SENSING WELLBEING
Sustainable Farming Fund project # 408140
July 2015 - October 2018

Summary and Recommendations Report

31 October 2018

Project Objectives

A driving motivation for Sensing Well-being was to develop methods for early detection of animal welfare issues such as misadventure, injury or illness in extensive production systems. By taking a design-thinking approach, insights from throughout the sheep value chain were used to inform ongoing applied research work. Animal welfare and ethical production expectations from consumers were considered alongside farmer views.

The long-term aim was to enable growers to utilise the data generated from the sensors to pre-empt negative welfare outcomes through earlier, more targeted intervention. Sensor information also presents an opportunity to optimise production outcomes, which will be crucial for the successful adoption of this technology by farmers.

Achievements

- Sensor technology for measuring sheep behaviour and welfare outcomes has been successfully prototyped.
- Well-being indicators for sheep are confirmed.
- Methods for collecting and communicating animal health and welfare outcomes to consumers are developed.
- New Zealand sheep farmers are more aware of sensor technology and the potential to use it in extensive sheep production systems.
- New Zealand sheep farmers better understand the commercial potential of improving and communicating animal health and welfare outcomes to consumers.
- A foundation for ongoing collaboration and investment in sensor technology for monitoring animal health and welfare has been established by industry and government agencies.

Research Approach

Phase 1

We gathered information on consumers' preferences for purchasing products with improved animal welfare standards. This included a literature review of animal well-being indicators and a New Zealand consumer survey to provide information on purchasing behaviour. The information from this work has been incorporated into developing the strategy of measuring welfare indicators.

Survey results showed that, although New Zealand consumers supported the use of monitoring technologies, there was a strong expectation that farmers will also respond actively to the information. These animal welfare and ethical production expectations from consumers were considered alongside farmers' views. Insights from growers made it clear that on-animal monitoring tools would need to demonstrate improved production and on-farm efficiencies to gain buy-in from farmers.

Phase 2

Prototyped technologies included GPS, Bluetooth-enabled proximity, tri-axial accelerometers and LoRa wireless networking.

A series of pilot trials were completed over three years, generating a significant volume of data:

1. Two initial sheep observation trials involving tri-axial accelerometers were completed in 2015 to build a library of data signatures that could be linked to sheep behaviour patterns.

2. An investigation of the potential to use sensors to identify date of conception via mating behaviour was carried out in 2016.
3. In 2016 and 2017, further on-farm trials were conducted. These trials looked at ewe behaviour around the point of lambing and the potential to identify dystocia events, as well as date of birth of the lambs. The latter trial work utilised both tri-axial accelerometer movement monitoring and GNSS/GPS location tracking.

Phase 3

A key challenge was shifting from data logging to deployment of real-time sensors. In response to technology delivery delays, the research team redirected focus to comprehensive analysis of existing trial data and observation information in early 2018. This resulted in two additional project outcomes: the establishment of an accessible SQL trial database and prototyping of advanced analysis techniques (machine learning and deep neural networks) to develop predictive behaviour algorithms.

Findings

Overall, the work indicated that individual autonomous monitoring of sheep was possible and of value, although the technology is currently not available at a commercial scale.

- Consumers do place value on animal welfare practices and there is some willingness to source and pay additional for welfare certified products. This varied considerably among survey respondents which was correlated with their spending capacity.
- Consumers were generally poorly informed about the potential of real-time monitoring and were sceptical of its value in some circumstances. For value chains that implement real-time monitoring in the future, it will be important for them to communicate the direct welfare improvements they are achieving as a result of system deployment rather than communicating the deployment of the system itself.
- Sheep farmers were generally excited about the potential of this technology. Primarily this was because of the potential to reduce time required in monitoring and to improve the productivity and profitability of their enterprises. They could also see the likelihood of improved welfare outcomes for sheep.
- Positive animal welfare indicators (such as grazing and walking), as well as negative animal welfare indicators (such as non-movement, indicating a cast animal or death, or those related to lambing issues) were able to be identified.
- The project has provided a clear pathway to enable real-time monitoring of sheep to be possible. Off-the-shelf equipment was used throughout this project. For real-time monitoring to become a reality appropriate technology that is specific to the sheep context needs to be developed. It seems only a matter of time until this occurs.
- The project investigated both location-based and accelerometer-based monitoring of sheep. While a conclusive answer on the relative value of each was not established during this project it is likely that a combination of both techniques is likely to be more able to determine animal welfare than either system on its own.
- Lamb-to-dam matching via Bluetooth proximity macro analysis was successful. This work has been developed further outside of the project through neXtgen Agri and Australian researchers at Murdoch University. This method is now routinely applied in research contexts. Further improvements in technology will enable this to be deployed more routinely on a commercial scale.
- The project clearly demonstrated that machine learning analysis techniques are the appropriate methods to analyse the type and volume of data being generated by these sensor systems. All other methods trialled did not provide any potential for predicting behaviour in real-time. This is simply a result of the volume of data that is generated by these systems and the subtle differences that need to be detected to correlate with behaviour outcomes.
- The combination of sensor data, visual observations and machine learning analysis techniques proved to be a very effective way to move towards predictive algorithms that could be deployed at paddock scale. Future development using this approach is highly likely to yield very valuable systems for the New Zealand sheep industry.

Further research (beyond the scope of the *Sensing Well-being* project) is required to achieve real-time monitoring and decision-making tool development.

Benefit to the Industry

This project has enabled the New Zealand sheep sector to explore and prototype emerging sensor systems to monitor animal welfare within an extensive sheep farming context. Technology has advanced significantly, leading up to, and during this project. This has enabled us to consider, for the first time, a world where individual animal monitoring is possible in sheep production systems.

Through this project, we have explored a range of potential uses of this new capability and have clearly established that farmers see real value for their enterprises in what this technology will bring to extensive production. In addition, we have established that consumer facing brands can see a very real benefit of having a 24/7 animal monitoring system as part of their back story. In previous innovations, where there is an on-farm benefit, combined with an improvement in market acceptance, adoption by the primary sector has been swift and impactful. We expect this to be the case for on-animal sensors once a commercially viable system is released on to the market.

Applied research drew on leading Australasian academic and industry expertise. Collaborators included Massey University's International Sheep Research Centre (Palmerston North, New Zealand), Central Queensland University (Australia), neXtgen Agri Ltd (Christchurch, New Zealand), Callaghan Innovation (Wellington, New Zealand), La Trobe University (Australia), Murdoch University (Australia) and an active New Zealand farmer reference group.

The collaborations formed during this project have been many and varied and this has been a true strength of the project. These collaborations have enabled the team to extend the testing and research well beyond the level that would have been possible for this project alone.

The project has largely adopted a strategy of sharing information rather than trying to develop a unique approach. This strategy has allowed open sharing across a number of groups and ultimately resulted in good progress being made for this project. It has also provided a valuable opportunity to train both undergraduate and post-graduate student in research methods and data collection and management.

Additional Project Learnings

- In the rapidly-developing field of smart sensor technology, being able to pivot as new information or new equipment has become available has been essential.
- While the capabilities of the technology are not quite ready for the direct application within a commercial sheep farm, using the 'not-quite-ready' alternatives that are on the market has enabled us to develop significant understanding of the capability that will be required and the various use cases within a commercial setting. With the amount of activity in the market it is clear that systems that meet the price point requirements for a sheep enterprise can be developed in time.
- The proximity capability of the sensors used in the work carried out within this project and within collaborator projects proved to be highly effective at matching lambs to their dams. The project developed systems to semi-automate this process so that rapid establishment of dam pedigree could be completed. A range of testing was carried out around the necessary thresholds to have in place to allow an accurate match. Part of this work was completed with collaborators in Western Australia. We have now established that after 22 hours of having sensors on both the ewe and the lamb an accurate prediction of pedigree can be made.
- Commercial 'lamb-to-dam' matching systems that exploit proximity capability have become available to farmers during this project. The amount of labour required to get sensors on and off the sheep, as well as the cost of the units and data handling, remain as barriers to large-scale adoption of this component of the technology.
- Managing and analysing the large datasets that are generated with these new sensor systems is a fundamental project element. Classical data analysis techniques proved ineffective at developing algorithms that could be predictive of animal behaviour. Machine-learning analysis techniques are required.
- The application of machine-learning techniques to the accelerometer data was successful. The project provided the opportunity to explore a range of machine learning techniques and determine the best approach; the project successfully identified a model that could accurately predict the behaviour of an animal that had not been included in the analyses. The final models developed in this project were highly predictive and clearly demonstrate a pathway forward for this area of work.

- Machine learning has showed promise with predicting sheep behaviour from accelerometer data. Using both the raw acceleration data and derived metrics have had some success in being used to train machine learning classifiers. Some behaviours (standing, sitting), however, have proved resistant to classification. The fact that these behaviours were more accurately predicted when the model was tested on sheep used in the training may indicate that the dataset had too few sheep observed. The project has only used limited locational data, future work should consider testing the relative utility of location and accelerometer data.
- Through insights research and prototype trials, the Sensing Well-being team has also explored how positive welfare outcomes can be communicated to the end-market. The research has gathered valuable insights into consumer perceptions on animal welfare, purchasing behaviour and trusted sources of information. Considering the most trusted source of information was found to be farmers, non-government organisations and third-party auditing systems, it is essential for growers to establish a transparent supply chain. It was particularly significant that grazing, ruminating and walking were able to be successfully identified during advanced analysis. These aligned with positive indicators that the animals were eating and moving.
- Insights from famers demonstrated that they believe they would benefit from data that aids in decision making, improves animal well-being and subsequently, animal production. This emphasises the need to develop a real-time system to monitor animal health and well-being.
- The three guiding principles for this project and any recommendations flowing from it are that any work should improve the desirability, feasibility or viability of a sensor-based approach to monitoring animal well-being. The desirability of the opportunity that sensors provide has clearly been confirmed with discussions and workshops with farmers throughout this project. A key component of the desirability component is the ability to accurately assess outcomes from sensor outputs. The work done during this project has given great confidence that, with the appropriate amount and types of data, this will be achieved. Similarly, the work done in the final stages of this project has made a major contribution to the feasibility and viability of a sensor-based approach. With a functional machine-learning algorithm, the work described here has made a major contribution towards a sensor-based approach to monitoring animal welfare. The key gap remaining is for a real-time system to be developed and/or deployed.

Where to from here?

1. Base behaviour data

   Developing a data set with an additional 40 animals with (1) accelerometer data, as well as (2) location data matched with their behaviour recorded in 10 second intervals for 2 hours at random times of the day, would allow considerably more robust machine learning models to be developed and allow real-time capability.

   It is recommended that attention be given to when sheep are transitioning from sitting to standing and standing to sitting. This transition data may be able to be used to help the model differentiate between the standing and sitting state by knowing when it changes.

   In addition, it will be important to have the accelerometer placed on the ear (i.e. more likely where it would be placed in a commercially deployed system).

2. Labelling of video already captured

   The project has captured a significant volume of video that has not yet been labelled with observations. Adding observations for more sheep may improve the accuracy of the classifiers.

   Additionally, experiments with different numbers of sheep in the training set may make it possible to predict the optimum number observations and sheep to use for training the machine-learning classifier with tri-axial acceleration data.

3. Abnormal behaviour data

   Abnormal behaviours are classified as those things that would ideally be alerted in a real-time system. These include yearly events like oestrus, mating and lambing. These also include times when well-being of a sheep is at risk including: difficult births, internal parasites, lameness, becoming cast and flystrike.

The data set had a small number of these observations recorded. However, there are videos that have been collected by this project and by collaborators that could be labelled and the data used to test the predictability of these events using the DNN's developed in this work. Further collection of abnormal behaviours, where there is a combination of accelerometer data as well as accurately time stamped physical data, is encouraged.

4. Further machine learning development

   If the above datasets were collected, there would be a need for further development of the machine-learning algorithms that have been developed under this project. The learnings from this project could be directly applied making rapid progress. The further development of these models would allow additional analysis of the data already collected in the project. Once a predictive model for normal behaviour is established, this can be used to predict abnormal outcomes.

5. Machine learning on both location and accelerometer data and a combination

   The work to date has focussed on accelerometer data only. However, there are data sets that have both accelerometer and location data. Considering that both accelerometers and location devices (GPS) use available power, it is likely that a low-cost system deployed in a commercial environment would have only one of these capabilities. It is therefore of interest to determine which of these data types provide the most useful information.

6. Collaborations with companies with a minimum viable product (MVP) version of real time systems

   Forming collaborations with companies that are either developing or have developed real-time systems would be worthwhile. For the work completed in this project and the further work recommended will only be able to be utilised by industry once embedded within a commercial system that is being developed for commercial producers. Unfortunately, over the period of this project, an extensive sheep monitoring tool has not been available on the market.

NZM will continue to explore extension opportunities through its Wool Unleashed (W3) Social license to Operate work stream. Planned research towards the "Technology for Monitoring and Improving Sheep Welfare and Performance" subproject include continued collaboration with CQU. In response to data analysis recommendations, W3's recently completed 2018 parturition trial used axivity, ActiGraph and GPS devices. This will enable crossover between neXtgen Agri's advanced analysis methods based on earlier trial work and CQU approaches.

The SheepWellbeing SQL database, which is hosted by NZM and managed by neXtgen Agri, remains an asset of the project. It is NZM's intention to share access to stored data for further analysis as an 'industry good' action. This should help continue building capability and interest in this space, especially toward predictive modelling, real-time sensor development and app design specific to sheep welfare and production.