RopePlus: Bridging Distances with Social and Kinesthetic Rope Games

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract
Rope-based games such as jump rope, tug-of-war, and kite-flying promote physical activity and social interaction among people of all ages and especially in children during the development of their coordination skills and physical fitness. Our RopePlus system builds on those traditional games by enabling players to participate remotely through interacting with ropes that connect physical and virtual spaces. The RopePlus platform is centered around the rope as a tangible interface with various hardware extensions to allow for multiple playing modes. In this paper, we present two games that have been implemented in detail: a kite-flying game called Multi-Fly and a jump-rope game called Multi-Jump. Our work aims to expand tangible interface gaming to real-time social playing environments.

Keywords
Tangible Interface, Social Game, Exertion Interface, Remote Playing, Enhanced Reality, Athletic Interaction, Kinesthetic Interaction, Computer Supported Cooperative Play

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User interfaces

General Terms
Design, Experimentation, Human Factors

Introduction

Rope-based games such as jump rope, tug-of-war, and kite-flying are universal games that are enjoyed world-wide regardless of race, age, and social status. Multi-player, physically engaging games are not only good for encouraging physical exercise, but they also help facilitate positive social interactions. However, games such as these require that players be in the same physical space and usually the number of players is also limited. In our approach, we utilize telecommunication technologies including web cameras, video projectors, and live video feeds to create a remotely shared gaming environment. This allows players from around the world to connect, interact and learn from each other.

Additionally, most conventional video games use mice, keyboards, or touch screens which lack the physical metaphors of manipulating virtual components. In contrast, traditional rope games use a rope as a familiar and intuitive interface for gameplay. Ropes can serve a variety of functions with simple actions, such as releasing, rotating, pulling, intertwining, skipping over, folding, and translating [Figure 3]. In our gaming system, we seek to translate the metaphor of a physical rope into a tangible interface. In RopePlus, rope serves as both the game controller and interface controller; the user can manipulate information in the digital world by acting upon the rope. During gameplay, the rope becomes an extension of the user's arm – a seamless continuation of the user's body into a combined physical and digital experience [Figure 1].

Goals of the RopePlus Project

We have designed RopePlus as a shared gaming platform with a variety of plug-ins for rope-based games. Its goals are to:

1. demonstrate a system for shared exertion gaming for children using a tangible augmented rope
2. explore physical and spatial implications for a remotely shared game space
3. study the effects of remote exertion gaming on the social, cooperative and educational nature of play

Related Work

Various human computer interfaces have been developed with an emphasis on physical activity and exercise. For instance, Mueller has developed exertion gaming, which requires players to utilize gross-motor body movements [9], such as the remote air hockey [12] and social jogging [10]. Exertion gaming has recently seen increased popularity in arcade systems such as Dance Dance Revolution and Jumpin' Jack pot!, along with home systems such as the Nintendo Wii, Playstation Move and XBOX Kinect. Exertion games such as these are believed to provide a number of benefits, including improvement of physical health from additional exercise, increased social interaction through the gaming experience, and improved motor skills required by full-body game play [14]. PingPongPlus [8] from Ishii's group is another "athletic-tangible interface", which combines full body movements with a digital game-augmented environment. Kick Ass Kung-Fu [4] is another game installation involving physical movements.

There are many prior examples of tangible interfaces that utilize the metaphor of manipulating everyday objects in order to augment the interaction with and functionality of those familiar objects. People use existing skills when they interact with familiar objects, which makes it easy for them to learn the basic interaction in a new human computer interaction system [6]. Examples include I/O Brush [13], which utilizes a brush to select a color from physical objects and paint onto a digital palette, and musicBottles [7], in which the act of openning glass bottles can trigger music. In our RopePlus system, we chose rope as the augmented object to interact with digital information. Similar concepts, such as video game of tug-of-war [5][2] and kite-flying [1][3], have been previously described. But these are single-user or co-located multi-user games. Harfield, et al [5], developed a remote tug-of-war system. However, the authors chose to concentrate on one particular game. In our case, we seek to explore the affordance of playing with ropes and to use a single rope to play multiple games.

In another perspective, our work is related to multi-user systems that encourage people to interact and collaborate with each other remotely. Prior art has focussed on these areas individually and in combination with each other. Through separate setups, players can easily see each other's actions within the game system – in the form of body shadows, live video, or gameplay. This is similar to Shadow Boxing, where people try to hit each other's shadows by remotely boxing [11].

System Description

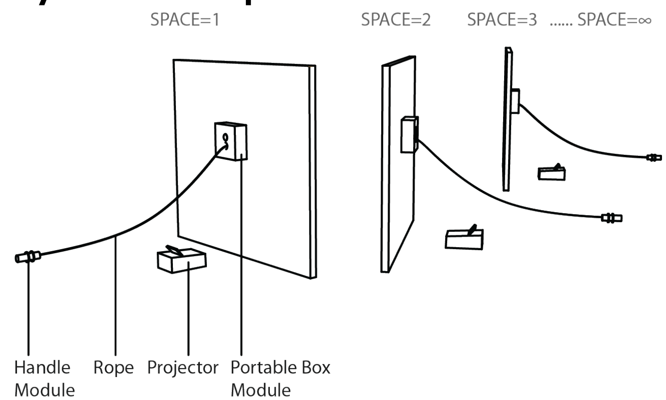

Figure 1: System setup.

We have developed a system [Figure 1] that enables multiple players to participate in rope games remotely. Each player's game space has a portable game module that consists of a box that houses hardware (including a rope, a camera, and a motor that can actively control the rope position) that can be connected to a computer. A digital game interface, controlled by the computer, is displayed in front of a player via a projector. The box is affixed to a surface, such as a wall or tabletop, by means of magnets or suction cups to appropriately anchor the rope for the current game. The rope extends out of the box to serve as a game controller as well as perform user-interface actions (game-level selection, location selection, etc.). The free end of the rope has a handle, which houses an accelerometer and a wireless communication module.

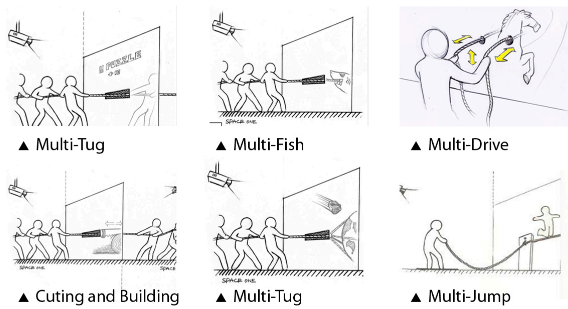

Figure 2: Preliminary game designs.

Based on this setup, we designed a series of games [Figure 2]. Possible game modes include: players from multiple locations competing against each other ("war mode"), players from multiple locations collaborating to achieve a unified goal ("give and take" mode), and players from one or more locations competing against a virtual character (virtual "war mode"). For example, Multi-Tug is a set of games inspired by the traditional tug-of-war game. One variation might involve war mode, in which players can virtually increase their strength by solving puzzles during the game (this is possible because the rope's pulling resistance can be actively controlled using a motor). In contrast, another variation might involve give-and-take mode, during which players from multiple locations can collaborate to manipulate objects in the virtual space to complete tasks (for example, picking up and stacking objects in a certain configuration without making them fall). In the Multi-Fish game, real and virtual players can participate in virtual war mode to catch as many fish as possible.

Rope as a Tangible Game Interface

We are interested in exploring universal activities that are simple yet engaging. From Figure 3, we can see a variety of ways that ropes can be used for play, including releasing, rotating, pulling, intertwining, skipping over, folding, and translating. A player's intuitive interaction with the rope in RopePlus varies and is implied by the game being played. For instance, the functionality of the rope could easily transition between that of a jump rope or a kite string, depending on the video projection that provides context for the game.

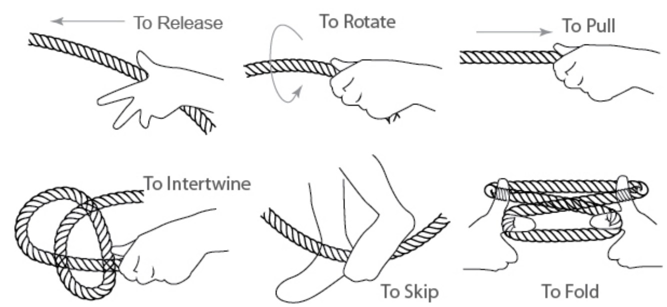

Figure 3: Ways of playing with ropes.

Social Gaming Over a Distance

By blending the physical and digital world, our system allows users to interact remotely despite geographical separation. The real-time linked environments can help to dissolve boundaries and foster the development of personal bonds. Potential users include distant family members and friends, children in school, and people who want to share different culture and languages.

Seamlessness Between Physical and Digital World

We are interested in creating the visual illusion that virtual and real worlds are connected. Typical video game controllers hold few visual connections with virtual games. In our system, physical ropes serve as game controllers that extend into virtual spaces [Figure 4].

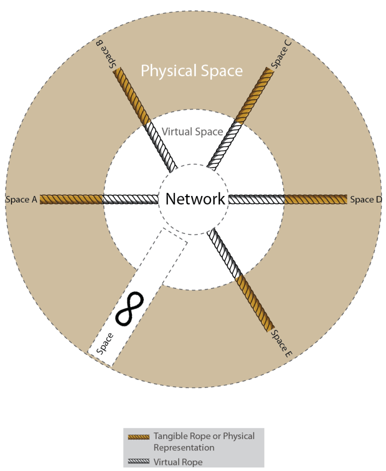

Figure 4: Rope serves as connection between physical and virtual world.

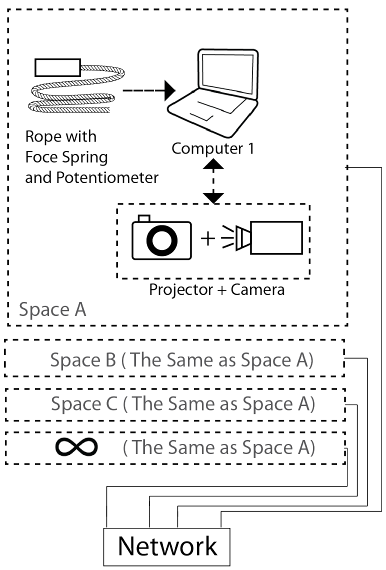

Figure 6: System diagram for Multi-Fly.

Learning While Playing

We combined various educational elements into the game design, transforming rope games into not only physical exercise, but also educational activities. For example, we layered orientation and geographic learning into the game of Multi-Fly.

Combining the Advantages of Traditional Physical Games with Multimedia

Co-located physical games, such as playing football and flying kites, engage the entire body. On the other hand, video games can create multimedia effects that enrich a person's imagination, which is not as easily achieved in real life. By combining physical rope games with multimedia elements, we seek to preserve the fun aspects of traditional rope games while enhancing the games and their social benefits.

In the following two sections, we describe two games that we have developed in detail: a kite-flying game called Multi-Fly, and jump-rope game called Multi-Jump.

Multi-Fly

Overview

Figure 7 shows images of the projected game interface for Multi-Fly at various stages of the game. In the first stage, labeled as (2), players utilize a pull-and-release scheme with the rope to select their own kite from a palette projected on the wall. Similarly, in the following stage (3), players can select from available geographic locations that they would like to fly their kites in. Different background images and music can be played based on a player's selection. Currently, the available locations include: Africa, Canada, China, France, India, and North America. Players participating in the same virtual location are shown via live video feed along the bottom of the screen to simulate everyone being in the same location together, with their virtual kites being extensions of their real ropes. Therefore, the kite-flying game becomes a shared experience through a virtual environment.

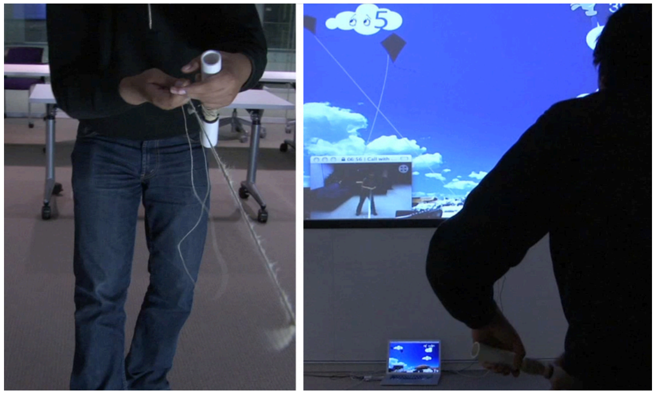

Figure 5: Multi-Fly.

Once gameplay begins in stage (4), the players use their ropes to control the kite's position with the goal of hitting the clouds with their kites to gain points. Players can compete with each other remotely. There are several ways to interact with the rope to control the kite [Figure 8]. Holding the rope makes the kite stay in the original position while the kite drops slowly; releasing the rope causes the kite to spin and fall down; and pulling the rope causes the kite move in the direction that the kite is pointing to. Using a simple interface like a rope gives the user freedom in terms of how he/she handles the rope, allowing for individual users' intuition to take over.

Technical Implementation

Figure 9 illustrates how the virtual and physical ropes are continuations of each other at the position of the portable box module.

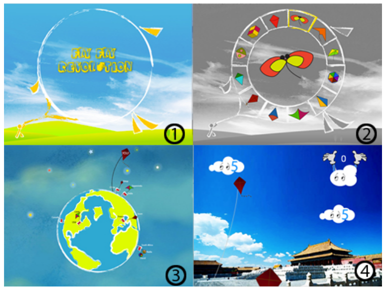

Figure 7: User interface of Multi-Fly.

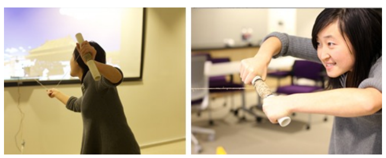

Figure 8: Different ways of interaction with the rope in Multi-Fly.

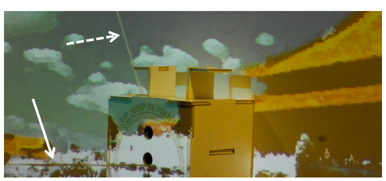

Figure 9: The real rope merging with the virtual rope in Multi-Fly.

Figure 6 shows the whole system design. Currently, the prototype of Multi-Fly was implemented as a single-player game. An important aspect of this game was the force-feedback component, in which a constant-force spring was used. A possibility for future implementations would be to use a motor, as it would be able to provide variable resistance and/or feedback. The position of the rope was measured with a 10-turn rotary potentiometer. The software was implemented in Processing (the animations for the kites were rendered in Rhinoceros 3D) and the communication hardware interfacing was done with Arduino [Figure 10]. For the full system, we envision having a 2-way video communication channel, along with a data stream to transmit the motion of the rope.

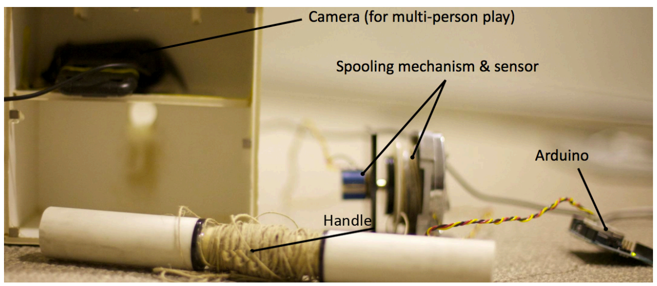

Figure 10: Hardware for Multi-Fly.

Multi-Jump

Overview

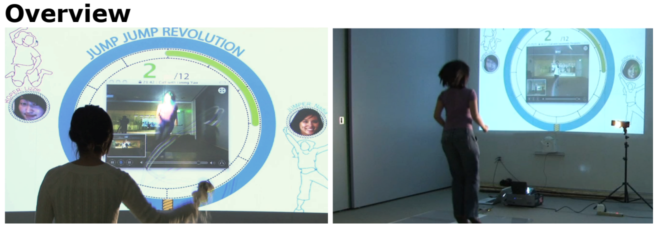

Figure 11: Multi-Jump in two-person mode.

We have built a prototype for a jump roping game that supports two or more players in different geographical locations [Figure 11]. The gameplay of the remote jump rope game is as follows:

- One person acts as the rope-twirler while another person is the jump-roper in a separate location. This can be extended to have multiple people jumping with the "same" rope in multiple locations.
- Both players can see real-time projections of the other player(s).
- On the rope-twirling side, a 3-axis accelerometer is embedded in the rope's handle, so that every time the rope descends, a digital signal is sent out to control a pad that lights up in the jumper's space.
- On the jump-roping side, the player jumps on a pad that houses an RGB LED strip and a pressure sensor. The illumination frequency of the indicates when the rope is hitting the ground so that the jumper has a sense of the rhythm In addition, the projected digital interface includes a graphical representation of the rope's location.
- During play mode, the players' faces will be shown on the projected digital interface. Moreover, they can see and talk to each other remotely through a video connection between the locations.

Once the game starts, the jump-sensing pad detects the player's jumping frequency. A colored bar will accumulate on the projected digital interface if the two sides coordinate perfectly, and the score will restart from zero if a player makes a mistake and cannot jump in sync with the rope. In addition, when the game is extended to include more than two players, if multiple players jump in multiple locations, the score is based on the general performance of all players combined.

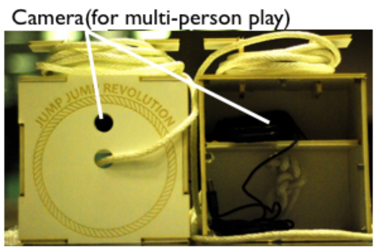

Figure 13: Hardware for Multi-Jump.

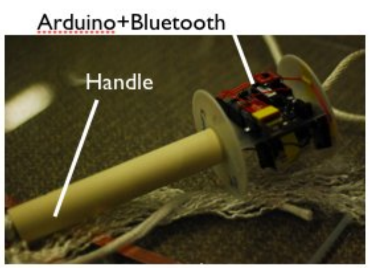

Figure 14: Controller for Multi-Jump.

Technical Description

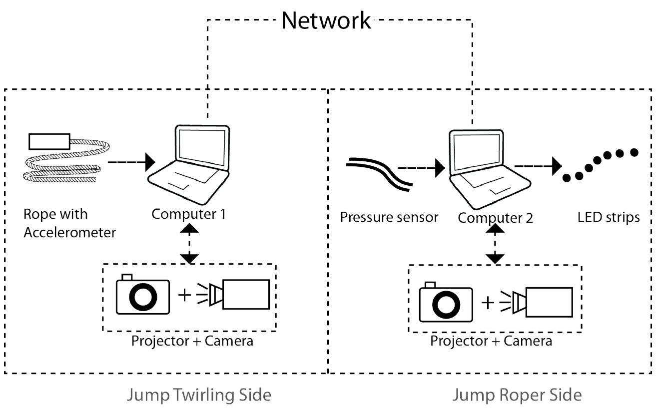

Figure 12: System diagram for Multi-Jump.

For the prototype of Multi-Jump, the motion of the twirler's end was estimated using a 3-axis accelerometer that communicated with a computer via Bluetooth [Figure 14]. This computer also had a webcam attached to it [Figure 13], and the video data from the webcam, along with the accelerometer data was streamed over the network to a second computer at the jumper's end [Figure 12]. The second computer streamed video from its respective webcam back to the rope twirler's end, creating a 2-way video communication channel. The data from the accelerometer was interpreted by the second computer, and matched with data from a pressure sensor under the jumper to drive an RGB LED. A mismatch in the pressure sensor data and accelerometer values indicated that the jumper was jumping incorrectly, and the score of the game would be updated accordingly.

As with Multi-Fly, all the software was implemented in Processing, while the hardware interfacing was done with Arduino. Skype was used for the video communication.

Preliminary Observations

Each of the previously described systems: Multi-Jump and Multi-Fly were tested to gain qualitative insight on the user experience to help guide future implementations. Test subjects participated as players in various game modes.

In the multi-jump game, we set up two systems in two separated spaces. One person acted as the jumper in one space and the other acted as the rope-twirler in the other space. Among all the elements we designed – including a live video feed, LED lighting, GUI interface and sound – the video feed is most effective for the rope jumper. Subjects reported that they felt as if they were playing together in the same space. Also, players in both spaces could easily communicate, and enjoyed greeting each other and fine-tuning their motions for greater success. At the same time, we realized that the system should have stronger visual effects when a rope jumper makes a mistake, in order to notify both sides of errors. We also found that a larger live video feed screen is more effective. Users also enjoyed the projected visual interface and audio effects, noting that they enhanced the game experience.

Multi-Fly was tested in a multi-player mode: each player could see the other kites in the virtual space in addition to the live feed of other players along the bottom of the screen. In the specific mode that was tested, the purpose of the game was to get the most points by controlling the location of your kite–by either pulling or releasing the rope–to 'hit' clouds in the virtual space. At the time that the tests were conducted, players could not affect other players' kites (for example, to hook and drag another player's kite) due to software limitations. Users were satisfied with the force feedback and response time of the physical rope, noting that it felt like flying a kite in calm weather. Users were also satisfied with the intuitive nature of the interface and control, as they felt like the rope was an extension of their virtual kites. In addition,

Game Name	Ways of Interaction with Tangible Rope	Collaboration or Competition	Forms of Physical Exercise	Learning Components
Multi-Fly	pulling, winding, letting go	competition	running	direction, angular geometry
Multi-Jump	twirling	collaboration	jumping	physical coordination
Multi-Tug	pulling	competition or collaboration	exerting strength	knowledge through puzzles; direction
Multi-Fish	pulling in various direction, holding up	competition	exerting strength	knowledge related to fish and ocean; direction

Table 1: Various game modes with RopePlus

users enjoyed the projected visual interface and audio effects–especially the location-specific music that matched the global location of the kite during game-play–noting that they were engaging and entertaining. This is all encouraging because it indicates that the functionality of the rope can successfully be augmented and dictated by the projected game environment.

Discussion and Future Work

Through the RopePlus project, we investigated a design space that tested the full potential of interaction with a rope system. Table 1 illustrates the factors we considered while designing various game modes, including ways of interacting with tangible rope, remote collaboration or competition, physical exercises and other learning factors enhancing the games.

We plan to further develop some new games in order to explore our ideas of using one platform that contains multiple metaphors of augmented ropes. In different game modes, players use the rope in various ways, and receive many learning and collaboration experiences. In the next step, we will also focus on the social aspect of the RopePlus system. We will add new components to the interface, which will help players establish social networks with other remote players. For example, at the start of the game, players can search and choose online friends. They could chat, collaboratively achieve a goal, save and restore the game process, etc. Also, we think one of the important design factors is to enhance the feedback in the physical world. For example, we plan to connect vibration and moving motors at the end of our rope module, in order to provide richer haptic experiences at key moments of the games.

A general concern for the overall system is that network lag, for multi-player gameplay, could adversely affect the game experience. Of the two games we developed, this is especially true for Multi-Jump, as it is crucial that both players are synced for accurate feedback. The sensing capabilities for both games could also be vastly improved.

Conclusion

We have described a gaming/activity system called RopePlus that centers around the use of a rope as a tangible user interface and controller. The primary appeal of the system is that the context of the rope is intuitive yet diverse, and can be dictated by visual and audio cues. In addition, the rope serves as a tangible connection to a virtual space to allow multiple people to play and interact with each other remotely. This enables geographically distant players to share physical and social experiences. Both remote and co-located groups of players can also use the system to participate in fun and exciting virtual scenarios.

To date, we have designed and prototyped two games for the RopePlus system: a jump-roping game called Multi-Jump and a kite-flying game called Multi-Fly. Multi-Jump allows people to remotely play multi-person jump rope games that traditionally require that people be in the same location. Multi-Fly utilizes the rope in the real space as an extension of the kite's string in the virtual space, enabling players to immerse themselves in virtual environments, such as locations all over the world.

Referring to the three previously defined project goals, we have shown significant work in (1) demonstrating a system for shared exertion gaming for players using an augmented rope. Future work will continue to (2) explore physical and spatial implications for a remotely shared game space, and (3) study the effects of remote exertion gaming on social, cooperative, and educational nature of play. Qualitative user feedback for both games is encouraging and is helping us design future implementations.

Acknowledgements

We would like to thank Dr. David Rose and the 2010 Tangible Interfaces teaching staff and class (MAS.834) at MIT for their support and encouragement.

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