# Drive-By-Wire Conversion of an Electric Golf-Cart for Self-Driving Vehicles Research

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***Abstract*—In this paper, we present the drive-by-conversion of an electric golf-cart and summarize how it is used for self-driving vehicles research. This work is basically a major progress compared to our earlier work presented in [1]. The drive-by-wire system has a touch-screen control panel driven by a Raspberry Pi device, but all of the timing critical tasks are executed on microcontrollers. We used industry standard DIN rails and panels to organize the control hardware and the electrical wiring. The developed system have three different modes of operation (1) Fully manual, (2) X-box wireless controller based remote controlled operation, and (3) Drive-by-wire mode where all control commands are expected to be sent from an "external" computer over a USB/serial connection. The drive-by-wire system is designed to be used to together with an x86-64 or ARM processor based device equipped by GPU hardware. This on-board computer, is called the vehicle computer, or the "external" computer, and it is mainly for more heavy-weight AI algorithms and decision making. Once steering decisions are completed, they are all sent to the Pi and/or microcontrollers to operate the actuators. The electric golf-cart also has a GPS/GNSS sensor, and solar panels with an MPPT device which are used to charge the batteries while the vehicle is being used or driven. A short demo video of the developed system is available at [2].**

***Index Terms*—Drive-By-Wire conversion, Embedded Systems, Self-driving vehicles.**

## I. Introduction

In 2019, Florida Polytechnic University received an NSF grant about autonomous vehicles research, and before the end of that year, we started working on the drive-by-wire conversion of an electric golf-cart for self-driving vehicles research. Our first design was presented in [1], and it was mostly inspired by similar research projects known at that time, see [3]–[7]. The new design presented in this work is basically a complete redesign with several major improvements, resulting a system with improved maintainability and clearly defined layers of abstraction. In the Section II, we will present the details of the new drive-by-wire system architecture, with a detailed justification of why certain design decisions are made in a specific way, and in Section III, we will summarize possible future research directions.

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Figure 1. Drive-By-Wire capable Electric Golf-Cart demo video, https://www.youtube.com/watch?v=oRRvCas3oOU

## II. Main Results

The drive-by-wire subsystem developed in this work, Fig. 1, consists of four major components: Steering control subsystem, Pneumatic breaking subsystem, Electronic throttle control subsystem, and touch-screen based control and configuration panel. This section contains a detailed discussion of each of these subsystems.

### A. Steering control subsystem

For the drive-by-wire conversion of the steering, we used a stepper motor, and a chain coupling system as shown in Fig. 2. Stepper motor is controlled by a Gecko G201X stepper motor drive unit which is driven by an ATmega328 microcontroller. As the main DC energy source we are using the 48V battery of the vehicle. Stepper driver can be disabled in software, and in this case the steering can be controlled manually with no noticeable extra friction.

### B. Pneumatic breaking subsystem

Electronic breaking is achieved by using a pneumatic actuator, see Fig. 2. There is a small compressor on the back and it runs by 12V DC which is obtained from the main 48V battery through a buck converter. There are total three electrically activated pneumatic valves, see Fig. 1, one of which is reserved as an emergency break, and the other two are for regular operation. Breaking responsiveness can be controlled by adjusting the pneumatic valve pressure levels.

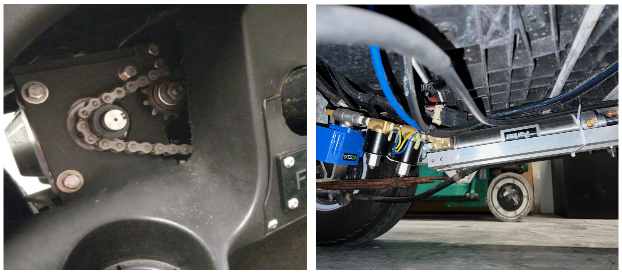

Figure 2. On the left, the stepper motor and the chain coupling to the steering column. On the right, pneumatic regulator and cylindrical actuator for breaking.

Steering mechanism also has two limit switches as shown in Fig. 3. If the stepper motor is instructed to turn the steering mechanism beyond a certain point, one of these limit switches will be activated and the motor driver will be forced to turn the other direction at the hardware level. Otherwise, a catastrophic mechanical failure may occur, and the chain mechanism may break down. These limit switches provide an additional level of protection in the event of software failure. They also allow for the stepper microcontroller to center the steering since the limit switches are at an absolute position.

### *C. Electronic throttle control subsystem*

Our electric golf-cart has a DC motor driver which expects 0 to 5V signal input to adjust the motor speed. The manual foot pedal provides this 0-5V voltage levels, but we also have an RC filter driven by a PWM signal which is used to generate a 0-5V signal purely in software. Switching between these two 0-5V voltage sources is achieved by a relay mechanism, see Fig.3.

### *D. Touch-screen control panel*

Our research vehicle has three separate modes of operation: manual, Xbox controller based, and full drive-by-wire mode. Selection of the mode of operation and other configuration related settings are all done through this touch-screen control panel, see Fig. 3.

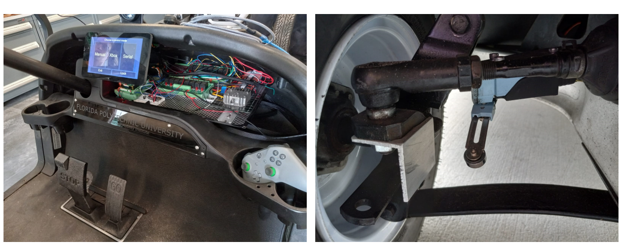

Figure 3. On the left, touch screen control panel and electrical wiring with DIN rails. On the right, limit switches for the steering mechanism.

The overall system can be viewed as a complete hardware-software co-design project. The electrical system has a 3.3V subsystem, a 5V subsystem, and 12V and 48V subsystems. Timing sensitive tasks like pulse counting for the stepper motor are done on a bare-metal system. Other less time critical tasks, like the operation of the touch-screen control panel, is handled by a Python program running on the Pi.

Figure 4. Forward looking camera with C-mount adapter for machine vision.

## III. Future Work

Compared to our earlier work presented about 2 years ago, [1], we know have a much more stable and professional design. However, we also have a couple ideas for future work. These include (1) Ultrasonic sensors to improve safety and small space maneuvering confidence. Our plan is to use four in the front and four in the back. (2) Medium to long range high-bandwidth wireless communication between the electric golf-cart and a PC running the self driving algorithms for added user flexibility. Currently, we can run self driving algorithms only on a laptop by using the forward looking camera shown in Fig.4.


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