Sphero Dance! Final Report

Andrew Dong
University of Calgary
2500 University Dr. NW, Calgary, AB T2N1N4
ahdong@ucalgary.ca

Charlie Cheung
University of Calgary
2500 University Dr. NW, Calgary, AB T2N1N4
ccheu@ucalgary.ca

Abstract

Our individualism is strongly correlated with our ways of self-expression, notably in regards to the arts. With the advancement of human-robot interaction, humans are presented with a new challenge of demonstrating uniqueness and intelligence in robots. A common way of researching this is by pairing robots with music for dance. For our term project, we designed an interface for the Sphero that allows a user to interact with two individual Spheros simultaneously. The Spheros attempt to follow a song and move in synchronized movements similar to a dance. The Spheros will also follow the user's movements as they dance to a song. As our project evolved, so did our design and interface. We found motivation from not only previous works in research but through music and the expressiveness of human dancers. This final report will provide a detailed explanation and discussion about our final project and provide an overview of our interface, our motivation for this project, the strengths and weaknesses of our design, and how we plan to improve it in the future.

Keywords

Sphero; robotic intelligence; personality; music; human-robot interaction; dance

1. Introduction

The Sphero 2.0 is an app-enabled robotic ball designed by Orbotix that can be controlled by a smartphone or a tablet via Bluetooth. It is capable of displaying LED lights and moving in any direction as well as on water and other terrain types.

As of current, there are already several applications and games developed for the Sphero. Most of these applications involve controlling the Sphero with a smartphone or tablet, allowing a user to control the movement and colours displayed.

Through experimenting with these applications on our own, we realized how dependent the Sphero is on the skill of the user controlling them. The Spheros in these applications are not autonomous and though they could potentially be choreographed to complete complex movements, there was no expressiveness in their actions, unlike a human dance performance.

As with our project, we hope to synchronize two Spheros to perform a dance. However, we wanted to combat the supposed lack of expression felt through many robotic performances. This required us to find a way of interacting with the Sphero while retaining it as an autonomous entity. The motivation for us to incorporate this idea was central to our project and our design evolved and shaped around it as we reviewed it throughout the weeks.

Furthermore, we discovered that if all robots acted in the same manner, there is no perception of individuality and intelligence. A group of dancers may all be performing the same movements however, even a person not so experienced in the art will eventually be able to tell who in a group is a stronger or a weaker dancer. We decided that this perception needed to be incorporated into our project if we were to design individual and intelligent robots. The importance of this transcends our project, given that one day, humans aim to develop robots intelligent enough to be integrated into society.

From our proposal [3], we thought of questions that we wanted to answer with the design of our interface. How can we design a robot so that it is perceived to be intelligent? Can we show a robot to be distinct from another? Could a robot still be unique when following the instructions of a human? From the implementation of our project we developed more questions we would like to answer. What does it mean for a robot to dance? Can a robot without a voice, face, and limbs be seen as expressive?

Similar questions were asked in another study dealing with how the design of a robot influences its animacy and perceived intelligence [2]. In that study, the robots used were designed resembling an animal or a human. The question regarding dance has also been explored in research. Most studies were done using humanoid robots, like the RoboNova, HUBO, and Nao. All have a face and limbs unlike the Spheros.

Guided by the related works discussed in the following section, we will convey our motivation for completing this project. An overview of our project will be discussed and we will describe how it was designed and how it was built technically. This final report will also review our implementation using the evaluation methods described in class. We will reflect on the strengths of our design as well as its weaknesses. Finally, to conclude this report we will elaborate on future features our design can implement to achieve a better understanding of the questions and concepts we've decided to answer.

2. Related Works

There has been a great deal of research done on robots that can dance, have personality traits, and are intelligent. Since our project is based on these concepts, we reviewed some of the research done in each of these topics and considered how we can use their results to best design our Sphero project. To add to our study, we will review expressiveness and skill in dance involving humans in an effort to apply these ideas and techniques to our project.

2.1 Robots and Dance

Dance can be used as a type of communication so by developing a robot that can dance, entertainment can be provided in various points of view and a new way of communicating can be developed. The use of humanoid robots is often paired with dance in an attempt to instill in viewers the feeling of pleasure, expression, and energy because of their similarities with humans.

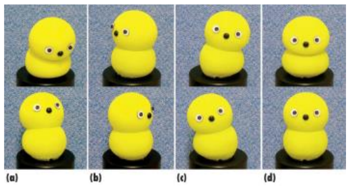

Figure 1: The Keepon and its degrees of movement.

Figure 2: The Keepon dancing with a child. The soft paddle includes an accelerometer that transmits rhythmic-movement information to the robot to enable synchronized dancing.

One of the important issues in a dancing robot is whether it can dance in accordance with a rhythm. Another is whether or not the robot's motions reaches a level that can be called a dance [6].

For our Sphero project we decided to focus on the fluidity of the robots and the speed in which their actions would take place. Rhythm is highly valued in dance, therefore we turned our attention to studying a robot that moved rhythmically without the use of arms and legs.

With regards to motion, we reviewed the design of the Keepon robot because like the Sphero, it lacks human arms and legs yet it can be described as a dancing robot [1]. Though it lacks a range of motion, the Keepon is perceived as rhythmic by nodding its head, rocking its body side to side, and by compressing and extending itself. The Keepon is able to move in a compelling manner through its quickness and random combinations of movements that can be attributed to different dance styles. The Keepon was so successful, children would join it in dancing. We reflected on this and decided that for the Spheros to be able to conjure the same reaction, they must move rhythmically, in quick succession, and express a joyfulness when it is dancing.

Through the Keepon, we noted that it is possible to have a robot dance without arms and legs. Next, to gather an understanding of skills in dancing, we took to studying human dancers and the traits that determine a skilled dancer and an unskilled dancer. We wanted to see if we could incorporate those traits into our Spheros to better define them as robots that dance instead of robots that move.

2.2 Human Dancing

When studying human dancers, certain techniques and points of interest determine a good dancer. Since most of these techniques involve actions capable by a human but not of the Sphero, we focused only on musicality and difference in style.

Musicality describes a dancer's ability to understand the complexity of the music they are dancing to. Music has many different layers to itself and a dancer needs to be able to hit the movements like they are imitating the sound. For example, a hard snare sound should be hit with a stiff movement and a sudden stop. A heavy bass sound should make a slower and bigger movement that travels through the beat.

In reference to musicality, a dancer should be able to understand the difference in styles of music. A good dancer knows when to smooth out their dancing to a song or when they should be heavy and hard hitting. Movements need to be done with confidence and demonstrate a variety of movements using a dancer's full range of motion.

Taking this knowledge into consideration, another feature we designed into our Sphero Dance! project was the perception of musicality. Could we program the Spheros to show that they understand the music and could the choreography demonstrate they understood what movement was needed to fit the music? When discussing how we would incorporate this into our design, we had the idea to show a skilled dancing robot and an unskilled dancing robot. From there, we decided to show how a robot could be perceived as intelligent

Figure 3: Simple colour and emotion theory chart [4] Angry is red. Afraid is orange. Surprised is yellow. Green is happy. Blue is sad. Purple is disgusted.

and whether we could design robots with personality convincingly.

2.3 Personality and Intelligence in Robots

Our research on the topic of personality and intelligence in robots have been researched extensively in human-robot interaction. As we had studied the connection between human dancers and robots dancing, we were inclined to find any links between human and robot personality traits.

The personality of robots is important for spontaneous, intimate, and effective interaction between humans and robots [5]. A personality is also necessary for an emotional relationship between a human and a robot. Among the various methods to express personality, the appearance, attitude, behaviours, gestures, speeches, and the tasks of a robot can be considered when designing a robot. Since the Sphero is limited to movement and colours in expressing its personality our task requires us to show uniqueness limited to these qualities only. As we considered the idea of adding a personality to the Spheros, we thought a skilled dancer and an unskilled dancer should be distinctly recognizable. Their movements and colours should reflect their understanding of the music. A good dancer should be able to adapt to the music if the style were to change suddenly while a bad dancer should not. When dealing with personality, emotional intelligence is also a factor. For example, a good dancer should be able to correct their movements if a mistake is made and a bad dancer should not while also reacting negatively. For the Spheros, we must be able to show these traits, actions, and reactions through only movement and colours. We plan to show these emotions by changing the Sphero's colours and blink rates in accordance to the chart in Figure 3.

After thorough research into these topics we were motivated to continue our project with these concepts in mind.

3. Motivation

The motivation for our final project comes from wanting to create expressive robots. Our goal was to design an interface where the Spheros could seem intelligent and unique and challenge our perception of how these traits can be shown. Our second goal was creating an environment where the Sphero and user can interact without the user directly controlling the Spheros. For this goal, we were motivated by the idea of an autonomous robot and the concept of a human and robot working together in a creative environment as a unit.

4. Overview

4.1 Design Evolution

The first iteration of our design began with a simple 'Simon Says' game between the user and the Spheros. The user would input a set of dance movements in a sequence and the Spheros would attempt to follow the instructions. We quickly realized how underwhelming this design was but we still liked the idea of having the robots follow the user in a dance.

Before we came up with our current design, we also ran into the problem of having the Spheros be completely dependent on the human. We revised our idea to create an interface where the Spheros would follow the user but also act autonomously.

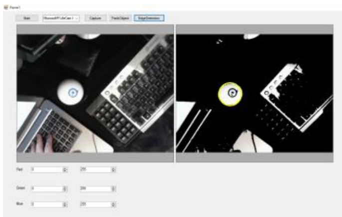

Figure 4: Our Sphero tracking screen done using video capture. A yellow ring around the Sphero on the right image indicates the Sphero is being tracked.

Figure 5: General interface set up for Sphero Dance!

4.2 Current Design

Our project became one of creating a dance sequence with a group of Spheros. For the human-robot interaction part of the project, we wanted the robots to dance with the user. Our idea began with implementing a smartphone application where the Spheros would use Bluetooth to find the user and follow them.

We were introduced to the concept of tracking and our project removed the smartphone and replaced it with a webcam where the Spheros' and the user's location could be tracked simultaneously.

The motive for the dance sequence was to imply that the robots were intelligent enough to follow the music. For our design, we choreographed the Spheros to dance in accordance to a song. After both demonstrate being able to do so, the Spheros will begin to differ in their movements in an effort to indicate individuality and personality. One Sphero will continue dancing skillfully while the other will dance off beat. The skilled dancing Sphero will continue to match the mood of the music through motions and colours. The less skilled Sphero will exhibit awkward movements and change colours to show an emotional reaction. For example, the less skilled Sphero will shake and blink red to show frustration and anger at not being able to dance well.

The Spheros will reset once the user appears on the stage. Both Spheros will follow the user's movements and blink in time with the music. Due to technical issues we will discuss in the Technical Aspects section of this paper, this will be done using the Wizard of Oz approach. Eventually, the less skilled Sphero will start falling behind again and become frustrated with their abilities. When the performance ends, it should be clear which Sphero was the better dancer to viewers.

5. Technical Aspects

5.1 Spheros

For our project we were planning on using three Spheros, but one of them did not work so we ended up implementing our project using two. We will be using the two Spheros to represent a group of synchronized dancing robots.

5.2 Java and C#

For our project implementation, we are using both Java and C# as the programing languages. We are primarily using Java to handle the Spheros movements and C# to handle all the motion tracking of the Sphero. We are using two programming languages is because of the problems that we ran into when connecting a Sphero to a Windows machine. We could not get Sphero working on our own windows machine so we had to implement an Android app using Java to control the movement of the Sphero. Our initial goal was to have everything run on a Windows machine, and due to time constraint we decided to just implement the Sphero movement controls using an Android application instead. The tracking is done using a simple C# program and using the C# AForge Framework. The C# app will get the position of the Spheros and send the coordinates to the Sphero via Wi-Fi.

5.3 AForge and Logitech Webcam

As mention above, we are using the C# Framework AForge to handle the tracking of our Spheros. We are using AForge shape detection, colour filtering, and motion detection to track the Spheros. We are also using a Logitech Webcam as a video capture device to capture the Spheros motion and processing the video using the AForge libraries.

6. Design Review

In this section, we will go through a detailed review of our design following the taxonomy of human-robot interaction and review the strengths and weaknesses of our design based on the evaluation methods presented and discussed in class including Norman's Design of Everyday Things and Nielsen's 10 Usability Heuristics for User Interface Design.

6.1 Design Taxonomy

Following the HRI Taxonomy, the Spheros are specifically designed to dance which puts their critical task evaluation at a low. The robots are functional because they bear no resemblance to humans or animals. Our project was designed with a 1/2 human-robot ratio and since Spheros are the only robots in our design, the robot team composition is homogeneous. In the design, the two robots are not aware of each other but both interact with the user. With respect to the Time/Space CSCW Matrix, our design is synchronous and co-located. When the user is on the stage, the user is controlling the robot through their movements. The humans can be considered a supervisor when the Spheros are dancing on their own. Once a user appears on the stage, that user becomes a teammate to the Spheros in the dance. Since we are experimenting with the Wizard of Oz approach, we will also be controlling the Spheros as an operator. The operator will be provided the location of the Spheros through tracking. When the Spheros are dancing their choreographed sequence they are 100% autonomous. When the operator is controlling the Sphero to follow the user, intervention is at 100%.

6.2 Strengths

Our design is very intuitive and provides instant feedback. The Spheros will track the user as soon as they appear on stage. Based on the movement and the music in the background, we expect the user to know to start moving to interact with the robot. By doing all of the tracking with the webcam, the user does not need to learn how to use an application to interact with the Spheros. The design is also minimalistic and can be implemented in any room and in the dark.

Since the Spheros will be performing a choreographed sequence, they will always be aware of their status in the near future. Once the user appears on stage, the control of the Spheros will turn to the operators.

We will be using motion tracking for the Spheros and the user. The screen will always show the Spheros and the user so all of the critical information will always be visible. Our design is efficient because we will show the Spheros in one window. The environment is set up like a stage, similar to a real world experience. We are also able to deal with possible random movements of the Spheros as any imperfection in their movement could strengthen the concept of individuality.

Our design incorporates many of the ideas that could advance human-robot interaction. Learning about how humans interpret robot movement and how personality and intelligence is judged could prove advantageous in other areas of research in human-robot interaction. This is extremely beneficial when considering how we want robots to be socially functional in daily life. Our design is also flexible and gives the user a lot of freedom when they are interacting with the Spheros.

6.3 Weaknesses

Based on the Design of Everyday Things presented by Norman, our design does not show the constraints of our system. When the user is on the stage, other than the physical restrictions of the room, there is no indication of how far they can travel and still have the Spheros following them. The user may also be tempted to move their arms when dancing but the Sphero will be unable to follow those movements. The user also has no control of the Spheros colours when interacting with them. Our design does not have any help documentation but because we are using Wizard of Oz in our experiment, we will be able to provide help should the user need it.

Though we are tracking the Spheros with a webcam, we will not be providing information on the past locations of the Sphero. Therefore, the Spheros lack some degree of situational awareness because they will not be following the user on their own. We hope to improve this in a future implementation of the project.

7. Future Works

7.1 Music Processing

Our current implementation is using more of a 'Wizard of Oz' approach when it comes to making the Spheros Dance. For the current implementation we are using a set song then mapping a set of Macro movements of the Spheros to match the beat of the song. In the future, we would like to add in a feature that allows the user to upload a song and the Sphero application would process the song, analyze its frequency, and map the appropriate Sphero movement depending on the song frequency.

7.2 Multiple Dancer Support

As of right now we can only detect one dancer at a time. In the future we would like to add a feature that supports multiple dancers.

7.3 One Device Support

Our current implementation requires both a computer and a mobile device running Android. We would like to run everything on an Android tablet in a future implementation of this project. This would be accomplished by using the built in camera of the Android tablet and track the Spheros using OpenCV.

7.4 Sphero Interaction

The Spheros are interacting with the user in the current implementation. For a future feature, we would like to increase the number of Spheros that we are able to track and have them become aware of one another. By doing so, we hope to implement more advanced dance movements for the Spheros where they must interact and coordinate with each other.

8. Conclusion

In this report, we described our Sphero Dance! project where two Spheros will move in a choreographed sequence of movements to a piece of music. A user will show up on the stage and the Spheros will follow the user as they move. One of the Spheros will imitate a good dancer, following the rhythm of the music. The other Sphero will imitate a poor dancer and perform the dance with mistimed movements. Through this performance, the Spheros can demonstrate their intelligence and personality by how well they follow the music or the user.

Our project hopes to prove that a robot can still be expressive without facial features, limbs, and a voice. While limited to only movement and colours, a robot can seem not only expressive but able to dance in time with music in a way that seems natural to viewers. We could make a robot seem intelligent, unique, and working as an equal with a human on a stage so that it would exceed the current expectations of robots.

By making these traits the focus of our project, we hope to benefit future research in this area by expanding on the capability of the Spheros and providing an example of not relying on humanoid robots to be considered for dancing. Our design is simple and intuitive. Given the time we had for this project we have many ideas for features that could be added into our project. Since the idea of robots interacting with humans will only continue to grow as technology develops, a robot that could perform with a human could lead to various forms of entertainment and be a step forward in having robots and humans form stronger and more meaningful relationships.

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