ROYAL ACADEMY OF ENGINEERING

Innovation in agri-tech

Summary of an event held on Monday 12 October 2015
at the Royal Academy of Engineering

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Photo: Farmers face increasing challenges in the fight against weeds. The success of herbicides is diminishing and certain weeds are becoming resistant to the remaining options. Precision guided hoes are the main tool for non-chemical weed control within the vegetable industry and with organic cereal growers
© Garford Farm Machinery Ltd

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1. Foreword

Over the past four years, the Royal Academy of Engineering has organised a series of half-day events that have explored and highlighted innovation in engineering sectors that are seen as having potential for growth and for global reach.

On 12 October 2015, leading engineers and business people gathered at the Academy to discuss *Innovation in agri-tech* and the trends and issues in this branch of engineering that is fundamental to the sustainability of the industry. The event heard presentations from researchers and manufacturers with an emphasis on engineering and technological advances being exploited to deal with the specific and often complex requirements of agriculture.

This report is not a verbatim record of the event; rather, it seeks to highlight some of the issues raised and to contribute to further discussion.

Photo: Robocrop precision guided hoes use video cameras and bespoke image analysis software to accurately locate crop rows ahead so facilitating accurate and fast inter-row guidance
© Garford Farm Machinery Ltd

> the UK's agri-food supply chain accounts for an annual turnover of £96 billion with revenues of £10 billion

2. The agri-tech sector

Agriculture is one of the oldest industries, and arguably also one of the most important. In 2015, agriculture, together with food preparation, was the UK's biggest single productive sector. Food business is global and there are significant complexities in terms of regulation, climate, logistics, supply chains and customer demands.

As a whole, the UK's agri-food supply chain accounts for an annual turnover of £96 billion with revenues of £10 billion. Chair of the event, Professor Richard Godwin FREng, who holds emeritus and visiting professorships at Cranfield University and Harper Adams University respectively, said that it accounts for 7% of the UK's GDP, and employs around 3.8 million people.

The agri-tech industry, supporting farmers and growers with machinery and other kinds of technology, is also a multi-billion pound sector; the UK has a 4–5% share of the world market. Farmers worldwide face a common set of issues – population growth, dwindling land, water and energy resources, climate change, and the need to increase efficiency and lower costs – but there is potential for increasing exports and yields.

The potential for the UK to take a leading role in agri-tech has been recognised in an industrial strategy for the sector. Issued in 2013, it brings together three government departments – Department of Business, Innovation and Skills,

Department of Environment, Food and Rural Affairs, and the Department for International Development – as well as industry and academia. Included in this was a £70 million agri-tech catalyst fund to help commercialise UK agricultural innovation. As well as a £90 million joint industry/government programme for Centres of Agricultural Innovation, co-ordinated through Innovate UK.

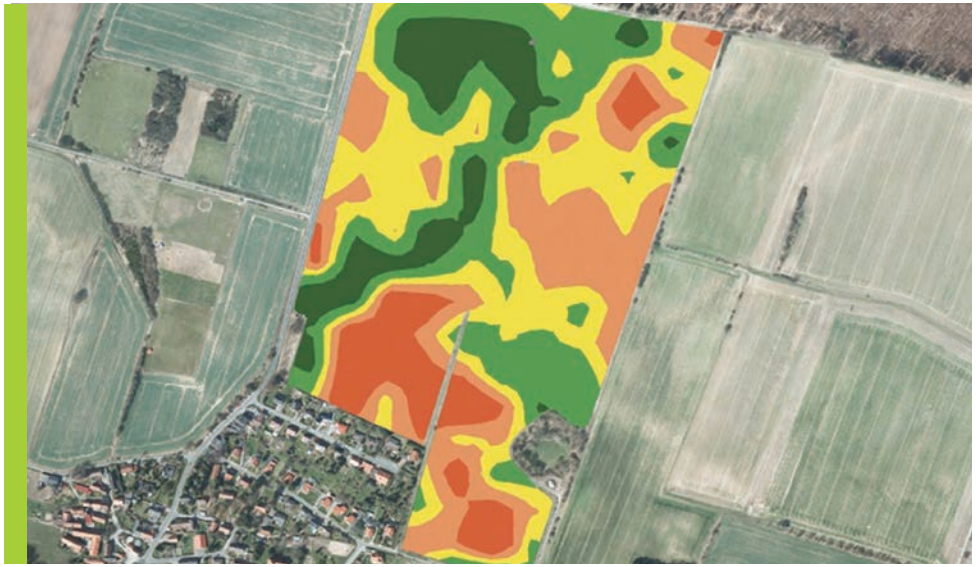
> Precision farming has the potential to be the most disruptive technology to modern agriculture, as disruptive as biotechnology was

3. Centres of agri-innovation options

The first of the Centres of Agricultural Innovation is already under way and is applying informatics and big data in agriculture. An emerging theme from the event was the potential of adapting innovations and techniques from other branches of engineering for use in agriculture and food businesses: from unmanned air vehicles and satellite imaging through to complex algorithms and analytics software.

Willie Thomson, technical director at Harbro Limited, is industrial lead of the group bidding for one of the next Centres of Agricultural Innovation – the Agricultural Engineering Precision Innovation Centre (Agri-EPI Centre). This will focus on engineering for precision agriculture: the application of increased measurement precision offered by new engineering techniques. His group of 75 industrial partners includes many of the big companies in agri-tech, but also more surprising names such as Williams Formula One Racing and Boeing (aerospace), which attests to both the breadth of engineering and the attractiveness of the sector.

"Precision farming has the potential to be the most disruptive technology to modern agriculture, as disruptive as biotechnology was," Mr Thomson said. Precise measurement can drive future biological science and agri-tech developments, but in the context of the industry it can also enable greater understanding of exactly what was happening in existing processes: "The inability to measure things properly has limited us up to now," he said.



Yield mapping © Claas

The centre that Mr Thomson is hoping to establish would go to the core of one of the features of UK agriculture – the wide variation in performance between different farms and the wide variation in crops and livestock even within farms. Variability is symptomatic of a wider malaise, he said: UK farming had been rated fourth out of eight advanced nations in terms of production efficiency in 1973, but had sunk back to eighth place by 2011, in part because of a focus on subsidies at the expense of efficiency.

"The UK has been dominant in much of the science and technology, but has under-invested in the use of it," he said. The agri-tech strategy formulated in 2013 was an attempt to address this and the lack of data was quickly identified as a key issue – hence the first Centre's focus on informatics and big data.

The Agri-EPI Centre, is one of three candidates for funding: others could cover livestock and crop technologies, and the aim, he said, would be for all three, if approved, to link together on some issues, particularly these performance variances found between different farms, and within individual units.

In food processing units such as abattoirs, variance in animal sizes is a significant drag on the overall efficiency of the food chain. "Variation management is hugely expensive if you look at it from a factory point of view," Mr Thomson said. The Agri-EPI Centre proposal is for a network of precision monitoring sites to gather and analyse data from ranges of crops and animals to understand the causes of variation and to test new ideas that might reduce it.

One core application is sensing and how existing and emerging innovations can be used in agriculture. As an example, he cited the potential for using 3D imaging technology to provide a continuous monitor of weight and growth in farm animals. "We can now see detailed growth in individual animals, and new tools are opening up possibilities that we have never had before." Remote monitoring and data analysis techniques used in other industries can be applied to agriculture but first there is a need to better characterise the opportunities and how new technologies can be applied.

In food processing units such as abattoirs, variance in animal sizes is a significant drag on the overall efficiency of the food chain

4. Innovation in agri-machinery

The Claas EASY on Board App was developed as a direct result of customer feedback. Connected by WiFi, a tablet can monitor, control and log data from equipment attached to the tractor © Claas

Part of the UK's agri-tech strategy is to address overarching issues such as data collection and analysis. 'Smarter' machinery can collect better data and is already delivering impacts and benefits to individual farmers. The event heard from two companies that manufacture such machinery.

Claas is a leading manufacturer of agricultural engineering equipment, supplying machinery that can harvest many crops types. The focus for the group, said UK CEO Trevor Tyrrell, is on increasing efficiency for the user. Where in the past, this meant ever bigger machines, increasing size is no longer an option. Physical limits from rail bridges for transporting new equipment, gates, roads and access to farms have now been reached.

Instead, efficiency gains, Mr Tyrrell said, were being achieved by making machines smarter. Integrating electronics-based capabilities into farm machinery, and interconnecting different machines to create a systems approach, enables technology to become part of the overall system of systems. Examples of new capabilities include the integration of GPS and automated steering into harvesting machinery, and the use of yield mapping.

Mr Tyrrell said, "the challenge with many of these things is bringing the operators and farm managers along with us". Farmers who have an intimate and often long-standing connection to their land may need convincing that systems can tell them things they did not already know. "So we have to show that our systems can allow less experienced people to be more efficient and productive and enable the more experienced people to do even better," he said.

Claas's research and development strategy concentrates on four specific areas: automation of operations; steering systems; data management; and the interfaces through which the operator or the farm manager back in the office interacts with the systems.

For example, automation has come from integrating 3D camera technology into tasks such as the filling of trailers to deliver greater precision to operations such as mowing and weeding. In steering, smart systems can be shown to improve yields from the headland where machinery turns at the ends of fields.

Another benefit of smart machinery, Mr Tyrrell said, was in terms of improved logistics, and the interconnection of machines and operations. Creating a fleet view, can contribute to broader business efficiency and environmental goals such as fewer farm movements and reduced fuel consumption.

Automation is also the focus for farm supplier Garford Farm Machinery. Philip Garford, managing director, heads the small manufacturing business which has a £3 million annual turnover. The event heard about its Robocrop range, innovative systems automating mechanical and chemical weed control.

Garford machinery uses video cameras and bespoke image analysis to locate individual plants and

activate systems that deliver a precise jab of a hoe or a targeted shot of weedkiller to any unwanted plants in the vicinity that might interfere with crop growth.

Precision and speed are the central requirements, and over the past 15 years, system capabilities have advanced dramatically. Using two cameras, Garford Machinery is able to identify up to six plants per row per second, or three hectares of crop per hour. Multi-dimensional imaging has enabled a much wider range of crops to be handled. Only a tiny amount of foliage needs to be visible and the system works on different coloured crops. Looking to the future, the company is researching 3D imaging.

By automating traditional mechanical and chemical weed control, the precision at which these systems deliver opens up new questions. Mr Garford said that the next generation of spot sprayers offered the potential of reducing the amount of weedkiller needed by 98% or 99%. In addition, rules on chemicals drawn up for an era of widespread and indiscriminate spraying perhaps needed to be revisited in an age where such precision is possible.

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The Robocrop InRow Weeder analyses images up to 30 frames per second. Firstly locating the crop row and then the individual plant along the row © Garford Farm Machinery Ltd and Tillett and Hague Technology

An important part of agricultural science and technology is the development of techniques and methods that augment the knowledge that farmers have built up over millennia

5. Innovation in agri-management

An important part of agricultural science and technology is the development of techniques and methods that augment the knowledge that farmers have built up over millennia. The event heard of two such developments, one in crop production, the other in animal husbandry, that seek to use new technologies to improve farm practices.

Dr Mark Else leads the resource efficiency for crop production programme at East Malling Research. He outlined work that his group has been doing to optimise crop production against environmental pressures and wider economical demand in the use of water and fertilisers with a focus on the cultivation of soft fruits and berries.

His programme aims to draw up guidance that might eliminate wide variations in common practice: water use in the cultivation of raspberries can vary by as much as 13-fold, Dr Else said. Among some fruit farmers, there has been a policy of insurance irrigation, a default procedure to water plants unless it is obviously not needed. There is a similar default on fertigation: when in doubt, the growers use fertilisers.

The potential for wastage and environmental damage from these practices is significant even in temperate climates such as in the UK. Water resources are under pressure in large areas of England and groundwater levels have fallen over recent decades. There are also concerns about the use of fertilisers and their runoff into watercourses.

High value horticulture, such as soft fruit and fruit tree sectors, continues to invest heavily in science and innovation © East Malling Research

Growers now have access to an increasing range of measurement technologies that might enable them to monitor and adapt their water usage

Growers now have access to an increasing range of measurement technologies that might enable them to monitor and adapt their water usage: sensors that assess the volumetric water content of plants, and evapotranspiration monitoring which enables them to calculate how much water the crop is losing.

Dr Else's work hopes to add further measurement techniques for farm use. "Our aim is to understand how plants respond to a range of conditions such as water availability," he said. This includes new ways of measuring moisture content, but also involves other metrics: measuring the stress that a plant experiences under different conditions and applications of nutrients.

Watering or applying fertiliser might encourage a plant to produce more leaves rather than more fruit, for example, and there are qualitative measures such as fruit flavour that need to be considered. Technologies such as digital imaging and thermography are starting to be used to answer the questions that arise. If some kinds of stress inhibit growth or fruit production, other kinds may actively promote the desirable characteristics.

Test results have so far shown water savings of up to 36%, fertiliser savings of 25% and yield increases of 18%. But, Dr Else admitted, some of this is highly counter-intuitive, and agriculture often tends to be a cautious industry: less water and fewer chemicals could be regarded as unduly risky.

The second example of how agri-tech can optimise farming practices suggests, however, that caution within the sector can be overcome when the technology proves itself. Professor Toby Mottram, farmer-turned-entrepreneur, has pioneered the use of wireless monitoring technology in animal health through his invention of the eCow rumen bolus.

Milk yields and quality vary in line with the acidity in a cow's stomach. Sub-acute ruminal acidosis (SARA) is a digestive disorder in dairy herds. SARA is difficult to measure, relying on vets assessing stomach acidity by inserting a needle into the cow's stomach. However, acidity varies

Rumen bolus telemetry is becoming routine. The bolus is retained in the reticulo-rumen with raw data on pH and temperature downloaded onto a handset. Nutritional management is changing as a result of the data © eCow

across the stomach, throughout the day and between animals therefore a one-off measurement is not always helpful. SARA, Professor Mottram said, affects up to 30% of cattle.

The answer he devised with eCow is to put a permanent wireless sensor inside the cow's stomach to measure pH. The sensor is contained within a bolus that is swallowed by the cow and transmits constant measurements that can be picked up by a mobile phone app. The continuous stream of data provides long-term monitoring of cattle health but, he said, the real benefit comes when it is linked into other data controlling feeds, turning what had been a veterinary problem into a tool for farm management.

Professor Mottram says that this rumen monitoring is becoming increasingly routine and he is turning his attention to other wireless telemetry applications within animal husbandry, such as monitoring fertility.

6. Future directions for agri-tech

The event concluded with a panel of experts debating a wide range of questions about the future of the agri-tech sector

Professor Simon Blackmore, head of engineering at Harper Adams University, opened the discussion on what he saw as the most promising developments in agricultural engineering. Professor Blackmore was sure that engineering had a major part to play in future agriculture, and technologies derived from IT, space exploration and control systems would all have a role. "In the future it'll be about the ability to bring all these things together to come up with new kinds of mechanisation based on smart machines," he said.

Challenges for the future would be to raise productivity while minimising energy use: agriculture currently, he felt, tended to be quite wasteful of resources, and there was a need for the new infrastructure of agri-tech to be intelligently targeted towards these twin aims. "And if there is a single killer application I'd like to see in robotics for agri-tech, it'd be laser weeding, which would tackle very small weeds with fewer chemicals and lower energy use."

The economic and political reality of agriculture was addressed by Dr Helen Ferrier, chief science and regulatory affairs adviser at the National Farmers' Union. Dr Ferrier described how the sector managed to grow even in the recent economic downturns. "But we are still, in the UK, a net importer and one of the key performance indicators for the future has to be to move towards greater self-sufficiency in food."

Growth within the sector requires investment and would benefit from greater stability within the

whole agriculture and food supply chain, she felt. The personal and emotional investment that the farming community makes in their businesses is peculiar to the industry and gives a social context that should also be taken into account. Dr Ferrier highlighted two important factors that remained uncertain: politically, the UK's membership within the European Union, and technically, the true availability of some technologies whose delivery depends on rural connectedness, mobile signals and access to broadband.

Dr Robert Merrall, president-elect of the Institution of Agricultural Engineers, identified several technologies from robotics and machine vision through to electronics and IT where the agri-tech sector could exploit advances in other branches of engineering. He cited as examples the linkage between research and commercialisation which has been a focus in other parts of engineering in recent years; for example, the lean and agile business organisation philosophies that have swept through manufacturing, and the way that pharmaceutical industry uses rigorous product and system validation processes through field trials. Within the whole agricultural sector, engineers and farmers, there were opportunities to develop innovative skills.

The question on how the UK might best capture ideas to the benefit of farmers and agricultural engineers was addressed by Calum Murray, the programme leader for sustainable agriculture and food at Innovate UK. As a leading partner, Innovate UK is responsible for delivering parts of the agri-tech strategy. Mr Murray described how Innovate UK had already funded 200 projects in this area, 100 of them specifically through the agri-tech catalyst fund.

The most effective way of delivering innovation for the UK, Mr Murray said, was through industry-led challenges in which a key component was talking to farmers and other producers to understand the issues in the market. "But we also need to spread the word to bring ideas in from other sectors, even technologies that don't seem to be a natural fit. And we need to help people in this sector to get their ideas across by helping them think like an investor, and that way we'll get innovative ideas that are achievable and exploitable."

The opportunity in agri-tech, Mr Murray said, was very big. "I see agri-tech and the whole bio-economy as the last big prize that is ripe for picking," he said

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7. Further information and reading

Ingenia magazine, Issue 64, September 2015 – Precision farming
http://www.ingenia.org.uk/Ingenia/Articles/972

National Farmers' Union – EU Referendum: UK farming's relationship with the EU
http://www.nfuonline.com/assets/52824

8. Acknowledgements

We would like to thank the following speakers for their contribution to *Innovation in agri-tech*:

Chair

Professor Richard Godwin FREng
Visiting Professor, Harper Adams University; Emeritus Professor, Cranfield University

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