MODELLING PARTICLES IN THE ELECTROMAGNETIC FIELD FOR HIGH SCHOOL PHYSICS COURSE

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Abstract: This paper explains bachelor's thesis - software program able to simulate influence of electromagnetic force on subatomic particles. This program could be used for improvement of high school physics education. Requested attributes are intuitive user interface, low system requirements and explanatory graphical output.

Keywords: C++, Qt, OpenGL, simulation, physics, particles, electromagnetism, education, improvement

1 INTRODUCTION

The purpose of this work is to create a simulation program describing the behaviour of an electrically charged particle in an electromagnetic field. This issue takes place in high school education. For better understanding of this phenomenon, computer aided visualization is helpful [1].

There are some simulators covering this issue, e.g. online applets [5], but the output is barely understandable for new user (1). Interface need to be simple and straightforward.
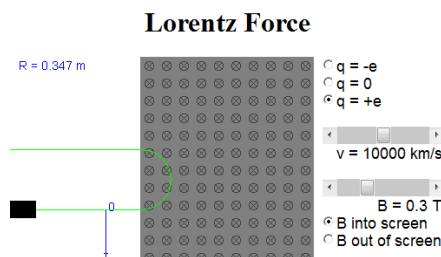

Figure 1: Online Java applet

2 PRINCIPLES OF ELECTROMAGNETIC THEORY

In 19th century James Clerk Maxwell has formulated his electromagnetic theory - unification of experiments and equations of electricity, magnetism and even optics into a consistent theory [2]. High school physics goes out of this theory [3].

2.1 PARTICLES

Subatomic particles are simplified to be point-like particles with no size, but with electrical charge (q) and mass (m). Elementary charge is $e = 1.6021765 \times 10^{-19} C$ (the charge of proton).

Particle	Mass [kg]	Charge [C]
Proton	$1.672621637 \times 10^{-27}$	$1.6021765 \times 10^{-19}$
Electron	$9.1093826 \times 10^{-31}$	$-1.6021765 \times 10^{-19}$
Neutron	1.6749×10^{-27}	0

Table 1: Particle properties

2.2 FIELDS

There are many different types of fields in this theory, depending on which property of general electromagnetic field we need to emphasize. First distribution is by type of force, which the field consist of. Thereby we know electric and magnetic fields. Second distribution is by type of intensity of given force. Intensity is represented by force lines. Their shape divides fields into uniform (parallel force lines) and radial (radial force lines).

2.3 FORCES

Electrical current is caused by change of electromagnetic field. Thus, every moving charged particle generates electrical current. Outer electromagnetic field interacts with particle and creates force (Lorentz force). This force affects velocity (v) of particle but the impact depends on field type (1).

$$F = q[(B \times v) + E] \tag{1}$$

Magnetic field (B) causes that particle changes its direction, but the magnitude of velocity (kinetic energy) remains the same [4]. Electric field (E) changes kinetic energy of particle.

3 SOFTWARE SOLUTION

According to project task, typical school PC runs different versions of Windows (95, 98, XP, Vista). Thus, simulator should have minimal possible system requirements. I decided to create desktop application with use of Qt Toolkit. Qt offered multiplatform development, native look-and-feel, integrated OpenGL widget, garbage collection, rich documentation and I was already familiar with its use.

3.1 SOFTWARE ARCHITECTURE - MODEL-VIEW-CONTROLLER (MVC)

Program respects object-oriented programming paradigm. There are classes for storing informations about particles and fields, for controlling simulation, graphical output, setting up values etc. All data about objects in simulation are stored in DataModel. Class Simulator controls simulation progress and updates values in this model. Class GLWidget takes this data and represents it graphically. Data in text form are available in TreeView. User can access and edit them in this TreeView via Delegates, which take care about creating editors for this data.

3.2 3D GRAPHICAL REPRESENTATION

Main goal was to deliver easily understandable visualization, showing movement of particles and cause of this movement. Particles and radial fields are shown as spherical objects. Uniform fields are shown as prisms with arbitrary polygon base, within bordered area. These graphical representations correspond to intuitive thoughts. User has the possibility to display another helper objects, i.e. let the vectors of velocity and force show, let the labels of these vectors show and let the particle trace show. Particle trace is a chain of previous positions - user can easily see behaviour of particle in time.
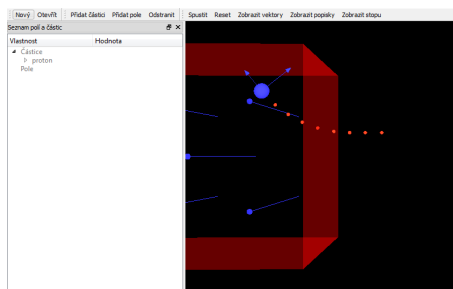
Figure 2: Screenshot of application with one particle in magnetic field

Simulator itself is able to work with a number of different fields and particles in one simulation, but user interface is adapted for easy work with textbook examples. At first, user defines an EM field. Then he can add particles. Position coordinates are absolute, but velocity is defined by its magnitude and angle with field force lines.
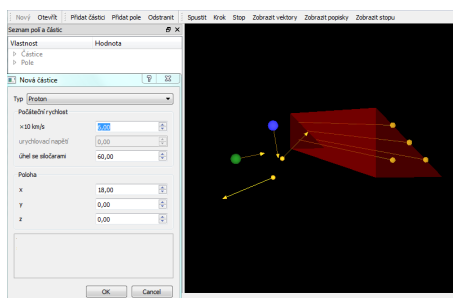

Figure 3: Adding of a new particle into simulation with triangular prism

4   CONCLUSION

Methods for displaying and manipulating data are strongly separated. This ensures future upgradeability and maintainability. Important part of work was to provide output in more understandable way than before. There is set of typical examples made after textbook, and program allows users to define new scenarios. 3D graphical representation is much more comfortable and easier to understand, than simple 'curve in the square' simulators.

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