MAKER: Urban Search and Rescue Robot: Visual Localization and Navigation

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Abstract

Students will design, build, and control a robot using Tetrix Urban Search and Rescue Robot. They will familiarize themselves with the structure, control, and vision sub-systems. The vision subsystem will be the focus of the mobile robotic build. The Tetrix Urban Search and Rescue robot is a real-time image-processing engine. It has a vision sub-system with on-board processor and a protocol interface that is accessible through a standard wireless connection. Programming is not required in this lesson as the robot is 100% remote controlled.

Motivation

Stereo visual odometery is using one camera to navigate an unknown terrain, avoid obstacles, and image matching/mapping. Streaming video is seen by a human operator to map unknown environments such as the ocean floor, underground caverns, or planetary environments. Robot ground vehicles with cameras are being used on Mars rovers to map the terrain. The vision system has evolved from an “extra credit” capability to a critical vehicle safety system [1]. Robots with similar systems are utilized on underwater submersibles to study marine life and deep ocean environments. The computer vision systems on robots determine a fixed point from which to start. The camera “sees” the next focal point and transmits the collected data for human evaluation.

The computer vision system (camera) has become a popular mainstay among many industries such as law enforcement, tourism, entertainment, military strategy, surveying, search and rescue teams and communication. “In GPS-denied environments, such as underwater and aerial, VO has utmost importance.” [2] Students will discover during this lesson how to track an object using a single stereo input, determine local based on multi -angled images, and applications for the computer vision system.

Prior to visual odometry becoming commonplace, wheel odometry was used for terrain mapping. In the classroom, shaft encoders are used to teach students about determining distance, speed, and mapping based on the wheel turn count over varied textured terrain. VO gives students and industry leaders the ability to navigate without the images being affected by a diverse tactile terrain. Streaming video will transmit captured images regardless of ground texture, lighting, or proficiency of operator control. In the classroom, students can traverse stairs, ramps, tile, carpet, classrooms, and offices regardless of their familiarity with the control system or location.

Search and Rescue Robots have become mainstays in disaster search and rescue robotics. According to Dr. Robin Murphy of the Center for Robot-Assisted Search and Rescue at Texas A&M University, since 9/11, robots have been used in 49 disasters in 17 countries. 24 of those disasters used UGVs- with the majority using the robot models from 9/11. [3]. Giving students the opportunity to familiarize themselves with the controls, purpose, and design of USAR’s incorporates real world applications. Regardless of a students after high school career choice they have a usable technological skill. The military, urban planners, law enforcement, and municipal safety personal use a variety of USAR's to collect data, bombs, bodies, and pictures of unknown impassable areas. [4]

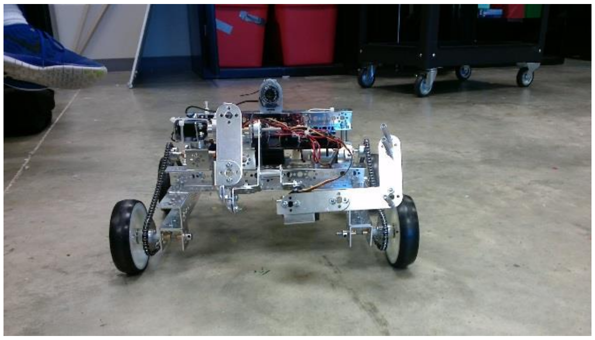
Robotics and Automation Texas High School Course

The first author teaches Robotics and Automation at a Texas High School Career Academy to students enrolled in the Systems Engineering Pathway. The primary knowledge and skills the students acquire are based on the Texas Essential Knowledge and Skills. TEKS 130.370 (5)A, (6)D, and (9)B are structured benchmarks were by students learn to build a robot based on specific criteria, engage in the understanding of how integrated systems are necessary for robot operation, and open and closed control loop systems are used to mimic real-world application.

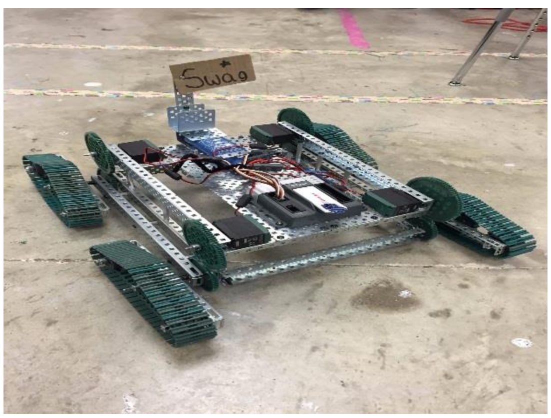
A Tetrix Urban Search and Rescue Robot Kit is used to teach four of the integrated robot systems needed for operation. The kit comes with all components for structure, motion, control, and vision sub systems. The included build instructions are very detailed and procedural. This is an asset to differentiation of instruction. If the class consists of diverse learners, the instruction guide allows for flexibility in design options. The instructor will discover that some students will require step by step instructions on building a robot and controlling the platform. Other students will see different design options. The kit allows for differentiation and reinforces the ideation and improve step of the Engineering Design Process. The USAR Robot Kit allows the instructor multiple gains in teaching concepts with a district friendly budget project based learning kit.

The Tetrix USAR Kit is not the only robot platform with a camera. There are many others provided by Vex, Pitsco, and Lego. The aim of the lesson is to teach students visual odometry. This goal can be achieved by using a cellular camera, smartphone, or other mobile camera device with streaming video capability. The instructor has taught this lesson for two years using Tetrix, Lego, and Vex. In addition to the camera that comes with the kit, students have mounted personal devices to either robot platform using various copyrighted apps such as Snap Chat, FaceTime, Periscope, Facebook Live, and Livestream. The multitude of options allow this lesson to be taught regardless of budget, robot platform, or skill level of students. Vex and Lego are robot platforms that allow for an additional subsystem of programming to be included. This increases rigor and allows for an additional level of differentiation for General Education, Gifted and Talented, Limited English Language Learners, and Special Education students.

Bill of Materials & Flowchart & Pictures.



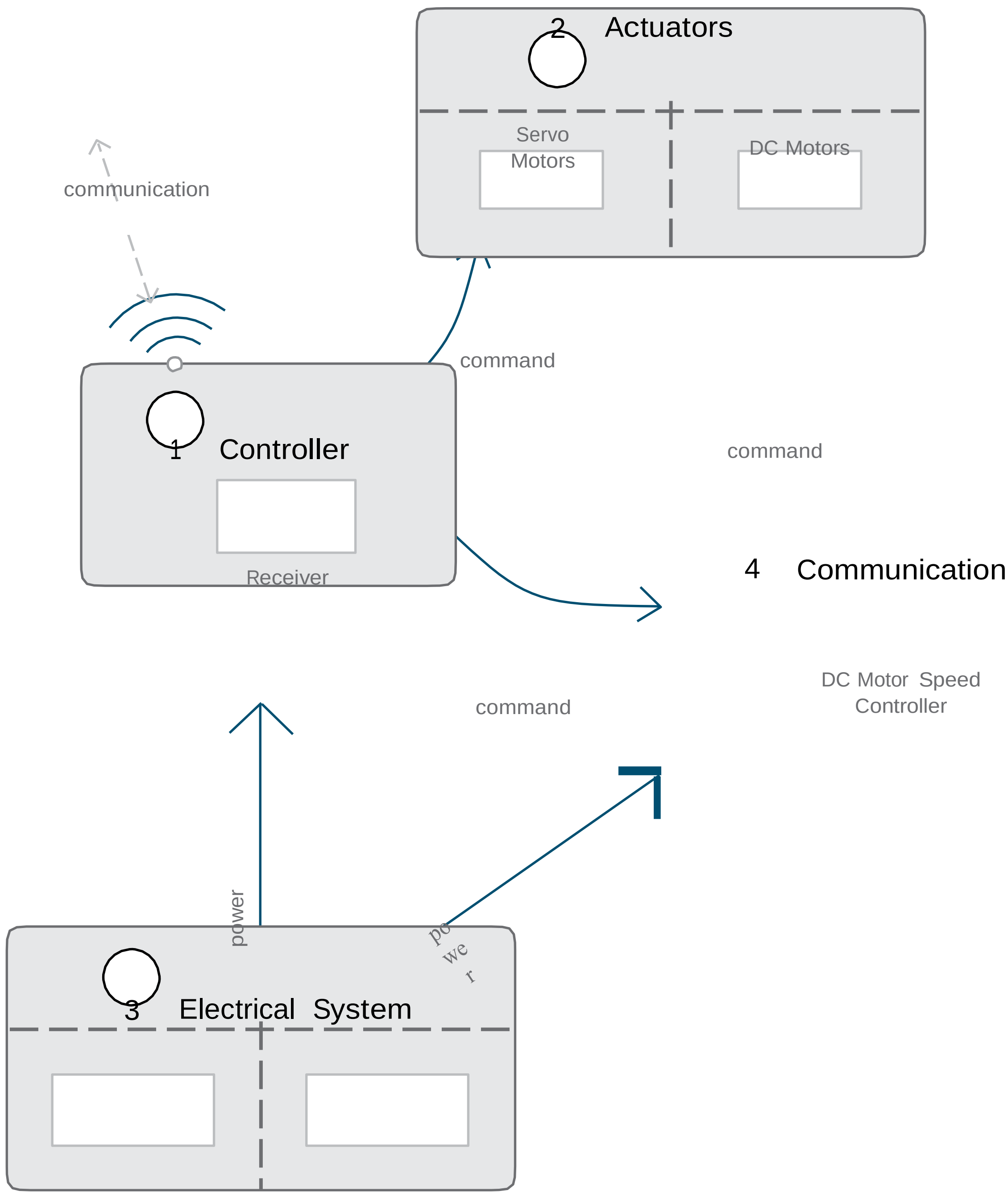
The current Ranger Bot is one of five potential design options. The build kit is a versatile structure system. You are able to merge metal to accommodate class needs.



4" Wheel	6
16T Sprocket	4
24T Sprocket	6
32T Sprocket	2
Chain w/Link	1
Chain Breaker	1
Gear Hub Spacer	10
100 mm Axle	12
DC Drive Motor	2
Motor Mount	2
Axle Set Collar	12
288 mm Channel	6
160 mm Channel	4
96 mm Channel	4
32 mm Channel	6
L Bracket	6
Flat Building Plate	2
Flat Bracket	6
2" Standoff Post	12
1" Standoff Post	12
180 Servo	2
Single Servo Bracket	2
Bronze Bushing	24
Axle Hub	12
Motor Hub	2
1/8" Axle Spacer	24
3/8" Axle Spacer	6
Motor Power Cable	2
On/Off Switch	1
12-volt TETRIX Battery	1
Motor Speed Controller	1
1/2 SHCS	200
Hex Keys	1
Zip Tie Pack	20

Sub Systems Relationship Diagram

R/C Transmitter



Pre/Post Test & Opinion Survey Results

Using a class composed of 19 students, a 10 question survey was distributed prior to the lesson being taught. The questions were multiple choice and asked did they recognize a variety of robot acronyms. There followed a class discussion of about how the robots looked, what each system consists of, and where the students had seen them in the real world.

80% of the students scored 60 points. Their reasoning's upon being questioned was some prior knowledge and word association. The lecture was taught in 2 hours. Prior to beginning the build, students took the same exam again with 100% making 100 points.

Implementation

Students were required to create a design sketch with a BOM to determine their team's primary building platform. Two teams used the Tetrix kit and five teams used Vex. Each team was required to video two opposing teams operation of the vision system and robot control. They then analyzed in open discussion possible improvements and successes.

Teams were given five 90-minute sessions to design, build, program, and test. Each teammate is required to maintain an engineering design notebook. Daily student team members document the groups activity on the project. The requirements are write in complete sentences, create a detailed account of what has occurred that session using correct terms for parts, tools, and systems, and evaluate successes and failures.

The sixth and seventh session are reserved for challenge completion. Teams are challenged to a scavenger hunt on campus. The team that finds the most objects in the least amount of time wins.

Evaluation

The initial lecture was composed of a slide presentation and research project. The research paper was eliminated due the timing of the lesson being taught. The students had in prior months focused on integrating various programming elements for VEX and LEGO systems. They were ready for a platform and challenge variation. During their team work common challenges were availability of pliers, hex keys, and chain breakers. Students created "tool use only here" station per style of tool. This allowed multiple activities to occur without handicapping another group. The station set up throughout the room kept students engaged and responsible for class safety, progress, and success.

The scavenger challenged created additional questions from the students about vision systems uses in common places in life. The questions consisted of "Is this how satellites communicate with our GPS apps?", "Does CCTV work the same in home security systems?", and "Are Ticket (traffic) cameras using a sensor at the toll?". Through identifying real word uses the in class robot was no longer a toy. The students named their team robots, created more detailed notebooks with technical drawings, and there was seen an increase in the use of official terms for systems and parts. Students began analyzing individual performance within groups. The class created groups of programmers, designers, builders, operators, and evaluators. The largest group consisted of builders and operators. The self grouping was motivated by student interest. This made it easier to teach varied concepts. The students in turn went back to their teams and shared acquired knowledge. In essence, the whole class was one team with multiple integrated parts.

Acknowledgement
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References

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[2] Fraundorfer, Friedrich; Scaramuzza, Davide; "Visual Odometry Part II: Matching, Roboutness, Optimization, and Applications.
[3] Murphy, Dr. Robin http://crasar.org/2016/09/11/the-legacy-of-911-for-disaster-robotics/ This entry was posted on Sunday, September 11th, 2016 at 9:53 am and is filed under Breaking News, Director's Blog, Disaster Zone, Homepage News, In the News, News, Press Releases, Rescue Robots. You can follow any responses to this entry through the RSS 2.0 feed. Accessed on November 21, 2016
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Appendix A - Visual Subsystem Pre/Post Assessment

1. What does USAR stand for?
    a. Ultra Sensitive Autonomous Robot
    b. Urban Search and Rescue
    c. Unique Surveillance Aerial Recorder
    d. Underground Sensor and Recognizer
2. How do USARs interact with the environment?
    a. Sensors
    b. Actuators
    c. Manipulators
    d. All of the above
3. Which sensor is utilized on an USAR?
    a. Vision
    b. Ultrasonic
    c. Infrared
    d. All of the above
4. Which subsystem do cameras go into?
    a. Structure
    b. Motion
    c. Control
    d. Sensor
5. Who can utilize USARs?
    a. Law Enforcement
    b. First Responders/Emergency Disaster Rescue Teams
    c. Medical
    d. All of the above
6. UAV stands for
    a. Unmanned Aerial Vehicle
    b. Unmanned Air Vehicle
    c. Ultrasonic Aerial Vision
    d. Unique Airplane Vision
7. Which is a type of USAR?
    a. Unmanned Aerial Vehicles
    b. Unmanned Marine Vehicle
    c. Unmanned Ground Vehicle
    d. All of the Above
8. UMV stands for
    a. Unmanned Man Vision
    b. Unmanned Marine Vehicle
    c. Unmanned Mobile Vehicle

    d. Unmanned Mammal-like Vehicle
9. UGV stands for
    a. Under Ground Vehicle
    b. Unmanned Ground Vehicle
    c. Unique Ground Vision
    d. Unknown Ground Visual
10. Robots can be tethered using wireless signal or cables.
    a. True
    b. False

Appendix B - Vision Subsystem Opinion Survey

Did you learn something new? Yes or No

Did you like what you learned? Yes or No

Did you like how you learned? Yes or No

Do you want to learn more? Yes or No

What would you like to learn more of? ____
____
____
____
____
____
____
____

What could have been better about this lesson/topic? _________________________________
____
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____
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Appendix C - Activity List

Activity I: Think-Pair-Share- What activities would Ranger be doing in these areas. In their Engineering Notebooks students should write down at least two possible applications and what Ranger would be doing.

Research Activity II: Students look for rescue robot images and compare and contrast two within their Engineering Design Notebook. Students should compare the sensors, controls, actuators, manipulators, structure, operational environment, and purpose.

Activity 3: In teams of 3 search the designated disaster area (room) for survivors. The Control Operator will send Ranger to search the room. Ranger is sending a real time video transmission to the base. The Data Specialist is writing down the location of all survivors and non-survivors. DS will communicate to the Field Technician the local of any survivors. Later, once all survivors are found and recovered the DS will send teams to claim the non-survivors. The Field Technician establishes recovery teams at each survivor location. Only give each team five minutes. The team that finds the most survivors in the least amount of time wins.