2018 FLYSET FTC Workshop

Mecanum Drive
(9/3/2018)

Evan Li

- **Builder**
- Started with the team in FTC (rising 5th year)
- Went to South Super-Regionals in 2016, 2017, and 2018
- Went to Houston Worlds in 2017
- Main Driver at SSR in 2018 (Athens, GA)
  - Held record for fastest cypher completed (52 seconds)

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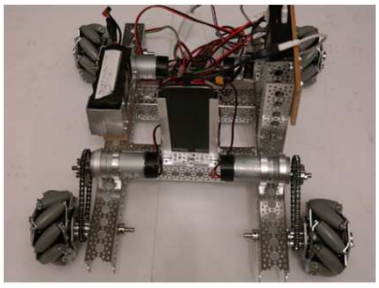
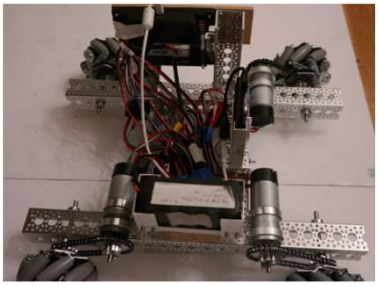
Chassis Specification

4-Wheel Mecanum Drive

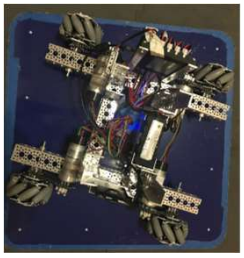




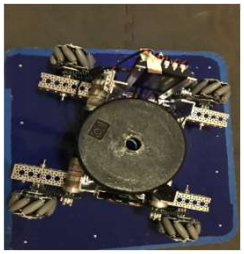
Base Weight: **14.7 pounds**

4-Wheel Mecanum Drive

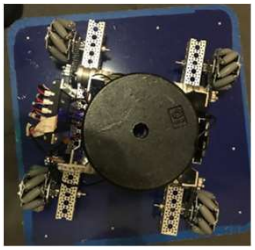
No Load

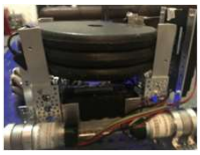


15 lbs Load



30 lbs Load





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4-Wheel Mecanum Drive

- Actobotics based chassis
- Four NeveRest 40 motors
- Four wheel independent chain drive
- Gear ratio from motor to wheel: **24:16** (equivalent to NeveRest 26.7)
- Consists of two pairs of mecanum wheels
- REV expansion hub is vertically mounted on the robot chassis
- Base chassis weight: 14.7 lbs
- 4 support columns that act as inserts for the weights to be mounted

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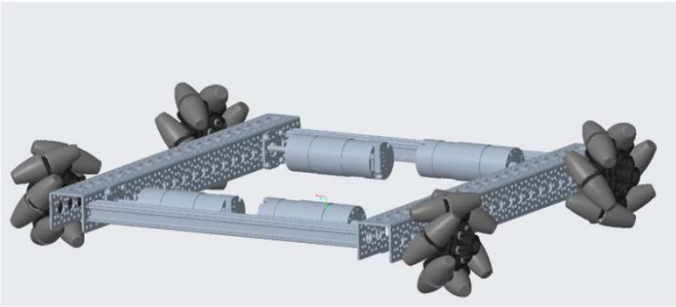
Chassis CAD Design

4-Wheel Mecanum Drive in Design Phase



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4-Wheel Mecanum Drive CAD Notes

- Could not find the correct mecanum wheels used for the real build (am-3062L)
- Layout of chassis was tentative; changed to the H chassis in the real build
- Extrusions taken out (used Actobotics channels in the real build)
- Direct drive → Independent Chain Drive
- 4-Wheel Drive stayed the same

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Chassis Test Results

4-Wheel Mecanum Drive Build Notes

- **Inspiration: last season Relic Recovery; personally, as a driver, felt the need for versatility on the field**
- Build Order
  a. Mecanum Wheel Assembly
  b. H-frame with 4 Actobotics Channel
  c. Initial Chassis Assembly
  d. Motor and Chain Attachment
  e. Modules + Wiring
  f. Phone Holder, Weight Rack, other accessories, etc.
- H-frame chosen for stability + more capacity
- Mecanum assembled in X-formation to enable general movement and strafing ability
- 4-Wheel Independent Chain Drive chosen for agility (started with 20s but too fast → 40s)
- REV Expansion Hub attached vertically to save space + gyro turn test

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4-Wheel Mecanum Drive Build Notes

- Equivalent length channels on frame to prevent drifting in forward speed test
- Wheels MUST protrude in front of channels, cannot climb balance stone if so
- Motor testing to find two pairs of matching motors to prevent drifting
- Chain slippage on motor shaft due to high torque → double D-clamp attachment
- 20 → 40 bc 20 was too fast, however, 40 was too slow → sprocket change to speed it up to gear ratio 26.7 : 1
- Weight rack assembled to balance center of mass → distribute equivalent weights to all 4 mecanum wheels

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4-Wheel Mecanum Drive Build Notes

- Motor Testing:

Motor	Right-Back Motor	Right-Front Motor
Port on REV Hub	Port 0	Port 1
Encoder reading #1	16,076	16,889
Encoder reading #2	16,171	16,879
Encoder reading #3	16,167	16,817
Encoder reading #4	16,159	16,763
Encoder reading #5	16,076	16,763
Encoder reading #6	16,151	16,702
Encoder reading #7	16,139	16,678
Encoder reading #8	16,070	16,637
Encoder reading #9	16,051	16,609
Encoder reading #10	16,047	16,592
Encoder reading #11	16,015	16,550
Encoder reading #12	16,003	16,554
Average	16,094	16,703

Motor	Left-Back Motor	Left-Front Motor
Port on REV Hub	Port 0	Port 1
Encoder reading #1	16,282	16,102
Encoder reading #2	16,226	16,059
Encoder reading #3	16,167	16,031
Encoder reading #4	16,152	15,997
Encoder reading #5	16,148	16,005
Encoder reading #6	16,094	15,974
Encoder reading #7	16,067	15,933
Encoder reading #8	16,092	15,935
Encoder reading #9	16,003	15,978
Encoder reading #10	15,986	15,864
Encoder reading #11	15,994	15,864
Encoder reading #12	15,963	15,850
Average	16,098	15,966

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Test 1: Forward Speed Test

- Drive forward in autonomous mode for 5 seconds at full power (100%) (Sensitive to voltage)
- 11 x 2 official FTC field tiles were used for running this test case
- Distance traveled was measured in meters

	No Load		15-lbs Load		30-lbs Load	
	Distance	Voltage	Distance	Voltage	Distance	Voltage
Test Run #1	6.46	13.25V	6.12	13.13V	6.3	13.37V
Test Run #2	6.35	13.21V	6.11	13.09V	6.24	13.32V
Test Run #3	6.32	13.17V	6.42	13.44V	6.06	13.28V
Average Value	6.38		6.22		6.20	

- Distance traveled was sensitive to the battery voltage level. Some test runs were done with the battery voltage level below 13.25V.
- Load on chassis had some impact on the distance traveled, but the impact was not significant.

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Test 2: 3 Second Turn Test

- Spun in autonomous mode for 3 seconds at full power (one side 100% power forward, other side 100% power backward) (Sensitive to voltage)
- 2 x 2 official FTC field tiles were used for this test case
- The degree that it rotates were measured, using the IMU sensor
- 360 degrees were added to the measurements for each full rotation.

	No Load		15-lbs Load		30-lbs Load	
	Degree	Voltage	Degree	Voltage	Degree	Voltage
Test Run #1	557.3	13.32V	508	13.24V	466.7	13.51V
Test Run #2	558.4	13.29V	533	13.22V	467.6	13.47V
Test Run #3	539.1	13.27V	532.3	13.19V	467	13.45V
Average Value	551.6		524.4		467.1	

- There were some variations in the measurements. Some test runs were done with the battery voltage level below 13.25V.
- The chassis spun in less degrees with more load.

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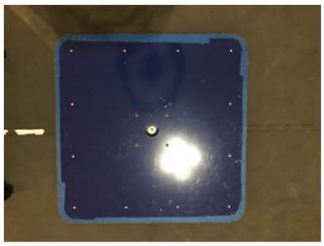
Test 3: Balance Stone Balancing Ability

- Drive onto the Relic Recovery balance stone manually, and then attempted to balance on the stone.
- Record whether the drivetrain can get onto the balance stone and how many seconds it can stay on after the joystick control is released.
- The balanced stone was put on official FTC field tiles.

	No load	15-lbs Load	30-lbs Load
Go on the stone?	Yes	Yes	Yes
How long on the stone? (forever is settled on the stone)	Forever	Forever	Forever



- Issue: The drivetrain had some trouble to complete the task by moving forward directly onto the balance stone, since its frame would hit the balance stone first.
- Resolution: By turning diagonally and using the wheels to climb, the drivetrain was able to get onto the balance stone.

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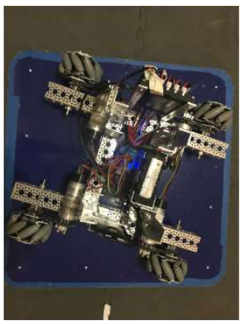
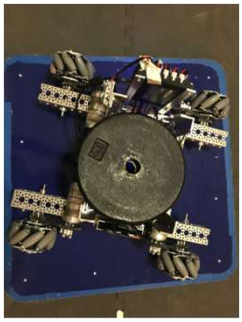
Test 3: Balance Stone Balancing Ability

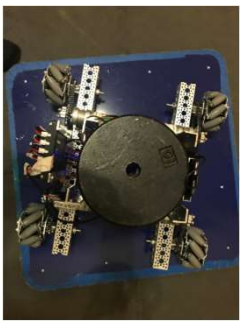
No Load



15 lbs Load



30 lbs Load



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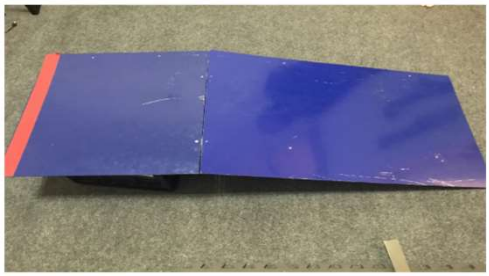
Test 4: Driving Up/Down A Ramp

- Drove up and down a ramp in TeleOP mode'
- Ramp from FTC Cascade Effect Challenge was put on official FTC field tiles
- Record whether it can drive up and down the ramp,

	No load	15-lbs Load	30-lbs Load
Up ramp	Yes	Yes	Yes
Down ramp	Yes	Yes	Yes

- Issue: Drivetrain got stuck on the top of the ramp, as the REV Expansion hub mount bracket extended below the chassis frame
- Resolution: Drivetrain was able to get up and down the ramp smoothly, after the Expansion hub mount bracket was raised.



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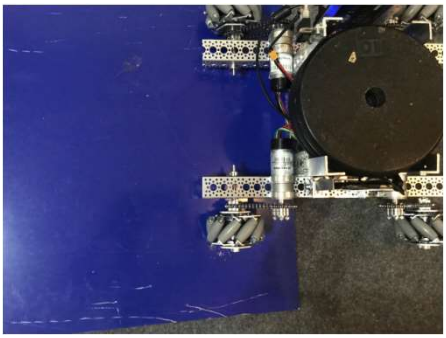
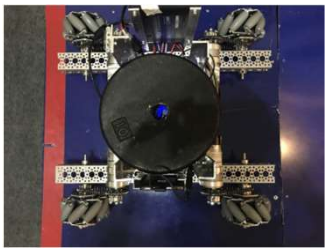
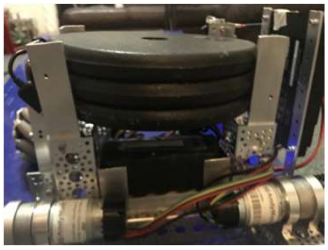
Test 4: Driving Up/Down A Ramp







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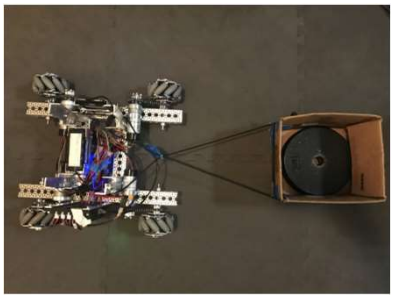
Test 5: Pull Strength Test

- Drove forward in autonomous mode to cover 10 feet at full power (Sensitive to voltage)
- Weights put into a cardboard sled pull by the drivetrain with a string.
- Weights added in an incremental manner (10 lbs, 20 lbs, 30 lbs, and 40 lbs)
- 11 x 2 official FTC field tiles were used for running this test case.
- Time took to travel 10 feet was measured in seconds



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Test 5: Pull Strength Test

Test 5.1: Pull test (10lbs)	No Load		15-lbs Load		30-lbs Load	
	Time (Sec)	Voltage	Time (Sec)	Voltage	Time (Sec)	Voltage
Test Run #1					4.11	13.57V
Test Run #2					4.13	
Test Run #3					4.33	
Average Value	4.83		4.50		4.22	

- Most of the raw data were lost, except the average values
- No issues for the drivetrain to pull the weight of 10 lbs.
- The heavier the chassis (plus extra load) was, the less time it took to complete the task

Test 5.2: Pull test (20lbs)	No Load		15-lbs Load		30-lbs Load	
	Time (Sec)	Voltage	Time (Sec)	Voltage	Time (Sec)	Voltage
Test Run #1						
Test Run #2						
Test Run #3						
Average Value			5.98		5.27	

- Most of the raw data were lost, except the average values
- It took a little longer for the drivetrain to pull the weight of 20 lbs.
- It was unable to pull the weight of 20 lbs with no load, since the wheels became too slippery.

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Test 5: Pull Strength Test

Test 5.3: Pull test (30lbs)	No Load		15-lbs Load		30-lbs Load	
	Time (Sec)	Voltage	Time (Sec)	Voltage	Time (Sec)	Voltage
Test Run #1			8.16	13.48V	8.76	13.46V
Test Run #2			8.23		8.31	
Test Run #3			8.46		8.49	
Average Value			8.28		8.52	

- It took much longer to complete the task, when pulling the weight of 30 lbs.
- The rollers of the Mecanum wheels were slipped on the tiles lots of time, which caused the chassis being pulled sideways.
- It was unable to pull the weight of 30 lbs with no load.

Test 5.4: Pull test (40lbs)	No Load		15-lbs Load		30-lbs Load	
	Time (Sec)	Voltage	Time (Sec)	Voltage	Time (Sec)	Voltage
Test Run #1						
Test Run #2						
Test Run #3						
Average Value						

- It was unable to pull the weight of 40 lbs in all conditions.

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Test 6: Straight Line Drift Test (Optional)

- Drove forward in autonomous mode to cover 10 feet at full power.
- Motor encoder on left_front wheel needed.
- 11 x 2 official FTC field tiles were used for running this test case.
- Horizontal drift, perpendicular to the drive train's motion, was measured in inches.
- Drivetrain jerked at the start point as well as at the end point, when it started or ended at the full power → due to the less traction of mecanum wheels.
- A ramp up/down algorithm was developed for reducing the jerk with the power being increased or decreased in multiple stages → It did not help for this drivetrain.

Test results with the full power:

	No load	15-lbs Load	30-lbs Load
Test Run #1	10.5	10.2	6
Test Run #2	10.1	6	10.3
Test Run #3	7	2.5	4
Average Value	9.2	6.2	6.8

Heavier load helped reducing the drifting.

Test results with the ramp up/down algorithm:

	No load	15-lbs Load	30-lbs Load
Test Run #1	30	12.5	7.5
Test Run #2	27	8.6	4
Test Run #3	23	9.5	2
Average Value	26.7	10.2	4.5
Starting Voltage	13.74 V	13.87 V	13.4 V

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Test 7: 90/180 Degree Turn Offset (Optional)

- Turned 90 and 180 degrees respectively in autonomous mode at 60% power.
- Use built-in IMU in REV Expansion Hub (vertical mount).
- 2 x 2 official FTC field tiles were used for this test case.
- Offset was measured in degrees from target angle, as read from IMU displayed on the driver station phone.
- Kp was tuned with 15 lbs load.

Test results for 90 degree turn:

90 Degree Turn	No load	15-lbs Load	30-lbs Load
Test Run #1	1.3	1	8
Test Run #2	8.4	0.2	7
Test Run #3	7.6	1.7	8.4
Average Value	5.8	1.0	7.8
Starting Voltage	13.31 V	13.23 V	13.21 V

Test results for 180 degree turn:

180 Degree Turn	No load	15-lbs Load	30-lbs Load
Test Run #1	8.1	0.7	7.9
Test Run #2	9.3	1.9	7
Test Run #3	9.7	1	7.8
Average Value	9.0	1.2	7.6
Starting Voltage	13.53 V	13.68 V	13.48 V

Kp was first tuned with no load, but it did not work well for the runs with 15-lbs and 30-lbs loads.

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Test 8.1: Sideways Speed Test (Optional)

- Special test for Mecanum wheel strafing capability

	No Load	15 lb Load	30 lb Load
Distance traveled	**12.71V** • 4.7m • 4.64m • 4.61m	**12.67V** • 3.61m • 3.608m • 3.612m	**14.08V** • 3.33m • 3.28m • 3.24m

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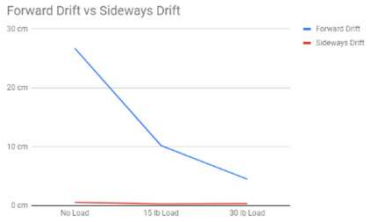
Test 8.2: Sideways Drift Test (Optional)

- Special test for Mecanum wheel strafing capability

	No Load	15 lb Load	30 lb Load
Distance Drifted	**13.76V** • 0.57m • 0.55m • 0.54m	**13.65V** • 0.32m • 0.31m • 0.28m	**13.45V** • 0.2m • 0.7m • 0.12m



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4-Wheel Mecanum Drive Summary

Pro:

- Drive train was extremely mobile and versatile
- Can move at any angle → advantage in turning and directional driving (strafing)
- Heavier load benefits mecanum traction issue

Con:

- Less traction than normal wheels (slippage under high stress testing such as pull test)
  - Disadvantage on field if defensive plays are occuring
- Not able to hold its ground in sudden movement (start/stop jerk motion esp in autonomous)

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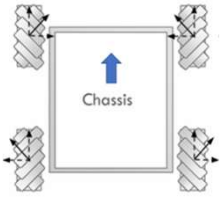
Mecanum Control Logic

Driving the Mecanum Chassis

1. **Driving Forward/Backward**



a. Mecanum in X pattern
b. Horizontal force from left + right wheels cancel out in dynamic equilibrium
c. Net force pushes the chassis forward
d. Motor power set negative, chassis moves backward under same reasoning

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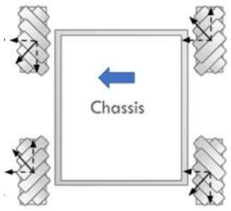
Driving the Mecanum Chassis

2. **Strafing Left/Right (Crab movement)**



a. Left wheels drive toward each other + right wheels drive toward each other → force cancels out
b. Net force pushes chassis left
c. Vice versa for right strafing

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Driving the Mecanum Chassis

3. **Rotating Clockwise/Counter-Clockwise**

a. Left forward, right backward → combined force spins the robot clockwise (like normal wheels)
b. Vice versa for counter-clockwise

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Driving the Mecanum Chassis

Chassis Motion Direction	Left-Front Wheel	Right-Front Wheel	Left-Back Wheel	Right-Back Wheel
Drive Forward	+	+	+	+
Drive Backward	-	-	-	-
Strafe Left	-	+	+	-
Strafe Right	+	-	-	+
Rotate CW	+	-	+	-
Rotate CCW	-	+	-	+

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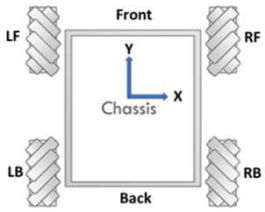
Driving the Mecanum Chassis

4. Gamepad Logic



a. Pushing the right joystick on its y-axis gives a y-value
   i. (+ = forward, - = backward)
b. Pushing the right joystick on its x-axis gives a x-value
   i. (+ = right, - = left)
c. Pushing the left joystick on its x-axis gives a r-value
   i. (+ = clockwise, - = counter-clockwise)
d. Left joystick y-axis unused

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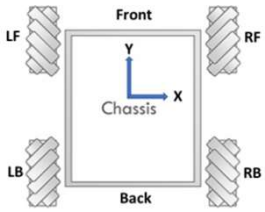
Driving the Mecanum Chassis

4. Gamepad Logic (Drive Algorithm)



a. Front_Left_Power = + x + y + (k*r)
   Front_Right_Power = - x + y - (k*r)
   Back_Left_Power = - x + y + (k*r)
   Back_Right_Power = + x + y - (k*r)

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Driving the Mecanum Chassis

5. Diagonal Driving

a. Left-Back + Right-Front drive at full power → forward right diagonal
b. Right-Back + Left-Front drive at full power → forward left diagonal
c. Vice-versa for backward diagonal driving