Issues and Updates on Agricultural Guidance Systems

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Abstract

Accurate positioning is the foundation for precision farming and guidance. This technology will not only enhance the current methods of farming, but will also provide the opportunity for more efficient and better farming practices. It will be possible to farm better with less inputs; accomplishing the desired benefits of organic farming, yet controlling the weed and trash problem. This paper speculates on how positioning technology will be used in the future and describes the current state of affairs for auto-steering and pre-determined field courses. It is hoped that this will serve as a catalyst for more discussion, debate and feedback with the intent of developing a better means to farm.

Introduction

Throughout history there has been an ongoing quest to make farming better. Better can be expressed in terms of profit for the farmer, quantity and quality of the produce, and cost of production. It can also envelop concerns for the environment and stewardship.

Unquestionably throughout the years, there has been an increase in yield. Yields have increased, but all the other factors for better farming are worse. Production costs are up and environmental concerns are at an all time high. The question to be asked: Can farming be made better in terms of the above mentioned? How?

Precision Farming has been suggested as better, but perhaps precision farming with a lower case 'p' would be more appropriate. To best explain this, let's view the farm operations as they may appear in the future.

Future Scenario of a Farm Field Season

The operations in the field will be preprogrsmmed. A predetermined course will be customized for each field and will be followed by the planter and all subsequent field activities. Most of the obstacles and perimeter of the field remain constant, but there are some boundaries that tend to change from year to year. The boundaries of these will be revised as needed. This is done by recording a new boundary as the farmer drives an ATV(All Terrain Vehicle) over it. Establishing a boundary requires judgement and accuracy. It is only the farmer that can make these decisions and it is necessary to have first hand information at close quarters to decide exactly the location of a boundary.

The position file is brought back to the farmer's office and superimposed on the file containing the fiied boundaries. This file is input to a course generating computer program along with the implement width, and preferred working direction and pattern. Perhaps the starting point and preferred end point as well as rendezvous points for the seeder will be put in. With all this data an optimum course is generated.

This preprogrammed course is an important tool and contains some very interesting information before one seed is planted. The course not only contains the guidance information for the seeder to fallow, it also contains the controlling clues to turn the seeder on or off as well as variable rate information. The exact area to be seeded is known a priori, therefore the precise amount of seed and fertilizer can be purchased beforehand. The distance traveled along with the predetermined velocity will give the time of operation. This is important for scheduling fill and service stops.

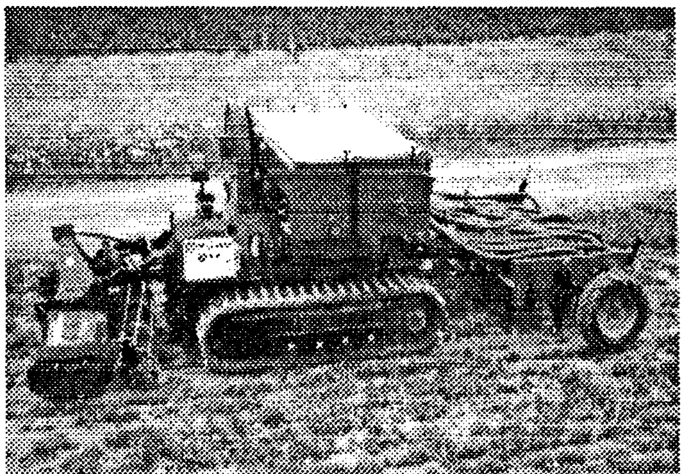

Figure 1. Robotic seeder built in Finland around 1986

The seeder is small, perhaps only 12 feet wide and carries a payload that will keep it busy for four to six hours. It requires no driver. After being loaded with seed and fuel, it goes about its business of planting at only three mph. A quarter section takes a day and a half to seed. However a farmer could easily operate four or five of these units simultaneously which would produce a seeding rate of about a section per day. The planter is made to minimize soil disturbance. Seeds are essentially punched into the ground in the wake of a trash remover, and then are gently packed with a packer wheel. The seeds are planted in rows that are one foot apart and within the row they have equal spacing. This has a double purpose; first it minimizes the amount of seed that is needed and secondly these seeds will grow up to be visible plants that are used as beacons to guide a weeder. If fertilizer is used, some will be introduced with the seed, some side dressed near the seed during this operation, but most would he applied later.

The planting is the first operation that the field experienced. There is no pre-seeding burn-off, and there will be weeds. As soon as the crop comes out of the ground the weeding operation starts. As did the planter, the weeder will follow a predetermined course that mimics that of the planter. There is however one important difference to the guidance system of this weeder; it is a two level system. At the higher level the weeder will use an electron RF positioning system to get into the right row. Once in the row the weeder will use a visual system. It uses the plants as guidance beacons. It is noted that the crop was seeded in rows with a known width, and the plants in the rows were at equal spacing. The plants in this grid pattern will be considered 'good guys' and anything that is not in this grid will be considered bad and should be terminated.

The visual guidance system has two purposes. One is to precisely guide the weeder up and down the rows and provide the information to exactly locate the weeder relative to the crop. The second function of the visual guidance system is to spot and locate all green blobs. The good green blobs will be the crop and the bad blob coordinates will be sent to a weed terminator. The weed terminator is a high pressure water knife that is mounted on a rotating turret that aims at the ground at an angle. When a weed's coordinate comes in the field of view of the water gun, it is turned on to slice the weed at its base.

Since the exact location of the weeder is known, the wheels can be kept in the rows and not on the crop. The crop is not trampled by wheels, nor is the crop traumatized by chemicals.

The weeder is only 13 feet wide and travels slowly at only 3 mph. It will take more than a day to work a quarter section. This weeding operation is done every three weeks so a field may have three or even four operations done to it. During this operation, fertilizer could be side-dressed into the crop rows.

Analysis of Scenario

Driving accurately in a predetermined field can reduce the distance traveled by 15 to 20%. This not only reduces the amount of inputs and fuel used, it also reduces the time required. For in crop operations there will be less crop trampled. Contrary to popular belief, smaller equipment is more efficient. This is because relatively less time is spent in the headland. It is more efficient, and less risky to have several small pieces of equipment than a larger one of accumulated equivalent size. Not only are the operational costs less but also the capital costs. With manned vehicles, there is a tendency to favor the use of larger equipment to capitalize on the productivity of the operator. Obviously this is not the case for unmanned vehicles and the efficiency analysis must be re-evaluated. Invariably it leads to the conclusion that *'small is beautiful'*.

In addition to being more efficient; smaller equipment is easier to maintain, to service and to transport. In terms of risk, the smaller outfit is more attractive. If a farmer has two machines working and if one breaks down the production is reduced to half. If however the farmer has one large outfit, and it breaks down, productivity is zero. Today most farms are overcapitalized to compensate for the large break-down risk factor.

The advantages of zero-til have been well documented and have been proven with practice; but this practice is not without problems. Weed control must be done without cultivation and there is an abundance of trash. It is not aesthetically pleasing and the trash can be a problem for seeding. The weeds can be controlled with a water knife and the seeder can be redesigned to accommodate the trash.

Punch Seeder

The current air-seeder is a pretty simple method of getting seed and possibly fertilizer in the ground. Then again they must be simple because they are so big. The amount of complexity on any given shank or row must be kept to a minimum. However if one considers a much smaller seeder, then perhaps some complexity could be tolerated.

The task at hand is to get the seed placed into the ground at exactly some predetermined depth and to pack the soil gently but firmly around it. There is an additional requirement of this seeder, if the plants are later to be used as visible reference points for the weeder, the seeds should be planted with equal spacing.

Let's consider one shank or row of this new seeder. Picture a little rotary lawn mower that is only three inches wide. It clears the trash and blows the clippings in the space between the rows. Its vacuum action leaves the ground almost bare. A flat belt winds its way from a seed bin down to ground level. The belt has holes in it to accommodate one seed. These holes are equally spaced along the belt. A spoked wheel inside the belt, presses the seeds out of the belt and into the soil to the desired depth. A spoked packer wheel follows. The spokes are larger than the planter spoke and they gently press soil above the seeds and do not pack any other area. The features of such a seeder:

- Minimum soil disturbance.
- Handles trash.
- Equally spaced plants in equally spaced rows.
- Weed seeds are not seeded or packed.
- No draft, and therefore very little power

Such a seeder design is feasible, but it is only practical in the context of the use of small slow moving equipment. This in turn is only practical for unmanned vehicles which in turn is entirely dependent on positioning and guidance systems.

Transition to New Technology

The implementation of this new technology will take some time. It would not be wise for farmers to abandon their current capital investment immediately. It will also take some time to fine tune the technology and have the farmers comfortable with it. The first step will have auto-steering driving the parallel lines and the headland turns will be done manually. This will happen fairly soon for spraying and seeding.

The next advancement will be the automatic execution of U-turns in the headland. The operator will initiate a U-turn by pressing a Left or Right button. A map will be painted for him on a screen, and it will still be the task of the farmer to plan the pattern. The majority of the driving will be done automatically.

Generating and following pre-determined field patterns will prove to be quite beneficial. By minimizing lateral overlap and by following an optimum field pattern, the distance traveled to work the field can be shortened by 20%.

We now come to an interesting juncture in the process of adopting this new technology. An operator following a predetermined path doesn't have much to do. All the driving is now done for him and the applicator is turned on and off automaticaly. His only job will be to monitor the process for failures. The obvious question will be: Can't I do this remotely? The answer is yes.

The point at which the operator comes to terms with a driverless operation is crucial. The equipment now used is big to capitalize on the operator's time. With no operator, all rational analysis concludes that smaller equipment is more efficient.

Self-guided small sprayers will be seen first, followed by automatic robotic seeders. Water knife weeders will be on the scene next and they will clarify the need for precise punch seeders. Robotic combines will be the last to be automated.

Where are we now? What has been Done

Inexpensive positioning has been demonstrated with GPS and Accutrak. Automatic guidance and auto-steering requires angle sensing and gyros and this has been demonstrated. A Wilmar sprayer has been outfitted with an Accutrak auto-steering system it is capable of driving very straight parallel tracks at high speeds. Further tests with U-turns will take place this summer at Lemburg.

Some work has been done in generating pre-determined field courses, but there is more work to be done. Currently we are completing a report that investigates the feasibility of a robotic weed scouter. The intent of the scouter is to have images of a crop gathered automatically with a small robot following a predetermined field path. This robot has the functional characteristics of future operator-less farm vehicles.

What is to be Done, The Challenges

Previously it was mentioned that more work is needed on the U-turns and the generation of the pre-determined field patterns. There is no doubt that these can and will be done; it is after all only software. However software development is time consuming and expensive. The interface software that controls and drives the vehicle from the field pattern must also be written. To date the control software is only capable of following straight lines.

A vehicle without a driver conjures up thoughts from horror movies. Even though the vehicle is small and is committed to following a pre-determined path; it is possible that something, or someone could get in its path. In this event, it is essential that the thing is detected and that the vehicle stop immediately. To detect an obstacle, a light bumper with collapsible struts could extend several feet out in front of the vehicle. Any force on the bumper would activate switches, which would shut down the vehicle immediately.

Sonar sensors built into the struts could scan for objects in front of the vehicle and inform the controlling processor that, something is in the path. The field could also be posted to dissuade trespassers from entering. These measures of security would have to be thoroughly investigated and tested.

There has been a considerable amount of work on row-following using visual techniques such as video cameras. This work would be enhanced to include the determination of weed positions between the rows, and to have the ability to lock onto a grid pattern of equally spaced plants within a row. This requires only crude image processing and these techniques are in common use in other industries. The imaging techniques require the transfer of technology to be used on a moving vehicle. This is certainly feasible, but again requires some development work.

The water-knife weeder is also technology that is in common use. Water knives are used to cut three-inch steel plates, and to cut hundreds of layers of cloth in the garment industry. The challenge in having a water-knife cut down a weed, is a question of controlling the knife with speed and accuracy. There is plenty of trial and error development work to be done here.

The punch seeder would be the ultimate planting machine, with a bit more sophistication than conventional seeders. Cbviously more work in this area is needed.

Conclusions

It is evident that positioning and guidance are more than just driving a vehicle accurately. The technology opens the door to dramatically changing the farm field operations from seeding, to weeding to harvest.

Farming with small automated vehicles is a better way to farm. It is better for the farmer, the consumer, the environment and the land. Most of the technology needed is now in use in other industries, but it must be transferred, developed, and integrated. Farm production costs could be reduced significantly, by as much as 50%. To achieve this better way of farming, it will take the effort of the research community, the cooperation of the farmer, and the political will and support of the government.