Robot Teams: Adding Excitement to Technology Education

by

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Abstract:
Competitive robotic programs provide an interactive and stimulating learning environment for STEM subjects resulting in high levels of student participation. Managing a competitive robotics team is a complex job, however, establishing a partnership with an existing national or regional competitive robotics organization provides a significant advantage. This article considers a variety of competitive robotics organizations that are active at the high school level and below. All of the organizations reviewed require the participation of adult leaders, however the extent of adult involvement varies from administrative support and safety to full involvement in all team functions. Two techniques are commonly used to operate robots during competitive events: autonomous control and remote operator control. Autonomous control uses a computer program that receives input from sensors to direct the actions of the robot. Operator control uses control handles (similar to video games) to direct the actions of the robot. The cost for participating with national or regional organizations varies from a few hundred dollars to over $10,000 a year. Materials used to build the robots range from commercially available products to custom kits supplied by the national or regional organization.

Introduction:

Properly implemented, a competitive robotics team will provide a stimulating learning environment for science, technology, engineering, and math (STEM) subjects. This interactive experience can increase the level of student participation in technology education programs and inspire students to consider careers in Engineering Technology. Competitive robotics brings technology education out of the laboratory, combines it with the excitement of sporting events, and publicly celebrates intellectual achievement. A competitive robotics program can be integrated directly into the classroom or as an extracurricular activity.

Starting and maintaining a local competitive robotics team is a serious undertaking, significant benefits are obtained by developing a partnership with an established national or regional competitive robotics organization. Most of the national and regional organizations have good support systems for starting and maintaining a robotics team. The challenge is selecting an organization that reflects a philosophy and characteristics that are consistent with the local technology education program. Another important factor to consider is the level of funding required to start and maintain a competitive robotics team that is associated with one of the

national or regional organizations. The cost of participating with the different organizations varies greatly, ranging from a few hundred dollars to over ten thousand dollars. Fortunately, there are a variety of funding agencies and funding strategies available to support a competitive robotics team.

Most of the robotics organizations that involve middle school or high school students conduct an annual competitive event that requires the robotics teams to develop a strategy to solve some type of problem or complete a mission. Time restrictions, material restrictions, and a variety of other limitations are imposed on the teams in an attempt to simulate the requirements of real world projects. A common 'problem' used in the competitive events is to move an object of a particular color or shape from one area of a playing field to a goal some distance away. Several of the robotics organizations have videos available on their web sites showing prior competitions.

Many good competitive robotics organizations are operating today, and all of them are dedicated to bringing excitement to technology education through competitive robotics programs. The following six organizations representing seven programs have been chosen to illustrate the wide variety of characteristics to consider when selecting a competitive robotics partner organization: BEST Robotics, Botball Educational Robotics, FIRST Robotics Competition (FIRST/FRC), FIRST Lego League (FIRST/FLL), Robofest, National Robotics Challenge (NRC), and EARLY Robotics. Please note that including an organization here does not imply a recommendation of that particular organization and should not in any way limit the search for other competitive robotics organizations to consider as partners.

Fundamental Characteristics:

Adult leaders are involved with all of the organizations reviewed, however, the level of involvement varies greatly. Some organizations integrate adult leaders into the core of the robot team operations while others attempt to limit adult involvement to administrative or safety roles. The FIRST/FRC organization has a philosophy that requires students and adult leaders to work closely together in all team functions. This approach is intended to facilitate the transfer of knowledge and to develop mature working relationships between the students and adults with the adult leaders perceived as respected peers. The Botball and Robofest organizations encourage student and adult interaction, but do not permit adults to participant directly with the student team members during the tournaments. No adults are allowed in the pit area during these competitions. This approach attempts to guarantee that the students will develop the skills and knowledge needed to modify and repair their robot and to ensure that adult leaders, however well intended, do not take over the project.

Two primary techniques are used to control competitive robots: autonomous control and radio/operator control. The interests and skills of potential student team members should be considered when selecting the robot control method and partner organization. Radio/operator controlled robots use a wireless radio frequency console to direct the actions of the robot based upon input from a student operator. A student operator moves control handles (usually joysticks) on the control console that in turn directs the actions of the robot. In addition to controlling the direction and speed of a robot, the student operator often must control a mechanical arm or other mechanical device to manipulate an object (perhaps a ball or ring). Autonomously operated

robots typically include a small computer and one or more sensors (light, heat, touch, etc.) that direct the robot to complete a task. Teams must analyze in detail the requirements of the competitive event and then write a computer program to control the actions of the robot based on information obtained from the attached sensors. Students interested in computer programming and problem solving may find autonomously controlled robots more interesting. Students interested in engineering or mechanics may find operator controlled robots of greater interest. In any case, the robot control method is an important characteristic to consider when selecting a partner organization.

Many organizations have a similar sequence of events for their competitive programs. Usually the competition season begins with organizational and administrative work such as leadership workshops, recruiting adult leaders and students, establishing a schedule of activities, and obtaining the resources needed to operate the team. Next, the competition rules are published, followed by the design and build period for the robot. The "build period" rules for some organizations are very strict, while others are relatively informal. The official FIRST/FRC competition rules are announced to the world in early January using the NASA television channel and the organizations web site, 42 days later the robot must be packed in a shipping crate and picked up by a freight company before midnight of the last build day. FIRST/FRC teams do not have access to their robot again until arriving at their first regional competition site in March. The Robofest build period is less formal; draft rules are published in late December, official rules in January, followed by tournaments in March and April.

Cost and Materials:

The cost for a local robotics team to participate with a national or regional competitive robotics organization covers a wide range. The high end of the range (FIRST/FRC) will require a budget of $10,000 to $15,000 (or more) for competition event entry fees, required robot building materials, travel, and other incidental expenses. A low end budget could be only a few hundred dollars for travel, materials, and small competition fees. The BEST organization supplies the entire set of robot building materials and competition fees; local teams need incur only travel and incidental costs.

The type of materials used for robot construction varies as much as the costs. Several organizations require that robots be constructed using the popular Lego® MindStorms® product (see figure #1) and commonly available accessories. Two organizations (BEST and FIRST/FRC) restrict building materials to only a supplied kit of parts or a supplied kit of parts with the option to purchase approved additional parts within strict dollars limits. Other organizations have few or no limitations on the robot building materials other than the general rules for the competition and those related to safety concerns.

The physical resources needed to support a robot team must be factored into the decision making process when selecting a partner organization. Organizations using autonomously controlled robots give emphasis to solving problems in terms of computer programming with mechanical solutions secondary. Teams that construct autonomously controlled robots (Lego® MindStorms® and others) normally require little more than a school classroom, a computer, and perhaps a storage cabinet. Organizations that use operator controlled robots tend to emphasize mechanical

solutions to competition problems. Teams that construct operator controlled robots will almost certainly need access to a machine shop, power tools, and direct adult supervision.

Figure #1: Students working with Lego® MindStorms® NXT

Organization Overview:

The following organizational overview can serve as a starting point for identifying a potential competitive robotics program partner. Additional information is available on each organization's official web site.

BEST Robotics

BEST Robotics (Boosting Engineering, Science & Technology) is a large organization operating primarily in the south central and south eastern area of the USA with teams in over 600 schools and reaches over 10,000 students. Activities are targeted for middle school and high school students and are conducted during the fall term. Students build operator controlled robots. Materials to build the robot are restricted to the supplied kit of parts, must not weigh more than 24 pounds, and must fit within a 24-inch cube. BEST teams are organized around local competition sites called "Hubs" that support 8 to 30 teams. The first year cost for operating a hub that can support 24 teams is approximately $24,000. Primary funding for BEST teams is at the hub level, teams are provided with robot building materials and are not charged any type of fee to participate in BEST competitions. The teams have a 6-week build period starting in September followed by hub competitions. Teams that win at the hub level advance to one of three regional competitions. The majority of BEST teams operate in the south central and south eastern states, however teams are active in Ohio, Pennsylvania, Connecticut, and most recently North Dakota. For more information check the BEST Robotics web site at www.bestinc.org.

Botball Education Robotics

Botball is a national organization with over 290 teams across the USA and three international teams. Activities are directed at middle school and high school students and are conducted during the spring term. The Botball program uses autonomous or "smart" robots based on Lego® products that should not require a machine shop. Adults are not allowed in the pit area on tournament day. The $2,300 registration fee includes a 2-day professional development workshop, robotic equipment, computer software, tournament participation, and 10 Botball T-shirts. Leadership workshops begin in January followed by regional competitions starting in March. Teams have seven weeks to design, build, document, and program their robots. In 2007

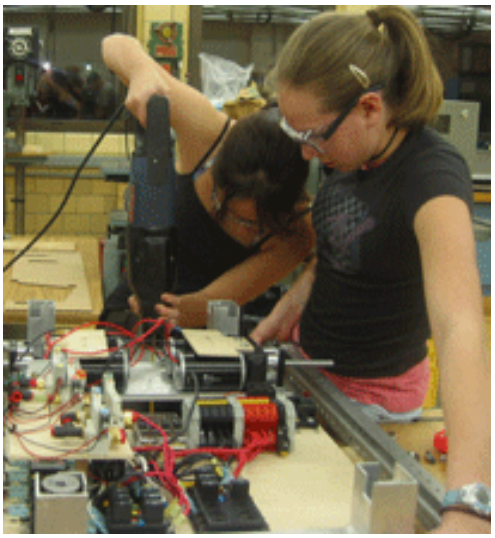

Figure #2: Students hard at work

Botball conducted 14 regional competitions across the country in addition to international competitions. Botball teams are encouraged to apply for Toyota TAPESTRY grants in addition to seeking local funding support. For more information see the Botball web site at www.botball.org.

FIRST/FRC

FIRST/FRC (For Inspiration and Recognition of Science and Technology/Robotics Competition) is a large international program with over 1,300 teams around the world with the majority located in the USA. Activities are directed at high school students and are conducted during the spring term. Primarily operator controlled robots are built by FIRST/FRC teams with some emphasis on autonomous control. Robots are constructed from a supplied "kit of parts" with the option to purchase additional materials within strict cost ($3,500 for 2007) and safety limitations. These robots are relatively large often exceeding 100 pounds and their construction will require access to a machine shop and power tools. The $6,000 registration fee includes the basic robot

building materials and the fee for one regional competition. The robot build period begins in early January and continues for 6 weeks. Teams must qualify (with a few exceptions) at a regional competition during March in order to advance to the national competition in April. NASA is a major sponsor of this organization by awarding $6,000 grants to many first and second year teams in addition to support provided at the national level. Students participating with FIRST/FRC teams are eligible for approximately 8 million dollars in educational scholarships and grants. FIRST also has a mid-level robotics program for high school students called the "FIRST Tech Challenge" (FTC), this program has a participation cost of only a few hundred dollars, much lower cost than the FRC program. The FTC program was pilot tested as the "FIRST Vex Challenge" until it was officially approved for the 2007 season. For more information refer to the FIRST web site at www.usfirst.org.

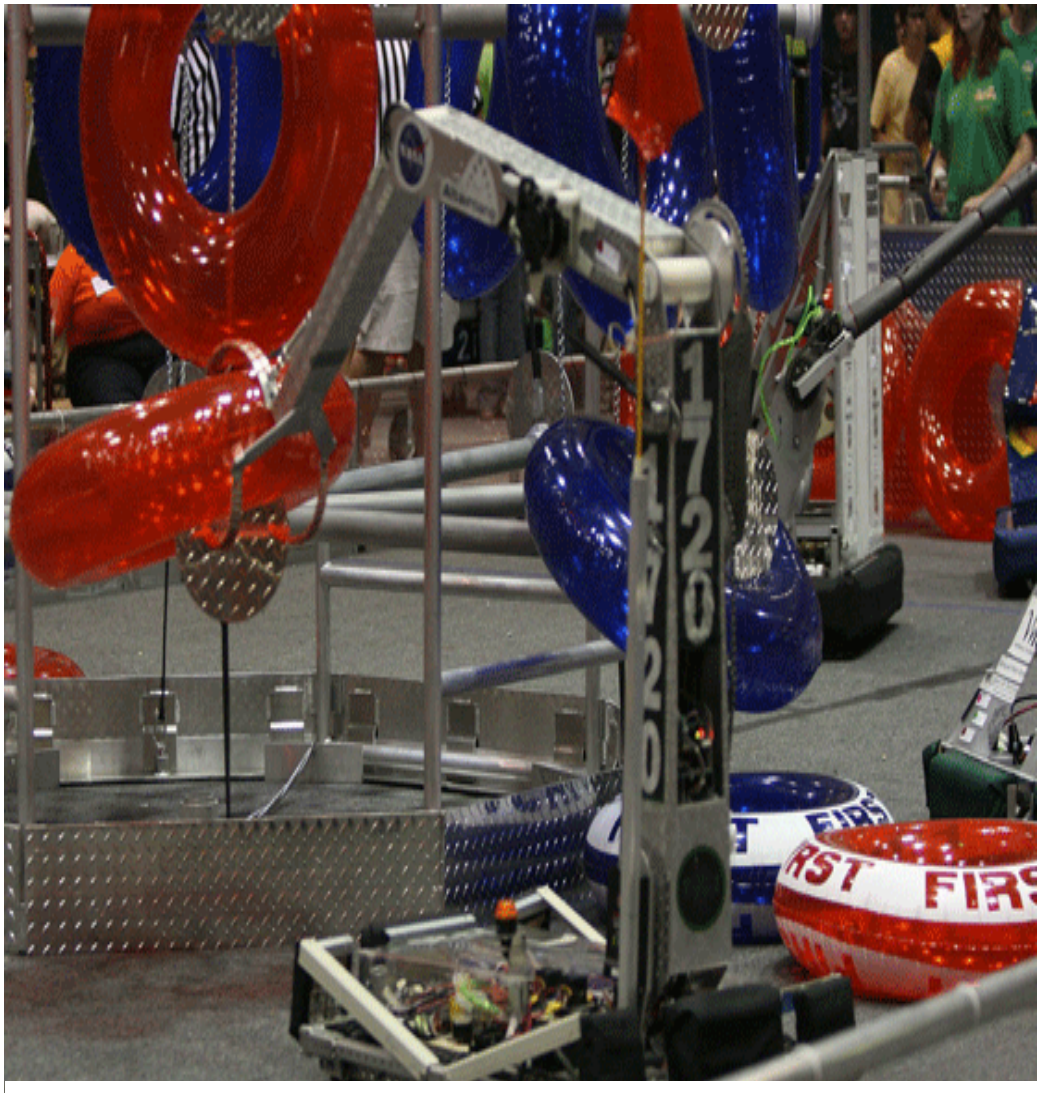

Figure #3: FIRST/FRC – 2007 "Rack 'n Roll" Competition

FIRST/FLL

FIRST/FLL (For Inspiration and Recognition of Science and Technology/Lego League) is a very large international program with over 8,800 teams around the world. Activities are directed towards middle school students and are conducted during the fall term. Middle school students build autonomous robots based on Lego® MindStorms® with additional parts supplied each season as needed for the mission challenge. The direct cost for first year FLL teams is approximately $600 and $300 for returning teams. The FLL build period is 8 weeks long beginning in September followed by regional tournaments in November and December, and completing the season with a world festival competition. During the 2006 season FLL was active in 45 countries with 9,250 teams and over 92,000 students participating. FIRST also has the "Junior FIRST Lego League" (JFLL) program geared for children in the 6 to 9 year old age group. For more information consult the FIRST web site at www.usfirst.org.

Robofest

Robofest is a regional organization operating primarily in the state of Michigan with over 230 teams. Activities are directed at middle school and high school students and are conducted during the spring term. Two fully autonomous robots must work together during the Robofest competitions. Some aspects of the competition problem are unknown until the day of the tournament. Adults are not allowed in the pit area during the tournaments. The Robofest team registration fee for 2007 was only $40 and competition fees not more than $20. Specific robot building materials are not required by this organization, teams are free to select practically any type of material for the construction of their robot. An icon-based graphical programming language is used in the junior division (5^{th}-9^{th} grade), in the senior division (9^{th}-12^{th} grade) a text-based high level programming language is recommended. For more information check the Robofest web site at www.robofest.net.

National Robotics Challenge

National Robotics Challenge (NRC) is a small regional organization operating primarily in the state of Ohio with 23 high schools, 4 middle schools, and 4 post-secondary schools participating in March 2007. The NRC has a wide variety of competition divisions. The 2007 NRC event offered 12 contests in 3 divisions. Participation costs are low with a school fee of $30 plus $8 per event. The NRC was originally sponsored by the Society of Manufacturing Engineers (SME) and consequently includes several contests directed at solving problems related to manufacturing. One interesting contest is the "Robotic Problem Solving – Rapid Application Development" activity where students are challenged with a robotic manufacturing related problem, and then given three hours to demonstrate a solution. Formal presentations to judges or written reports are required for several contests. For more information see the NRC web site at www.nationalroboticschallenge.org.

E.A.R.L.Y.

E.A.R.L.Y. Robotics (Engineering And Robotics Learned Young) is a regional organization operating primarily in the state of Texas with about 2,000 students and 300 active teams. Activities are directed at 7-12 year old students and are conducted during both the spring and fall

terms. Students in 2nd to 5th grades design and build operator controlled Lego® type robots that do not require a computer. Startup cost for an EARLY team is approximately $500 for Lego® Simple Machine kits and materials to construct the playing field. Typical recurring costs include materials to update the playing field and robot kit replacement parts. Teams are encouraged to apply for EARLY Exploration grants. For more information refer to the EARLY web site at www.earlyrobotics.org.

Summary:

Competitive robotics can bring excitement, fun, and visibility to a technology education program. Partnering with a recognized competitive robotics organization is almost certainly the best method of establishing a local robotics team. Selecting an appropriate partner organization is vitally important to the success of a local team.

To help assure a successful team the following actions should be taken when evaluating a potential competitive robotics partner:

- Determine if adequate financial resources are available. If not, can adequate funding be developed?
- Determine if the potential students have an interest in building the type of robot used by the organization.
- Determine if the physical resources are available to support the robotics team.
- Determine if adult leaders with appropriate skills are available.
- Confirm the level of support the partner organization can provide.
- Attend an official competitive event, ask questions and learn first hand how the organization actually operates.

The 2005 Brandeis University study of FIRST Robotics Competition participants between 1999 and 2003 revealed a number of positive program impacts. Eighty-nine percent of the program participants entered college compared to a national average of only 65%. Data from the U.S. Department of Education's Beginning Postsecondary Student study indicate that 41% of program participants became Engineering majors compared to the national average of only 6%. Minority participants declared Engineering as a major at comparatively high rates: 33% for women, 27% for African-Americans, and 47% for Hispanics.

Competitive robotics teams can bring fun and excitement to technology education programs and promote an interest in Engineering Technology related careers to young adults.

Resources:

Brandeis University, "More Than Robots: An Evaluation of the FIRST Robotics Competition Participant and Institutional Impacts," Center for Youth and Communities, Heller School for Social Policy and Management. April 2005.

Full report is available at www.usfirst.org/who/content.aspx?id=46

National Aeronautics and Space Administration (NASA), Robotics Alliance Project web site:
robotics.nasa.gov

RoboGames: large robotic competition with over 70 different events:
www.robogames.net

Robot Magazine: hobby, science and consumer robotics;
www.botmag.com

Servo Magazine: projects and articles on robotics, available in print and online versions:
www.servomagazine.com