Can precision farming technologies be applied to grazing management?

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Abstract. In arable farming, precision is used to monitor and manage crop variability. The same precision approach can be used to manage grassland, by using crop sensing, targeted fertilizer/herbicide/pesticide application and forage yield measurement when it is harvested mechanically. An additional challenge in grassland agriculture is developing precision approaches to manage the grazing process. This requires technologies to determine where an animal is, when, what and how much it is grazing which the system then needs to use in conjunction with other sources of information to control where the animal grazes next. This paper reviews the existing technologies in these areas. However, any grassland-oriented precision technologies will need to be cost effective for farmers to adopt them.

Keywords: Precision livestock, grazing management, virtual shepherd.

Introduction

The onset of the industrial revolution in the mid-eighteenth century had a big impact on agricultural practices, bringing increasing levels of mechanisation and industrialisation to farming (Overton 1996). These changes continued into the second half of the twentieth century, with some production systems being increasingly intensified in the quest to produce cheap food. These high-intensity production systems typically focus on overall production (e.g. at the ‘farm’ level) rather than the production from individual animals. Human civilisation is currently undergoing another revolution: the information revolution (Freeman and Louçã 2001) and this is already starting to have an impact on some agricultural sectors. The first impact was in the arable sector with the development of precision agriculture.

Precision agriculture

In arable farming, precision is used to monitor and manage crop variability (Whelan and McBratney 2000). Before the onset of precision agriculture, fertilisers, pesticides and herbicides were typically applied at a standard rate across the field, even though it is usual to have considerable spatial variability in soil fertility, pests and weeds within a field. This results in some areas of the field getting too much and/or other areas getting too little of these treatments. The precision agriculture approach is to monitor the crop and apply the treatments (e.g. fertiliser, pesticide or herbicide) only where they are needed. This precision approach uses sensors along with precise position information, usually from Global Navigation Satellite System (GNSS) receivers, to precisely control the application of treatments only where they are needed. The same precision approach can, to a large extent, be used to manage grassland (Schellberg et al. 2008), by using crop sensing, targeted fertilizer/herbicide/pesticide application and forage yield measurement when it is harvested mechanically. An additional challenge in grassland agriculture is developing precision approaches to manage the grazing process. This requires technologies to determine where an animal is, when, what and how much it is grazing which the system then needs to use in conjunction with other sources of information to control where the animal grazes next. This paper reviews the existing technologies in these areas. However, any grassland-oriented precision technologies will need to be cost effective for farmers to adopt them.

Existing grazing management technologies

At its most basic, grazing management consists of measuring the available herbage and then matching this to the intake requirement of the animals to be grazed, typically by allocating a certain area of pasture for a particular amount of time. Grazing management is already benefiting from some relatively simple technology – the “pasture meter”. This gives an estimate of the average herbage mass of an area of pasture, and can be used to determine the area of pasture that needs to be allocated to meet the intake requirement of the animals to be grazed. The mechanical counters used on early rising plate meters are being replaced by more sophisticated electronic counters (e.g. Filip’s Electronic Rising Plate Meter, Jenquip, Feilding, New Zealand), and a pasture meter that uses a capacitance method to estimate herbage mass is also available (GrassMaster II, Grazetech, West Ryde, NSW, Australia). A vehicle-based pasture monitoring system is now available (‘Pasture Meter’, C-Dax Ltd, Palmerston North, New Zealand) and is suited to managing areas of more intensively grazed pasture, whilst satellite surveillance (e.g. ‘Pastures from Space’, CSIRO, Australia) provides farmers with estimates herbage availability over large areas of rangeland (Hill et al. 2004).

Technology is also being used to help control access to grazing i.e. which animals are allowed to access pasture and when. Several dairy equipment manufacturers have automatic gates (e.g. Grazeway, Lely Holding S.à r.l., Maassluis, The Netherlands) that can be used to control whether or not a dairy cow can access an area of pasture.
These can be combined with robotic milking systems and can be used to ensure cows are not given access to pasture if they are due to be milked. A timed or remote gate release device is also available (Batt-Latch Gate Release Timer, Grazetech, West Ryde, NSW, Australia) which can be used to automatically open up a new area of pasture at a predetermined time (or can be operated by remote control). A robotic moving electric fence was launched in 2007 (Voyager, Lely Holding S.à r.l., Maassluis, The Netherlands), although at the time of writing the product no longer features on the company website.

Future grazing management technologies

Although these existing technologies are helping to improve the efficiency of grass utilization by grazing ruminants, they are still operated at the ‘group’ level, and they do not give much precision in their control of grazing management. In order to more precisely manage the efficient grazing of domestic animals, three key technologies need to be integrated into a commercially viable system. These technologies need to determine where an animal is, when, what and how much it is grazing, and the system then needs to use this (and other sources of) information to control where the animal grazes next. The following three sections review the existing technologies in these three areas.

Animal location

The Global Navigation Satellite System (GNSS) has become the de facto choice for determining location, and was first used to determine the location of domestic ruminants (sheep) in a research study in 1993 (Rutter et al. 1997a). Although the cost and power consumption of GNSS receivers have dropped since they were first introduced, their on-farm use still faces challenges, and using base stations to triangulate the position of radio-transmitting ear-tags may be more feasible (Trotter 2012). However, for managing the grazing of animals in more extensive conditions, especially upland areas where line-of-sight communications to base stations is likely to be difficult, the GNSS will probably have a role to play, especially if power generation can be achieved on the animal (e.g. solar power or using the animal’s body heat). Technology to determine animal location is already well developed and is starting to appear in commercial use. For example, CowView (GEA Farm Technologies GmbH, Bönen, Germany) uses active ultra-wideband radio frequency identification (RFID) technology to precisely locate (30-50cm) individual cows fitted with a collar. The system is used to help detect oestrus, and can help the stock person to easily locate individual animals.

Animal foraging

Researchers have historically tried a variety of technologies to record the foraging behaviour of domestic ruminants (see Rutter et al. 1997b for a review). Head mounted accelerometers can be used to estimate grazing time and estimated intake with a precision between ±1.2 and ±1.4 kg DM/cow/day (Oudshoorn et al. 2012). Alternatively, the recording and analysis of the sounds associated with grazing shows considerable potential (Ungar and Rutter 2006). Such a bioacoustic approach also has potential for monitoring foraging on-farm for several reasons. Firstly, the rich acoustic signal produced by a grazing animal can be used to determine both bites and chews (Laca et al. 1992), as well as an estimate of the quantity of dry matter intake (Laca and WallisDeVries 2000) and, potentially, plant species being eaten (Ungar and Rutter 2006). Although the original research into grazing bioacoustics used the human ear to identify grazing, computer algorithms have now been developed to perform this task (Milone et al. 2009). Secondly, the viability of using bioacoustics on-farm has already been proven as part of a commercial system that monitors rumination (the VocalTag Rumination Time Monitor, SCR Engineers Ltd, Netanya, Israel) with changes in rumination behaviour being used to help detect oestrus and health problems. One potential problem with bioacoustics is that the acoustic sensor on one animal may ‘hear’ the foraging sounds on other animals that are grazing nearby (Ungar and Rutter 2006). One way to overcome this problem could be to combine the use an acoustic sensor with data from an accelerometer i.e. the accelerometer could be used to eliminate any grazing sounds that were not accompanied by the appropriate head movements. Although some further work is needed to develop a foraging sensor that is feasible for use on commercial farms, the basic scientific validity of these approaches have already been established.

Animal control

The final component required to manage grazing animals is some way to control where they are allowed to forage. For the majority of the domestication history of ruminant livestock, this control was achieved through the direct supervision of a human ‘shepherd’, and this approach is still used in some parts of the world. This time-consuming task was usually undertaken by children, until legislation (e.g. the 1870 Elementary Education Act in England and Wales) required them to attend school, at which point static fencing was introduced in many regions to control grazing (Umstatter 2011). In the 1940’s, electric fences were introduced, allowing a more flexible approach to controlling grazing. Although electric fences normally require human labour to move them, a robotic electric fence has been developed (e.g. the Lely Voyager as discussed earlier), bringing the possibility of some automatic control.

With a traditional electric fence, an energiser creates a regular high voltage ‘pulse’ in the fence line, which animals learn (by trial-and-error) to avoid (because they get a shock if they touch the fence). An alternative approach is to put the energiser on the animal. The animal receives a warning sound as it approaches a ‘signal’ cable placed on the ground, and then receives an electric shock if it continues to move towards the cable. This system is known as an ‘invisible fence’, although in practice the animals can see and learn to avoid the signal cable (Umstatter et al. 2012). Such a system has recently become commercially available for use with cattle (BoviGuard, Agrifence, Gloucester, United Kingdom). A more sophisticated approach (which removes the need for a physical signal cable) is to combine the animal-mounted energiser with a positioning (e.g. GNSS) receiver. This
allows ‘virtual fences’ to be established i.e. the warning signal (and shock if required) are delivered when the animal approaches a virtual boundary defined by a series of latitude and longitude coordinates (Anderson 2006). The advantage of a virtual fence over a real (or an invisible) fence is that it can be dynamic i.e. the boundary can be moved simply by sending new latitude and longitude coordinates to the unit on each animal. Virtual fence boundaries are not as secure as traditional fences, but virtual fencing has been shown to be effective at controlling grazing within a secure perimeter (Jouven et al. 2012). Although there are several patents associated with virtual fences (Umstatter 2011), there are not, at the time of writing, any commercially available virtual fencing systems.

One potential problem with virtual fencing is concern for animal welfare over the use of animal mounted ‘shock collars’. Umstatter et al. (2009) tried different sounds (e.g. humans shouting, dogs barking) as aversive stimuli rather than electric shocks, but the mixed results they observed were attributed to the animals habituating to the sounds. An alternative to using aversive stimuli as punishers in a virtual fence system is to use positive reinforcement to ‘reward’ an animal for moving to the desired location. To date there is just one patent (Lalor 2005) describing the use of positive reinforcement to get dogs to return to a reward zone. However, positive reinforcement (e.g. a concentrate feed delivered by a robot) could be used to guide ruminant livestock to fresh pasture, or being led to fresh pasture may itself be a sufficient reward. This approach requires further research, but a combination of positive reinforcement and aversive acoustic stimuli could potentially be used in a virtual fence system to guide animals without the need for the use of electric shocks.

The virtual ‘shepherd’

Traditionally, shepherds monitored the animals in their care, moving them on to new areas of pasture when required. The combination of animal location technology, foraging sensing and virtual fencing brings a new possibility to the management of grazing animals – the “virtual shepherd” (Rutter 2012). Just as a human shepherd can monitor and respond to the behaviour of their stock, the virtual shepherd could monitor foraging behaviour and move animals on to new areas of pasture when required. The next area to be grazed could be identified with the help of imaging from unmanned aerial vehicles (Herwitz et al. 2012) from AVHRR NDVI and climate data. Remote Sensing of the Environment 93, 528-545.

Animal health and welfare benefits

As well as facilitating the precise management of grazing, the monitoring of animal position, foraging and other behaviours can bring considerable benefits for animal health and welfare (Rutter 2012). The onset of animal disease is normally accompanied by subtle changes in animal behaviour. By continuously monitoring each animal in the herd/flock, any small deviation from ‘normal’ behaviour (for that individual animal) can be quickly identified and flagged to the farmer. The virtual shepherd can also respond to these changes in behaviour, and could even guide the sick animal, along with a few other animals that the system has recognised as her closest flock/herd mates, back to an enclosure where the sick animal can be seen by a vet. These health and welfare benefits will be most noticeable in extensive upland or rangeland systems, where animals are normally only inspected a few times a year.

Conclusion

Although the development of precision livestock farming has to date, focused on high-input production systems (principally dairying), there is no fundamental reason why such technologies cannot be applied to the management of grazing animals. Indeed, the technology discussed in this review has the potential to bring to grassland-based farming the level of monitoring and control normally associated with intensive livestock systems. This is achieved by monitoring and managing animals as individuals, bringing with it improvements in animal health and welfare as well as increasing the efficiency of production. Grassland farming is often adopted to cut costs, and the utilisation of a high-technology approach might seem to go against this principle. Consequently, grassland-oriented precision technologies will need to be cost effective if they are to be adopted by farmers.

References


