

Automatic Guidance for Farming Tractors

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Abstract

A vision guidance system has been designed, built and commissioned which steers a tractor relative to the rows of a crop such as cotton. It was required to be insensitive to additional visual "noise" from weeds, while tolerating the fading out of one or more rows in a barren patch of the field. The system integrates data from several crop rows, testing for image quality. At the same time, the data processing requirements have been limited by the use of frame-sequential strategies to reduce the image space which must be processed. The current prototype employs an embedded 486 PC notebook computer and shows great promise of cost effective commercial exploitation.

Experimental results are reported and further sensing systems are explored to enhance performance in difficult environments.

Introduction

There is a need for automated guidance of agricultural vehicles, not to remove the presence of a driver but to allow greater attention to be given by the driver to the cultivation operation. Automatic steering also promises to improve the effectiveness of "controlled traffic", a technique where by repeatedly using the same "footprint", vehicles minimise compaction damage to the soil. Under manual control, this increases the pressure on the driver to maintain precise control of the track of the vehicle. The experimental vehicles are already capable of much more accurate sustained control. For spraying operations, high speeds are desirable to enable a ground vehicle to challenge the role of a crop-spraying aircraft. Once again, the driver's task is made

more demanding and an "auto pilot" becomes highly desirable.

Many guidance methods can be considered, ranging from buried leader cables to beacons, surveying instruments or even satellite navigation. All have their drawbacks. The most appealing method is to follow human practice and take guidance from the crop itself, steering the vehicle by means of the view of the rows ahead.

There are, however, many complications as the condition of the crop changes through the growing cycle. Initially the plants appear as rows of small dots among scattered random dots, the weeds. Later they fuse to form a clear solid line. Before long, however, the lines have thickened and threaten to block the lane ways. Many variations of the vision algorithm are thus required to fulfill all the seasonal requirements.

Vision systems can acquire data at a very large rate. A full-colour high-resolution image can require 1.4 megabytes of memory to hold it, and twenty-five such images are received from a conventional camera each second. Many vision projects have become congested by such data rates, requiring massive computing power to extract the simplest of features. The policy in this project has been to limit the acquired visual data to a modest level and to use frame-sequential analysis methods to select only that fraction of the data for analysis that will yield the necessary steering data.

Within a single 486 computer, software was implemented for both image analysis and on-line control of the tractor. Initially a stepper motor was used as the steering actuator, but the very restricted steering slew which this could achieve meant that limit-cycle instability was prone to occur at all but the lowest velocities. The use of a variable-structure control algorithm gave substantial improvement, but the system was still sensitive to the accuracy of initial calibration.

The stepper was replaced with a geared DC motor as used in a cordless drill. The computer interface employed two relays for the final output, so that the bang-bang operation would emulate the control of hydraulic steering valves in a future

implementation. The performance was dramatically improved and the steering mechanism was no longer seen as a limitation.

Although the machine performed well, its appearance was most inelegant. A 250 volt inverter and a computer tower-case were taped to the roof of a tractor, while the monitor screen was held on the bonnet in front of the driver by even more adhesive tape. A camcorder was similarly taped to the front of the tractor.

Funding of A\$150,000 was at that stage granted by the Cotton Research and Development Council and J I Case donated the long-term use of a Maxxum 5130 100 horsepower tractor. The research which had up to then proceeded with minimal resources was put onto a sound footing.

The cordless drill motor was replaced by a specially designed hydraulic valve system for direct actuation of the steering. A notebook computer with expansion rack was substituted for the tower case. The vision sensor is still a camcorder, now neatly fixed to the bonnet with Velcro, but the overall appearance is much more impressive. The vehicle is already capable of traveling through a crop at over 25 kilometres per hour with only a centimetre or two of waver.

Image acquisition

The system uses a camera interface targeted at the consumer market, the "Video Blaster". It is available at a relatively low price and has some very impressive features. A full colour image is captured in the on-board memory, and can be merged "live" as a window forming part of the VGA display. The image can be scaled horizontally and vertically with no use of the processor time of the host computer. Lines and other graphics can be superimposed on the screen image, so that the performance of the analysis system becomes very clear to see.

The benefits gained far out way any limitations. It is now possible to use the chrominance signal rather than luminance to capture an image based on the "greenness"

of each point. The spatial resolution of chrominance is nowhere near as sharp as that of luminance, but resolution is not of the greatest importance.

Excellent performance has been achieved, although some processing speed is lost in decoding the colour information.

Figure 1 best describes the image analysis of the system

Continuing work

With a series of very successful demonstrations the project is by no means at an end. The final objective is a system which can be used literally "in the field" on a commercial basis.

There are many decisions to be made concerning additional sensors for operating in other modes. When the field is first to be marked out, the task of ruling straight furrows perhaps two kilometres long is a taxing one. A flux-gate compass unit has been interfaced to the system to address this problem.

At planting time, the furrows exist but no crop is present. It is possible that under suitable daylight conditions or at night with suitable headlights the furrows could be made to stand out with sufficient contrast. The attractive alternative is to use tactile sensing of the furrows with an electromechanical transducer.

When the canopy has closed in, no gaps can be perceived between the rows. The addition of tactile stalk-sensors can be used for more accurate guidance of harvesters and post-harvest stalk-pullers.

These and many others are aspects under investigation for the generation of a wide-capability system.

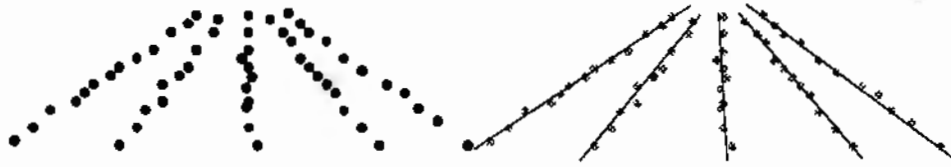
With additional funding being injected into the project by JI Case, six prototype systems will be put into the field during the 1994/1995 growing season. This will give excellent feedback as to the field operation of the guidance system.

Conclusions

A program of research combining theory and experimentation has resulted in the verification of a practical guidance system, despite early limitations of very meagre resources. Now that adequate funding has been allocated, the system can be prototyped to professional standards and its performance enhanced to achieve industry acceptance.

References

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- Smith A.L, Schafer R.L, Young R.E (1985); Control Algorithms for Tractor Implement Guidance. Transactions of the ASAE, Vol. 29(2):415-419.
- Campbell N.W, Thomas B.T (1993); Navigation of an Autonomous Road Vehicle Using Lane Boundary Markings. Paper Preprint 1st IFAC International Workshop on Intelligent Autonomous Vehicles, Pgs. 169-180.
- A Vision-guided Agricultural Tractor, J Billingsley, M Schoenfisch, Australian Robot Association Conference, Robots for Competitive Industries, Brisbane, July 14-16 1993.



Newly sprouted plants appear in relatively neat rows

1.

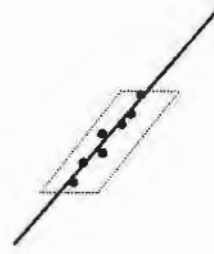
Steering information can be derived from lines fitted to the row images

2.



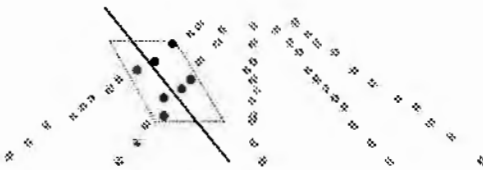
Part of the image is selected in a window

3.



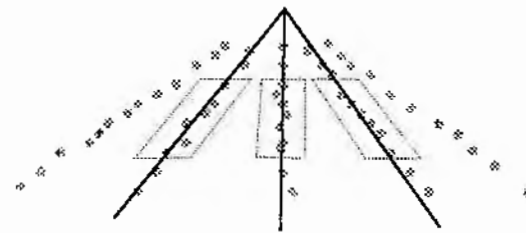
A regression line is fitted to the points

4.



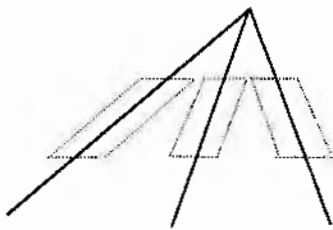
The moment about the regression line gives a measure to guard against errors

5.



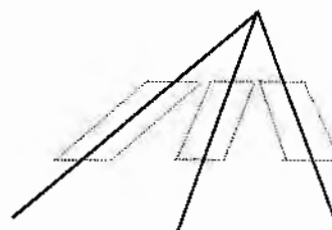
A group of three windows is updated by corrections to all valid regression lines

6.



Movement of the vanishing point indicates a change in heading

7.



Movement of the pattern centre indicates lateral displacement of the vehicle

8.

Fig. 1. Slides illustrating the image analysis algorithm.