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Application of Robotics in Modern Agriculture

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Introduction:

Agriculture is humankind's oldest and still it is the most important economic activity, providing the food, feed, fiber, and fuel necessary for our survival. To meet the increasing demands for food and bioenergy for the expected global population of 9 billion by 2050, the agricultural production must double.Given limited land, water and labour resources, it is estimated that the efficiency of agricultural productivity must increase by 25% to meet that goal, while limiting the growing pressure that agriculture puts on the environment. Robotics and automation can play a significant role in this context. In agriculture, opportunities for robotics to enhance productivity are immense and the robots are proving its efficiency in farms in increasing numbers.So, an autonomous and time saving technology in agriculture is the need of hour to have efficient farm management. The researchers are now focusing on the same to design autonomous agricultural vehicles against conventional farm machineries relied on crop and topography. Robotics helps in various fields like agriculture, defence, medicine, mining and space researches. Till date the agricultural robots have been researched and developed principally for transplanting, harvesting, chemical spraying, picking fruits and monitoring crops. Robots are perfect substitute for manpower to a great extent as they deploy unmanned sensing and machinery systems. The prime benefits of development of autonomous and intelligent agricultural robots are to improve repeatable precision, efficacy, reliability and minimization of soil compaction and drudgery. The robots have potential for multitasking, sensory acuity, operational consistency as well as suitability to odd operating conditions. Emerging applications of robots or drones in agriculture can play the role of

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vertical integration with the food production system to increase productivity in upcoming days.

History and Background:

The idea of robotic agriculture (agricultural environments serviced by smart machines) is not a new one. Many engineers have developed driverless tractors in the past but they have not been successful in the applied life. Most of them assumed an industrial style which could work entirely in predefined ways like a production line. The approach is now to develop smarter, intelligentmachines enough to work in an unmodified or semi natural environment. These machines must exhibit sensible behavior in recognized contexts. In this way they should have enough intelligence embedded within them to behave sensibly for long periods of time in a semi-natural environment, while carrying out a useful task. One way of understanding the complexity has been to identify what people do in certain situations and decompose the actions into machine control accordingly. This is called behavioural robotics and a draft method for applying this approach to agriculture is given in Fountas*et al.* 2007.

Modern agriculture grabs a lion share of energy in various forms viz. fertilizers, chemicals, machineries and fuel. The Phytotechnology approach tries to target the induced energy to improve efficacy. Chamen (1994) identified that 70% energy saving can be made in cultivation energy by moving from traditional trafficked systems (255 MJ/ha) to a non-trafficked system (79 MJ/ha). This was for shallow ploughing and did not include any deep loosening. From this we estimate that 80-90% of the energy going into traditional cultivation is there to repair the damage done by large tractors. It would be much better to not cause compaction in the first place which is one of the reasons that leads us to consider using small light machines.

Robotic application in farming:

Questions may arise of the economic justification but will certainly be an extraordinary approach in high value crops where a smart machine can replace expensive repetitive labour. If this approach were taken, it would appear that the crop production cycle could be reduced to three stages: seeding establishment, plant care and (selective) harvesting.

1. **Seedling Establishment:**

❖ **Seed bed preparation:** Ploughing is one of the most important primary cultivation processes and has been carried out since from the start of civilization. It is effectively the inversion or mixing of topsoil to prepare a suitable seed bed. A small robot utilizing current technology does not have the energy density to sustain ploughing over a large area due to the high levels of energy needed to cut and invert the dense soil.

❖ **Seed Mapping:** Seed mapping is the concept of passively recording the geospatial position of each seed as it goes into the ground. It is relatively simple in practice as an RTK GPS is fitted to the seeder and infra-red sensors mounted below the seed chute. As the seed drops, it cuts the infrared beam and triggers a data logger that records the position and orientation of the seeder. A simple kinematic model can then calculate actual seed position (Griepentrog et al. 2003). The seed coordinates can then be used to target subsequent plant-based operations.

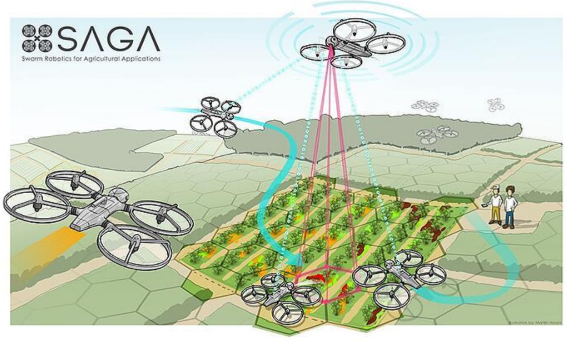

Fig 1: Seed Mapping

❖ **Seed placement:** Rather than just record the position of each seed it would be better to be able to control the seed position. This would allow not only allow the spatial variance of seed density to be changed but also have the ability to alter the seeding pattern. Most seeds are dropped at high densities within each row, whilst having relatively more space between the rows. From first agronomic principles, each plant should have equal access to spatial resources of air, light, ground moisture, etc. Perhaps a hexagonal or triangular seeding pattern might be more efficient in this context. If suitable controls are fitted to allow synchronization between passes, then there is the possibility to plant seeds on a regular grid that can allow orthogonal inter-row weeding.

Fig 2: Planting seed with robotics

2. **Crop care:**

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- **Crop scouting:** One of the main operations within good management is the ability to collect timely and accurate information. Quantified data has tended to be expensive and sampling costs can quickly outweigh the benefits of spatially variable management. (Godwin et al. 2001) Data collection would be less expensive and timelier if an automated system could remain in the crop carrying a range of sensors to assess crop health and status. A high clearance platform is needed to carry instruments above the crop canopy and utilize GPS. Smaller sub canopy machines have been developed in student competitions.
- **Robotic weeding**: Knowing the position and severity of the weeds there are many methods that can kill, remove or retard these unwanted plants (Nørremark and Griepentrog 2004). A classic example is to break the soil and root interface by tillage and promote wilting of the weed plants. This can be achieved in the inter row area easily by using classical spring or duck foot tines. Intra row weeding is more difficult as it requires the position of the crop plant to be known so that the end effector can be steered away. Within the close-to-crop area, tillage cannot be used as any disturbance to the soil is likely to damage the interface betweenthe crop and the soil. Non-contact methods are being developed such as laser treatments (Heisel 2001) and micro-spraying. Machine vision can be used to identify the position of an individual weed plant and a set of nozzles mounted close together can squirt an herbicide on to the weed. Tests have shown that splashing can be reduced when a gel is used as a carrier rather than water (Lund and Søgaard 2005).

Fig 3: Herbicidal spray using Robotics

- **Robotic irrigation:** A robotic irrigator in the form of a mechatronic sprinkler (to simulate a travelling rain gun) was developed to apply variable rates of water and chemigation to predefined areas. The trajectory and sector angles of the jet were controlled by stepper motors and could be adjusted according the current weather and the desired pattern by a small computer. When the airborne water was blown down wind, the jet angles could be adjusted to compensate by measuring the instantaneous

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wind speed and direction (Turker et al. 1998). This system could not only apply the required water in the right place but could irrigate into field corner.

3. Selective Harvesting:

Selective harvesting involves the concept of only harvesting those parts of the crop that meet certain quality thresholds. It can be considered to be a type of presorting based on sensory perception. Examples are to only harvest barley below a fixed protein content or combine grain that is dry enough (and leave the rest to dry out) or to select and harvest fruits and vegetables that meet a size criterion. As these criteria often attract quality premiums, increased economic returns could justify the additional sensing. To be able to carry out selective harvesting effectively, two criteria are needed; the ability to sense the quality factor before harvest and the ability to harvest the product of interest without damaging the remaining crop. Most agricultural equipment is getting bigger and hence not suited for this approach. Smaller more versatile selective harvesting equipment is needed. Either the crop can be surveyed before harvest so that the information needed about where the crop of interest is located, or the harvester may have sensors mounted that can ascertain the crop condition. The selective harvester can then harvest that crop which is ready, while leaving the rest to mature, dry, or ripen etc.

Fig 4: Selective Harvesting with Robotics

Alternatively, small autonomous whole crop harvesters could be used to selectively gather the entire crop from a selected area and transport it to a stationary processing system that could clean, sort and maybe pack the produce. This is not a new idea, but updating a system that used stationary threshing machines from many years ago. Alternatively, a stripper header could be used to only gather the cereal heads and send them for threshing.

Conclusion:

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Farmers have always been playing the role of moderators in the farming fields, he knows what acreage gives how much production by following classical approach. But with the modern data collecting devices of today's world, agriculture is in the midst of high-tech revolution where a robot can help the farmer from picking fruit to pulling weeds, from nursery planting to herbicidal spraying. Agricultural robots can reduce the cost of cultivation by controlling the high cost of labour, efficient use of fertilizers and pesticides. The jobs in farm field are a drag, dangerous, require intelligence and swiftness, thorough highly repetitive decisions hence robots can be rightly substituted with human operator. This approach may reduce the workload of the farmers and may emerge as a boon for the farming communities in the near future.

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