The Good, The Bad and The Ugly: Advanced Technology in Agriculture

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Introduction

A few years ago, mentioning the words GPS, vehicle guidance or computers at a farm show or talk normally earned a look of disbelief, concern or ridicule. Today, times have changed. GPS and yield monitors are virtually standard equipment on most grain combines. An increasing number of farms have access to the Internet. Vehicle guidance, however, still seems like a distant, futuristic technology.

Automatic steering systems have been available for several years. Mechanical feeler systems, including the Tri-R system², can provide moderate performance at a reasonable cost, but face limitations (Figure 1). Mechanical feel systems are crop limited and require a relatively stiff crop that has reached sufficient maturity for the feeler to detect. The feeler systems are both speed and curve limited due to the design.

Newer commercial systems take advantage of sophisticated sensors and computer systems to guide the vehicle under a range of conditions. Beeline Navigation, IntegriNautics and Trimble Navigation are three companies who have introduced GPS based guidance systems in recent years. The systems are expensive, leading many farmers to question, “should I buy one?”

Background

When we start to talk about guidance systems, there are two basic types of systems: automatic and autonomous. An automatic guidance system is one in which the operator remains with the vehicle, but uses a control system (computer) to simplify things. An autonomous system is a driverless system. The distinction between the two is

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² Tri-R is a trademark of Tri-R Innovations. Mention of trade name, proprietary product or specific equipment does not constitute a guarantee or warranty by the University of Delaware, and does not imply the approval of the named product to the exclusion of other products that may be suitable.
important because it determines not only the cost of the system, but the sensors and complexity required.

With an automatic system, the system controls only a few functions, steering or throttle, for example. The driver remains on the vehicle and pays attention to the implement or operation. The operator takes control of the vehicle to turn at the end of the row or when there is a problem in the field. The operator drives from the farm to the field. Since the operator remains on the vehicle, they can function as a “safety sensor” and take corrective action when something is wrong.

With an autonomous system, the entire vehicle is controlled. Switching to a completely computer controlled system allows the entire vehicle to be completely redesigned. The cab, for example, is not needed on an autonomous vehicle. The cost and weight savings by eliminating the cab can be significant. Eliminating the cab and the manual controls, however, can make it difficult to perform simple tasks around the farm (i.e. pull a wagon, plow the road, etc.). Without an operator on the vehicle, the length of the working day isn’t a concern – the system works the same 24 hours a day, day in, day out. If the tractor or combine can be used longer, it creates opportunities for smaller, more efficient vehicles.

The sensors are one of the keys to a successful automatic or autonomous system. The sensors provide information about the location or surroundings. Ideally, agricultural guidance systems would utilize a single sensor that was accurate, reliable, provide local and global information and be affordable. Unfortunately, there is no single ideal sensor for agricultural vehicle guidance.

The systems available on the market have utilized GPS as one of the primary sensors. Uncorrected stand-alone GPS systems are not accurate enough for agricultural use; however, real time kinematic (RTK) GPS systems provide the accuracy required to enable row crop guidance in high value crops. Current RTK systems offer 1 in. (2.5 cm) accuracy, but come at a price. In 2002, a typical RTK GPS system required a base station, radio and mobile receiver at a total cost of approximately $40,000 - $50,000. GPS is an all-weather sensor that can provide accurate global location information. While GPS can indicate where the receiver is located, it cannot detect information about the immediate surroundings. GPS is normally used for map-based control, but if there are changes to the field that are not on the map (i.e. your neighbor’s truck in the middle of the field), the system has no knowledge of them.

Machine vision has been utilized for several research automated guidance systems. Machine vision utilizes one or more cameras located on the vehicle to look at the field. The video from the camera is sent to a computer, which processes the image and locates features of interest (i.e. crop rows) in the image. The position of the vehicle relative to the row is used to guide the vehicle. Machine vision has the advantage that it can be used in a field with little set up time (unlike a GPS based system which requires a predefined map). Machine vision-based systems, however, are typically only intended to handle a very narrowly defined crop system. Changes in the crop, whether man-made or natural, can cause the system to operate incorrectly or erratically. Since the images are based on the natural surroundings, the system cannot be used before emergence (i.e. planting) or when plants are missing (i.e. low spots). Machine vision-based systems normally do not provide a true location, only relative measurements. The relative measurements can be a problem when trying to mix different types of systems.
In spite of the difficulties, machine vision has been successfully used to guide agricultural vehicles in the field, as shown in Figure 2.

A properly designed multisensor system can compensate for the shortcomings of an individual sensor and provide redundancy. For example, RTK GPS relies on radio signals from the government satellites and from a local base station. Tree lines, buildings and distance between mobile (vehicle) receiver and the base station can cause a loss of signal, which significantly decreases the accuracy of the system. What happens if you’re cultivating when the radio link goes down? If there are other sensors on board (i.e. machine vision or inertial), the vehicle can continue to operate. Multisensor systems, however, are expensive and require additional equipment. It should be noted that many of the current GPS-based guidance systems include additional heading and acceleration sensors to improve performance and redundancy.

The Good

Why are people even looking at guidance systems for agricultural use? Guidance systems have been successfully demonstrated under a variety of conditions. Guidance systems offer a reduction in the driver effort required and promise an increase in efficiency.

Practical vehicle guidance systems have been demonstrated under a variety of conditions. Researchers at Stanford University (O’Connor et al. 1995; 1996; Bell et al. 1997) have developed a GPS guided tractor that was capable of line tracking accuracies of better than 2.5 cm. Machine vision-based systems have been used to cultivate at night or during the day on straight or curved rows (Reid et al., 2000). Without the cultivator, the system was able to control the tractor at speeds of up to 17 km/h in row planted soybeans. Researchers working with New Holland were able to develop a robotic windrower that utilized fly-by-wire and machine vision technology to successfully cut alfalfa under typical field conditions (Figure 3) (Ollis, 1997; Ollis and Stentz, 1996; Fitzpatrick et al., 1997). The systems have been demonstrated, although mainly in limited acres.

Figure 2. Machine vision guided tractor developed by the University of Illinois at Urbana-Champaign in the field.

Figure 3. Robotic windrower developed by NREC and NH.
Reducing driver fatigue and effort has been commonly cited as one of the main reasons for adding a guidance system. The operator is one of the greatest limitations to increased vehicle performance (Fitzpatrick et al., 1997). As the size of the vehicle increases, the operator has to spend more and more time steering, leaving less attention available for implement performance (Wilson, 2000). Most operators do not function at the same level all day (i.e. they get a little sleepy after lunch). While the automated systems may not always be as good as the best operator, the systems operate at a constant level that is better than an inattentive operator.

The early guidance systems did not compare well to a human operator. They required more set up time and could not operate at the same speed or accuracy as a good operator. Today, the trend is changing. The current systems can operate at speeds faster than a human operator would find comfortable. In many manual operations, 10% overlap is required to avoid skips; with GPS based light bars and a human operator, overlap can be reduced to 5%. Some operators claim that by going to a GPS based guidance system, they were able to reduce row spacing and increase the available area for planting. Palmer and Matheson (1988) estimated that an improved navigation system could reduce up to ten percent of field crop production costs.

The Bad

While there are potential advantages for agricultural vehicle guidance, agricultural vehicle guidance also faces a number of problems including safety, economics, demonstrating utility and equipment concerns.

Safety is critical for a practical agricultural guidance system. Safety includes everything from obstacle detection to stability and control at speed. There is currently no reliable single safety sensor. GPS, as mentioned before, lacks real time information about the immediate surroundings. GPS – or any map-based control – is only as good as the map on which it’s based. Supporters of machine vision-based systems inevitably cite obstacle detection as an advantage of machine vision systems. Unfortunately, very few of the systems have actually incorporated reliable obstacle detection. The few times when obstacle detection was added to the system, it was typically turned off or removed to improve performance. Because of safety concerns, the current generation of systems require an operator on the vehicle to function as a "safety sensor".

Agricultural vehicle guidance is currently an expensive proposition. In 2001 prices, a Trimble system listed at $54,000, IntegriNautics at $48,000 and Beeline at $46,000. Each of the systems utilized a RTK GPS system, which meant that an accurate GPS was required both on the tractor and at the base station.

There are a number of issues interfering with actually gaining useful work out of the systems. The navigation systems on the market were largely developed elsewhere in the country and dealer support is largely not available in the Mid-Atlantic. Beeline, for example, had no units east of Colorado and would not even consider selling one to Delaware. Trimble has GPS dealers in the area, but in Fall 2001, the closest navigation dealer was Ohio. IntegriNautics didn’t intend to be any closer to Delaware than a visit to Michigan for an equipment show. The GPS systems available are limited to straight fields. Trimble indicated that their system was not capable of circular fields, but “updates to the software should add the capability.”
Base station range limits the utility of the current systems. Most of the base stations available have a range of six to eight miles. Radio repeaters can be used to extend the range, but add to the cost. The base stations require a known, surveyed location for maximum accuracy, but can be moved from site to site. Moving the base station, however, takes time and energy.

**The Ugly**

The current systems are difficult to justify, especially for smaller producers. One manufacturer, Beeline, suggested that a minimum of 2,000 acres and a minimum of three operations are necessary to pay for a system. Gan-Mor and Clark (2001) estimated that a guidance system for variable rate and pesticide applications would require approximately 25,000 acres.

Given the cost of the systems and the acreage required to pay for the systems, obsolescence is a concern. Computer technology changes very rapidly and farmers cannot afford to replace agricultural equipment at the same pace. Additional features can be helpful, but long-term supportability of the technology is critical. GPS is a critical technology for a number of industries and is unlikely to be phased out any time soon. GPS correction services, such as Satloc, have changed with more regularity. The hardware tends to have a longer functional life than a useable lifespan. The equipment still functions when the next generation – the one supported by the company – has come out.

**Making it work for Delaware?**

Is it possible to make the guidance systems work for Delaware? Yes. Will simply add a guidance system to your vehicle and making no other changes pay? Not likely.

The guidance technology is a tool, but like any tool, is only effective when utilized effectively. For example, if guidance technology can be used to eliminate a cultural practice, then there are potential economic and agronomic benefits. Luckily for Delaware, guidance systems will be most profitable in high value crops, where a small increase in efficiency can more directly translate to an increase in profitability. Researchers estimate that guidance technology can result in a 10% improvement in yield, which would translate to a $40 to $900 per acre increase in profit depending on the conditions and crop (Gan-Mor and Clark, 2001).

Guidance systems can be used to control the traffic in the field, which has several potential improvements. Compaction and long-term field use reduces yield 15% to 25%. A controlled traffic situation reduces the compaction, which can eliminate or reduce the tillage needs. Controlled traffic would allow drip irrigation lines to be permanently placed in the field. Controlled traffic fields, however, require the fields to be managed the same way year to year.

In conclusion, agricultural guidance systems are coming. At some point in the not-to-distant future, they will be the yield monitors or air conditioned cabs of today. Many of the technological hurdles have been dealt with or are under research. The technology, however, has not been proven at the farm level. While the focus has been on developing the technology, there has not been the same amount of emphasis on learning how best to utilize the technology.
About the Author

Dr. Eric Benson is an Assistant Professor in the Bioresources Engineering Department at the University of Delaware. Dr. Benson graduated from the University of Delaware in 1996 (B.A.S., Agricultural Engineering Technology) and from the University of Illinois at Urbana – Champaign in 1998 (M.S., Agricultural Engineering) and 2001 (Ph.D., Agricultural Engineering). While at the University of Illinois, Dr. Benson was part of a team that developed six different automatic or autonomously guided agricultural vehicles. Dr. Benson’s research concentrated on the development of an automatic guidance system for agricultural combines.

Sources:


Companies mentioned:

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