Snigdha Reddy Danda, Cameron Gregory, Jack Turk
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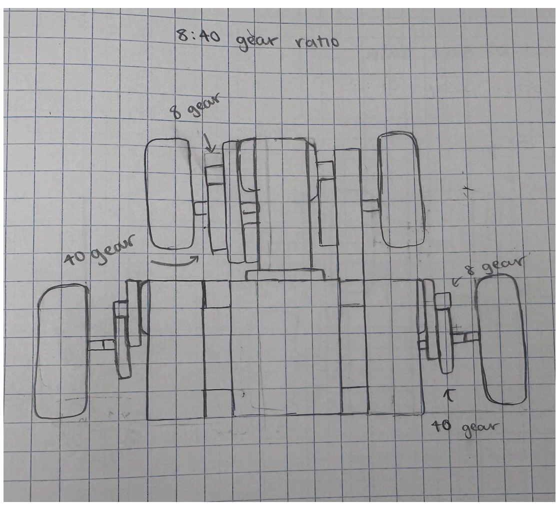
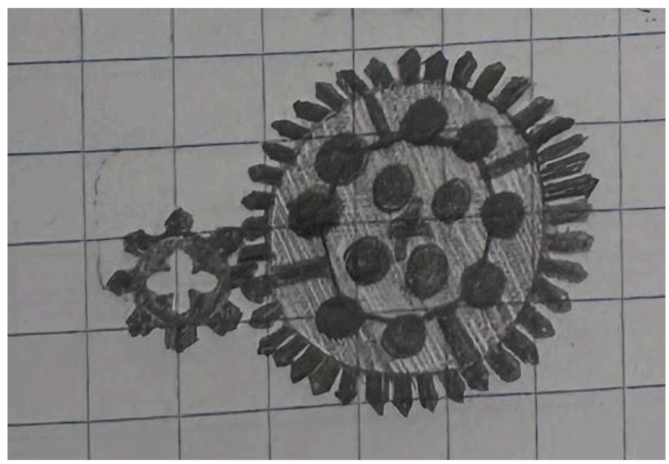
Engineering Academy

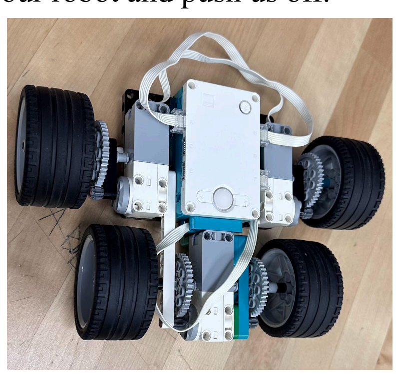
Introduction:
Our team was tasked with building a LEGO sumo robot which is capable of pushing an opponent off a table. We had to build, design, and test several different prototypes before deciding on the one that worked best for this project. The robots were required to fit in a 12x12 inch square and use no more than three motors. Although we tested multiple gear ratios, we ultimately chose a design focused on speed rather than torque, as most of our opponents were building robots with smaller gear ratios.

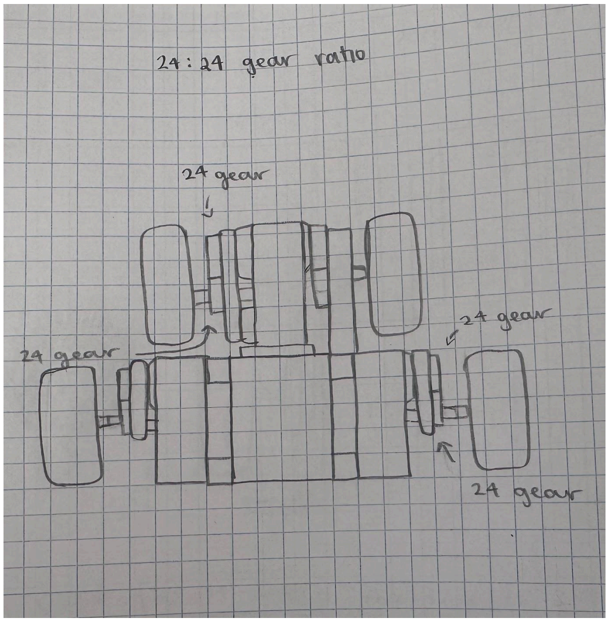
Design Process:

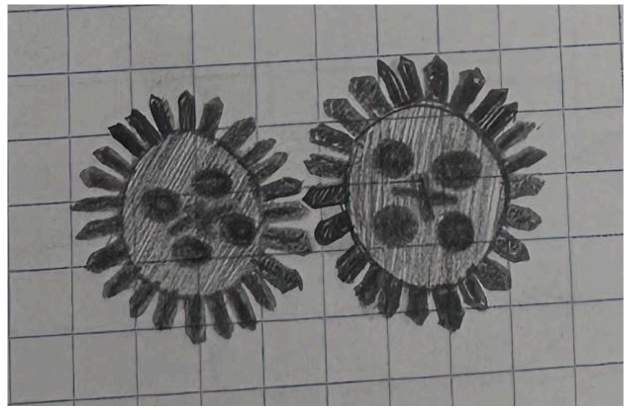




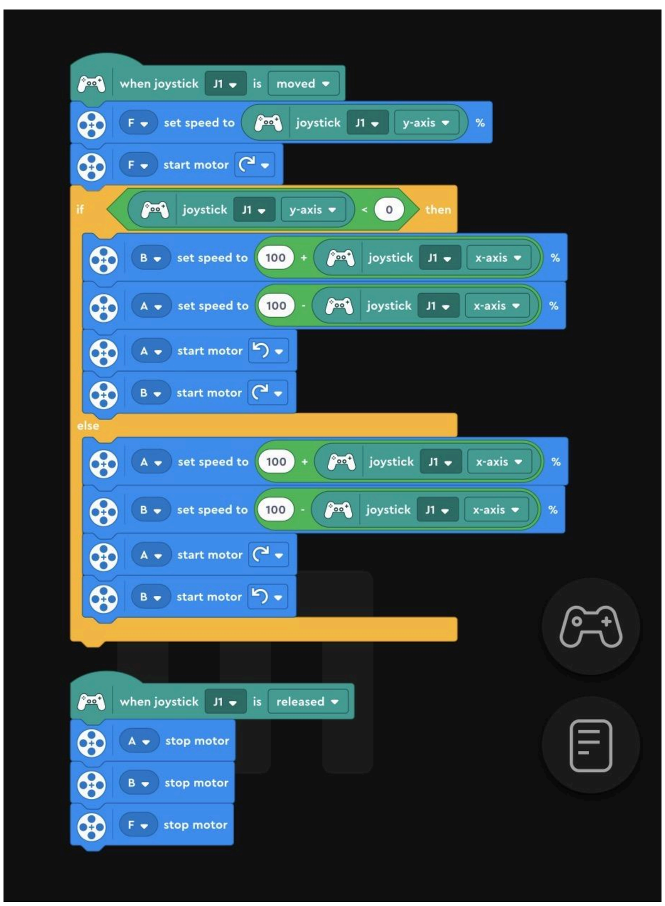
Our team decided to keep the overall design of the robot simple, and instead focus on selecting the best possible gear ratio. We first started with a 8:40 gear ratio, with the 8 gear on the motor and the 40 gear on the wheel. When testing this out, we found that it had a large amount of torque and was not easy to push against, which worked in our favor. But as we were analyzing other robots around us, we saw that everyone was taking the same approach: using the smallest gear ratio in order to become hard to move. In addition to that, some groups were adding wedges and ramps onto the robot that would get under our robot and push us off.







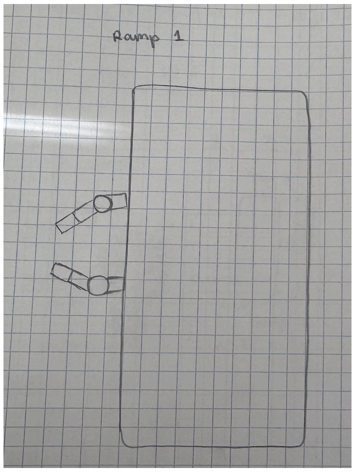
After much deliberation, we decided our robot wasn't better than the other groups at outright pushing, and thus we decided to base our robot off of maneuverability. We decided to use a 1:1 gear ratio so that we could be faster than other robots but still have some torque to prevent our car from being pushed off too easily.

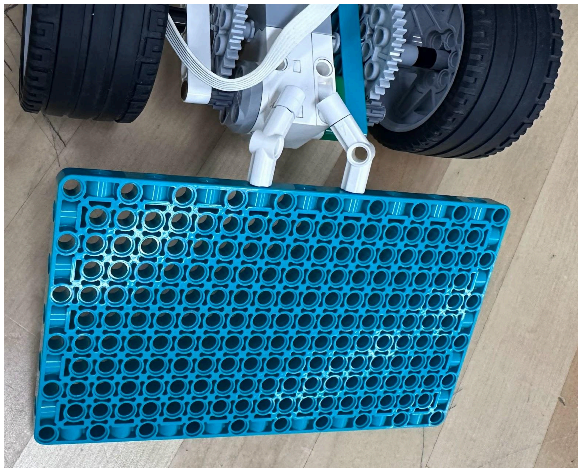


One problem about trying to build a maneuverable robot was that up to this point we had no way of turning our robots. To solve this problem, we downloaded the LEGO Mindstorm app on our phones and created a program where a joystick could control the motors and therefore the wheels on our robot.

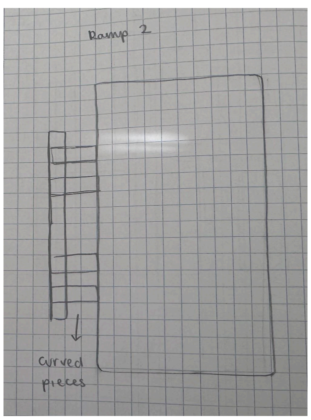
This is what we used to control our robot.

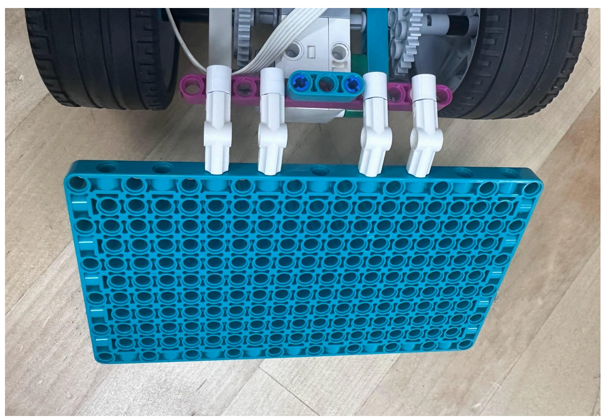
As for our ramp, the piece that does the actual pushing against our opponent, we had two variations.





The first one was connected directly to the motor for the two front wheels; because it had only two connectors, both of which were angled so that the entire ramp could fit, the ramp was weak and looked as if it was bending due to the push force exerted by the opposing group. This would cause our front wheels to lift off of the ground entirely, drastically decreasing our pushing force. At first we tried to lower the front wheels by one block to prevent this, but it only provided minor improvements.





Ultimately, we decided to remodel our ramp so that it could have stronger connecting points to the actual robot itself. This version of the ramp significantly enhanced the robot's resistance to being pushed and was able to push the opponent.

<u>Podcast</u>:

After completing our practice matches, our team recorded a short podcast to reflect on our design process and what we learned throughout the project. In the discussion, we talked about the challenges we faced while testing, how our design evolved after each issue, and what changes we would make for future competitions. We also shared our thoughts on other teams' robots and what strategies seemed most effective during the matches. You can listen to our full conversation right here: [Listen to Our Podcast!]

Data and Analysis:
To calculate the theoretical top speed of our robot, we used the same process that we used before for our drag car project. We started with a formula, ((RPM/Gear ratio)*pi*D)/60, that finds top speed based on the motor's RPM, the gear ratio, and the diameter of the wheels. The RPM, 185, represents how many times the motor spins in one minute. The gear ratio is the number of teeth on the gear attached to the wheel divided by the number of teeth on the gear attached to the motor. The wheel's diameter, 2.68 inches, was converted into meters to match the units in the formula. Because we used the same car design, only changing the gear ratios, the weight of the car stayed the same at around .5 kilograms. We calculated the top speed for each setup, and we could see how different gear ratios affected the final speed. The higher the ratios gave more torque but a lower top speed, while lower ratios did the opposite. We also calculated the theoretical torque of the robot using another formula, (N)*(tmotor)*(G) that multiplies each motor's torque by the gear ratio. So N is the number of motors, tmotor is the stall torque of the motor in meters and then G is the gear ratio. This shows how torque increases when the gear ratio gets larger, which helps the robot push or pull with more strength even though it moves slower.

Combo 1						
Time	X (m)	Y (m)	Velocity X (m/s)	Velocity Y (m/s)	Acceleration	Force
0	0	0	0	0	2.57179	1.2859
0.00263	0.00001	0	0.00649	0	2.36577	1.18288
0.00609	0.00004	0	0.01423	0	2.11962	1.05981
0.00999	0.00012	0	0.02202	0	1.87237	0.93619
0.01434	0.00023	0	0.02963	0	1.63071	0.81536
0.01869	0.00037	0	0.03625	0	1.42024	0.71012
0.02337	0.00056	0	0.04242	0	1.22432	0.61216
0.02827	0.00078	0	0.04798	0	1.04772	0.52386
0.03317	0.00102	0	0.05274	0	0.8966	0.4483
0.03835	0.00131	0	0.05702	0	0.76055	0.38028
0.04353	0.00161	0	0.06065	0	0.64515	0.32258
0.04936	0.00198	0	0.06408	0	0.53616	0.26808
0.14497	0.00887	0	0.08015	0	0.02572	0.01286
	Gear ratio	Theo Torque	Max speed	Theo. Speed	Mass	
	5/1	2.7Nm	0.08015m/s	0.132m/s	.5kg	

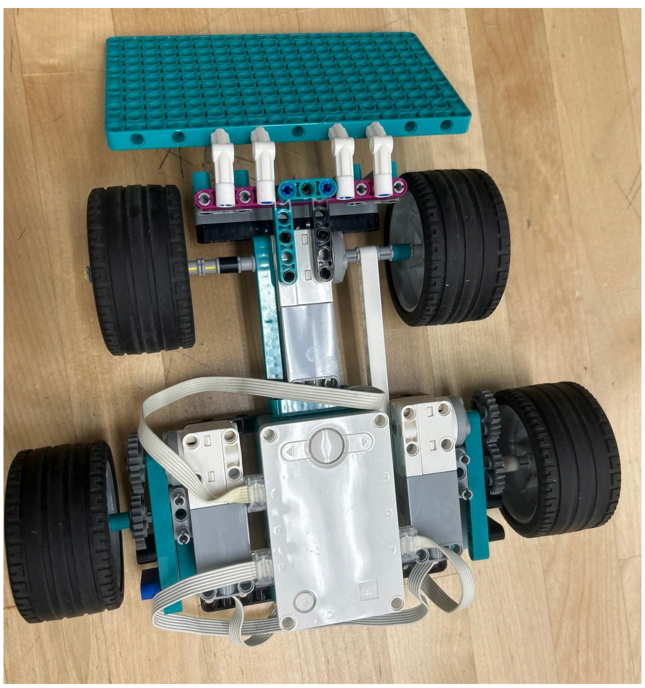
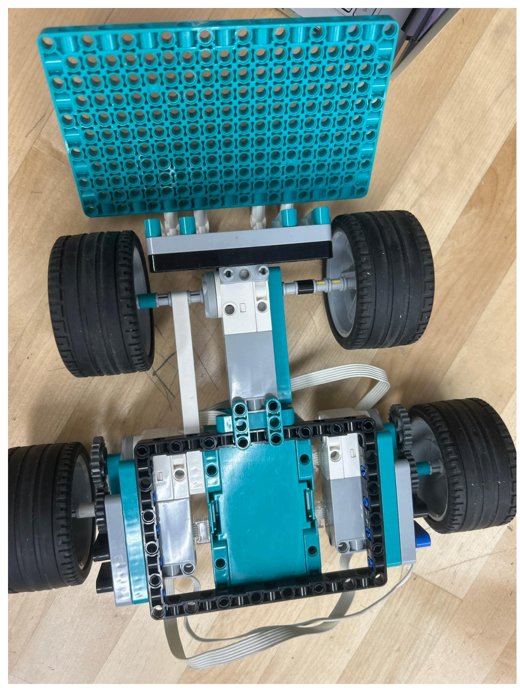
Combo 2						
Time	X (m)	Y (m)	Velocity X (m/s)	Velocity Y (m/s)	Acceleration	Force
0	0	0	0	0	2.57179	1.2859
0.03477	0.0014	0	0.08024	0	2.06203	1.03102
0.08043	0.00692	0	0.16195	0	1.54285	0.77143
0.13202	0.01703	0	0.22982	0	1.11169	0.55584
0.18977	0.03185	0	0.28356	0	0.77025	0.38512
0.24729	0.04923	0	0.32067	0	0.53446	0.26723
0.30955	0.07005	0	0.34816	0	0.35987	0.17993
0.37412	0.09315	0	0.36722	0	0.23876	5
0.44241	0.11868	0	0.38045	0	0.15472	0.07736
0.51167	0.14533	0	0.38912	0	0.09964	0.04982
0.58322	0.17337	0	0.39485	0	0.06325	0.03162
0.65879	0.20335	0	0.39864	0	0.03913	0.01957
0.72485	0.22976	0	0.40075	0	0.02572	0.01286
	Gear ratio	Theo Torque	Max speed	Theo. Speed	Mass	
	1/1	.54Nm	0.40075m/s	0.658m/s	.5kg	

For the actual measured top speed, we used the Vernier analysis software again. We recorded a video of the robot moving in a straight line and uploaded it into the program. After marking a known distance in the video, the software automatically tracked the robot's position and calculated its velocity over time. The measured top speed was taken at the point where the robot's acceleration was near zero, which was around 99% of its real speed. That gave us a good estimate of the actual top speed for each gear ratio. To find the exerted force, we first calculated the robot's acceleration at each time point using its change in velocity over time. Then we multiplied that acceleration by the robot's mass to find the force it was exerting at every moment. This let us see how the force changed as the robot sped up and got closer to its top speed. The results showed that the force was highest at the start, when acceleration was greatest, and decreased as the robot approached constant velocity.

<u>Final Design</u>:
When we began testing our robot before the competition, we ran into a major issue: the back wheels kept falling off whenever they got caught in the cage-like structure of our opponents' robots. This made the robot lose traction and sometimes completely stop moving during test matches. To fix this, we first added straightLEGO pieces that better secured the wheel to the motor, hoping that this would prevent it from detaching.

During the next round of testing, the improved support helped at first, but we quickly realized that the entire motor assembly was now being pulled off instead of just the wheel. This showed that while the connection to the wheel was stronger, the connection between the motor and the frame still needed reinforcement.

Finally, we added several stoppers on the outer side of each back wheel to physically prevent them from slipping off their axles. This adjustment successfully solved the issue — the wheels stayed in place, even during intense pushing matches. With the wheel and motor assembly now fully stabilized, we used this setup in our final robot. These small but important changes made our robot much more durable and reliable in competition.

<u>Conclusion</u>:
Although our results from the competition were lower than what we hoped and expected, the robot was still an overall success. From early on we realized that our high torque robot could not beat the other high torque robots and thus we had to switch our focus to speed and maneuverability. Throughout the building process we worried that this sudden refocusing of our efforts would not be successful as we often had problems with our steering and the structural integrity of our robot vs others. Much to our surprise, we managed to beat the heaviest and highest torque robot, and the eventual overall winner, in the first round which was to the delight

of every other team. However, with our steering problems and a lackluster front ramp, we only went on to beat one more team and finished 2-3. One thing we wished we had looked into was a two wheel design. Throughout the design and building process we noticed that most other groups only had two wheels in the back and thus were able to have their front ramp flush with the ground. Another thing we wished we could have done better was create a better steering system where the turning wasn't dependent on the speed of the robot. Finally, if we had another chance we would create a wedge or ramp on the rear of the robot in case the other robot got around ours. Overall, although the results may not show it, our sumo robot was a success and we are happy with how it turned out.