RoBallet: Exploring Learning through Expression in the Arts through Constructing in a Technologically Immersive Environment

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Abstract: We present the RoBallet environment as an interesting area for learning in a variety of domains through augmenting performing arts with technology. In the RoBallet environment children choreograph dance movements while wearing sensors and wireless microcontroller boards as well as having more sensors and devices in the environment. The children build robots, and program them, animations, light, and music they compose to respond to their movements. We have a few primary goals in this endeavor; to open new areas for exploration, to use technology to augment expression, and to open creative and expressive uses of technology, mathematics and science to children who may otherwise have no interest. We describe a workshop we ran in conjunction with the National Dance Institute, discuss what we learned, and present our ideas for future development.

Keywords: Robotics, Performing Arts, Expression

Introduction

The Epistemology and Learning Group at the MIT Media Lab pioneered development and application of robotic and programming environments for learning [Papert, 1980, Resnick et. al., 1996]. In recent years some of us have focused on integrated approaches to change in the learning environment for children in both formal and non-formal settings. When we presented opportunities for children to choose their own projects using robotics, children created many wonderful projects of robots and devices along rather familiar lines. These include a wide variety of vehicles, many optimized for speed, devices optimized for strength along some dimension, others for control, and so on.

However, recently we observed what we found to be an extremely interesting phenomenon that we chose to explore and support at a much more focused level. A growing number of children, girls in particular, were building highly interactive projects, for example robots with which they could dance, or pets with whom they could play. Without demeaning the design and construction of fast vehicles or strong devices, we found the highly interactive dancers and pets to be extremely sophisticated and demanding endeavors. It is not trivial to sense movement so that another object can interact in real-time. Nor is it trivial to construct a robot to move in a delicate and responsive enough manner that one could consider its movements "dance" and to dance interactively with a person. Moreover, the sophistication of the programming required to control and interact in a variety of ways is non-trivial as well. One can begin projects building dancers and companions in a rather straightforward manner, but we observed that children would continue to develop, refine, and enhance these projects over quite an extended period of time, truly enriching the experience. These projects had more "staying power" than the typical vehicle. This provides an excellent example of Papert's design goal of "low threshold, high ceiling" [Papert, 1980]. It also illustrates how technology and the "hard" sciences are not exclusive to any particular gender or learning style, but can be open to a wider variety of people. It also illustrates how we, through our choice of projects and our own tastes and previous experiences, can bias who is attracted and what counts as meaningful projects and, often unwittingly, can drive others not like us away.

RoBallet is an explicit attempt to access some of the ideas raised by these interactive, expressive projects. We developed RoBallet as a new set of tools to open up new content areas for students to think about both artistic expression and engineering. Another goal was to introduce new ways of thinking about art and engineering to a wide range of people, who may be interested in particular aspects of the project, and who by virtue of their participation in the environment, may create connections to other areas not previously considered.

An important element of our design process was to create an environment that fostered intellectual diversity by creating a space in which art and science share equal footing in the creation of a final product. This is to be contrasted with the common approach of creating an environment where one provides a vehicle for the other, an approach that ultimately trivializes both domains. One becomes subservient to the other, or becomes a method of "tricking" students into enjoying the other.

RoBallet provides a place for dancers to incorporate technology to enhance their art. Similarly, technology may be used to full effect without being "softened" by the introduction of performance. This combination serves to open up both the arts and technology to a wider range of students without trivializing either domain. Instead, experience in one area can provide new insight into the other.

Our goal was not necessarily for the children to become better dancers, choreographers, composers, or performance artists. This is not our area of expertise. Rather, we focused on how this environment could potentially be a rich learning environment for exploration of a wide variety of areas, not just the arts, but also math, physics, programming. Our goal was also not to learn in a more connected way only the disciplines in and of themselves, but also how their interconnections enrich each other. We wanted children to experience how through technology we can extend artistic expressions that otherwise is difficult or even impossible; how more people can make these expressions without having to follow the traditional paths of mastering a musical instrument before composing. We also wanted children to experience how math, programming, and physics can be expressive and have aesthetics, and are not dry, lifeless, or merely instrumental.

We drew from other sources of inspiration besides our empirical observations of children doing robotics. Our colleague Tod Machover not only has a long history of innovative development of technologically-augmented musical instruments (hyperinstruments), but also recently has developed tools such as Hyperscore for his Toy Symphony project [Farbood, 2001]. Our colleague Joe Paradiso has not only created new microcontrollers and sensing devices, but has worked in innovative ways with dancers on using dance to drive musical expression [Paradiso, 2002]. One of the authors, Anindita Basu, developed the Full-Contact Poetry environment as a means of extending multimedia creative expression for children [Basu, 2002]. MIT Media Lab doctoral student Marc Downie along with Professor Bruce Blumberg in the Synthetic Characters group has created tools and pieces in collaboration with Paul Kaiser, Bill T. Jones, and Merce Cunningham, developing ideas in motor system representations and behavior-based music [Downie, 2002]. We find that many others are incorporating similar technologies to create new forms of artistic expression in music and dance. Our focus remains not only on how this is an especially rich domain for children to express themselves using technology, thereby attracting more children who may not be so inclined, but also on how such technologically-augmented expression creates new opportunities for learning.

RoBallet

We designed our RoBallet environment so that children could choreograph dances, use and or build sensors to place on their bodies and in the environments to control music they compose, robots they build, animation they program, lights they control via programming, and other devices they can choose to place in the environment. We do not expect them to learn by things happening and being presented to them in an immersive space. The space should not control the children. The children should control the space. They design and decide what should happen. We did not want to present the elements we used (i.e. music, robotics, programming) as fixed and determined. We wanted them to explore movement through space in time, what sounds pleasant and what not and which musical elements combine to create which types of feelings, how these could be different; how lighting can be mixed, can be expressive, can combine with the other elements, and so on. We wanted the children to have fine-grained design control over these elements so that they could explore the concepts in a non-trivial, personally meaningful ways. The immersive environment serves to create a rich experiential space for this exploration. We also chose to design our tools not just for direct manipulation, but in an environment for expression that can later be built piece by piece, taken apart, modified, reflected upon, modulated, and experimented with. However, with such ambitious design goals and not a lot of experience and domain expertise, we chose to run a workshop and use that as an "object to think with," to help us to see the possibilities and limitations [Papert, 1980].

Thus, for our initial foray into this space, we decided to build some prototype tools and use some existing software to experiment concretely early in the design process, knowing that we would in all likelihood not use those specific tools. We used both Stack boards from Paradiso's group and GoGo boards designed by Sipitakiat [Benabast et.al., 2003, Sipitakiat et.al., 2002]. The Stacks are more sophisticated and advanced, with not just wireless communication but also accelerometers and gyroscopes on board. The GoGo board is simpler, designed to be accessible by being low-cost, using easily available components, and possible to assemble by hand. We have used different versions of the GoGo board in a variety of learning projects to integrate robotic control into other projects for learning. In this sense simpler and accessible have some advantages over sophisticated and advanced even if giving something up in terms of power, speed and capability.

We converted a traditional stage setting into a responsive environment that could dynamically interact with lighting and music systems, and added an animation system that could be projected into the dance space (Figure 1). After beginning their choreography, the group embedded sensors in the stage floor and the environment, allowing the students to program triggers for certain events. In addition, we provided a set of sensors that students could wear on their bodies. The body sensors plugged into small wireless wearable devices, both the Stacks (Figure 2), which students attached to belts and wore around their waists, and the GoGo boards. The Stacks transmit data from the body sensors to a server that we programmed, which in turn sends the sensor information to the computers that operated the lights, music and animation.

Figure 1. The RoBallet environment.

For music and animation we decided to use what would be closest to what we would want, but easy to assemble rapidly for the workshop. We knew that for music nothing yet existed that would suit all of our design goals. However, to build what we desired would take too long and would delay our initial workshop. So, for music we programmed an environment in MaxMSP to enable the students to lay out what they wanted along various dimensions such as melody, rhythm, pitch, etc., and then program what effect change in sensor values should create. For animation we used both Microworlds Logo and an environment we built in Squeak. The environments would respond to sensor data and change the animation as programmed. We also built an interface in Squeak so that the lights could be programmed to respond to the sensor data as well.

Workshop

Another reason to do a workshop with children early in the process was that we had the opportunity to work with Jacques d'Amboise. d'Amboise is the former principal dancer of the New York City Ballet, and the founder of the National Dance Institute (NDI). d'Amboise was accompanied by Dufftin Garcia, who runs the NDI center in Trenton, New Jersey. Garcia is also a former student of d'Amboise's from the NDI work in New York City, and is currently studying computer science. The two agreed to work with us in a workshop with children in July, 2003 at MIT. We agreed that for the purposes of this workshop, we did not want children with lots of experience in either dance or programming. We wanted to see what "average" children would make of our space.

During our design of RoBallet, we had an initial generative theme in mind: for students to create dance pieces that expressed a particular emotion. We wanted children to think about how to express an emotion using all of the various elements available to them, from choreographing movements, to composing music, to designing lights and creating animations, and also to consider how these different media best augment each other.

While the girls who were making robots to dance with inspired RoBallet, our first instantiation of the project did not feature robots, as there were many other elements that we wanted to work with. Since we had an extremely limited amount of time (8 days), and so many ambitions, we felt that if the children were to build robots and program them that would use up a significant portion of the time. Because we have had many years of experience working with children doing robotics, and wanted to maximize the talents of d'Amboise and Garcia as well as test out the other elements of the environment that were new, we decided to omit the robotics for the first workshop (an ironic decision given the name of the project). We began with a desire to provide students with multiple expressive tools that related to dance, so we first examined various elements of a traditional dance performance.

Once the environment was constructed, we held a workshop with a group of nine 9-12 year old children. The workshop was supposed to be a one-week event in which we could test the environment and have some preliminary feedback on the ideas, but at the request of the children, we extended the workshop for another week, and allowed them to invite friends to participate. During the first, "official" workshop, the NDI facilitators helped the children learn to choreograph, to think about what steps can be appealing, to express themselves through movement, to understand how to control movement through space in time, to match music and movement, and to keep in mind how a performance appears to an audience. Exposure to such expertise and experience was critical to us all to bring an understanding of dance.

Since the first workshop included professional dancers as part of the facilitating group, the students were introduced to the methods used by dancers to develop steps and combinations. This exposed an interesting similarity between dance and programming. d'Amboise taught by breaking dance steps into counts of eight and naming the steps with something the children could understand. For example, running in a circle to the left with knees high in the air was called the "pear." Running in the opposite direction was called "apple." Then he called out the names of steps in sequences to create combinations, which were then given names such as "fruit salad." This mapped directly to how the children were creating programs to run their music, lighting and animation. They mapped environmental events either to particular dance events or to particular dancers and named events accordingly. The programs were named like the step combinations, as a superset of the individual events. There was even an overlap between trying out steps one at a time in various combinations, and once one is satisfied, to name them and bundle them to be used in different combinations and variations. We were amazed by the similarities between how Jacques introduced choreographing dance and how we introduce programming.

In the second week, we encouraged the children to explore choreography on their own, to both invent and name steps and to take a step combination and perform it with different intentions, such as happiness, anger or frustration. We opened the workshop every day with a set of physical warm-ups and improvisation exercises to encourage children to both experiment with how to express emotions and formalize what they were doing.

The workshop in week two was completely open, so children chose their groups, emotions and how they wanted to approach their projects. In some groups, children wanted to work on different elements in parallel, so one would compose music for the emotion, while another worked on lights. In other groups, the students wanted to execute every part together. All of the groups had to revise and debug their programs however they approached them, however, since when they saw all of the elements combined, some aspects inevitably clashed or were not coordinated. This led to many different discussions, from which sensors to use and how to create effects most naturally to trying to more effectively convey an emotion through the combination of media.

Glorianna Davenport, head of the Media Lab's Interactive Cinema group, and her students videotaped the entire proceedings and ran a video weblog of the event. We kept it private to protect the security of the children involved. Still, this provided a rich source of material for analyzing and debugging not only our environment, but also how to run such workshops. The constant video presence also inspired us to see how it could be used within the RoBallet environment itself, by videotaping and displaying images that also can be interactive and computational.

Interaction

Since the environment has so many parts, the easiest way to explain how it was used is to trace through a project that a nine-year old participant, "Toby," created. While the example is fairly straightforward, there are many other possibilities within the environment that will be explored further.

The emotion that Toby decided to portray was anger. Instead of mapping out every aspect of the piece before beginning, he decided to implement one part at a time before trying to merge all of the components. He had a few ideas for steps that he might use, but did not begin with choreography. First, Toby composed creepy sounding music in a minor key. As he worked on the music, he commented on particular steps he might perform at various points in his composition. He then moved to the lighting computer to experiment with "angry" lights. He chose a combination of red and white lights that would sometimes strobe. Then he created an animation of dark red objects that would fly through a dark blue space "biting" other objects. He finished by trying to put all of the pieces together with his movements.

As he tried to pull the components together, he modified each part. He needed a way to trigger events and experimented with floor sensors and body sensors and tried to figure out which would blend into his choreography the best. Toby finally decided on two body sensors and placed them on his palms, so that he could press them easily no matter how he was moving. As he began to put the pieces together, he went back to revise the pieces he had already created so that they would mix together more effectively. Toby changed his lighting sequence, for example, so that it would match the timing of the music and his movements. He also tested various sensors and tried to see which would work best. When Toby began working on his project, one of his ideas was that he wanted to use a bend sensor, which he would place on the inside of his elbow to control the lights. During his implementation, however, he realized that a touch sensor would work better than a bend sensor for his piece.

When the children worked on pieces individually or in groups, they had to negotiate between various media and technologies to create these interactive pieces. While the example that we described is simple, the environment was also used in more complicated ways, with children interacting with animations that they programmed, or using a body sensor to dynamically control some aspect of the environment. A good example of the latter is a project in which the students used a bend sensor to control an animated curtain, which lowered itself when the dancers bent their elbows and raised itself as their arms straightened.

Discussion

The RoBallet environment is new and we have held only the described two-week long preliminary workshop. Nevertheless, we have found encouraging evidence that Roballet is a compelling learning environment. The first important aspect is that the environment was engaging to all of the children who worked with us, in both workshop groups, despite their diverse backgrounds and interests. None of the children had danced before, and most had limited programming experience. But during the workshop, all of the children both danced and programmed; stepping out of familiar territory to experiment with all of the environment's capabilities.

In this space, students must be truly interdisciplinary. They looked at the idea of emotion through many lenses, from the many types of media they use to their own bodies. How do angry lights differ from angry sounds? How do movements complement or detract from the mood one has created in the environment? How does it feel to move angrily as opposed to joyously?

While the stage is a responsive environment with sensors embedded in the floor, it is also a dynamic exploration space for children. The children use components of the space as tools to create their interactive expressions instead of choreographing their movements to fit predefined functions. This is important as it allows children to engage with many levels of creation and to truly experiment with expression and programming.

Since children were using sensors on their bodies and in the environment to drive the rest of the stage setting, they needed to map sensor values to mood. How does amplitude relate to intensity? If an arm is bent in an angry piece, should the pitch increase in the music, or the volume? Maybe the speed should change? Does it have to change at all, or should that sensor control the strobe rate or color of the lights instead? Where should the sensor be placed on the body and what should be sensed? Is it a simple trigger, or a continuous control? If it's a trigger, should a floor sensor be used, or should the dancer wear the sensor? How does that affect the choreography of the piece?

It is precisely because there are no “right” answers to such questions is why we find this area so interesting. Students are free to express what they think. In order to express, they explore thinking about elements of sound, light, and movement. In order to express what they want, they meet interesting mathematics, physics, engineering, electronics. This creates a virtuous circle where they learn to think in these areas in order to express what they want. As they incorporate this thinking, they are able to express more, which leads to deeper thinking.

Figure 2. A wearable Stack computer modeled by a student.

One interesting aspect was that there seemed to be a common language for expression by movement. Acute angles expressed more conflict. Rounder forms were calmer. Sharp movements were more to express anger. Slower movements were kinder. Expressing emotion through dance, music and light enabled eloquence in a different way than words.

The environment also returned to ideas raised by Seymour Papert in his early work with Logo. In this work, Papert described why the turtle was a compelling character: Children could anthropomorphize it and mentally map their bodies to the behaviors of the turtle. In the case of RoBallet, the students' bodies actually drove the environment. If they changed their choreography, the environment would also change dynamically instead of always performing the same canned set of actions. The children were breaking down and formalizing their movements in order to describe and coordinate the other events in the environment.

Using the body also gives a way of thinking of issues in physics and mathematics very concretely. Dancers experience matters of force and tension through their movements and can associate these ideas with intention in movement. They can clearly feel the difference between lifting their legs to a 45-degree angle versus a 90-degree angle. While the connection between these feelings and concepts in physics do not arise simply from movement through space, explicit connections can be made in context by a facilitator as was described previously in the connections made between choreography and programming. These connections serve the same purpose as in any method of interdisciplinary study, that is, to provide the ability to examine something from multiple perspectives simultaneously, allowing the knowledge from each domain to strengthen understanding of a concept.

The students spent a great deal of time "debugging" and "revising" their dance pieces. This formed another concrete relationship between the performing arts and engineering and helped students understand each concept more deeply. They had to debug their programs when using one sensor caused an unexpected result. The child expected the sensor to trigger a change in lighting, but instead, the music grew louder. Oftentimes children's animations did not work the way they planned, either, because of an error in their code. But beyond making a piece functional, working as planned, they revised their dances to make them either more cohesive or more effective emotionally. Their dances had meaning and an intended effect, for the audience to understand and feel the emotion they were trying to portray. Their projects went more deeply than simple functionality or simple effect, but searched for an intersection between the two.

We were struck by the potency of examples. The strength of Jacques's character and the beauty of his choreography stuck with the children. In the second week of the workshop when they were free to do as each one pleased, they used, modified and built upon his steps. However, they also utilized his means of using the sensors. We expected the children would be more adventurous in their use of the technology. However, they stuck pretty much with what Jacques did. One aspect of this was using familiar things when experimenting in unchartered domains. Another aspect is that we had limited time and a multitude of tools. We eagerly look forward to working with children in the next version of the RoBallet environment over longer periods of time.

Finally, we noticed a certain "performance" bias. There was a much greater concern about how the performance would appear to the audience than we are accustomed to. We usually work with children on projects just for the sake of learning and doing, not for the sake of a performance. Although we appreciate the value of public performance and certainly of final artifacts, this bias drove much of the workshop and diminished possibilities for exploration.

Future Work

As mentioned above, the workshop was the first feedback step in the process of designing RoBallet. There are three categories for future development; the development environment, the hardware, and the connections to learning. Obviously, we would like to include robot building in the project, since that served as the inspiration for RoBallet. However, we want to improve upon the materials used so that we have stepper motors, a wider variety of mechanisms for movement, and the ability to mount artifacts on a scale large enough for performances. We do not want to restrict ourselves only to performance spaces and scales. We still maintain that a child making one robot with which to dance is incredibly compelling. We also will use new generation of wireless chips that provide both greater capability and lower costs.

We plan on modifying the programming environment that the students used in the preliminary workshop by changing the interface and some of the interaction. We need to adapt Logo to be more open to adding other objects to it as well as to improve its response time. We are still determining whether to base everything in Squeak and Smalltalk, making a new interface specific to RoBallet. This has obvious advantages of bringing in objects, running native and therefore fast, being open source, and having a community of developers assisting us. We will develop an interface for handheld devices so that the child is not required to perform in one space, then run off-stage to re-program, then run back on to test, and so on. We felt that this running back and forth interrupts the beauty of using the body as the system's control.

We need to determine what software we will use for music composition, or to write an application if we find none suitable for our needs. The more seamless the programming of the animation, robotics, lights, music, and video is, the more satisfied we would be.

Perhaps most important from the standpoint of our potential contribution is the connections to powerful ideas in mathematics. We believe that utilizing our sense of our body's movement in space as a means of understanding the mathematics of movement in three dimensions, of coordination, of dynamics is an area rich in possibilities. By sensing the movement and using it as parameters for functions mapped across a variety of domains also can provide a concrete basis for other rich areas. We are currently examining what mathematical content is applicable, and are using the ideas to inform our software language and environment design.

Our first experiments with RoBallet were exciting, fun and interesting for the facilitators and the participants alike. Although we know we have just begun, we are convinced that this is a rich area for exploration. The workshop experience reveals great potential and, with these additions in place, we feel confident that our environment will become a rich environment suitable for deeply exploring a space where the arts and engineering meet.

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