XeroPathGenerator

Introduction

One of the big challenges in FRC robotics is the autonomous mode. This is the 15 second time period at the start of a match where the robot must be 100% controlled by software. Within autonomous, moving the robot to a desired location is a big part of the challenge. To date, the best approach for doing this is some form of path following algorithm. Path following is exactly what is sounds like it should be. A path is defined and the robot does its best to follow the path. Generally, the path is defined on a computer and then downloaded to the robot. The robot follows the path using a follower algorithm. There are several types of follower algorithms and it is not the intent of this document to get into these algorithms here. What is key is that these following algorithms either want the waypoints along the path as input, or they want some type of periodic information describing the behavior of the robot drivebase. The XeroPathGenerator was written to provide a powerful and flexible application to generate these paths.

Another goal of this program was to provide information to help teach students about path following. To that end, this program shows plots of the generated velocity profile for the path. This program can also run in demo mode, showing the motion of the robot. Finally, when running in demo mode, the program can show a rough diagram of the forces acting on the robot.

The XeroPathGenerator was written to be easy to extend. There are two key extensions that are possible. New game fields can be added to the program by providing a graphics image for the field and a JSON file describing the field. This format is identical to the format used by the First provided path editing software (FRC Path Weaver). Generators can be added by adding a new executable program that reads path description and robot descriptions, and outputs trajectories. This new executable is accompanied by a JSON file describing the generator.

The program ships with the PowerUp field and the Deep Space field. The program ships with the PathFinder V1 can be found in github (https://github.com/JacisNonsense/Pathfinder). It also ships with a backend generator known as XeroGen which was created for this application, but leans heavily on ideas, concept, and algorithms from Cheesy Poofs.

The program supports tank drive and swerve drive style drive bases. Error Code Xero is actively building a swerve drive as a summer project, but as of the writing of this document, it is not ready for test of this code by software. Therefore, all swerve drive support is very experimental and has not been tested on a real robot yet.

As of this point, this program is very much an alpha release. Do not rely on this for a competition robot until it has had more testing by more people. All feedback is welcome.

Coordinates

Anytime we are dealing with the location of the robot, there is a coordinate system used as a reference. The XeroPathGenerator uses and X/Y coordinate system with the origin at the lower left-hand corner of the field. The X axis increases left to right along the long edge of the field, and the Y axis increases top to bottom along the short edge of the field. The heading is measured in degrees. Zero degrees heading

is looking in the direction of the positive X axis. Ninety degrees heading is looking in the direction of the Y axis.
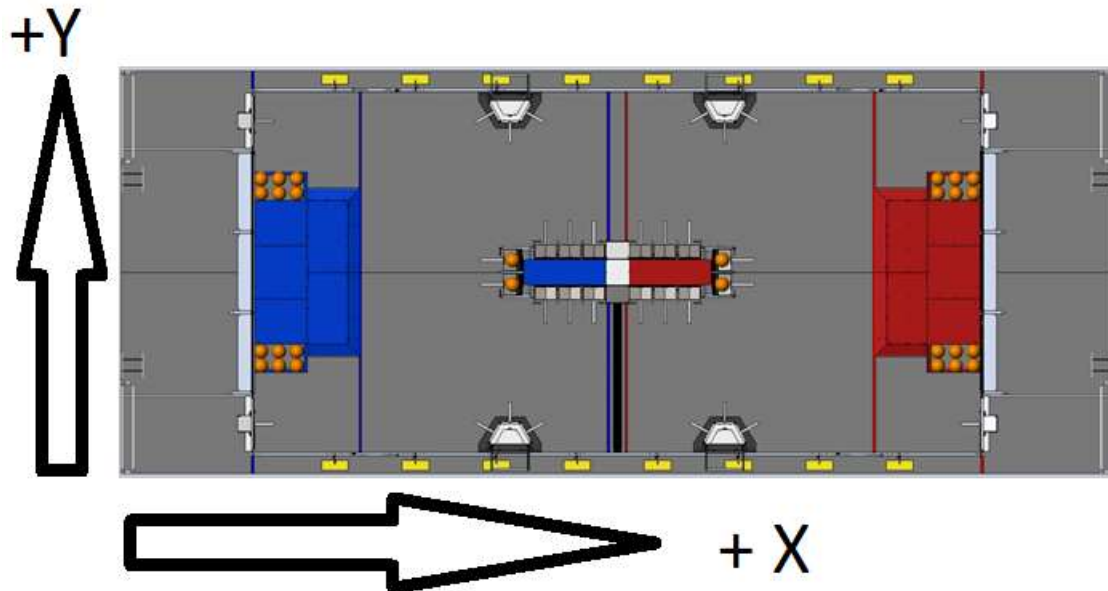

Definitions

|	
Waypoint	A waypoint describes the location and orientation of the robot. It is represented by an X and Y coordinate as well as a heading angle.
Path	A path is a set of waypoints that describe the desired path of travel for the robot.
Path Group	A path group is a set of paths grouped together. While these paths can be grouped based on any organization, generally path groups are intended to describe a single autonomous mode.
Velocity	This is the speed of the robot, measured in distance per time.
Acceleration	This is the change in speed of the robot per unit time, measured in distance per time squared.
Jerk	This is the change in acceleration of the robot per unit time, measured in distance per time cubed.
Trajectory Point	A trajectory point describes the position, velocity, acceleration, and jerk for a single entity (robot, wheel, etc.) at specific point in time.
Trajectory	A trajectory is a set of trajectory points that describe a path for an entity to follow. These points are usually provided at a fixed time or distance, but that is not a requirement.

Windows

This section describes each of the windows and their purpose.

Path File Window
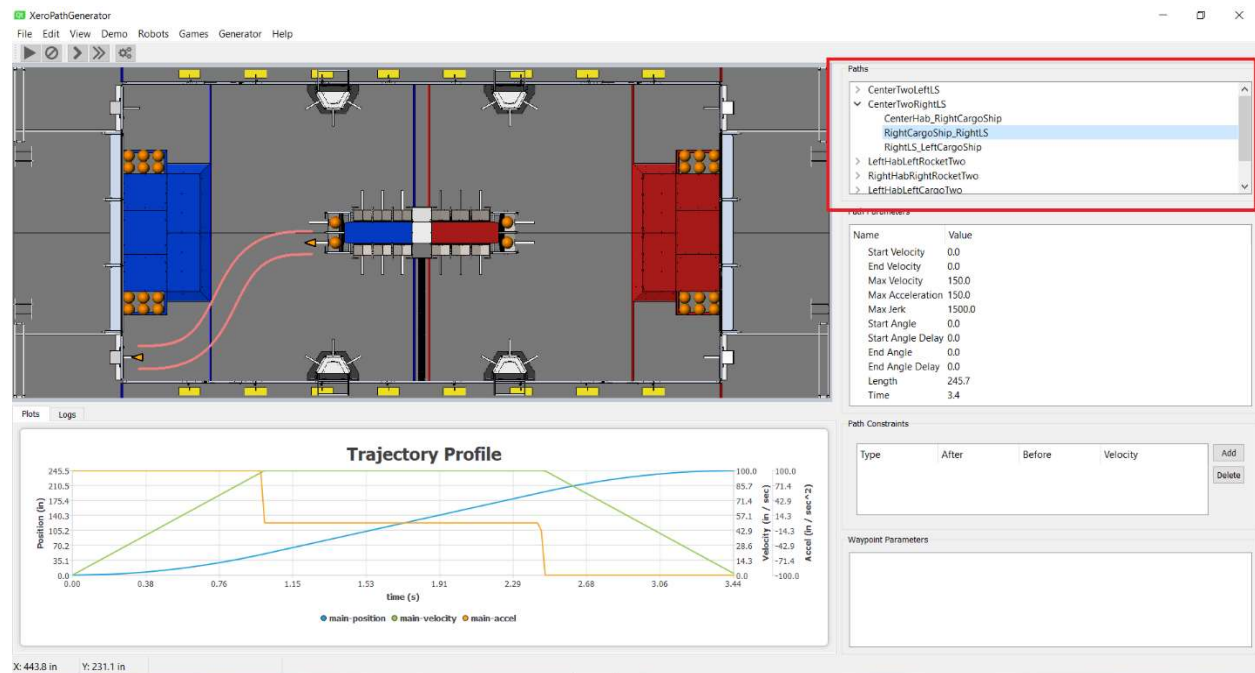
The path file window is in the upper right side of the application (highlighted here in red). It is a two-level display with the list of elements at the top level being the set of Path Groups. The elements below Path Groups are the Paths. Selecting a specific Path causes the path to be displayed in the Path View window and causes the Trajectory Profile to be displayed in the Trajectory Profile window.

Path Properties Window
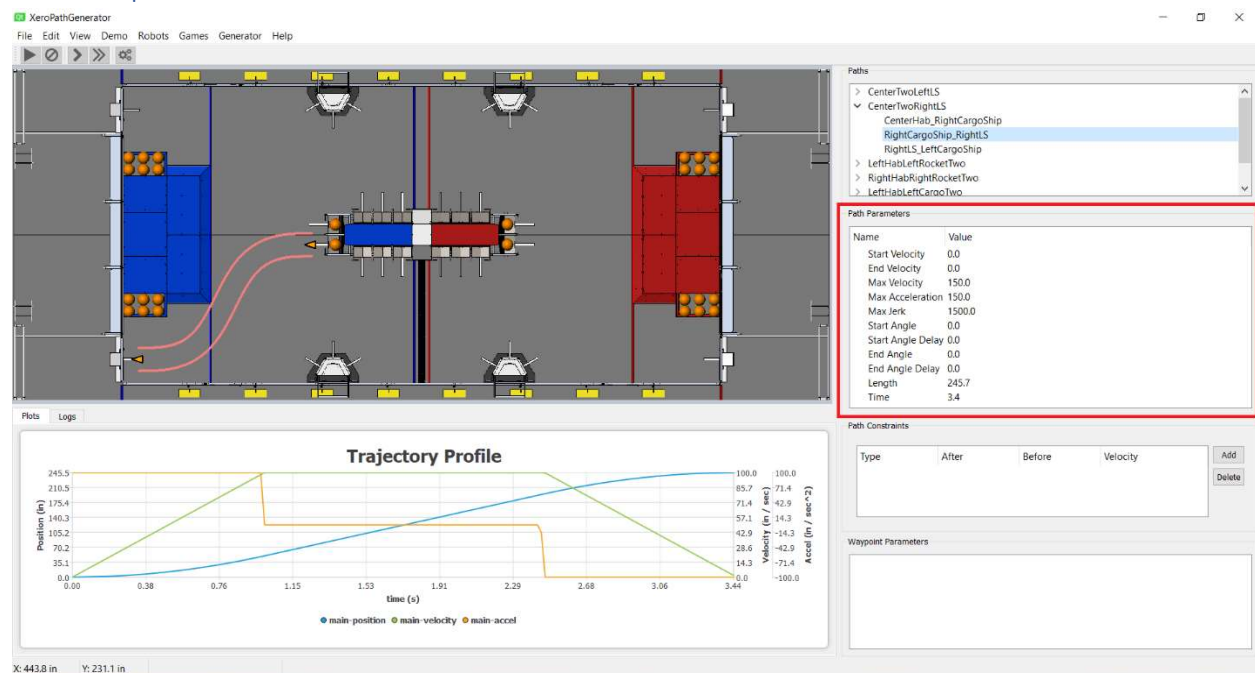
The path properties window is a property editor window just below the Path File window. This property editor provides a way for the properties associated with a path to be changed. The following properties are available.

| Name	Description
Start Velocity	The starting velocity of the robot when this path is started. This allows two paths to be concatenated with the robot in motion.
End Velocity	The ending velocity of the robot when the path is complete.
Max Velocity	The maximum velocity of the robot when executing this path.
Max Acceleration	The maximum acceleration of the robot when executing this path.
Max Jerk	The maximum jerk of the robot when executing this path. Not all path generators honor this value.
Start Angle	For swerve drive only, this is the angle the robot is facing at the start of the path.
Start Angle Delay	For swerve drive only, this is the delay from the start of the path before the robot starts to rotate to the desired end angle. This value gives the robot time to clear any obstructions before trying to rotate.
End Angle	For swerve drive only, this is the angle the robot is facing at the end of the path.
End Angle Delay	For swerve drive only, this is the delay from the end of the path when the robot much reach the end angle. This prevents the robot from trying to complete a rotation as it approaches and obstruction.
Length	This property is read only and display the length of the path in the user's chosen distance units.
Time	This property is read only and displays the time of the path in seconds.

Constraint Window
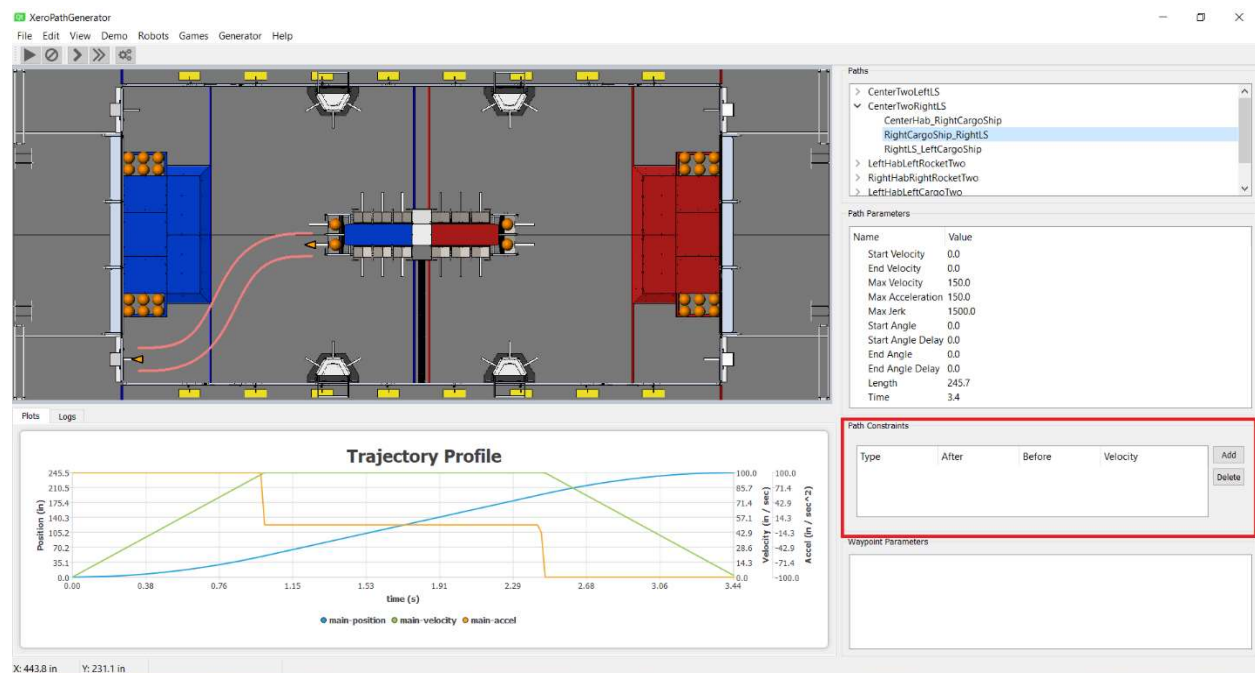
The constraint window provides a way to add constraints to the current path. Currently the only type of constraint is the ability to limit the velocity of the path for portions of the path. The portion of the path is selected by an "after" distance along the path and a "before" distance along the path. The constraint is specified by the velocity given and is applied after the "after" distance and before the "before" distance. Note, not all path generators can process these constraints. If a path generator cannot honor the constraints, the constraints window will not be active.

Waypoint Window
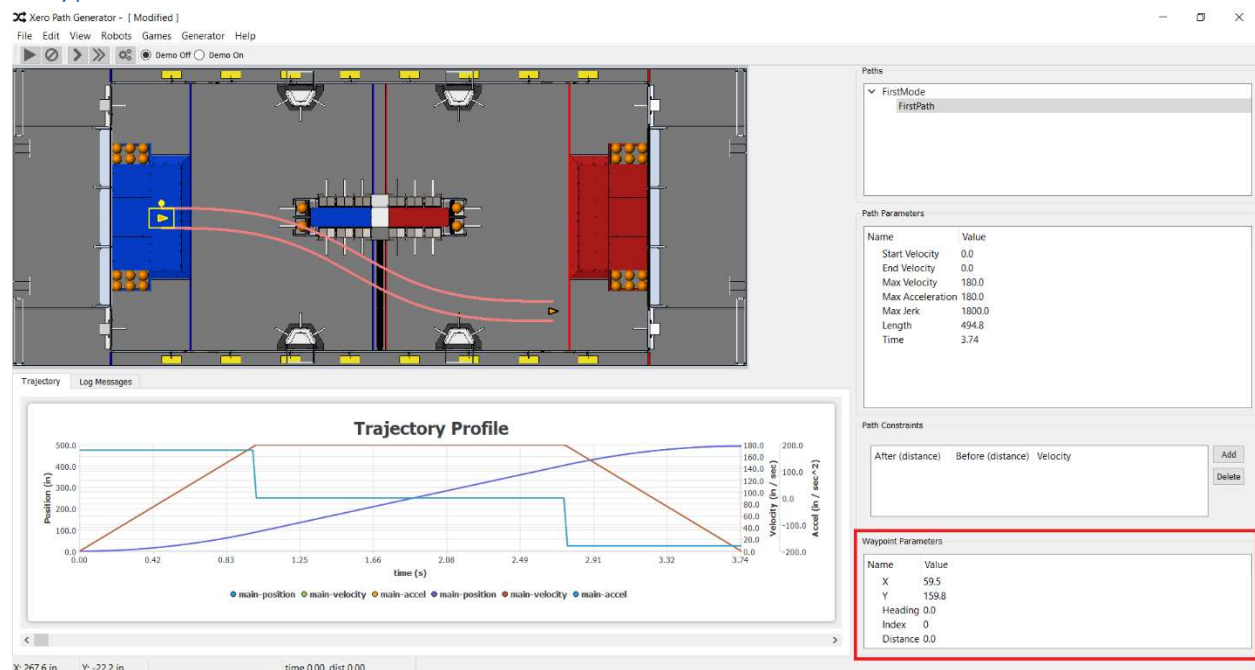
The waypoint window displays the properties of the current waypoint if a waypoint is selected. This window displays the X and Y coordinates, the heading, the index, and the distance along the path for the selected waypoint. The X and Y coordinates as well as the heading can be edited in this window.

Path Editing Window
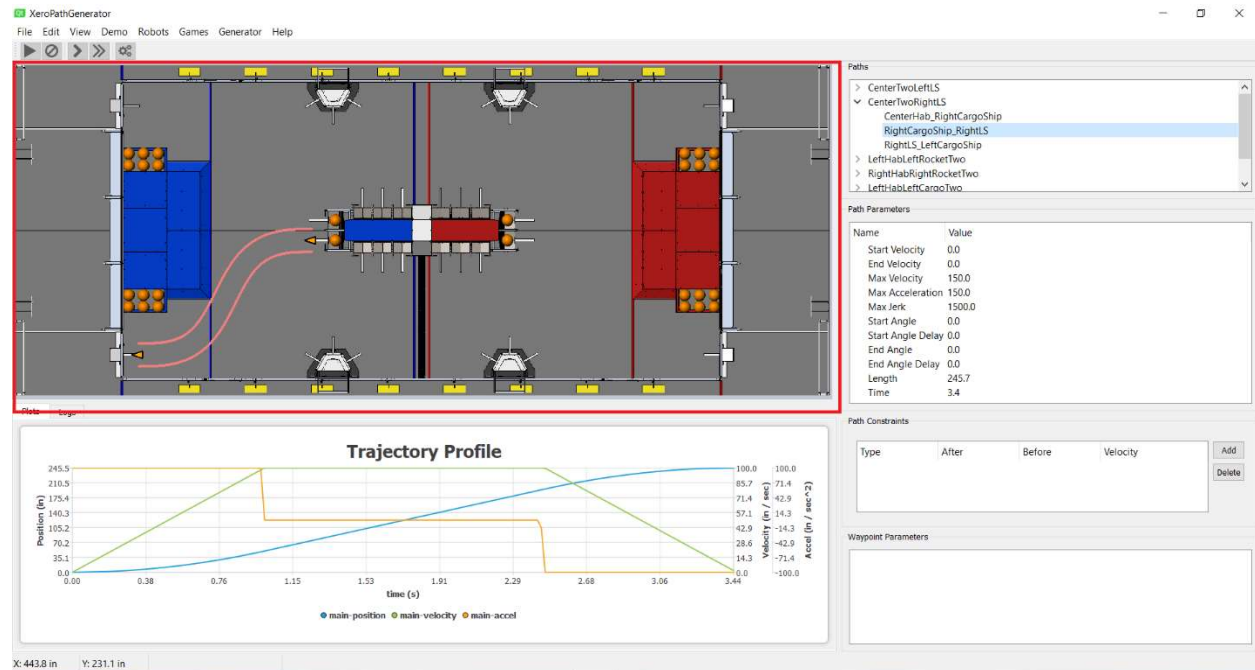
The path editing window is used the edit path. When a path is selected in the Path File window, the path is displayed in the path editing window. Here, individual waypoints can be selected with the left mouse button. Selected waypoints can be moved by dragging the waypoint with the left mouse button down. Finally, a waypoint can be rotated by dragging the yellow rotation circle attached to a selected waypoint and moving the mouse around the waypoint. In addition the following keys are useful.

Up Arrow – moves the waypoint up 12 inches

Shift Up Arrow – moves the waypoint up 1.0 inches

Down Arrow – moves the waypoint down 12 inches

Shift Down Arrow – moves the waypoint down 1.0 inches

Left Arrow – moves the waypoint left 12 inches

Shift Left Arrow – moves the waypoint left 1.0 inches

Right Arrow – moves the waypoint right 12 inches

Shift Right Arrow – moves the waypoint right 1.0 inches

Page Up - Rotate current waypoint counterclockwise 5.0 degrees

Shift Page Up - Rotate current waypoint counterclockwise 0.5 degrees

Page Down - Rotate current waypoint clockwise 5.0 degrees

Shift Page Down - Rotate current waypoint clockwise 0.5 degrees

Insert – Insert a new waypoint after the current waypoint, unless you have the last waypoint selected

Delete – Delete the currently selected waypoint, unless it is the first or last waypoint

Trajectory Profile Window
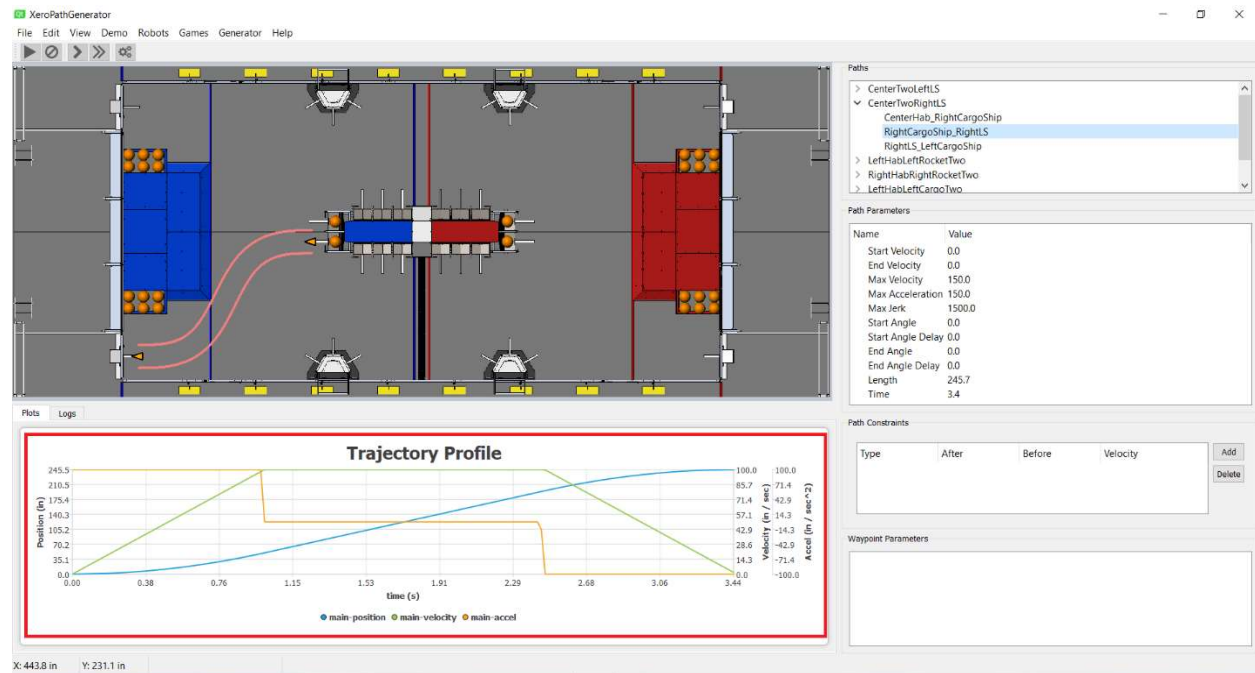
The trajectory window is located below the Path Editing window when the Trajectory tab is selected. This shows the generated trajectory for the currently selected path. There are many different variables that can be displayed and these are selected by the View/Plot Variables menu item. By default, the position, velocity, and acceleration of the robot are displayed.

The left mouse button can be used to zoom in on a specific area of the plot. The follow keys are also useful:

+ : zoom into the plot

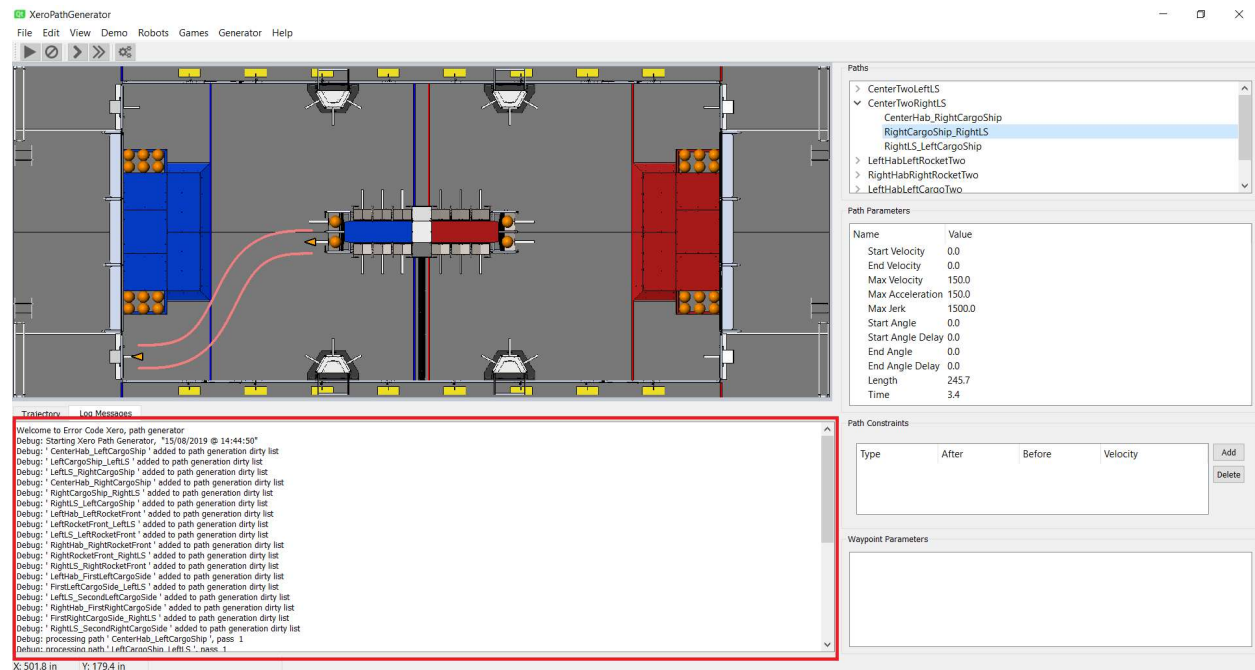- : zoom out of the plot

Left Arrow: pan the plot left

Right Arrow: pan the plot right

Up Arrow: pan the plot up

Down Array: pan the plot down

Home: reset the zoom and pan back to its original state

Log Window

The Log File window is displayed below the Path Editing window when the Log File tab is selected. This window should be rarely needed but is useful when something is not working as expected.

Cursor

The cursor and scrollbar are used to identify locations along a path. This is especially useful for finding specific distances along the path for distance constraints. There are three areas of note highlighted in the picture above. First, on the path in the Path Editing window the robot current position is highlighted

with a yellow and green box. The yellow is the outside of the robot and the center of the green bar is the center of the path.

The scroll bar along the bottom is used to move the robot cursor along the path. Grab and move the scroll bar to see the robot cursor move. Finally, in the status bar, the current time and distance for the path is displayed.

Getting Started

This section documents what is needed to get started with the XeroPathGenerator program.

Define a robot

When the program is first started, no robot is defined. The program will prompt you to create a robot. Creating a robot consists of describing the physical attributes of the robot. This includes the width, length, maximum velocity, maximum acceleration, maximum jerk, drive type, and the timestep for the robot control loop controlling the drive base. Note, additional robots can be defined at any time via the Robots/New Robot menu item. Robots may also be deleted via the Robots/Delete Robot menu item.
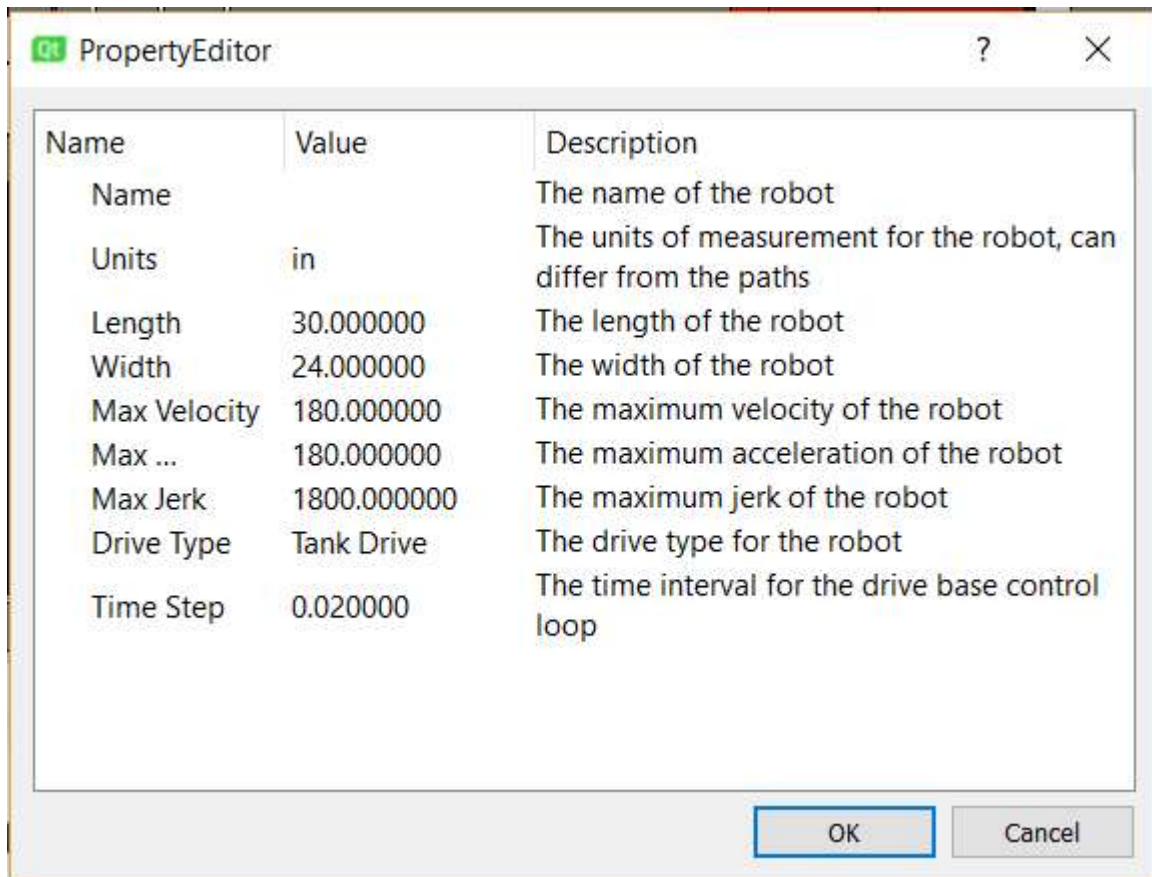

Create a path group

Now create a new path group. Creating a new path group is done with the Edit/Add Path Group menu item. This creates a new path group named "New Group" which will be seen in the Path File window. This path can be renamed by double clicking the name "New Group" in the Path File window.

Create a path

Now create a new path by selecting the path group in the Path File window and selecting the menu item Edit/Add Path. A new path named "New Path" will be created and can be seen in the Path File window.
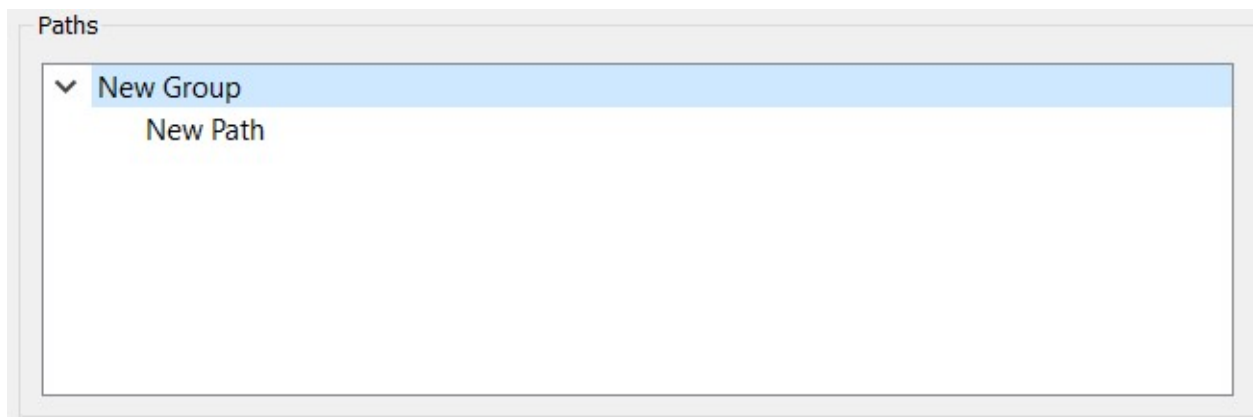
Edit the path

Selecting the path in the Path File window will cause the path to be displayed in the Path Editing window. Each new path starts at the origin (0, 0) and extends right 100 inches. To edit the path, grab the first waypoint at the origin and move it to a new location on the field. To make fine adjustments for a path location, either use the arrow keys (with shift down for really fine adjustments), or type the coordinates desired in the waypoint window. Insert new waypoints using the insert key. Note as the path is edited, the trajectory window will update after a small delay with the updated trajectory.

Save the path file

When all the desired paths are complete, save the path file via the menu item File/Safe (or File/Save As). Navigate to the desired folder and save your paths.

Generate the trajectories

Finally, to generate paths, use the File/Generate (or file Generate As) menu item. This will generate a set of trajectory files in the chosen directory. Several files will be generated for each path. Each of these files will contain the name of the path group, the name of the path, and the target element for the output file. Target elements include the robot, and for a tank drive, the left and right motors. For a serve drive, a trajectory file is generated for the main robot and each of the four wheels.

Menus

File Menu
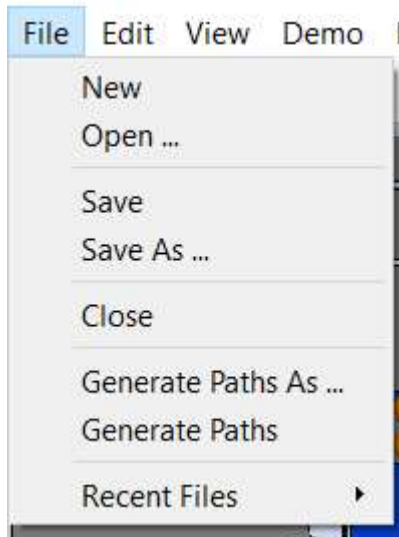
The file menu contains the following menu items:

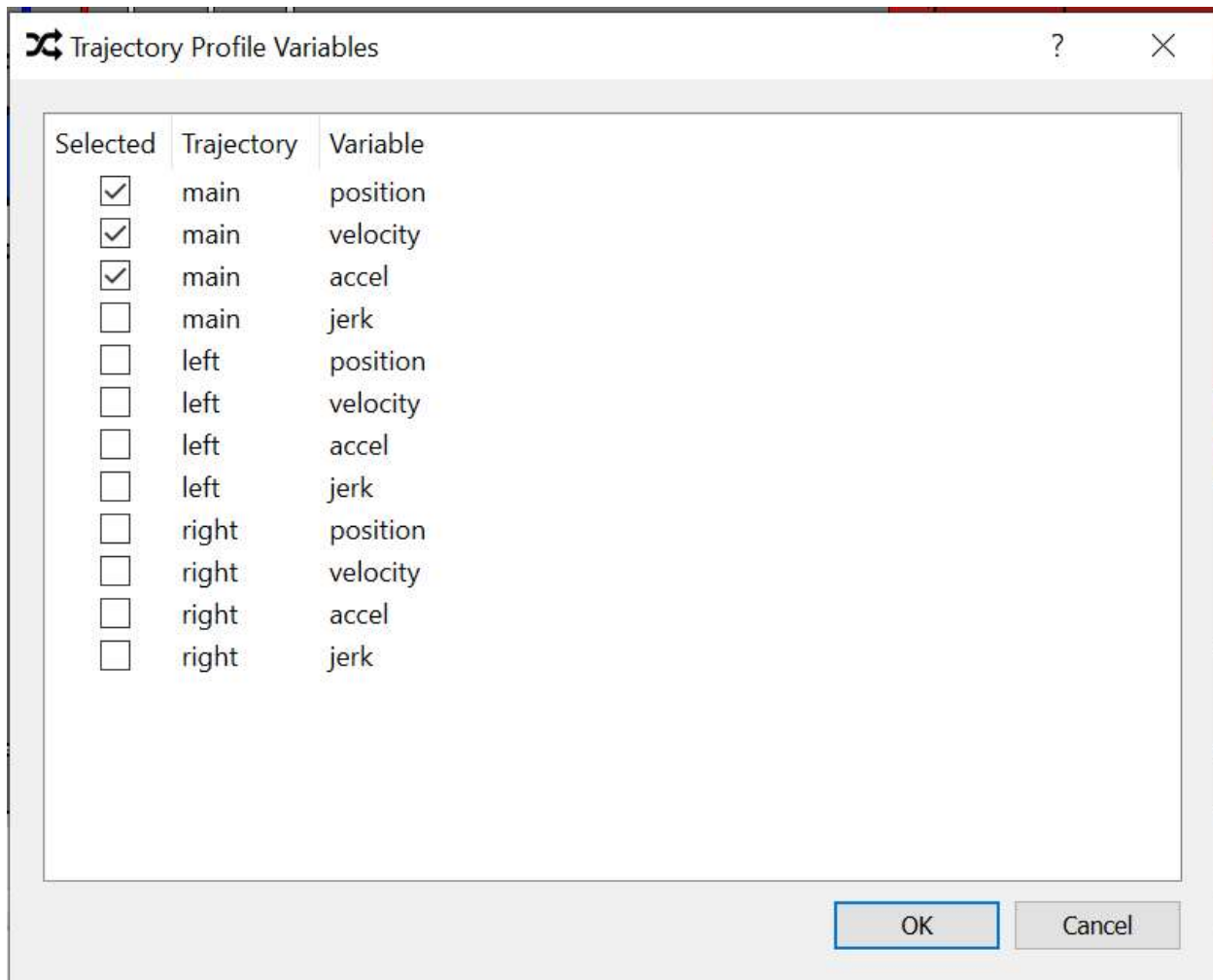|	
New	Create a new path file. If there are any unsaved changes with the existing path file, you will be prompted to ensure they are not lost.
Open	Open a new path file. A file dialog is opened to allow you to select a new path file. If there are any unsaved changes with the existing path file, you will be prompted to ensure they are not lost.
Save	Save the current path file to disk. If there is no filename associated with the current path file, the program will prompt for a new file name.
Save As	Save the current path file to disk, prompting for the name of a file on disk.
Close	Close the current path file.
Generate Paths As	Generate trajectory files for the current paths. The program prompts for a directory to store the generated trajectory files.
Generate Paths	Generate trajectory files for the current paths. If there is already a destination directory, these files will be saved there. If not, the program prompts for the name of a directory.
Recent Files	This is a submenu that contains the names of the last four path files that have been successfully opened. This is an easy shortcut to open a recently used file.

Edit Menu
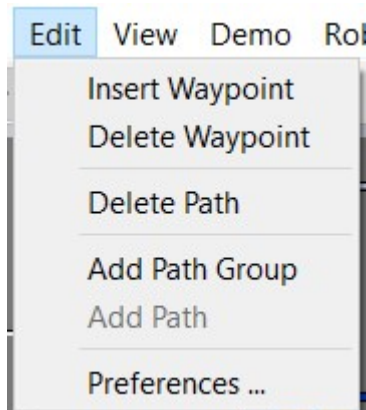
The edit menu contains the following menu items.

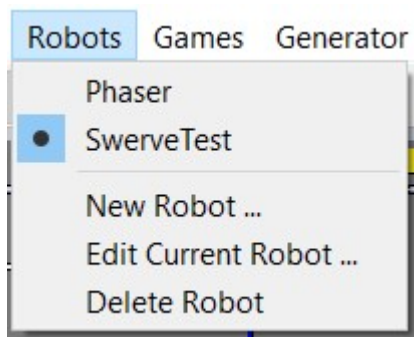| Insert Waypoint	This menu item inserts a new waypoint. It inserts the waypoint after the currently selected waypoint. The new waypoint will have a position and heading that is the average of the selected waypoint and the one following the selected waypoint.
Delete Waypoint	This menu item deletes the currently selected waypoint. This item does not work for the first or last waypoint in a path.
Delete	This menu item will change names depending on what is selected. If a Path Group is selected, this will be Delete Group. If a Path is selected, this will be Delete Path. This menu item deletes the item selected in the Path File window.
Add Path Group	This menu item adds a new path group to the Path File window.
Add Path	This menu item adds a new path to the currently selected Path Group.
Preferences	This menu item brings up the preference editor. There are currently two preferences. First are the units used by the program (inches, feet, meters, centimeters, etc.). Second is the output format for the generated paths (CSV vs JSON).

View Menu
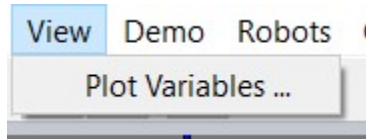
The view menu contains a single menu item which brings up the Plot Variable window below. This window allows for the selection of the trajectory items to be displayed in the Trajectory Profile window.

Trajectory Profile Variables   ?   ✕

Selected	Trajectory	Variable
☑	main	position
☑	main	velocity
☑	main	accel
☐	main	jerk
☐	left	position
☐	left	velocity
☐	left	accel
☐	left	jerk
☐	right	position
☐	right	velocity
☐	right	accel
☐	right	jerk

OK   Cancel

Robots

Robots Games Generator

Phaser
● SwerveTest

New Robot ...
Edit Current Robot ...
Delete Robot

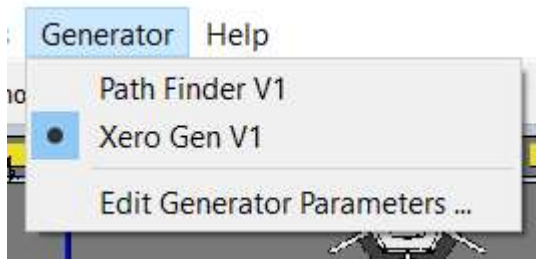| RobotName	Above the first separator is a the list of defined robots. The names visible are based on the robots that have been defined. Selecting one of these menu items make that robot the currently selected robot for path generation.
New Robot	Define a new robot. The robot properties dialog will be displayed to define the characteristics and name of a new robot.

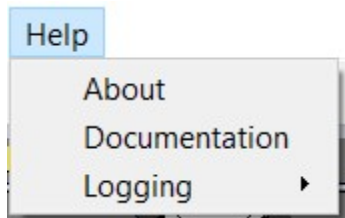|	
Edit Current Robot	The robot properties dialog will be displayed to allow the characteristics of the current robot to be changed.
Delete Robot	A dialog will be displayed to select a robot to be delete from the robot list.

Games
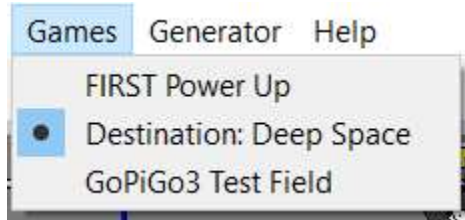
The list of defined games will be listed here. A game is defined by having an image file and JSON describing the field stored in the fields directory. By default there will be two fields installed. The FRC Power-Up field and the FRC Deep-Space field.

Generators

Path Finder V1	This menu item selects the PathFinder V1 path generator as the generator to use. This path generator was created by Jaci and is widely used with FRC Robotics. It can be found at https://github.com/JacisNonsense/Pathfinder. This path generator creates an "S" curve type velocity profile but does not support velocity constraints.
Xero Gen V1	This is the Error Code Xero path generation V1. While this is heavily based on the work of the Cheesy poofs. This path generator creates a Trapezoidal type velocity profile but supports velocity constraints as a function of the distances along the path.
Edit Generator Parameters	Each path generator has a set of parameters that are specific to that generator. These parameters are specific to the path generator and can impact the performance of the path generation process and the quality of results.

Help

About	Displays the program about dialog box.
Documentation	Displays this document
Logging	This program has an internal message logger that logs messages that are useful if something is not working. These messages are logged to a file. In addition, these messages can be logged to the log window. The Logging menu provides a submenu to turn on or off error messages, warning messages, info messages, or debug messages.

Demo Mode

The demo mode demonstrates a path or autonomous mode in action. Demo mode is activated by selecting the Demo On radio button the toolbar at the top of the screen. For this to be possible, a path or path group must be selected in the Path File window. The demo mode is controlled by the set of buttons in the tools bar across the top. In order these buttons are:

Play – play the path or path group in a continuous loop

Stop – stop the execution of the demo. The program remains in demo mode, but it is no longer running

Forward 1 – move the demo forward one time step

Forward 10 – move the demo forward ten time steps

Robot Forces View – bring up a window displaying the orientation of the robot and the velocity and acceleration being applied