Robotic Football Dance Team:

An Engineering Fine-Arts Interdisciplinary Learning Experience

Danielle Desmond Madeline Horton Adam Morrison Sami Khorbotly

Department of Electrical and Computer Engineering
Valparaiso University
Valparaiso, IN, USA

Danielle.desmond@valpo.edu Madeline.horton@valpo.edu Adam.morrison@valpo.edu Sami.khorbotly@valpo.edu

***Abstract*—With the increasing focus on the importance of interdisciplinary projects in the academic setting, it still seems as if most of these projects are either collaborations between disciplines in the STEM fields or collaborations between disciplines in the Liberal Arts fields. Despite the fact that they complement each other, a significant barrier still exists between STEM and Liberal Arts students. This paper describes the joint work of three Electrical and Computer Engineering students with one Fine-Arts student on an extracurricular project. In preparation for the robotic football competition, a team of our Engineering students decided to create a robotic dance team to complement the football playing robots. In order to create this team, Engineering students assembled, calibrated, and programmed a team of ten robots. Multiple Fine-Arts student were recruited but only one joined the team to help with the music selection/creation and other aesthetic aspects of the robots. The interdisciplinary nature of the collaboration highlighted the need to knock down some of the barriers between the technical and Fine-Arts disciplines. The team dynamics showed that students from different disciplines need to get out of their respective comfort zones and collaborate for the sake of their projects. The paper includes a full description of the project and a review of the lessons learned from the collaboration.**

Keywords—interdisciplinary, robots, Engineering, Fine-Arts, collaboration, teamwork.

I. Introduction

Robots are gaining increased importance with the tremendous growth of their applications including children's toys, manufacturing lines, military applications, medical procedures, or even space exploration missions. Due to the recent miniaturization of robots, the drastic decrease of their size, and the advancements in computing and communications technologies, swarms of compact robots are also becoming very popular, which opens a whole new world of opportunities and applications.

According to Bill Gates [1], robots and the robotics industry are emerging in these days in the same way the computer industry emerged 40 years ago. He compares the 2007 robots to the main frame computers in the 1970s and envisions robotic devices becoming a nearly ubiquitous part of our daily lives in the near future. From an economic point of view, the Japanese Robot Association estimates the Japanese robot market at approximately $27 billion in 2010, and forecasts it to be $72 billion by 2025 [2].

Around ten years ago, the Department of Aerospace and Mechanical Engineering at The University of Notre Dame, started the mechatronic football competition. In this competition, senior-level undergraduate students are asked to design and build football playing robots for their capstone design projects. The projects lead to a combine where the different robots showcase their capabilities and a robotic football game where two teams of robots, each consisting of eight robots on the field at a time compete in a game of modified rules football. In the last few years, the idea has evolved to become an intercollegiate event where teams from multiple universities are yearly competing in robotic football games to win the Brian Hederman Memorial Trophy [3].

Every year, participating Engineering students work on building football playing robots that are strong, durable, and fast enough to beat the other teams. In the recent years, some teams have tried to use advanced technology to improve other features in their robots such as the coordination between the quarterback and the receiver [4], the maneuverability of the running backs, or the kicking distance of the kicker/punter.

For the first time this year, as an analog to the traditional cheer or pep squad seen in collegiate and professional American football, a team of our Engineering students wanted to create a robotic football dance team. The goal of the newly created team is to perform during the intermission and to generate crowd enthusiasm through a variety of synchronized movements while playing selected music. The team is made of a swarm of ten robots that communicate timing as well as position signals during their routine.

In order to create an aesthetically pleasing, yet technically functional product, it was vital to have a collaboration between students with backgrounds in both Fine-Arts and Engineering. This, apparently trivial task turned out to be a bigger learning experience than was originally anticipated. The paper describes the project as well as the lessons learned along the way. The rest of the paper is organized as follows: Section II provides some background and reviews similar work. Section III describes the robotic platform used to implement the dance team. Section IV describes the Engineering modifications to the robots to make them more artistically inclined. Section V explains the process and the difficulties encountered when creating the music to be played. Section VI includes some quantitative assessment as well as some observation from an Engineering education perspective. The paper is then concluded with a summary.

II. Background

It is a well-known fact that learners and professionals in various disciplines have different approaches to acquire the necessary skills to excel in their respective fields. Documented research in the area of various learning environments dates more than 50 years ago [5]. While the education of Engineering students is fundamentally different from that of their Fine Arts counterparts, many studies have shown that both parties would benefit from an interdisciplinary exchange between technical and artistic disciplines. According to [6], interdisciplinary projects in the Arts and Engineering are necessary to produce a well-rounded education for engineers. The authors of [7] suggest that the infusion of Arts in the Science, Technology, Engineering, and Mathematics (STEM) education improves the learners' creative process and design thinking. In another work [8], it is suggested that, not only the students, but also the educators can benefit from the interdisciplinary exchange.

These perceptions of the benefits of interdisciplinary education have materialized into the creation of innovative courses in Interdisciplinary Design [9] and multi-disciplinary experience [10]. In a truly multidisciplinary effort [11], a capstone design course was designed to incorporate students of Mechanical Engineering, Electrical Engineering, Marketing, and Arts and get them to work together on the same projects. In another case, the creation of a whole new interdisciplinary program at the University of Utah [12].

The main difference between our work and the aforementioned efforts is the fact that while others are trying to create an interdisciplinary course or a degree-granting program, our work addresses an extracurricular project. In other words, students involved in our project are not getting any credit for their work and are accordingly not subject to accountability or any performance evaluations of any consequences. This detail, explicitly discussed in [13], significantly reduces the advisor's control and authority over the team and changes the dynamics of the team formation as well as the day-to-day operations.

For this extracurricular project, students are involved and are working exclusively for the love of learning and the pleasure of doing interesting robotic work. Considering the artistic nature of the project, the team's advisor (an Engineering faculty member) encouraged the team members to invite (at least) one Fine-Arts student to join the team. This suggestion was not particularly received with a lot of enthusiasm by the Engineering students. The following are direct quotes describing some of the feelings:

- I have played an instrument since middle school and have been in many bands and choirs since I was in elementary school. So I am confident in my ability to work with the Arts side of the project.
- I know how hard it is to work with people from different disciplines because they tend to have completely different work ethics or mannerisms than that of your own discipline.
- I feel capable enough to be creative for most aspects that would be needed on a project.

It was obvious that Engineering students preferred to work exclusively with fellow Engineering students. Even when the job to be done was a Fine-Arts related one, they prefer to do the work themselves, over having to get out of their comfort zones to reach out to a Fine-Arts student. However, with some encouragement from the advisor, those feelings were overcome and a Fine-Arts student was eventually invited to join the team.

III. Robotic Platform

The robots used in this research project are the ActivityBot robots from Parallax Inc [14] shown in Figure 1. These small, yet capable robots are programmed to perform the routines planned for the cheer sequences. Each robot consists of a main microcontroller board, which houses the main processor. This board sits atop a frame holding two servo motors facing outwards to the left and right of the robot. On these servo motors are attached small plastic wheels with rubber grips surrounding the wheel to give it traction. A battery pack resides under the frame and requires 5 AA batteries to power the robot. Each robot came with the ability to be interfaced with a variety of sensors, including an ultrasonic distance sensor that can clearly be seen in Figure 1.

The robots are programmed using the Parallax integrated development environment SimpleIDE, which interfaces the robot with a computer and allows the development of the code in Propeller C (a modified version of the C language). In this language, a variety of commands are used to perform various robotic functions such as driving forward and backward, rotating left and right, and playing a pre-loaded music file. The code also includes functions that implement trigonometric and other mathematical calculations to convert real-life movements into hard-coded numbers and angles for the robots.

Some sort of communication between the robots was needed in order to make sure that they simultaneously start their routines and stay, to some extent, synchronized. The adopted solution was using the XBee wireless radio modules. These modules are an excellent choice for the project at hand since each of them consists of a small circuit board with an antenna, roughly one inch in length and one inch in width that could send and receive radio signals coming from other XBee modules. The circuit board is easily interfaced with the ActivityBot's microcontroller board.

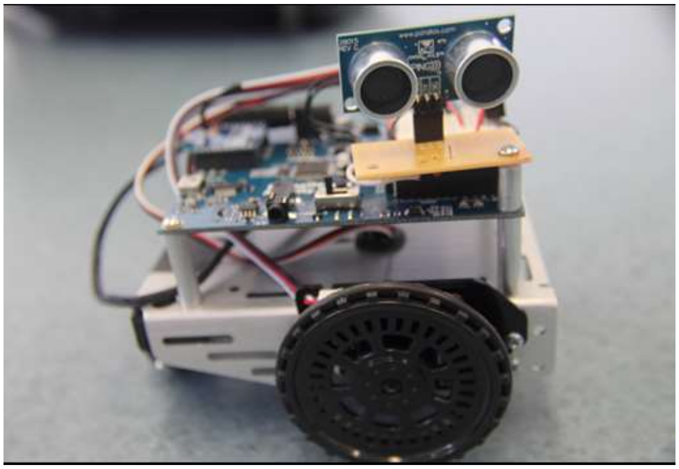

Figure 1. The ActivityBot robot used to create the robotic dance team.

Additional programming was necessary to ensure the timely communication of information. As a result, the XCTU configuration platform was used to program the XBee modules with specific settings from a computer before being connected to the ActivityBots. The settings that were changed gave every XBee the same network ID, which allowed them all to communicate on the same network with one another. Each Xbee also had a unique personal ID that allowed them to be distinguished from one another.

A singular robot was designated to be the starting commander for all of the robots to begin a routine. The sequential operation was then maintained through the coding of a distinct character from the English language that would be sent out by the command XBee to the other receiver XBees on other robots. For example, the character "g" was used to signal the first part of the routine, and the character "t" signaled the second part of the routine, and so on. The commander robot redundantly sends each signal 10 times to ensure that all of the other robots have received the signal, and then starts its own routine. The receiver robots wait to receive a signal from the commander XBee to begin their own routines. The redundant transmission of the signals is accomplished at a fast enough rate to not cause any humanly noticeable delay between the starting times of the different receiving robots.

IV. THE ARTY ACTIVITYBOT

Halfway through the design process, an Art vs Engineering problem was encountered. From an artistic point, dancers in a dance team must move some of their "body" parts in order to perform a choreographed dance. The Engineering reality, however, is that the only movement our rigid robots can perform is moving the whole robot from one point to another. As a result, during the design portion of the project, the team realized that the routine would more accurately resemble a Marching Band than a Cheer or dance Team.

It was therefore determined that the robots would need to play music, much like a marching band does when giving a performance. Conveniently located on the circuit board of the ActivityBot is an auxiliary jack for a speaker or headphones. The speakers used were the Parallax Veho 360 speakers [15]. These speakers are small and light, and are compatible with the ActivityBot making it an easy decision for our team. The only problem was being able to attach the speakers to the robots without limiting or slowing down their mobility.

Parallax sells a small attachment device for these speakers, but they are sold separately. Instead of buying the attachment devices, our team decided to design and 3D model an attachment that can be easily and quickly 3D printed in our manufacturing facility at the College of Engineering. This was a much more cost effective solution compared to purchasing the attachment devices for the speakers. During this portion of the project, the team learned a lot about reverse Engineering designs and coming up with quick and out-of-the-box solutions. The 3D printed support is the u-shaped red part mounted on the ActivityBot shown in Figure 2. Similarly, Figure 3 shows the whole Arty ActivityBot including the original ActivityBot, the Veho 360 speaker, and the 3D printed mounting support.

This decision was also the first chance to observe two significantly different lines of thought between the Engineering and the Fine-Arts sides of the team. On the Engineering side, the cost effectiveness of the solution, coupled with the availability of a manufacturing suite at the team's disposal and the teams' familiarity with the process made the 3D printing decision an obvious one. On the Fine-Arts side of the team, it was not surprising that the first thought was to purchase the supports. However, the manufacturing option was received with a lot of interest and a lot of inquiry about the process. One student even mentioned that he would like to learn how to 3D print and that he would maybe try taking a class sometime in that area.

Figure 2. The 3D printed speaker support mounted on an Activitybot.

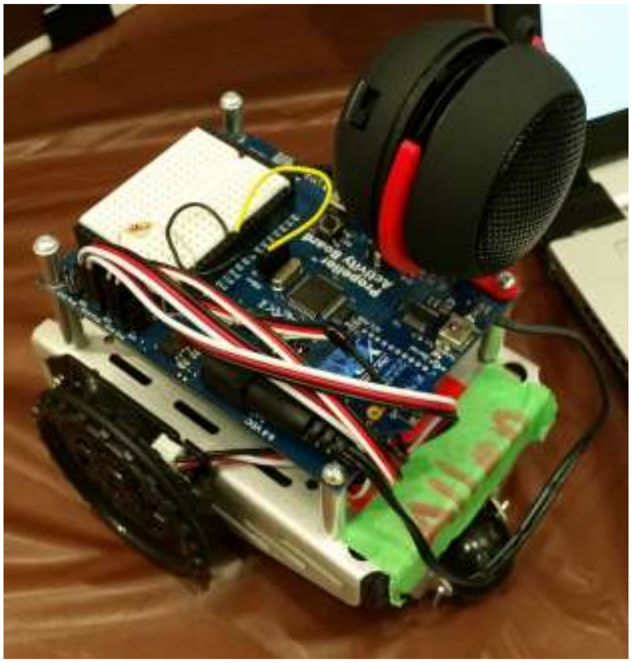

Figure 3. The Arty Activitybot including the Veho 360 speaker fitted on the 3D support.

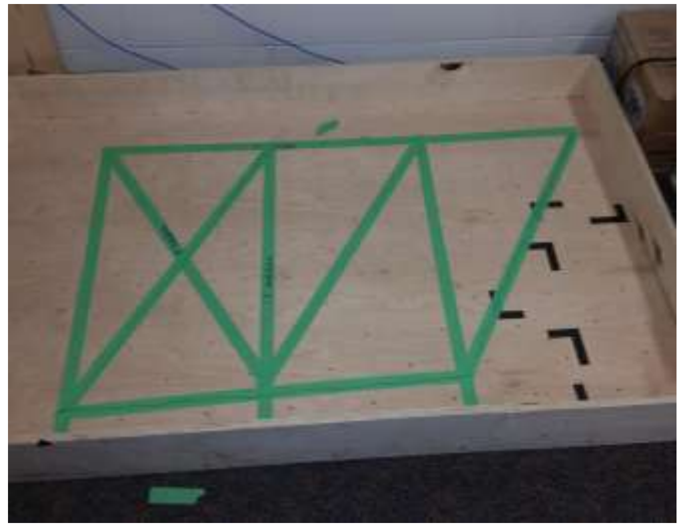

Figure 4. The pattern created to guide the robotic marching routines.

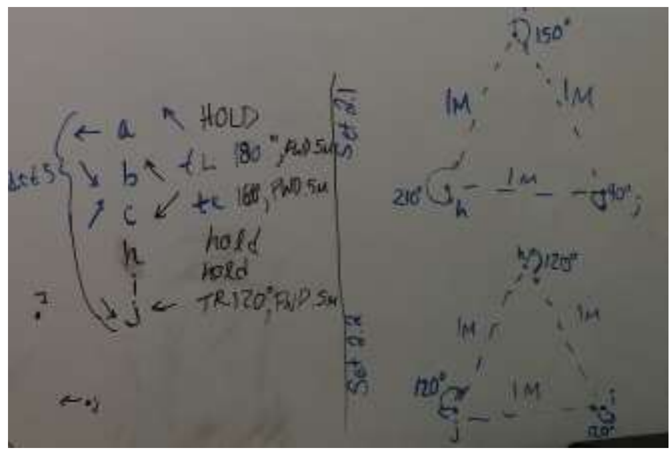

Figure 5. Some of the Mathematical calculations guiding the implementation of the robotic marching routines.

Once the Arty ActivityBot was ready, the focus shifted to the routine design. The marching routines were designed and implemented in a multi-step process. It all started by creating a pattern on the robotic arena to guide the general shape and the routes that the robots will follow. The patterns are shown in the arena in Figure 4. These patterns then evolved into a set of mathematical and trigonometric equations to calculate the angles of rotations and the number of ticks for each wheel in every robot. These equations were exclusively developed by the Engineering side of the team. Some of those Mathematical calculations are shown on a white board in Figure 5. The last step was to translate these equations into propeller C code that generates timely instructions to the robots' various actuators.

V. The Music

The audio component is a large part of the project. It was very critical to select an appropriate music clip for the robots to play. A decision was made to seek out a student majoring in music to possibly compose this clip or at least recommend and compile a short soundtrack for the project. The music clip needed to be about two minutes or less if it was looped. The major difficulty appeared when trying to find a music student. The first person that was contacted was a sophomore music education major. Although she originally expressed interest in joining the team, she later became non responsive and took more than a week to respond to any contact. Eventually, the Engineering team grew impatient and decided to move on to find another individual who will be easier to work with. The new student, was much more accessible, although still busy. The Engineering students met with him and he improvised a sample music composition to show what he could possibly do. The decision was on him composing a minute or so piece that he would perform and record. Although it took him several weeks to accomplish this task, he eventually came through with the finished piece.

It was eye-opening to find through this process how difficult it was for the Engineering students to connect with someone in an area outside of the College of Engineering. Although we are a relatively smaller university, where people know one another, it still took several weeks just to get in contact with a music student and to explain the project and what the team was looking for. Once the individual was identified, it wasn't too difficult to get them to understand the project and what was expected from them to do, as long as they didn't have to deal with the technical side of the project.

It was a good learning experience for Engineering students to communicate requirements and specifications to someone who doesn't speak their technical language. It was also a learning experience to see that getting out of one's comfort zone and recruiting outside help, while challenging at first, can lead to excellent results in the end. As stated by one of the Engineering students, when asked about her interdisciplinary collaboration experience: “It was interesting and beneficial to our project to involve a person from the Arts. It enriched our research to incorporate more than just our skills and expertise from the Engineering side”. Another Engineering student, when asked the same question responded: “I have no issues collaborating with students from another major, and think that it is good that we mimic real-life situations where everyone on a team may have certain areas of expertise or varying backgrounds”.

On the flip side, when Engineering students were asked about things that could have been done better, the consensus was that establishing communication with those outside of Engineering and starting the collaboration with them was the toughest and the most time consuming part. According to one of the Engineering students: “if we wanted to involve people from another area, such as music, it is necessary to contact months in advance of when we want the finished product”.

VI. Assessment And Observations

Considering that this project was a volunteer-based extracurricular activity and not a course, no formal course assessment was required or performed. However, an informal one-on-one assessment was performed at the end of the project. And while the small number of participating students (only 3 Engineering students), makes any quantitative assessment statistically irrelevant, the results still display some interesting trends that are worth sharing. The first question that was asked of students was:

Had the advisor not brought up the idea of inviting Fine-Arts students to the team, would you have thought about it? why?

To that question all three students responded negatively. The reason for the answer is that they all felt that they have enough capabilities to carry out the required Arts related tasks and that any additional help was not necessary.

The second part of the assessment was a two part process with the goal being assessing any change in the students’ opinions about working with others outside of the College of Engineering. In order to do that, the students were asked the following questions:

Before the project - ***on a scale of 1-10 (with 10 being the most likely), how likely are you to invite a Fine-Arts student to work with you on a project?***

After this project - ***having worked with a Fine-Arts student already, on a scale of 1-10 (with 10 being the most likely), how likely are you to invite a Fine-Arts student to work with you on a future project?***

The results, graphically illustrated in Figure 6, indicate that two out of the three participating Engineering students are significantly more likely to invite Fine-Arts student in future projects. While relatively improved, the “After” likeliness for both these students was still limited to 5/10. This can be blamed on the frustration caused by the difficulty finding the right person(s) and establishing communications with them. The one student who is not more likely to invite Fine-Arts student in future projects was already fairly open to the idea and therefore did not have too much room for improvement.

When asked to evaluate the performance of the Fine-Arts student, one Engineering student was not impressed but still gave credit when credit was deserved: “To be honest, we would not have found that song if not for the Arts student, but I feel like they were not as involved as they should have been with the project”. Another Engineering student is more sympathetic and tried to find an excuse: “This is because they have no reason to be compelled to work on a project which is something extra from the workload they already had”.

From an advisor’s perspective, it was nice and refreshing to see the students’ self-confidence and their willingness to take on tasks outside of their areas of expertise. It was, however, fairly surprising to observe their reluctance and hesitation to reach out to and collaborate with Fine-Arts team members. Also from an advisor’s perspective, a greater level of enthusiasm and involvement was anticipated from the recruited Fine-Arts students. It was a bit discouraging for the students to be turned down by multiple recruits before finally identifying one. In retrospect, it seems that having students approach other students may not have been the most efficient recruiting strategy. The recommendation for the future is to recruit a Faculty member from the Fine-Arts who in turn may identify and recruit the appropriate students.

VII. Summary and conclusion

This paper described an extracurricular learning experience where three Engineering students worked on creating a robotic dance team/marching band. Due to the artistic nature of the project, the Faculty advisor suggested the addition of at least one Fine-Arts student to help with the artistic efforts such as choreography and music creation. While it was a bit challenging at first, a Music student eventually joined the group. At the end of the project, and while not extremely impressed, Engineering students do recognize the valuable contributions of the Fine-Arts student and are, on average, more likely to invite other Fine-Arts students to join their teams in the future.

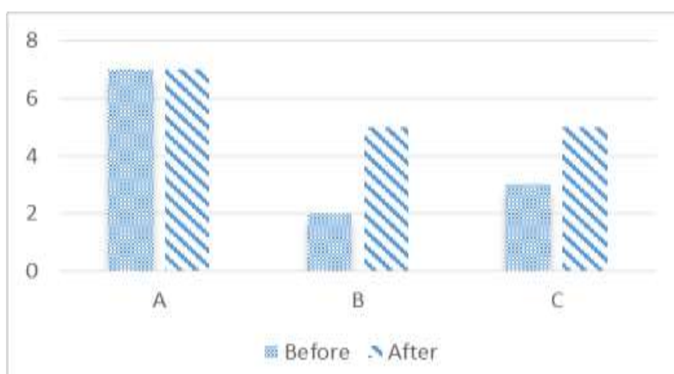

Figure 6. A before and after comparison of the answers of 3 Engineering students to the question: on a scale of 1-10 (with 10 being the most likely), how likely are you to invite a Fine-Arts student to work with you on a project.

From an educator's perspective, this work shows that while our Engineering curricula have made great strides in teaching communication and team work skills to our students, there still is some room for improvement when it comes to communicating and teaming up with individuals from the Fine-Arts community.

References

[1] B. Gates, "A Robot in Every Home". *The Scientific American*, January 2007.

[2] Japan Robot Association Estimates: http://www.welding-robots.com/articles.php?tag=495.

[3] Notre Dame Robotic Football Page: https://www3.nd.edu/~rfc/

[4] A. Stephon and S. Khorbotly, "A camera-based target tracking system for football playing robots". *IEEE Southeastern Symposium on System Theory*, Jacksonville, FL, 2012.

[5] A. Astin, "Classroom environment in different fields of study". *Journal of Educational Psychology*, vol 56, Oct 1965.

[6] E. Wuerffel and J. Will, "Engineering in the Humanities: Interdisciplinary Projects in the Arts and Engineering". *ASEE Annual Conference and Exposition*, Seattle, WA, June, 2015,

[7] J. Bequette & M. Bequette, "A Place for Art and Design Education in the Stem Conversation". Journal of Art Education, vol. 65, no. 2, March 2012.

[8] L. Barker, K. Garvin-Doxas, and E. Roberts, "What can computer science learn from a Fine-Arts approach to teaching?", *SIGCSE Technical Symposium on Computer Science Education*, St. Louis, MO, Feb. 2005.

[9] T. Cotantino, N. Kellam, B. Cramond, and I. Crowder. "An Interdisciplinary Design Studio: How Can Art and Engineering Collaborate to Increase Students' Creativity?". *Journal of Art Education*, Nov. 2015.

[10] R. Gorbet, V. Schoner, and G. Spence, "Impact of learning transformation on performance in a cross-disciplinary project-based course," *IEEE Frontiers in Education Conference*, Saratoga Springs, NY, 2008.

[11] L. Thigpen, E. Glakpe, G. Gomes, and T. McCloud, "A model for teaching multidisciplinary capstone design in mechanical engineering," *IEEE Frontiers in Education Conference,* Savannah, GA, 2004.

[12] R. Kessler, M. Langeveld, and R. Altizer, "Entertainment arts and Engineering (or how to fast track a new interdisciplinary program)". *ACM technical symposium on Computer science education*. 2009.

[13] S Khorbotly and K Al-Olimat, "Engineering student-design competition teams: Capstone or extracurricular?", *IEEE Frontiers in Education Conference,* Washington DC, Oct. 2010.

[14] https://www.parallax.com/product/32500

[15] https://www.parallax.com/product/900-0001