1640 Swerve Drive

7-November-2019

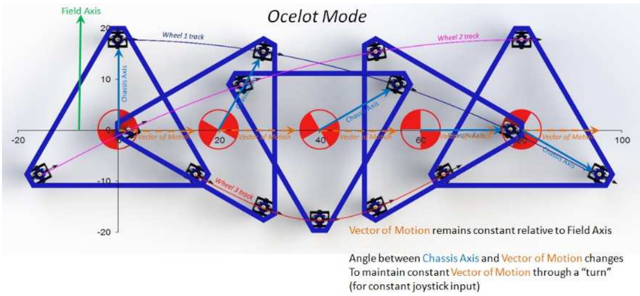
What is Swerve Drive?

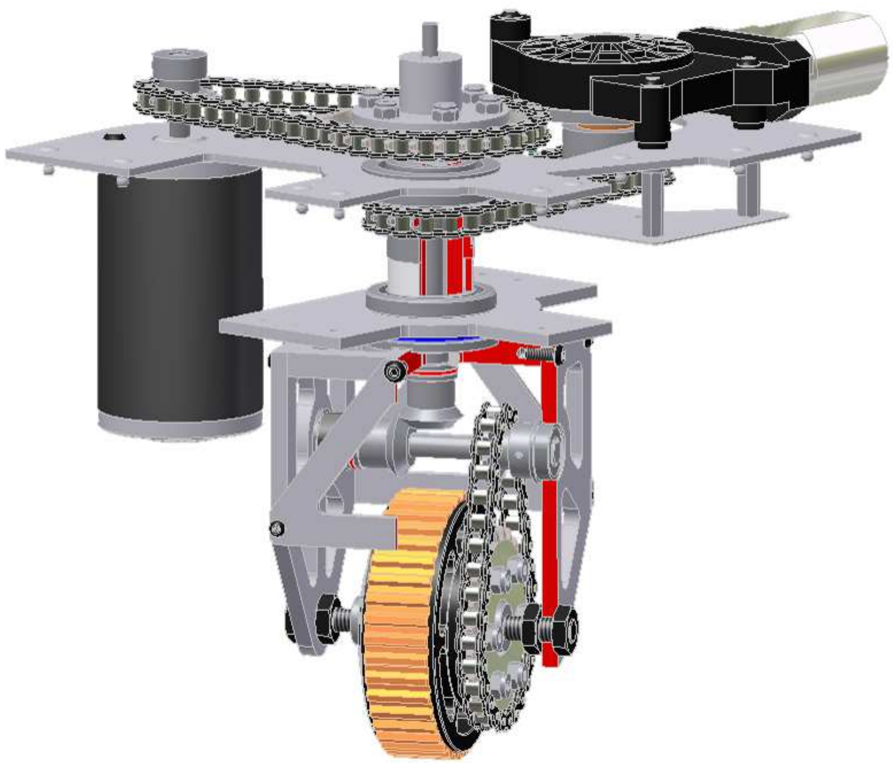
- A Drive Train in which all drive wheels are independently driven and steered.
- Utilizing traditional wheels (not Mecanum)
- A Holonomic drive train allowing the robot to move in any direction and independently translate its chassis orientation.

FRC 1640

1640’s Swerve History

- Started as a 2009 summer project
- 1st Swerve robot in 2010
- Have used swerve every year since except 2016
  - Modules in 2011
  - Identical modules in 2012
  - Dynamic driving 2013
  - CVT in 2017
  - Field-centric driving 2018
  - Drive-straight swerve 2018





Why did we do this?

- In 2008, 1640 was really a terrible team
- We needed a cultural change, stat!
- That year, we started summer projects. We studied and tested drive-trains first because we observed that robots that could move and maneuver did a lot better in competition.
- This helped. In 2009, we picked Swerve Drive for a summer project because:
  1. It had some clear attractive technical attributes
  2. It was going to be very difficult
  3. In fact, it would be impossible without dramatically changing the team's attitude about how we design, build, plan, train, and everything else

FRC 1640

Swerve Benefits

- Agility – True 2-d drive train with drive direction divorced from chassis orientation
- Normal traction
- Tactical stealth – no need to telegraph intentions via chassis reorientation
- No need for rotational aiming (turrets, turntables) for scoring devices
- Compatible with game-specific drive modes
- Able to “roll-off” defenders
- Minimal steering hysteresis
- Compatible with Field-centric driving
- Serviceability due to modular design

FRC 1640

Swerve Drawbacks

- Complexity/difficulty – Not easy to execute, but good COTS systems reduce barrier to entry
  - Control software is in a whole different class vis-à-vis Tank
  - Steering backlash needs to be managed
  - Shifting complex because 4x
- Mass – 26.8 lb_m in 2019 (24.8 lb_m projected 2020)
- Cost - ~$1,200
- Motor Budget – (8) motors dedicated to drive-train
- Driver training – Not optional
- 1640's design puts tall devices in all corners – high chassis frame

Development

- In summer 2009, the project started with a Vex model
- Also in summer 2009, basic math for swerve drive was developed – (2) white papers and a worksheet
- In autumn 2009, (CAD) design developed through four major and many minor design variants
- In December 2009, a prototype was built and tested (and design revised based on this testing)
- Subsequent developments based on annual critique of design, followed by CAD strawmen and further reviews
- CVT was prototyped using an old module as a base
- Significantly new designs were prototyped in 2018 and 2019 – (4) 2019 prototypes made and installed in chassis

FRC 1640

Development

FRC Team 1640 Pivot Drive

Progress indicators in Value Engineering

Model Year	2010	2011	2012	2013	2014	2015	2017	2018
Cost/pivot	$364.85	$375.72	$340.68	$284.43	$280.96	$310.79	$334.93	$282.17
reduction		($10.87)	$35.04	$56.25	$3.48	($29.84)	($24.14)	$52.76
as % of previous		-3.0%	9.3%	16.5%	1.2%	-10.6%	-7.8%	15.8%
Mass/pivot	10.0	9.3	8.6	7.9	8.1	7.4	8.5	8.7
reduction		0.7	0.7	0.7	-0.2	0.8	-1.2	-0.2
as % of previous		7.0%	7.5%	7.9%	-2.3%	9.3%	-15.6%	-2.4%
Changes impacting reliability and/or servicability								
Modular	×	✓	✓	✓	✓	✓	✓	✓
Shiftless transfer axle	×	✓	✓	✓	✓	✓	✓	✓
Ambidextrous	×	×	✓	✓	✓	✓	✓	✓
Integral tread wheels	×	×	in-season	✓	✓	✓	✓	✓
Welded pivot tubes	×	×	in-season	✓	✓	✓	✓	✓
EZ-change steering motor	×	×	×	✓	✓	✓	✓	✓
Clip securing 56T pulley	×	×	×	✓	✓	✓	✓	✓
Frame rivet nuts	×	×	×	✓	✓	✓	✓	✓
Clamp Flex-coupling	×	×	×	×	✓	✓	✓	✓
Anderson Connectors	×	×	×	×	✓	✓	✓	✓
Designed wiring harness	×	×	×	×	×	×	×	✓
Changes impacting utility								
Narrow cage	×	×	×	✓	✓	✓	✓	✓
Encoder-ready	✓	×	×	✓	✓	✓	✓	✓
Encoder-equipped	×	×	×	×	✓	✓	✓	✓
Continuously Variable Trans	×	×	×	×	×	×	✓	✓
Quadrature Encoder	×	×	×	×	×	×	×	✓
Low-backlash steering	×	×	×	×	×	×	×	✓
Changes impacting manufacturability								
Water Jet Milling	×	×	×	×	×	✓	✓	✓
2-D Pivot Side Plates	✓	×	×	×	×	✓	✓	✓
Braces replaced w/ standoffs	×	×	×	×	×	✓	✓	✓
Extensive use of 3-D printing	×	×	×	×	×	×	✓	✓

Tools

- Use Solidworks for CAD
- The team’s wiki is used to document designs, projects and tests. It used as a tool to retain institutional knowledge

Backlash Management

- Objective: Drive straight with Swerve
- Measured backlash and identified all the sources
- Replaced BaneBot P60 132:1 planetary gearbox with 100:1 Stepper Motor gearbox with extremely low backlash from China
  - Printed mounts designed for motor & gearbox
- Care taken to assure that all keyed shaft connections are tight – no undersized keys!
- Shifted from purchased to printed HTD5 pulleys
- Changes reduced total steering backlash 85%
- This (plus accurate encoders for distance) allowed complex autonomous routines which were critical in 2018

FRC 1640

Field-Centric Driving

- Objective: Make driving easier and more intuitive
- Our normal drive mode since 2018
- Makes driving by direct vision a lot easier
  - Robot-centric used when driving by camera (i.e. during Sandstorm)
- Left joystick controls robot direction (vis-à-vis field) and speed
- Right joystick controls chassis rotation (left-right control only)
- Software controls CVT
- This was as much a cultural change as technical

FRC 1640

Flotsam & jetsam

- Calibrate all modules identically relative to module
- Hate set screws
- Organize wiring harness
- Plan tool access
- 1st Design Priority – make things easy for the drive team
- 2nd Design Priority – make things easy for the pit crew

FRC 1640