SEMI-AUTONOMOUS RESCUE TEAM 2024 TDM

Team Description Materials 2024

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Semi-Autonomous Rescue Team

Team Description Materials 2023

Logistical Information

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1. Introduction

The Semi-Autonomous Rescue Team (S.A.R.T.) is a group of STEM enthusiasts originally formed in early 2015 with the intent of developing and creating a robot capable of competing in the 2016 Rapidly Manufactured Rescue Competition (RMRC) at RoboCup in Leipzig, Germany. The team consists of students between the grade levels of 10 to 12, mentored by committed STEM teachers. The RMRC simulates a real-world natural disaster through small individual test methods. This is used to test teams on their engineering expertise and problem-solving skills.

2. Reflection on experience at RoboCup in 2023

S.A.R.T. participated in the 2023 RoboCup located in Bordeaux, France. S.A.R.T. was tasked with creating a robot capable of travelling through a small course filled with various obstacles. Points were awarded based on the number of times that the robot could traverse back and forth through the course within a specific time limit. The robot was controlled remotely by a driver who was only able to see through cameras and any other sensors attached to the robot.

We worked tirelessly day and night to achieve our projected goals and due to our hard work, we successfully came third place overall. S.A.R.T. came out with a total of three significant recognitions in the RMRC. We were awarded open source and innovation, class mobility/manoeuvring and equal first place in dexterity. Our robot was able to travel the course with ease and the turning ability was superb. Another feature of the robot we were praised for was the exploration and mobile sensing of the robot. Although we were rewarded with these two separate accolades, there was one prize that was won which holds far greater importance. The team was rewarded with the Open Source and Innovation award. This specific award is granted with a trophy and is the most prestigious and sought-after prize in the RMRC. Our hard work and tireless nights were paid off as S.A.R.T. achieved our goals and more, and the team will be looking to follow up on that impressive performance in 2024 in the Netherlands. During the beginning of the final maze, the arm of our robot broke due to stress caused by the inflexibility of the shoulder joint. The robot also struggled going up the stairs because there was no mechanism to ensure this ability, this caused a great amount of pressure as we were unprepared for this obstacle. Beaching was another issue we faced during the competition as a result of our tracks, as they were too far apart and if the robot was turned on the K-beams it would beach. The servo horns also wore and were not able to move as the competition progressed, this was due to the teeth having been progressively stripped away. The motor gears also snapped as it consistently collided with the side of the track, this drove the shaft through the gear head, which caused the gears to shred. Another complication we faced came as a result of the bandwidth continuously cutting out due to other networks cutting into our bandwidth. During the competition, it became evident that we required a more advanced QR Code scanner. We noticed this was a problem as the software would look for a code, then take the first one that was found, read it, and print the link. However, last year's competition structure as well as the number of codes exceeded our expectations. Additionally, multiple QR Codes were bundled together, with up to eight various sized QR Codes on a single sheet of A4 paper. We observed that other teams using software that could capture multiple codes simultaneously, rather than one in succession. This allowed the other teams to have the ability to get a quick and clear shot of the paper and collect all points instantly. Our onsite coder during the competition eventually found and adapted a suitable program for the robot using the Raspberry Pi microcomputer, although, the robot struggled to run on this. This year, we will investigate new ways to create a scanner capable of picking up multiple codes simultaneously, as well as one that is light enough for our computer to run more efficiently.

3. System Description

Hardware

The 2024 SART robot will take the flaws of past editions and creates a new and innovative product. The SART robot in 2024 will vary significantly from the previous editions and present a new challenge for the SART team.

Arm

Figure 1 – Render of Arm Claw 2023

The robot arm in 2023 had four degrees of freedom which were the shoulder, elbow, wrist, and fingers. We will keep the base function of the arm as it appeared to work efficiently in the competition. But, when the arm attempted to grab something, the fingers would open outwards pushing the objects forward. The new arm will look to limit lineal movement to make it easier to grab objects.

Figure 2 – Render of Arm (Full Assembly)

Chassis and Tracks

In this iteration of S.A.R.T., most of the main components of the chassis and tracks were kept the same from the Bender robot. The first section we decided to keep the same was the material of the robot. The Bender robot's chassis was constructed using both 3D print and acrylic materials. The reason for this was because it was easier to design and create the chassis if it was 3D printed. We were able to design the chassis using Fusion 360 and directly export the file and 3D print it making the whole process much more efficient. The acrylic was used for the bottom and the top of the Nibbler robot. This material was much easier to acquire and cut to the desired size. Moving away from the material of the chassis, the robot was also designed to be much narrower. This was done to fit the arm on top of the robot without causing any issues of the robot being too tall so the arm would get caught on things. We also had the front and back of the robot be much more rounded so that when it is travelling over various obstacles the Chassis won't restrict its ability to get over the obstacles.

The tracks on the Nibbler robot are the same as both the Flexo and Bender robots as they have been proven to be very effective in competition test methods. One issue that has always encountered S.A.R.T. robots is sand. Sand gets lodged in the tracks and when that happens the tracks fail to move and a large amount of stress is placed on the motor controller. To combat this, we drilled holes in the tracks to allow the sand to leave the tracks to ensure the tracks can work without interruption. When we tried to install the tracks onto the robot, we realised that they were too tight and if they were to be used, they would place too much stress onto the motor controller. In this discovery, we also found out that each link of the tracks is a different size. To ensure that the tracks are not too tight, we needed to compare each link and separate by size. We then used this to create the longest possible tracks to use on the robot. Once that was done, the tracks were much less tight and were ready to use on the robot. Finally, we are also using the same motors we used in the Flexo robot. This is because the motors worked well in last year's iteration and there is no reason to change the motors.

The chassis that was used in the 2023 competition worked sufficiently and could withstand most of the rigors of the test methods. Despite this, the 3D printed materials would wear and grind on walls causing minor danger to the contents inside. To fix this, the new chassis will be built out of the metal stripped from an old 3D printer. This should result in increased strength of the chassis when compared to the one used in 2023 and keep the inner workings of the robot intact. This also means that we were able to make the robot's chassis significantly smaller, making it easier to manoeuvre. The tracks used in the 2023 competition were commercially built products, that contain individual pieces of varying lengths which made it extremely difficult to make the two tracks the same length. To fix this, in 2024 we are investigating making our own tracks. We have already 3D printed the moulds for our tracks with the intention of creating our own. Additionally, the issue of beaching plagued the robot during the k-beam runs. To solve this, the tracks will be much closer together to prevent the issue of beaching.

Figure 3 – Finished chassis of Nibbler Robot

Figure 4 – finished chassis of Flexo robot.

Bender, Flexo, Nibbler Chassis Comparison

While all three robots are built on roughly the same base, there are plenty of notable changes in the design of the chassis. In terms of Bender vs. Flexo, the most obvious change is the addition of the arm. This arm was the first iteration of S.A.R.T. arms and is currently what Nibbler's arm is being based on. In addition to the arm, the battery's angle has been noticeably lowered to accommodate this additional bulk on top of the robot.

Nibbler and Flexo on the other hand are a lot more alike, Nibbler is more like an improved and refined version of Flexo. The most notable changes between the two are Nibblers clear acrylic top, making it possible to see inside of the robot without having to take it apart, and the new and improved arm. While the render shown below doesn't show Nibbler's new arm, the idea was based off Team TUPAC's robotic arm, which had a three-prong gripper design which inspired our team to try something similar. Other than the three-prong gripper, the arm design stayed loyal to the original arm design, just with all round improvements.

2024 Updates

The 2024 edition of the SART robot is the most unique out of the three, this is due to the make-up and materials used. For example, we used metal from an old 3-D printer and it is also much smaller in size and easier to manoeuvre. These changes make the 2024 robot quite different and could potentially give us a competitive edge.

Figure 5 - Bender (Left) Flexo (Middle) Nibbler (Right)

Figure 6 – Comparison of Nibbler claw (Left) and Flexo claw (Right)

Control System

In contrast to previous years, the new robot and control panel will be using the new 'Sights Lite', which aims be a more simplified and stable version of the original Sights software. The robot will be controlled using the same control scheme as previous years, with the movement using either the arrow keys or WASD, and the number pad for the controlling of the arm. In addition to the control scheme, many other features were carried over from last year's robot, namely the Sabretooth motor controller, and the Raspberry Pi servo hat used to control the servos and motors. This year we once again used the previous fixes done which was made using the Sabretooth possible with the Raspberry Pi, which can be found in our previous TDM.

2024 Update

The use of 'Sights Lite' will be carried over from 2023 as it served as an easy-to-understand control panel that worked well in tandem with the Wi-Fi network. This year, we have decided to move on from the Raspberry Pi and change microcontrollers to the Latte Panda. Latte Pandas are a full computer that have a built in Arduino. This means that the Arduino will take care of the sensors and the Latte Panda takes care of the web tasks. This means that there will be faster processing speeds, especially with real time sensors.

Control Panel

Contrary to previous control panels, this year's control panel will consist of a much simpler design, instead using a laptop as the brains of the control panel, along with a basic USB monitor, wireless access point, a full-size keyboard (for the number pad), and a Ryobi drill battery to outlet adapter. A notable change when compared to previous years in our networking of our wireless access point is in the use of a tripod designed for a camera. The tripod allows our access point to be positioned higher than most other team's AC's, which means there will likely be significantly less interference and provide a much better connection with the robot.

The USB monitor and the access point were both powered by the Ryobi drill battery, while the laptop was powered through its inbuilt battery. There were two decisions involved in the decision to change the control panel design. The first reason was due to the compactness and the lower weight of the new panel, as a majority of the weight from the old panel was from the uninterruptable power supply (UPS), along with the much bigger pelican case, whereas now everything is powered through the drill battery which is much lighter and smaller than the UPS. The second reason is the simplicity of the new panel, with only a few cables connecting each component. The whole panel was simplified not only make construction simpler for the people in the S.A.R.T. team, but also making setup simpler for first responders as everything is relatively straight forward in where they go.

Figure 7 – New Control System for Nibbler robot

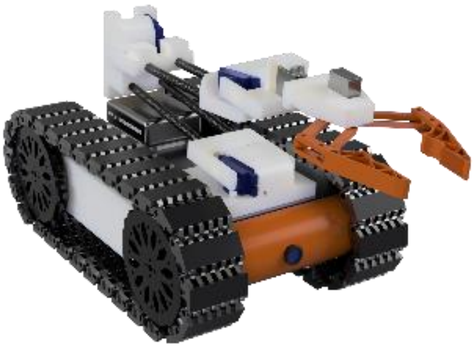

Figure 8 – Flexo Render

Software

Vision

The S.A.R.T. robot has multiple capabilities regarding interpretation of its surroundings, including recognition of Hazmat warning signs and reading of QR codes (Figure 9, 10). All our computer vision software runs on the control panel computer, using video feed received from the web socket server on the robot. This allows us to offload computations from the robot, preserving its computation power.

Our QR code reading program is a python script that uses the "pyzbar" package and its in-built QR code reading function. We apply rotation to the image at many angles and apply pyzbar to each rotation to increase efficiency. The output of this script can be seen in Figure 8.

Figure 9 – QR Code Reading

Our hazmat detection python script is a two-stage process running on the control panel. We first apply a YOLO v4 object detection model, trained on custom data, to calculate the location of the sign in the image. Once we have found the location of the sign, we apply a K-nearest-neighbours (with K=1) test (to the region of the image found by the YOLO v4 model) to classify the sign. We use sample sign images as our KNN point cloud. The final output of this process can be seen in Figure 7. The biggest advantage of this method is that the YOLO v4 model only calculates position and does not do classification. Doing classification in the YOLO v4 model would require roughly 20x more training data to achieve the same accuracy.

As for multithreading in the hazmat detection python scripts, we have continued using what was experimented with last year with running every comparison check (between sign samples and camera cutout) on separate threads. Additionally, we've added several improvements to further increase detection speed.

The code that was used in 2023 was created years ago and in extenuating circumstances. This means that the code was very messy and hard to navigate. For the 2024 competition, the programmers at SART will attempt a complete overhaul of the code and a rigorous clean up. This should make the code more streamlined and easier to navigate.

Figure 10 – Hazmat Detection

4. Operational Procedures

Setup

The setup process of the robot and control panel was designed to be as simple as possible. As mentioned previously, first responders in a rescue situation typically rate 'ease of use' highly amongst the requirements of a rescue robot. Thus, one of our core design philosophies for user experience was simplicity, meaning the setup process should be straightforward and intuitive.

Mission Strategy

During operation, the teleoperator has primary control of the robot using their choice of a keyboard or any compatible controller, with easy switching between robot driving and arm operation with a single button press. The teleoperator's primary vision for navigation will be the optical cameras however the suite of other sensors including map of the environment are displayed on the control panel so that the teleoperator has all the information necessary to control the robot.

Given that in a rescue situation, resetting or freeing the robot of an obstacle is not possible, this means that the teleoperator really only gets one attempt at the rescue situation so extreme caution has to be taken. For example, in a disaster situation, visibility of the path ahead may be blocked by obstacles or debris, meaning the path may be unknown to the operator, it is in the best interest of the teleoperator and the entire rescue operation to perform a risk analysis. Given that the stakes are incredibly high as the operator has little opportunity to reset the robot in a real-world situation, backtracking in an attempt to find a less risky and safer route is to be taken. Although this backtracking will likely result in a slower response time, it is the best outcome overall, as if the teleoperator makes the decision to take the risk and venture without aid from the robot's cameras, the robot is of no use whatsoever if it is stuck and cannot proceed into the situation, collecting valuable intel that can prove extremely useful in rescue operations.

Referring to the risk analysis performed by the teleoperator, it is not always possible or viable to backtrack to find a safer route, given situation-specific individualities. This is why it is not a concrete rule to backtrack to find a safer way, as in some situations, the risk of venturing into a situation with minimal to no aid from the robot's cameras is less than the risk if the robot does not reach the destination in a certain amount of time. Because of this potential, the decision is left up to the telecommunicator who is operating the robot to make the decision in order to achieve the most desirable outcome given the constraints and individualities of the situation.

Pack-up

Once the robot has been recovered, the power-off process is relatively simple, with four main steps. Step 1 is to safely shut down the robot using the power options in the SIGHTS lite interface. Step 2 is to cut power to the robot by removing the Makita drill battery located near the rear of the robot. Step 3 is turning off the control panel using the usual way in the desktop operating system. The final step involves, power can be cut by removing the Ryobi drill battery located inside the control panel. Additional pack up steps may include placing the robot in its foam-lined hard carry case, which would require the robot's arm to be removed before storing in the carry case. o

5. Experiments and Testing

The SART uses a range of test methods to improve the functionality of the robot. These test methods are of modular design to test a range of engineering methodologies and validate changes to the robot. The First stage of testing is utilising a flat box which is used to simulate driving ability on 'flat ground', this test method was primary used to test camera angles and locations. Second test method involved a range of vertically angled platforms which allowed the S.A.R.T to test the rigidity of the chassis and validate its ground clearance.

The third test method was an adaptation of the second featuring more gradual steps to softly test the robot's functionality. Lastly, the fourth test method involve the S.A.R.T using a range of PVC pipes to simulate log and or smooth climbs. This method was far by the hardest and allowed us to test the robot in its entirety (with the arm). The use of these test methods has greatly improved the functionality of the robot through rigorous engineering physical testing.

6. Future Developments

Future developments will continue to focus on vision processing and autonomy. This will include taking advantage of our new hardware's capabilities in machine learning and vision processing to improve our autonomous functionality and computer vision processing. In future we would like to put significant development into a new innovative control interface, utilising virtual and augmented reality technologies to provide a significantly improved interface between the teleoperator and the robot.

7. Conclusions

The S.A.R.T Nibbler robot represents an improved design of the previously created robot by observing what parts of the robot needs to be improved upon and structuring the design process around those areas. The arm is still present on the robot to enable our robot to undergo dexterity and manipulation tests. The addition of a robotic arm to this iteration not only allows us to compete in more tests and therefore gain more points in the competition, but also expands the diversity of applications of our robot in rescue situations.

2024 Updates

The 2024 robot presents a new opportunity to expand the capabilities of the SART robot. This year has been the year where we will attempt new things and experiment extensively to create an improved product. This means that the robot that hits the track in Eindhoven will vary significantly to last year's edition, but hopefully this wave of innovation will provide us with a way to be successful in the competition.

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9. Appendix

Component	Price (USD)	Quantity	Total (USD)
Raspberry Pi 4	$ 45.00	1	$ 45.00
MLX90640 IR Camera	$ 66.72	1	$ 66.72
ELP 5MP HD USB Autofocus Camera	$ 56.23	3	$ 168.69
Adafruit SGP30 CO2 / TVOC Sensor	$ 19.95	1	$ 19.95
MLX90614 Infrared Temperature Sensor	$ 7.57	1	$ 7.57
50:1 Metal Gearmotor 37Dx54Lmm 12V	$ 35.00	4	$ 140.00
2-pole rotary switch	$ 6.16	1	$ 6.16
Cables	$ 17.11	1	$ 17.11
Track	$ 25.11	3	$ 75.33
Servo Tubing Connector	$ 6.95	1	$ 6.95
Carbon Fibre Tube (1m x 24mm)	$ 30.00	1	$ 30.00
Acrylic Sheet (4mmx400mmx400mm)	$ 10.00	1	$ 10.00
Gripper	$ 40.00	1	$ 40.00
Turnigy 1300 mAh 3S 25C Lipo Pack	$ 12.87	2	$ 25.74
Ultimaker ABS 3D Printer Filament 1kg spool	$ 32.00	1	$ 32.00
Quanum 12V-5A (7.2 - 25.2V) Dual Output UBEC	$ 10.25	1	$ 10.25
Sabertooth 2x12 Dual Motor Driver	$ 97.98	1	$ 97.98
Adafruit 16-Channel PWM Servo HAT Raspberry Pi	$ 23.96	1	$ 23.96
Total			**$823.41**

Component	Price (USD)	Quantity	Total (USD)
SE830 Waterproof Protective Case	$87.00	1	$87.00
UDOO x86 Ultra	$267.00	1	$267.00
Energizer AC Sine-Wave Inverter	$50.64	1	$50.64
AOC E1659FWUX USB Monitor	$92.38	1	$92.38
Ubiquity Unifi AP AC Pro Access Point	$148.84	1	$148.84
Power-Over-Ethernet Injector	$8.00	1	$8.00
Microsoft All-In-One Media Keyboard	$45.60	1	$45.60
Turnigy 4000mAh 4S LiPo Battery	$36.95	2	$73.90
Acrylic Sheet (3mm)	$20.00	1	$20.00
Power Button	$3.00	1	$3.00

Total	**$796.83**