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INNOVATIVE ROBOTIC APPLICATIONS FOR BEEF PROCESSING

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Abstract

Industrial Research Limited (IRL) has engaged in world leading research in the area of automated beef processing. Two innovative applications of automation are beef belly ripping and beef brisket sawing. The challenges faced in these applications, the methods used to meet them and the results achieved are described.

1 INTRODUCTION

The key challenge in meat processing is the carcass variation. The meat-based product items such as lamb and beef carcasses are all 'the same but different': generic properties can be pre-determined but each individual product item (e.g. beef carcass) will have its own unique characteristics. A further challenge is the harsh environment of the meat processing works: all equipment requires a wash-down after each shift with a high pressure hot water solution for sterilisation purposes, and must have smooth surfaces for effective cleaning to ensure hygienic operation [Taylor and Templer, 1997].

The fundamental requirements for meat processing apart from being rugged and waterproofed include the capability to adapt the process to each individual carcass and deal with its variation successfully and reliably. A successful system must therefore be able to accommodate this variability in objects by individually-tailored processing of each object [Friedrich & Temper, 2001]. This can be accomplished by the use of sensory information concerning characteristics of each object to be processed, and modifying a generic task and path plan.

In principle, three major control modules are required:
– a sensing and perception module,
– a control module and
– an actuation module.

The sensor-perception module processes raw sensor data using sampling and filtering techniques. This module also combines data interprets results and extracts significant information and acts as a perceiving mechanism. The relevant changes e.g. required path or position modifications are communicated to the control module.

From a generic operation containing the process description for the particular application, sensor-based adjustments are made. Depending on the nature of the application, the control module can generate commands such as a path for a robotic operation e.g. for cutting, or the commands for a handling operation

In the actuation module, the control parameters and actuation requirements are converted into machine specific format, i.e. from geometric path information to motion commands and transmitted to the actual controller. The key issue is the efficient and intelligent utilisation of sensor information to enable adaptation to many individual product item variations.

The effective use of appropriate sensor information is the key to extending system capabilities including self-correcting actions. In our applications described below we use *static* data from the environment *prior* to the operation so that a plan of actions can be derived. Sensor information is processed prior to the robot operation. In fact, processing of carcass information and selecting the best cutting path have been proven as challenging tasks in itself.

In the following two key application examples in meat processing are described from a practical implementation point of view.

2 BEEF BELLY RIP

In a beef processing plant, belly ripping is the task of cutting through the hide (skin) of a beef carcass. This task is performed manually with a knife and can be very demanding if the carcasses are not keen.

2.1 Automation Challenges

The key automation challenge is the variation in the carcasses. Just as every human being is a different size and shape so are cattle.

Every beef carcass is different, with weights ranging from 200kg to over 1000kg. Carcasses may have long or short hair, have horns, be cows, bulls or steers and may come from a wide variety of breeds.

In addition to this natural variation there is also variation caused by environment. The carcass may be clean or dirty, have flaws in the hide (caused by old wounds) and the tasks performed prior to belly ripping (known as workup) may or may not have been performed correctly.

For the belly rip task to succeed it must cut the skin from the crotch to the neck along the centre line of the carcass, as shown in Figure 1. The carcass is inverted and supported by the back legs. The legs are cleared of the hide down to the navel (the workup). The belly rip cuts from the navel to the throat.

Figure 1. A beef carcass with the belly rip cut performed.

2.2 Solution

There are four parts to the beef belly rip solution, a hide cutting tool, a robotic manipulator, a sensor system and control software.

2.2.1 Hide Cutting Tool

The hide cutting tool must perform the same task as a normal knife and variation of this were considered as a first approach. However the use of a fixed blade created three problems, the blade pulled out of the hide, cutting forces were high and the blade required constant sharpening.

These problems were overcome by using a circular blade with a tangentially mounted spike. The spike ensures the cutter remains in the hide and the circular blade cuts the hide by a shearing action reducing the need for sharpening. This solution was trialed by hand using the tool shown in Figure 2. The Tool was pneumatically powered, and is an adaptation of a pneumatic grinder.

Figure 2. The hand held belly rip tool

The handheld tool proved successful, and was used as the basis of the robot mounted tool. An assembly drawing of the tool is shown in Figure 3. A servomotor, permitting the monitoring of motor loads, powered the robot-mounted tool.

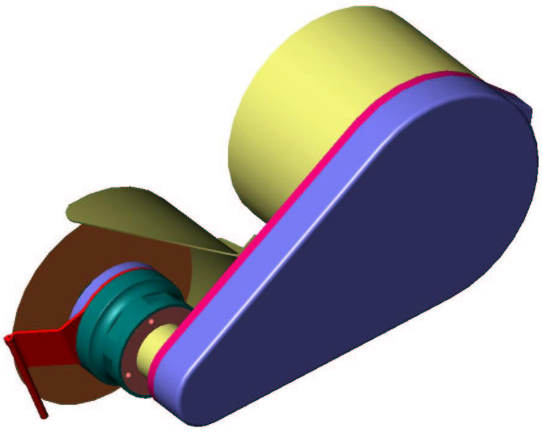

Figure 3. Robot mounted hide cutting tool.

2.2.2 Robotic Manipulator

Analysis of the task and size variation of the carcass determined the working envelope required by the robot. Because of the harsh environment faced inside a meat processing plant, the decision was made to use a custom made highly corrosion resistant robot.

The robot designed was a four-axis cylindrical type robot, with a working envelope approximately 1.6m x 1.6m x 2m. Motion Design Ltd. of New Zealand manufactured the robot, shown in Figure 4. The robot stands approximately 2m tall.

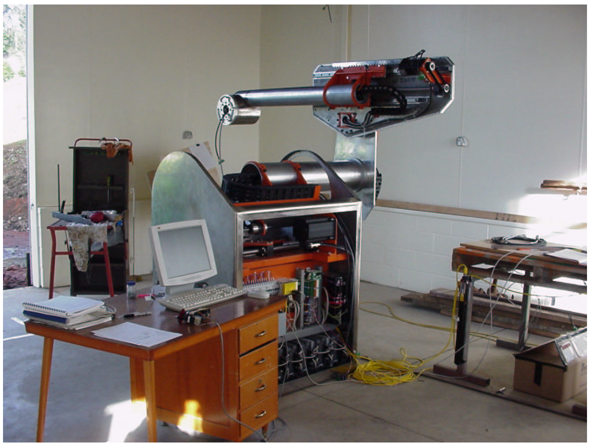

Figure 4: *The partially assembled beef-processing robot.*

2.2.3 Sensor System

The sensor system chosen for the belly rip process was a SICK laser time in flight system. This system creates a two dimensional profile of any object placed in front of it, by swinging an infrared laser in an arc and recording the time taken for reflection (and thus the distance to the reflective object). The raw data from the SICK sensor requires image processing to deliver smooth images and the system was tested by members of the team standing in front of it, as shown in Figure 5.

Figure 5. The side profile of Mr Andrew Osborn as captured by a SICK sensor.

2.2.4 Control Software

The complete system was controlled by a custom software package written in DELPHI running on a Windows operating system. Real time control was achieved by the same, windows based, software.

2.3 Results

The world's first beef belly rip robot, is shown in Figure 6. The fully automatic beef belly rip system is capable of cutting through the belly hide of a beef carcass, at 6 carcasses per minute.

Figure 6*: The beef belly rip robot in action.*

The system was installed at Excel Beef in Schuyler, Nebraska. Following a significant period of refinement they system was able to operate fully autonomously within the plant.

The automatic belly rip system consistently achieved greater than 99% success (cuts completed compared with viable carcasses presented. It has successfully cut hundreds of thousands of carcasses.

2.4 Future Work

IRL has negotiated the world wide rights to commercialise the belly rip system. Future systems will however use different robots.

Our success in the US also opened opportunities in Europe. IRL now has a partnership agreement with KUKA Robots of Germany to use their robots for sheep and beef processing. KUKA has developed special enclosures to protect their industrial robots when they are inside a meat processing plant. These were initially developed for pork processing and are shown in Figure 7, a 125kg payload robot suitable for use in wash down environments.

Figure 7. The KUKA KR-125 WD2,

3 BEEF BRISKET SAWING

Brisket sawing involves sawing through the sternum of beef carcasses and is the first task in the evisceration process. The carcass is suspended head down and the pelt has been removed. Once the diaphragm has been located the system cuts in a straight line from just under the diaphragm, down the sternum and exits at the neck.

3.1 Challenges

In addition to all the challenges described in section 1.1, the brisket sawing system has the additional challenge of deterring the exact location of the diaphragm. This is not viable.

3.2 Solutions

Industrial Research has developed two prototype brisket-sawing systems. The first works on stationary carcasses, the send can brisket saw while tracking a moving carcass. This is required for high speed processing.

3.2.1 Stationary Brisket Sawing

Together with MRC and Anztek, IRL designed, built, tested and successfully proved the world's first beef brisket-sawing robot [Templer, Nicolle at all, 2000].

In the first system, shown in Figure 8, the diaphragm position was determined using a tactile contour-following system and analytical software. In order to ensure a straight cut the carcass is clamped in place.

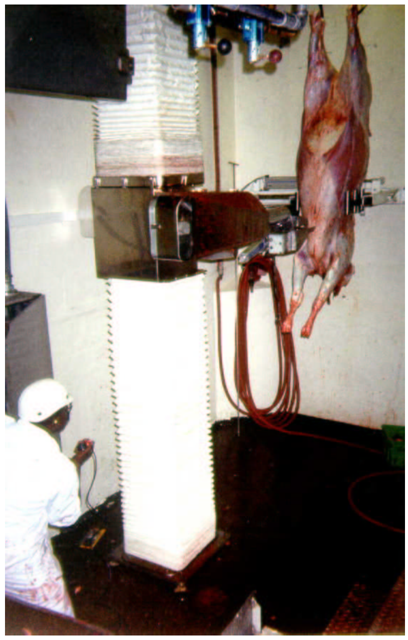

Figure 8: *The world's first fully automatic brisket saw in action.*

The low speed system was a successful proof of concept, sawing the briskets of five carcasses in an industry demonstration.

3.2.2 High Speed Brisket Sawing

The high-speed system uses an identical robot, sensing system and base software as the high-speed belly rip system.

The cutting tool, shown in Figure 9, has the same action as the cutting tools used by human workers. It is however larger and more powerful in order to ensure the robot can complete the cut in the available time.

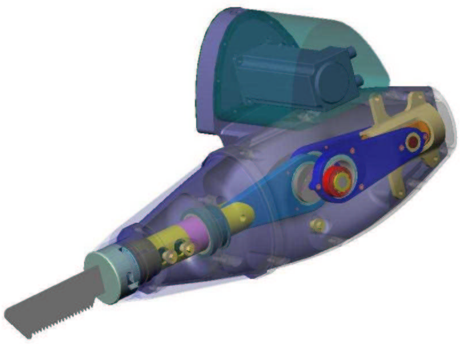

Figure 9: *A Solidworks model of the brisket-sawing tool.*

3.3 Results

The system has been trialed at an Excel Beef plant in Schuyler Nebraska, USA, shown in Figure 10. Note that both the robot and the clamping system must track with the chain and then return for each carcass. While the system was an effective demonstration as a proof of concept, it did not achieve the production success rate target (99%).

The plant in Schuyler had a large number of carcasses whose backs were broken during hide removal. This resulted in a twisted carcass. The system was unable to straighten the carcass and complete the cut in every instance. The system also struggled to meet the very low cycle time (9 seconds).

Figure 10. The high-speed fully automatic brisket saw.

3.4 Future Work

IRL have rights to commercialise the system and plan to do so using a KUKA robot. The additional degrees of freedom and power in a KUKA robot should allow the system to overcome the issues discussed in the results section.

4 Conclusions

The successful belly rip and brisket sawing projects have demonstrated that even the most demanding tasks can be automated. It requires an in depth understanding of the process, innovative robotic, mechanical and software engineering.

It also requires significant funding, hard work and dedication.

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