outputted or to trigger an alarm.

iii. number of cartons of each primal cut packed at any time.

iv. number of cartons distribution over time e.g. per hour, for each primal cut type. The difference between this distribution over different days, or any difference from an expected or a reference distribution, can be outputted or to trigger an alarm.

Deviations can be used to track back upstream even to the hourly performance of groups of operator responsible for each primal cut.

2.3.2 A Robotics Cell for a Typical One Cryovac System.

Therefore, to fulfil the above objectives, a typical System configuration (initially to match a 40 per minute Cryovac output) will comprise:

a. A Manual QC & ID and auto check-weighing functions at the entry into our System.

b. 4x Robot Modules, with each robot module handling a primal cut each 6 seconds, so that the overall handling rate is 1.4 seconds per primal cut.

c. Space for 32x cartons (or 24 types of primal cut types plus 8x spare cartons) over the 4x Robot Modules.

d. 3x carton sizes that will be program selectable.

e. Full cartons labelling at the System’s output.

f. Real-time production data reporting.

Such a 4x Robot Module System is shown below.

Essentially, the main features are shown in Figure 2.3 below:

1. wrapped primal meat cuts are incoming on a belt conveyor from the left side, where a QC/ID operator will check the quality of the meat cut as well as the vacuum seal, and at the same time ID the primal cut.
2. This primal cut will then be tracked to and off-loaded to one of the four Robot Modules by a cross pusher from the main infeed conveyor.
3. Within each Robot Cell the primal cuts are queued spaced apart on a chain conveyor to the robot pick-up position. There could be 5 to 8 primal cuts in this queue.

4. Arrayed to each side of this infeed chain conveyor are 4x cartons for packing into.
5. The robot is mounted inverted overhead on a portal frame, and is equipped with a universal gripper designed to handle the range of primal cuts sizes and shapes that it is expected to encounter. The chain conveyor on which the primal cuts infeed is an important feature that will allow the robot gripper to pick-up a primal cut in a way that allows it to be placed, edge-on or even upside-down in the destination carton.
6. A 3D scanner will be used to scanner the incoming primal cut as well as its destination carton(s).

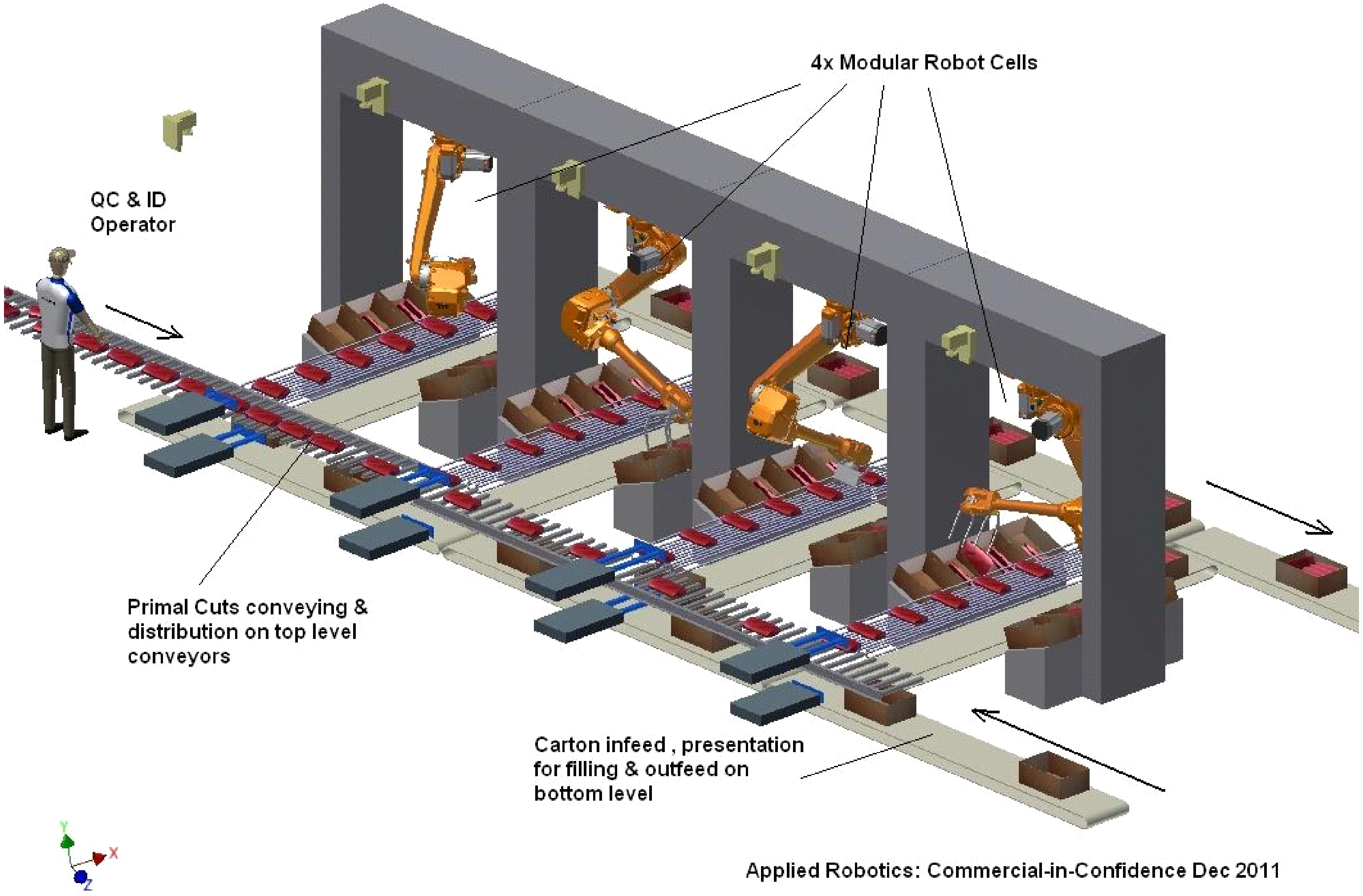


Figure 2.3 – Main features of a robotic solution.

2.3.3 The Elemental Technologies for our System

In this section, we discuss the main technology elements and the novelty of each of these elements:

a. Individual primal cut volume, shape and dimensions scanning. This is a proven off-the-shelf device employing both Machine Vision and Laser Distance scanning from SICK (Germany) - called a 3D Vision System. As such, when scanning each primal cut for robot pick-up and carton packing, the 3D scanner will read the 3D volumetric shape of the primal cut (as depicted in Figure 2.4 below) – this will be used to establish the best nested packing position of that primal cut in its usually semi-filled destination carton.

b. Carton empty volume scanning. Again, this will use the off-the-shelf SICK device to measure the shape and size of the remaining space in the partly filled carton. Here the 3D scanner will read the carton and its semi-filled contents to establish the remaining empty space in that semi-filled carton. The System software will then “trial-fit’ the incoming primal cut to establish the adequate and most efficient position to place that primal cut, thus nesting it efficiently and stably into the semi-filled carton (as shown in Figure 2.4 below) – given the carton has not already reached its overall target weight.

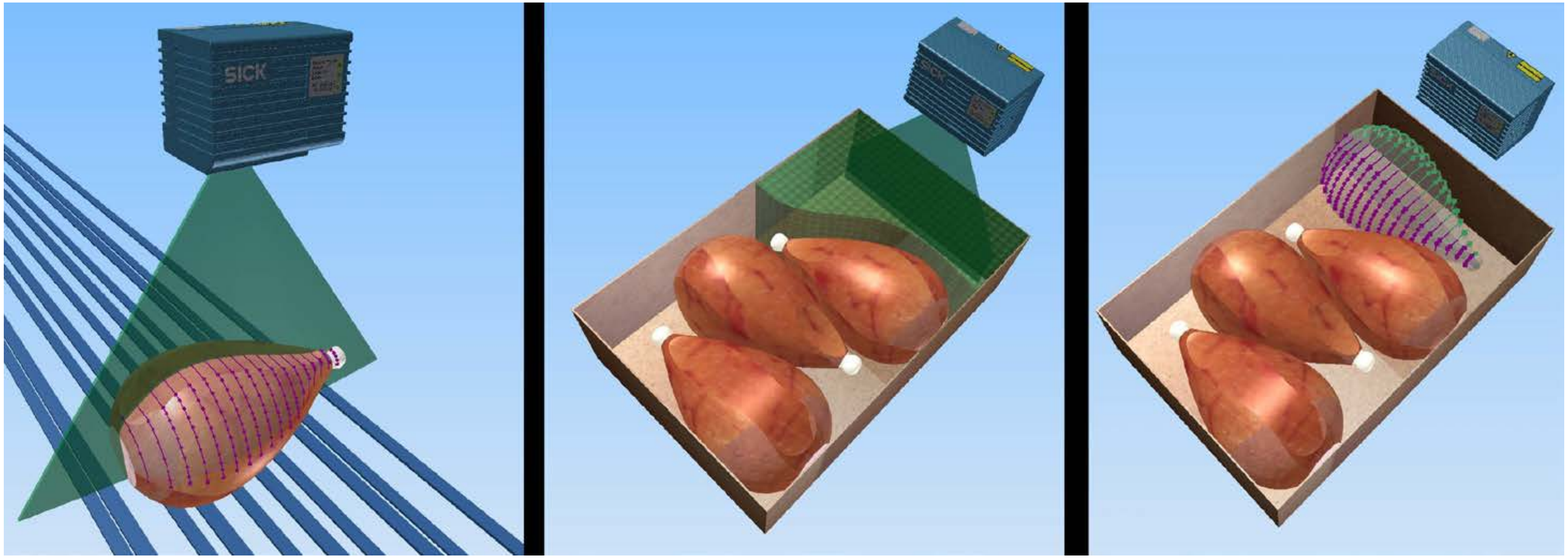


Figure 2.4 – 3D scanning process for packing wrapped meat cuts into cartons.

c. The weight of each primal cut is first ascertained on a weigh-scale at the time of its identification to allow the cumulative weight of its overall carton to be tracked. When the carton is nearly full, the System will select the closest weight primal cut to complete that carton - an over-weight incoming primal cut will be placed into a new carton, or buffered for a subsequent pick.

d. Picking up a primal cut for placement into a carton, nesting it in any angle and orientation with the existing contents is carried out using a 6-axes Robot equipped with a universal gripper.

e. Designing a universal gripper that can pick and place the all the sizes and shapes represented by a set a primal cuts is Applied Robotics’ forte, developed over its 26 years of handling difficult and variable work pieces. The universal gripper as shown in Figure 2.5 below will be able to place that primal cut in a position and orientation that is different to that when picked, i.e. its placement could be rotated and upside down to achieve the best nesting in the semi-filled carton. The design and development of this universal gripper will form one part of the proposed R&D programme.

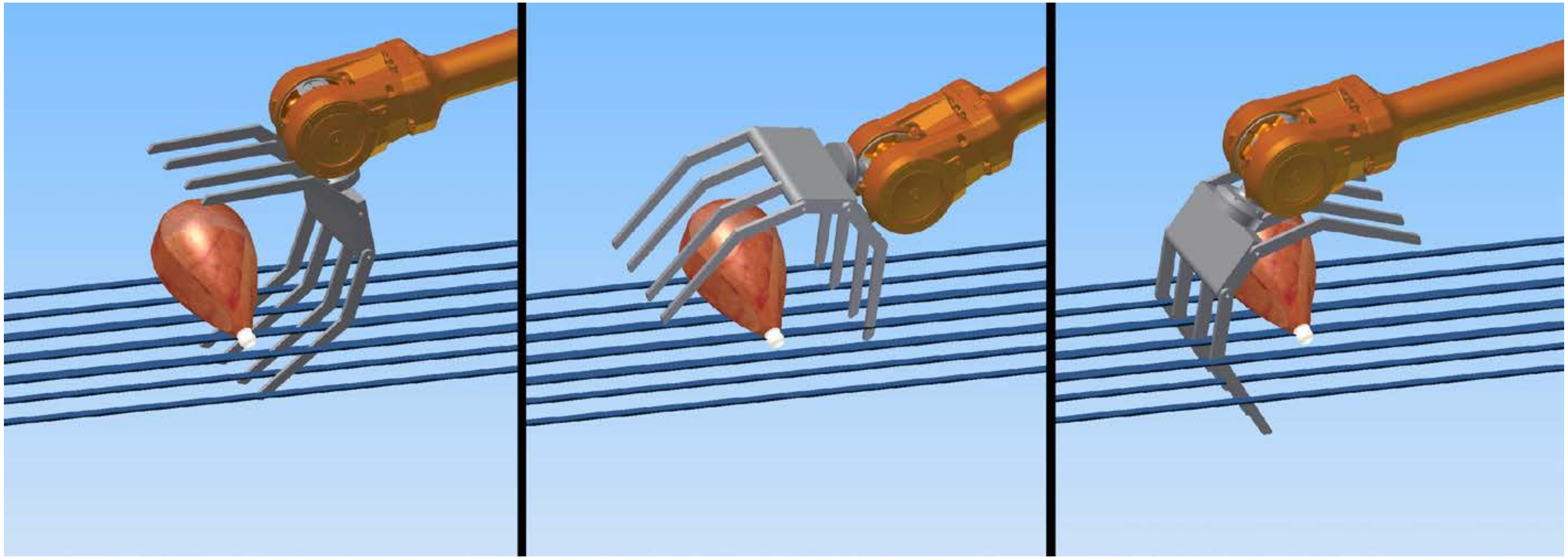


Figure 2.5 – Dexterity of robotic gripper.

f. Automated primal cut recognition was originally an essential technology, but following discussions with potential users, it was suggested that since a QC operator was necessary to ensure quality control at the primal cut entry into our System, this in the first System he may as well carry out the ID function as well.

g. Automated ID of the primal cut will be explored in this first implementation, as for each primal cut we will be logging data for that primal cut with the view that this data over time can be used for the extraction of specific properties for that primal cut that eventually will support a method for automated ID.

In summary, all the elemental technologies are proven and existing, but have not been integrated for this task before. What is required is good engineering and integration experience.

2.3.4 The detailed description of each Functional Station.

a. The QC & ID Station as shown in Figure 2.6 on the following page.

i. Here a QC Operator will check each incoming primal cut on the Infeed Conveyor and remove the 1% to 2% expected rejects and pre-orientate the primal cuts approximately in a line.

ii. If the primal cut is already bar-coded then a bar-code reader will acquire the ID of the primal cut, otherwise, the Operator will enter it by voice recognition or by a keypad.

iii. From here on, the PLC stores this data and tracks that primal cut to divert it to the assigned Robot Module (the 24x types of primal cuts will be shared over 4x Robot Modules).

iv. Depending on the extent of the QC/ID task assigned to the Operator, this infeed station can be “twinned” into two side-by-side primal cut streams attended by 2x face-to-face Operators.

v. We expect that a single Operator can handle up to 30 to 40 cuts per minute from one Cryovac, but if the outputs from 2x Cryovacs are combined then a combined flow of 60 per minutes can be seen – this is where the twinned infeed streams layout is relevant to meet this higher rate.

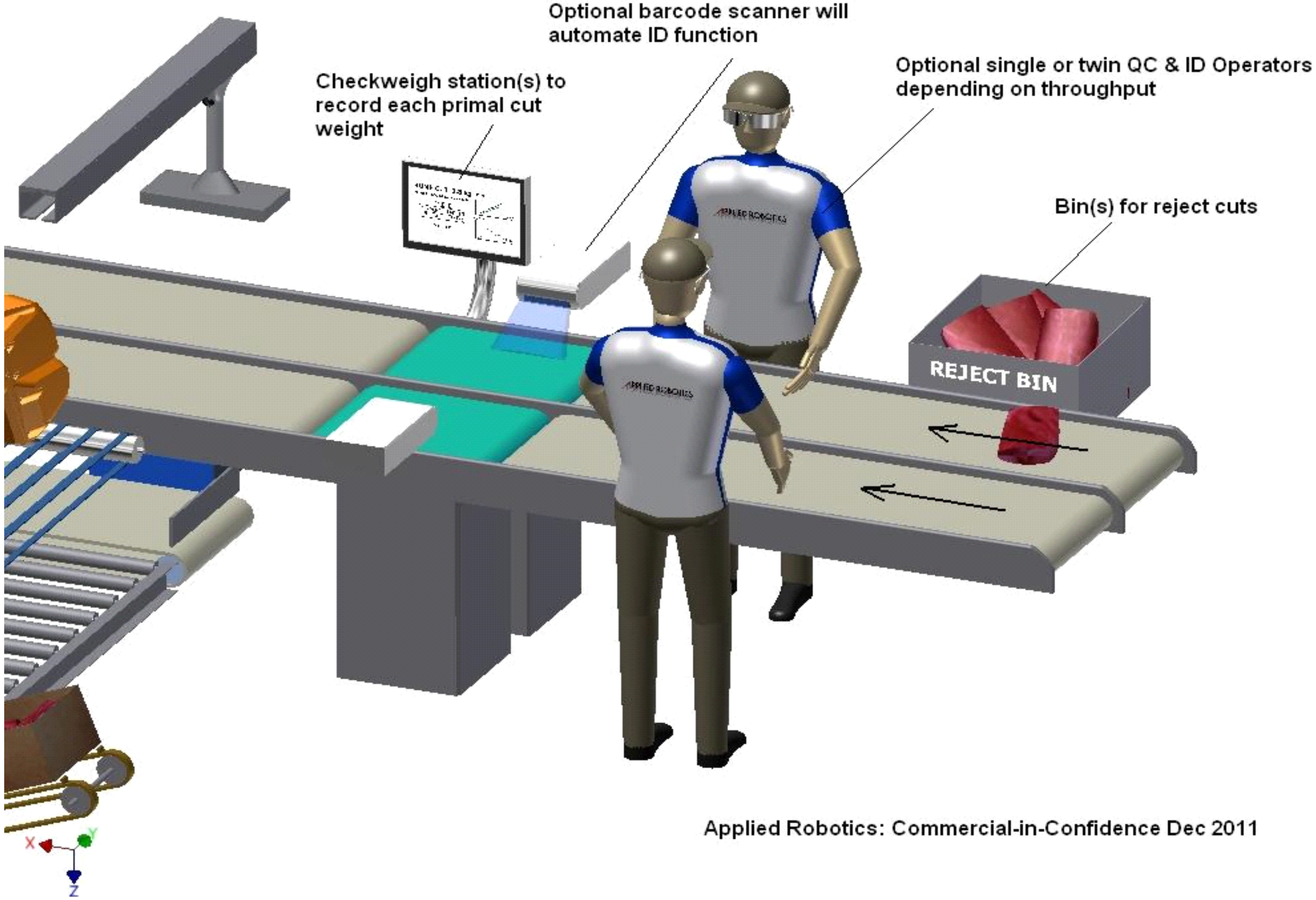


Figure 2.6 – QC & ID Station

b. The Primal Cut transfer into each Robot Module as shown in Figure 2.7 on the following page:

1. The PLC tracks each primal cut and diverts it to its assigned Robot Module. The diversion is performed by a pick & place unit equipped with a universal, shape-conforming vacuum gripper that will maintain orientation of the primal cut throughout the diversion process (and on the twin infeed streams layout, enables the outside primal cut to “jump over” the inside lane).

2. If the production rate is more than 40 cuts per minute, then the Infeed Conveyor is lengthened and additional Robot Module(s) can be added.

3. This layout is called a Ladder Layout in which the System is modularly expandable by adding “rungs” to the ladder.

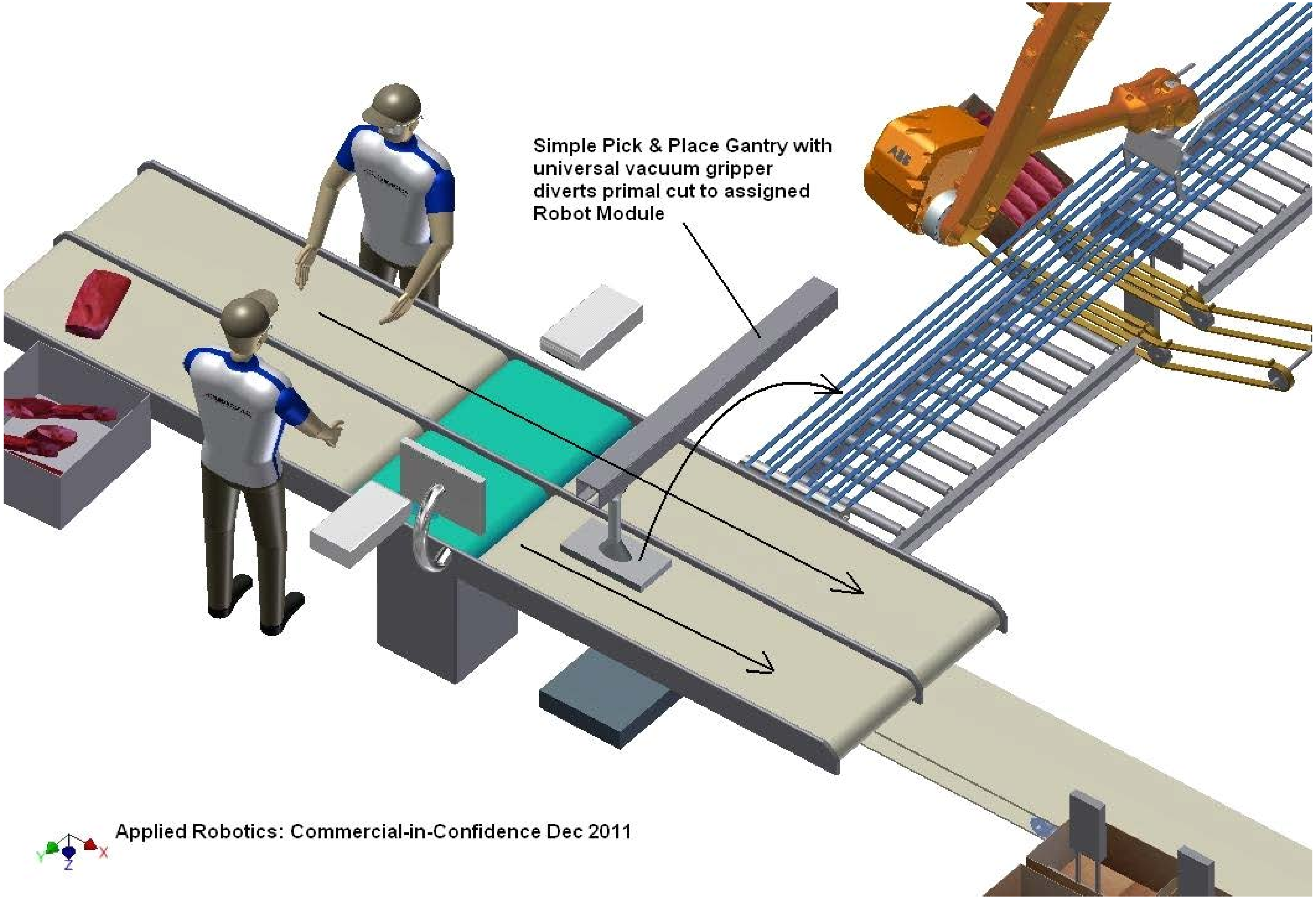


Figure 2.7 - Primal cut transfer into robot module

c. The Robot Modules (as shown in Figure 2.8):

i. The primal cuts are diverted onto and buffered on the multi chain Conveyor that infeeds into each Robot Module, feeding each cut to under the invert-mounted Robot. The chain conveyor enables the Robot equipped with an universal gripper to acquire the primal cuts from any angle.

ii. To each side of this infeed chain conveyor are arranged a set of 4x cartons, angled to provide stability to its contents.

iii. While a particular Robot Module has only 6x assigned primal cuts, extra cartons are provided at each station so that during the replacement of a filled carton with an empty one, the Robot has an alternate carton in which to place another of the same primal cut.

iv. Primal Cut 3D Scanning and Carton Empty Volume Scanning:

v. Mounted above the primal cuts is a 3D Vision System that will look at each arriving cut to measure its 3D dimensions and shape, its orientation and “sit” and calculates its volume. At the same time the 3D Vision System will scan all the arrayed cartons and measure their empty volumes.

vi. Volume matching algorithms are then employed to best match each incoming primal cut to the empty carton volume in its assigned carton. Once this has been calculated, the Robot will be instructed to pick-up the primal cut in a certain way that enables its placement into the carton in the required position and orientation to give best nesting. Since we know the overall dimensions and the volume of the destination carton, the algorithm will calculate the “negative space” that remains in that carton, and then perform a “best fit” analysis for the incoming primal cut.

vii. This proposed 3D scanning technology is already being researched by Applied Robotics in the identification and position detection of aluminium extrusions for a Robotic Extrusion Pack Making system.

viii. The illustration below illustrates this methodology for the primal cuts application:

ix. If the immediate primal cut is unsuitable, then another similar primal cut further up the buffer may be selected for a better fit. Alternatively, the immediate primal cut can be buffered into a new empty carton.

x. Since we know the weight of the primal cut as well as its ID, the Robot is able to sort the primal cuts into weight ranges, and carton them appropriately.

xi. Similarly, the Robot is able to calculate the cumulative weight of each carton as it loads (if there is a maximum carton weight limit).

xii. If necessary, the PLC can store each carton weight for recording purposes and/or for labelling the carton along with other data, when the filled carton exits our System.

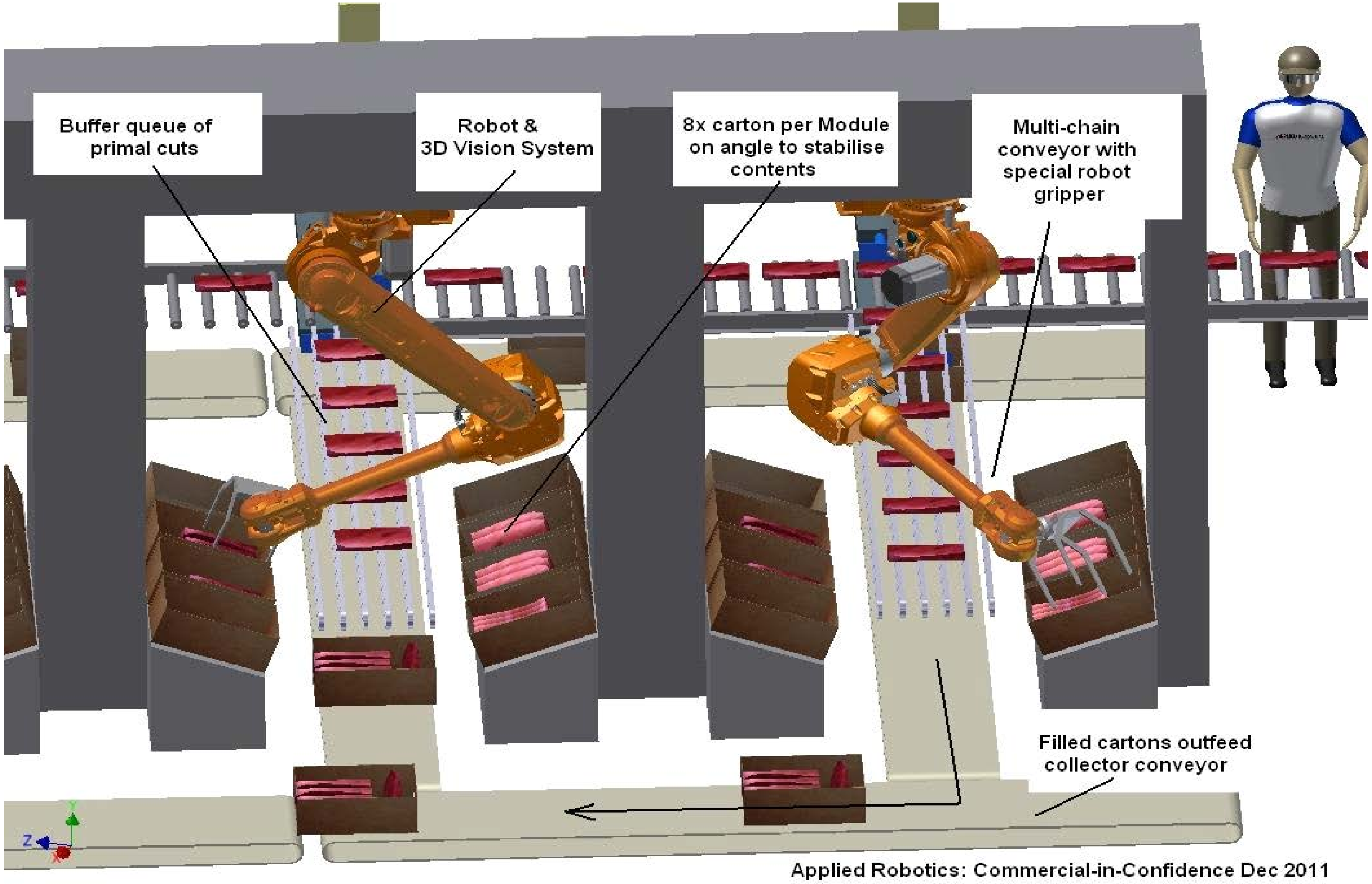


Figure 2.8 – Robot modules

d. Cartons Handling:

i. Positioned in a level below the primal cuts conveyors and directly underneath them, is the carton handling conveyor system.
ii. Under the primal cuts infeed conveyor is the empty Carton Infeed Conveyor – its carton are drawn as required from 3x buffers each holding a different carton size.
iii. Under each multi-chain conveyor, is the Carton Delivery Conveyor on which the empty carton proceeds to where it is required and pushed into the arrayed position each side of the multi-Chain conveyor for robot filling. After it is filled, this carton is returned onto the Carton Delivery Conveyor to be carried away from under the Robot to merge into the shared full Carton Outfeed Conveyor that carries the full carton pass the inkjet/labelling station.

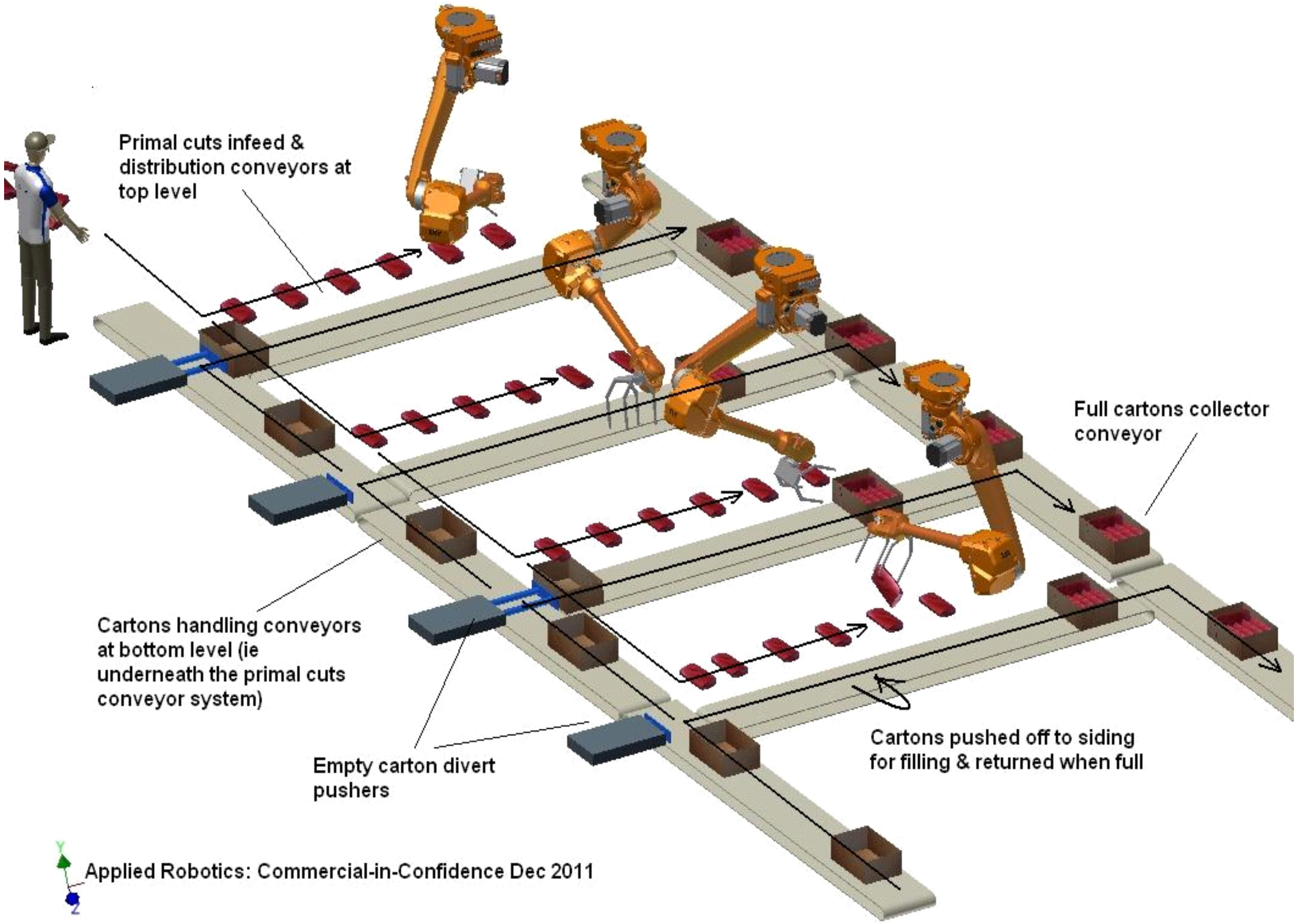


Figure 2.9 – Layout of conveyers and pushers for carton handling.

e. Advantages & benefits. The labour savings and the other benefits of use are listed below:

i. Labour savings: for a 30 to 40 cuts per minute production rate, on average, there is a labour savings of 4 packing operators.

ii. Ergonomics: relieves people from carrying weighty work pieces all day long.

iii. Consistency: once programmed the Robot will correctly identity/pack each primal cut, sort into weight ranges, optimize the carton nesting, pack by count or by weight and be cognizant of overall carton weight upper limits.

iv. Combat labour shortages, high turnover, quality inconsistency and the continuing need for operator training.

v. Real-Time Production Management information: as each primal cut is identified and weighed at its entry into our System, a wealth of timely and detailed production data is available for real-time production control (as opposed to many current data gathering systems where this data, in a highly bulked way, is available only after that production batch is completed). This real-time raw data in many ways for recording or for trending; suggestions are:

- real-time cumulative production (count/weight) for each primal cut and comparison to target/budget
- within each primal cut group, we can show its weight/size/volume distribution on a dynamic basis, for indications of out-of-norm cuts: for example a bi-modal distribution will indicate that one slicer is consistently under/over trimming.
- Industry analysts suggest that this efficiency improvement could be valued at 1% to 2% of turnover.
- Cartons output data is also recorded and available in real-time.
- Traceability. In this System, the PLC tracking of every primal cut will allow its traceability to each carton.

3 FIELD WORK

3.1 Abattoir Visits & Response.

The abattoirs visited in the course of this study are outlined in Table 3.1 below:

Table 3.1 – Abattoirs visited during study

Region	Abattoir	Times Visited
Queensland	JBS Dinmore	2
Queensland	Stanbroke	2
Queensland	Nippon Oakey	2
NSW	JBS Riverina	1
NSW	Cargills, Wagga	1
NSW	GM Scott	1
South Australia	Thomas Foods	1

In all cases, there was an existing recirculating conveyors set-up in which the incoming wrapped primal cuts were inspected, sorted, weighed and nested into their respective cartons by a weight limit. There were on average 4x packing operators stationed at the recirculating conveyors. The floor space occupied was around 6m x 4m.

However, to employ our Robotic solution would in all cases involve the use of more floor space and the complete re-arrangement of the floor in that locality – in all cases this would represent a major logistic re-arrangement of the existing machinery and conveyors.

4 INDUSTRY RELEVANCE

4.1 Applicability.

In our various presentations, it was acknowledged that there are benefits to be had by the application of this technology in its described implementation, or a variation of it.

However, because of its space requirements, the wholesale re-arranging of this part of the factory floor to enable its adoption represents a difficult problem. In other words, because adoption required significant changes in the up and downstream systems, for adoption to occur there needs to be convincing evidence of significant benefits.

What is needed first is a firmer indication that the technology works and a firmer indication of the benefits.

It would appear then that the best way to promote the adoption of our Robotic solution would be to set up the trial System in a neighbouring and larger fresh space and divert the output of the Cryovac(s) to that new space. In this way, the Robotic solution can be trailed in a practical environment and hard data be measured.

If this confirms our estimates, this hard data can be used to support a wholesale re-arrangement of the existing factory floor.

In summary, our first conclusion is that to adopt our Robotics solution would mean a re-arrangement effort that would be significant and as such diminishes the attractiveness of the solution. Where there is an adjacent space available, or where a green fields site was being contemplated, then our solution would be feasible.

Our second conclusion is that the technology was seen to be novel at this time and therein lies a technical risk.

Our third conclusion is that since the industry sector is in general still exploring the potential benefits of industrial robotics, there is not a body of experience in successful implementations to give confidence to each new potential implementation.

If there was a demonstration unit available and technical feasibility can be witnessed and data can be measured to support our claims for commercial feasibility, then the technology and commercial risk elements can be removed, then there will be grounds for serious consideration of the System’s implementation.

4.2 Future Applicability.

If the System’s applicability is muted at this time, we predict that in the medium term future it will much improve.

To support this supposition, we need to look at what has happened in the Australian non-abattoir sectors in general, where automation is the active stage of development rather than the mechanization stage in which the abattoir sector is still in. In other words, the general industry sector (i.e. what there is in Australia) is much further up the automation “S curve”.

In the general context, the Australian manufacturing sector makes a vital and significant contribution to the economy. The sector has been growing at an average annual rate of 0.9% since 2000 (in dollar terms), accounting for 8.7% of GDP. The sector also continues to be an important contributor to exports, accounting for around 34% of total exports.

4.2.1 The Need for Productivity Increase.

The manufacturing sector is a significant contributor towards overall employment, with almost 1 million people currently employed by the sector. However, **employment is falling, largely due to labour productivity growth rates** and significant falls in employment in the Textile, Clothing and

Footwear industry since the late 1980s.The manufacturing sector has become increasingly integrated with global value chains, making it prone to fluctuations in global input costs and the Australian dollar. However, despite the current highs of the Australian dollar and the increasingly

competitive nature of global manufacturing, the Australian manufacturing sector still accounted for 34% of total exports in 2011.

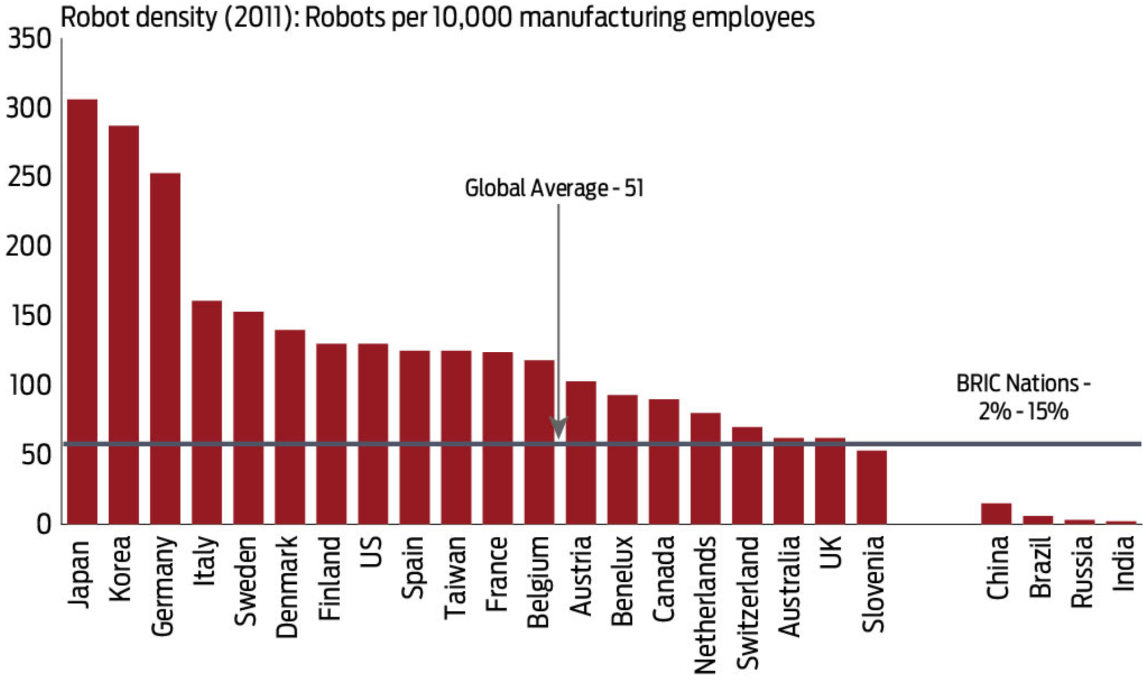
4.2.2 The Relevance of Industrial Robots

The general purpose industrial robot has over the last 30 years established for itself the hegemonic position as the “full and accepted” technology solution for industrial automation. As a consequence, its affordability has improved in relative terms, as like the motor car due to increasing production volumes the today we are getting an increased capability for a reducing price.

The level of adoption of robots therefore can be seen as a good measure of the level of embracement of automation technology in general. As an illustrative example, in Applied Robotics’s own engineering of automation solutions for Australian industry over the last 30 years, we have seen the ratio of off-the-shelf robots to specifically engineered automation, increase from around 20% in the 1980s to some 80% in 2010. Today, of a manipulator requires more than 2 axes of controlled movement, as a “rule of thumb” we will specify a robot (as being a more capable yet lower cost way to obtain that motion).

The following graph shown in Figure 4.1 is a good indicator of the relative level of automation in the general Australian manufacturing sector. It shows the number industrial robots per 10,000 manufacturing employees in the developed industrial economies which in general has eschewed manufacturing sectors for which automation is not available versus the less-developed manufacturing economies which has embraced the un-automated, labour intensive sectors. In other words, between an advanced manufacturing sectors that are well up the automation “S” curve and those at the bottom of the “S” curve.

We contend that this comparison holds for the Australian non-abattoir sector and its abattoir sector.



Sources: CSFB, IFR World Robotics 2011, J.P. Morgan Asset Management

Figure 4.1 – Robot density per nation

The graph shown in Figure 4.2 below supports this assertion – its shows the annual adoption rates of industrial robots by industry sector. This confirms the low rate of adoption in the food sectors in general, even although there are elements within this sector such as beverages, and processed foods (biscuits, canned food, etc.) that is highly automated, the balance is the large fresh food preparation sector or which automation is much less available.

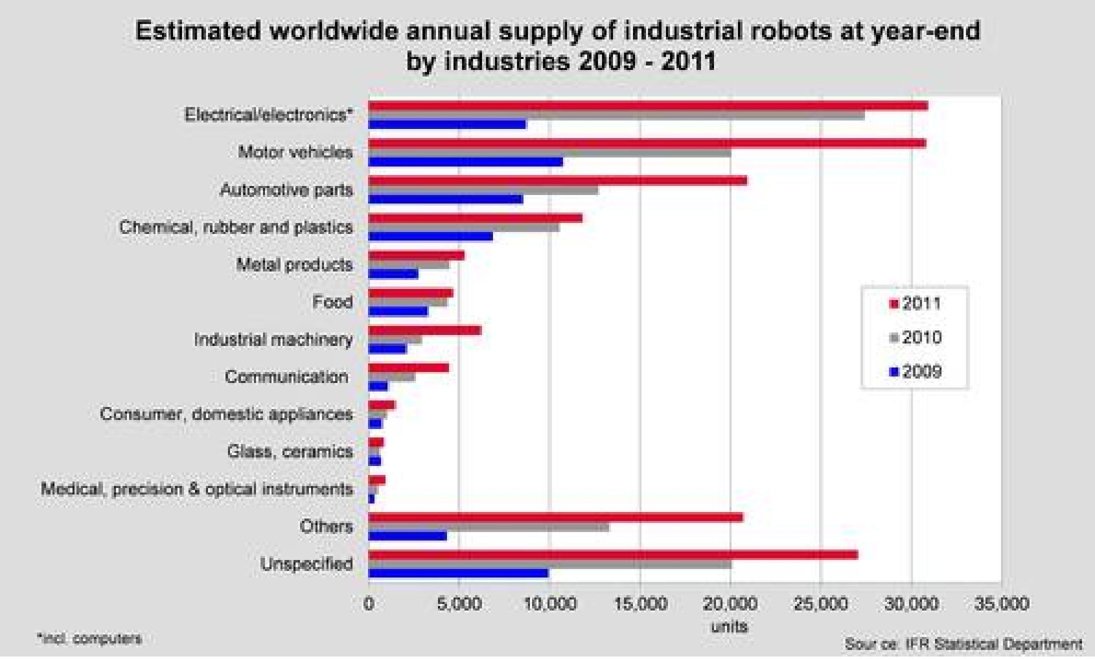


Figure 4.2 – Estimated worldwide annual supply of industrial robots

Shown in Figure 4.3 below is the graph showing the annual increase in the adoption of industrial robots worldwide. Apart from the downwards dips due to the GFC in 2009 and before that to other recessions, the general trend has been upwards at an increase of some 6,000 units shipped each year.

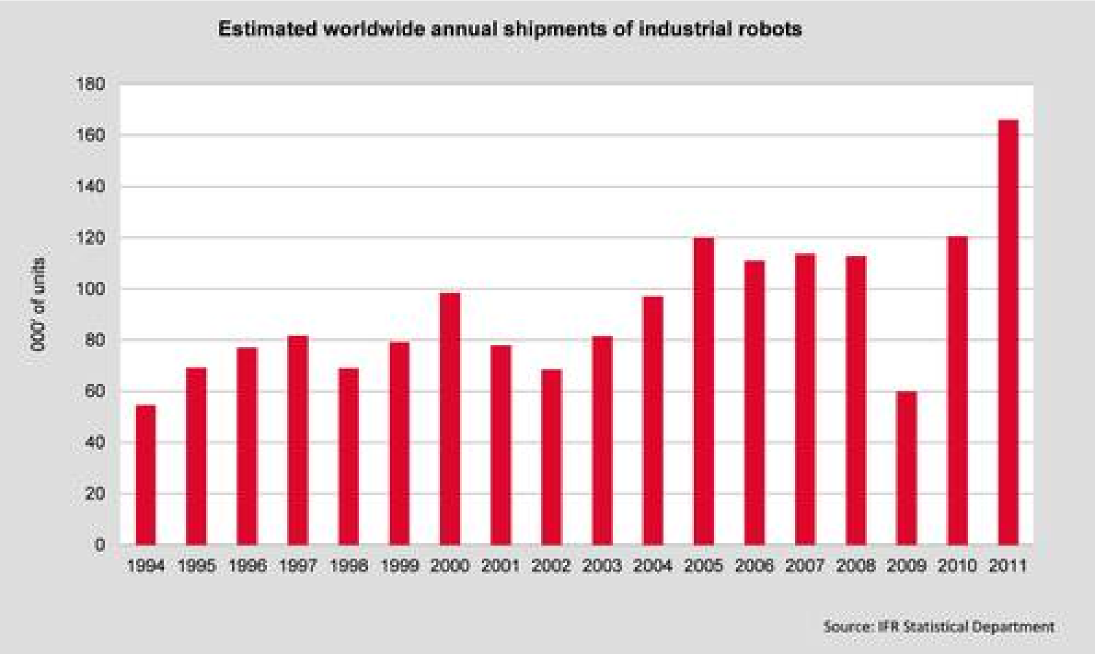


Figure 4.3 – Estimated worldwide annual shipments of industrial robots.

We need to see the specific Australian manufacturing in context of these worldwide trends. The ABS Statistics below show the relative importance of the food and beverage sector and its perceived barriers to innovation:

a. The major markets for Australian manufacturing are outlined in Table 4.1 and Figure 4.4 below:

Table 4.1 - Major markets for Australian manufacturing

Market	Percentage of Manufacturing
Food, beverage and tobacco products	**21%**
Metal products	21%
Machinery and equipment	20%

Source: Australian Bureau of Statistics

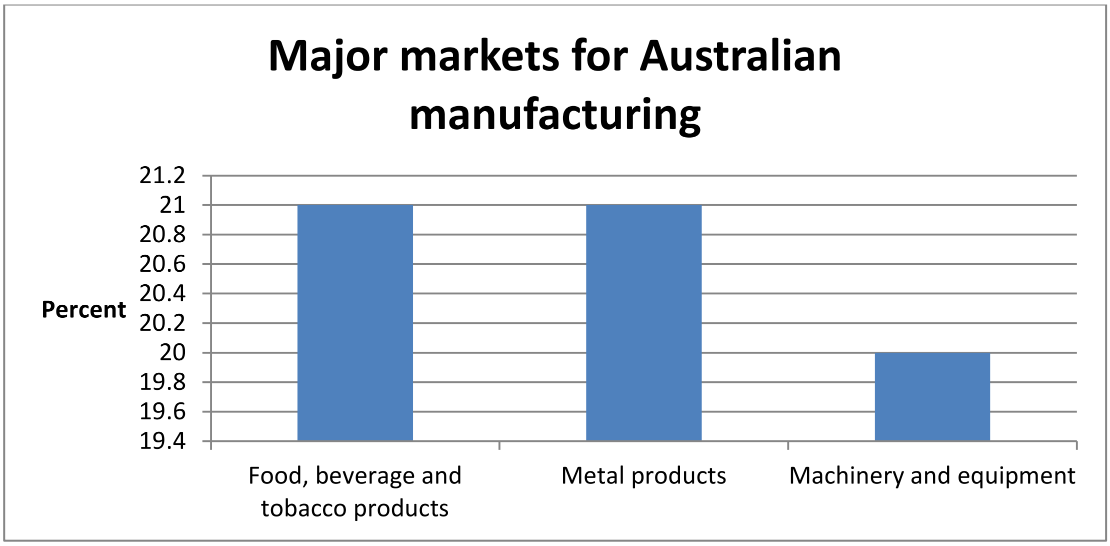


Figure 4.4 - Major markets for Australian manufacturing

b. For the manufacturing sector in general the barriers to innovation listed are outlined in Table 4.2 and Figure 4.5 below.

Table 4.2 – Barriers to innovation in the manufacturing sector

Barrier	Percentage of total barriers
Lack of skilled persons	**24.8%**
Uncertain demand for new goods or services	20.3%
Lack of access to additional funds	22.1%
Cost of development or introduction/implementation	18.2%
Government regulations and compliance	12.5%
Adherence to standards	5.3%

Source: Australian Bureau of Statistics

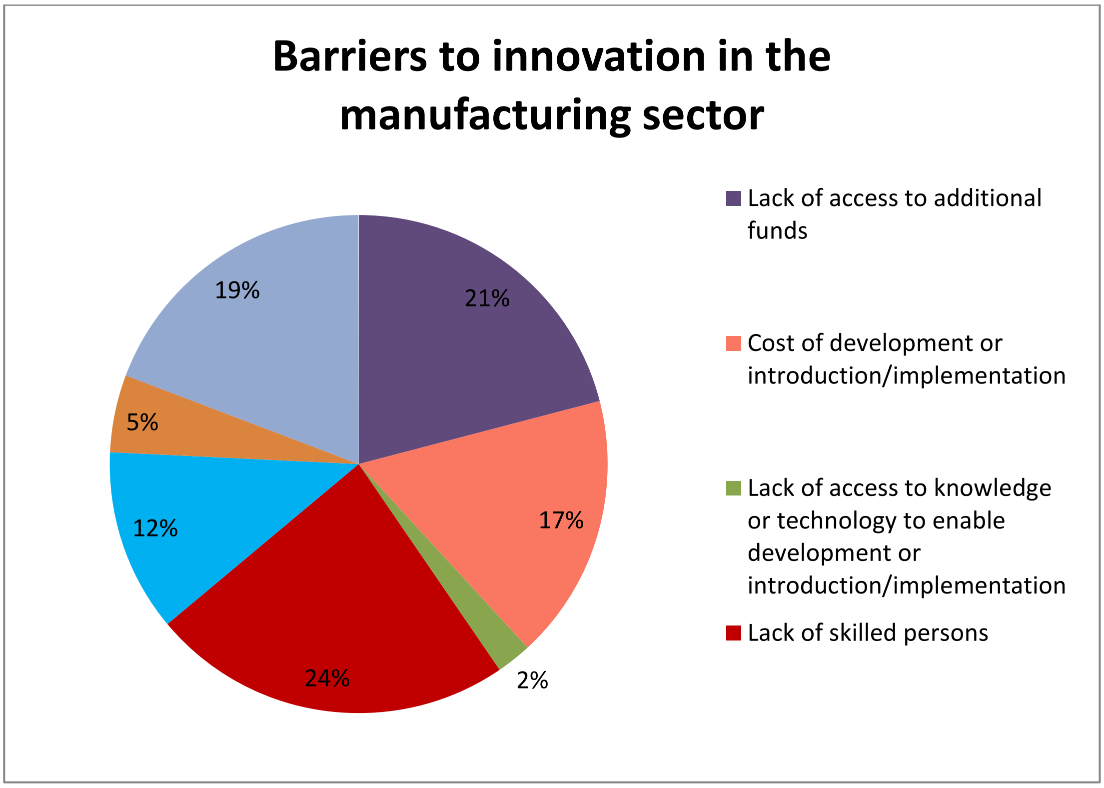


Figure 4.5 – Pie chart of the barriers to innovation in the manufacturing sector

In Applied Robotics' own experience over the last 20 years, we have seen that our customer companies such as those in Building Products, Food Manufacturing, Plastics, Pharmaceuticals, Metal Working, etc. who are currently well up the automation "S" curve, would be eager to invest in the automation of manual tasks that take now take 3 to 4 people, particularly, if the tasks are carried out over 2 or more shifts.

For example, it would be highly unusual to see manual carton palletizing in the non-abattoir sector. Yet, in all the abattoirs we have visited, the sortation of the incoming cartons and their palletizing has been exclusively manual.

Currently, the non-abattoir companies would jump at a 1.5 to 2.5 years payback opportunity, and they would see a 2.5 to 3.5 years payback to be acceptable. If for strategic reasons or there is the need to remove people from hazardous tasks, then up to 4.5 years payback is acceptable. In these sectors, the nominal all-up cost per person per shift is around the $80k mark.

Once the scope of mechanization is realized to be exhausted, and beyond this the benefits of automation is fully embraced by the abattoirs sector, and it gains experience and confidence in automation technology, we predict that manual tasks such as the primal cuts sorting and cartooning, will be targeted for automation. Because of the weights lifted and the number of people involved, we believe that the Wrapped Primal Cuts Sorting & Cartoning application will be one of the first to be targeted.

A not insignificant incentive for a company to embrace automation is what their peers in the industry are doing (as like most Australian industry sectors the sector is small and information is quickly disseminated).

If an industry leader is seen to have successfully adopted a particular innovation, this will be a motivation for the followers to evaluate such an innovation for themselves. We believe this is where the MLA/AMPC can encourage/promote an innovation genre by providing incentives for an industry leader to be a first adopter in an innovation that the MLA/AMPC believes in. This, of course, is the eternal challenge for industry bodies such as the MLA/AMPC – to be able to pick the potential winners to support within limited funds.

4.2.3 The Next Wave in Industrial Robotics Advancement.

Since the infancy of robotics technology in the early 70s, and from an overview perspective, there has been a number of waves of change and we believe that we are again at the groundswell of the next major wave.

The first Industrial robot genre was the play-back robot – a program flexible manipulator that played back precisely and untiringly the sequence of moves it was taught. It started with the Unimates of the mid 70s, these were hydraulically actuated because electric motors then did not have the power density to be useful for medium to large robots. Over the next 20 years, electric servomotors took over as the robot's primary drives offering greater serviceability and eventually more power and controllability.

Each generation of development not only gave improvements in performance, reliability and increased controllability, but due to the maturity of the contributing technologies and the increasing robot production volumes, it led to massive gains in its performance/cost ratio.

Nevertheless, the bulk of robots now in production use are play-back robots, which in the industry parlance, work within a “highly structured” environment – everything in this environment - the workpiece and the workstation are precisely known, predictable and do not change.

However, where there is variability, then currently a man instead of a robot, must be used to cope with this variability. For example, every production manager is aware of his many sophisticated and high speed processing machines which while being very automated in themselves still require manual loading at the infeed end. This is because the most common and economic means of bulk presentation of the inputs to these process machines is an “unstructured input” to the current generation of robots – in other words the robots that cannot pick from a leaning, twisted or flowering stack, or approximately placed workpieces, on an infeed pallet.

Extending the robots' capability to embrace these less-structured areas of manufacturing environment is the next major wave of change.

Already, the beginnings of this next S-Curve have been happening since the late 90s when pioneers in the technology have started to add sensory technologies that enable the robot to make small adaptations in their pre-programmed moves to account for variations in this otherwise structured environment. Examples of this adaptive capability is the seam tracking welding robot, the use of early vision systems to "see" the precise orientation of a variably presented workpiece so that the robot can adjust itself to pick it up, the use of vision system to perform rudimentary parts identification so the robot can sort the articles they are handling.

As these sensory technologies increase in capability, speed of processing and in real terms become less costly, and they become more and more integrated within the robot's controls, this combination will fuel the rapid adoption of this next genre of **Adaptive Robotics Technology.**

First among these new sensory technologies will be increasingly able and faster Vision Systems – leading the charge will be the integrated vision and distance sensing systems already being marketed by leading sensor companies. Omni-sensors that will image the entire workspace, coupled with adaptive and predictive computer modelling afforded by increasingly powerful, fast and low cost computers, will give these robots a more precise awareness of their variable work environment than was ever available for human operators.

We are not talking about robots working in totally unstructured environments, as even when the technology eventually becomes available, it will never be efficient to run a manufacturing line with that degree of disorder.

Not only will these robots cope well with the simple task of de-stacking an untidy pallet, but their new capability will open up new swags of manufacturing tasks in which the workpieces themselves are "unstructured" in that they change their form continually, or simply vary greatly from one to another. These are the pliable, soft, elastic and simply limp workpieces such as fabrics and soft polymer products, raw food items, or low tolerance assemblies such as wooden crate.

Of course, for robots to perform effective work in these new areas, there will need to be accompanying developments in manipulators such as multi-armed robots, as well as in their end-effectors such as super-dextrous grippers, sensory grippers, grippers that can handle limp and porous materials, fragile workpieces, etc. The ability to perform real Quality Control as an embedded capability will also be important, particularly if this function is integrated with the robot’s manipulation functions.

Clearly, imbuing robots in general with such peripherals in a cost-effective manner will enable their scope of usage to be greatly expanded, thus increasing further the normal benefits of automation to the manufacturer.

The technologies that are needed are more evolutionary than revolutionary, indeed much of its development is already well under way. Like the robots themselves, these peripheral technologies will advance to a point, perhaps in the next 5 years, when they will be fast and capable enough and then with increasing usage starting in high value applications, their effective cost will reduce so that once the critical mass point is reached, their affordability will make them commonplace and even cost-effective when not efficiently used. This is the hegemonic effect of a “full and accepted” technology.

At the moment, the performance/cost ratio is holding back many potential applications – only the high-end applications are being implemented.

Applied Robotics has long been at the forefront of this wave. Even back in 1988, we exhibited one of the first Vision System applications in

Australia – show visitors were invited to randomly toss a flimsy fabric workpiece onto a table where a Vision System would scan and acquire its position and orientation, and thereafter instruct a robot equipped with our proprietary flimsy fabric gripper, to pick it up flat and stack it on top of others in a neat stack.

Applied Robotics' first vision guided robot assembly and welding system was installed back in the mid-90s. This system "looked" to identify the incoming product to be assembled and welded, measured its position, and instructed the assembly robot to carry out its specific assembly, and after that the welding robot to perform its task.

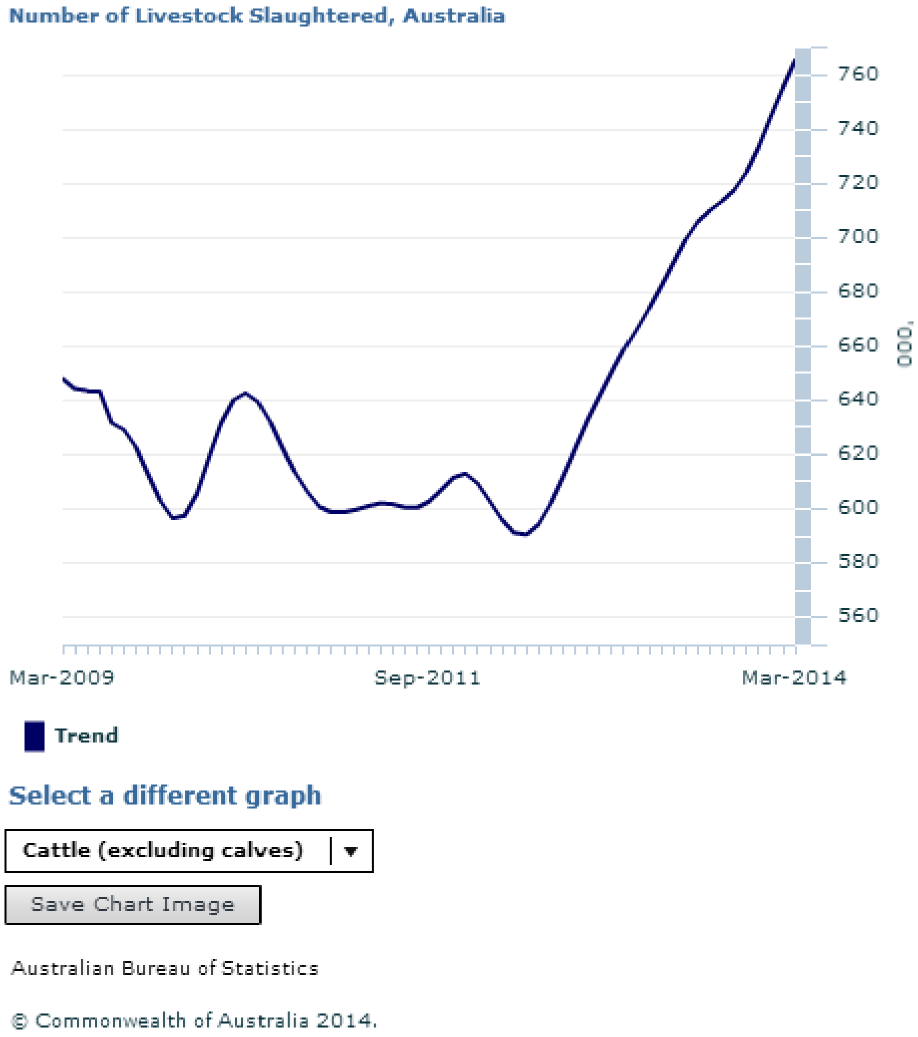
Our first untidy stacks de-palletising robot cell was installed in 2002. Using robot-mounted sensors, we searched the position of ach article for pick-up. Provided the stack was not collapsed on the ground, we would find and pick-off the article.

Currently, Applied Robotics has been contracted to develop robotics and sensory technologies to ultimately perform full automated sewing for the furniture industry in Norway. This project will encompass that new technologies - vision systems, tactile sensors, advanced robot controls, special grippers and novel concepts of workpiece handling.

4.3 Potential Extent of Application.

The following graphs in Figures 4.6 – 4.7 show the number of annual cattle and sheep slaughter in Australia.

From these graphs we can get an idea of the general applicablity of the Wrapped Primal Cuts Sorting & Cartoning System for cattel and sheep abattoirs.



Australian Bureau of Statistics

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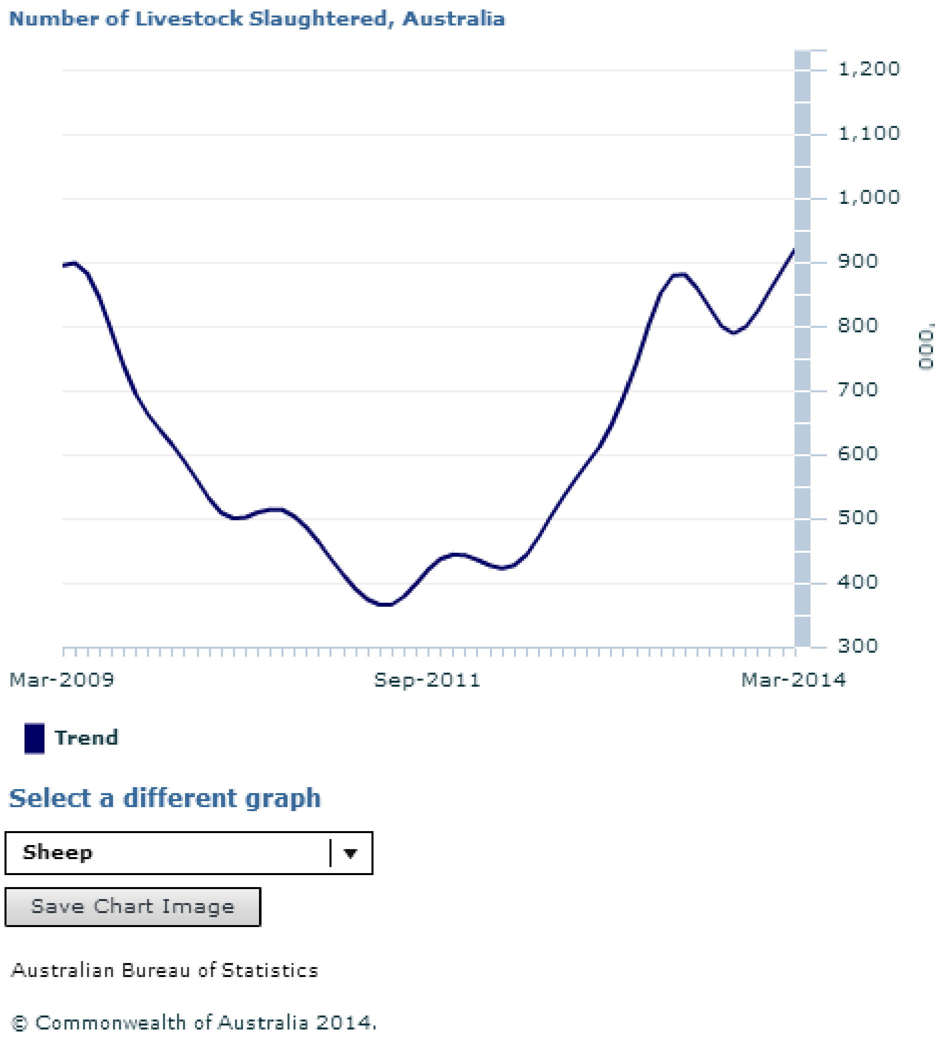
Figure 4.6 – Number of Cattle slaughtered in Australia 2009 - 2014

For cattle it can be seen that in 2014 there are 760,000 slaughters. If we use the number of primal cuts to be say 60 cuts, i.e. two per animal, then the total primal cuts will number around 15M pieces, or using an average of 10 pieces per carton, we will get the number of primal cut cartons packed annually to be around 1.5M.



Australian Bureau of Statistics

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Figure 4.7 – Number of Sheep Slaughtered in Australia 2009 - 2014

For sheep it can be seen that in 2014 there are 900,000 slaughters. If we use the number of primal cuts to be say 30 cuts, i.e. two per animal, then the total primal cuts will number around 37M pieces, or using an average of 12 pieces per carton, we will get the number of primal cut cartons packed annually to be around 3M.

In total then there are 4.5M cartons packed annually in Australia, for the national cattle and sheep slaughter. If 1/2 of these cartons are packed in abattoirs large enough for automation to apply, then the number of cartons that can be automatically packed will reduce to some 2.25M cartons per annum.

5 FURTHER WORK TO BE DONE

5.1 Technical R&D work to be done.

As already mentioned in Section 2.3.3 Elemental Technologies for our System, the novel technology elements are:

a. the 3D scanning of the incoming Primal Cut and the its semi-filled destination carton, and

b. the design of the universal Primal Cuts Robotic Gripper.

Given there is a desire to proceed to a demonstration Robotic Cell, we suggest that following staged approach:

a. R&D Stage 1. To prove the technical feasibility of 3D scanning of the vacuum-wrapped Primal Cut and the semi-filled carton, along with the development and proving of the algorithms to best nest that primal cut into the remaining space in that semi-filled carton.

b. Evaluation of the above developed base technology and a Go/no Go Decision.

c. R&D Stage 2. A greater detailed assessment of the user needs, ideally through working closely with a partner abattoir, resulting in a re-working of the specification of the Robotic Solution, and a re-costing of a Practical System.

d. Evaluation of the above developed Practical System and a Go/no Go Decision.

e. R&D Stage 3. Design and build the practical Demonstration Robotic Cell comprising a single Robotic Module tailored for the partner abattoir site. Off-site pre-commissioning of this Demonstration Robotic Cell for FAT trials, performance data collection, and demonstration to the industry in general.

f. R&D Stage 4. Installation and commissioning of this Demonstration Robotic Cell, and its actual performance monitoring and data gathering, at the partner abattoir site.

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See our website at www.appliedrobotics.com.au for general information and history of Applied Robotics.

Appendix A: APPLIED ROBOTICS MILESTONES 2012

Applied Robotics has been building special purpose automation and robotics machine systems for Australian and export markets continuously since 1985. We are celebrating our 28th birthday in 2013.

To date we have installed over 500 systems worldwide. All of these are full turnkey systems – engineered from concept through mechanical, electrical controls and software design, and built, installed and commissioned by our own team of engineers and technicians.

The strategy at Applied Robotics has always been to combine new technologies and novel techniques with proven automation technologies and our experience, to tackle our clients' automation tasks in a better way. About 50% of our projects target a task that haven't been automated before and thus have a R&D content. As a result, many of our solutions have made available a quantum jump in machine capability or performance, offering our clients a world first or a world fastest automation solution. Such systems have underpinned our export success to markets in the US, Japan and Europe.

Some of the more interesting milestones over the years include:

1. First Vision System demonstrated in Australia at a public exhibition, University of NSW, TCF Machinery Exhibition, 1986. We invited guests to throw fabric workpieces randomly onto table, a Vision System locates its position and orientation, and instructs Robot to pick up and stack each workpiece into a neat stack.

2. Strategic alliance with CSIRO for collaborative projects on very high speed vision systems for food QC and sortation applications at above 45 pieces per second with full colour capability. Resulting in world first machine systems for Buderim Ginger Ltd, Golden Circle, etc. 1991 – 1995.

3. Our largest project overseas has been the design and supply of 8x Machine Lines for the high-speed handling of carpet tiles for Milliken & Co's new 25 acres carpet tile plant, in Georgia, USA in 1995/96. The Tile Stacker working at up to 4x tiles a second is still the fastest carpet tile handling solution in the world.

4. Licensed our unique technologies for wind speed and direction sensing to Raytheon Corporation (USA). To this day it continues to underpin one of their current products in the nautical electronics market.

5. 14 high-speed toothbrush-packaging machines for ORAL-B, Iowa, USA. Picks and places toothbrushes at speeds of 1.25 second per brush. We had to design a special robot arm to perform at this speed since off-the-shelf robots were too slow in 1997.

6. Robot/Vision guiding multiple robots for assembling and welding hot-water cylinders boasting tool-less and zero set-up times for batch changes (Dux Hot Water, 1998). First in Australia.

7. First of its kind in Australia, Robotic TIG welding line for 0.5mm thick stainless steel component. Three Robotic Cells continues to produce

for ZIP Heaters since installation in 1999. Continues to make all of ZIP's production needs.

8. Robot & Vision Robot for the loading & unloading of a Powder Coating Line. Luxfer Gas Cylinders, California, USA. Hand-eye coordination between Robot and Vision System to hook gas cylinders onto moving and variably positioned hooks. First in world in 2002.

9. 6 x Silicon Wafer Chemical Etching Lines for solar cell manufacturing. We developed a chemical resistant polypropylene Gantry Robot and auto etching-solution make-up from PLC recipes. BP Solar, 2000 – 2003.

10. Photo-voltaic Cell Assembly system for Origin Energy, 2004. Unique machine

    concept resulting from a preliminary $1M R&D Project, resulting in a specially designed, vision-guided, Gantry Robot with a +/- 20 microns repeatability.

11. Robot and/or Vision Guided Bricks QC & Stacking projects – stacking of green bricks & pavers, dis-assembly of ex-kiln bricks hacks, individual brick QC for fine cracks and chips and colour, flexible palletizing at rates in excess of 12,000 bricks per hour (CSR/PGH Bricks, Shinagawa Refractories. 2006 - 2009).

12. Norwegian Government. R&D Project to develop Fully Automatic Sewing of

    furniture clothing in a 5 year programme. This project was won against the

    leading R&D laboratories in the USA, Japan and Europe. 2008.

13. Fletcher Building Products, 2009. Project to almost double the packaging capacity of a major insulation batts factory. We had to develop the world’s fastest Batts Bagging Machine for this project.

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