Video analysis of motions

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Abstract

Video analysis using program Tracker (Open Source Physics) in the educational process introduces a new creative method of teaching physics, makes natural sciences more interesting for the students (Brown, 2009). Exploring the laws of nature in this way can be amazing for the students because this educational software is illustrative, interactive, inspires them to think creatively, improves their performance and it can help in studying physics. With the help of a high-speed camera (for the preparation of motion files - video experiments) and the program Tracker the students can study certain motion in detail. The video analysis gives the students simple and easy way to understand the process of movement. 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. A post-instruction assessment of the students' ability to interpret kinematics graphs indicated that groups which used video analysis tools generally performed better than students taught via traditional instruction (Beichner, 1996). It has been confirmed that the competencies of the students have been more developed and their knowledge has been more increased through working with program Tracker as opposed to groups taught by traditional methods (Hockicko, 2012). Video analysis and modeling help the students to understand the natural sciences principles and natural phenomena more deeply, develop skills of abstraction and projection, awake curiosity towards nature and the surrounding world and make physics a lot more fun.

Keywords: video analysis, conceptual thinking, ICT – in education, attractiveness of education, computer aided learning

Summary

This paper deals with increasing the key competencies in engineering by analysing real life situation videos (physical problems) by means of video analysis and the modelling

tools using the program. Video analysis, using the program Tracker (Open Source Physics), in the educational process introduces a new creative method of teaching physics and makes natural sciences more interesting for students. This way of exploring the laws of nature can amaze students because this illustrative and interactive educational software inspires them to think creatively, improves their performance and helps them in studying physics.

Introduction

Many authors confirmed that during the last two decades, entry-level engineering students' basic abilities in Physics (and Mathematics) have decreased dramatically (Tilli *et al.,* 2013; Krišťák *et al.*, 2014). 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 already shown their potential in teaching scientific subjects. New techniques attract students' attention. If studying physics is accompanied by a computer program, a new form of very attractive education arises (at all stages of the educational process - starting at primary schools and ending up at universities) (Hockicko, 2010). It is very important to use multimedia tools in other subjects, including primary education, to make science and technology more appealing and to address the scientific apathy crisis of young people (Bussei *et al.,* 2003). Online literature, online tutoring system simulation and the association of the remote experiments can result in an online practical course, which can be very useful in engineering studies and can be helpful for engineering students throughout their academic studies and during their engineering careers (Khachadorian *et al.*, 2011). Physics is based on experimental observations and quantitative measurements. The fundamental laws are expressed in the language of mathematics - the tool that provides the bridge between theory and experiment. Teachers constantly work on improving students´ understanding of various phenomena and fundamental laws. One of the new creative methods of teaching physics which makes natural sciences more interesting for the students is video analysis using the programs Tracker (Open Source Physics) or Coach (Brown *et al.,* 2009). Collaborative projects based on digital video analysis provide an educational, motivating, and cost-effective alternative to traditional course-related activities in introductory physics (Laws *et al.*, 1998).

Several innovative methods in physics education were described and evaluated and the impact of these methods on the learning outcomes of physics students was investigated. In the 1980's David Hestenes and Ibrahim Halloun (Halloun *et al.*, 1985) published papers on didactic research, whose object were students of secondary schools and universities, dealing with misconceptions in Newtonian dynamics. One of the research results was the test (Force Concept Inventory (FCI)) (Hestenes *et al.*, 1992) containing questions from Newtonian mechanics dealing with everyday life. The authors decided to research whether students understand the basic mechanics concepts sufficiently; how they are able to work with them and apply them into various everyday situations. The global test results showed that the traditional teaching of the Newtonian mechanics in the early years of university studies eliminates the wrong perception of students acquired during their secondary school studies only to a small extent. One of the most important features of FCI is that it can be used to notice the common-sense misconceptions students have when trying to apply Newtonian mechanics ideas (Martín-Blas *et al.*, 2010). It was also shown that traditional lectures or seminars help to acquire only basic knowledge without deeper understanding and ability of problem solving; the students do not show conceptual understanding of the subject which should result from a sufficient number of solved quantitative tasks and from logically clear lectures (Redish, 2003).

This paper deals with real life situations video analysis using programs Tracker.

Tracker and video analysis of motion

All we need for a video analysis is a camera (mobile phone, tablet) to prepare motion files - video experiments. With the help of a high-speed camera and the program Tracker 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. Video analysis gives 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 use videos (via point-tracking) to measure.

A Casio Exilim Ex-FH25 and EX-ZR1000 cameras were used for preparing the video files; we assigned this task to students. These cameras allowed us to record videos with 30, 120, 240, 420 and 1000 frames per second (fps) (these cameras are cheaper than a professional high-speed camera).

The main task of a video analysis is to build the right conception of the natural phenomena and in the next step to use them for physical analysis. All we need is:

- a final video in the following formats: avi, mov, mpg;
- to know the video´s number of frames per second (fps) (for calculation of Δt);
- real dimensions in the video, for example 1 meter.

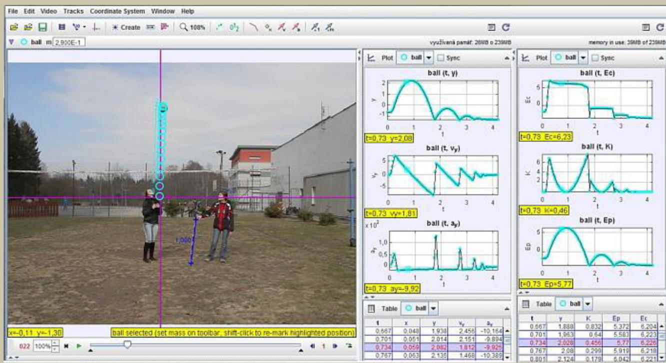

Fig. 1. Video analysis of a thrown ball in y-direction using program Tracker

Students can find some important parameters in a description of a task (e.g. mass), other parameters can be found only by carrying out the task using the programs Tracker (e.g. velocity, acceleration, momentum, energy).

By means of the Tracker (or Coach) students can detect the relationship between physical quantities and describe a motion using time dependencies. The Tracker offers time dependencies of 22 physical quantities (and/or we can define other) and data processing by means of graphs and tables. From the number of frames per second (30 fps or 120 fps usually) the time is deduced ($\Delta t = 0.033$ s or $\Delta t = 0.0083$ s) while the position can be measured in two dimensions (x, y) using a calibrated video image. The autotracking function in this program allows accurate tracking without a mouse. The studied motion can be divided into two parts: the horizontal component and the vertical component (Fig. 1). These two components can be analysed individually and the results can consequently be combined to describe the total motion (x(t), y(t), vx(t), vy(t), ax(t), ay(t)).

One of the tasks for students: analyse the motion of a ball after throwing it into the air. Find the expression for the speed and the position of the ball as a function of time (the effect of air resistance has been considered to be negligible). What is the acceleration/deceleration of the ball in different positions (in move up of the ball, in maximum position and move down)?

By means of the program Tracker (Data Tool) we can apply infinitesimal calculus and the program calculates velocity and acceleration from the time changes in different positions. The students can fit the time dependencies of position (Fig. 2), velocity (Fig. 3), acceleration and other time variables using a data tool which provides data analysis, including automatic or manual curve fitting of all or any selected subset of data. The position and the velocity can be plotted and fitted to see the correlation between the real data and the kinematic equations (Hockicko 2010, 2012).

Figures 2 and 3 show the analysis of position (squares) and velocity (circles) of the volleyball ball in the vertical direction. By doing a mathematical fit (Fig. 2) students can observe that the trajectory of this ball (squares) is always a parabola which can be described by means of the equation

y = at2 + bt + c . (1)

The projectile motion of the ball in the vertical direction can be mathematically described by equations valid for motion at a constant acceleration ayy = 1/2ayt2 + v0yt + y0 . (2)

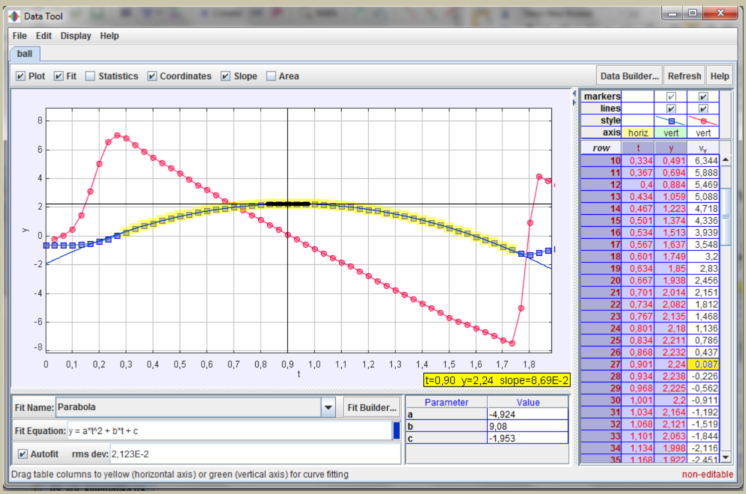

Fig. 2. Analysis of a y-position of a thrown ball using program Tracker (Data Tool)

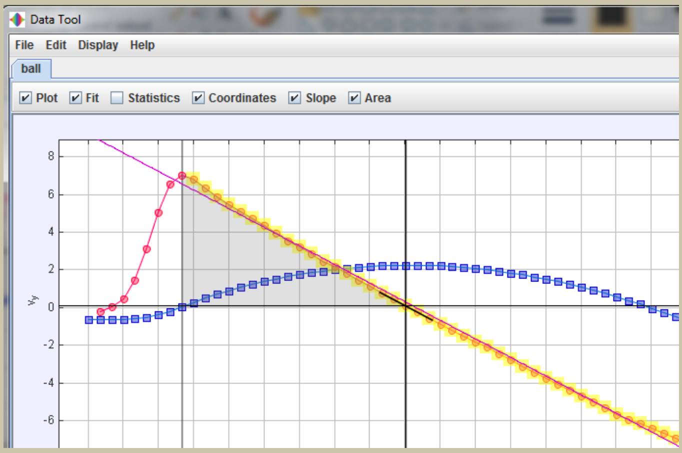

Fig. 3. Analysis of a y-velocity of a thrown ball using program Tracker (Data Tool)

Comparing equations (1) and (2) gives a = 1/2ay, b = v0y, and c = y0. From this fit students find out that ay = - 9.848 m.s-2 which is in a good agreement with the value of the free-fall acceleration. The second parameter b = 9.08 m.s-1 corresponds to the initial velocity (v0y) of the ball in the vertical direction after throwing it into the air. The third parameter c = -1.953 m corresponds to the initial position (y) of the ball (it can be changed by modification of the position of axes; in ideal case we can determine initial position y(0)).

Analogically the mathematical fit of the velocity of a ball in vertical direction (Fig. 3) is always a straight line which can be described by the equation

vy = at + b = ayt +vy0 . (3)

Eq. 3 gives ay = - 9.871 m.s-2 which is in a good agreement with the value of free-fall acceleration, too. The second parameter b = 9.194 m.s-1 corresponds to the initial velocity of the ball in the vertical direction (we can find it using extrapolation of linear fit).

Using the functions Slope and 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= 0.90 s shows the value 0.0869 which is the same as the velocity at this time (see the table in Fig. 2). Integration of the function vy(t) in the range from t8 = 0.267 s to t27 = 0.901 s shows the value area = 2.20 (Fig. 3) which is very close to the difference of y-positions at these times (y27 – y8 = 2.24 m – 0.038 m = 2.202 m). Function Slope shows the value -9.92 which means the value of the free-fall acceleration at the time t27 = 0.901 s (vy(0.901) = 0.09 m/s which is very close to zero velocity in the maximal vertical position of the ball). As students can see from Fig. 3 the position (velocity) of the ball in the y-direction increases and decreases (decrease and increase) in the time interval (0.267 s – 1.74 s) but the acceleration of the ball (slope) is the same in the whole investigated time interval. (Not zero, as the majority of students wrongly think about acceleration in the maximum position of the ball!)

Next motivation for analysis is: “What was the force exerted by the student throwing the ball?” Program Tracker offers two types of models: analytic and dynamic. The analytic one defines position functions of time, while the dynamic one defines force functions and initial conditions for numerical solvers. The students have analysed the motion of the ball after throwing it and defined position functions of time and force functions with initial conditions in two directions. The students have thought about the 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).

Feedback

Students were asked to make comments on the learning carried out by means of video analysis and modelling tools. What have they considered to be positive about this form of education?

- cooperation with the teacher, professor's individual approach to each student, supporting the self-reliance of the individual;
- quick explanation of the principles of problems, quick and clear form of the studied problems, time saving;
- not only one student was solving a problem the blackboard, all students worked independently on solving the problem using the computer;
- comprehensibility (picture information), the large number of solved problems during practicing, I think that it will be good to continue with this form of education;
- accessibility of information (equations) and solved problems, availability of instructions for solving new problems, an opportunity to find information in a short time;
- a very advantageous form of learning, if I don't understand anything, I can ask quickly but I have to think and find the information individually;
- I usually participated in discussions, when I discussed with the others, I learned more. In my opinion, discussion made the lessons more motivating – I've had new ideas. Finally, the answers were discussed with the teacher and it was important for the learning;
- the learning was very good, lively, congenial atmosphere, gingering us up, something new for us, it was quite a good change, I was delighted with this form of learning, I liked this form of learning;
- these tasks were unusual, they did not require calculations like normal exercises do but knowledge of concepts;
- I have learned and understood a lot but just the exam will show if it was enough.

Conclusion

The use of interactive methods in teaching physics have significantly influenced the level of students' knowledge. The students´competencies can be developed and their knowledge can increased by working with the program Tracker.

Students have declared that the video analysis and modelling tools helped them to understand the natural sciences principles and phenomena more deeply, developed their abstract thinking and projection skills and their understanding, aroused their curiosity towards the surrounding world and nature, interconnected physics with the real word and made physics a lot more fun.

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