Multi-Jump: Jump Roping Over Distances

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Abstract
Jump roping, a game in which one or more people twirl a rope while others jump over the rope, promotes social interaction among children while developing their coordination skills and physical fitness. However, the traditional game requires that players be in the same physical location. Our 'Multi-Jump' jump-roping game platform builds on the traditional game by allowing players to participate remotely by employing an augmented rope system. The game involves full-body motion in a shared game space and is enhanced with live video feeds, player rewards and music. Our work aims to expand exertion interface gaming, or games that deliberately require intense physical effort, with genuine tangible interfaces connected to real-time shared social gaming environments.

Keywords
Tangible Interface, Exertion Interface, Athletic Interaction, Computer Supported Cooperative Play

ACM Classification Keywords
H5.m. Information interfaces and presentation: User Interface

General Term
Design, Experimentation, Human Factors

Jump Rope as Social Exertion Game

Jump rope games are popular with children worldwide. We talked to people from different parts of the world, including Asia, North America, Africa and India, and found that jump-roping is considered to be a simple yet engaging game, especially among children. For example, multi-person jump rope games, such as 'double-dutch', are inherently social games and are enjoyed worldwide regardless of race, age and social status. Our Multi-Jump game promotes social interaction among children while developing their coordination skills and physical fitness. In the system, we seek to combine the universal jump rope game with interactive video, audio and communication technologies to create a new exertion game that enables individuals to play and interact remotely.

Connecting through Jump Rope

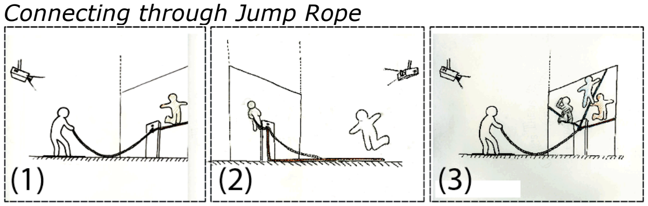

Figure 1. Users are playing jump rope together remotely. Two or more people can play at the same time.

An important aspect of our Multi-Jump game is the remotely shared gaming environment that is achieved with telecommunication technology, such as web cameras, video projectors and live video feed. The disparate physical spaces in which game-play occurs are connected in a shared virtual space. The augmented rope that players manipulate appears as if it blends into this shared space, thus becoming an invisible extension of the players' physical bodies into the virtual space of the game [Figure 1]. This allows users to interact remotely despite geographical separation while engaging in the jump rope game. The real-time linked environments of players can help to foster the development of personal bonds, thereby enabling people from around the world to connect, interact and learn from each other. Potential users include distant family members and friends, children in school, and people who want to share different cultures and languages.

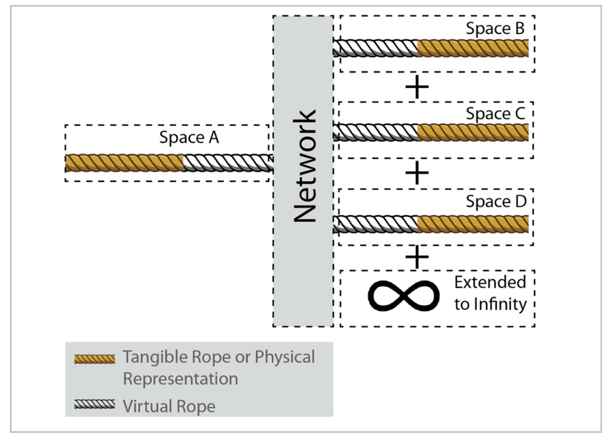

Figure 2. Tangible rope can be manipulated directly, while reflected in the virtual game space simultaneously.

Exertion Game for Exercise

Multi-Jump can be categorized as exertion gaming. Exertion games are presumed to have numerous benefits, including improvement of players' general well-being due to increased social interaction and exercise, as well as improved motor skills due to full-body game play [10]. The proposed design for the virtual jump rope game physically engages a user's body with a tangible object in real space. The game

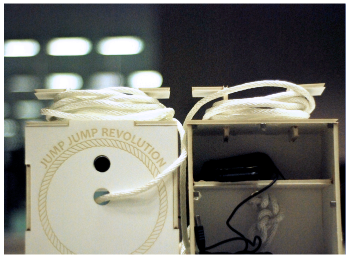

figure 5. portable anchor box

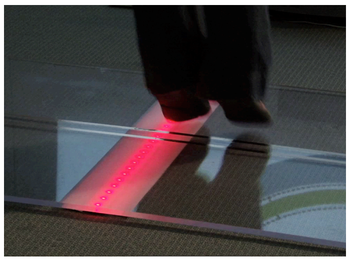

figure 6. jump sensing board with pressure sensor and led light strip

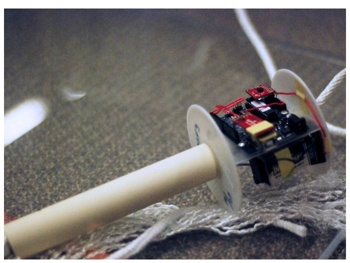

figure 7. handle embedded with acceleration sensor and Bluetooth

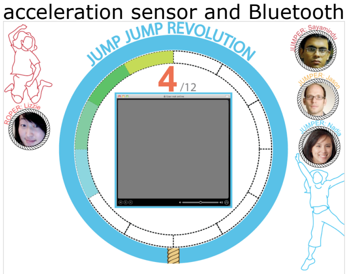

figure 8. digital interface

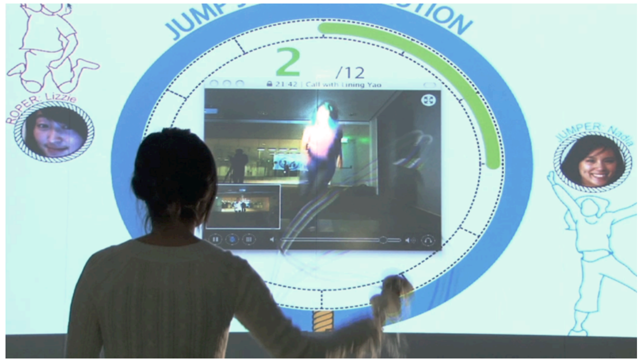

Figure 3. Rope-twirler's game space

requires that players interact with their immediate spatial surroundings, developing a body-spatial awareness. Physical exercise can put participants in a heightened state of alertness that supports social bonding [8].

Tangibility of Game Interface

Children develop various skills for sensing and manipulating objects while interacting with the physical world. However, most of these skills are not harnessed by standard video games. We are interested in giving physical form to digital game elements. In our system, a rope serves as a familiar and intuitive interface combining the physical and digital worlds. During game-play, the rope becomes an extension of the user's arm to serve as a seamless continuation of their body into a combined physical and virtual experience [Figure 2].

Design of Multi-Jump

In two-player mode, one person acts as the rope-twirler [Figure 3] while another person is the jumper [Figure 4] in a separate location. Both players have access to a standard game module that is composed of a box [Figure 5] that houses both a rope anchored at one end and a camera that enables live video. The

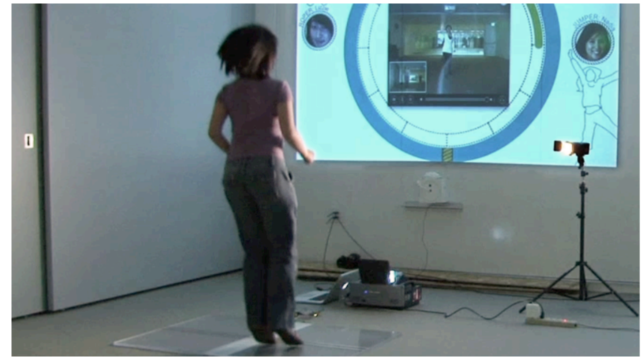

Figure 4. Jumper's game space

rope-twirler controls a real rope as if participating in a co-located jump rope game. The jumper, on the other hand, does not interact with a rope in the physical space; rather, he/she participates in the game based on input provided by a live video feed of the rope-twirler and other visual and audio cues in the physical space, such as a floor pad [Figure 6] that lights up to indicate when the rope hits the ground. Additional cues are described in the following paragraph. Because of the shared, virtual space, this set-up can be extended to have multiple jumpers in multiple locations with a single rope-twirler.

A digital interface [Figure 8] is projected in each player's space to help connect and synchronize multiple players. This interface includes:

- A projection of real-time video that shows other players to allow people to interact remotely.
- Names and images of players on both sides of the interface: one side for the rope-twirler and the other side for jump-ropers. This makes it easy to identify game participants.
- The cross section of a virtual rope that moves along a circular path on the screen to reflect the location of the real rope.

- A scoring system that indicates how many continuous jumps have been achieved. A colored bar will accumulate if two sides coordinate perfectly, and the score will restart from zero if one person makes a mistake and misses a jump.

The game also has a countdown interface at the beginning and a winning indicator at the end. Audio cues, such as fun "boing" sounds to reflect when the jumper is jumping, are also included throughout the game to make the game more engaging.

Implementation

On the twirling side, an Arduino-based [2] motion detection system was developed to track the circular movement of the jump-rope handle [Figure 7]. The entire Arduino and associated sensor circuitry were attached to the rope handle. A 3-axis accelerometer attached to an Arduino Uno board detected changes in direction of the rope handle. This input was broadcast wirelessly to a nearby computer via a Bluetooth module which was also attached to the Arduino Uno board.

At the jumper's end, a custom-made pressure sensor was integrated into a pad [Figure 6] upon which the jumper lands to track the jumper's movement, thereby determining whether he/she successfully clears the rope controlled by the other player. The state of this sensor was monitored by a computer via another Arduino Uno board. The jumper's pad also had an RGB LED light strip extending between the jumper's feet and controlled by the Arduino Uno board. The purpose of the LED light strip was to indicate when the virtual rope is hitting the ground.

The computers at both ends were equipped with a projector and a webcam. The projector displayed the game interface directly in front of the player, and the rope (at the twirler's end) was anchored in a box which also housed the webcam [Figure 5].

To ensure accurate detection of the movement of the handle, data from the accelerometer was aggregated over 10 milliseconds and then averaged. A detected change of direction of the handle was sent to a computer at the twirler's end, which transmitted the message via TCP/IP to a computer at the jumper's end. The computer at the jumper's end compared the messages from the twirler's end with the state of the pressure sensor, and illuminated the LED accordingly. For example, when the direction change was from down to up, it could be assumed that the rope was in its lowest position, and if the pressure sensor was high at that point (indicating that the jumper was still on the ground), the computer would set the color of the LED to red, indicating a 'trip condition.' Each successful jump would increase the score by one, and a 'trip' would cause a penalty of one point.

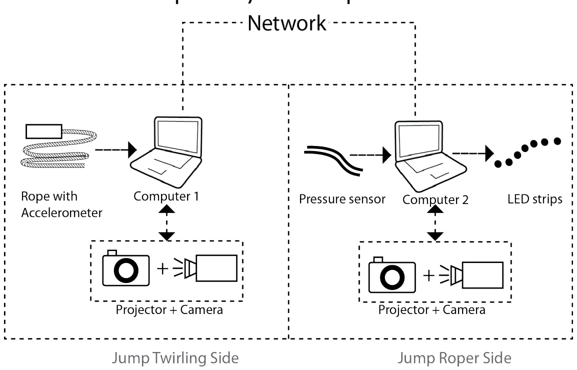

Figure 9. Schematic framework for prototype implementation

Related Work

The primary attributes of the Multi-Jump system can be broadly characterized by two main areas in human-computer interaction and interface design: 1) physical exertion games, and 2) remote and social play. Prior art includes work that focuses on these areas individually and in combination with each other.

Mueller has done significant work in designing and analyzing 'exertion games' in which players in multiple geographic locations can participate in physical game-play, such as air hockey [9], table tennis [11] and shadowboxing [7]. Several of the goals of the work in this paper align well with the purpose of Mueller's work, which is to encourage and investigate the positive coupling of physical exercise and social interaction [8][10]. In related work, Ishii's group has developed the PingPongPlus system, which integrates sensors and video projection into a traditional ping pong game set-up to enhance the playing experience by creating a more interactive and responsive playing environment [6]. PingPongPlus is an example of how technology and multimedia can be used to augment traditional games to encourage physical activity.

Physical gaming and interactive systems that involve the use of a rope, both physical and virtual, have also been developed. Similar to our work, ropes have been used as part of tug-of-war [3][5], jump rope (the Wii system), and kite-flying [1][4] systems. Most of these are either single-user or co-located multi-user systems. Harfield, et al, have proposed to develop a remote, multi-player tug-of-war system that uses sensing and active control to realistically create a tug-of-war scenario; however, a fully functioning system has not yet been realized [5].

Preliminary Test

Preliminary tests were conducted with a two-player set-up: one person acted as the jumper and the other acted as the rope-twirler. Users noted that seeing the live video feed of the other player was the most effective form of stimulation and feedback during the game. On the jumper's side, even with the virtual rope-tracking via the video projector and the LED light strip, users said that they primarily watched the video feed of the other player to determine the timing and location of the rope. In addition, players on both sides were surprised that they were interacting with each other and playing the game as if they were part of a traditional, co-located game. These results are encouraging because they indicate that the system can successfully enable players to remotely share a physical and social experience. Users also enjoyed the projected visual interface and audio effects, noting that they enhanced the game experience.

Discussion and Future Work

We plan to develop more sophisticated playing modes that would require players to work around additional challenges. For example, players could be required to jump with a certain rhythm and speed, as dictated by a musical track, challenging both the jumper and the rope twirler. Similarly, we could incorporate choreographed footwork into the jumping routine, as advanced jump-ropers often do. We would also like to exploit the game's remote playing capabilities by allowing multiple jumpers to play with a single rope-twirler. Because jump-roping is universal and is especially popular amongst children, we envision our system being used in playgrounds across the world to bring children together with a common interest. At all stages during the design process, we would like to test our system with avid jump-ropers to aide us in designing a system that is enjoyable for users of all levels.

A concern for the overall system is that network lag could adversely affect the game experience, as it is crucial that both players are synced for accurate feedback. These types of issues can be mitigated using available video-chat resources. The sensing capabilities for both games could also be vastly improved by using existing sophisticated gaming technologies (Nintendo Wii, XBOX Kinect). Using these modules, especially in the early development stages, could allow us to focus on more important and novel aspects of our work. Furthermore, sophisticated versions of our games could also utilize dynamic game balancing, in which game parameters can be updated to better accommodate a person's skill level to keep the game interesting.

Conclusion

We have described an exertion gaming platform that allows people to remotely play multi-person jump rope games that traditionally require people to be in the same location. We have demonstrated a two-player system in which a rope-twirler uses a real rope to control the rope position while a jump-roper acts based on feedback provided by a live-video feed and virtual projections of the rope. In addition to enabling remote, social play, this novel system provides a fun and enjoyable means of exercise. Qualitative user feedback is encouraging and is helping us design future implementations.

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