Team Inspiration 2021 RobotX WAM-V Application

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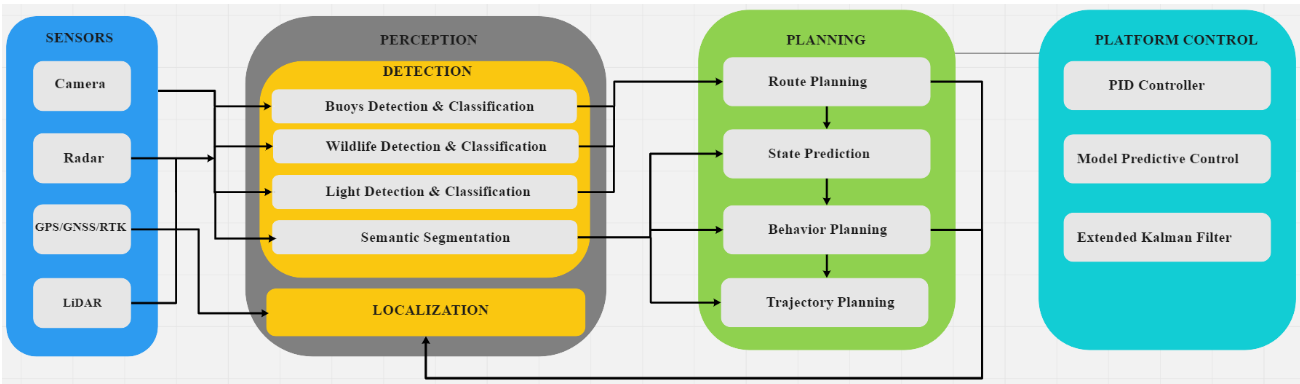
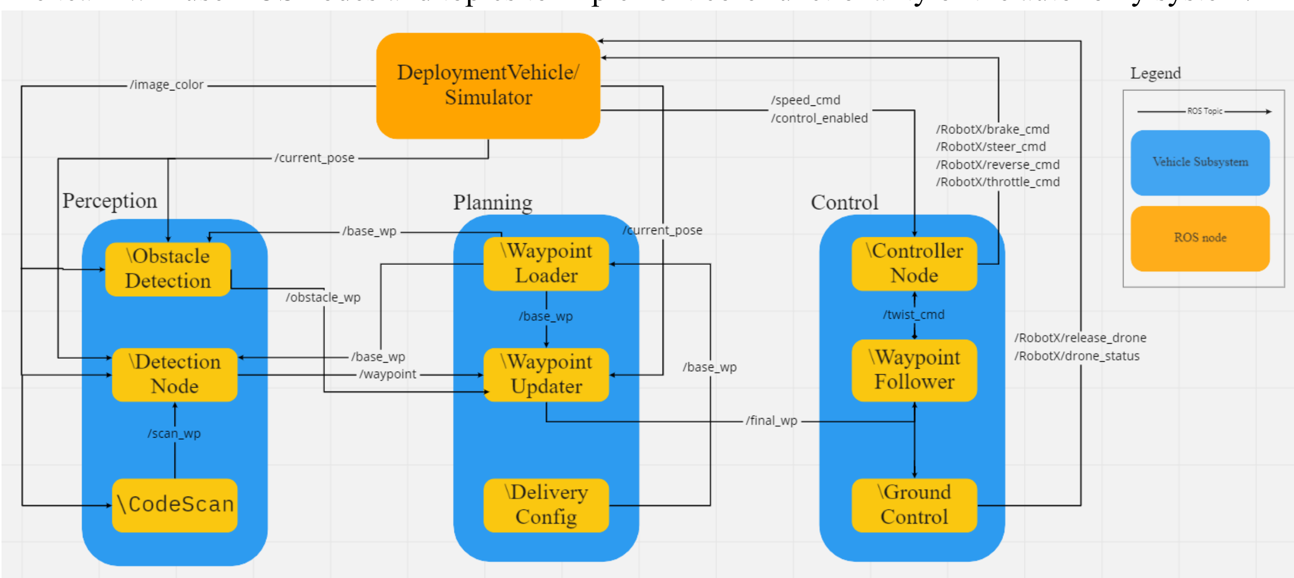
Technical Approach and Justification

Team Inspiration shall organize the technical approach in two items: system integration and simulation analysis. The system integration will embed the simulator that interfaces with ROS code and have autonomous capabilities tested before deployment to the vehicles (WAM-V and the UAV). Below is the preliminary architecture of how the system will work:



The team will use ROS nodes and topics to implement core functionality of the autonomy system.



Detection, Classification & ROS Topic/Messages

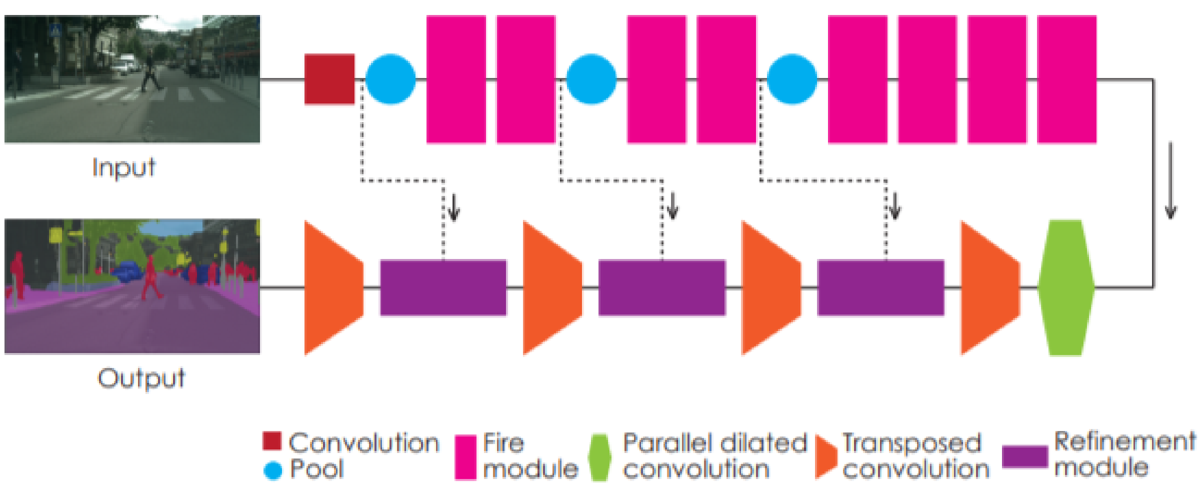
Buoys Detection and Classification: The buoys detection will use the classifier that builds over the InceptionV3 pretrained model and uses transfer learning. The training data that the classifier uses will be taken from Kaggle boat-types-recognition. We will train the model using TensorFlow or similar platforms and compare the performance over darknet YOLO, AlexNet, LeNet, and other convolutional neural networks (CNN). The measure of performance for the model is that it should run under an embedded platform environment that passes the classification and detection stream as an ROS message. The classification and detection node will pass the information to the control node which the planning algorithm relies on, like the Hybrid A* or similar decision making algorithms.

Wildlife Detection and Classification: The detection and classification for animals will need separate preprocessing outside of the Buoys Detection and Classification. In order to effectively train machine learning models, train-time augmentations are extremely important. The model that we plan to use for this challenge is the ResNet model. ResNet is one among several extremely good architectures which are popular for wildlife classification tasks. ResNet relies on the residual layers to train deeper networks in a more stable manner, along with being able to model more complex linearities. We will use Tensorflow to train our model, implementing the model in both Tensorflow and Keras, using the official/models repository of Tensorflow. We train with a batch size based learning rate, which decays every 30 epochs, following the learning schedule used to train on the more complex Imagenet-1000 task. Similar to the buoys detection, we will send the detection node passed as an ROS message.

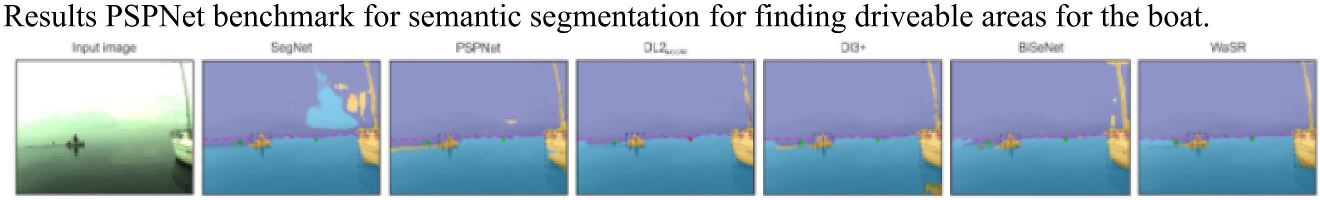
Light Detection and Classification: The detection is similar to the traffic light classifier. We will use MobileNet classifier to build stronger predictions out of the German Traffic Light Dataset (GTSRB). We will perform transfer learning based on the MaStr1325 dataset and Multimodal Marine Obstacle Detection Dataset 2 (MODD2). The MobileNet classifier will use the same label and test data for detecting the lights/buoys.

Semantic Segmentation: We plan to color-code pixel segmentation masks by assigning a different color for every category for visualizing them, then we will get something like an image from a coloring field for WAM-V. We can see this application as finding the driveable area. This method will be used to develop a redundant perception over the waypoints follower and base points as the main messages to drive WAV-M.

Since the primary information to drive the WAV-M could be from RTK/GNSS, the semantic segmentation will work as an input for updating the information for the waypoint follower. We propose a novel deep network architecture for image segmentation that keeps the high accuracy while being efficient enough for embedded devices. The architecture consists of exponential linear unit activation functions, a SqueezeNet-like encoder, followed by parallel dilated convolutions, and a decoder with SharpMask-like refinement modules. We will use MaSTr1325 data set (datasets and semantic segmentation tools for obstacle detection using unmanned surface vehicles) to train and test the new network to achieve higher segmentation accuracy.



Results PSPNet benchmark for semantic segmentation for finding driveable areas for the boat.



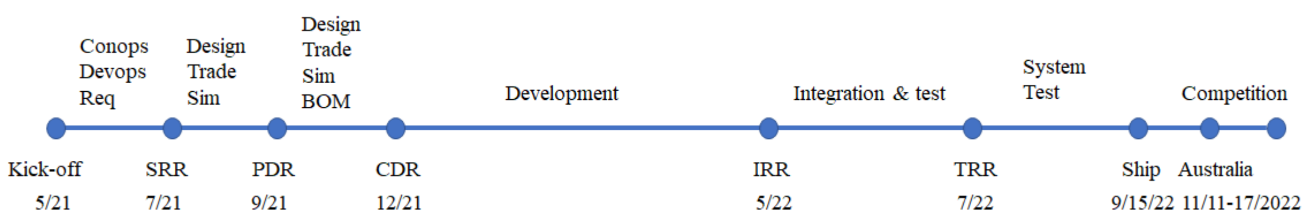
Competition Tasks Strategy:
Task 1 - Entrance and Exit Gates: We will use Buoys Detection & Classification described above.
Task 2 - Follow The Path: We will use ROS Planning Subsystem, ROS Object Detection and Obstacle Avoidance Node
Task 3 - Wildlife Encounter Avoid: We will use Wildlife Detection & Classification described above.
Task 4 - Scan The Code: We will use Light Detection & Classification, (ROS Detection Node - Semantic Segmentation)
Task 5 - Dock and Deliver: We will use ROS Planning Subsystem, ROS Object Detection and Obstacle Avoidance Node
Task 6 - UAV Replenishment: We will use ROS Planning Subsystem, ROS Object Detection and Obstacle Avoidance Node, Semantic Segmentation

UAV strategy: The UAV and WAM-V will have a high capacity WiFi link over which WAM-V will send navigation / scouting controls to the UAV and receive the aerial images. All image processing will be done by the WAM-V onboard computer. In case of wireless link loss, UAV will use onboard GPS and will have the ability to trace back its path to get closer to the WAM-V and re-establish the communication link.

Wireless communication strategy: We will use the wireless link allowed by the competition rules. We will utilize a reliable transport layer protocol for data communication between ground station and WAM-V. We will also use a backup communication link for emergency scenarios.

Test Strategy: For testing, we will rely on about 80% testing using simulators. This strategy provides a means to test the developed capabilities in a repeatable, controlled, and safe environment. By utilizing a GPS offset in our navigation measurements, the testbed can be made to believe it is operating at full mission area. For each test consisting of given task scenarios and a particular test condition, a set of test criteria will be computed and measured against pass/fail thresholds. These criteria span a wide breadth of capabilities across the architecture system and range from low to high level. The sample set of test criteria is shown below:
Navigation Accuracy - Max{|positionMeasured(t) – positionTruth(t)|} < 2.0 meters
Integrity Classification - Probability of correctClassify(fault) > 95%
Perception Throughput - Total of execution time < 0.25 sec and Max Execution <0.5 sec
Tracking Accuracy - Max{|positionMeasured(t) – positionTruth(t)|} < 1.0 meters
Recognition Accuracy - Probability Correct Command > 75%, Confidence Correct Command > 50%
Control Accuracy - maxError < 1.0 meters

Risks and Fail-Safe strategy: Sensor hardware failure is a potential risk and we shall design redundant systems with cross reference to provide backup coverage. Equipment will be protected with watertight Pelican boxes. A secondary system can be remotely invoked in case of failure of the main system. To learn autonomous capabilities, we shall include capability to remote control the boat and UAV from the ground station. We will compare performance to goals to optimize algorithms.



Team Qualifications

Mabel Szeto - Systems engineer, spec writing, incoming UCSD freshman, Northrop Grumman (NG) systems engineering intern, captain of 2019 RoboSub team, 2019 & 2020 INCOSE presenter

Colin Szeto - Project engineer, mechanical engineer, CAD designer, simulation, incoming UCSD freshman, NG mechanical intern, captain of 2020 RoboSub team, FIRST world championship

Steven Chen - Virtual reality, machine learning, artificial intelligence, perception, unity, data science, Simulink, Berkeley junior with 3.97 GPA studying EECS, robot engineer, Berkeley Deep Drive

Eesh Vij - PCB designer, signal processing, drone/robocar/boat/RoboSub developer, high school sophomore, engineering apprentice, beacon localization, vehicle communication, sonar, integrator

Rishi Veerepalli - Localization/perception, control feedback, navigation, engineering apprentice, high school sophomore, computer vision, network configuration, data logging tool, Gazebo

11 other middle school/high school/college team members - web development, programming, computer vision, mechanical, tester, driver, robotics instructors, conference speakers, cyber security

Industry advisors - Alex Szeto, 35 years program management, systems engineering, simulation, modeling; Dr Jack Silberman, UCSD autonomous vehicle design professor; Kevin Bowen, 40+ years surface and undersea vehicle experience; Venkat Rangan, founder of computer vision company, ex-Qualcomm engineering director; Andrew Tsai, autonomous vehicle developer, AI/machine learning experience SME, previous RobotX team advisor; Amit Goel, 20+ years software engineering manager.

Facilities

RobotX development will be integrated at the Team Inspiration lab. The lab has a secure outdoor and pool area for the boat integration and hardware-in-the loop testing. The adjacent indoor lab has basic machinery tools to support fabrication, cutting, 3d-printing. For precision and complex assembly, the team has access to a local machine shop Metal Master, a previous sponsor. The lab has a high-end CAD workstation with capabilities that can support full SolidWorks and other modeling software processing including thermal and stress analysis. For computing and network processing, the lab supports data server, router, internet connection, WIFI, Bluetooth communication for in-lab and remote access to provide 7/24 availability which has been demonstrated in 2020 RoboSub development. Team members were able to remotely configure, operate and test robots from their homes. Full digital simulation paired with hardware-in-the-loop simulation would be our early and continuing testing strategies to prepare for the eventual in-water testing.

For in-water testing, there are many accessible lakes (Hodges, Miramar, San Vincente, Carlsbad) and bay (Mission) in the San Diego area that we can launch and operate the robotX. The WAM-V will be on a trailer and be towed to the test area. The team also has access to a motor boat from team supporters that will lend their hands during in-water WAM-V testing to monitor, recover, and ensure safe operation. Emergency shutoff-switches will be installed including remote activation option.

For shipping and logistics, the team has the support of Northrop Grumman logistics and shipping group in San Diego. Battery will be shipped early or procured locally to mitigate the international battery shipping restriction.

Sponsorships and Partnerships

Team Inspiration has been fortunately supported by the many organizations in addition to vendor discounts, material donation, and family contributions. We have proven records in traveling and co-hosting international events such as Benin & Paraguay robotics competitions. The team is confident to raise even more funding for RobotX. See 16 organizations on our sponsor page, including Medtronics, Sempra Energy, MathWorks, and SolidWorks.

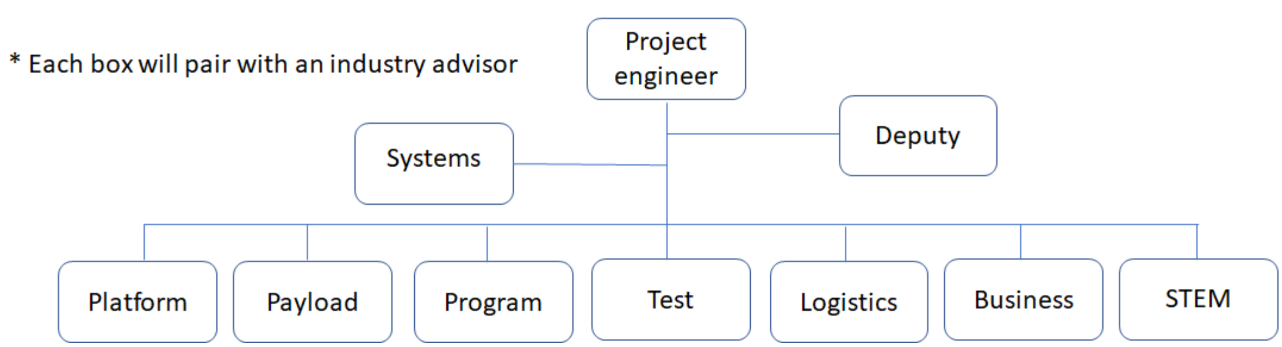
Qualcomm - VP Autonomous group - Siva Veerepalli - sivav@qti.qualcomm.com - 858-437-3301
Northrop Grumman - Mission System - Alex Szeto - alex.d.szeto@ngc.com - 858-243-4199
Biosero - CEO - Tom Gilman - tomgilman@biosero.com - 858-880-7376
ASTA - Board member - Teresa To - thto@san.rr.com - 858-243-7679
NVIDIA - Embedded system - Lynette Farinas - lfarinas@nvidia.com

As the 2021 FIRST regional competition Connect award winner, our team is recognized for our close network with corporations, professional organizations, and communities. The team is supported by Advancing Science, Technology and Arts, a non-profit 501(c)(3) organization, and can accept tax deductible monetary and material donation. The projected funding is within the team's capabilities, and we are confident in raising money needed for the RobotX participation.

Management Approach

We shall generate top level requirements, concept, functional block diagram, technical approach, organization charts, team member responsibilities, schedule, and budget. This information shall be captured in a Microsoft Project management tool. This provides a clear description of tasks, resources, task loading, schedule, dependencies, schedule margin, critical path and Gantt Chart, Excel compatible reporting. We shall develop a Risk and Opportunities Management system that identifies performance, schedule and cost risk as well as mitigation strategies. Opportunities will focus on identifying mentors, material loaners, and funding.

The team will implement the proven agile systems engineering experience utilized in FIRST and RoboSub competitions leveraging the knowledge of creating a competitive autonomous underwater vehicle in 20 weeks in 2019. The 16 current and alumni members will serve as the core team, and will recruit additional support as needed to supplement skillsets via UCSD/Scripps Institution of Oceanography students that Dr. Jack Siberman has a connection with. The leadership team will pair with key advisors listed in the proposal, and can draw on additional mentors including members of the San Diego Marine Technology Society and Singapore Team BumbleBee.



Rough Order of Magnitude Cost
Computing platform: NVIDIA Tegra; NVIDIA Drive PX2.
Computer Vision Hardware strategy: SEKONIX camera is selected to cover horizontal 110 degrees and vertical 15 degrees, and each sensor has 100 degrees FOV. NVIDIA DrivePX2, having a capacity of 12 GMSL interfaces, is chosen to get the advantage of the use of multiple EO sensors. This EO system has only four EO sensors with high resolution and one image processing computer.

Sensors for Autonomous Control and Navigation: Velodyne HDL-32 (eBay $1,800), Sekonix GMSL ($400 each), Stereo Camera, Velodyne VLP-16 (eBay $2,000) , Bosch LRR3 ($8,000), Delphi Radar ($5,000), SwiftNAV Piksi ($2,000), NVIDIA Tegra, network hub, Drive By Wire Controller ($20k)

Rough sensor cost is roughly $40k + material cost of the platform/sensor integration including batteries of $10k based on past robotics competition experience. Motor cost is $3.5k for 4 transom mount motors. 2 drones + accessories estimate at $7k. Shipping logistics estimate at $15,000 round trip via ship. Air freight is too high for consideration. Traveling of 12 members/mentors of $30,320 ($1,150 airfare per member + $170 per day lodging/car/meal expense for each team member for eight days). Quad lodging accommodations + 2 vans for team members and equipment transportation.

Total estimated cost: $40k + $10k + $3.5k + $7k $15k + $30k = $105.5k (not including the WAM-V)

The rough cost estimate is with the existing lab infrastructure, and can be minimized by existing sensors, drones, equipment trade-off, loaner from members of San Diego Marine Technology Society and additional team sponsors. The projected cost is less than past team expenditures.

Summary

Team Inspiration is a young team with much to learn. Our mentors have guided us with the vision far beyond our ages when we first started with Lego robotics in third grade. We visited FIRST robotics, RoboSub, NASA JPL, Northrop Grumman, General Atomics, and Qualcomm. We met with NG CEO, Qualcomm CTO, Benin U.S. ambassador, and have been teaching robotics for four years. We learned planning from hosting FIRST competition, local and international events. We learned systems thinking, engineering best practices, and advanced technologies. We have presented in professional conferences including INCOSE, Marine Technology Society, San Diego County Engineering Council, and UCSD.

Our team members have earned opportunities to work as engineering interns on Triton UAV, 7th in division ranking at FIRST robotics championship, National Merit Scholars, global finalist in business competition, National Cyber Patriot champion, 1st place international RoboCup@Home SP, IEEE Innovation award, and 1st place in RoboSub. However, recognition and trophies are not important. These past events taught us systems thinking, planning, goal driven, solution oriented, and having grit. It is with these skills that we are confident that we will be prepared to compete in Sydney.

The proposed solution and approaches are what we learned from our industry advisors, and we are aware that we have a steep climb. Early in our RoboSub journey, many have advised us to learn Sea Perch first. We did and learned that in a couple weeks and dove head first into RoboSub. We will apply Keep It Simple Silly (KISS) strategy to ensure a solid engineering solution within our capability. We shall apply sensor integration, simulation, and quick prototyping on what we have accomplished in the past. It will be our honor to receive the WAM-V and defend our title of being the #1 Young Inventor again on ABC's "The List" in 2022 to inspire global youths.