final report

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Enhanced current hand tools using telerobotics

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Executive summary

This report documents the deliverables of Milestones 1 and 2 of PRTEC.041 Enhanced Current Hand Tools Using Telerobotics.

The specification for shackling requires that the orientation of the animal as it is presented to the telerobotic system must be consistent, with the head towards a defined direction and the leg to be captured on a repeated side. This is compatible with a knocking box cradle or a slat conveyor.

The initial specification for stunning is without head restraint in a controlled light environment. Dependant on technology and process development, head restraint or movement restriction may be applied at a later project stage.

Within the scope of milestones 1 and 2, real-time tracking technology providers with current telerobotic system sub-components or "component tools" are presented and potential collaborators identified. Areas of interest discussed and their general synopsis included:

- Human eye / face tracking providers — technology is application specific (i.e. for humans) and as such not directly applicable to cattle;
- Industrial machine vision suppliers — matches the "pattern" of known articles and is therefore not relevant to the unstructured environment of beef animal variation;
- Military and Medical — application specific;
- Academic institutions — applications specific; also project work is structured around postgraduate studies and is not relevant for commercial application as knowledge is developed through study not as currently available tools;
- CSIRO — application and technology specific.

No "off-the-shelf" technology provider option available was suitable to do the sensing required for this project. Three potential collaborators with relevant sub tools were however identified and evaluated. The CSIRO Mathematical and Information Sciences (CMIS) Biotech Imaging Group have been identified as the preferred collaborators with a broad suite of currently developed telerobotic component sub-tools including traditional object tracking methodologies, feature extraction, image segmentation and of particular interest in stereovision. CMIS has also worked on past projects in the beef slaughter environment, including stunning, in conjunction with Food Science Australia. Erentronix, a small commercial software consulting company with some experience in human face and feature tracking, may potentially also be utilised as a collaborator, as they have developed some specialised algorithms based on autonomous vehicle SLAM (Simultaneous Localisation and Mapbuilding) techniques. A third potential collaborator, the School of Biomedical Sciences at the University of Newcastle, is also evaluated based on research into tracking the behaviour of rats but are considered to have minimal transferable experience or existing developed component tools for the stunning and shackling applications.

Contents

INTRODUCTION

This report presents results and findings from two areas. One concentrates on what domestically available technology is available for real-time object tracking (or part thereof for example predictive movement algorithms), either commercially "off the shelf" or academically. The other area covers the development of a specification as to what a system would require to be implemented in an abattoir to perform the stunning and shackling processing tasks.

2 PROJECT AIM

This project is aimed at completing the intermediate step of real-time object tracking required to successfully implement Telerobotics in meat slaughter processing. The benefit of a telerobotic system for stunning and shackling process tasks is that it allows human operators to be relocated from a historically hazardous work environment while still utilising their skill in detecting the specific features required to complete these tasks via automation. There is also potential that as sensing technologies mature and become more advanced, target point feedback will no longer require human interaction.

The Objectives for Milestones 1 of this project are as follows:

1. Review current stunning and shackling tasks, reviewing the requirements for installation, and develop technical specification for operation.
2. Investigate current real-time tracking technology and options including visits to up to 5 alternate technology suppliers in Australia and their abilities.

Milestone 2 is the development of a report defining the scope of available telerobotic tools, their ability to be used in the stunning and shackling process tasks, and recommendations on how to progress this project.

At the submission of this report a "Go — No Go Point" has been reached requiring permission from MLA/ AMPC to proceed to successive project milestones concerned with the development/ customisation of real-time object segmentation, detection and tracking for shackling and stunning in the abattoir environment.

3 TASK REQUIREMENTS

This specification details the stunning and shackling requirements for real time object tracking to be applied, with some operator involvement, to the stunning and shackling tasks during the slaughter of cattle. While the primary objective of this project is to source and/or develop a real time object tracking system suitable for the stunning and shackling tasks, integration of such a system into processing plants has to be considered. To facilitate industry uptake of the technology, compatibility with existing stunning and shackling arrangements would be desirable. Stunning and carcass rollout arrangements and designs vary greatly between processing plants and it is unlikely that an object tracking system could be applied to all arrangements.

3.1 Stun

Most processing plants use captive bolt or percussive stunning during the slaughter of cattle. The animal is restrained either on a vee-restrainer or belly conveyor or standing in a knocking box and an operator applies the stun device to the head. A blank cartridge impacts either a penetrating or non-penetrating (mushroom head) captive bolt against the head causing insensibility. In some cases, the captive bolt is propelled by compressed air. This process requires the operator to accurately position and locate the stunner against the moving head of the animal. This can lead to inaccuracy and animal welfare issues. There are also OH&S issues for the person performing the stun operation.

Figure 3-1 Stun Task

For the purpose of this project, the object tracking system should be able to be applied to bovine stunning in both a conveyor restraint system, and a conventional side roll out knocking box. Animal welfare and religious requirements also have to be considered.

3.1.1 Conveyor Restraint

High throughput plants are likely to utilise a "belly" conveyor system such as the Temple Grandin system shown below (Figure 3-2). This arrangement transports the animal with its hooves off the floor resulting in a more predictable movement.

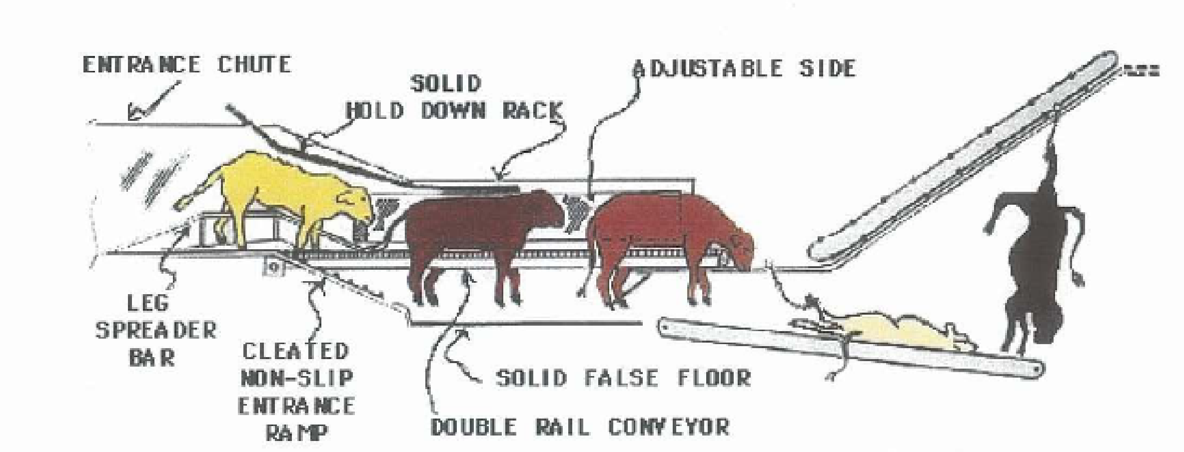


Figure 3-2 Conveyor Restrainer (Grandin, 2006)

Ideally, to minimise animal stress, no head restraint would be required. However, it is likely that some restraint may be necessary to keep the head in a reasonable working envelope. For example, the sides of the conveyor and a chin restraint may be used to loosely constrain the head position and orientation. FSA has already developed an automated stunning system utilising vision sensing and a neck bale arrangement for positive head capture.

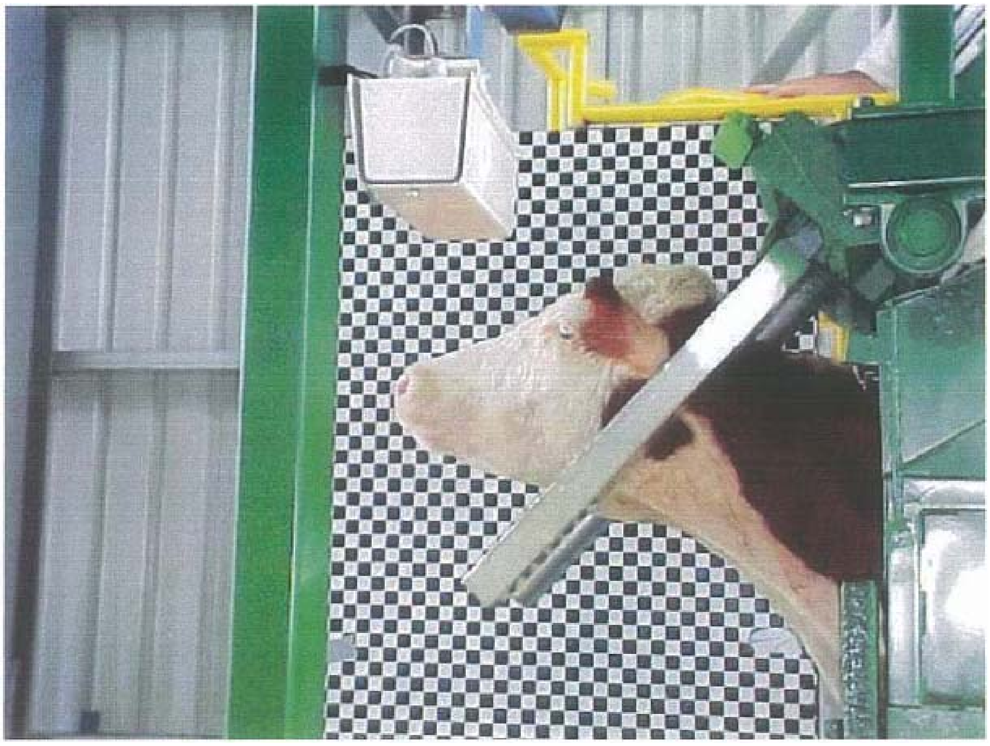


Figure 3-3 CSIRO Head Capture and Vision sensing

A head capture system potentially presents issues of animal welfare and stress. Suitable mechanical design and a minimal delay between head capture and stunning may address these issues, however the use of head capture should only be considered if head restraint is not practical.

3.1.2 Knocking Box

Conventional knocking boxes have the added issue that the animal is still standing on its own feet and able to move around more. This movement can be rapid and violet if the animal is frightened and isolated from its kind.

As with a conveyor based system, the head should ideally be tracked and stunning carried out without head restraint. If this is not practical, head restraint should be utilised. Neck restraint and chin lifting devices are already used in some knocking boxes (i.e. Jarvis) to assist in manual stunning and could be utilised to assist in tracking the head.

The FSA automated knocking box uses a pusher paddle to encourage the animal into position, and a drop away floor that leaves the animal suspended by a 2 rail cradle in a similar manner to a ''belly' conveyor system.

Figure 3-4 Support Rails and Drop-away Floor

Both of these features could potentially be used to reduce animal movement prior to stunning.

3.2 Shackle

Shackling is generally carried out in a cradle, dry landing area or on a slat conveyor. In some cases, it is carried out while the animal is still on the restraint conveyor. A short length of chain is looped around the leg and attached to a roller which is then hoisted up onto a rail. There are some variations to this but generally require a chain to be looped around the leg. This is a particularly dangerous operation as a stunned animal can still kick violently, resulting in injury to the operator. Injury can also occur if the chain is kicked off.

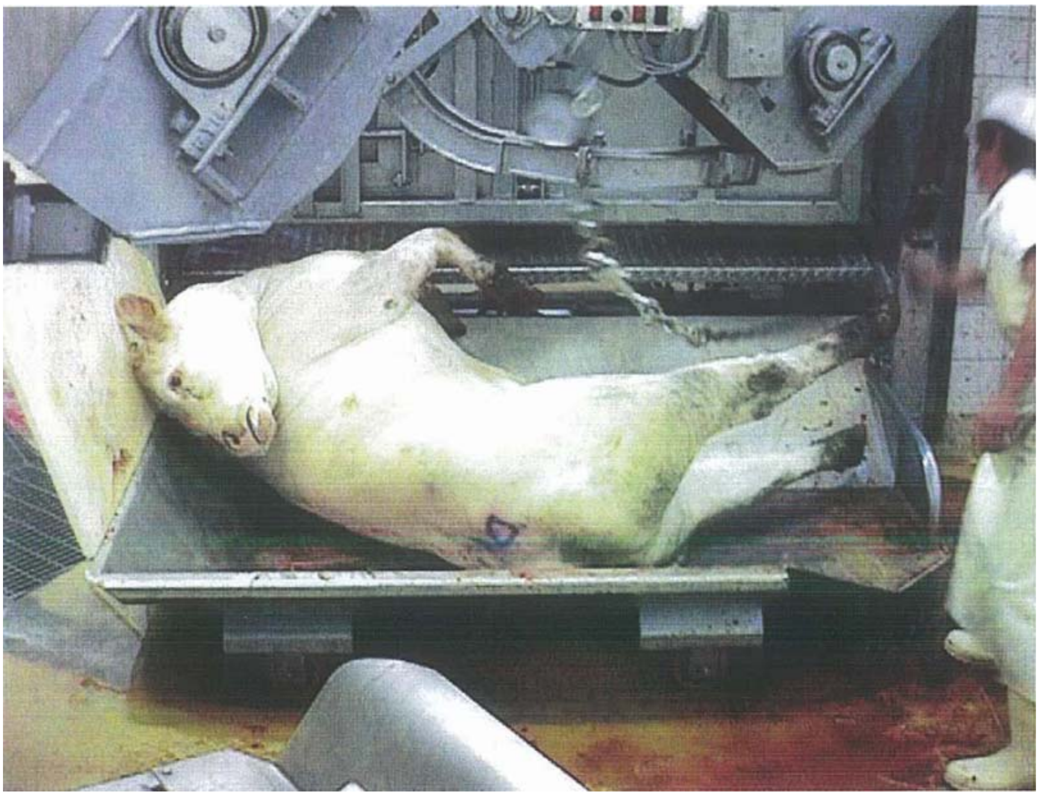


Figure 3-5 Shackling - Chain Attached

For the purposes of this project, object tracking for shackling requires a particular leg of the animal to be reliably tracked. To achieve this, the animal will have to be presented correctly orientated each time.

3.2.1 Slat Conveyor

For a slat conveyor arrangement, the animal will be presented on its side with the leg to be shackled uppermost. Electrical immobilisation may be required to separate the hind legs and to eliminate kicking,

3.2.2 Cradle

If the animal is discharged into a cradle or onto the dry landing area, it will be required to be correctly orientated and positioned within a reasonable area.

Figure 3-6 Rollout Cradle

4 TECHNOLOGY PROVIDERS

To achieve the telerobotic location of the stun and shackling positions on an animal the "real-time tracking" task can be broken down to several elements, which can be generic and hence developed for other purposes, but used in combination to solve the current applications. As such the stunning and shackling tasks need to be considered from the sum of some of these elements to ensure relevant technology providers are captured. For example, the solution could require:

- Locating features reliably then successfully detecting identified features in successive images. If feature detection can be carried out fast yet reliably in a single data image, subsequent tracking may not be required.
- Alternatively, as the head or leg moves, the minute change between frames of a desired texture that differs from its environment may aid detection of the required feature.

To successfully evaluate possible technology providers or collaborators for these tasks consideration must be given to elements such as image segmentation, predictive path algorithms, what prior knowledge of the application environment is required or even to collaborators willingness to work in this area. Staff from several academic based institutions with relevant research fields have expressed a reluctance to work on abattoir, particularly beef, process tasks due to moral concerns as they are vegetarian or on religious grounds as cattle are considered sacred animals. Although some of these institutions were still prepared to present the stunning and shackling applications to other members for discussion this issue has occurred in no less than four circumstances.

4.1 Commercial – “Off the Shelf”

4.1.1 Human Eye / Face Tracking

There are several commercially available software packages for tracking human eyes and faces for such applications as monitoring driver alertness, automated document scrolling or security verification. Unfortunately these technologies are not suitable for adaptation to stunning as the structure of the human eye is quite different from cattle. The human eye generates an effect called "bright pupil illumination" which occurs due to light reflecting back from the retina. It is also what is referred to as "red eye" in photos. Tracking systems often use infrared to enhance this. Unlike humans other species have a mirror like reflector behind the retina called a Tapetum Lucidum, which reflects light into the retina, increasing the amount or intensity of light available assisting animals like cats to see at night. This effect, although it may seem similar to the "red eye" effect, is based on interference rather then reflection and as such human targeted software is not cross compatible.

In addition to "bright pupil illumination" these systems are strongly based on the ability to train algorithms based on a series of representative data and to be able to apply "a priori" knowledge in the form of approximate constraints or relationships about features on a human face. These options are not available for the current project application.

Most tracking technology providers contacted about their human eye, gaze or face tracking software responded that their product or application was unsuitable for cattle or would require considerable redesign and customising. An example of this is the faceLAB™ software from Seeing Machines in Canberra, which is a spin off company developing academic IP generated in this area. When beef shackling and stunning applications were discussed with their principal research scientist Sebestian Rougeaux, he responded quite dearly that faceLAB is currently designed for the tracking of human faces and would be of little value for the proposed tasks.

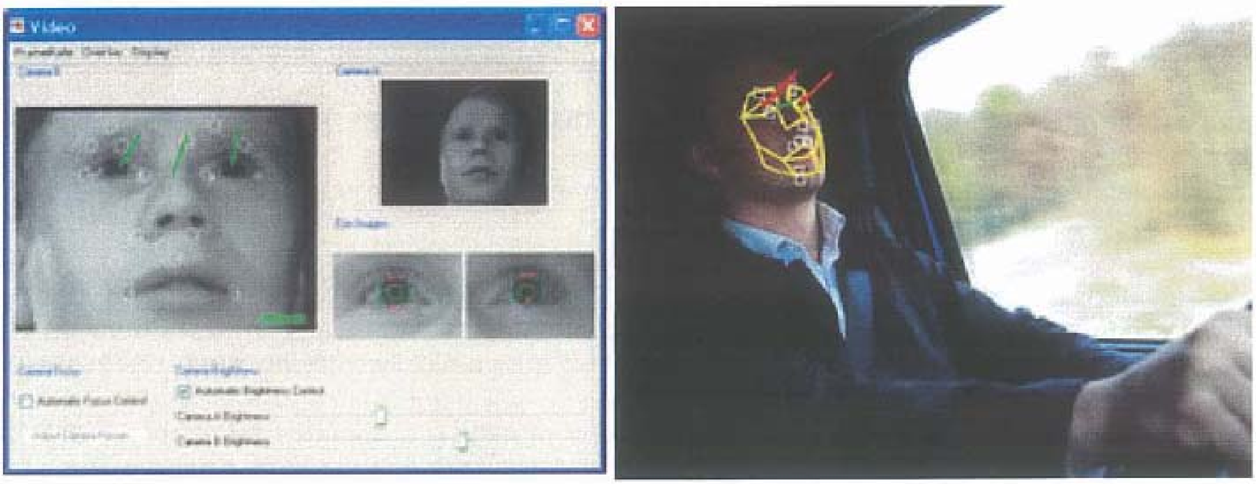


Figure **4-1** FaceLABTru v4.2 Promotional Results (Graphics courtesy of Seeing Machines, 2006)

There is potential that some of the elements used in eye and face tracking could be applicable as a component of telerobotic realtime tracking software and one company, Erentronix, is exploring this possibility. This contact is presented for further discussion and evaluation as a potential collaborator.

4.1.2 Industrial "Machine Vision" suppliers

Several companies supply application kit software for detecting specific objects and tracking its movement. Feature detection is usually strongly based around "pattern matching" and as such requires a representative set of 'training" images or a fixed property model — something which is not possible with the variety of animal conditions that can be expected in the Australian beef environment. These type of systems also usually require very restrictive control of lighting conditions to be successful with an example of a factory conveyor application where the light intensity changing during the day and between winter and summer being enough to cause false readings. Examples of these companies are Cognex, DVT and Omron.

4.2 Related Industries

4.2.1 Military

The military has developed several systems for tracking laser, satellites, etc and for targeting missiles at a moving object. These applications are not relevant for the abattoir environment however some of the tracking schemes may have relevance. Although due to the sensitivity of military projects a high level of technical information is not available for evaluation some assumptions can be made about the basis of tracking related software as given the scale of the detection environment small changes in an image (i.e. a tank location) could be correlated to a moving target.

4.2.2 Medical

Significant technological advancements are occurring in medicine including the development of systems that allow doctors to operate telerobotically on patients in locations remote from themselves. "Vision platforms" with intelligent actuation tracking guide surgical implements along path trajectories initiated by human operators, assisted by specialised haptic sensors to provide the surgeon with force feedback during an operation task like cutting. Although system configurations vary medical applications can utilise sensing mediums like NMR and MRI that provide high resolution images to aid in the manual set up and pre registration of the patient and operation to the imaging system — something that is not available to the shackle and stun applications. Along with these fixed registration points, remote or image guided surgery is based around moving a tool relative to a controlled environment. Additional verification from hospital staff other than the primary surgeon is also accessible.

Another medical application investigated, particularly in relation to the shackling task, was limb or gait analysis. It was found that these commercial systems rely on the detection of manually applied artificial markers to detect motion automatically, making them undesirable for this project as to apply these markers manually still places an operator in the danger zone. The systems also use predetermined motion models (e.g. human). An example of this type of software, as shown in Figure 4-2, is the Ariel Performance and Analysis System (APAS) which is used by the Australian Institute of Sport.

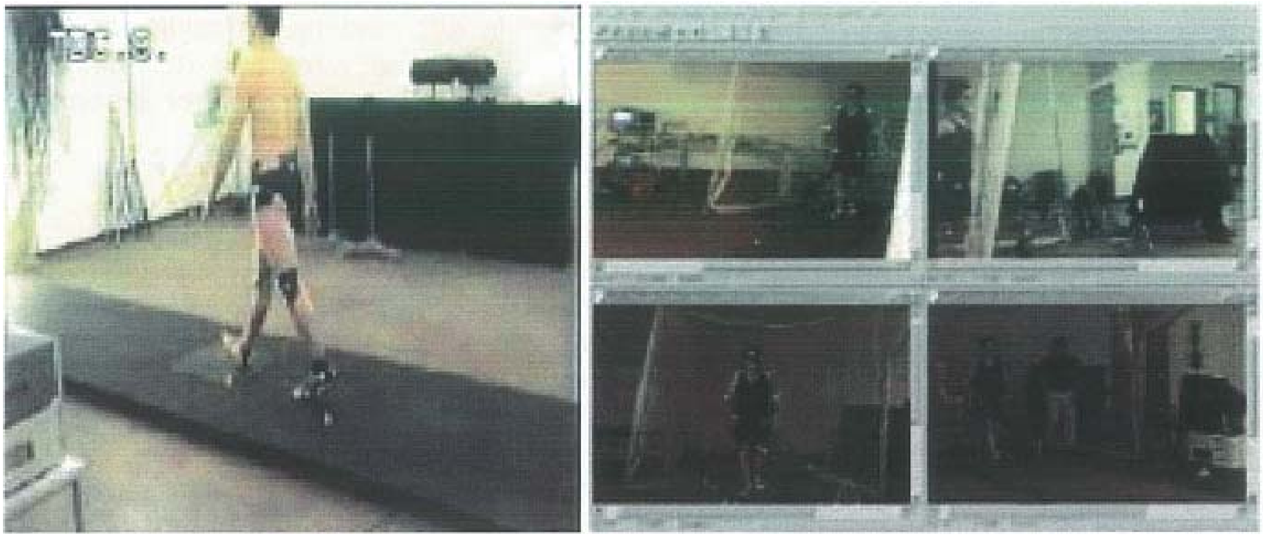


Figure 4-2 APAS Data Capture (APAS, 2006)

"Tracking" and gesture recognition algorithms are also being developed and used in systems to interpret sign language. At this stage systems are still in the academic arena and based around recognition and training over restrictive or discrete data sets or use aids like data-gloves (e.g. Cyberg love, Powerg love products) which have "flexsensors" and fibreoptic loops around joint features, LEDs and photo sensors built into them to collect additional data.

4.3 Science, Research and Academia

4.3.1 Academic

Several university collaborations exist which are in areas of interest to develop realtime tracking applications. Developed for projects loosely based around computer vision and autonomous motion these groups include National Information and Communications Technology Australia (NICTA) [Australian National University (ANU); University of New South Wales (UNSW)1; the Australian Research Centre for Perceptive and Intelligent Machines in Complex Environments (PIMCE) [Monash University; Curtin University; University of Melbourne; Australian National University]; and the Centre for Autonomous Systems (CAS) [Australian Centre for Field Robotics (ACFR) at The University of Sydney; Artificial Intelligence Group from the School of Computer Science and Engineering at The University of New South Wales and Mechatronics and Intelligent Systems Group from the Faculty of Engineering at UTS]. Other universities with groups of interest contacted were the University of Western Australia who have worked on a "sheep shearing robot", the University of Adelaide, RMIT machine learning group, the University of Queensland (eye tracking) and the Schools of Engineering Systems (Electrical) and Human Movement Studies at the Queensland University of Technology.

Project areas included:

- Localisation
- Mapping
- Object Detection
- People Recognition for Security and Counter Terrorism Applications
- Video Surveillance Analysis
- 3D Multiview Reconstruction
- Machine Learning and Training

The projects and technology areas discussed with the different universities were very application specific, and to be suitable for use in shackling and stunning would require a lot of "customisation", to the point of being new processes which is outside the scope of this milestone which is to evaluate collaborates on their current tool elements. Within a department or group an advanced group of tools could be available but may, for example, be restricted to only 2D, or involve several people's project experience, with no one group coming across as a cohesive vector to capture and utilise these skills or enough of the required tool elements to justify collaboration on this project. The universities are also not interested in short term project contracts with restrictive timeframes and generally suggested their collaboration in the tracking for either shackling or stunning was realistically under a masters or PHD topic which would mean a postgraduate student developing "on-the-job" although most expressed interest that this was a "good / interesting project".

The School of Biomedical Sciences at the University of Newcastle have been involved in developing tracking software for monitoring the turning behaviour (among other things) of white mice as a measure of mental condition or response to a specific stimulus. This group is now at the stage where they want to explore other applications for the system and algorithms they have developed. As such this contact is presented for further discussion and evaluation as a potential collaborator.

4.3.2 CSIRO

The following CSIRO groups were considered of interest as having tools that may be applicable to this project

- *CSIRO Information and Communication Technologies (ICT) Centre — Collaborative Virtual Environments (Networking Technologies)*

  While not relevant for online tracking this group has done work in augmented virtual reality and web based telerobotics. Projects have generally been based in the medical industry and have included the development of a "workbench" with specialised haptic sensors for surgical tutoring or interactive information display applications. This group could be of potential interest for the future development of the interface to get the data from the plant operator into the system as to the correct stun and shackle positions required by the "complete" telerobotic system.

- *CSIRO Information and Communication Technologies (ICT) Centre — Robotics (Autonomous Systems)*

  This group has project applications tracking artificial targets (barcodes) from moving vehicles (eg forklift trucks moving pots of molten metal), which is unfortunately not applicable for tracking stunning or shackling features as the option of manually applying a marker will only be considered as a last resort. This CSIRO group are using particle filters techniques (used in some cases to estimate predictions for unknown models) to perform the tracking and may be able to assist in a very limited technical capacity if this method is used.

- *CSIRO Manufacturing and Infrastructure Technology* (CMIT) — *Complex Systems Integration*

  Projects of interest include "Roadcrack" which is a real-time machine vision system that detects cracks in road surfaces and "Safe-T-Cam" which uses machine vision to detect vehicle registration plates. These applications work in a definable environment (ie possible road surface condition states and registration plate targets) which is not of relevance to the current project. The group has also developed specialised hardware for high-bandwidth real-time parallel computing, however this is less essential with the speeds and capabilities now available from improved commercial product developments.

- *CSIRO Mathematical and Information Sciences (CMIS) — Biotech Imaging*

  This group has a project portfolio that includes tracking of moving objects and image processing tools such as stereo vision, point registration and image segmentation. This contact is presented for further discussion and evaluation as a potential collaborator.

5 DISCUSSION

5.1 Evaluated Collaborators

It should be noted that collaborators are contributing and being evaluated on currently developed tracking and tracking component elements and as such any IP that is involved with this previous work or "Background Intellectual Property" remains the property of the supplier. As per the PRTEC.041 "Enhancing Current Hand Tools Using Telerobotics" contract any project intellectual property belongs to MLA.

5.1.1 School of Biomedical Sciences — University of Newcastle

The School of Biomedical Sciences uses the motion of albino rats to investigate their behaviour and responses to different stimulus as a model to understanding the brain. To monitor these responses Newcastle staff have developed some Labview (National Instruments) software tools.

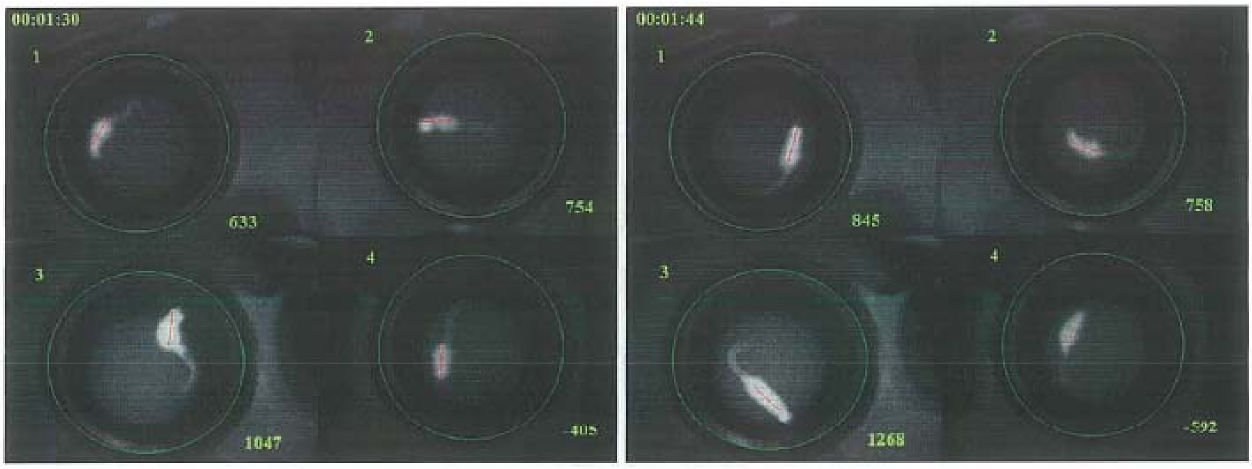


Figure 5-1 Newcastle Rat Tracking Results (Dielenberg, 2006)

With further investigation the following observations / evaluations about this potential collaborator have been made:

- Background investigating and enhancing the physiological characteristics of animals 4 Use of infrared to enhance the data capture of fur images; the physical structure of the eye
- Have developed an "adaptive background image subtraction" tool 4 not of potential interest as many variants to perform this operation are available
- 5 point rat tracking algorithm 4 not transferable
- "Region of interest" developed tool 4 still requires manually setting the template which is not useful for real-time tracking but may be applicable for getting information from the plant operator as to the correct stun and shackle positions if the current project progresses further.

The team at the University of Newcastle had a lot of concepts on how to "solve" the shackling and stunning tracking problems but unfortunately their experience is realistically restricted to this one application. Suggestions of using stereovision, structured lighting, 3D laser profile capture and Kalman predictive filters are in the right area but are unfortunately not current skills that this group can bring to the table. The current work that has been developed is too specific to the rat — laboratory environment to be transferable to beef. The recommendation is that this group is not suitable for collaboration.

5.1.2 CSIRO Mathematical and Information Sciences (CMIS) Biotech Imaging Group

The Biotech imaging group have developed tools and skills in automated object segmentation, feature extraction, statistical analysis of extracted features, stereo vision, image motion and tracking as well as work in spectroscopy and hyperspectral imaging. In the late 1990s this group worked with Food Science (FSA) on a stun application funded by an overseas customer. The complete project was aimed at a "best-in-class" slaughter floor front-end (see Figure 5-2) which included an "Autostun" module.

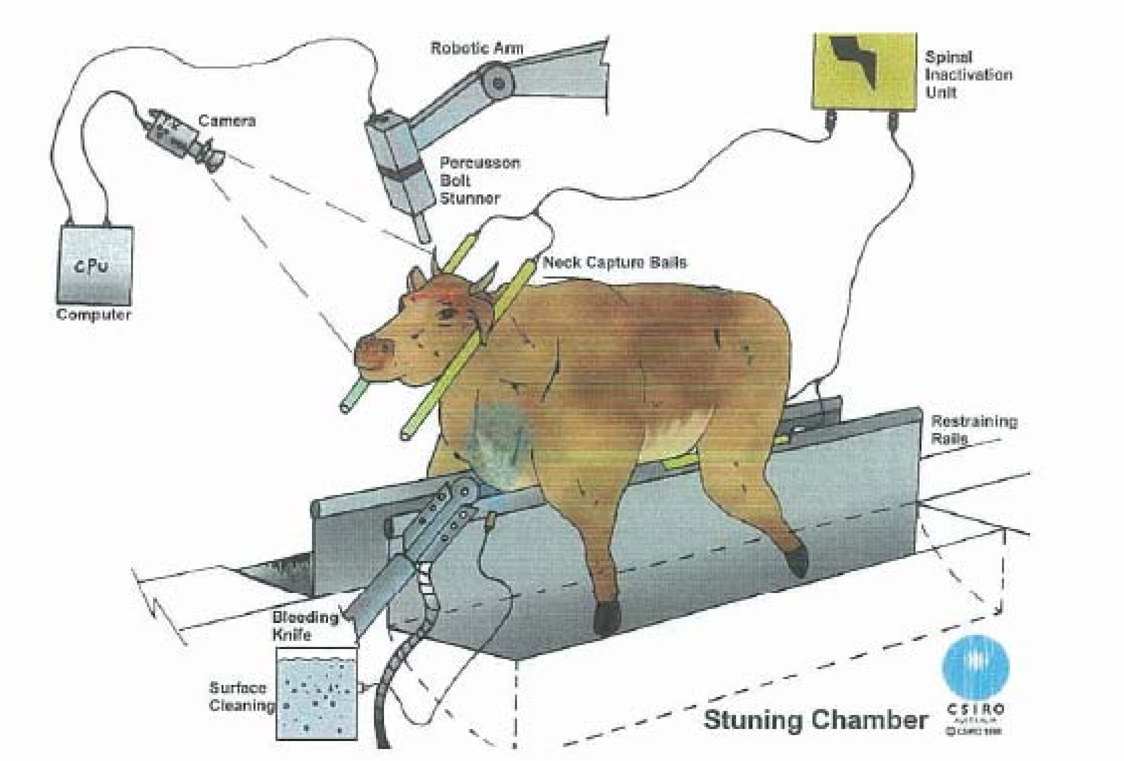
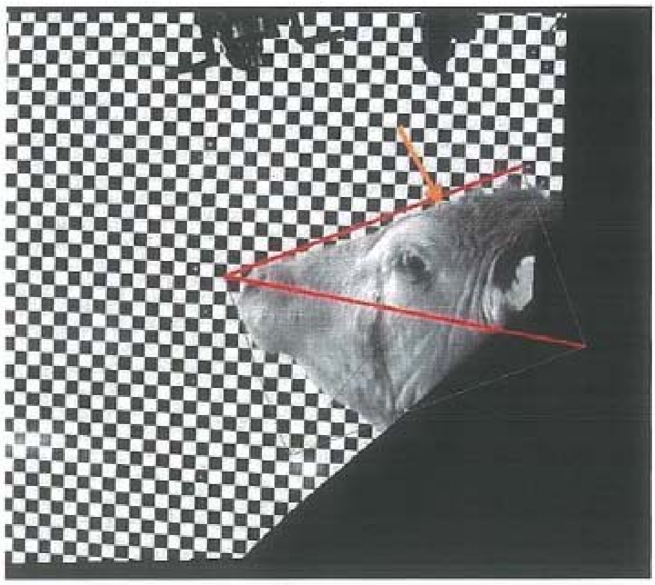


Figure 5 -2 1998: CSRO Stunning Chamber



5-3 CSIRO Autostun Analysis

The Autostun module had a different scope to the current project in that the animal's head was "captured" causing any movement to be restricted. This meant that the analysis could be carried out on a 2D image, and that some assumption as to placement of image masks could occur relative to the neck bales in the physical environment. A checker board was also implemented to improve discrimination of the head outline by disruption of the repeated square pattern (refer to Figure 5-3).

The basis of the current project is the premise that hardware and software technology has evolved so that these restrictions are no longer essential.

The Biotech Imaging group has also been involved with another FSA project involved with tracking the spine of a beef carcase from an ultrasound image in real time to control a carcase splitting band saw. Figure 5-4 shows an image processing artefact generated after the analysis has been completed, that is the compilation of the spine with each vertical line of the image representing a frame and the red "dot" (which forms. a line in the horizontal plane) representing the analysed spine position

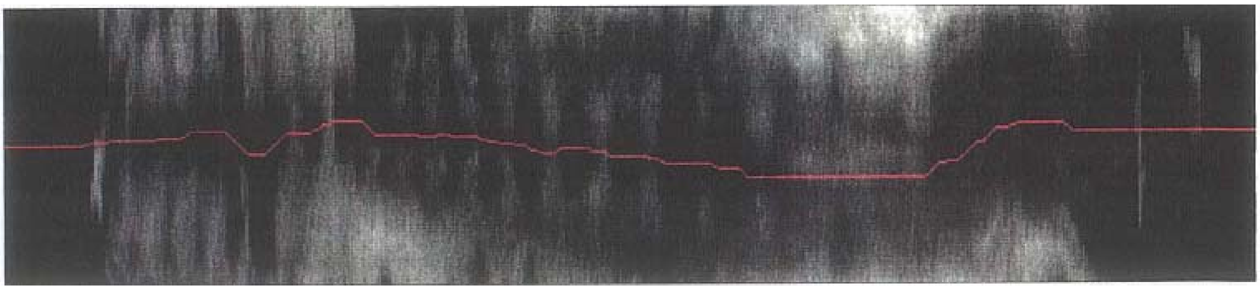


Figure 5-4 Spine Analysis Tracking Artefact

In addition to meat related projects the Biotech group has increasingly focused their work in the medical industry, with several staff members involved in projects tracking components in blood, segmenting melanomas in skin or detecting neurite branching in cell neurones (involves detection as well as reconstruction / prediction of path lines).

Of particular interest to the stunning and shackling project application is the work this group has done in stereo vision. Stereo vision is broadly described as taking 2D image data from a pair of cameras and using triangulation of the same point or feature in both images to derive three dimensional information. It is finding these corresponding points or feature projections, and the algorithms to relate them, known as "matching" then deriving a "distance map" that CMIS has developed their expertise in.

CMIS Biotech's group other skills of relevance to the current project include image segmentation (identifying a certain region of interest), object tracking, feature extraction and symmetry analysis.

Based on experience and the wide range of tools this group has currently developed the CMIS Biotech Imaging Group has potential as a collaboration partner.

5.1.3 Erentronix

Erentronix has done work in the area of face feature tracking. As mentioned earlier in this report face tracking generally uses "training data" to teach the system the features to detect within a loosely constrained approximation of how features are related to each other. Although Erentronix does use these principles in its system it has enhanced this basic model with additional tools (which shall be outlined) which are of interest as relevant to tracking for stunning and shackling. An example of the results from the Erentronix face feature tracking is shown in Figure 5-5.

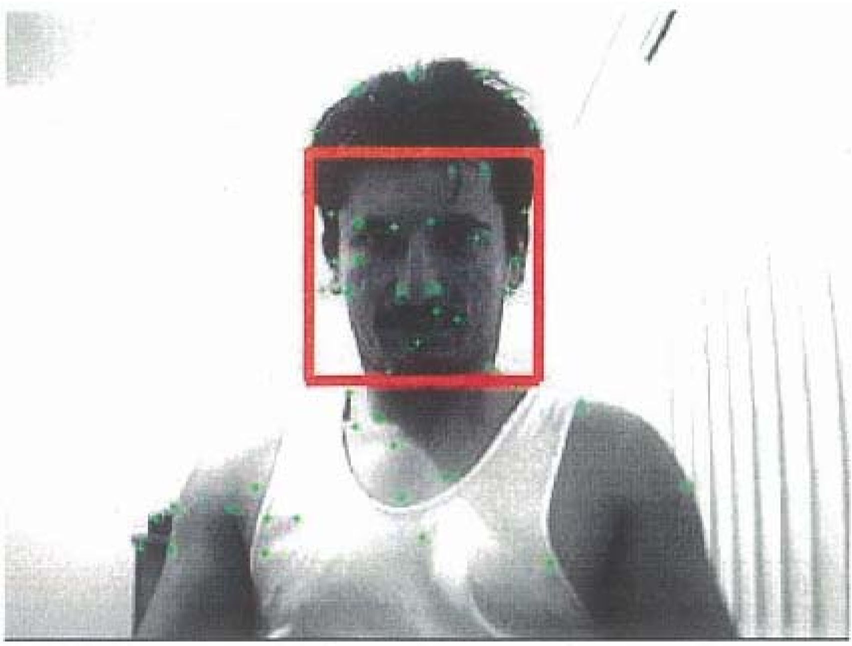


Figure 5-5 Erentronix Face Analysis (Eren, 2006)

Erentronix have developed tools based around:

- The SLAM (Simultaneous Mapbuilding And Localisation): Developed originally for systems involving autonomous vehicles it is based around a vehicle starting in an unknown location in an unknown environment and through relative observation between landmarks or "features" incrementally building a 'map" of the environment while simultaneous defining location. In the terms of the current project the "vehicle" is a stationary camera with the "landmarks" or features of interest for detection being points on an animals head or leg.

- Kalman filters: These can be considered in a basic form as a predictive filter that places a confidence rating as to where an object or feature is going to move based on its previous motion. Different techniques are available to influence this confidence rating.

As the above tools develop a lot of data for each scene (all possible states for every feature) Erentronix has developed tools to help restrict the analysis area. Erentronix also has conventional tools such as edge detection, motion flow analysis, background subtraction and object clustering. Although Erentronix has worked with 3D positional data on past projects, work in image analysis has only been carried out in 2D.

Erentronix has demonstrated component tools that are of interest to this project and is a potential collaboration partner.

5.2 Specification

While the primary aim of this project is to assess and develop object tracking systems, application of these systems in the abattoir environment has to be considered. While the stunning and shackling tasks are fundamentally similar between processors, the procedures, equipment and plant layout can differ greatly between sites.

A process specification or task requirements outlined following should, in general, only be considered as a guide otherwise it may unnecessarily restrict the development of a suitable object tracking system. This specification sets preferred targets and boundaries for the tracking system, but should be reviewed against development of final slaughter system operation.

5.2.1 Stun

It is envisioned that the object tracking system will allow a conventional type of percussive stunner to be mechanically delivered to the correct position on the head. Compatibility with both conveyor restraints and knocking boxes should also be an objective, but should not unreasonably restrict development of a system.

Restraint of the animal, in particular the head, can range from none, which is the ideal proposed in the cope of this project, to some head restraint, through to full head capture. The amount of restraint necessary will be determined by the development of the object tracking system. The use of no head restraint is the preferred option as it is likely to minimize stress on the animal. If this is not practical, restricting the amount of movement of the head may be necessary. It may be required to achieve this by restricting the space around the head (eg using neck bales) and/or devices such as chin lifters. Full head capture would only be used if the other options are not practical, or if issues such as animal welfare indicate that head capture is required. For example, head capture may be preferred to eliminate the possibility of a badly located stun due to animal movement.

Because of the animal welfare issue, the object tracking system needs to be highly reliable. Severely injuring an animal by applying the stunner to the wrong location is not acceptable and must be avoided. If systems such as conventional vision and/or laser system can not be developed to provide this reliability, alternative options such as applying reference markers would be required for consideration if practical.

5.2.2 Shackling

For the purposes of this project the object tracking system for shackling will locate, possibly with some operator input, the required hind leg of the animal, and track the movement of the leg. While ideally the system would be able to track a leg in any orientation or location, such as when a stunned animal is rolled out onto an open dry landing area, for this project the requirement is that there is restriction to position and orientation being the animal must be on its side with the shackling leg in a repeated orientation (ie the head is always in the same direction). Some plants already have this requirement as it is necessary for other processing tasks such as halal slaughter access on a slat conveyor.

In terms of application to the process environment roll out cradles and slat conveyors tend to provide suitable conditions

6 RECOMMENDATION

It is recommended that to complete this project CMIS Biotech Imaging group has the broadest range of currently developed "component tools" and experience to assist in developing realtime feature tracking in the abattoir environment as a collaborator. Erentronix has potential for use as a collaborator/ consultant for specialist tracking if necessary. No single collaborator has all the tools currently developed as required to successfully complete this project.

Broadly the final system can be seen as having two parts or modules that are interconnected — tracking and identification/ detection. Tracking involves capturing and processing the data in a form that can (a) give 3D positional coordinates; and (b) detect the object (head or leg) and its motion relative to its environment. Identification or detection relates to finding areas of "texture" or sufficient contrast on the moving object to be classified as a feature or point of interest and developing relationships or analysis as to how these features are related.

As with all sensing options simplest approaches will be investigated first and complexity added as required. This means for stunning the first pass would involve tracking analysis on a 2D image with the third dimension generated through laser distance measurement or mechanical extrapolation while the animals head is in "the field of view" or ideal stun orientation — similar to what occurs now in manual stunning. Although a 2D system is going to be investigated initially for stunning, it is probable that it will be insufficient to perform the analysis task as aids such as neck bales and chin lifts are not going to be utilised unless necessary, meaning the tracking and detection will be potentially required over a large movement window — graduating the system to stereovision or a 3D distance map. Similarly shackling will initially investigate a 21/2D system which involves using 2 cameras with planar views. The more data required to be able to track with confidence and minimise issues like occlusions means greater infrastructure (hardware and software) required to implement the system, including the complexities of processing large amounts of data.

To assist in obtaining the best initial data for detections the following techniques will also be investigated and potentially utilised:

- Thermal imaging / infrared cameras
- Structured lighting (including infrared)
- Possible use of water sprays and background temperature controls
- Background substitution

The hierarchy to achieve accurate stunning and shackling in real time is as follows:

- detection starting out in the ideal situation with the animal having free movement of the head and leg;
- followed by controlling the environment through the use of mechanisms to restrict the analysis window;
- to worst case - applying an easily identifiable artificial marker, to achieve a robust analysis result.

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