Institution: University of Strathclyde

Unit of Assessment: 13

Title of case study: Electronic monitoring of dairy herds increases efficiency and reduces costs for UK and EU farmers

1. Summary of the impact (indicative maximum 100 words)

Research undertaken at Strathclyde during 2006-2009 produced a decision support platform combining artificial intelligence with low power wireless sensor technology, which was capable of alerting farm staff to animal conditions requiring human intervention. ETS Ltd, a privately owned University Spin-out company was founded in 2009 to develop and market the new technology, and now employs 7 full time staff. Since 2010 more than 250 farms in the UK and Europe have adopted the technology, enabling them to reduce operating costs, maximise milk revenue, with an estimated increase of £10k per 100 cows per annum. The new technology has also improved the performance of other existing businesses and has helped retain jobs in the supply chain in Scotland.

2. Underpinning research (indicative maximum 500 words)

Context:

Precision Livestock Farming (PLF) is core to satisfying the increasing world-wide demand for sustainable food products of good quality and the increasing societal concerns over animal welfare and health. Animal husbandry involves monitoring animal health, wellbeing and productivity and then responding in an appropriate way to optimise all three. This management is still largely executed by humans using skills that have not changed significantly in many years, but this approach is increasingly difficult to sustain as farms increase in size. To operate more cost-efficiently, farmers are looking to technology to deliver results. Wireless Sensor Networks (WSNs) are a key enabling technology in this regard. PLF requires that key information relating to the welfare condition of livestock is communicated to a decision support platform that assists farmers in the execution of their daily operation. The decision support platform relies not only on obtaining valuable data, but also on effective tools and algorithms to process and represent this data meaningfully. Research carried out within the ITI Techmedia Condition Based Monitoring programme (2006-2009) focussed directly on each of these areas.

Key Findings:

Core animal science provided by the Scottish Agricultural College (Prof M Mitchell, Dr J Hyslop and Dr D Ross) and The Royal (Dick) School of Veterinary Studies (Dr A MacRae) highlighted behaviour changes that relate to welfare conditions, e.g. restlessness associated with oestrus. Strathclyde researchers identified that standard statistical analysis would be inadequate in this context and used machine learning and artificial intelligence strategies to identify and quantify the behavioural patterns from collar based accelerometer readings [References 3,4,5]. These have subsequently been demonstrated to detect parameters such as oestrus in dairy cattle with an accuracy of around 95% when tested against hormonal analysis [Reference 6].

A detailed experimental investigation of animal (cow) behaviour on farm and antenna locations [Reference 1] determined an optimum strategy for implementing a communications protocol to backhaul animal welfare data from collar to a user interface - a farm PC [Reference 2]. This work laid the basis for the implementation of a robust protocol that allows a cow to be monitored continuously for a period of 7 years using two AA batteries.

The research defined the boundaries of what would be required to transmit back to the central user interface in order to communicate with farm operatives in a meaningful manner, thus defining the bandwidth constraints of the communications network [References 3, 4]. In addition, the research defined the degree of data compression that would be tolerable and yet still allow new algorithms to be developed from pre-processed data. By executing the bulk of the processing intelligence on the collar itself, the data download requirement was reduced by 99.8%.

Key Researchers at Strathclyde: Dr C. Michie (Senior Lecturer, Faculty of Engineering 2006-present), Prof I. Andonovic (Professor Faculty of Engineering 2006-present).

3. References to the research (indicative maximum of six references)
References 1, 3 and 5 indicate the quality of the underlying research.

1. K Sasloglou, I. A. Glover, H. G. Goh, K. H. Kwong, M. P. Gilroy, C. Tachtatzis, C. Michie, I. Andonovic, 'Antenna and Base-Station Diversity for WSN Livestock Monitoring' Wireless Sensor Network, vol.1, no.5 pp 383-396, Dec 2009, DOI: 10.4236/wsn.2009.15047

2. B. Stephen, C. Dwyer, J. Hyslop, M. Bell, D. Ross, K. H. Kwong, C. Michie, I. Andonovic, 'Statistical Interaction Modelling of Bovine Herd Behaviours', IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews, Issue 99, pp 1-10, October 2010, DOI: 10.1109/TSMCC.2010.2073464

3. K Kwong, T Wu, H. Goh, K Sasloglou, B. Stephen, I. Glover, C Shen, W Du, C. Michie, I. Andonovic, "Implementation of Herd Management Systems with Wireless Sensor Networks", IET Wireless Sensor Systems, Vol. 1, Is. 2, pp 55-65, March 2011
DOI: 10.1049/iet-wss.2010.0057

4. K.H. Kwong, T. Wu, G.H. Goh, K. Sasloglou, B. Stephen, I. Glover, C. Shen, W. Du, C. Michie, I. Andonovic, "Practical Considerations for Wireless Sensor Networks in Cattle Monitoring Applications', Computers and Electronics in Agriculture, Vol. 81, pp 33-44, 12 pages, Feb 2012
DOI: 10.1016/j.compag.2011.10.013

5. I Andonovic, K Kwong, M Gilroy, C Michie 'Evolution and Applications of Wireless Sensor Networks', Keynote Address, CMC 09, Kunming, Jan 2009
http://dx.doi.org/10.1109/CMC.2009.367

6. C Michie, I Andonovic, M Gilroy D Ross, C-A Duthie, L Nicol, 'Oestrus Detection in Free Roaming Beef Cattle', European Conference on Precision Livestock Farming, Leuven Belgium, September 2013

Evidence for Quality of Research
Grants which have supported this research include

- "Animal Health Monitoring" ITI Scotland, £740k, May 04 - Oct. 08, Michie, Andonovic
- "Scottish Sensor Systems Centre" SFC Horizon, £1.2M, Oct. 11 - Sept. 13, Andonovic Strathclyde, Glasgow, Aberdeen.
- "Animal Electronic Recording, Transmission and Synthesis (ALERTS)" Technology Strategy Board, SAC, WellCow, ETS, Harbro, Morrisons, NMR, Strathclyde £1.3M, Dec. 11 - Nov. 14,
- "SARA: multidisciplinary approach to understand and prevent a multifactorial disease" BBSRC, £316k, Oct. 12 – Sept. 15, Michie, Andonovic
- "The Use of UHF Transponders as Potential Replacement for Cattle Passports" Scottish Executive, £98k, 2011, Michie, Andonovic, Irvine, Glover
- "Dairy ICT" European Union, £82k, Apr. 2013 - Mar. 2016, Andonovic, Michie

4. Details of the impact (indicative maximum 750 words)
Process from research to impact:
The ITI Techmedia funded Condition Based Monitoring programme (CBM) was a collaboration between the University of Strathclyde, the Royal Dick Vet School (RDVS), Scottish Agriculture College (SAC), The Technology Partnership (TTP) and Plexus. The research contribution of the Scottish Agricultural College and The Royal (Dick) School of Veterinary Studies was to identify behaviour changes that relate to the onset of oestrus in cows. The Strathclyde research focussed on decision support methodologies combining animal behaviour analysis with information technology, communications, signal processing and artificial Intelligence (AI) for PLF support tools.

On completion of the Condition Based Monitoring programme in 2009, Prof Andonovic, Dr Michie and Dr B Stephen (also a researcher at the University of Strathclyde) founded Embedded Technology Solutions (ETS) Ltd. to engineer a proof of concept demonstrator into a commercially viable product, a collar which would monitor animal behaviour, now marketed as the Silent Herdsman®. Ahead of the launch, ETS carried out a trial with the Scottish Agricultural College at

Acrehead farm, Dumfries. The trail tested 150 cows over an eight week period and successfully demonstrated Silent Herdsman's ability to detect accurately Oestrus events in dairy cows. In many instances, the Silent Herdsman detected the events up to two days earlier than competing solutions.

Types of Impact

Commercially successful spin out company:

Embedded Technology Solutions (Source A) was formed in 2009 to market Silent Herdsman collars, and now employs 7 full time staff. Within its first year ETS formed a strategic partnership National Milk Records, NMR (Sources B and C) who are the primary channel to market and who have a team of around 20 to support this activity. NMR deliver milk analysis services covering 1.8M cows in the UK. The total addressable market worldwide stands at 110M dairy and 450M beef cattle. Collar based monitoring systems will not be deployed over all of these but 10% penetration of collar deployments equates to a market in excess of $1billion; ETS projects that a realistic target market is 10% of the collar market segment, which translates into a company of net worth in excess of $100M. In the UK there are ~2M dairy cows, ~9M in the US and in both geographies, the average herd size is increasing; hence the reliance on technology is compelling.

Adoption of new technology:

The technology platform consists of an electronic collar recording individual cow neck movements continuously using a 3-axis accelerometer. The activity data is processed on-collar using artificial intelligence software to identify behaviour changes related to welfare conditions, e.g. the onset of oestrus or heat. This heat event is downloaded to a PC wirelessly whenever a cow enters the receiving area of a base station, usually located near the milking parlour. Cows entering heat are displayed on a local PC enabling the farmer to schedule insemination. Accurate heat detection significantly increases the likelihood of pregnancy. Oestrus detection is difficult in modern dairy herds and can be as low as 40%. Often visible signs are manifest for a short, 2 hour period, between 22.00hrs and 06.00 hrs. A missed insemination window can cost a farmer upwards of £100 per cow. The Silent Herdsman® detects around 95% of heats and thus has helped farmers to optimise their fertility programmes and consequently milk yield.

Rigorous validation [Reference 6] indicated that the signature algorithm predicts with an accuracy of 95% of all oestrus events, including some that on visual inspection, are not demonstrably displayed by the cow. Competitor technologies process data off line and are therefore vulnerable to data gaps. Silent Herdsman®, processes data on the collar and sends alerts which are retained on the collar until acknowledged by the decision support interface, resulting in a profound reduction of the volume of data required to be downloaded to the application and a more robust implementation.

Economic benefits to farmers:

Most profit in dairy farming goes to the supermarkets, leaving farmers to balance rising feed, labour and infrastructure costs. In the UK alone, an average of two farms per day abandon dairy farming and those that remain operate increasingly larger herds to maximise profit through scale. An important factor in increasing milk yields is oestrus detection, which identifies the most appropriate time for insemination in the reproductive process, leading to calving and in turn higher milk yields. Dairy farmers worldwide consider oestrus detection to be the most labour intensive and skilled task their staff have to perform. It is estimated that $2 Billion a year is lost in global milk supply revenue due to missed heat detection. From 2010, the Silent Herdsman® system has been installed in over 250 farms in the UK and Europe.

The cost benefit to the farmer using the Silent Herdsman collar in a dairy herd is estimated at approximately £10k per 100 cows per annum (Source D) achieved through a combination of increased milk revenue (£5 per day for 21 days), feed costs (non-producing cows still require feed) reduced insemination cost (£25 unit cost) and reduced vet costs (fewer examinations). Farms of 100 or more cows have already demonstrated an increased milk yield of more than 10,000 litres per annum. The largest farm deploying the system has 1100 cows. A farmer from Leicestershire (Source E) states that *'With Silent Herdsman I often find positive heat detection results in certain*

animals I would have missed when solely relying on observation. Now we can pin point the exact time for insemination with Silent Herdsman® allowing a cost effective solution overall.' Another farmer from Northern Ireland states that *"With a large herd like mine I cannot afford the time to be standing over every single animal to observe heat detection. I was looking for an easy to use solution that could take care of this farm management issue for me…. Silent Herdsman is the solution."*

While the immediate application of Silent Herdsman® is to detect oestrus, other aspects of animal health are indicated by activity measures from the collar. The system is also able to predict the onset of illness which could potentially be core to stopping the damaging spread of diseases such as BSE which cost the industry ~£7B on the last occasion it occurred. General improved detection of other health problems will also deliver higher quality milk and reduce costs.

Improving performance of existing businesses:
The Silent Herdsman® is manufactured locally within Scotland at Dynamic EMS (Source F), using a component supply chain also based in Scotland. NMR plc supplies dairy management services, including the market leading software system InterHerd, to around 50% of dairy producers in Britain and the majority of leading dairy vets and consultants. The Managing Director has noted that *"Silent Herdsman brings enviable accuracy levels and significant advances to fertility monitoring on our dairy farms ... Movement technology has advanced considerably and, at the same time, heat detection is becoming far more challenging. Priced competitively, we are confident that the system will be attractive to many progressive producers in Britain. And looking ahead, we are keen to see the technology develop, linking in with our current software systems and being applied to other important management functions"* (Source G).

More recently partnerships have been formed with Semex Ltd. (Source H) to grow the opportunity within Europe beginning in Germany with 50 farms in 2012, and with Micro Beef Technologies, owned by MWI (Source I), taking the system into a high value market in the US. The link with MWI also aids penetration of the beef market and the company has captured 60% of a total USA market of 9M beef cattle. Each of the above partners have benefitted directly through sales of the Silent Herdsman® product.

5. Sources to corroborate the impact (indicative maximum of 10 references)

A. http://www.embeddedtech.co.uk/ ETS is a successful spin-out company

B. http://www.nmr.co.uk/silentherdsman/ Links with NMR to market the technology

C. http://www.proactiveinvestors.co.uk/companies/news/15942/national-milk-records-expands-offering-with-silent-herdsman-distribution-deal-15942.html Links with NMR to market the technology

D. National Field Manager, NMR plc, can be contacted to support economic benefits to farmers

E. Statement from farmer in Burton Overy, Leicestershire, and statement from farmer in Newton Stewart, Dumfriesshire online at http://www.embeddedtech.co.uk/company_testimonials

F. http://www.dynamic-ems.com/index.html - evidence of economic benefit to Scotland

G http://www.scottish-enterprise.presscentre.com/Press-releases/Spin-out-company-delivers-high-tech-solution-to-boost-milk-production-22c.aspx - improvement to business performance of NMR

H Managing Director Semex Ltd – can be contacted to confirm links with ETS and sales in Germany

I. Information Systems Manager Micro Beef Technologies, Ltd (www.mwivet.com) can be contacted to confirm links with MWI and opportunity in the US