

live export

LIVE.106 Automatic Counting of Sheep

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1. INTRODUCTION

This is the final report of our research to study alternative technologies for automatically counting live sheep, particularly as they are loaded on and off ships, and to carry out preliminary development of the most promising concept. The technologies investigated included machine vision, radio frequency tags, and races capable of singulating sheep mechanically.

Australia presently exports about 5,000,000 live sheep each year, of which some 4,000,000 leave from the port of Fremantle. At present, all these sheep are manually counted several times, not only at the ports of embarkation and disembarkation but also at feeding lots where sheep are kept for a number of weeks prior to export. Counting at the ports is done by tally clerks.

For the technology to be appropriate to the Australian livestock export industry three criteria appear to be essential:

Accuracy. The industry's principal motivation for automation is not the labour costs of tally clerks, estimated to be about 5¢ per sheep per count, but the lack of 100% accuracy inherent in human counting of large numbers of animals that superficially look alike. Of particular concern to industry is the discrepancy between the number of sheep counted when they leave Australia and when they arrive at their overseas destination.

Exporters receive about \$A80 for each sheep counted at its overseas destination, and hence lose this amount for every sheep that is delivered overseas but is not counted by an overseas tally clerk. This loss is estimated to be about .3% of the sheep exported, suggesting that about 15,000 sheep are shipped each year that are not counted overseas. This amounts to an annual loss to the industry of about \$1,200,000.

For an automated counting system to be adopted by industry it must be at least as accurate as, and preferably more accurate than, the manual system it replaces. Therefore, machine vision systems installed overseas that count pedestrians at a claimed accuracy rate of 90% or 95% are unsuitable for this application, even if they could be adapted to count sheep instead of people.

(This adaptation would not be easy because the two situations are significantly different. One essential difference is that, when people enter a railway station or department store, their heads generally do not touch each other. Machine-vision systems designed to count pedestrians generally exploit this gap between heads to distinguish one person from another. At present, however, sheep are not singulated, i.e., separated on all sides by a gap, when they board or leave ships. Not only may adjacent sheep touch each other but one sheep may be partly on top of or under another sheep.)

We conclude that only technologies promising accuracy >99% are suitable for further development.

Cost. In contrast to cattle, horses and 'companion animals' such as dogs and cats, the value of a sheep is low. Technologies that can be utilised cost-effectively to count higher-value animals therefore may be unsuitable for counting sheep.

For example, a radio-frequency bolus swallowed by a sheep that broadcasts, when interrogated, a unique 'sheep identification number' appears to be an effective technology for counting sheep accurately. This technique, however, is unacceptable because of its price, currently about \$A3.20 per bolus. Even though electronic animal identification offers advantages beyond counting (e.g., farm management, identification of lost or stolen animals, ability to trace an animal's source when it arrives at an abattoir), the Australian export industry, which receives no government subsidy, clearly cannot justify an annual expenditure of \$16,000,000 to combat losses of \$1,200,000.

We conclude that only technologies promising a reasonable return on investment with respect to the current annual financial loss of \$1,200,000 are suitable for further development.

Speed. Because of the cost of chartering ships and the comparatively high cost of Australian labour, it is imperative that automated counting procedures not delay the loading or unloading of ships. We understand that sheep presently are loaded at rates as high as 9,000 sheep per hour = 150 sheep per minute at the port of Fremantle, although they are unloaded overseas at a much slower rate, typically 1,500 sheep per hour = 25 sheep per minute.

Therefore, if a single automated counting system cannot accommodate at least 9,000 sheep per hour, multiple systems that work in parallel will be required. Although a single machine vision system potentially can accommodate arrival rates much faster than 25 per minute, or even 25 per second, mechanical systems are inherently more limited in their capacity. *The total installation cost must offer an acceptable return on investment.*

The chart on pages 3–6 summarises the results of our investigation of alternative technologies for automatically counting live sheep. Each technology then is discussed in greater detail in the subsequent sections. Finally, we recommend how the mechanical system that we consider most likely to provide accurate and affordable sheep counting can be further developed, tested and trialled.

COMPARISON OF ALTERNATIVE TECHNOLOGIES

<i>Technology</i>	<i>Estimated Costs</i>	<i>Pros</i>	<i>Cons</i>
Mechanical Singulation (by a novel sheep race)	<i>R&D: \$50–\$100K Per Installation: \$30–\$50K Per Sheep: nil</i>	<ul style="list-style-type: none"> • Accuracy probably >99% • Australian technology 	<ul style="list-style-type: none"> • Moving mechanical parts may require frequent maintenance • Space is required to install system • Multiple systems required where sheep are to be counted at a port immediately prior to loading a ship
Machine Vision (from imagery acquired by an overhead camera)	<i>R&D: \$100–\$200K Per Installation: \$30K Per Sheep: nil</i>	<ul style="list-style-type: none"> • Unobtrusive installation possible on ships or at ports • No need to change existing sheep races or loading procedures • After development, a single system could accommodate sheep arrival rates in excess of 9,000 per hour 	<ul style="list-style-type: none"> • Accuracy and hence acceptability of system cannot be determined before R&D is done • In contrast to mechanical singulation, counting method not transparent to observers
Identification via RF bolus swallowed by sheep on farm; the bolus transmits a number assigned to that sheep	<i>R&D: nil Per Installation: \$10K Per Sheep: \$3.20</i>	<ul style="list-style-type: none"> • Accuracy probably >99% • Allows each individually numbered sheep to be traced to flock of origin; such 'traceback' increasingly being required by governments • Useful for farm management of sheep as well as for counting 	<ul style="list-style-type: none"> • Price unacceptably high without government subsidy, which is unlikely to be forthcoming in Australia

<i>Technology</i>	<i>Estimated Costs</i>	<i>Pros</i>	<i>Cons</i>
Identification via RF eartag	<p><i>R&D:</i> nil <i>Per Installation:</i> \$10K <i>Per Sheep:</i> \$3.20, but most tags presumably could be recovered and reused, thereby spreading the tag cost over several sheep</p>	<ul style="list-style-type: none"> • As above • At overseas destination, eartags could be manually removed and returned to Australia for reuse 	<ul style="list-style-type: none"> • Loss of eartags on ships ($\approx 1\%$) is too high for eartags to be the sole basis of automated counting. However, overseas labour engaged to remove eartags also could count sheep whose tags have fallen off on the journey • Time and space would have to be allowed overseas for eartag removal and for tallying sheep without tags • Although sheep with intact tags could be automatically counted upon arrival overseas, reliance would have to be placed on overseas labour to count the remaining sheep accurately
Machine vision of thermal imagery (acquired by an overhead infrared camera)	<p><i>R&D:</i> unknown <i>Per Installation:</i> \$40K? <i>Per Sheep:</i> nil</p>	<p>It is hypothesised that infrared imagery of sheep could be more easily segmented into portions corresponding to individual sheep than imagery from the visible spectrum, on the assumption that a thermal 'hot spot' could be found on a part of a sheep's back that generally neither touches nor is occluded by a neighbouring sheep. If this hypothesis were valid then such spots could be tracked and counted readily, and from their number one would know how many sheep had passed by</p>	<ul style="list-style-type: none"> • No infrared images of sheep appear to have been studied, so there are no data to confirm or refute this hypothesis • Thermal imagery of horses has shown that the 'hottest spots' are at the eyes and nose, and these parts of a sheep often will be absent from an overhead image • Fleece growth reduces thermal transmission from a sheep's body • Thermal systems used to locate enemy soldiers, illegal immigrants, etc. detect the presence of people but do not count the number of persons detected

2. MECHANICAL SINGULATION OF SHEEP

Developments in automatic sheep handling appear to be more advanced in Australia than elsewhere. As part of the R&D into robotic sheep shearing in the 1970s and 1980s, a number of different mechanisms were investigated to handle sheep and to present them one at a time for shearing. Following the demise of these automated shearing R&D efforts, one sheep-handling mechanism, the Simplified Loading and Manipulation Platform (SLAMP) originally built at the University of Western Australia, has been further developed by a private company, Slamp Limited, together with other technologies for automated mechanical handling of sheep.

Slamp Limited now have in operation a system that, with little human intervention, channels sheep from a pen onto a conveyor on which sheep travel one after another in a single file, at a speed of about 900 sheep per hour. This system, which we have seen working, is used on a Victorian farm to present sheep one at a time for (manually administered) drenching. The present conveyor speed matches the needs of that application.

In the shed where this system is operating, sheep are transferred from a pen onto the conveyor by passing them through a narrow race, urged on by sheepdogs. One-way mechanical slides are installed to stop a sheep from travelling backwards in the race, and stubborn sheep are urged forward towards the entrance of the conveyor by means of a novel manually operated 'sheep prompter' that, when activated, physically pushes a sheep forward in the race.

From our observations it appears that only one person is required to monitor the transfer of sheep onto the conveyor and to intervene occasionally in the transfer process, in particular by operating this animal 'prompter'.

The conveyor width and entrance have been set so that two sheep cannot fit side by side on the conveyor. A bar above the entrance stops one sheep from travelling on the back of the preceding sheep. The width and bar settings are manually adjustable, but have to be changed only when a batch of sheep is processed that differs substantially in size from the previous batch. (Sheep are exported in batches; in each batch, they come from the same variety and are approximately the same age and size.)

The conveyor itself is a standard 'VE' sheep conveyor. Its two conveyor belts securely hold sheep by their sides, preventing them from escaping or from moving forwards or backwards while travelling. Slamp's improvements include inclining this conveyor upwards so that, during travel, a sheep's legs are above the ground.

Although successive sheep may touch each other while travelling on the conveyor, at the end of the journey the forward sheep is discharged from the 'VE' conveyor while the following sheep remain held by the conveyor belts. The moment when a single sheep is ejected from the conveyor while the following sheep are still held provides an opportunity to count that ejected sheep, as it then has become singulated from the others. See *Figure 2* on page 19 below. For this method to work, previously ejected sheep must have moved away from the end of the conveyor at the time of counting.

We discuss this opportunity in greater detail below.

Slamp believe that the speed of this system can readily be increased to handle 1,500 sheep per hour = 25 sheep per minute safely. This belief must be confirmed by tests. If so, one such system would work at the speed at which sheep commonly are unloaded at overseas ports, but up to six systems would have to be used simultaneously to count sheep at the port of Fremantle to meet the peak loading rate.

Although it is premature to specify a final installed price at the present stage, we are confident that installation of six such systems can be accomplished for a price that offers an attractive return on investment with respect to current annual losses of \$1,200,000.

One exporter has suggested counting sheep at a feeding lot shortly before they are sent to the port, in place of counting at the port itself. In this case, it is possible that fewer mechanical systems would be required, because sheep could be counted at the feeding lot at a slower rate than they are loaded onto ships. Another exporter has questioned whether a count done prior to arrival at a port would be acceptable to overseas purchasers of live sheep. It should be recognised that different exporters have different particular requirements regarding the place and time where sheep are counted.

We have examined the patent and technical literature for other relevant mechanical concepts. Some systems have been devised to enable cows to proceed automatically one at a time into a milking parlour, presumably at a comparatively slow speed. A French patent describes a gate made from soft materials that opens when the head of a sheep is detected and prevents the following sheep, in a single lane of sheep, from proceeding until the first sheep has advanced. The aim of this invention is to sort sheep into batches. We have no information whether this system has ever been implemented and, if so, the speed of its operation and the reliability of its performance. The patent does not indicate how two sheep are prevented from travelling side by side on the in-feed race.

3. MACHINE VISION

Examination of publications and patent specifications indicates that the most advanced research to develop machine vision systems to track animals that are not fitted with transmitters has been carried out by the Silsoe Research Institute in England. A machine vision system on which they have worked for several years to monitor the growth and behaviour of pigs is currently being commercialised by Osborne Europe Limited, a division of an international firm that supplies technology to the pig industry. The Silsoe researchers currently also are carrying out R&D for the aquaculture industry to investigate the use of machine vision to determine the number and size of fish in a tank prior to harvesting.

The main goal of the pig project (which its leader, Dr John Marchant, has dubbed 'the eye in the sty') has been to provide 24-hour unmanned surveillance of a pigpen from an overhead camera, in order to alert the farmer if any pigs are fighting or are not eating properly. A subsidiary effort has been undertaken to determine whether a portion of a scene contains an image of a single pig or of more than one. The researchers have reported success in developing techniques that can separate the portions of an image of two touching pigs into the components that belong to each pig.

However, discussions with Dr Marchant by telephone and e-mail indicate that, in the system being commercialised, imagery is acquired of troughs, each of which has been physically constructed to accommodate just one pig. Although two pigs sometimes squeeze into the same trough, including one pig on top of another, this mechanical constraint apparently prevents more than two pigs from fitting into a feeding area at the same time. The machine vision task accordingly has been simplified to determining whether, at any one time, 0, 1 or 2 pigs are present at each trough.

Dr Marchant was visited about a year ago by the Danish Meat Research Institute (DMRI) in Roskilde, Denmark, who asked whether the Silsoe technology could be adapted to count unsingulated pigs as they are loaded on and off trucks. He told them that the technology could be adapted to count pigs, but doubted that the DMRI's requirement of >99% accuracy could be met without a simplifying constraint such as the narrow troughs.

He has not heard from the DMRI since their visit, and our inquiry to the DMRI about the status of their pig-counting investigation has not been answered. Presumably their efforts have not progressed, as they do not list any such research on their Web site, and the Pig R&D Corporation in Canberra, who liaise regularly with DMRI, have not heard of any such project.

Based upon the success of the Silsoe researchers in separating imagery of adjacent pigs, it is plausible that machine-vision software could be written to track unsingulated sheep as they are loaded on and off ships. An advantage of such a concept is that existing races and loading procedures could continue to be used; the only physical addition required would be an overhead box containing a camera, lighting and computer. This could be mounted at the doorway of a ship or in an overhead gantry on the port under which the sheep travel.

However, without actually developing the software, it is impossible to predict how accurate the software will be. After several months of effort a system might be created that could count sheep in an unconstrained environment with, say, 90% or 95% accuracy, but considerable further refinement and testing under a variety of lighting and environmental conditions would then be required to increase the accuracy. It is entirely possible that after spending, say, \$200,000 on R&D, a system might be developed that attains 98% accuracy. This would be an impressive achievement but still unsuitable for industry implementation.

Another U.K. group, at the University of Leeds, is currently investigating the use of machine vision to track poultry, and has also studied the use of machine vision to track cows. The Leeds researchers inform us that their technology now enables them to track accurately 95.4% of birds from successive images of a broiler-house scene. While this level of accuracy is clearly unsatisfactory for counting sheep, the researchers currently are striving to improve the performance of their system.

A video of live sheep loading at the port of Fremantle was supplied to the University of Leeds to enable them to assess the applicability of their software technology to identifying individual sheep in such scenes. (Although Dr Marchant was offered the opportunity to see this video, he declined, as he was confident that the requirement of >99% accuracy could not be achieved by a simple extension of the Silsoe Research Institute technologies.)

After viewing the video, the Leeds researchers expressed optimism that, after about a year of research to develop their current technology, 99% accuracy could be achieved. As this accuracy level still is below the 99.7% currently achieved by tally clerks it appears unlikely that the live export industry would consider such a system suitable for implementation.

Considerable research has been undertaken overseas to use machine vision to track moving objects, particularly people and vehicles. For instance, with support from the U.S. Government's Defense Advanced Research Projects Agency, the Robotics Institute of Carnegie Mellon University and the Sarnoff Corporation recently developed technology that tracks multiple moving objects in a scene. A commercial outcome of this is the 'video tracker' electronics board now marketed by Pyramid Vision Technologies, part of the Sarnoff group. This board (which fits in a PC) together with associated software reportedly tracks individual moving objects such as cars travelling on adjacent lanes of a highway.

Discussions with Sarnoff confirm that their current technology would not be capable of counting unsingulated sheep. Essential differences are that cars do not touch each other, unless they have collided, and are rigid bodies, so that the changing form of an image of a car as it travels down a highway can be reliably predicted. A sheep's body, by contrast, is said to be 'deformable'—it can change shape owing to breathing, to changes of posture, etc., in ways that are physically impossible for cars and are difficult to predict. Sarnoff engineers told us that they were unaware of any machine vision technology that can track multiple deformable objects reliably.

The Canadian company Point Grey Research presently manufactures a stereo system that counts and tracks people in a scene. A number of these systems have been installed in North America. As mentioned earlier, their system in fact tracks people's heads, which are comparatively rigid bodies and which generally are not touching the heads of neighbouring persons. Their system fails when two heads touch, e.g., when a mother picks up her baby, and for this and other reasons Point Grey claim an accuracy rate of only 90–95%. This rate apparently is adequate for their intended application of estimating the number of people who have entered a designated site, but is considerably below the requirements of the sheep exporting industry.

The video of sheep loading also was shown to and discussed with Ms Leane Bischof and Dr Richard Beare of the Image Analysis Group, CSIRO Mathematical and Information Sciences, North Ryde NSW, and with Dr Len Hamey of the Macquarie University Department of Computer Science. Although both organisations have experience in machine vision applications neither group has had prior experience in applying machine vision to tracking animals or people. Each of these groups commented on the difficulty of the task. They would be interested to undertake exploratory research in this area but are unable to estimate in advance what accuracy rate they would be likely to attain, and there is no reason *a priori* to expect that they would achieve accuracies of 99.7% or greater in the short term.

4. ANIMAL IDENTIFICATION SYSTEMS

Counting sheep would be trivially easy if each sheep were fitted with a device that uniquely identified it, and which could transmit the animal's identification number to a receiving station as the animal approached. Because of the advantages of individual animal identification for farm management, for tracing lost or stolen animals, and for tracing the origin of an animal when it finally arrives at an abattoir, governments round the world increasingly are requiring animal identification.

Canada, for instance, is planning to implement a national identification scheme for sheep on 1 January 2002. (The Canadian national identification scheme for cattle, in which each animal is identified with a barcode eartag, was implemented on 1 January 2001.) Many people in the Australian sheep industry believe that it is only a matter of time, perhaps five years, before all sheep in this country are individually identified by one or another method.

Indeed, all sheep exported from Western Australia, and therefore the vast majority of sheep exported from Australia, now wear eartags. However, these tags, which cost about 20¢ each, are unsuitable for automated counting for the following two reasons. (1) It has been the exporters' experience that about 1% of eartags fall off during the voyage from Australia overseas, so any counting system relying on the presence of eartags at the overseas destination would not meet the industry's accuracy requirement. (2) Simple eartags that identify an animal by means of printed numbers or a barcode cannot be automatically read. For a barcode reader to recognise the number of a tag, the barcode has to be within line-of-sight of the reader. But if a sheep turns its head away from the reader or hides its head behind another sheep, this condition will not be met. And if someone is required to hold a sheep so that its eartag is in a position to be scanned, that person may as well count the sheep directly, without bothering with the eartag.

Eartags containing electronics that broadcast the animal's identification number when interrogated avoid problem (2), but still suffer from problem (1). Moreover, radio-frequency (RF) eartags presently cost in excess of \$A 3 apiece, which makes them unaffordable unless they can be recycled and returned to Australia for use on subsequent sheep. A procedure involving overseas labour (a) to remove RF eartags after the sheep wearing them have been counted overseas and (b) to count manually the ≈1% of sheep that have arrived without a working RF eartag is conceivable, but we doubt that it would be the best solution to implement.

Problem (1) of eartags is avoided if, in place of an eartag, each sheep swallowed a RF bolus that transmits the animal's identification number when interrogated. Studies in Canada have established that lambs weighing 20 kg or more are capable of swallowing and retaining such boluses for at least four months. The boluses are ultimately removed from the sheep's rumen at an abattoir. However, this technique also is unaffordable for the counting application, as a RF bolus presently costs about \$A 3.20, even in large-quantity orders.

Researchers overseas are working on alternative RF animal identification technologies that may be available in the future at a lower price. However, we have found no indication that their research is likely to reduce the price from \$3 or more to 25¢ or less in the next few years.

5. THERMAL IMAGING AND OTHER CONCEPTS

We had envisaged that an infrared image of multiple touching sheep might be easier to separate into components corresponding to individual sheep than an image taken by a conventional camera in the visible portion of the spectrum, on the hypothesis that the backbone area of a sheep would be thermally distinguishable from its sides.

However, although there has been considerable thermal imaging of horses, cats and dogs for veterinary applications, we have not uncovered any prior studies involving infrared imagery of sheep. Accordingly, considerable infrared imagery of sheep would have to be collected and studied before this hypothesis could be investigated. It appears also that fleece growth is likely to attenuate infrared signals, and that the thermally 'hottest' part of a sheep is likely to be the area around its face, which would not always be captured in imagery acquired by an overhead camera.

Discussions with Raytheon and other US companies involved with thermal imaging indicate that the 'night vision' technology currently used to locate enemy soldiers or illegal immigrants does not presently extend to counting the number of persons so detected.

For these reasons we have rejected further consideration of this concept in the present study.

Although heartbeats can be detected remotely, we have found no evidence of any technology that is capable of counting the number of simultaneously beating hearts in a crowd.

Several other concepts that were suggested during the course of this study have been rejected as unsuitable.

It was suggested, for instance, that each sheep might be marked on its back by a large coloured line or disc made from food-quality dye. The mark could be applied without too much expenditure of labour just after the sheep are finally shorn prior to export, while they still are singulated. A machine vision system then would be programmed to recognise and count the presence of appropriately sized and shaped coloured marks, rather than to recognise and count the sheep themselves. This would be a considerably simpler task than recognising unsingulated sheep, because even when sheep are huddled together the marks usually would not touch each other.

If this idea were to be pursued, the issues to be investigated would include the effects of fleece growth during the overseas voyage on the visibility of these marks (could one mark then appear to the machine vision system as two?), and the possibility that a mark could be partly or completely obscured if one sheep is beneath another when it passes under the camera.

However, we understand that the live export industry considers that marking sheep in this way would be undesirable for commercial reasons, and the concept has not been pursued in this study.

It also was suggested to us that, in place of a comparatively expensive bolus, each sheep could be made to ingest a small metallic substance which, like the bolus, would lodge in the sheep's rumen. Then a metal detector could count sheep as they pass by.

The problems with this concept are that sheep would still have to be mechanically constrained to travel in a single file to ensure that two sheep were not detected as one, and that forcing sheep to ingest metallic substances for commercial purposes could be regarded as detrimental to their welfare.

Current weighing technology is insufficiently accurate to substitute for counting sheep, particularly as the mass of each individual sheep when it boards a ship will differ from its mass at disembarkation. As long as sheep continue to be sold by count rather than by weight, weighing does not appear to be a viable method for ensuring that a designated quantity of sheep has been shipped.

6. RECOMMENDATIONS

The research reported above has convinced us that, although machine vision conceivably could be developed, with considerable effort, to solve the automated sheep-counting problem, mechanical singulation technology appears to offer, in the short term, the promise of achieving an affordable, accurate solution to this problem. No other technology that we have examined offers this promise.

Accordingly, it is our recommendation that the system described in Section 2 be developed and extended, tested and then trialed. The recommended next steps involve:

- Increasing the speed of the 'VE' conveyor so that sheep can travel on and off it at a rate of at least 1500/hour instead of the current 900/hour. Slamp Limited believe that a 1500/hour speed can be achieved without difficulty, whereas considerably faster speeds might stress the sheep. The feasibility of the 1500/hour speed needs to be confirmed by trials.
- Construction of a novel 'counting ramp' onto which each sheep would slide immediately after it is ejected from the 'VE' conveyor. The top portion of the proposed ramp would be equipped with a pressure sensor (an inductive proximity switch) that would respond to the impact of a passing sheep by adding one to the number of sheep counted. Electronic controls would prevent the registration of false alarms if the sensor has been depressed for either too long or too short a time. The proposed counting ramp would be robust (it would have no moving parts) and it would be able to be washed down for cleaning. The ramp would be angled so that at most one sheep can activate the sensor at any one time. In particular, preceding sheep would be unable to climb back onto the counting area of the ramp.
- Testing the use of the faster conveyor together with the proposed ramp to count multiple sheep, and making appropriate system adjustments where necessary to improve system performance. The system design then would be optimised to determine, for instance, the shortest 'VE' conveyor that is feasible for this application. Other desired features of a useful system—for instance, how counts should be displayed or printed; whether each batch of sheep should be separately counted; whether a clock is desired to record the times when the system is in operation; etc.—then would have to be determined in consultation with the live export industry, so that these features can be incorporated into a subsequent prototype system for field testing.

Figure 1 on page 12 shows an outline of the proposed system. *Figure 2* on page 13 shows sheep leaving an existing 'VE' conveyor, one at a time.

Following the development and testing suggested above, which could be carried out most inexpensively by modifying an existing 'VE' conveyor on a sheep property, we recommend that a stand-alone system be built for rigorous testing at a port or a feedlot. This prototype system should be enclosed to permit operation in all weather conditions and at all hours of the day. Enclosure also will prevent sheep being distracted by seeing other sheep outside the counting area. Lighting is an important consideration, as we understand that sheep are encouraged to travel onto a 'VE' conveyor if they see a brightly illuminated space at the end of the conveyor, but are reluctant to proceed into dark places.

Sheep in infeed queue. Entry into conveyor ushered by 'sheep prompter'.

Sheep constrained by their sides while travelling on the conveyor.

Conveyor rises so that sheep's legs do not touch the ground.

Sheep ejected one at a time onto a pressure counter while the following sheep are held by the conveyor.

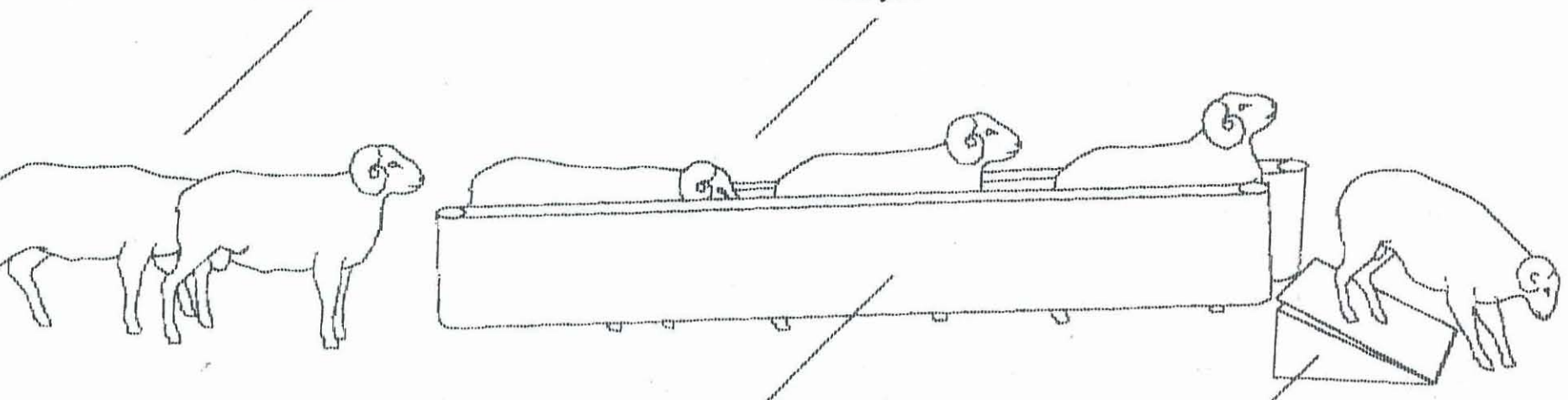


Figure 1. Proposed System for Counting Sheep.

limited property in Victoria. Sheep travel on this conveyor in a single file, held by their sides. While on this conveyor one sheep may touch the next but, at the time of leaving, the first sheep escapes while the following sheep are still held. It is proposed to count each sheep when it leaves this conveyor onto a proposed pressure-sensitive slide. The bottom photo shows a sheep being held just before it leaves the conveyor.



Figure 2. Sheep Leaving a 'VE' Conveyor, one at a time.