Rope Revolution: Tangible and Gestural Rope Interface for Collaborative Play

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ABSTRACT

In this paper we describe Rope Revolution, a rope-based gaming system for collaborative play. After identifying popular rope games and activities around the world, we developed a generalized tangible rope interface that includes a compact motion-sensing and force-feedback module that can be used for a variety of rope-based games. Rope Revolution is designed to foster both co-located and remote collaborative experiences by using actual rope to connect players in physical activities across virtual spaces. Results from this study suggest that a tangible user interface with rich metaphors and physical feedback help enhance the gaming experience in addition to helping remote players feel connected across distances. We use this design as an example to motivate discussion on how to take advantage of the various physical affordances of common objects to build a generalized tangible interface for remote play.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces–Input devices and strategies, Interaction styles, Prototyping.

General Terms

Human Factors

Keywords

Tangible Interface, social game, remote playing, enhanced reality, sports, computer supported cooperative play.

1. INTRODUCTION

The use of rope dates back to prehistoric times as an essential tool for activities and tasks such as hunting, climbing, and transporting heavy objects. Not only has rope has become a ubiquitous necessity in modern times, but rope-based games such as jump rope, tug-of-war, and kite-flying have also been enjoyed worldwide regardless of background and age. Ropes can serve many functions through a person's simple actions, such as releasing, rotating, pulling, intertwining, skipping over, folding, and translating; a rope is an example of an object with rich physical affordances [6]. In our system, we utilized common affordances of ropes to develop a novel gaming interface for people to play multiple rope-based games using different gestures and body movements.

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Figure 1. A group of children is introduced to and playing the kite-flying game.

In addition, researchers have begun to explore how to bring together geographically distant participants together through gaming rather than traditional audio or video sharing [11]. Similarly, we are interested in understanding how people would respond to playing rope games remotely, and how this tangible gaming system can enhance remote, social gaming. Both the tangibility interactions and the social aspects were evaluated through user studies and discussed in this paper.

In short, we describe a study of a social gaming system we designed called "Rope Revolution", which allows players to use a generalized tangible rope interface to remotely play multiple rope related games. We present an initial analysis of user data that provides an understanding of how such rope games can be played remotely. Our conclusions describe implications for the design of future games in the field of utilizing tangible objects with real-world metaphors to create a shared gaming and social experience for geographically distant players.

2. DESIGN PROCESS

2.1 Previous Work

In our previous work, we explored the use of rope–which has many physical affordances–as a tangible interface for rope-based video games [17][18]. We developed both a jump-rope and kite-flying game to investigate how using rope as a generic and intuitive interface benefits multi-player games (both remote and co-located) [figure 2]. Each game set-up had its own sensing hardware: the jump-rope game had an accelerometer embedded in the rope handle for the rope twirler (in addition to a pressure sensor pad for the rope-jumper to jump on), and the kite-flying

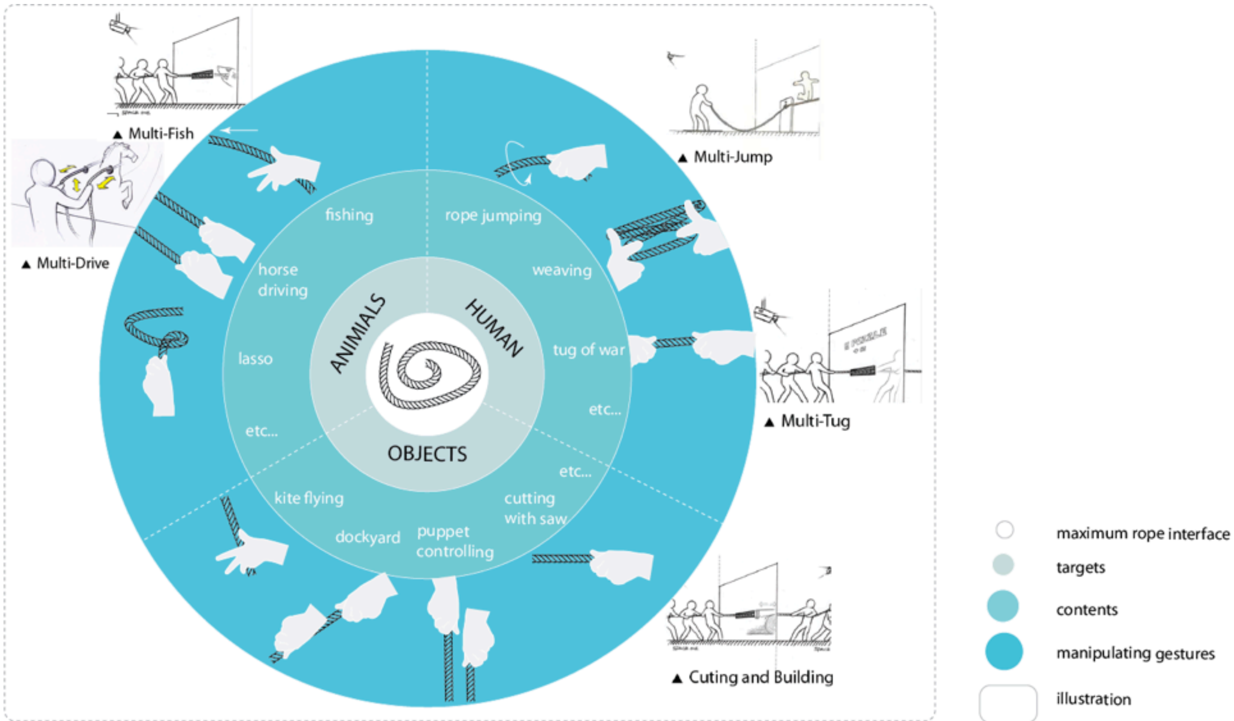

Figure 2. Design space of the tangible rope interface.

game included a constant force spring and a rotary potentiometer attached to the end of the rope mounted on the wall. One of our goals is to have games such as these as part of a broader rope-based gaming system in which a single rope and compact sensing system can be used in multiple games.

Preliminary studies were conducted to gain user feedback for both the jump-rope and kite-flying games. We have conducted some preliminary studies with adults and school-age children and the overall feedback has been positive. People have especially enjoyed how the games are physically engaging. In addition to helping us identify aspects of the games that can be improved, test subjects also indicated ways to expand our rope-based gaming system as a whole. For example, some participants mentioned that the rope interface reminded them other rope-related activities, such as lassoing, fishing, and horse-driving; users noted that they would want to see games such as these integrated into our system. Through these preliminary tests, we also noticed how participants would intuitively control the rope in ways other than those specified (this was especially true for the kite-flying game). One possibility for future implementations is to allow users to teach the system their own control gestures to make the rope interface and virtual game more seamless for individuals.

In this paper, we focus on the development of a multi-functional rope interface, in which various rope-based games can be played with a single system. As with the jump-roping and kite-flying games, control gestures should be intuitive so that the virtual projection of a game would provide adequate context for a user to intuitively control the rope, allowing for a seamless transition between different games. The following research contributes to an understanding of how the experience of using a generalized tangible interface differs from a single-function, pre-defined tangible interface.

2.2 Motivating Investigation

One important goal of this work is to build a vocabulary for discussing rope interfaces used in collaborative play experience. To explore the scope of rope's physical affordances based on people's real world experiences, we conducted two small-scale user studies with school-age children and college students. In the first study, we showed people ropes and strings in various lengths and thicknesses, and asked them to list all the rope-related games and activities they could think of. We also asked them to talk about any experiences they might have had with rope-based games and activities. In the second test, subjects played with an early version of our system. Users were led through a series of simple rope game tasks. For example, they were told to make a virtual horse on screen move forward, stop and jump, or make a virtual kite move in different directions. The purpose of this latter test was to get an understanding of people's intuitive gestures and body movements when interacting with various game content.

From these tests, several important design considerations emerged. People have different experiences with using ropes, and people had very specific reasons for favoring different games: "Today's a sunny day, I really want to fly a kite", "I remember I went crazy when I rode a horse with my sister, it is so much fun." We observed that, in order to design an intuitive yet engaging game system, the rope interface should embody various physical metaphors. Based on the investigation, we explored ways of interaction with ropes and build up a tangible interaction library around ropes, which we could take advantage of in designing the game and system.

We also found that, for a given game (e.g., kite-flying), people have different intuitive interactions with the rope. In addition, it was interesting to see how some people used minimal and mostly arm movements to control the rope while others tended to use more full-body movements. We need to design our system in such a way so that it can be flexible and easy to use for all players.

2.3 Design Space

Figure 2 shows the design space for the rope interface as well as the design process we used. We have separated the design space into five main layers: targets, scenarios, interactions, interfaces and add-ons.

Targets. People interact with virtual targets by controlling a rope. Targets can be divided into three categories: people, animals and inanimate objects. For example, people can play rope-based games by themselves or interact with other players using ropes (e.g., jump rope). People can also play with or control animals and manipulate objects using ropes.

Scenarios. For each target, we present various game contents, or specific game scenarios. Under the "people" category, tug-of-war and jump-rope are examples in which players interact with other people, while weaving and cat's cradle are activities for individuals. For the "animals" category, games such as fishing, horse-driving and lassoing are listed as examples. Finally, the "objects" category includes activities such as kite-flying, puppet-teering and wood-sawing.

Interaction Library. Here we illustrate various gestures that players can use to control the rope for different game scenarios. Ongoing research is being conducted to identify the most appropriate gestures for each game; from our preliminary user studies, we have found that people have a vast gestural library for rope interaction.

Interface Design. We designed a generalized tangible rope interface that can be used for the various game scenarios and gestures that we've presented. During gameplay, the rope becomes an extension of the user's arm to create a seamless continuation of the user's body into a physical and digital combined experience. Each game requires a unique sensing algorithm along with unique force feedback, if appropriate.

Add-ons. While rope serves as the game controller and the primary interface and source of feedback (both physical and visual), some games can be further enhanced with additional stimulation or feedback. For example, a kite-flying and sailing game experience can be significantly enhanced by adding "wind" stimulation by simply adding several fans as part of the game system.

Four games were selected from the design space to be implemented based on the popularity, feasibility and diversity: these games are kite-flying, jump-rope, horse-driving and wood-sawing.

3. RELATED WORK

3.1 Augmented Physical Objects

Augmenting familiar everyday objects is one of the most important concepts in tangible interface design [9]. A series of tangible "tools to think with" were invented at the MIT Media Lab. The goal is to take advantage of the richness of human intuition and skills developed throughout a lifetime of interaction with physical objects, and to utilize real-world metaphors to design tangible interfaces. Former work includes musicBottles [10], I/O Brush [15], HandScape[14], and LumiTouch [9], which explored the affordance of bottles, paint brushes, tape measures and picture frames, respectively. In examples such as these, both the functionality of and people's interaction with these physical objects is considered. For example, in musicBottle, the affordance of a bottle is its ability to store contents, while the way to access its contents is by removing a cork. In the same way, music can be "stored" in the bottle and be released or played by removing the cork to open the bottle.

Many exertion games are also based on augmenting traditional physical interfaces. Tug-of-war with the use of rope has been previously attempted [23]. MouseGrip [7] exploits the way people interact with the traditional handgrip to play computer games. PingPongPlus [11] uses tangible Ping Pong paddles and full-body motions to interact with digital content on the Ping Pong table.

Along this track, our work aims to go a step beyond by considering people's broader experiences with rope to enable people to easily transition between recognizing various physical affordances to play different rope-based games in a single gaming system.

3.2 Extending Device Capabilities through Implicit Input Gestures

Researchers have attempted to design various interfaces to understand a user's intentions by capturing implicit input gestures [12] [4] [16][5]. For example, MTPen [16] demonstrated how the user could indicate different "modes" of a digital pen by detecting different finger gestures and grips on a tangible pen that served as the "controller." Graspables [4] demonstrated how different grips can affect the form-factors, and influence the function and input of a device. Projects such as these demonstrated how gesture-based device manipulation can provide users with greater flexibility and convenience.

These types of projects require researchers and designers to study and identify typical user habits and how they can be best used in their new interaction techniques. For example, researchers conducted an initial study before designing the MTPen [14] to identify different grips that experts usually use when working with digital pens. We use a similar approach in our work to design an optimal rope interface, in which required input gestures are designed to best suit players and their intuitive interaction with rope.

3.3 Remote Collaborative Play with Force Feedback Mechanism

Our work is also related to an area of research that focuses on understanding how people in geographically distant locations can interact with and collaborate with each other effectively by "feeling" each other's presence through a certain kind of force feedback.

Back in 1986, there was a networked project called Telephonic Arm Wrestling [21]. Two players could play arm-wrestling games remotely through a mechanical device that can measure and apply force across a telephone line. In another example, InTouch[20] utilized synchronized rotating motions to add touch and physicality to remote communication to create the illusion of shared physical object for remote users. In the SPIDAR system [13], string was used to provide users with feedback about the position and orientation of the force applied by a remote counterpart. Using ropes, Harfield, et al [1], introduced the concept of "distributed tangible technology" by developing a remote tug-of-war system. The system was played between groups in Finland and South Africa. Based upon previous work, we explored various playful activities around ropes systematically. In our system, the force feedback is varied within the same hardware system based on different rope games and corresponding metaphors.

4. ROPE REVOLUTION SYSTEM

We chose rope games as a target theme and designed a remote gaming system, through which multiple rope-related games can be played collaboratively over distance. The tangible rope module we built has the capability of sensing different motion patterns when players interact with rope. Physical feedback was also taken into consideration in the tangible rope interface.

4.1 System Setup

The basic components of our system include a rope module with a motion-sensing handle at the free end (i.e., that the user holds and interacts with) and a force feedback mechanism that the fixed end is mounted to. Players also use a wall on which the digital interface is projected. The system is designed in such a way that mounting the fixed end of the rope along the bottom of the digital projection creates the illusion that the real rope and the virtual rope are one. Each single system reaches out and connects with others via Internet. Figure 3 shows the system setup.

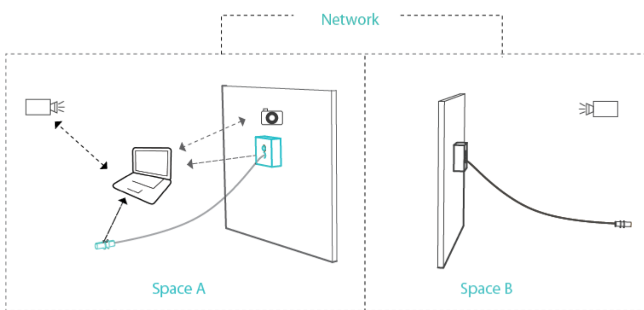

Figure 3. System Setup

4.2 Hardware

The core hardware is the rope module, which includes a force feedback and potentiometer-based motion sensing mechanisms on the mounted end, and an accelerometer-based motion sensing mechanism at the user's end [Figure 4 Left].

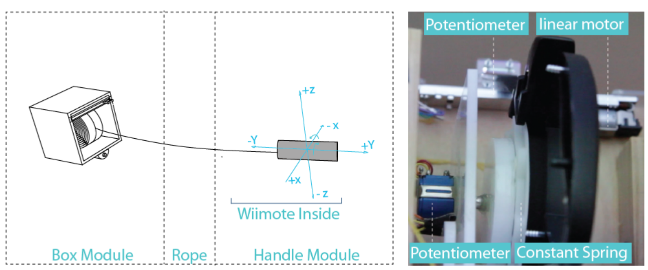

Figure 4. (Left) The core hardware; (Right) The Box Module

Force Feedback and Motion Sensing Box. The force feedback box that is fixed to the wall houses a constant-force spring that controls the rope's direction into and out of the wall and a linear actuator that controls the rope's direction along the width of the wall [Figure 4 Right]. In this way the rope module gives force feedback for both +/- y and +/- x direction. The mounted end of the rope is fixed to the spring and is fed through a sliding bar that is controlled by the linear actuator, which is fixed to the box. The spring provides players with quick, passive force feedback for games such as kite-flying, in which players can feel like the kite is tugging at them. Similarly, the sliding bar can simulate the kite's direction as going to the right or left of the player. The active feedback of the linear actuator can be synchronized with changes in the virtual environment, such simulating the direction that wind is blowing the kite in.

In addition to the physical feedback mechanisms, a webcam is also mounted in the box to enable real-time communication between players.

Gesture Recognizing and Motion Sensing Handle. The handle at the user's end of the rope has two main functions: gestural recognition and motion sensing. Both of the functions rely on a 3-axis accelerometer, which communicates with a computer via Bluetooth. Gesture recognition can be used at the starting game menu, at which players can use gestures to select which game to play. Motion sensing is required during game play to enable interaction between multiple players and/or players with a virtual environment. For the current implementation, we chose to embed a Wiimote[18] as the primary sensing unit inside the rope handle.

4.3 Software

The whole software was built in Java. We developed several gestural patterns built into our rope gesture library. Later on, if players play a certain gesture related pattern, their motion can also be sensed using a corresponding algorithm. With the Wiimote as our sensing mechanism, Wiigee library [22] was used as a basis to perform gesture recognition and motion sensing.

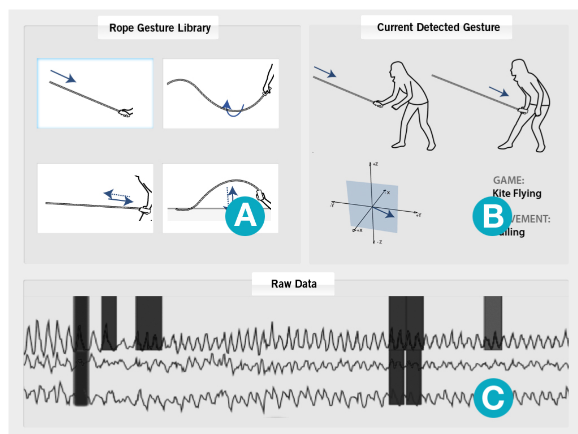

Figure 5. A rope gesture library was built based on open source Wiigee Library. A) Pre-added rope gesture library; B) Current Detected Gesture; C) Raw data from the accelerometer in a Wiimote.

An initial study was conducted to determine common gestural patterns for the four games to be implemented. These gestures are recognized through Wiigee Library. While our current implementation relies on pre-defined gestures, we would like to allow users to define their own gestures in future versions of our system [Figure 5].

Motion sensing during the game play was achieved by a combination of the data analysis from both the 2-axis potentiometer inside the box module (for games such as kite-flying, in which the rope needs to be reeled in and released) and the 3-axis accelerometers from the handle module. The data can be sent to a computer via Bluetooth. For remote players, computers from different locations can communicate over the Internet.

5. GAME PLAY

For the current implementation, we developed two main parts of game process: the game selection interface, in which players use game-specific gestures to select games to play, and individual games (kite-flying, jump-rope, horse-driving, and wood-sawing).

5.1 Gestural Menu Selection

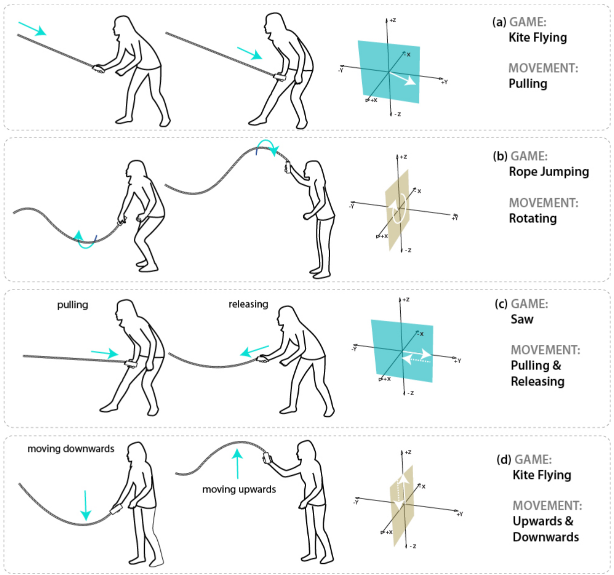

Figure 6. Gestural Menu Selection

When players start Rope Revolution, they are brought to the main menu, or game selection interface. Here, users can select which game to play by performing gestures related to the desired game [Figure 6]. The concept of using activity-specific gestures at this stage of a gaming process differs from traditional systems and even newer systems like Wii, in which buttons or simple directional movements are used for menu selection. Our goal is to take advantage of the rope interface at all levels during the game.

5.2 Game Modes

We have implemented four game modes into the current tangible rope game system. Each game requires unique gestural patterns. Figure 8 shows the different gestures that are designed for each of the games. Depending on different game modes, players could play either collaboratively or competitively.

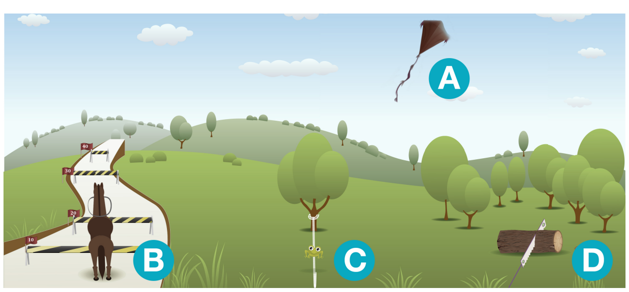

Figure 7. A scene where the four rope games happen. A: Sky for kite flying game; B: Road for horse driving game; C: Rope for rope jumping game; D: Stumps for wood sawing game.

At this stage of implementation, all the games take place in a single nature scene in the virtual world [Figure 7]. Each game is "set up" in a designated portion of the larger scene; as players participate in different games, they move to different parts of larger space, and the focus as seen on the digital display updates accordingly. The scene is designed with various environmental components, such as sky, lawn, road, forest, etc. For example, wood-sawing typically takes place in the forest in real life, and therefore wood-sawing also occurs in a forest in the virtual world.

Score-keeping is cumulative across different games. Players' task is to control the character that they interact with and try to hit the points, which locate in various places inside the game scene. People can also be connected through the virtual space even if players are in the different geographical locations. They can communicate with each other via webcams and be updated on each other's progress, as if they were both located in different parts of a larger space.

Figure 8. Two people are playing in kite flying mode.

Kite Flying. At the game-selection stage, players utilize a pull/release motion along the direction of the rope to select the kite-flying game [Figure 8]. The virtual scene moves to the sky portion for this game mode. A virtual kite shows up on the screen, serving as an extension of the real rope controlled by the player. The player pull the rope to allow the kite to be lifted higher; the kite remains in the same location if the player does not interact with the rope; and it falls downward if the rope is released.

The kite flying game supports both co-located and remote collaborative play. Players share the same goal, which is hitting the cloud and getting the point. They collaborate to achieve a certain point and win the game.

To enhance the kite-flying gaming experience, we implemented an augmented wind environment with fan-towers on each side of the player. Wind in the virtual scene is randomly generated and is synchronized with fans turning on in the real space. In addition, the linear actuator can pull the rope from side to side to further simulate the wind pulling on the kite.

Rope Jumping. At the game-selection stage, players can select the jump-rope game by twirling the rope with large motions, after which the game scene would transition to a lawn. During the game, the system detects when the rope descends to determine the twirling motion and timing.

The jump-rope game can be played either by a singer player or by two players remotely. In the single-player mode, the player acts as the rope-twirler to control the rope in the virtual space. A virtual character, such as a bouncing rabbit, can be the rope-jumper in the virtual space. Players gain points when the two participants are synchronized. In the remote multi-player mode, one person acts as the rope-twirler while another person is the rope-jumper. The jumper's space can have a pressure sensor pad to detect the player's jumping.

Horse Driving. A player can select the horse-driving game at the game-selection stage by whipping the rope up and down for several seconds [Figure 9]. For this game, the scene transitions to a long, curved rode. The game's objective is for the player to keep the horse on the road while traveling. Markers along the path, such as flag posts, can indicate locations that the player needs to reach successfully to gain points. Players can drive the horse by holding the rope handle sideways with two hands and whipping the handle up and down. Similarly, the horse can be steered by controlling the yaw position of the handle. The horse driving game can be played by multiple players, when each one drives a single horse in a competitive mode.

Figure 9. A player is playing in horse driving mode.

Wood Sawing. A player can select the wood-sawing game at the game-selection stage by pulling and releasing the handle, with short quick motions, along the length of the rope several times, after which the game scene transitions to a forest. During the game, trees can be sawed by pulling and releasing the rope. The score in this game depends on how quickly players can saw and successfully cut a tree down.

6. USER EVALUATION

We designed an informal study to gain a better understanding of how people might experience Rope Revolution. We were interested in answering the following research questions:

- First, we consider people's personal interactions with the rope interface. How do the physical and metaphorical aspects of the rope interface affect the playing experience? What does this teach us about the power of tangible interfaces for remote play?
- Second, we focus on the remote collaboration aspect to understand how a tangible interface affects people's interactions with each other. What factors influence remote playing experience?

6.1 Method

To answer these questions, we recruited six pairs of participants, with a total of 4 men and 8 women, aged 20-29. Two pairings consisted of friends, while the other four were pairings of strangers. Even though we designed the system primarily for young adults, we were also interested in seeing how children would respond to the system, so we observed two school-age participants as well. The findings below come primarily from analyzing the young adults' interactions. However, we identified some interesting comparisons between the behaviors of adults versus that of children. For example, while most adults tended to control the rope using more complex gestures, children were more likely to use simple gestures. A woman who described herself as "having no patience at all" also tended to use more simple gestures and movements to control the rope.

To address our first research question in understanding people's individual experience with the rope interface, players each chose two of our existing games to play. We also asked to include their reasons for their selections. Test subjects played each of the games twice: once with a Wiimote without the rope module and once with the rope module. The order of playing with or without the rope was random to avoid any conditioning bias.

Before receiving any instructions for how to play and control the games, subjects were asked to play the games based on whatever control movements came to mind. The purpose of this was for us to compare our implemented motion recognition patterns with people's intuitive control gestures. If players attempted to play a game for a while and still had difficulty controlling the game, we would give them instructions based on our implemented motion patterns. After becoming familiar with each game, players were first asked to focus on controlling the interface efficiently and reach a certain score. Afterwards, they were asked to play the game however they wanted to. At the end of each game, we asked subjects things such as how comfortable they were with using the specific controller, and what aspects of the games they liked or disliked. We also asked participants which controller they preferred (with or without the rope) as well as they thought of each controller.

To address our second research question, after playing as individuals and becoming familiar with the games, pairs of players were asked to play both the kite-flying and jump-rope games together in a remote collaboration setup using the rope interface. At the end of this phase, we asked subjects for their thoughts on each game in the collaborative mode, as well as for their preference in whether they preferred playing the games individually or with others.

During these trials, we also conducted a video analysis that focused on aspects of body expression and control movements, such as the variety of gestures people used in each game, and the different levels of engagement between individual and collaborative playing modes.

6.2 Findings

As previously discussed, the main concepts we are exploring in this paper are the overall tangible rope gaming experience and remote socializing via our system. The themes below are used to help evaluate these concepts based on our user studies.

6.2.1 Engagement and Tangibility

We first considered how the rope interface influenced people's interactions with the gaming system. All of the test subjects except for one preferred playing the games with the rope interface rather than without it (i.e., with just the Wiimote). Players' experience with the rope interface can be analyzed using the following categories:

Acting through the rope. Past research has investigated the relationship between initial conditions and sequential experience while people interact with physical objects; there typically exists a transition of behavior from acting on an object to acting through an object [2]. We observed the similar transition with people using our system. As subjects became more familiar with the rope interface, they showed increasing enjoyment. Compared to the Wii remote as the sole controller (without the rope), the rope interface made people "feel like the body was extended into the screen." Subjects noted how they increasingly saw the rope not merely as a controller, but more as an inspiration and medium for their body expression.

Physical feedbacks. In most of the games we implemented, the inertia of the rope provides adequate physical feedback to make the game more realistic and engaging. Games such as kite-flying have additional feedback mechanisms, such as a spring that passively applies a pulling force on the rope. Several users indicated that they felt they were "directly controlling the kite" when they are using the rope interface as opposed to just controlling a distance, virtual object when using the Wii remote. Other interesting user feedback for various games include: “In the horse game, it’s definitely more interesting to see the rope following my swing”, “I can get a better rhythm when I am rotation the rope [for the jump-rope game]”, and “I can feel the wind when I am pulling [in the kite-flying game].”

Some users also pointed out that the rope interface provided visual feedback in addition to physical feedback. For example, in the jump-rope game, a user mentioned that the rope’s movement helped him or her visualize the progress and effect of his motion, and thus made him more confident about his movement. Clearly, using a passive tangible interface as simple as a rope can significantly enhance the gaming experience.

Metaphors and flexibility. Another consideration of the design is the variety of physical affordances that our rope interface can embody. We found that in order to design a universal and popular gaming experience, multiple game modes and motion sensing affordances help. Different users had different preferences for which games to play. For example, some users chose games because they wanted to be challenged in an unfamiliar activity while others chose games based on activities they were already familiar with. Our system should be flexible in accommodating a large range of preferences and experiences.

6.2.2 Collaborating and Socializing

All the users except for one preferred the collaboration to single-player mode; the outlier indicated that he or she did not feel a difference between the two. Several new behaviors were observed in collaboration mode compared to the single-player mode:

Figure 10. Users enjoying a collaborative game.

Communication media. We aimed to design a system that enables fun and enjoyable experiences through remote communication. Salen and Zimmerman explain that in the social play, participants communicate via game play, “in which a game becomes a context for stylized communication, mediated through social interaction” [19]. We observed behaviors that somewhat support but also slightly deviates from this observation. In multi-player mode, people initially tended to be more competitive in achieving higher scores than they did in single-player mode. As games progressed, however, people began to treat them as platforms for communicating and interacting with each other rather than simply competing with each other [Figure 10]. Because our system allows for direct communication (either in person or via a webcam), participants tended to vocally share their enthusiasm with each other, thus providing them with more enjoyment and social activity during the game.

Observing, comparing and coordinating. Participants tended to be much more excited and enthused during multi-player mode than single-player mode; for the former, we observed more displays of emotion such as laughter. In single-player mode, participants were more focused on achieving a personal best using the scoring system. In collaborative mode, however, people seemed to be more interested in observing, comparing themselves to, and coordinating with the other player’s gaming behavior. Notable comments from the studies include: “It’s so fun to share the playful experience with the others”, and “Wow, that will be exciting if I can jump-rope with my sister in Miami.” Participants also indicated that being able to watch their counterpart during gameplay made the game more enjoyable than playing alone. In collaborative games such as jump-rope, people especially enjoyed achieving a goal with someone else [Figure 11].

Figure 11. Participants playing jump-rope took turns being the rope-twirler and the jumper. Each player could see his or her counterpart digitally projected in front of him or her.

Shared physical objects. In remote Rope Revolution, the rope interface serves not only as a local controller, but also as a medium that helps people feel connected in a shared physical experience even if they are in separate locations. We observed that the rope helps to create the feeling of the other player’s presence for both sides. In the jump-rope game, for example, participants who acted as the rope twirler tended to make larger swinging motions with their body to accommodate the other player compared to when they played as a single player with the virtual jumping frog. One player said: “I feel like my rope flies out to my friend!” Similarly, participants who acted as the jumper usually jumped as if an actual rope was present.

Video stream helps. We observed that participants viewed the video stream for remote playing not only as a communication tool, but also as a medium for physically bringing one player and his or her rope into the other player’s space. Especially for the jump-rope game, in which the majority of the graphical display is the video feed to simulate two players standing right in front of each other, participants noted that they felt like they shared a physical space with the other player. One player mentioned “It feels real with the rope going in front of the camera”.

6.2.3 Creative Expression

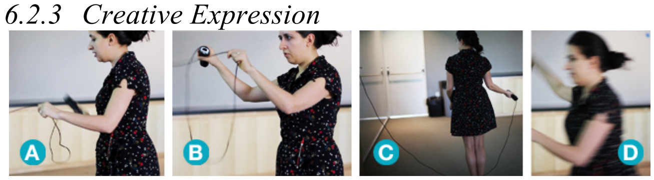

Figure 12. Creative expressions via rope: (A) with right hand moving up and down to make the horse move, and with left hand to pull to make the horse stop; (B) with two hands going up and down to make the horse run; (C) jumping over the rope; (D) rope jumping together with the virtual frog

We are also interested in investigating how our system can assist creative play, or individuals’ freedom to use their own gestures--intuitive or not--to successfully participate in a game. Although our system does have some pre-defined motion patterns, participants enjoyed exploring their own ways of interacting with the rope. Moreover, people are capable of generating new interactions based on their understanding of the system’s sensing techniques [Figure 12]. For example, in the single-player jump-rope game, in which participants acts as the rope-twirler, one player twirled the rope with one hand and also jumped with the rope, as seen in Figure 12. There was another player attaching the rope handle to his body, jumping upwards by himself to make the frog jumps on the screen.

7. DISCUSSION

Through our user studies, we concluded that the sense of sharing a physical object–in this case, a rope–between remote participants can help people feel like they are experiencing a co-located activity. In game play, this sense of another person's presence can be aided by force feedback generated through the tangible interface, and by digitally portraying the other person (e.g., via webcam video feed). We also found that creative gesture and body expression based on people's real world experiences can be encouraged through our system.

Our design process and findings can be applied to designs in the field of utilizing tangible objects with real world metaphors to create shared playful experience across vast distances.

8. CONCLUSION

The work in this paper has focused on developing a novel tangible rope interface that allows people to play rope-related games across vast distances. Our aim is to contribute to an understanding of the role of tangible user interfaces that have real-world physical metaphors in facilitating a social experience. We have presented a qualitative study of a rope-based gaming system that supports various social games and activities related to ropes, such as kite-flying, horse-riding, jump-rope and wood-sawing. We found evidence that the tangible rope interface, that inherently provides both physical and visual feedback, can enhance gaming and social experiences. Our work can provide guidance for designers who want to facilitate social gaming experience by adding tangible game controllers and real-world-based gaming content.

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