The Trial of Galileo: A Game of Motion Graphs

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PRE-Print,
Final version to appear at
CHI PLAY '14, Oct 19–22 2014, Toronto, ON, Canada.

Abstract
This paper presents a 2D game designed to assist students in better understanding motion graphs. In this game the player's character is not controlled by a joystick or control pad. Instead the game employs a unique interface enabling the player to control the actions of a character by creating a motion graph. The motion graph represents the desired position, velocity, or acceleration of the player's character over time. The graph must be fashioned to move the character through various puzzle environments. Through trial and error the player may achieve a better understanding of what motion graphs depict in the real world.

Author Keywords
Educational game; physics; motion graphs; interface design; 2D platform game; game design.

ACM Classification Keywords
H.5.m. Information interfaces and presentation: Miscellaneous; J.2. Physical Sciences and Engineering; K.3.m Computers and Education: Miscellaneous.

Introduction
A game's content is just one educational component of the game. Its interface also can be used as an educational tool. For example it was shown board games based on a number line representation offer

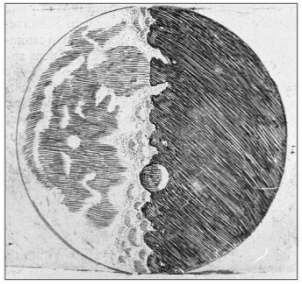

Figure 1: Galileo's Moon Sketch

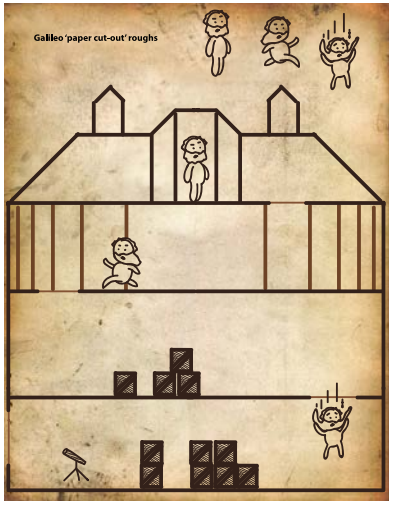

Figure 2: Concept Gameplay Art

greater advantages to numerical understanding than the same games implemented using a color based representation [16]. This implies the interface to a game can offer explicit enhancements to the educational value of the game. This can also be inferred from other evaluation methodologies [7, 9, 13].

This paper presents a 2D game designed to assist students in understanding physics and how motion graphs relate to that understanding. The game implements an interface of motion graphs to move the game character. This interface allows the player to experiment with the creation and manipulation of position, velocity, and acceleration graphs to move the character through increasingly difficult obstacle courses and puzzle environments.

Background and Motivation

Understanding motion graphs is important to animation and game design. In animation they have been used to create realistic, controllable motion from a captured set of data [11], to develop control policies to animate characters [6], and for real-time interactive character animation [4]. In game design they have been used to develop path planning algorithms to move characters through complex environments [5, 14], and have been used for in-game animation of characters [8, 18].

However, before such advanced application there must be basic understanding. Early exposure to motion graphs and the relation between position, velocity, and acceleration typically occurs while taking a math or physics course. Intuitively these relations make sense by definition and experience. Yet, for many, coming to understand and relate a set of graphs to real world behavior is difficult [12, 15]. Perhaps a game can help.

Most games use a joystick, control pad, keyboard, or mouse as an input device to allow the user to control the motion of a game character. The visual feedback is easily understood. This type of interface has become the default to use. However it does not have to be the only interface.

Games such as *Rabbit Wants Cake* [2] use an interface allowing the player to alter a graph of position relative to time. We propose this type of interface, in a suitable context, can be used to educate players on motion graphs and how they relate to real world behavior. The following describes a gaming environment designed to encourage exploration and understanding of how to use such graphs.

Game Concept and Setting

The player of the game controls a character named Galileo. At the beginning of the game, Galileo has used scientific methods and careful observation to resolve some controversial ideas; however, he is brought to trial to prove his findings and avoid heresy charges. Fortunately his evidence is strong enough that he avoids immediate sentencing. However, he must prove himself in further trials where he navigates deadly obstacle courses using only his (or rather the player's) understanding of physics.

Main Gameplay

The game is composed of levels. Each level is an obstacle course puzzle. To solve the puzzle the player must construct a motion graph to move Galileo from one place to another while avoiding obstacles. Points are awarded based on how well the player's motion graphs compare to a hardcoded solution. Additional points are given if the player can draw all three graphs

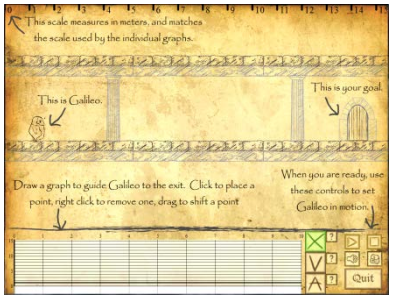

Figure 3: Actual Gameplay Screen

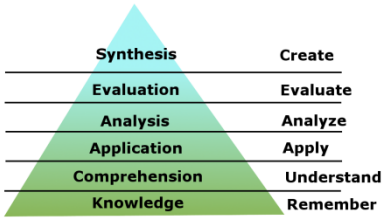

Figure 5: Bloom's Taxonomy

relative to each other (position, velocity, acceleration). Bonus points can be earned if the player opts to collect extra objects within a given level. Successful acquisition of these bonus objects, of course, requires more sophisticated motion graphs.

Game Aesthetics

The game aesthetics are intended to give the feel of the time of Galileo. So the background appears to be aged paper and the objects are displayed from a side view perspective with a hand drawn appearance. The general art style is based on Galileo's sketch of the Moon.

User Interface

The interface, as mentioned in previous sections, is a key educational component of the game to assist in understanding how motion graphs relate to actual, real, motion of objects. This interface allows the creation and exploration of motion graphs, providing visual feedback via the game character's motion.

The layout of the game's interface is such that the user is presented the puzzle space in the upper portion of the screen. In the lower portion the user is allowed to draw a motion graph by placing points on a piece of graph paper. The horizontal axis of the paper represents time and the vertical axis represents Galileo's position, velocity, or acceleration in the horizontal direction. Gravity and other game features automatically affect and adjust his vertical position.

Experiments were conducted allowing the player to have vertical control of Galileo using additional motion graphs. User feedback surveys indicated this made the interface too complicated. In response to the surveys we added a jump feature that can be placed on the motion graph at a desired point in time. This feature causes Galileo to be given an increased velocity in the vertical direction at the time indicated. Gravity then automatically reduces it which creates the appearance of jumping. Throughout this the player's motion graph still controls Galileo's horizontal movement. In later testing and user surveys, this feature was commented on for its ease of understanding. And it still maintained the basic premise of the interface.

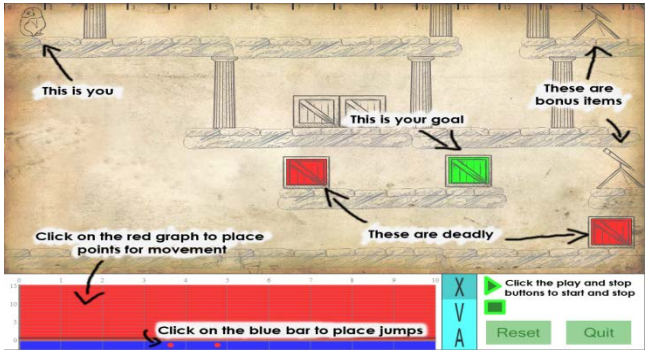

Figure 4: Conceptual Gameplay Screen

Another improvement in the usability of the interface, again based on test-user feedback, was the addition of a ruler-like metric to the top of the screen. This serves to establish the positive and negative direction of position as well as a visual indication of the unit of measure for distance.

Learning Retention

The educational merit of this game is based on Bloom's Taxonomy [1, 3]. We assume the player has an existing knowledge and comprehension of basic physics relative to position, velocity, and acceleration as well as definitional knowledge of motion graphs.

Game players (students) are given the opportunity to apply, analyze, and evaluate their knowledge and understanding of motion graphs. Over time players should achieve a higher level of understanding of the nature of motion graphs as well as physics in general. It is believed, players may then reapply this experience to other fields of interest and problem domains. While we do not yet have empirical results to explicitly indicate this, other studies on experimentation with graphs and visual feedback imply a positive result should be expected [10].

Summary

This paper has presented a game which uses a unique interface based on motion graphs. It serves to demonstrate how a game may capture the interest of a student and assist in teaching. It also emphasizes a point: The content of a game is not the only educational part of a game. The interface of the game is also a key component of the learning experience.

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