Science Center to Go

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SCeTGo Missions

Analytical Description of Scenarios

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1 Introduction

Science Center To Go (SCeTGo) is a project that is producing creative, computer-mediated, inquiry-based resources for learning science using augmented reality (AR). This document is a description of the five small exhibits (miniatures) that comprise the Science Center to Go system. It is intended for teachers and researchers involved with the project, and other interested parties.

The Science Center To Go (SCeTGo) suitcase contains the resources, which consist of a laptop computer loaded with the SCeTGo software, a webcam and the miniatures (Figure 1):

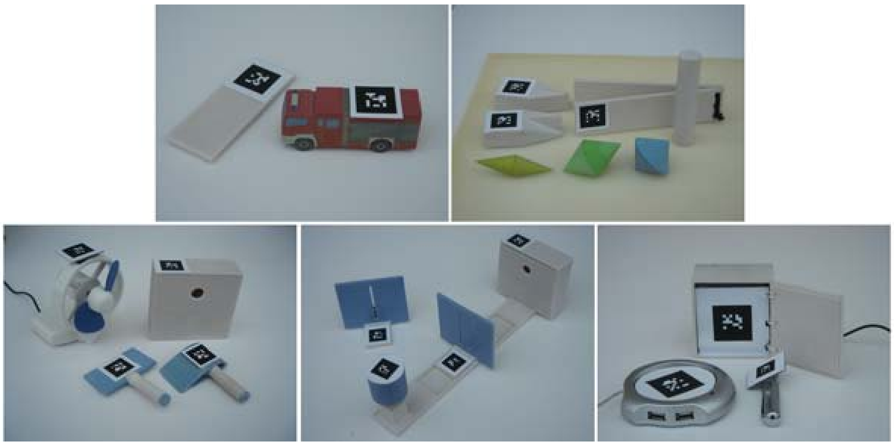

Figure 1
The miniatures: mini-fire truck, mini-double cone, mini-wing, mini-double slit and mini-cooler & heater

The miniatures are set up one at a time in the webcam's field of view. The webcam creates an image on the laptop screen. Software detects markers on the miniatures and uses this information to add an overlay to the image. As the miniature is manipulated, the overlay changes in response to the movement. The overlay depicts an aspect of the scientific phenomenon under investigation, for example trigonometric information or waves going through slits (Figure 2). This process of adding unseen elements to the image on the screen is the AR.

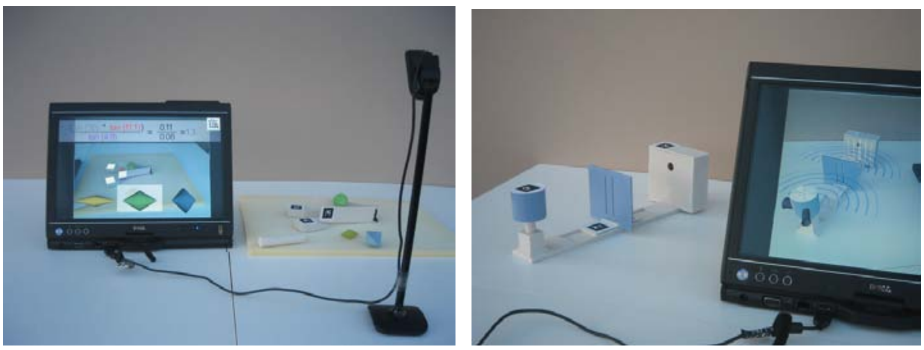

Figure 2
The AR adds elements to the image of the miniatures

The system and miniatures are described in more detail, together with suggestions for their use with different age groups, in English only, in the online manual available from the SCeTGo website (http://www.sctg.eu). The software and models were developed by the Fraunhofer Institute of Applied Information Technology (http://www.fit.fraunhofer.de/index.html)

2 Mini-fire truck (the Doppler effect)

Online demonstration: http://www.sctg.eu/miniature2.asp

The Doppler effect miniature consists of a model fire truck and a strip with an AR marker representing a microphone (Figure 3).

Figure 3
The mini-fire truck

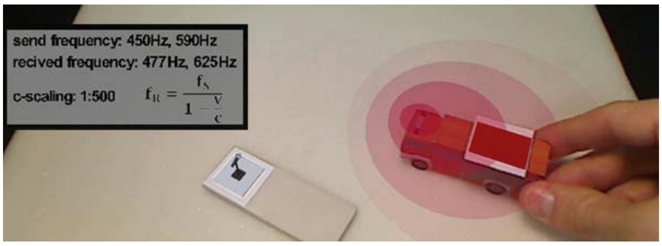

Figure 4
Fire truck as seen on the screen

Users activate the AR by moving the fire truck towards or away from the microphone (or by moving the microphone).

There are three elements to the AR:

1. visualisation of sound waves, represented by concentric circles, move out from the (theoretical) sound source, a siren at the front of the fire truck (Figure 4);
2. the fire truck's two-tone siren is audible, as received by the microphone;
3. the computed sent and received frequencies of the sounds appear in a panel on the screen (Figure 4). When the miniature is not moving the frequencies are 450Hz and 590Hz. Users can observe that they increase as the fire truck moves towards the microphone and decrease as it moves away.

The panel also displays the equation:

$$f_R = \frac{f_S}{1 - {}^{v}/_{c}}$$

where f_R is the received frequency, f_S is the emitted frequency, v is the relative velocity and c is the speed of sound. This equation applies when the fire truck is moving towards the microphone or the microphone towards the fire truck.

Users can listen to the siren, observe the spacing of the sound waves, note the frequencies of the sounds detected and make connections between these effects. The AR responds appropriately if the fire truck, the microphone or both are moving.

3 Mini-double cone (classical mechanics)

Online demonstration: http://www.sctg.eu/miniature5.asp
Online explanation, together with history, animations and trigonometry:
http://plus.maths.org/issue40/features/uphill/index-gifd.html

The SCeTGo double cone miniature consists of a set of rails whose slope and angle of divergence can be varied, together with three double cones and a cylinder (Figure 5).

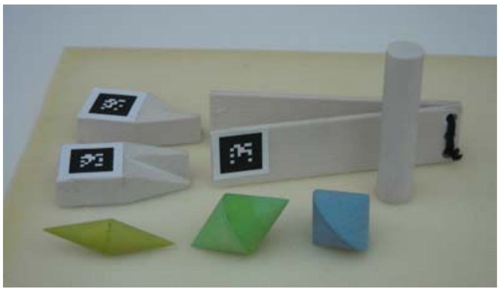

Figure 5
Components of the mini-double cone

The rails are set up on the rail supports to make a set of sloping, diverging rails. The cylinder always travels down the slope. But if the divergence of the rails is sufficiently wide for the centre of mass of the cone to drop, a double cone can travel up the slope (Figure 6).

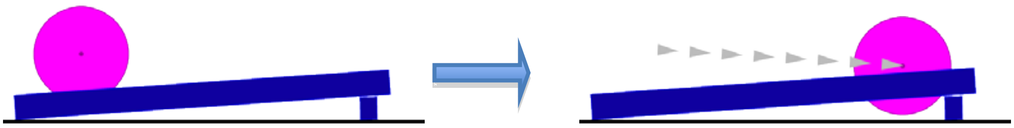

Figure 6
Double cone rolling uphill, starting and finishing positions

The objective is to investigate the conditions under which this happens. The AR facilitates this by measuring the variable angles. The angles of the apices of the 3 cones, 2γ (Figure 7), are 30°, 60° and 90°. The AR measures α, the angle of inclination of the rails (Figure 8), and β, half the angle of divergence of the rails (Figure 7).

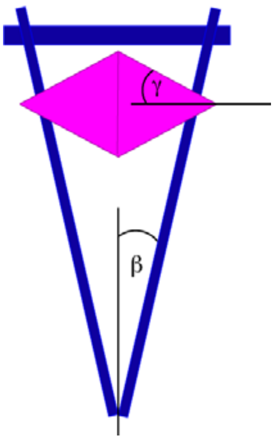

Figure 7
Angles β and γ

Figure 8
Angle α

The AR computes:

$$\frac{\mathrm{Tan}\ (\beta)\ \mathrm{x}\ \mathrm{Tan}\ (\gamma)}{\mathrm{Tan}\ (\alpha)}$$

If this is >1 then the double cone rolls up the slope. If it is <1 the cone rolls down. In figure 9 the cone is balanced. The colours of the elements of the formula onscreen correspond with the colour of the cone and the angles of the miniature.

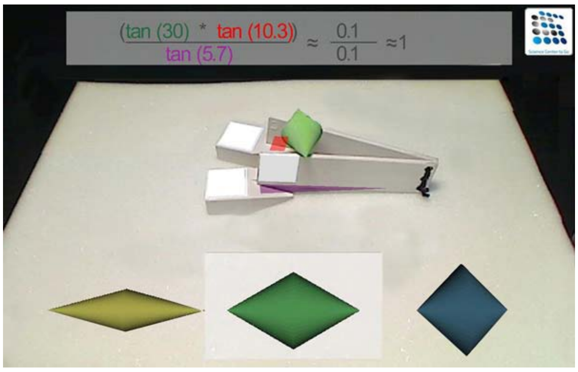

Figure 9
The double cone as it appears on the screen

4 Mini-wing (wing dynamics)

Online demonstration: http://www.sctg.eu/miniature1.asp

The miniature aeroplane wing (mini-wing) consists of an object shaped like a section of an aeroplane wing, connected to a box (Figure 10). The angle of the wing with respect to the ground can be changed. There is also a fan that is powered through a USB connection, and a flat wing for comparison purposes. This miniature is designed with a specific activity in mind, which is to help explain why aeroplanes can fly and to determine the angle of the wing that maximises the lift afforded to the aeroplane.

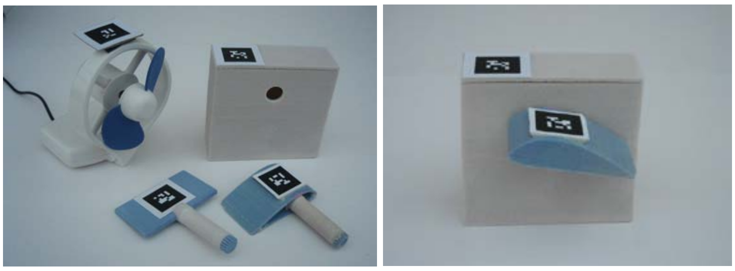

Figure 10
Components of the mini-wing miniature and wing set up for use

Users can set up the fan and adjust the angle of the wing. The AR measures this angle and overlays five elements to the image of the wing on the laptop screen (figure 11):

1. The body of the aeroplane.
2. The relative speed and direction of airflow above and below the wing. Curved green lines represent the direction of airflow. The blue and red arrows on these lines represent the relative speed of air above and below the wing. The airflow speed increases as the fan is moved nearer to the aeroplane.

3. Uplift. The solid green arrow pointing upwards from the wing represents the force acting to lift the wing.
4. Drag. The solid pink arrow represents the force acting against the wing's forward motion. If this is great the plane will stall.
5. Air molecules being sucked through the fan.

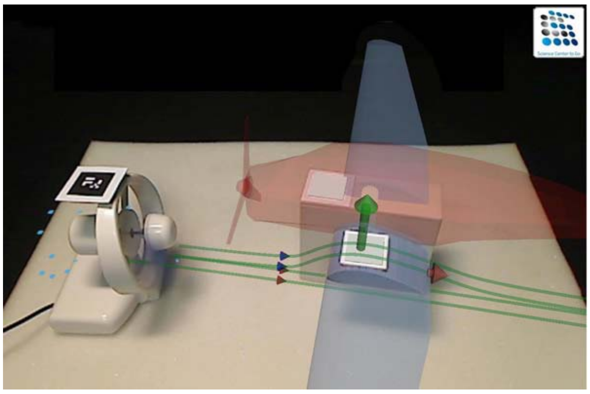

Figure 11
The mini-wing as it appears on the screen

5 Mini-double slit (quantum mechanics)

Online demonstration: http://www.sctg.eu/miniature3.asp
Simple animated explanation: http://www.youtube.com/watch?v=DfPeprQ7oGc

The aim of the mini-double slit is to use AR to simulate the behaviour of particles and waves passing through single and double slits. It also facilitates the exploration of the phenomenon of wave-particle duality.

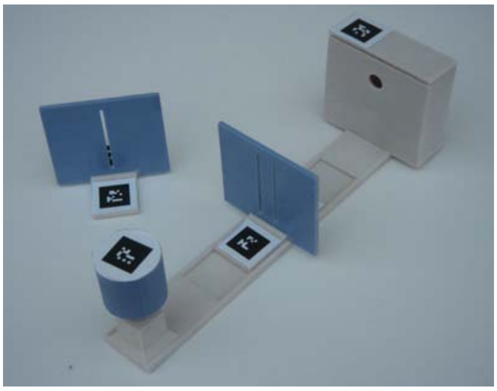

Figure 12
Components of double-slit miniature

The miniature consists of (Figure 12):

- a background box;
- a support for the screens with a track for the slits;
- two interchangeable screens, with single and double slits;
- a "cannon" that can be rotated to "fire" large particles, waves or electrons.

In particle mode the AR adds particles passing through the slit/slits and striking the background. The thickness of the lines builds up with time (Figure 13).

In wave mode the AR shows the effect of waves originating from the cannon. The lines on the background of the double slit version represent vertical extensions of the points where the waves interfere constructively (Figure 14).

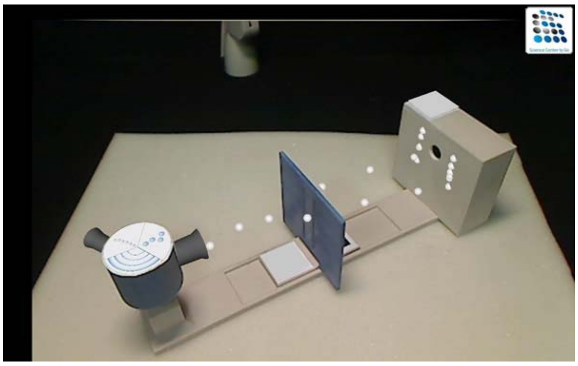

Figure 13
Double slits in large particle mode

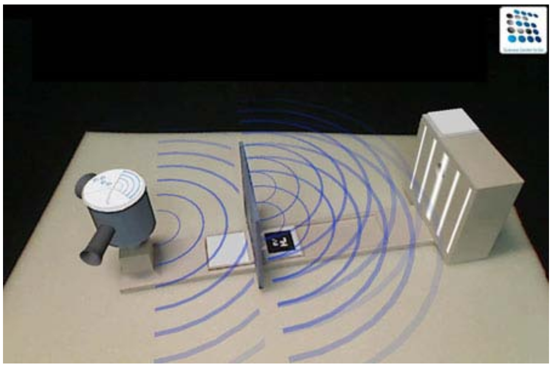

Figure 14
Double slits in wave mode

In wave-particle duality mode electrons are fired at the slits, and the pattern on the box when there are two slits shows several rows of particles building up, showing that electrons have properties of both waves and particles.

6 Mini-cooler & heater (kinetic theory of gases)

Online demonstration: http://www.sctg.eu/miniature4.asp

This miniature consists of a tiny working USB cooler and hotplate together with a thermometer (Figure 15).

Figure 15
Fridge, hotplate and thermometer

The purpose of the miniature is to visualise how the speed of gas molecules changes with temperature. The AR shows representations of molecules moving in the vicinity of the thermometer (Figure 16). The software detects the proximity of the thermometer to the hotplate or the fridge, and varies the speed of molecule movement accordingly.

The screen also shows a graph of molecule speed against temperature, based on the equation:

$$v = 20.5\sqrt{(\theta + 273)}$$

where v is the molecule speed in m/s and θ is the temperature in °C (Figures 23 and 24). A red line on the graph corresponds to the temperature on the AR thermometer.

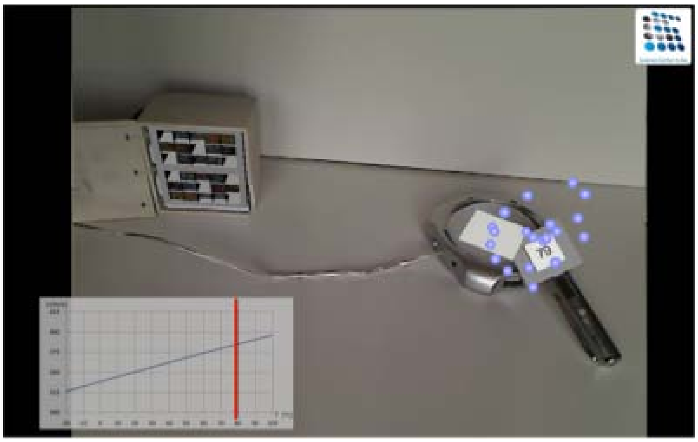

Figure 16
Screen visualisation of the mini-cooler & heater

The temperatures are theoretical and are not the actual temperatures of the hotplate, fridge or room. Also, in order to illustrate the underlying principles, the molecule speed observed is many orders of magnitude slower than the actual speed, and the difference in speed at different temperatures is exaggerated.