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TOWARDS ROBOTIC AGRICULTURE

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Developed agriculture uses massive amounts of energy in a myriad of forms, from the energy associated with chemicals used to control pests and diseases, through fertilisers, to the tractors themselves and the fuel to power them. This energy is often wasted as it goes off-target, is expensive and will become more so in the future.

Smarter machines should use the minimum amount of energy to turn the natural environment into useful agriculture thus cutting out wasted energy and reducing costs. As agricultural engineers we are continually looking to find ways of making the crop and animal production processes more efficient and have developed the concept of Precision Farming, where we recognise the natural variability found on our farms and change the management and treatments to suit. This variability takes both spatial and temporal forms. Spatial variability can be understood and managed by creating yield maps and soil maps. Temporal variability is often fundamentally linked to changes in weather over time resulting in the need for real-time management.

In industry, we used to have a production line mass producing one item and are now moving over to flexible manufacturing, where each item is developed individually. In agriculture we can see a similar approach by reducing the scale of treatments from farm scale, to field scale, to sub-field scale and even individual plant treatment.

Currently tractors and associated machines are increasing in size due to economies of scale. If you pay someone for an hour then it makes sense to have them work 20 hectares rather than 10 hectares. This leads to the machines getting bigger but as the machines get bigger the opportunity to work the fields gets smaller due to the fragile nature of the soil when wet. This cycle can only be broken by making the machines significantly lighter so as not to damage the soil and thus expand the available operational weather windows.

Let me give an example of how the current system uses too much energy. I estimate that up to 90% of the energy going into traditional cultivation is needed to repair the damage caused by the machines in the first place. Chamen (1984) estimates that between 60 and 70% of tillage energy is not needed without trafficking. If we include the 20-30% that is used for occasional deep loosening of the soil, we can see that there should be significant saving by not compacting the soil in the first place. Each kilonewton of draft (horizontal) requires a kilonewton vertically for traction, which is causing the problem. If we can find a way to stop dragging metal through the soil we can nullify the problem.

There are many other examples like this.

How do we overcome all of these problems and take advantage of new technologies? One way is to improve the current system and the other is to develop a completely new system.

Currently we are seeing new technologies being introduced into agricultural machines. Most new large tractors have autosteer systems that allow much more accurate positioning and driving to avoid overlap and skip of the field treatments. This saves on average 10-15% of time, fuel, treatment costs and wages. Many tractors now not only use a CAN bus for internal system management but also an ISOBUS to communicate with the attached implements. Instead of the tractor controlling the implement, it is now the implement controlling the tractor as it is the implement that is doing the task and not the tractor. For example, when a baler needs to drop a bale, it can command the tractor to stop and when the bale has been dropped it tells the tractor to continue. Telemetry is another innovation that allows new levels of management. New combine harvesters are X-by-wire so a lot of data about the machine is digitally available. Some manufacturers can now transmit this information back to the factory for analysis. If the machine starts to operate outside normal tolerances, say, a belt starts to slip then the driver can be alerted via mobile phone before a problem becomes a disaster.

An alternative way would be to start with a new paradigm that deals with many of these issues. We recognise that farmers today have many conflicting pressures. New legislation, environmental protection, variability of world prices, single payment scheme to name but a few. All of the drivers push towards more efficient production and the reduction of input costs. Combine this with the opportunity from new technologies leads to designing a new mechanisation system based on plant needs that addresses all the drivers which in turn leads to agricultural robotics.

Can we develop a new system of machines that can assess variability in real time and only introduce the minimum amount of energy to support crop development? The answer is clearly yes. We have not yet fully answered all the questions or developed all the technologies needed but many of them have now been prototyped and we can start to visualise a complete new mechanisation system.

Management of these technologies is fundamental to economic viability and environmental sustainability. They are tools that used in the right way can benefit both, used in the wrong way could be detrimental. If the management is sensitive to both economic and environmental drivers both can be improved by using smart management and smart machines. Sustainable intensification can be achieved through increased efficiency in the food production systems.

My vision for the future is one where small smart machines move around the field establishing, tending and selectively harvesting the crops. Ten years ago I developed an autonomous tractor that could mechanically remove weeds, thus achieving 100% chemical reduction. Even then the tractor was too big and used more energy than was needed. Now one of my old PhD students has developed a laser weeding system that probably uses the minimum amount of energy to kill weeds, by using machine vision to recognise the species, biomass, leaf area and position of the meristem (growing point). A miniature spray boom of only a few cm wide can then apply a microdot of herbicide directly onto the leaf of the weed thus saving 99.9% by volume of spray. Alternatively a steerable 5W laser can heat the meristem until the cells rupture and the weed becomes dormant.

These devices could be carried on a small robot no bigger than an office desk and work 24/7 without damaging the soil or crop.

Another example is called selective harvesting. Currently many vegetable crops are harvested by hand, which is expensive even when using ‘cheap’ labour. Between 20 and 60% of the harvested crop is not saleable to the supermarkets as it may not have the desired quality attributes. This may range from too small, too large, incorrect cutting, blemishes etc. Selective harvesting envisages a robot assessing all of the quality requirements and only harvesting produce that has 100% saleable characteristics. If some plants are too small they can be left until later until they grow to the correct size. As we know the position, size and expected growth rates we can schedule a more accurate second or third harvest regime.

By looking at all the operations needed to establish, care for and harvest crop plants and identify ways to minimise inputs, we can see how a new mechanisation system can evolve. If we stop defining what we now do by the way we have done it in the past and look at the fundamental requirements we can identify new techniques that not only meet the economic, environmental and legislative drivers but also do a better job of looking after the plants.