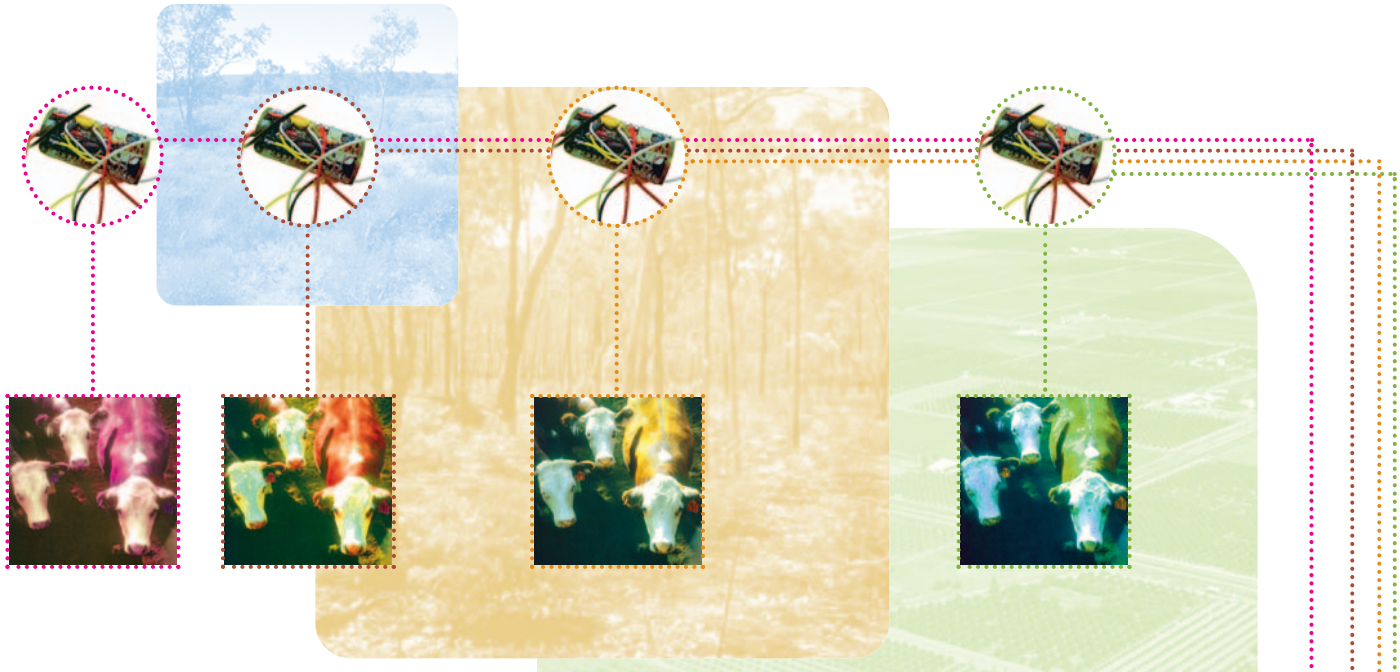


Rural remote control

Small, distributed computer devices are being developed to act as embedded, self-learning environmental 'agents' on rural properties, remotely reporting and managing complex agricultural processes, monitoring the behaviour, health and productivity of stock, and optimising environmental conditions. Farming, as we know it, could be revolutionised.

Making a living from natural resources in the driest continent on earth is difficult. Doing it in a socially, economically and environmentally sustainable way is even harder. Landowners, natural resource managers and communities have to juggle many conflicting demands and constraints while working hard to run successful operations. Information overload is a real problem – many agricultural and environmental systems are just too complex for humans to understand holistically, let alone manage. Even so, an intelligent solution may be just around the corner. In fact, it's already in early, promising, development.

CSIRO scientists and engineers from what's called the Smart Spaces initiative are suggesting that a new breed of computers may be up to the task. Ultimately, it's a project that seeks to understand how to combine diverse information on livestock physiology and movements, local climate and landscape function, to optimise rural district productivity and environmental quality.

Smart Spaces is a collaborative initiative involving five CSIRO divisions, the Australian National University (ANU), private landowners and multinational companies. It brings together researchers with interests ranging from information systems architecture to signal measurement and telemetry, with a unique focus on an environmental demonstration project, called *SmartLands*.

'Rural and environmental systems are complicated in terms of the vast numbers of interacting processes and volumes of information tied up in them, and complex in terms of the unexpected and emergent interdependencies in the systems,' says CSIRO Land and Water scientist and *SmartLands* Project Leader, Mike Trefry. Conventional computer-aided resource management systems can only use relatively sparse field data in decision making for planning and automatic control. This works well for aspects of the rural environment that are essentially predictable, but the failures can be spectacular where decisions are based on inadequate information.

As Geoff James, CSIRO Smart Spaces lead scientist, puts it 'The weakness is in the architecture of the approach – trying to specify beforehand all the

Mike Trefry (based on a CSIRO Land and Water image)

A distributed communication network of 'agents' might form a reporting array to comprehensively monitor the conditions of a particular region.

Monitoring stock from inside out

Rumen temperature and pressure, along with other physiological data, can be transmitted by radio signal to an ear tag or rump unit

Dr Keith Ellis, a former CSIRO Livestock Industries animal scientist, is working with the Smart Spaces team to push the boundaries of farmers' capacity to understand, monitor and control the physiological processes and movements of individual and herded stock.

Inspired that the largely unknown, but dramatic, changes which occur in the rumen of cattle were important for combatting problems such as bloat and sudden milk production drops, Dr Ellis and ICT technicians are developing micro, remote-sensing electronic units that can be employed harmlessly inside the rumen and on the ears or rumps of stock. Rumen temperature and pressure, along with other physiological data, can be transmitted by radio signal to an ear tag or rump unit which then uses mobile phone technology (GPRS) to relay the data to a computer monitor.

The small stock devices which are currently being tested and integrated with the wider *SmartLands* neworks of reporting agents, could ultimately – within a total farm reporting system – provide a unique way of optimising animal performance, local environmental conditions, and of monitoring stock disturbances – such as rustling.

Keith Ellis

Early-stage stock-mounted units are currently being tested and perfected at Binalong. Reports from this particular steer can be read online from anywhere on the globe.

'We believe that a powerful tool for prediction and precise management of stock will arise from the detailed data that individual devices can provide on immediate physiology and location,' Ellis says. 'With the ability to monitor many parameters together, one can paint a much more informed picture of what's going on than with just one or two, particularly when the data is linked to an 'intelligent' network.

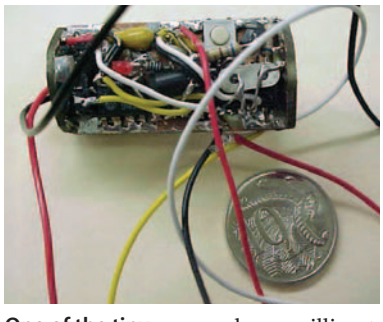
'We like the idea of being able to cross-reference physiological information, location readings, and data about the proximity of other animals in a herd to make really incisive predictions and decisions about stock behaviour and management – such as, say, when a cow may be coming into season, or when certain plants might be causing bloat.' Field trials of early stage units will be established at the Binalong site.

Contact: Keith Ellis, Keith.Ellis@csiro.au

information required to make a complex decision. Humans are limited in their choices of data sources, and limited in their understandings of data correlations.' Instead, Geoff and his team are trying to shift the burden of analysis from a relatively small number of humans to a vast array of new, cheap, and ultimately disposable, computers, called 'agents' that collectively learn the best management responses.

Intelligent agents

On the lowest level, a computational agent is an artificial device that is able to sense, think (i.e. perform logic), act and communicate. There is, therefore, the possibility of both physical (hardware) and virtual (software) agents. The Smart Spaces vision involves vast numbers of cheap agents deployed throughout a space, sensing variables, analysing data, performing actions and communicating with each other.



Keith Ellis

One of the tiny units being developed for individual stock monitoring. It can be swallowed by an animal to report on immediate physiological changes.

The vision has been solidified with the increasing availability of tiny but powerful sensing and communicating technologies, ranging from the new, cheap millimetre-sized computers called 'Motes' developed by the University of California, to mass market handhelds. These physical agents incorporate hardware with publicly available standards for computation and wireless communication, and have the capacity to self-organise into communicating networks.

Rural and environmental data sources

SmartLands aims to test these new agent technologies on an operating livestock and pasture farm near Binalong, New South Wales, over the next two to three years. As a first step in developing the site network, fixed agents will be deployed to measure climatic variables, surface and ground water, and soil moisture. Mobile agents will be mounted on individual animals to measure location and direct physiological data such as body temperature, feeding characteristics or rumen properties.

These data will then be combined with satellite measurements of pasture quality and quantity to provide a rich and real-time picture of the farm's biophysical conditions. The landowner would effectively then have access to constant information on the location, health, and feed conditions of the livestock, together with paddock-by-paddock water-use efficiency.

Controlling emergence

But a farm system doesn't just contain plants, animals and people; it contains crops, flocks and communities. The combined actions of many individual animals or entities, can cause startling behaviours to emerge, such as stampedes in cattle, and elaborate nest building in termites. These events may be common or rare, but they are important to the operation of natural systems. In a farming context, a farmer needs to know if a flock of sheep is behaving unusually, perhaps in response to an environmental stress, like thirst or frost, or perhaps because they are being stolen in the dead of night.

'Characterising and understanding these emergent, or critical, states is the route to managing complex natural systems,' says Mike Trefry. 'We need to design our agent network to measure a system's basic states, detect any impending critical changes, and to manage those for a beneficial outcome.'

Geoff Poulton, Project Leader for CSIRO's GREM^{Lab} (Laboratory for Global Response Engineering for Multi-agent Networks), part of the CSIRO Centre for Intelligent System Design, goes further, saying 'The multi-agent network deployed in *SmartLands* is itself capable of emergent behaviour, in

CSIRO SmartLands

At the Binalong trial site, solar-powered field units are operational and reporting on environmental conditions, such as water quality, to central 'smart sheds'.

the manner in which the agents communicate, self-organise and respond to contingencies. The challenge is to engineer the agent system so that emergent behaviours that are beneficial are encouraged, and those that are detrimental are not.'

Beginnings at Binalong

Agents will be integrated with fixed sensors to collect data at Binalong. Mobile agents will also be attached in or on livestock, initially measuring their locations, but with a view to sensing more sophisticated measures of animal status. This mixed network of fixed and mobile agents will provide continuous information on the spatial distribution of roaming livestock and, through correlations with fixed agents, how the livestock interact with the farm landscape, water and food supplies.

The agent communication network is completely wireless, using local radio links, cellular phone networks, and positioning or locating systems such as GPS. Even in a research mode, it is a lower cost option than many conventional data communication solutions. The agents themselves, however, are not so common.

Ken Taylor, Doug Palmer, Ying Guo, Vadim Gerasimov and Phil Valencia, at CSIRO's ICT (Information and Communications Technology) Centre, have the job of designing the *SmartLands* agent software that will allow the agents to learn automatically about their local agent communities, their local physical environments, and to self-organise into functioning networks. 'The GREM^{Lab} approach to designing the right emergent behaviour with agent networks like these is somewhat unconventional – we've found a fascinating approach to robust systems design which lets us contribute to worldwide ICT research,' says Phil Valencia.

Planning ahead

Once the agent software has been deployed, *SmartLands* will move into specific application areas. Livestock management is one of these – using autonomous agents to manage whole flocks. For example, 'mustering' agents might be deployed in robotic four-wheel motorbikes or miniature helicopters and trained to behave like sheepdogs, and communities of agents will act to detect and foil stock theft.

At a broader level, the Smart Spaces project will be working with other researchers to expand the capabilities of this new technology for the optimum holistic management of districts, at a scale beyond rural properties. A major aim is preparing the way for large-scale uptake of increasingly cheap technology, say five to 10 years ahead – a growth cycle that will make possible the futuristic goal of comprehensive data gathering and intelligent response systems.

More information:
www.smartspaces.csiro.au/
Contact: Geoff James, Geoff.James@csiro.au

'The challenge is to engineer the agent system so that emergent behaviours that are beneficial are encouraged, and those that are detrimental are not.'