A FAIR GAME: A LOW-COST EASILY IMPLEMENTED ROBOTICS COMPETITION LEADS TO DIVERSE ENTRANTS

Abstract

Since 2006, we have run a robotics competition that attracted widespread participation (over 100 entrants) from local K-12 schools. This six-hour competition pits low-cost robotic systems built over several weeks by teams of two to four K-12 students (age range 14-18). These small, ten-inch robots come from an all inclusive, commercial kit like the ones offered from Parallax. The students implement common robotic topics such as autonomous robot navigation, localization and detection algorithms and robot design to complete engaging medically themed challenges. The challenges provide fun opportunities for students to apply science, technology, engineering, and mathematics (STEM) learning. This competition is designed for students with no prior engineering background and is designed to teach them basic programming and electro-mechanical design.

Our robotics competition is inexpensive (the robot kits are 40% cheaper than Lego Mindstorms) and less time-consuming (for organizers and advising teachers), compared to other more publicized robotics competitions, which makes it ideally suited to attract involvement by low-income schools. For the last three years, the robotic challenge has attracted many local public schools for those very reasons.

This competition was developed by a well-known robotics center with industrial partners. Its primary objective is to provide a rewarding and exciting experience that draws students into studying the STEM fields within higher education. Preliminary results from a questionnaire administered the day of the competition showed that 43% of students were more likely to go to college after participating in this event.

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Introduction

The engineering jobplace is expected to grow by 11% over the next decade [1]. To prepare students to study these subjects in college, they need a sufficient background of science, technology, engineering, and mathematics (STEM) subjects.

While course completion rates surged in topics such as advanced biology, chemistry, and physics in the 1990s, they leveled off in 2000-2005 [2], and students from disadvantaged socioeconomic backgrounds still attend college at substantially lower rates than other students. [3] Even despite the heightened educational expectations and rising college enrollment rates, many of them discontinue their education before graduating from high school [3]. On the 2003 Programme for International Student Assessment (PISA) math assessment, the quartile of American 15- year-olds with the lowest socioeconomic status was almost four times more likely to be among the bottom quarter of performers than the quarter of most privileged students. [4]

Our goal is to provide practical opportunities to precollege students, with an emphasis on those in lower socioeconomic class, to encourage them to attend college and enter into STEM fields. Opportunities to learn engineering should be low cost and easily implemented. We hope that application of courses out in practical situations help them understand the impact of the educational process and encourages them to continue their studies.

The multidisciplinary nature of robotics makes it a popular platform for STEM education. The development of a successful robot requires the integration of knowledge from various disciplines such as mechanical and electrical engineering, computer science, and math. Creating a robot requires many disciplines and often much money. It is our intention to offer young people an affordable robot construction experience.

At a robotics competition, students work, either as a team or individually, to build an electro-mechanical system that is programmed to serve a goal or purpose given a specified timeframe. Competitions are a chance for participants to showcase their work and compete against other robots for prizes. These competitions are a forum to educate the students as well as the general population who attend. The recent surge in precollege robotics programs shows the impact this has had on exposing future engineers to the excitement of the field.

This paper reviews the local robotics competition and uses our own, JHU RoboCompetition, as a demonstration of how a low-cost and easily implemented robotics competition can attract a diverse group of students into studying STEM fields.

JHU RoboCompetition is organized by the Johns Hopkins University Computer-Integrated Surgery Student Research Society (CISSRS). CISSRS is a group of undergraduate and graduate students involved in community education and outreach as part of the National Science Foundation Engineering Research Center Computer Integrated Surgery Science and Technology (ERC CISST). This paper's appendix describes, in more detail, the specific events in our competition. The authors will gladly provide more information about replicating the JHU RoboCompetition upon email.

The JHU RoboChallenge leverages the increasingly multidisciplinary field of robotics with the versatile but easy to learn board of education kit in an effort to introduce participants to robot building fundamentals in a fun and exciting environment. It gives students a hands-on tool to enhance their science, technology, engineering and math (STEM) education and learn critical skills such as teamwork, collaboration, critical thinking, professionalism and problem-solving, without difficulties in terms of cost, parental support, and time. It is also an opportunity to excite young students by providing them a positive, rewarding, and educational experience.

Background: Other local robotics competitions

Numerous other robotics competitions exist and each one has its own particular advantages. Since the Johns Hopkins RoboCompetition is held annually in Baltimore, MD, we discuss other robotics competitions that are held in the region and which draw local participation (see Table 1).

The FIRST Robotics Competition (FRC) is perhaps the largest robotics competition with over 1,300 teams of 10-20 high school students who build robots over a six-week period to enter in regional competitions throughout the country. FRC provides many commendable experiences for the students, but it is a very expensive undertaking. Teams are expected to raise $10,000 to compete in a regional competition and the hosts sites can expect expenses ranging from $150,000 - $200,000. Furthermore, the competition recommends that schools enlist the help of three to six engineers. Host sites require more substantial staffing to help coordinate, secure, and judge such a monumental event [5]. The FIRST Robotics Competition is a wonderful opportunity, but its costs and implementation requirements can be prohibitive.

The FIRST charitable organization also has a competition, the FIRST Lego League, for students aged nine to fourteen. This competition involves teams of three to ten students who use Lego Mindstorms© to construct robots which again compete in regional events. This event is less expensive; costs to participate are approximately $400 to $700 depending on whether the team has competed previously [6]. This event is substantially less expensive than FRC, however high school students may not compete and the costs may still be prohibitive to lower income teams.

The Vex Robotics Competition is an alternative to the First Events. Registration with the national organization is $75 for the first team from a school and $25 for every subsequent team. Additional costs include competition entry fees (the Northern Maryland entry fee is $125 for reference) [7] and purchasing commercially made VEX robotics kits. The Carnegie Mellon Robotics Academy recommends one robotics kit for every two students and sells robotics kits for the competition with MSRP costs ranging from $580 to $885 [8]. Once again, a relatively substantial investment is required for teams to participate in this competition.

The remaining local robotics challenge, simply named Robot Challenge, is affiliated with the Baltimore section of the Institute for Electrical and Electronics Engineers (IEEE). With this competition, students spend two hours a week for two to four months constructing a walking robot that races against other robots. The costs to participate in this event are very low. The competition provides one free custom-made robot kit to every school and additional robotics kits range from $49 to $186, which can be shared among two to eight students [9].

Table 1: Comparison of Local Robotics Competitions

Team Costs	FRC	FLL	VEX	IEEE Robot Challenge	JHU RoboComp
Total Cost	$10,000	$400 - 700	$650 - $950	$50 - $186	$160
Registration Costs	$6,000 includes kits (regional) $5,000 national	$600	$50-200 (locally $125)		$0
Team Size	10 - 20	3 - 10	2 – 10	2 - 8	2 – 3
Engineering Mentor Required	Yes (6 recommended)	No	No	No, Provided by competition	No, Booklet included
Preparation Time Commitment (man-hours)	Greater than 500	100-200	50-150	48 - 96	40 – 60
Competition Time	3 Days	2 Day	1 Day	2 Day	6 Hours
Number of Events at Competition	1	12	1	2	4
National Competition	Yes	Yes	Yes	No	No
Uses commercial robotics kits	No: Non-commercial kit required	Yes: Lego Mindstorms©	Yes: VEX robotic kits	No: custom supplied hardware	Yes: Parallax Boe-bot kit
Participation	2000 teams 42000 students	14000 teams 137000 students		100 teams	30 teams

The JHU RoboCompetition

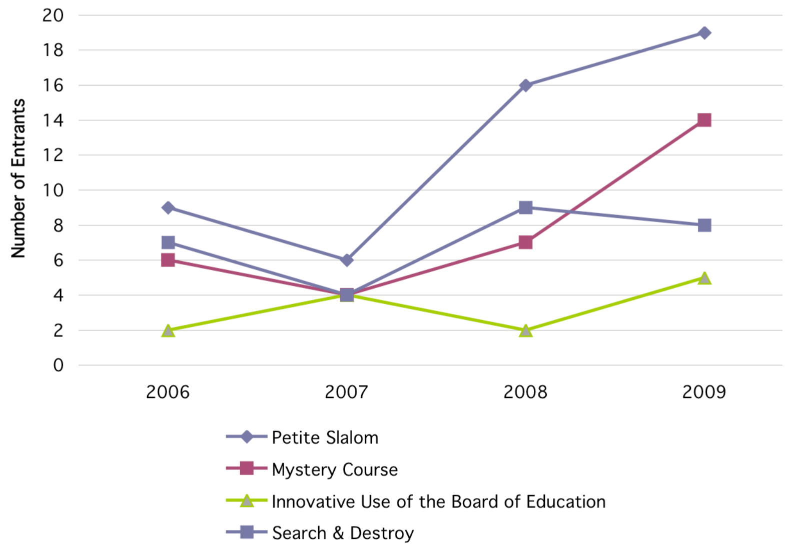

Figure 1: Number of Entrants in Different Events

The JHU RoboCompetition is most similar to the IEEE Robot Challenge in size and scope. Teams of two or three high school and middle school students construct a small mobile robot from a commercially available robot kit (Boe-bot by Parallax, inc.) and compete in up to four events (see Figure 1, Appendix 1) that occur on the same day. The kit, which costs $160, contains everything necessary to construct the robot to compete in the competition events including motors, a microprocessor, sensors, support hardware, and an educational text that teaches basic electronics and how to assemble the kit. Since the kit contains everything needed to participate in the competition, teams do not require engineer mentors who may be difficult to find. Based on the level of advisor involvement and the number of events entered, teams spend between 40 to 60 man-hours assembling and then programming their robots, which is comparable to the IEEE Robot Challenge. Through hands-on participation, students are exposed to fundamental electronics components and circuit design, programming, mechanical assembly, sensing technologies, and autonomous control. Many of these are booming engineering fields and all are excellent preparation for collegiate study.

Since 2006, Johns Hopkins University has hosted the RoboCompetition, which has drawn increasing participation almost every year (see Figure 2). In 2009, 46 entrants are registered to compete. An entrant is a group of students entering a single event at the RoboCompetition. To date, more than 250 people have been involved with the competition. The competition was initially funded through a National Science Foundation grant, but it currently survives through its ability to win continuing grants. The efforts have been successful at encouraging students to attend college; 43% of students attending the 2007 challenge report an increased desire to attend college afterwards.

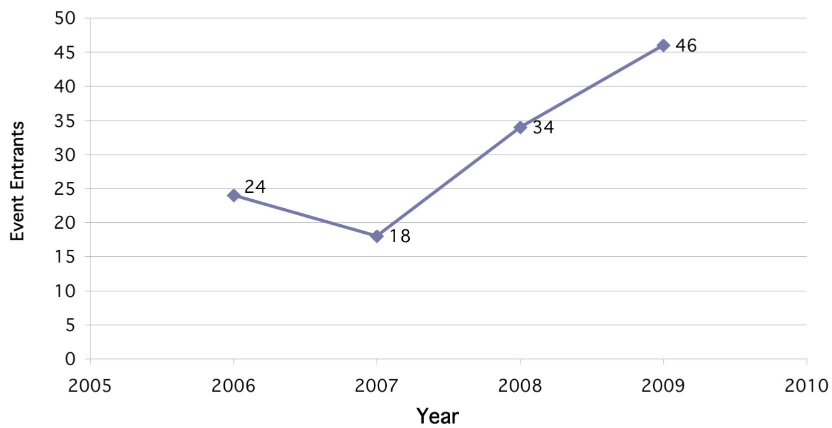

Figure 2: Total Entrants into Competition Events

The JHU RoboCompetition is substantially less expensive for teams than FRC, FLL, and VEX. Teams are required to spend $160 on the robot kit, although we loan out many robot kits without charge, and there are no registration costs. Since the competition is intended for local schools, travel costs are minimal.

Table 2: Anticipated Budget for 2009

Item	Cost
Competition Boards	$150
Signs/ Banners	$100
T-Shirts	$350
Prizes	$500
Robot Kits	$450
Tables and Chair Rental	$350
Mailing Supplies	$100
Food	$300
Competition Boards	$150
Total	**$2,300**

The JHU RoboCompetition is also much easier than FRC, FLL, and Vex for a host site to organize. The JHU RoboCompetition has an annual budget of $2,300, excluding the cost of room rental (see Table 2, Figure 3). Since the room rental costs can vary dramatically, they are excluded from the cost analysis. At Johns Hopkins University, the event is organized by a student organization, so there are no room rental expenses. For comparison, hosting a FRC event can cost 150 times more and require substantially more volunteers. The JHU RoboCompetition can be run by a total of 15 volunteers at the event who handle judging, registration, and event coordination. This makes it reasonable for a single organization to host a low cost robotics competition. The low cost also enables participants to be from any socioeconomic group.

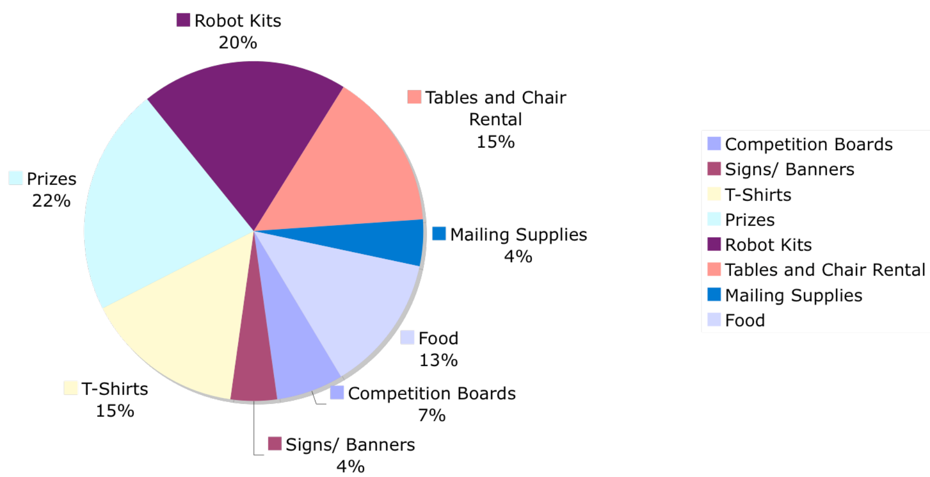

Figure 3: Breakdown of the costs of running the JHU RoboCompetition excluding room rental

Diversity

Two primary objectives in the creation of the JHU RoboCompetition were to excite students about studying technological fields in college and to promote diversity within these fields. Racial statistics on the entrants have not been compiled, but gender and socioeconomic factors have been recorded.

Like most of the STEM fields, gender gaps exist within the competition entrants. In 2009, for example, 30% of the registered participants are female; however, those gaps are smaller than many of the fields comprising STEM, especially many of the engineering disciplines where women constitute less than 15% of the workforce [10]. This statistic is not unique to the JHU RoboCompetition; the IEEE Robot Competition, another low-cost easily implemented robot competition, attracts over 30% female participants [11].

The JHU RoboCompetition draws participants from Baltimore City and the surrounding counties. Great socioeconomic diversity exists within that region. The Maryland Department of Planning estimates that in 2007 the median income in the region was $63k with Anne Arundel Country having the highest median income ($83k) and Baltimore City having the lowest ($38k) [12]. The JHU RoboCompetition has drawn participants from public schools whose mean household income is distributed throughout that range. The event has attracted schools with a mean household income of $75k and also schools whose mean household income is $30k [13]. The competition has also attracted many private schools, but socioeconomic statistics on those schools is not available to report.

The significant costs to enter the FRC are entry barriers that teams must overcome. The JHU RoboCompetition has strived to reduce costs for teams as much as possible by eliminating registration costs and loaning robot kits to teams who desire them. The IEEE

Robot Competition has also taken similar approaches by supplying the first team from a school with a free robot kit. The continued success of both competitions, despite the fact that there are local FRC and VEX events, demonstrates the need for low-cost competitions.

Conclusions

Robotics is a cutting-edge field that is rapidly growing. It can be used as an exciting platform to teach various (STEM) field topics. In this paper, we compare various robotics competitions available to local students. We focus on two low cost robotics competitions that draw diverse participation.

Acknowledgements

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Appendix 1: Details about the RoboChallenge events

Challenge 1 ***Petite Slalom***

In the Petite Slalom challenge, competitors program their robot to travel through a slalom course set up on the one end of a 3' x 6' sheet of tempered hardboard. Robots are programmed to run a designated path through a series of gates. The most successful robots will traverse the course correctly and be the fastest to accomplish the route. Since all the points where gates can possibly be placed will be known in advance, teams will be able to preprogram their robot to run segments of the course in preparation. They will then have to join these segments together at the competition to run through the correct gates.

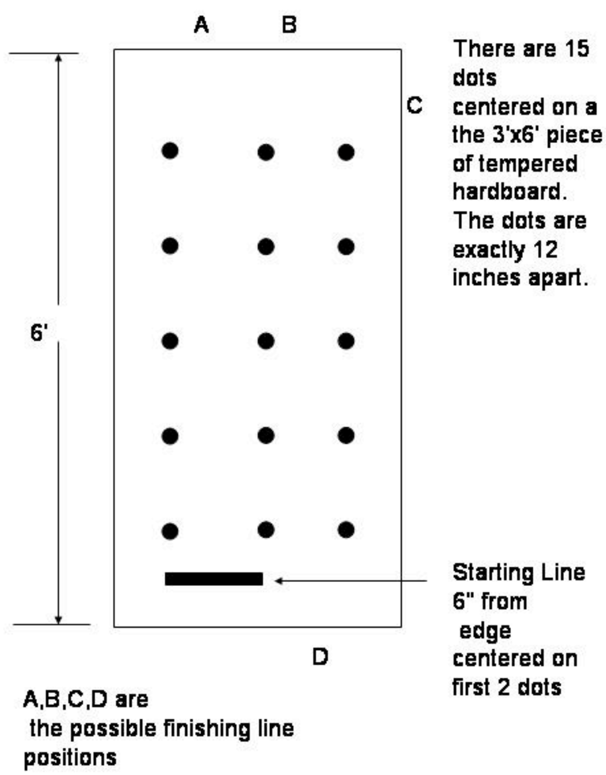

Figure A1: The Petite Slalom Course

Challenge 2 ***Mystery Course***

Teams will arrive at the competition with no knowledge of what the course will be. The mystery course will be unveiled upon arrival at the challenge and teams have 90 minutes to select the appropriate sensor and program their robot. The course may be a blind course that cannot be seen or an open course that is established after the programming period ends. For example the course could be open to view but has moveable walls.

The robot will requires sensors to maneuver through this maze. Team must come to the challenge equipped with a complete Boebot and the knowledge required to effectively use the sensors provided in the kit. The students will place their robot in line when they feel they have programmed it successfully. All robots will be tested, robots that complete the maze will be ranked by time, with the shortest time being the winner.

Figure 4: One year's mystery course resembled the human anatomy with the robot going through the intestine to the heart.

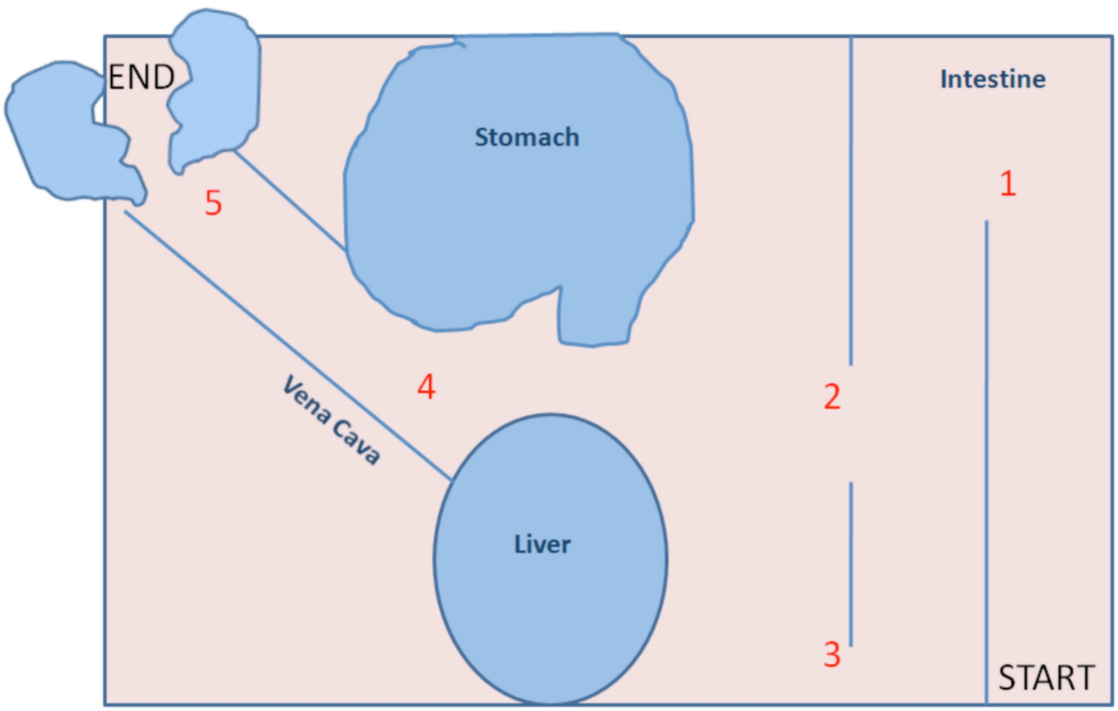

Figure A2: The Mystery Course

<u>Challenge 3</u> ***Innovative Use of the Board of Education***

Teams will design an innovative and practical new use for the Basic Stamp Board of Education. They will display a working model of their idea in an oral presentation along with a written report. Teams will be judged on quality of the idea, operation of the prototype, the oral report and the written report. Teams will also demonstrate a working model their proposal. This challenge is designed to teach students technical presentation and writing skills.

<u>Challenge 4</u> ***Search & Destroy (Robotic Brain Tumor Surgery)***

The purpose of this competition is to simulate the planning, searching, and signaling that takes place during robotically-assisted surgery. The number and location of tumors inside the brain (enclosure) will be random, so the robot should be pre-programmed to search the entire brain for hazardous tumors. Teams of Robotic Brain

Tumor Surgeons will design and program their Boebots to find all the "tumors" (large dark circles) at various unknown locations in the patient's brain, a 3' x 3' enclosure. The BoeBot will be placed in a random point inside the brain and should be able to detect the corners and sides of the enclosure and to search the entire brain for tumors on its own. When a tumor is found, the robot must signal to the surgeons (possibly a buzzer or LED). The robot should stop once the entire brain has been searched. Teams will be judged on their robot's ability to find all the tumors, time to complete the search, and efficiency.

The ability to work on small teams gives all exposure to building, designing, and programming the boebot kits.

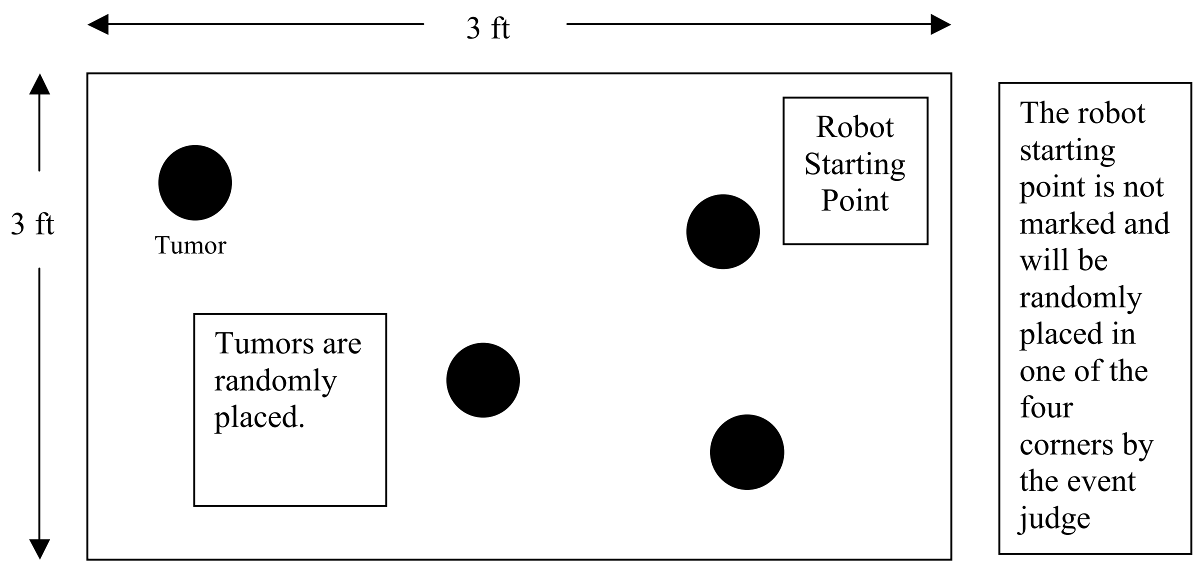

Figure A3: Search and Destroy Layout