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Citation

Lucas, Robert (2011). Using a virtual world for teaching the motion of projectiles. In: Norton, Andrew ed. Electronic Resources for Teaching and Learning. Milton Keynes: The Open University, pp. 40–43.

URL

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Using a virtual world for teaching the motion of projectiles.

Presented at The Open CETL Conference. 24-25 September 2008. The Open University. Walton Hall, Milton Keynes.

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Introduction

This project was developed as a demonstrator for the E-Learning in Physical Science for Sport (ELPS) [1]. Its purpose is to demonstrate the sort of application that can be developed to support Physics teaching using examples from sport. The idea was to develop an application that was more like a piece of kit that could be used in a variety of ways, rather than a multimedia title that you access in a linear way and is restricted to teaching exactly the material that it covers. The students could explore the application and perform a variety of experiments. To an extent the application was to be open-ended in that worksheets could be provided and used alongside the application at any point without the need for the application to be changed. In this way it was to be analogous to actually having a bow and arrow and being able to use it to perform a variety of experiments.

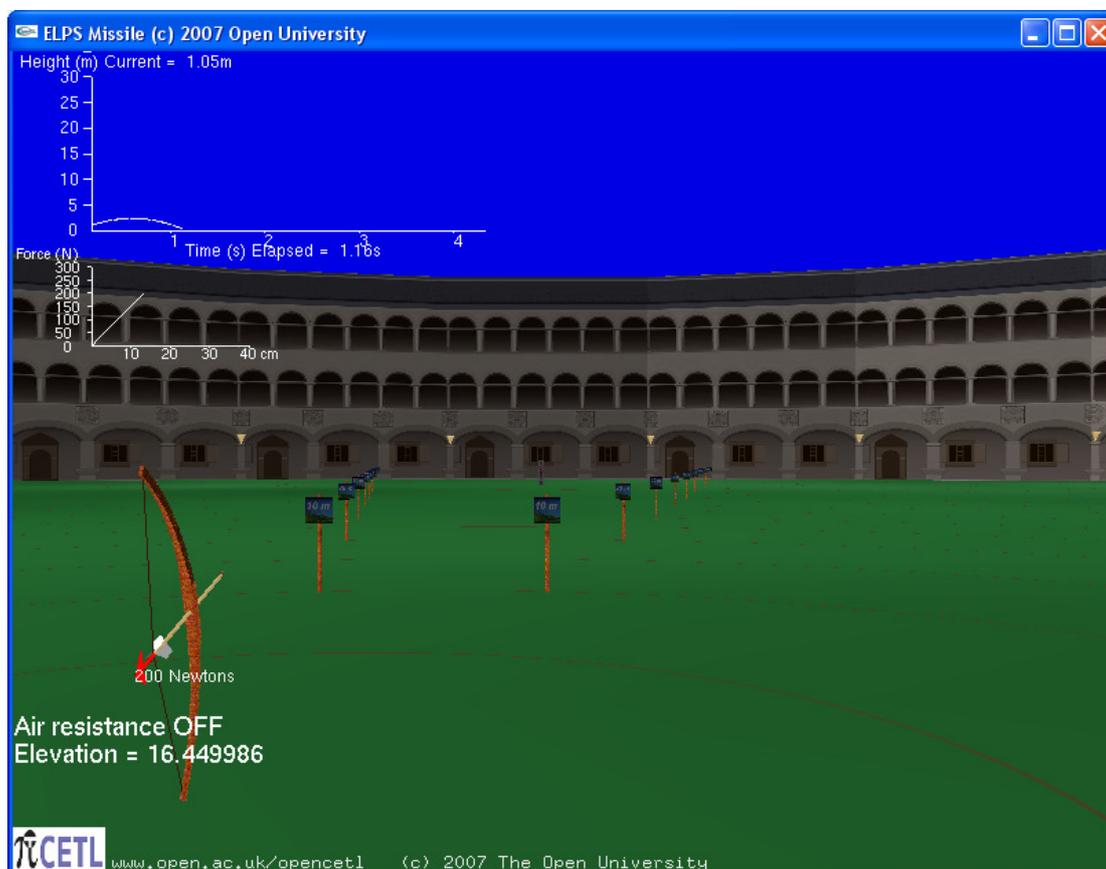


Fig 1 Normal screen view from behind the bow.

Implementation

The Archery application was implemented using C++ and the OpenGL package which had been used for earlier applications such as [2,3]. There is no collision detection or Physics engine included in OpenGL and both of these had to be explicitly coded. The use of Object Oriented programming was extremely beneficial allowing the implementation of programming objects for the main components of the application such as the bow and the arrows. This allowed a rapid development time of around four weeks and excellent stability. The only changes that have been necessary have been to the user controls.

Description

A virtual world has been created using OpenGL in which the user can move around and fire arrows from a bow (Fig 1). The trajectory in 3-D space is plotted in real-time and can be halted at anytime allowing the user to examine the components of its velocity vector (Fig. 2). The user's freedom to move in three dimensions means he can reposition himself close to the arrow to view its velocity vectors. He can also position himself in the line of fire if he so wishes and have the rather disconcerting view of arrows flying past.

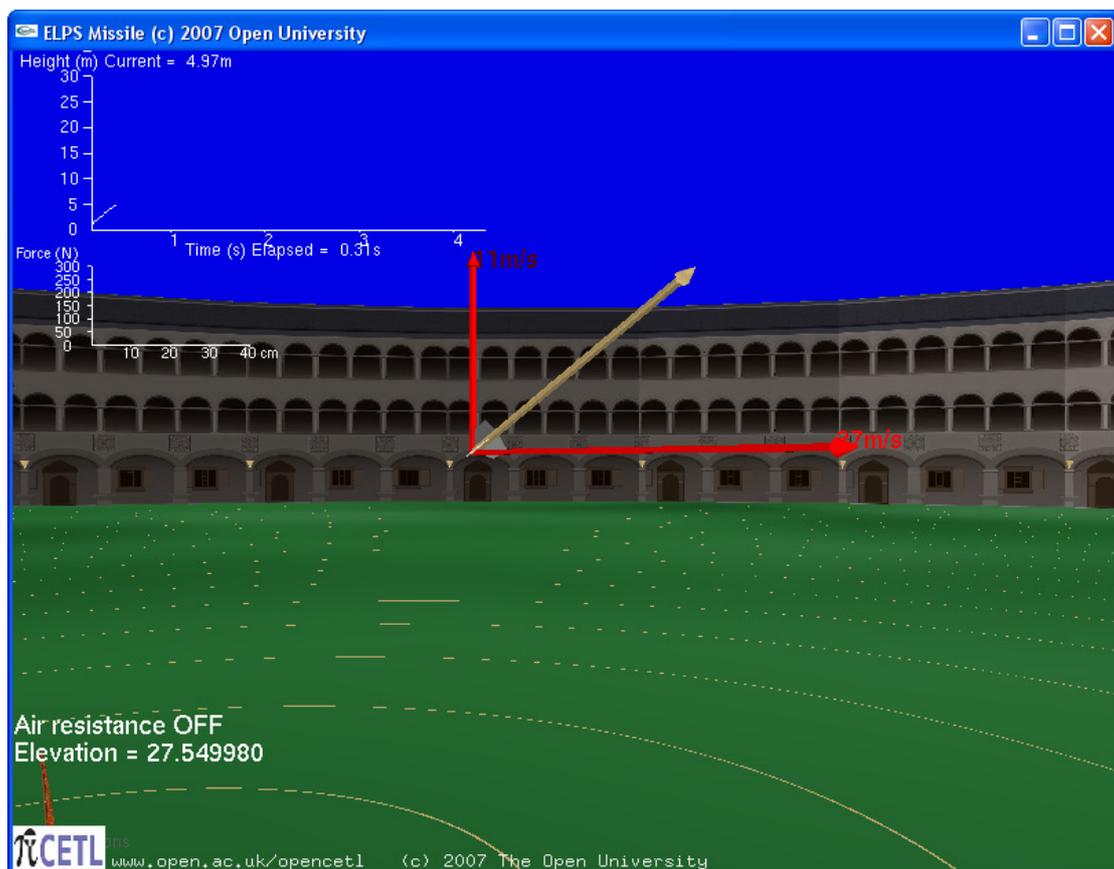


Fig2 Showing the velocity vectors

There is an option to include air resistance. Two-dimensional graphs of height against time and force against stretch are also plotted. All possible plots have deliberately been avoided to enable students to engage in their own graph drawing. My view is that students should be using pen and paper alongside the application to fully engage and understand the principles being

demonstrated. The arrow casts a shadow on the ground from an overhead light source. When there is no air resistance this shadow moves at a constant speed as the horizontal component of the arrows velocity is constant. This provides an effective demonstration of how the horizontal component, when it has no forces acting on it, is unchanging.

The package has been evaluated in the classroom by several teachers who have also indicated what material could usefully be added. Their comments and our responses will be discussed.

User experiences

These are some of the comments made by staff that evaluated the package:

In general simulation looks brilliant & certainly has great potential.

I love the idea of being able to stop the arrow mid flight & look at the velocity components. These vectors seem a bit small though, unless you zoom in, which means you are too close to be able to view the whole trajectory & easily compare components at different places along it.

The height/time graph is great, not sure if force extension graph for bow is useful?

First, the Y13s liked it – and enjoyed using it – however they were not sure how much they learned (they're quite good students and had projectiles well sussed last year!!)

They were surprised by the scream – but then, eventually, that seemed to be their driving motive! A good touch

The Y12s who are just starting projectiles liked it as part of a lesson – put things into perspective.

I usually start this topic with a home grown Powerpoint to convince them that horizontal and vertical motion are independent – then the text book – then this program would fit in well.

The following is a more subtle point:

I think it's important somehow to make it absolutely clear to students that this is a simulation and uses only those physical laws and relationships that have been programmed in. In a way, it's a sophisticated animated interactive diagram not an experiment. It will only tell them anything about the real world if the simulation is compared with real projectiles.

I'm not convinced of the importance of this remark. The application is very clearly a simulation as it is being carried out on a computer. It also does tell

the students something about the real world regardless of any comparison with real projectiles, although this is to be encouraged.

All of the negative remarks concerned the user interface:

I found the manipulation quite awkward (despite reading the ReadMe file assiduously), but maybe that's because I'm a complete novice at this sort of gaming stuff.

It wasn't intuitive – it took a while for the computer savvy students to figure out what was needed – there are several key conventions for game-players which these key-strokes did not follow.

moving around is tricky at first, but you do get the hang of it.

Perhaps a few buttons to return you to behind firing position/side view/behind target would be useful.

These comments and suggestions have been taken on-board and the user interface is now rather more intuitive.

Recommendations:

These were some of the suggestions made for how the application was to be used:

Concerning activities, I'd like to see at least some that refer to real live practical work alongside the simulation. I suggest the following (ideally preceded by play-time where students familiarise themselves with the simulation and its controls).

- 1 *Basic projectile motion*
- 2 *Turn off air resistance*

By trying a few examples, collect data to show how horizontal position and velocity change with time, and how vertical position and velocity change with time. Display the data graphically. Try different launch angles and speeds.

Experiment with some real projectiles (eg toy bow and arrow, catapulted marble, tennis ball) and see how range depends on the factors above. Be as quantitative as possible.

Compare the results with the simulated results.

Turn on air resistance and see if the simulated results become closer.

Conclusions

Although the approach was ultimately rejected for the ELPS project in favour of a conventional screen-by-screen title using Flash, it is felt that the evaluation showed the project to be very successful in terms of user acceptance and the rich learning experience it provided.

Furthermore, since the ELPS team have found it rather hard to provide all the screens necessary for their multimedia approach they have recently decided to use the Archery program to plug their shortfall.

Thanks to Elizabeth Swinbank, Jon Barker, Cecilia Collier and their classes for their evaluation and many useful comments.

References

[1]

<http://www.open.ac.uk/picetl/activities/details/detail.php?itemId=469e158dcc910&themeld=460261fae1b28> accessed April 2010.

[2] The Celestial E-Sphere (BBC Sky at Night cover disk. July 2008. Also www.open.ac.uk/picetl/projects/esphere accessed (2009)

[3] Lucas R and Kolb U (2009). Use of 3-D virtual environments in teaching astronomy and physics. *Frontiers in Science Education Research*. Ayhan Bilsel and Mehmet U. Garip (Ed.). Eastern Mediterranean University Press 2009.