Digital Systems Teaching and Research (DSTR) Robot: A Flexible Platform for Education and Applied Research

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Abstract

The DSTR (pronounced "Disaster") robot has a strong history of being adaptable to different user's needs, and there are many opportunities ahead that indicate that the sky, quite literally, is not the limit for this robust platform. This paper provides a historical perspective on the development of the DSTR robot as a collaborative design developed by the Mobile Integrated Solutions Laboratory (MISL) at Texas A&M University and ASEP 4X4 Inc. Texas Instruments has been a major partner in the integration of the control electronics, and Texas Space Technology Applications and Research (T STAR) LLC has played a significant role in the propagation of the DSTR robot as an adaptable applied research/education/STEM outreach platform. The paper will present examples of the strong industry-academic relationships that allow the DSTR robot to be utilized in a multitude of experiential learning environments. In addition to a number of STEM outreach activities, the DSTR robots are being used in the Introduction to Engineering course at Blinn College and in the Freshman Engineering curriculum at Texas A&M University. DSTRs have also been selected by NASA scientists as a low-cost lunar sample collector. The paper will also discuss the newly developed DSTR-E (DSTR Engineering) unit which requires students to perform several engineering tasks during the build process. The paper will also include the lessons learned from initial design through its transfer to the private sector for commercialization and future plans.

1. Introduction (What is DSTR)

As depicted in Figure 1, the Digital Systems Teaching and Research (DSTR – pronounced "Disaster") Robot is a four-wheeled, articulated-leg suspension mobile platform that can operate in a tele-operate or autonomous mode. The suspension is a unique aspect of the robot and allows the mobile platform to "walk" over obstacles it encounters. This feature makes DSTR highly desirable for applied research, education and Science, Technology, Engineering and Mathematics (STEM) outreach activities.

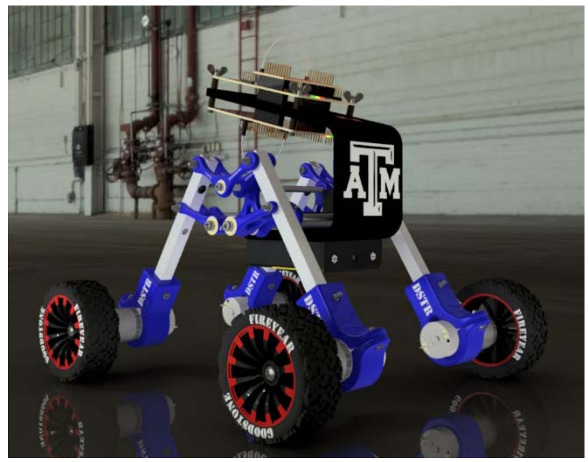

Fig. 1 DSTR Computer Model

The DSTR Robot was designed by a number of engineering undergraduate students in the Electronic Systems and Manufacturing-Mechanical programs working in the Mobile Integrated Solutions Laboratory (MISL) at Texas A&M University. Mr. Hebert Baumgartner, now an entrepreneur following his graduation, was lead mechanical designer of the mobile platform. Mr. Colby Ryan and Ms. Alexis Crandall, both seniors, led the embedded software and electronics development efforts, while Mr. Vince Rodriguez, now an applications engineer with Texas Instruments, developed the Android and iPhone apps that allow a user to control the robot via a Bluetooth or 802.11 wireless connection.

DSTR was designed so that it could be constructed from 3D-printed parts and other mechanical and electronic components which can be purchased at a local hardware store or from numerous on-line sources. The primary focus of the DSTR Robot is to be an experiential education manipulative that motivates and inspires secondary and college level students to pursue STEM-based careers, especially in engineering. DSTR has been designed using a system of systems approach thus making it applicable to a wide range of engineering disciplines including electronics, mechanics, embedded software, control and communications.

In the tele-operated mode, DSTR can be controlled via a game-controller like device, a computer or, more often, a cell phone. Control of the robot can be implemented using either Bluetooth or 802.11 wireless communications. The user interface available in the downloadable cell phone app (either Android or iPhone) provides either a single joystick or a two-finger, tank-like control methodology. In the autonomous mode, DSTR has used two different approaches. The first uses two line following sensors to perform path following. An updated capability that uses a camera and object recognition has also been implemented. This second line following method also allows the DSTR Robot to utilize its articulated leg suspension to "walk" over obstacles as it follows a path.

One design goal that was set in the development of the DSTR Robot was the ability to use a wide range of embedded intelligence devices/evaluation boards for control. To date, a number of embedded controllers have been used with DSTR including:

1. Texas Instrument SensorTag
2. Texas Instrument Launchpad
3. Texas Instruments Nspire Calculator
4. BeagleBone Black and BeagleBone Blue

Finally, with the addition of a small video camera, DSTR has the ability to be controlled using First Person Video (FPV). The video from the camera is transferred wirelessly to the FPV goggles worn by the driver.

Currently, the DSTR Robot is being used in STEM workshops, high school courses, college freshman engineering courses, a number of Capstone design projects, and is also being considered for a lunar exploration mission. DSTR is gaining recognition and interest across the state of Texas and around the world. A DSTR workshop has been offered to engineering faculty in China and was the topic of discussion during a recent visit from the provost of Saigon Institute of Technology.

2. Why is DSTR Important as an Educational Program?

The process of designing, assembling, programming, and customizing DSTR robots provides students an exciting introduction to engineering and technology through experiential learning. Throughout each of the above stages, students are actively engaged in the engineering design process.

Since the DSTR platform involves a "system of systems", students are typically split into teams, assigned roles focused on an individual system, and tasked with completing a project founded on understanding and implementing the robots[3]. For instance, in Summer 2017, the Mobile Integrated Solutions Laboratory (MISL) designed and hosted a Youth Adventures Program (YAP) workshop featuring the DSTR robots. As part of this outreach, students in 6th through 10th grade were split into teams of four, with roles covering mechanics (the structural system), electronics (the power distribution system), and programming (the control system), as well as media relations.

Fig. 2 YAP Workshop

Following the success of the YAP workshop, MISL and TI collaborated in another outreach workshop. In it, high school students were challenged with the seemingly daunting task of modifying the DSTR platform to serve as an autonomous line-following robot, programmed and controlled by a calculator. As shown in Figure 3, this involved replacing a TI CC3200 LaunchPad development board (and its C++-based programming language) with a TI Nspire graphing calculator (and its Basic-based programming language). Ultimately, the students were successful in meeting the challenge, while the DSTR was successful in demonstrating its versatility.

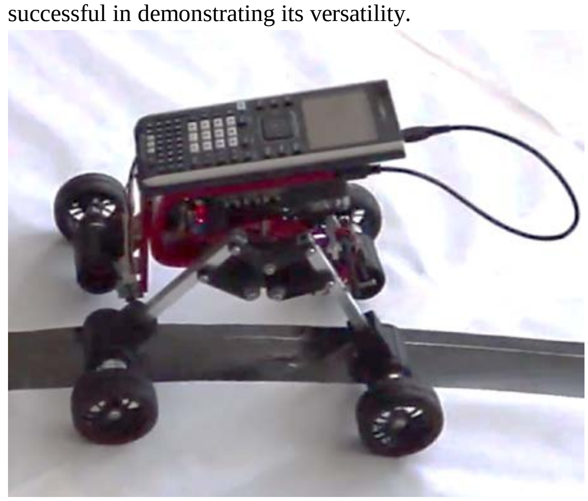

Fig. 3 TI Nspire-Controlled, Line-Follower DSTR

In addition to its use in outreach camps and workshops, DSTR robots are also currently used in several high school, community college, and university courses, including: Robotics II at Brandeis High School (San Antonio, TX), Introduction to Engineering at Blinn College (Bryan, TX), and the Foundations of Engineering sequence at Texas A&M University.

At Blinn College, 25 DSTR Engineering kits were purchased through an NSF Innovative Technology Experiences for Students and Teachers (ITEST) grant. The goal of this particular grant was to encourage and develop junior high and high school student interest, skills, knowledge, and career aspirations in engineering through authentic engineering design activities related to building automation. [1] In addition, Blinn College received two lab donation grants from Texas Instruments to support the development and offering of the new course. The role of Blinn College in this ITEST grant was to develop a dual-credit version of its Introduction to Engineering course that involved not only building automation, but also smart devices, the internet of things (IoT), and rapid prototyping via additive manufacturing.

In Fall 2017, before deploying its dual-credit course[4] [5] to surrounding high schools, Blinn College piloted a preliminary version on its Bryan Campus in four class sections composed of traditional community college students. Over the entire semester, students worked on a single ambitious project called the Plant Inspection, Patrol, and Emergency Response (PIPER) project.

The purpose of this project was to demonstrate that the DSTR robots could be deployed in chemical plants, manufacturing facilities, refineries, factories, and the like for not only routine security patrols and environmental data collection, but also in response to an emergency in which it was unsafe for humans to be present. Figure 4 shows the simulated disaster area the robots were required to patrol and inspect.

Fig. 4 Simulated Disaster Area for the PIPER Project

Starting with the raw materials in the DSTR-E kits, students were introduced to 3D modeling and printing to understand how roughly half of the DSTR parts were produced. Next, students learned how to cut and drill aluminum tubing, tap and thread for screws, strip and solder wires, heat and bend expanded PVC, and several other manufacturing techniques.

Fig. 5 Students Assembling T STAR's DSTR-E Kits

Once the frames and chasses were built and assembled, students learned how to use H-bridges on an L298 motor driver to distribute power and pulse-width modulation (PWM) signals between their batteries, motors, and microcontrollers. Then, using TI's Energia IDE, students were taught to read and modify code to control their robots using a cell phone app.

After the robots were fully constructed, powered, and programmed, students then proceeded to modify the base design to meet the needs of the PIPER project. This required students to collect environmental data (temperature, humidity, luminosity, and pressure, among others) and publish it to the cloud using Cayenne's myDevices IoT broker service. This allowed real-time viewing of the data using Cayenne's website dashboard and phone app, as well as storage of the data for later analysis.

The final challenge in the project was developing a satisfactory way to control the robot in an emergency response situation. This was accomplished by attaching a cell phone to the front of the DSTR and initiating a Skype video conference between that phone and another phone held by the robot's pilot, safely outside of the hazardous environment the robot was sent to inspect.

In the end, students demonstrated that the DSTR robot could be an ideal tool in many building automation applications. In the process, students were introduced to numerous engineering disciplines, learned of emerging careers in engineering and technology, researched their corresponding degree and licensing requirements, experienced firsthand the teamwork and design process used by engineers, and practiced the various techniques in which engineers present and communicate technical information. All of this was possible because the LaunchPad-controlled DSTR robots offered an authentic and engaging platform that kept the classes exciting and challenging for an entire semester, allowing them to be pushed further than past classes centered on more standard projects (from popsiclestick bridges to Lego MindStorm maze solvers and everything in-between).

3. What is DSTR's Future?

3.1 Current Plans

Currently, the DSTR Robot is being used in STEM workshops, high school courses, college freshman engineering courses[2] [5], a number of Capstone design projects, and is also being considered for a lunar exploration mission. DSTR is being considered in mining applications as well. DSTR is gaining recognition and interest across the state of Texas and around the world. A DSTR workshop has been offered to engineering faculty in China and was the topic of discussion during a recent visit from the provost of Saigon Institute of Technology.

3.2 Commercialization

T STAR is working with MISL to commercialize DSTR technology. T STAR has found that DSTR is a platform that lends itself to several market areas including education, space, and mining.

The educational market needs a DSTR type of platform that allows application of various skills by students. DSTR-E (Engineering) kits, like the one shown in Figure 6, require students to use a variety of skills, both mechanical and electronic. The students are required to cut tubes to the correct lengths, drill holes and solder wires. After the mechanical assembly is complete, students connect wiring to the electronics boards and use software to program the DSTR's movements. The instructors have the ability to tailor the DSTR curriculum to the level of students that are being engaged. To date, DSTR has been used in week-long camps and full semester environments with students from 5th grade through college freshmen.

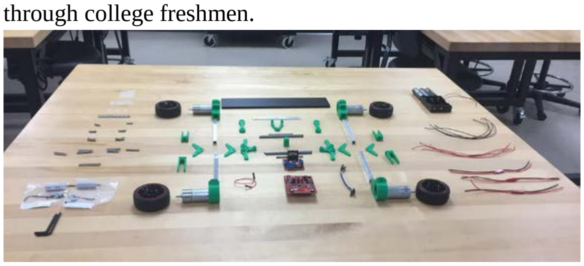

Fig. 6 Pre-Assembled DSTR-E Kit

The T STAR team is currently working with partners in Texas, Brazil, China, Vietnam, and Australia to increase the commercial educational footprint. T STAR is developing a collaborative forum where DSTR developers will be encouraged to post curriculum adaptations, software and hardware modifications and sensor packages that are being used with DSTRs.

The space industry is looking at the DSTR platform as an inexpensive and reliable platform based on the articulating suspension system and the adaptability of the intelligence and sensor packages. A Lunar mission slated for 2019 is considering using two DSTRs to do sample collection. After the sample return has occurred, the T STAR team will have control of the two DSTRs on the Lunar surface while they remain functional.

The mining industry has a need for an inexpensive robust vehicle that can explore active and abandoned mines to determine if the environment is acceptable for human access. DSTRs low cost, sensor packages, and articulating suspension system again make DSTR shown in Figure 7 an ideal candidate for this operational concept.

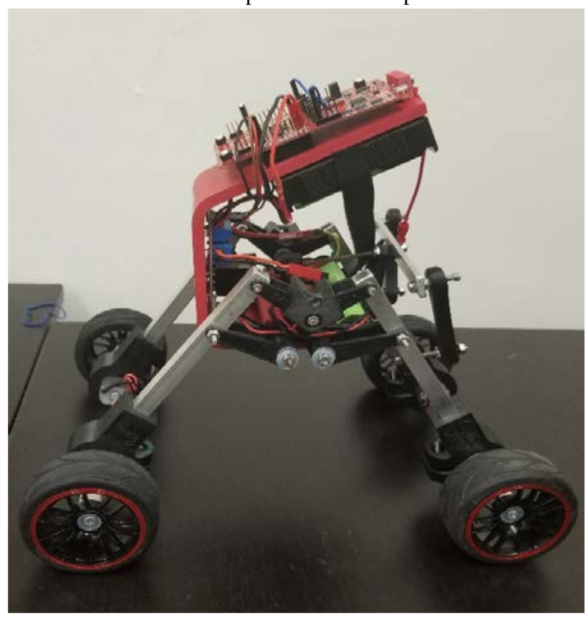

Fig. 7 Fully Assembled DSTR Robot

4. Summary

The Digital System for Teaching and Research ("Disaster") robot is a system of systems that has engaged multiple entities in the collaborative development process. Led by the TAMU MISL team with input from various educational and industry partners, DSTR has been successfully utilized in a wide range of educational environments from 5th grade through freshmen in college. The educational need for DSTRs has caused a rapidly increasing footprint for DSTR commercialization opportunities. The Blinn Freshman Engineering experience provided the latest and most detailed validation of the value of DSTR as an educational platform. The commercialization opportunities for DSTR are expanding in multiple markets with T STAR leading those effort. Look for a DSTR near you soon, or perhaps, on a Moon near you soon!

Acknowledgement

This work was performed as "DSTR Collaboration" project and supported by Texas A&M University Mobile

Integrated Solutions Lab, Blinn College, and Texas Space Technology Applications and Research (T STAR) LLC with some funding provided by NSF ITEST grant (award number 1614496) and lab donation grants from Texas Instruments.

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