Controlled Traffic and Guidance Systems

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Introduction

This paper outlines the requirements to effectively operate a Controlled Traffic farming system, with emphasis on the need for some form of automatic steering assistance for farm machinery. The material presented is based on work being undertaken at the U.S.Q. for the Cotton Research and Development Corporation. Project DDI 1L is developing guidelines for establishing controlled traffic farming systems. Project goals include the provision of a bolt-on, economical, reliable automatic guidance system for existing farm machinery.

Why use controlled traffic?

Control traffic farming allows soil compaction problems to be controlled and reduces production costs for most crops. For the purposes of this paper, "compaction" is defined as any form of structural degradation caused by the rearrangement of the soil particles so that void space is reduced. Such reduction is usually caused by soil particles moving over each other in response to loadings exerted by machinery wheels. The end result is a soil with less space available for the movement of water and air, and with an associated higher density and strength that will resist penetration by plant roots. As a result, crops more easily become waterlogged or water stressed due to insufficient air or water supplies in the soil voids.

The following general points can be made about controlled traffic farming:

- soil compaction is an inevitable result of farming with today's machinery

  Using the soil bin facilities at the National Tillage Machinery Laboratory in the U.S.A., Taylor et al (1982) found that 75% of the change in bulk density and 90% of the sinkage in the soil surface was associated with the first pass of a farm machinery wheel.

- such compaction already exists in many cotton farms in Australia,

  Dr Des McGarry (Qld Dept. Primary Industries, pers. comm.) has observed some degradation in the soil structure of all cropping farms recently surveyed for the National Soil Conservation Program.

- compaction does affect cotton growth and yield, although the effect is often disguised by other parameters such as nutrient levels

  Thomson and Cull (1989) investigated the wave patterns found in cotton crops in the Gwydir valley of N.S.W. They measured a 26% reduction in yield from plants over the wheel ways, with a 15% overall field reduction in yield. The compaction effect was estimated to extend for 1.5 metres from the wheels.

- the effects of compaction on cotton extends beyond the first season

  McGarry and Chan (1984) compared production from back-to-back and out-of-fallow cotton crops in the Namoi valley and concluded that compaction was having a long-term affect on yield.

- there is a yield penalty from uncontrolled compaction over a period of time, with the worst effects seen during wet and dry years

Advantages to a grower

Cox and Thomson (1989) interviewed growers and used computer models to estimate the cost of harvesting delays in cotton growing. Their values range from 0.2% yield loss/day in the Gwydir and Macintyre valleys to a maximum 4.2% yield loss/day in Emerald. Improved timeliness in harvesting through controlled traffic farming could reduce these costs to cotton growers.

Potential advantages to a cotton grower also include:

- the preservation of soil structure from gradual degradation under repeated wheel loadings,
- access to the crop under wetter soil conditions and hence greater timeliness in field operations,
- reduced fuel costs for most tillage operations, and
- possibly a reduction in the total amount of tillage required.

Key Elements of Controlled Traffic System

Adoption of controlled traffic farming requires all field operations to fit into an overall management system for the farm. Aspects that must be addressed in order to make this system work include:

- modifications to existing machinery so that wheel spacings are standardised on all equipment
- establishment of suitable guidelines for tilling the soil
- combating seasonal drift in the location of the permanent beds,
- in-season protection of beds from machinery compaction

The latter two requirements can be effectively met only with some form of automatic steering assistance for farm machinery.

Proper management of a controlled traffic system is intended to maintain permanent laneways in the field. Any movement in these laneways will result in the loss of a corresponding part of the production zone until the compacted soil is naturally alleviated. The length of time for the compacted soil to be restored obviously varies with soil type, but can be many years. It is essential that a machine does not waver in its path down the crop row, as this will result in the gradual widening of the compacted laneway at the expense of the crop production zone. The amount of wander in a machine's movement depends on the type of operation being undertaken and on the experience of the operator. In all cases it becomes more difficult to accurately steer as the speed increases.

The Role of Guidance Systems in Controlled Traffic

Guidance systems provide assistance to improve the steering performance of operators of farm machinery. Suitable systems must be able to meet the following objectives for a true controlled traffic system:

i) to establish the initial field layout, including laneway positions, consistently from year to year,
ii) to guide pre-emergence operations, including seedbed preparation and sowing,
iii) to guide weeding operations following emergence, with implements working as close as possible to small seedlings,
iv) to provide guidance through a mature crop so as to minimise damage.

A range of basic steering aids is commercially available to growers, but these devices satisfy at best only one of the above goals - most fit into the second or third categories. It should also be noted that the steering accuracy attained from available tracking devices is generally not sufficient to prevent the gradual widening or wandering of a compacted wheel laneway.

Work in Project DDI 1L to date has concentrated on leader cable and ultrasonically based systems as having the most potential for meeting more than one of the above criteria without resorting to expensive total positioning systems. These systems are cheaper because they can be built largely from off-the-shelf component modules.

Leader Cable System

A leader cable system provides a guide wire for the operating machine to follow. During use, a small current induces a magnetic field around the wire. A sensor, positioned slightly ahead of the tractor front wheel, uses two coils side by side to pick up this magnetic field. The sensor is precisely over the buried wire when the voltage detected by the two coils is the same. As the tractor moves away from the wire the voltages from the coils differ and cause a signal to be fed to an electrically-actuated steering pump or solenoid valve coupled to the tractor's steering system. This produces the necessary steering correction to keep the tractor as close to the wire as possible.

Laboratory testing has shown that the system could be used to steer a farm tractor but serious practical limitations are foreseen if the wire is buried for protection. The life-span of buried wire is unknown and the economics of such a system have proved difficult to establish. The capital cost of a wire system is also relatively high, and is perhaps the most limiting factor on the adoption of leader cable systems.

Ultrasonic System

An ultrasonically based guidance system is designed to follow a defined feature on the ground surface. It is claimed to be capable of guiding pre-emergence operations once the hills and furrows are in place and post-emergence cultivations once the seedlings are large enough to define the crop row.

The system uses two transmitter/ receivers, fixed about 0.8 m apart on the front of the vehicle, oriented diagonally downwards towards a furrow, ridge or some other physical feature. The time taken for an emitted ultrasonic pulse from each transmitter to be reflected back is measured by on-board equipment . While the vehicle remains on course this time will be equal for each transmitter. The times differ once the machine moves off-course and a correcting signal is then sent to the steering system to bring the vehicle back on line.

A field test program has found serious practical limitations to its use with cotton. Firstly, the sensors are operating to the limit of their sensitivity while the plants were small. As a result, they regularly lose the row and the system was found to be unsuitable for operations under objective iii). Other testing has shown that the system sensitivity to other ground features is not as high as expected, with the tractor exhibiting large amounts of wander during operation. Current indications are that such an "off-the-shelf" system would need considerably more development work before it could offer significant advantages over the guidance devices now commercially available.

Future Research Directions

The guidance work done to date on this project has established that no commercially available guidance device can meet all of the required objectives for a controlled traffic farming system, although some devices could be used to fulfil individual tasks in such a system. It has also been established that neither leader cable nor ultrasonic technology is likely to provide an acceptable alternative system to that now available.

The project is now proceeding to investigate the next level of sophistication (and expense) in technology that could be adapted to machinery guidance.

A new Mechatronics research group, established at the U.S.Q. under the direction of Professor John Billingsley has started to investigate high-speed optical guidance. A video camera provides a computer with images of the ground and crop lines ahead of the tractor. This information is combined with wheel sensor and other signals to optimise the dynamic performance of the tractor in aligning itself with the features in the field. It is anticipated that this form of guidance can remove the speed limitation of a human driver and fulfil the criteria ii), iii) and iv) above.

A parallel investigation is also planned, based on the concept of absolute positioning, as recommended by Schoenfisch (1989). A system that can track a farm machine and continuously provide its position in the field would be more expensive to produce then the alternative techniques investigated in this project. It would, however, meet all of the objectives for a controlled traffic system. Such a system would also allow current farming practices to be refined by varying the operational controls with position in the field. It becomes possible, for example, to apply a variable fertilizer rate to a field according to a prepared plan of its nutrient status - or to accurately apply herbicides in bands.

The technology available to develop an absolute positioning system is now available, and clearly represents the future in controlled traffic farming. The rate of adoption will however depend on the cost at which a reliable system can be produced. The parallel work on optical guidance at the U.S.Q. might well provide an interim solution for growers until the more sophisticated system becomes available.

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