FORMING OF PHYSICAL KNOWLEDGE IN ENGINEERING EDUCATION WITH THE AIM TO MAKE PHYSICS MORE ATTRACTIVE

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This paper deals with increasing of key competencies in engineering education as a result of using videoanalysis of real life situations as physical problems by means of the program Tracker - Video Analysis and Modeling Tool (Open Source of Physics). This computer program helps to calculate some physical quantities and makes studying of physics easier. As our previous investigation has revealed, the idea of technical universities students about some physical processes is in many cases distorted or even mistaken (e.g. braking trajectories of cars). By preparing video experiments and through realization of video measurements we can build in students the correct conception about the processes and phenomena around us. The prepared set of video experiments was placed at the World Wide Web as an aid serving for visual demonstration, explanation and physical analysis of real processes. The physical analysis using Tracker is for students more demonstrative, learning physical equations is quicker, application of the physical laws is more illustrative.

Keywords: videoanalysis, development of key competencies, physics popularization, Tracker

INTRODUCTION

Video analysis using program Tracker (built on the Open Source Physics (OSP) Java framework) in the educational process introduces a new creative method of teaching physics, makes natural sciences more interesting for students. Exploring the laws of nature in this way can be amazing for the students because this educational software is interactive, illustrative, improves their performance, inspires them to think creatively and it can help in studying physics.

Physics and technology are often considered to be difficult subjects. The main reason is that it is not easy to explain empirical laws and dynamic phenomena by means of textbooks. Multimedia technologies have shown their potential in teaching of scientific subjects. New techniques attract students’ attention. If studying physics is accompanied with work on computers, a new form of education arises that will become very attractive (at all stages of the educational process - starting with primary schools and ending with universities) [1]. Several innovative methods in physics education were described and evaluated and the impact of these methods on the learning outcomes of students of physics was investigated [2]. It was found that the use of multimedia teaching aids in technical education on the 2nd level of primary schools significantly affects the level of knowledge of pupils, particularly in terms of performing, remembering, understanding, specific transfer and active learning [3]. Online literature, simulation with an online tutoring system and association of the remote experiments can result in an online practical course, which can be very useful in engineering education and can be helpful for the engineering students throughout their academic studies and also the career as an engineer [4]. It is very important to use the multimedia tools in other subjects including basic education to make science and technology more appealing and to address the scientific apathy crisis of young people [5]. The game provides many examples that can bring physics to life in the classroom. Especially the mechanical properties of these materials are worth a physics classroom discussion [6]. All we need for video analysis is a camera for the preparation of motion files - video experiments. With the help of a high-speed camera and the program Tracker [7] the students can study certain motion in detail. They can
observe various characteristics of the motion and learn the basics of classical physics while having fun. The video analysis gives the students a simple and easy way to understand the process of movement. These activities are made possible by integrated ICT (information and communication technology) tools that are used for measurements by means of videos (via point-tracking). The program Tracker seems to be a useful modeling tool, too. The computer modeling enables the students to relate the results of measurements to theory, showing relations between the graphs obtained using a model and a measurement. Through direct visual comparison of the video images and model overlays the students can explore different model parameters and equations in real-work context, find differences and similarities between an idealized object and the reality.

**ANALYSIS OF MOTIONS USING TRACKER**

Tracker was designed to be used in introductory physics courses. Using this video analysis and modeling tool students can investigate how the body (its center of mass) changes its position, velocity and acceleration in time (Fig. 1). We used camera Casio Exilim Ex-FH25 for preparing video files which allow us to record videos with 30, 120, 240, 420 and 1000 frames per second (fps) (we can buy it for about 300 Euro at this time, which is cheaper than a professional high-speed camera). In a typical video analysis, students capture and open a digital video file, calibrate the scale, and define appropriate coordinate axes. From the number of frames per second (30 or 120 fps) the time is deduced, while the position information can be measured in two dimensions using the video image after calibration. The function autotracking in this program allows for accurate tracking without mouse. The motion can be divided into two parts: the horizontal component and the vertical component. These two components can be calculated independently of each other and then the results can be combined to describe the total motion \( (x(t), y(t), v_x(t), v_y(t), a_x(t), a_y(t)) \).

![Fig.1. Analysis of a motion of a ball using program Tracker.](image-url)
One can use user-defined variables for plotting and analyzing video motions. Students can fit time dependencies of position (velocity, acceleration and other) using a data tool which provides a data analysis including automatic or manual curve fitting of all or any selected subset (Fig. 2). The vertical position and the velocity are plotted and fitted to see the correlation between the real data and the kinematic equations.

![Fig. 2. Analysis of position and velocity of a ball in vertical direction.](image)

Figure 2 shows that the velocity of the volleyball ball (squares) prior to serve changes in the vertical direction nearly at the same rate throughout the motion (first part of motion). Because of this the average acceleration in the vertical direction over any time interval equals the instantaneous acceleration at any instant. Therefore, the motion of the ball in the vertical direction prior to the serve can be mathematically described by equations valid for motion at a constant acceleration $a_y$

$$v_y(t) = a_y t + v_{0y} \quad \text{and}$$  

$$y(t) = \frac{1}{2}a_y t^2 + v_{0y} t + y_0,$$

where $v_{0y}$ and $y_0$ are the velocity and position at the initial time $t = 0$; $y$ and $v_y$ position and velocity at some later time $t$. By doing a mathematical fit (Fig. 2) students can find that the trajectory of this ball (circles) is always a parabola which can be described by means of the equation

$$y = a't^2 + b't + c'.$$

Comparing equations (2) and (3) gives $a' = 1/2a_y$, $b' = v_{0y}$, and $c' = y_0$. From this fit the students will find that $a_y = -9.918 \text{ m.s}^{-2}$ which is in a good agreement with the value of the free-fall acceleration. Analogically the mathematical fit of the velocity of the ball in vertical direction is always a straight line which can be described by the equation $v_y = at + b$. Comparing this equation with equation (1) students get $a = a_y$, $b = v_{0y}$. This gives $a_y = -9.959$
\( m \cdot s^{-2} \) which is in a good agreement with the value of the free-fall acceleration, too. The second parameter \( b = 3.03 \ m \cdot s^{-1} \) \((3.014 \ m \cdot s^{-1})\) corresponds to the initial velocity of the ball in the vertical direction after throwing the ball into the air by a student.

To do a physical analysis we can think about "Projectile motion" which is a type of a two-dimensional motion in the \( xy \) plane with constant acceleration whose components are \( a_x = 0 \) and \( a_y = -g \). (We can assume that the effect of air resistance is negligible.) Usually it is useful to think of this motion as the superposition of two one-dimensional motions: (1) motion in the horizontal direction at a constant velocity and (2) free-fall motion in the vertical direction subject to a constant downward acceleration of magnitude \( g \) \[8\].

Using the functions \textit{Slope} and \textit{Area} in the program Tracker one can demonstrate the mathematical connection with the derivative and the integral of functions (the first derivative of the function \( y(t) \) at \( t = 0.63 \ s \) shows the value \(-3.32\) which is the same as the velocity at this time (see the table in Fig. 2); integration of the function \( v_y(t) \) in the range from \( t_1 = 0.033 \ s \) to \( t_8 = 0.264 \ s \) shows the value \( \text{area} = 0.356 \) which is very close to the difference of y-positions at these times \((y_8 - y_1) = 1.472 \ m - 1.115 \ m = 0.357 \ m\).

There are two types of models: analytic and dynamic. An analytic model defines position functions of time, while a dynamic model defines force functions and initial conditions for numerical solvers.

Fig.3. Analytic and dynamic models of motion with initial conditions.

Figure 3 shows how the students have analyzed the motion of the ball after serve (the second part of the motion, after \( t = 0.63 \ s \)) and defined position functions of time and force functions with initial conditions in two directions. From these models one can see that students have thought about constant-velocity motion in the horizontal direction and accelerated motion (with free-fall acceleration) in the vertical direction. The only force acting on the ball was the force of gravity (the effect of air resistance has been considered to be negligible).
It was interesting for the students to realize that the motion of the ball could be considered as a superposition of the displacement if no acceleration were present, and the term which arises from the acceleration due to gravity. Except for \( t \) (the time of flight), the horizontal and vertical components of the projectile’s motion were completely independent of each other.

After this analysis the students can copy and print pictures from any viewpoint which can be subsequently used in labs and studying materials. Thus using the program Tracker, the teacher can easily demonstrate the relationships between mathematical functions and the real world. Our example has demonstrated the fact that many of the real motions of interest can be described by analytic functions.

CONCLUSIONS

Comparison of the traditional teaching methods with the methods of the video analysis using the program Tracker has revealed that the interactive methods are easier for the students, they have fun when recording and analyzing their own videos, they can set individual pace for their work. They are usually working in pairs, which gives them the opportunity to exchange their actual pieces of knowledge. We can confirm that the competencies of the students are developed and increased by working with Tracker. This video analysis and modeling tool helps them to understand the natural sciences principles and phenomena more deeply, develops skills of abstraction and projection, awakes curiosity towards nature and surrounding world and makes physics a lot more fun.

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References