final report

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STAGE 2 BEEF SPLITTING SAW X-RAY SENSING AND CONTROL

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EXECUTIVE SUMMARY

This MLA project A.TEC.0058, Development of X-ray Sensing Technology developed a method of utilising an X-ray unit to as a tool for identifying deep tissue carcase features to control automatic devices. Of particular interest to Food Science Australia (FSA) and MLA was the application of identifying the centre-line of beef spines for splitting saw guidance.

It was determined in A.TEC.0058 that the X-ray unit used, the Philips BV-25 C-arm was not appropriate to sense production line quantities of beef cattle, particularly if they were from a larger weight range. Overheating occurred after relatively short periods of time. This type of specialised C-arm was also too heavy to control on the end of a robot arm, particularly in conjunction with a split-saw.

Research indicated that a built-up unit would be better suited to the task. It was decided that the best approach in the initial stages would be to construct our own light weight C-arm consisting of an X-ray source, a camera (imager) and a connecting frame for support and alignment. Once the efficacy of the X-ray was confirmed, the frame would be dispensed with and the two modules would be mounted on the inner and outer extremities of the robot-mounted split-saw.

The use of X-ray technology is subject to stringent regulatory control. As part of Milestone 1, the requirements of authorities such as the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and the Victorian Department of Human Services (DHSV) were addressed.

Discussion with ARPANSA indicated that approval for use of equipment at FSA's Cannon Hill site should be feasible after the issues covered by "Regulation 51" were addressed (but the timeframe for a decision cannot be guaranteed). ARPANSA do not have jurisdiction over commercial plants such as the abattoir suggested for full scale testing of the X-ray in Victoria. However, having ARPANSA approval for use at Cannon Hill would make DHSV approval more likely.

Strong commitment from the industry is required if the project is to advance to Milestones 2 and 3 and deliver a prototype operating in a plant in accordance with regulatory policies.

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1. INTRODUCTION

This research represents a continuation of the MLA project A.TEC.0058, “Development of X-ray Sensing Technology”. Basically, it was flagged during that project that the next stage in any extended development would be to introduce the X-ray technology to the meat industry as a tool for identifying deep tissue carcase features to control automatic devices.

A number of deficiencies with the apparatus were highlighted in A.TEC.0058 and these had to be overcome. The main concerns were that the C-arm was under-powered and over-weight. The power situation was manifested in the fact that the device overheated after a relatively small number of trials and also that the beam penetration whilst scanning the thick part of the spine, i.e. the thoracic region, did not illicit the level of contrast required by the control algorithm.

The weight issue meant that the C-arm could only be raised by the FSA robot with the aid of a supplementary counterbalance. This arrangement would not be ideal in an abattoir situation. Clearly, an unacceptably large robot would be required to manipulate unassisted a mass of the magnitude of the BV-25. A more cost effective solution is to design and create a task specific, light weight C-arm, complete with X-ray modules of our selection.

While X-ray technology has become increasingly common in industry, it is still subject to stringent regulatory control. Placing an X-ray source as proposed here, in an abattoir would be substantially different to most other applications. This would mean that a number of design and safety issues would have to be addressed. As part of Milestone 1, the requirements of authorities such as the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), Department of Human Services Victoria (DHSV) and other regulatory bodies were determined. Although ARPANSA only have control over Federal Government installations, having approval from them simplifies the process with regard to private industry.

This project was proposed to be completed in three stages as indicated below.

Milestone 1: (CSIRO and X-ray equipment supplier)

1. Develop conceptual and preliminary designs for an X-ray sensing system based on the findings of the Stage 1 beef splitting saw X-ray sensing and control project.
2. The equipment and installation designs will be submitted to regulatory bodies (e.g. ARPANSA and Victorian Dept. of Human Services) for preliminary approval.

GO / NO GO dependant on approvals being successful

Milestone 2: (CSIRO and X-ray equipment supplier)

1. Refine to detailed design of sensor

2. Purchase X-ray equipment and safety equipment
3. Development and manufacture of sensor arrangement
4. Undertake testing and further development at the CSIRO Cannon Hill facility.

Milestone 3: (CSIRO, Processing plant)

1. The x-ray sensor will be installed on the existing robotic processing plant splitting saw (saw removed).
2. Radiation shielding and OH&S requirements will be installed
3. Regulatory approval will be obtained
4. Trials carried out on sufficient carcasses to evaluate the suitability of the X-ray sensor to control an automated beef splitting saw.

2. DESIGN OF X-RAY SENSOR

Stage 1 of this project clearly showed that the existing X-ray equipment (i.e. Philips BV25 C-arm) was not appropriate for sensing all size carcases at a full scale production rate. The two main factors are the weight of the C-arm and the fact that the unit needed to be used in a high repetition fashion at power settings close to maximum. This resulted in the unit overheating after a small number of carcasses were scanned.

Concerning the weight issue, the trials at Cannon Hill with the C-arm could only be conducted with the addition of a supplementary counterbalance arrangement. The robot ear-marked for in-plant trials is larger; however a lighter X-ray device would be desirable, if not essential.

A limited amount of money, $40k, was allocated to this project for purchase of X-ray equipment, so cost is a major factor in the selection process. A number of potential suppliers were approached to determine what X-ray sources and cameras were available, both locally and from overseas.

Before any final plans could be made for a commercial set-up in Victoria, the new X-ray arrangement would require in-house trials at Cannon Hill. The set-up for these trials will not include the split saw. A support mechanism resembling a C-arm will need to be designed and constructed to enable the X-ray source and camera (imager) to traverse the backbone of beef carcases. The new “C-arm” will be mounted directly onto the end face-plate of the robot arm. The arrangement will be such that the “C-arm” is in a horizontal plane as it is guided down the carcase. The carcase would be hanging in a conventional manner on a beef rail, with the hind legs spread.

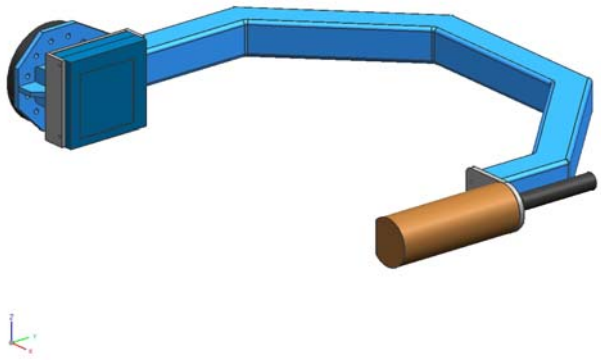

Figure 1, FSA designed C-arm with X-ray and Camera

There are logically two orientations available for the X-ray source and camera, with the source either facing away from or towards the robot. It was decided that the source will be at the outer extremity of the arrangement, facing inwards. The camera will be mounted next to the robot extremity face plate. This arrangement places the subject material (the spine) as close to the camera as possible. The resolution of the image will be better defined this way. Note that the routing of the X-ray cable to the source needs to be closely considered.

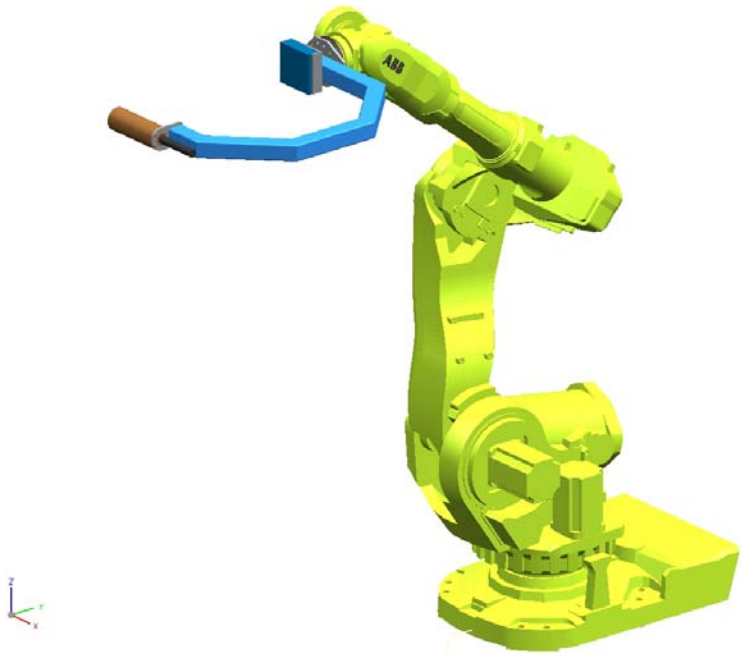

Figure 2, C-Arm mounted on robot

When in-plant trials are undertaken and an indication of efficacy of the arrangement, the two main items of the X-ray, the source and the camera, will be mounted at either end of the split-saw. They will also need to be on a horizontal plane lower than that of the saw blade. This way, the separate “C-arm” as used in the Cannon Hill trials, will not be appropriate.

The arrangement will require a brisket spreader mechanism to ensure that the source does not have to penetrate that part of the carcase before the rays reach the spine. This mechanism would probably be pneumatically powered and the brisket contact components would need to be sterilised between each carcase.

X-ray sources are available both as a complete unit and as a generator with a tube assembly attached by a high voltage cable. The latter has the obvious advantage that the relatively light-weight tube can be mounted on the frame or saw with the much heavier generator mounted separately. An important issue is the connecting cable. As high voltages are transmitted through this cable, it is generally recommended that any relative motion, i.e. bending and twisting, along its length be kept to a minimum. One option is to mount the generator onto a separate lifting device that has the same vertical travel component as the robot arm. The up-down motion of this secondary device would be controlled by

the same algorithm that governs the travel of the robot. The device would need to be robust enough to carry the 100+ kg of the unit.

Material selection for any components that have the potential to come in contact with the carcase needs to be considered. If any components are constructed of materials that do not meet food safety regulations, shrouding or encapsulation with a food grade materials such as plastic will need to be utilised. The X-ray source tube would be a critical item in this regard.

The two main types of camera that could be used are the tradition image sensors using CCD or CMOS technology or the newer Flat Panel Detector (FPD) imager. The present Philips BV25 uses a video camera tube. FPDs have an advantage in that they are considerably lighter than the other types of image sensors. Certain versions of both types were identified as possible candidates; however the cost of some devices would be prohibitive. During the selection phase, characteristics such as active area, frame rate and overall size need to be considered.

The selection of the camera must also be co-ordinated with the X-ray source as the camera rating must be such that it can handle the full power of the source. The X-ray unit deemed most suitable for this application are the Gulmay FL-160 Series unipolar generator and MXR-160 tube assembly. The tube weighs around 8 kg. The quoted price for this source was $AU39k. The choice of imager is the Varian PaxScan®1313. Weight is just under 2 kg. The quoted price was around $US38k, with a 6-8 week delivery.

3. REGULATORY APPROVAL

ARPANZA are the governing body for the use of radiation sources such as X-ray in Commonwealth Government property, and CSIRO/Food Science Australia comes under this scope. FSA currently has a number of ARPANSA approvals, including one to use the existing X-ray equipment at the Cannon Hill facility. Stage 1 of the Split Saw project indicated that Stage 2 would require the procurement of a higher powered radiation source to achieve the required quality of image. ARPANSA were approached and we were informed that an upgrade of our site ARPANSA approval must be obtained before any such device is purchased.

A critical part of obtaining approval under Regulation 51 is for a site survey to be undertaken. This was performed previously for the BV-25, but updated survey would be required for the new FSA set-up. The radiation scatter characteristics of the source and imager would be required as data for the survey as this has a bearing on the amount of attenuation that needs to be put in place

Jim Scott from ARPANSA is the person who organised the original approval for the FSA Split-saw X-ray. He re-iterated that an alteration to the existing

authorisation under Regulation 51 would be required if a higher powered source was required. We have since been instructed to deal with Helen Topfer from ARPANSA. Helen has dealings with others in FSA. The key points covered by Reg. 51 are as follows:

- Effective control
- Safety management
- Radiation protection
- Radioactive waste management (not required here)
- Ultimate disposal or transfer
- Security
- Emergency
- Undue risk
- Net benefit
- ALARA (as low as reasonably achievable)
- Capacity to comply.

As mentioned earlier, the ultimate goal of the project is to have a rig which includes a split saw and X-ray unit mounted on the end of a robot arm, such that the sawing process can occur automatically. It was envisaged that the final rig would be trialled in an abattoir in Victoria. As part of planning ahead for that stage, phone discussions were held with Neil Wain from the Department of Human Services, Victoria. He indicated that the over-arching issue is that because an X-ray source was involved, a Radiation Management plan would need to be developed for the site. Also, our research group, as users of X-ray equipment in a Victorian plant would require a Management Licence to conduct work involving the use of that radiation source.

Site staff at the plant where the equipment is eventually used, i.e. the Abattoir, will be required to apply for a site licence. This will involve a site survey, which is usually undertaken by an independent third party, to ensure that the radiation levels in the vicinity and for all persons liable to be subject to exposure, are within safe levels.

Factors to be taken into account before a site licence can be issued include:

- Specific shielding
- distance to persons (i.e. shielding through distance)
- measurement of possible scattered radiation
- possible time of exposure of persons in vicinity
- all persons likely to be in the area are to be considered.

Neil Wain explained that if FSA has approval from ASPANSA to use the X-ray equipment, then we would be seen as responsible managers of any such equipment. It appears that having that approval from ARPANSA would enable us to operate that equipment in the nominated Victorian plant, provided there is a site licence in place.

As part of the approval process, it would be likely that persons within the immediate area would be required to wear a radiation dosimeter such as a

thermo luminescent dosimeter (TLD). This would be a practical way of monitoring the exposure levels to any extraneous radiation caused by the X-ray.

4. SITE SELECTION

During the proposal stage of this project, it was envisaged that one of James Ralph's plants in Victoria would be used as the research site for the robot mounted X-ray unit. This was mainly based on the fact that the trials undertaken during Stage 1 of this project were performed at Ralph's Seymour plant.

Feedback indicates that the ABB6600 robot used in Stage 1 of this project is in storage in a container in Melbourne. The mechanical and electrical condition of the robot is unknown at this stage. To our knowledge, maintenance on the unit has not been undertaken since the time of its use at Seymour.

For reasons of regulation requirements and given the fact that there is already a robot (ABB4400) located in the FSA 'Boning room', it seems logical that initial trials of the X-ray (with no split saw) should be undertaken at Cannon Hill. As mentioned earlier, ARAPNSA regulations should not pose too many problems here and DHSV would not need to be conferred with at this stage. A site survey by, say, the person who originally examined the X-ray installation at Cannon Hill (Daniel Schick from Biomedical Technology Services) would highlight exactly what the requirements of final approval are. To simplify trials, it would be recommended to transfer the ABB4400 to the slaughter floor. This way, carcass handling will be greatly reduced.

For later trials involving the split saw, installation of the ABB6600 robot would not be a trivial matter. A dedicated robot base needs to be made specifically for the required location, and the control cabinet needs to be located in an appropriate place away from hose-downs. The base needs to be securely fastened to the floor, which also needs to be up to standard.

For plant trials, a favourable location for the set up would be on one leg of a parallel system where the beef carcases could be directed either through the usual split saw or through the robot controlled saw. However, the trials previously undertaken at Seymour with the Ultra-sound sensor were with the saw placed in line as a substitute for the original saw. This is the planned mode of operation for the new arrangement. The logistics of a split system would be much more complicated.

The site safety survey may indicate that substantial shielding would be required for the X-ray. It is feasible that a cabinet type arrangement may be necessary to ensure exposure to nearby persons does not exceed safe levels. This could entail a system of doors that virtually seals off the robot/X-ray when scanning/cutting is performed. The plant involved would almost certainly require a stop/start arrangement on the chain, such that the carcase is stationary during sawing.