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Teaching Precision Agriculture Technology with Modified Diesel Golf Cart

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Abstract. *A four passenger electric golf cart was donated to the Clemson University Agricultural Mechanization and Business (AGM) program. Creative Inquiry (an undergraduate research program) and senior capstone students replaced the existing electric drive golf cart by designing and building a powertrain utilizing a diesel engine with a hydrostatic transmission. A design constraint imposed required that the golf cart be suitable for use by Agricultural Mechanization & Business instructors as an educational tool to teach students activities in laboratories, most specifically as a mobile precision agriculture teaching platform. The golf cart is capable of carrying four people safely, and can be used to demonstrate agricultural power and machinery principles in addition to precision agriculture technologies. With the incorporation of GPS guidance and variable rate controllers, students have the opportunity to control and learn the technologies and operations as passengers, rather than as operators. Such in-field teaching activities would otherwise have to be conducted on a tractor or harvester with only a single operator, the student. Such a platform allows the students to place all of their focus on the precision agriculture technologies while in the field. After students are familiar with the on-board guidance, data acquisition, and controller technologies, they can proceed to in-tractor applications of the same technologies where they can place less focus on learning and more focus on applying what they have learned. The learning process is improved additionally by the ability of the instructor to be on board the equipment during student operation, to assist with trouble shooting and other learning barriers.*

Keywords. *Precision agriculture, Variable rate control, GPS guidance, GIS, Zone management, Teaching agricultural mechanization, Power machinery.*

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Introduction

Precision agriculture is an avenue in which many students have an interest. In 2012, the revenue for the Precision Agriculture Systems and Service industry was expected to grow at an annual rate of 1.3% in the next five years (AgFax, 2012). Due to the economic impact of precision agriculture and market for students' jobs, this industry has the potential to dramatically change agriculture in the 21st century. It enables the producer to monitor production, control operations, and collect data allowing for better decision making (Gautam et al., 2011).

Precision agriculture is a growing topic and plays an important role in an undergraduate agricultural mechanization program. An undergraduate precision agriculture course serves as an introduction to the role of the technology in the agriculture industry, and includes principles and hands on application of technologies supporting precision agriculture. When using hands-on precision agriculture activities, student evaluation of the educational benefit was overwhelmingly positive (Johnson, 2007). Topics discussed include global positioning systems (GPS), geographic information system (GIS) software, variable rate application (VRA) technologies, collection of spatial data, automated guidance of equipment, spatial data mapping and analysis, remote sensing, and economic considerations. GPS is used to geo-reference agronomic data and points of interest on the go as field operations are conducted. GIS software is used to store and analyze map data, and develop field prescription maps. VRA automatically adjusts the application rate to match the rates prescribed (Dickinson et al., 2006). Within a typical undergraduate precision agriculture course, each of these topics has a laboratory activity associated with it. Johnson (2007) discussed laboratory activities that were taught using a 45 horsepower tractor, allowing only one passenger or operator to utilize and control the technology. This did not allow for the full potential of the learning process, utilizing instructors and peers in the ability to give real time feedback and responses.

The Clemson University Agricultural Mechanization and Business (AGM) program has two classes that discuss precision agriculture. These two classes are Machinery Management (AGM 206) and Precision Agriculture (AGM 410). Both are hands-on classes, which allow each student the opportunity to operate equipment in a lab setting. Undergraduate students and their faculty mentors modified a golf cart to serve as a mobile precision agriculture teaching platform for use in these laboratories. The instructor and up to three students are able to ride on the golf cart and use the equipment. This is in contrast to using a tractor for introduction of precision agriculture technologies in field applications, where there is a safety factor involved and only one person can ride on the tractor. Some students have never driven a tractor before and this allows them to comfortably learn the precision agriculture equipment without having to focus on driving a tractor at the same time. After they are comfortable with utilization of the technology as a passenger, they can then "graduate" to on-tractor application of the same technologies. The project also consists of a belt driven power take off (PTO) shaft with an electric clutch that operates the pump of a 60 gal sprayer. The sprayer has been modified to be trailered or used as three-point hitch mount.

Objectives

The purpose of this project was to develop a precision agriculture teaching platform on which multiple passengers can safely ride and operate equipment, including a VRA sprayer. Objectives were to:

1. Convert a standard four passenger electric golf cart for suitability in agricultural field applications, with a diesel engine and PTO shaft.
2. Integrate GPS, GIS, VRA technologies, and a compact sprayer.
3. Develop lab activities allowing students to operate light bar, boom section control (manual and automatic), and field mapping technologies.

Methods

AGM has a special problems course (AGM 473) and senior level capstone course (AGM 472). This project was completed by two semesters of capstone groups (6 students) and three semesters of special problems groups (9 additional students). These students were responsible for design and build of the entire project. The precision agriculture teaching platform and sprayer has not only assisted in teaching the technologies, but also allowed for these groups of students to gain a better understanding of the mechanical and electrical systems.

Golf Cart Modifications

The golf cart (ClubCar J0036, ClubCar LLC, Augusta, GA.) donated for this project was powered by an electric motor and multiple deep cycle batteries in parallel. This vehicle had the ability for three to four students to safely ride in the field during operation. The original drive system was discarded in order to accommodate installation of a 19.8 kW (26.5 hp) diesel engine (Briggs & Stratton Daihatsu 58A447, Briggs & Stratton Corp., Milwaukee, Wisc.), made available by a donation to Clemson University. A hydrostatic transmission was chosen based on space constraints and desired field operation, including desire for continuously variable speed operation at fixed engine speed and reversibility.

In order to convert the current golf cart into a four passenger tractor with the ability to operate a VR sprayer and GPS system for precision agriculture equipment, the following tasks had to be addressed:

1. Safety
2. Engine installation
3. Transmission
4. Clearance for field operation
5. Power take off
6. Hitch point

Sprayer Modifications

A 227 L (60 gal), 356 cm (140 in) swath three-point hitch boom sprayer (LG-60-3PT, Fimco Industries, Dakota Dunes, S.D.) was purchased at farm supply retail store and serves as the base unit for this portion of the project (fig. 1). The sprayer was equipped with a 540 rpm pto-driven roller pump with a maximum flow rate of 36.9 L min⁻¹ (9.76 gal min⁻¹) and a maximum pressure of 1,030 kPa (150 lb in⁻²) (Hypro 6500C, Pentair, Ltd., New Brighton, Minn.). For typical applications with the nozzles selected, the sprayer needed to be operated at 276 kPa (40 lb in⁻²), which provided a flow rate of 32 L min⁻¹ (8.5 gal min⁻¹), exceeding the needs of the 7 nozzles. The manual boom included seven standard TeeJet® (Spraying Systems Co., Glendale Heights, Ill.) flat fan spray nozzles, and seven TeeJet® Triple Nozzle Body tips purchased for the automatic boom.



Figure 1. Sprayer before modification for manual or automatic boom section control. (Photo credit: www.tractorsupply.com)

For this project, a monitor was needed to control the electric boom section valves. Two different Ag Leader® (Ag Leader Technology, Ames, Iowa) monitors were considered, Versa™ and Integra. The Versa™ monitor was chosen because it was less expensive yet still performed the necessary operations to operate the sprayer. The Integra model exceeded the needs of this project as it can perform operations for advanced planting and yield monitoring such as: planter population monitoring, advance seed monitoring, smart report, harvest variety tracking, and several other operations. The Versa™ model does not have the capabilities to do these things but, since this monitor will only be used for spraying, the advanced planting and yield monitoring programs will not be required. The sprayer was assembled and then calibrated as a part of an AGM 206 lab activity.

Lab Activities

Precision agriculture builds on many different concepts, so it is only fitting that each lab activity builds on the

next. The golf cart allows students to not only see the equipment in the field but conduct setup and preparation before operation. Topics for which activities have been developed for use with the golf cart and sprayer are:

1. Field Mapping
2. GIS Mapping
3. Soil Sampling
4. Light Bar Guidance
5. Boom Control Technology

Results and Discussion

The golf cart and sprayer base models were modified to create a system to be used to teach precision agriculture technologies at Clemson University and public service events.

Golf Cart

Safety

Student safety was an overarching goal of this project; all moving parts were enclosed in aluminum sheeting (fig. 4). The braking system on the golf cart was not designed to overcome the new drive system, so a solenoid valve was added to bypass hydraulic flow to the gerotor motor. A two-position, two-way, normally closed valve was installed in the hydrostat loop in parallel with the wheel motor as seen in figure 5. A normally open limit switch, closed on operation of the brake pedal was used to supply current to the solenoid for the valve, effectively bypassing fluid flow to the wheel motor during braking. Once this was added the original golf cart braking system was able to stop the vehicle even when the forward or reverse drive was engaged.



Figure 4. Golf cart with sprayer engaged.

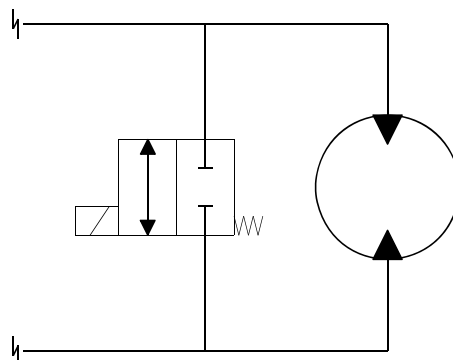


Figure 5. Partial hydraulic schematic demonstrating fluid bypass valve installed for braking.

Engine installation

The engine was placed in the rear of the golf cart directly over the axle. In addition to lifting the vehicle for

ground clearance, this added height made room for the larger motor, which consumes a portion of the cargo area that was on the original machine. Frame braces and motor mounts were designed and installed to withhold the added weight from the diesel engine.

Transmission

A hydrostatic transmission was used to provide fluid power transfer from the diesel engine to the rear end. A hydrostatic transmission is a pump hydraulically coupled to a hydraulic motor (Goering and Hansen, 2004). A diagram of a hydrostatic circuit similar to the arrangement used on the golf cart is included in figure 6. Power was transferred through a v-belt drive from the engine to an 18 cm³ (1.1 in³) variable displacement axial piston pump (Model 101018000012, White Drive Products, Inc., Hopkinsville, Ky.), hydraulically from the pump to a 74 cm³ (4.5 in³) gerotor hydraulic motor (Char-Lynn 101-1002, Eaton, Cleveland, Ohio), and through a v-belt drive from the gerotor motor to the golf cart's original differential and rear axle assembly.

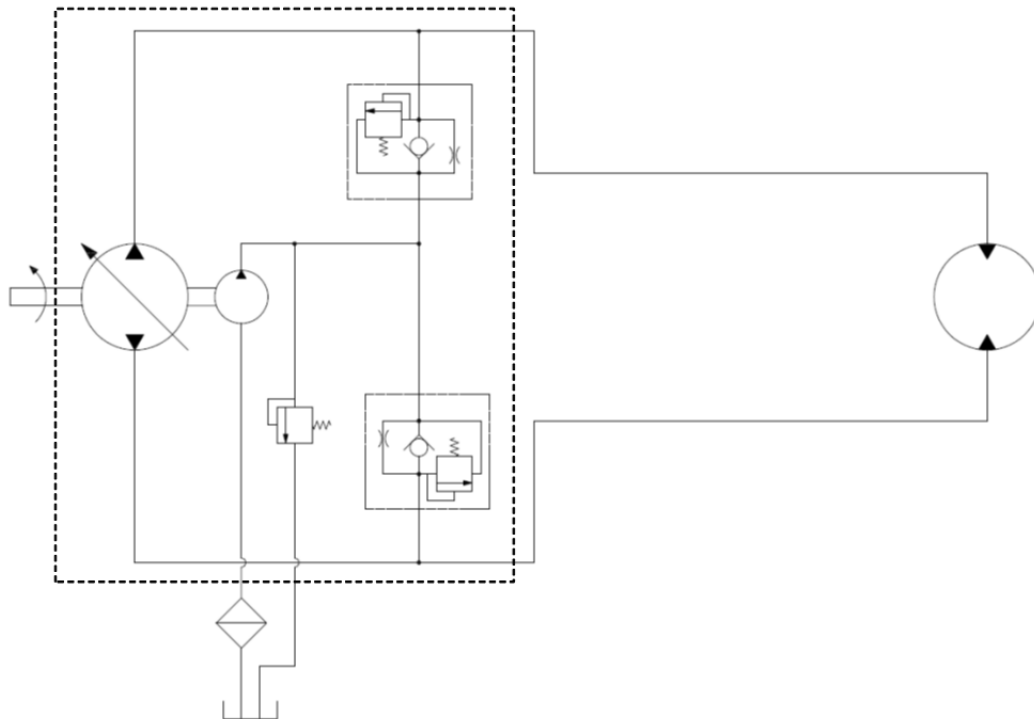


Figure 6. Schematic of a hydrostatic circuit similar to the one used for the golf cart transmission.

The area inside the dashed box of figure 6 represents the hydrostatic pump assembly. The main pump circulating fluid in the hydrostatic loop is variable displacement and bidirectional. The same drive operates a smaller unidirectional fixed displacement pump in the same housing, the charge pump, which replenishes fluid to the hydrostatic loop as it is periodically drained across the flow control valves to the reservoir for cooling purposes. Pressure relief valves are provided between the pump and motor on each side of the hydrostatic loop. The filter was placed on the suction line and the reservoir was placed beneath the front seat, which housed the battery charger on the original machine. The pump and motor assemblies were placed beneath the rear seat, which housed the batteries on the original machine.

Clearance for field operation

The vehicle was lifted three inches and tire diameter increased ten inches, giving a total lift of eight inches (fig. 4). Additional clearance allows for operation in rough field conditions. Lifting of the frame was accomplished at the rear end by moving the rear axle from above to below the leaf springs. Lifting of the frame was accomplished at the front end by blocking between the front leaf spring and frame and fabricating extended steering assemblies.

Power take off

A right angle gearbox was selected for rotary power transfer to the pto shaft, the gearbox input being driven by a v-belt drive from the engine flywheel. Upon searching for the appropriate gearbox, while keeping in mind that a large sheave would be space-prohibitive on the rear of the cart, calculations were made to determine that most of the gear reduction should be done through the gearbox and not through pulley sizing. A gearbox that is typically used on a rotary cutter was selected, which had a threaded shaft on one end and a six-spline standard

pto shaft on the other. The gearbox (OMNI Gear RC-20B, OMNI Gear & Machine Corp., Joliet, IL), had a 2.83 gear ratio (fig. 7) and the threaded input shaft was machined and keyed to accommodate installation of the v-belt sheave. Sheet metal shielding was fabricated to enclose the components associated with the v-belt drive. Tensioning of the v-belt drive was provided through adjustment screws that pressed against the rear bumper to extend the center distance between the drive and driven sheaves.

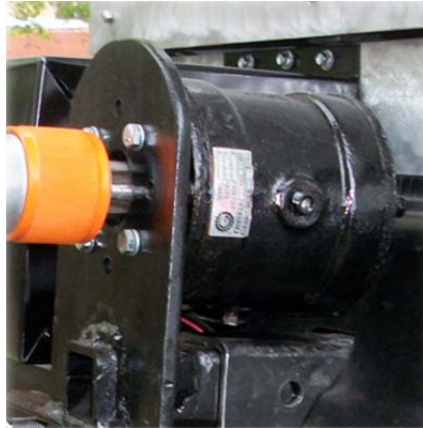


Figure 7. Gearbox for pto, installed at rear of golf cart.

Hitch point

The factory plastic bumper and hitch were removed and replaced with five inch channel iron (fig. 4), which allowed for the installation of a standard two inch hitch receiver. Because the bumper was mounted to an aluminum frame, gusset and plate reinforcements were added at the attachment to the frame.

Sprayer

The sprayer was modified to use with both a tractor (three-point hitch) and the golf cart (drawbar) by fabricating a removable 1.2 m (4 ft) tongue and axle assembly (fig. 8). Such an arrangement allows students to learn the technologies on the golf cart and utilize the same equipment in tractor application. The axle was placed centrally beneath the tank and is capable of pivoting up when the sprayer is being used on a three-point hitch (fig. 9). When the two bolts in figure 9 are removed, the entire axle assembly can be rotated 180 degrees and bolts reinstalled, so that boom height adjustment can be performed entirely through the three-point hitch controls on the tractor.



Figure 8. Spray with tongue to allow hitching to golf cart drawbar.



Figure 9. Axle pivot mount under the spray tank.

Three electrically controllable ball valves (TeeJet® DirectoValve® 344 Series, Spraying Systems Co., Glendale Heights, Ill.) and Ag Leader® sprayer controls were added to the sprayer to allow for the implementation of precision agriculture technology (fig. 10). This arrangement allowed for automated boom section control, allowing the students to see and measure the skips and overlaps. This information was then used by students to estimate the resulting yield or chemical loss.



Figure 10. Controls for boom control and rate control.

Lab Activities

Many of the students were new to this technology and required large amounts of instructor interaction. Each activity discussed was completed during a three hour lab.

Field Mapping

Using a handheld GPS groups of two students mapped field boundaries and points of interest (rocks, trees, poles, etc). These maps were later used to create management zones. The information gathered was loaded into Farm Works Software® (Trimble Navigation Limited, Sunnyvale, Cal.) and maps were manipulated into management, sampling, prescription, and yield zones.

GIS Mapping

With the field boundary determined the students imported USDA-NRCS National Cooperative Soil Survey data into Farm Works Software®. This resulted in a map showing different soil types within the field. Soil types

were then merged or split to reach manageable zone sizes, each between 1.0 and 4.0 ha (2.5 and 10 ac). As an alternative Farm Works Software® has a function creating grid sample map; it is important to introduce the students to both methods.

Soil Sampling

The zone or grid map was loaded into a handheld GPS and students returned to the field to collect samples from the zone or grid cell. This can be done with automated or manual process; based on past experiences with this course the students become more engaged using the manual process, where students use soil augers to collect composite soil samples from within each zone. These samples were tested and results were returned to the students for creation of lime and fertilizer prescription maps.

Light Bar Guidance

The golf cart was equipped with three different monitors: Ag Leader® Versa™ with boom control and auto swath (driver front), Ag Leader® Integra (passenger front), and Trimble EZ-Guide 250 (rear). Each of these units can operate as a light bar, while only one student can drive based on the light bar information, all passengers are able to set up and observe the process. With large lab size this allows for more students completing tasks for collecting data. Students operated the equipment with and without the technology and compared measurement of error (divergence) from a straight line.

Boom Control Technology

Students can compare manual, automatic, and no boom control. To do this, the overlap and skip is measured and recorded for each method and a cost can be associated with the error. One operator drives without any GPS assistance, another operator drives with the use of a light bar with manual boom control, and the last drives with the use of a light bar and the automatic boom section control. For the last operator prescription maps produced in earlier assignments are imported into the Versa™ monitor, allowing for on the go boom control. Other students on the golf cart can trouble shoot or set up and run the Integra or EZ-Guide 250 during this process.

Conclusion

A four passenger golf cart was customized for use in agricultural applications and equipped with precision agriculture technologies to be used as a mobile precision agriculture teaching platform. The golf cart and variable rate sprayer are used to teach topics in undergraduate classes in the AGM program at Clemson University, AGM 206 and AGM 410. This platform provides the opportunity to teach agricultural mechanization field technologies in an applied setting. The golf cart is capable of carrying an operator, three passengers, and will pull the full weight of a loaded sprayer. This teaching platform serves as an intermediate teaching setting for the students, whereby they can later complete field activities with a tractor and typical field equipment. As a part of allowing students (passengers) to focus on in-field application of precision agriculture technologies independently from operating machinery, the golf cart provides a safer environment for student learning than that of conventional agricultural machinery. This system is designed solely for educational purposes such as teaching labs and introducing new technology to students.

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