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Project Proposal

ChapR FCS

FTC Field Control System

With the new FTC robot control system in place for the 2015-2016 season, an opportunity arises to create a new Field Control System (FCS) for FTC. This new system serves two basic purposes:

1. *Provides the match timer, display, and sounds for live FTC matches*
2. *Provides Bluetooth Low-energy (BLE) start/stop control of robots*

Based upon the Raspberry Pi, the ChapR FCS is 80% software and 20% hardware, integrating mostly off-the-shelf parts. It also includes custom case design.

** all images simulated*

Problem Overview

The 2015-2016 FTC season has brought with it a wholesale change in the way in which robots are controlled and competition matches are run. Previous to this season, a control system called the Samantha FCS was used. Named primarily for the Wi-Fi interface module that robots used, the Samantha FCS is a PC-based software package that previously provided three important functions:

1. Transmission of joystick controller information wirelessly from each of the drivers to their respective robots
2. Start/stop control of the matches for the match referee
3. Match status and time display for the players and audience

Unfortunately, the Samantha FCS as a complete system had significant problems with the first and most important job of the control system: it was an unreliable system for driver control of the robot. Due to the combination of the old NXT controller, the Wi-Fi adapter "Samantha" module, and the centralized joystick aggregation and transmission, matches were often impaired or marred by one or more teams losing control of their robot. With such a complicated system of control, it was often impossible to determine the source of the problem leading to many match replays and frustrated teams.

Starting in the 2015-2016 season, FIRST has introduced a new control system to alleviate this problem. The main tenant of this system is that the control of the robot has been moved away from a centralized system, and instead placed into the hands of each team. Through the use of a direct Wi-Fi connection from the team's "driver's station" to the robot's controller, each team adopts complete responsibility of the control of their robot. This alleviates the need for a central control system to aggregate and transmit control functions and all of the problems that it entails.

However, while this solution eliminates the problems associated with robot control, it prevents match referees from effectively controlling matches. Since there is no longer a centralized connection between the referees and the robots, the referees can no longer effectively enforce safety protocols or start and stop matches fairly.

Match control can be described and grouped within the following functional areas (in priority order):

1. Safety and rule enforcement
2. Start and stop match control
3. Robot feedback and program control

Safety and Rule Enforcement – an overriding concern for all FTC match play is safety. When matches are in progress, the referees, judges, and field management personnel are responsible for the safety of the participants, the audience, and themselves. The robots and equipment that are routinely being using during match play have the potential to cause personal harm and harm to property. As such, the referees and judges are afforded (and need to be afforded) the tools and authority to enforce safety procedures and rules. Further, they need to be given the tools to immediately curtail unsafe behavior or to swiftly react to

unforeseen dangerous situations. Beginning in the 2015-2016 season, referees will no longer have the ability to effectively and quickly react to a dangerous situation by stopping a robot or match. Since there is no centralized control, all actions in response to safety concerns will have to be handled either physically by field personnel, or by team members reacting as quickly as possible to instructions given by them. In either case, a dangerous situation could easily get out of control.

Start and Stop Match Control – though not nearly as important as safety, the ability for the referees and judges to enforce a fair start and stop to matches is necessary to promote the sportsmanship and sense of "fair play" that all teams expect. The 2015-2016 FTC season introduces the concept of a "sports start" for matches, where the judge yells "go" and all teams are expected to press their **START** button at that time; not before, and not after. Further, teams are expected to press a pre-configured button that doesn't unfairly take advantage of autonomous field set-up that may have occurred since the team selected their autonomous program. With the advent of the "sports start," the possibility, and maybe *allure*, of unfair program starting is real. In addition, the job of the judges and referees has become more difficult in that they need to police both the starting and stopping of robot programs simply through observation of robot behavior.

Robot Feedback & Program Control – after addressing the more important issues of safety and fair play, the judges and referees are tasked with ensuring that FTC matches run as smoothly and successfully as possible. They do their best to ensure that teams and participants are able to compete well, generally attempting to ensure that the robot and team perform to the best of their ability. Judges and referees endeavor to help teams ***not*** make careless mistakes or those caused by simply being nervous. For example, in past seasons, field personnel were given a *heads-up* through the FCS when robot batteries were weak, allowing them to inform the team of the situation that the team had overlooked. Fortunately, the new system provides this feedback, but only to the team – referees will be unable to help notice these issues for a nervous team. More importantly, the previous FCS was designed to ensure (as much as possible) that teams run the *right* program for the driver controlled period. During the seconds between the end of the autonomous period and beginning of the driver controlled period, teams will now be expected to find and select the right program and hit the start button at the right time – an activity that will be fraught with nervous mistakes. The previous FCS allowed the team to pre-configure the driver controlled program, which the FCS would start automatically at the beginning of the driver control period.

While the new control system is a great leap forward for robot control and programming, it is a great leap backward for safety, fairness, and team match performance.

The Solution

Fortunately there is a simple and effective solution to all of the issues described above: the ChapR FCS. Created by the team that created the ChapR, the ChapR FCS works ***with*** the new FTC control system to add appropriate centralized control to the new direct Wi-Fi connection model.

It preserves all of the benefits of the new FTC control system, while adding back in the safety, fairness, and team performance features that were lost.

The ChapR FCS is a hand-held device based upon the Raspberry PI single-board computer. It is designed to be the center-piece in a competition field control system, driving both an external monitor and external amplified speaker. Match set-up and control are done through a combination of push-buttons and the integrated touch screen, which is independent of the external monitor. The operator has start/stop control of the robots and match at all times.

The ChapR FCS communicates to the robots through Bluetooth Low Energy (BLE) and an Android application that integrates into the existing FTC robot control software. Through a specialized protocol and data exchange, each robot before being placed on the field, connects to the field's FCS. The ChapR FCS registers the robot (by team number) and the operator assigns it to either the **BLUE** or **RED** alliance. The robot and ChapR FCS continue the specialized protocol, remaining in contact before and during the match, exchanging information ranging from battery level through program availability. The robot is also given information from the FCS including the alliance assignment, which it can optionally use as program input.[1]

When the match begins, the operator presses the START MATCH button, which causes all four robots to simultaneously start the pre-configured autonomous program. Through this mechanism, teams aren't responsible for starting the robot, nor do they have the opportunity to take into account autonomous field settings and covertly start a specialized program.

During match operation, the ChapR FCS remains in contact with each of the four robots. The operator can, at any time, disable each or all of the robots, instantly terminating any activity that the robot is performing. This

[1] The 2015-2016 FTC Challenge "Res-Q" requires the robot's program to differentiate between the two alliance colors and to pick its own color to score specific points.

can be done in response to an unsafe or emergency situation or in response to a referee deeming a robot "disabled."

At the end of the autonomous period, the ChapR FCS terminates the autonomous program simultaneously on all of the robots. This eliminates the possibility that a team inadvertently or deliberately neglects to use the 30 second program timer. It also eliminates the "run over" that could occur if a particular team accidentally or deliberately starts their program later than when the judge says "go." This latter situation will otherwise be nearly impossible for a judge to police.

After autonomous termination, and scoring by field personnel, the operator will start the driver controlled period or "teleop" period. When the operator presses the START TELEOP button on the ChapR FCS, all of the robots will simultaneously be sent the "start" command which starts the team pre-configured teleop program. The team drivers will then be in control of their robot through a direct Wi-Fi connection from their driver's station and the robot controller. At the end of the teleop period, the ChapR FCS automatically stops the programs running on the robots.

It is very important to note that the team's robot is always in contact with their driver's station controller. At no time is this link severed nor interrupted or interfered with. The ChapR FCS simply controls which program is run, and when it starts and stops.

What is the ChapR FCS?

ChapR FCS Console	ChapR FCS App
	
The ChapR FCS Console is a Raspberry Pi-based device with an integrated touch screen and additional physical buttons. Internally it includes a Bluetooth Low Energy (BLE) module controlled by the RPi. It runs the Raspberian Linux distribution. The graphical interface for both the touchscreen and monitor are programmed in Python using pygame utilizing the two separate framebuffers directly (no X windows). For simple match play or scrimmages, the console doesn't require a separate monitor or speaker, but for competitions they are recommended.	The ChapR FCS App is an Android application programmed in Java. It runs on the same control cellphone used by the FTC robots. It runs seperately from but integrates into the existing team-programmed control program through the use of the INTENT mechanism in the Android OS. The control system program must include a ChapR FCS library to enable its used by the ChapR FCS App. Eventually we hope the library will be included with the template application.

FAQ

Why isn't the ChapR FCS just PC software?

The ChapR FCS was designed to be a turn-key FCS for FTC. That is, it was meant to make using an FCS extremely simple, intuitive, and prone to very few problems. Using a PC for this task has numerous potential problems including: potential incompatibility as a BLE beacon, inability to guarantee response time due to OS interaction, potential additional Wi-Fi interference, software incompatibilities between different OS's and versions of OS's, and others. While these problems are not insurmountable, the ChapR FCS does an excellent job avoiding the problems altogether. However, we haven't ruled out a PC version of the ChapR FCS in the future.

Can the robot controller manage both Wi-Fi and Bluetooth communication at the same time?

Wi-Fi and Bluetooth are built to coexist within all modern cell phones, including those used for FTC robots. In fact, most phones have a single chip that handles both forms of communication. These chips have interference mitigation mechanisms allowing both Wi-Fi and Bluetooth to be used at the same time. So each individual robot controller is already capable of managing both Wi-Fi and Bluetooth together.

What about interference between robots?

While Bluetooth and Wi-Fi can share the same spectrum, they use different signaling protocols that work very well when used at the same time. Bluetooth uses a "frequency hopping" mechanism that scans the radio spectrum and finds an appropriate frequency that works the best, limiting interference for both the Bluetooth device and other devices sharing the same spectrum.

Can the robots use 5GHz Wi-Fi connections?

Yes – the 5GHz spectrum is far less crowded than the 2.4GHz spectrum, and Bluetooth operates exclusively in 2.4GHz. By using the 5GHz spectrum, robots will have to contend with far less "noise" and performance could improve.

*Is the ChapR FCS **necessary** for a match?*

The ChapR FCS is designed as an *overlay* upon the existing control system. This makes its use completely ***optional***. Teams can easily control the robot and the programs it runs from the driver's station. However, during matches, the team can use the ChapR FCS app to create the connection to the ChapR FCS relinquishing start/stop control to the match operator.