12th International Conference on
Multimedia in Physics Teaching and Learning,
13-15 September 2007, Wroclaw, Poland

Conference Proceedings

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Videomeasurements as a means of physical phenomena visualization

In the contribution there are examples of videomeasurements designed for the detailed analysis of selected physical phenomena presented. The examples are based at the analysis of motion of different kinds of objects from everyday life as well as the analysis of motion of the objects that are difficult to analyze with the help of other measuring tools.

1 INTRODUCTION

Physics teaching always tried to visualize physical phenomena. The visualization techniques such as demonstrations, simulations, models, graphs, films and videos can help in students understanding of the physical concepts. Videos and films appeared in physical education at the 1950s and from that time the video technology, thanks to computers and their potential, in particular, has achieved great progress. Since the 1980s such tools like interactive video, videomeasurements and videoanalysis and their use in physics teaching have been explored.

2 INTERACTIVE VIDEO, VIDEOMEASUREMENT, VIDEOANALYSIS

Interactive video (Zollman) is any video in which the user has more than minimal on-off control over what appears on the screen including:

- ✓ random access, which allows the user to select and display a segment or an individual frame (picture) with minimal search time,
- ✓ still frame, which allows any frame to be clearly displayed for as long as the user wishes to view it,
- ✓ step frame, which enables the user to display the next or previous frame,
- ✓ slow play, which lets the user play video at any speed up to real-time eiher forward or backward (real-time speed is 25 or 30 frames per second).

If there is such a video accessible then we can realize a videomeasurement, i.e. we can measure a position of a moving object by marking its position at each of the frames. Such measurements could be realized long ago when teacher or a student could measure the position of the moving object manually on the screen, frame by frame, e.g. making a mark on a plastic sheet placed on the screen. Advances in computer technology have enabled to digitize movies and generate graphs of moving objects in the video since the mid-1980´s (Beichner, 1999). Nowadays to realize videomeasurement means to capture the movie by clicking to the selected point of a moving object frame by frame using appropriate software. At the beginning the coordinate system and the video calibration is set in order to measure distances in real values. Such a measurement results in a table of measured values of position and time or a corresponding position vs. time graph.

The hardware and the software advanced in the point where students can concentrate on the physics depicted in the videos and not on the techniques required to collect the data (Beneson and Bauer, 1993, Molnar, 1995). Thanks to that students can put more attention to data analysis to get deeper understanding of the process captured in video. Most of the software provides a lot of processing tools, such as derivative, integral, fit function, slope, area, etc. that enables to determine further physical quantities, such as velocity, acceleration, force, momentum, energy and to present these quantities in appropriate graphs. This way, with the help of these additional tools students can realize a data videoanalysis.

3 WHY VIDEOMEASUREMENT?

There are several reasons why videomeasurements are good for teaching physics:

- It enables to study real processes from daily life rather than abstract or idealized models of real situation.
- We can prove physical laws at real situations that are close to students´ mind, such as motions of means of transport, rockets, sportsmen, dancers, etc.
- We can analyse motion in details, frame by frame using videoanalysis tools (One can select any frame to concentrate on the most important features of the motion).
- It enables to do real-time graphing. Real situation is connected with its graphical representation that helps in graph understanding.
- Data collection and processing is quick and relatively accurate.
- Videoanalysis tools are easy to handle, students can concentrate on physics rather than measuring techniques.

Several of these advantages are also connected to MBL real-time measurements. Nevertheless, Bryan (2004) point to three important advantages of video analysis over MBL techniques:

1. Video analysis allows for study of two-dimensional motion, such as revolving objects or projectiles.
2. More than one object can be analysed in any video, which can lead to detailed comparisons of multiple objects that are in the same system.
3. Video analysis can be performed without all of the cumbersome wires and sensors associated with MBLs.

According to Bryan (2004) the versatility of videoanalysis is also an important feature.

3 VIDEOMEASUREMENTS – TOOL FOR DETAILED PHYSICAL PHENOMENA ANALYSIS

There are some many physical phenomena that are difficult to measure and analyze with common measuring tools. One of the examples of such phenomenon is the motion of water in a capillary tube.

The motion of a liquid in a capillary tube presents several interesting features, both in static and in its dynamical properties. We consider a capillary tube of inner radius R immersed vertically with its lower end just beneath the surface of a viscous liquid – distilled water, with density ρ, viscosity η, and liquid – vapor surface tension σ. The surface tension produces a net force directed upward and, as a consequence, the water rises inside the tube. When the liquid has gone up a height h in the tube, the pressure difference driving the liquid up the tube is:

$$\frac{2\sigma}{R} - h\rho g$$

From the Poiseuille`s formulas for the rate of flow of a viscous liquid in a cylindrical tube, the rate of rise of the liquid column is given by:

$$\pi R^2 \frac{dh}{dt} = \pi R^4 \frac{\frac{2\sigma}{R} - h\rho g}{8\eta h} \qquad (1)$$

Integrating Eq. (1) we obtain:

$$h = h_0 \left[1 - e^{-\frac{h}{h_0} - \frac{t}{t_0}} \right] \qquad (2)$$

Where $h_0 = 2\sigma / R\rho g$ and $t_0 = 16\eta\sigma / R^3\rho^2 g$

Formula (2) shows that as t tends to infinity, h reaches the steady- state value:

$$h_0 = \frac{2\sigma}{R\rho g} \text{ or } h_0 = \frac{2\sigma \cos\Theta}{R\rho g}$$

Where, θ s the contact angle between liquid and solid.

The plot h versus t is indicated in Fig. 1 (blue line).

We have studied, by using the videomeasurement tools, the problem of rise of a fluid in a capillary tube with various radiuses. We can compare the real data from the video measurements with the mathematical model. For the water and capillary tube with parameters: σ=73.10^{-3}N.m-1, ρ=1000 kg.m-3, g=9,81 m.s-2, η=1,002 mN.s.m^{-2}, R=0,35mm, the results are presented in Fig. 1 (pink line).

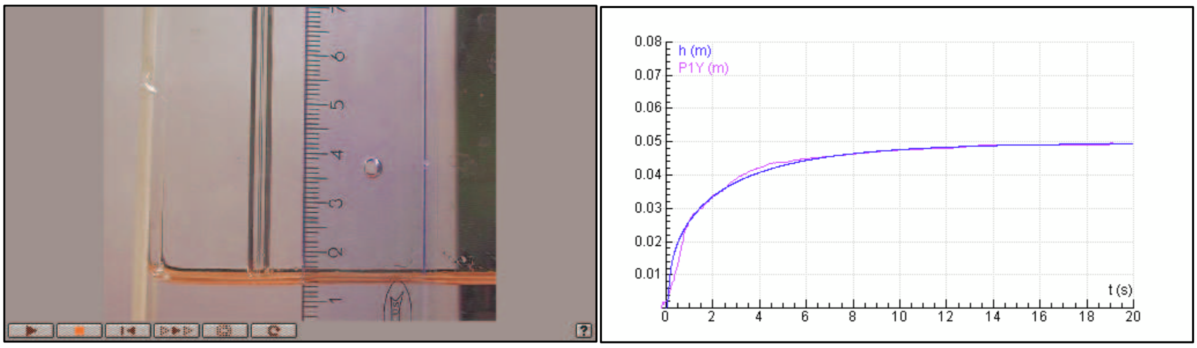

Fig. 1 Videoclip, experimental and theoretical results of capillary rise

4 PROJECT "VIDEOMEASUREMENT IN COACH SYSTEM"

Since 2004 we use videomeasurements with the help of COACH5 (COACH6) system that includes videoanalysis tools. We deal with:

- searching for videoclips appropriate for educational purposes or recording our own clips,
- designing videoanalysis activities as labworks for students active learning,
- preparing worksheets for students active learning,
- designed activities´ verification in teaching process.

During the school years 2005/06 and 2006/07 we realized a project Videomeasurement in COACH system (tab.1). The project resulted in visits of groups of students up to 24 that took part at the selected videomeasurement lead by our teacher. The main aim of the project was to verify the designed measurement in the field of the teaching methods, worksheets and students´ and teachers´ attitudes to this way of teaching. During the project realization videomeasurements and the corresponding worksheets were adapted and modified according to observations and discussions with teachers and students.

Videomeasurement	2005/06	2006/07	together
Uniform and uniformly accelerated motion	98	78	176
II.law of motion – force acting on the ball	236	105	341
Free fall and upward motion of a ball	78	37	115
Projectile motion (basketball)	24	29	53
Harmonic motion (oscillation)	0	21	21
Together	436	270	**706**

Tab.1 Number of participants at videomeasurements

The students realized designed videomeasurement with interest. Nevertheless, the project has shown that understanding of the basic kinematics concepts, i.e. average and instantaneous velocity, acceleration causes problems to students, mainly in the field of the concept of quantity change (Δx) understanding. On the other hand, the motion detailed videoanalysis enhanced by the discussion and active students participation could help to improve understanding, as both teachers and students claimed. Since the students came to practise the phenomena already explained in the class, we expected higher level of understanding and that resulted in quite an extensive labwork including a wide range of problems to solve. That proved to be too much and the videomeasurement should be shorten to just a several problems (e.g. uniform motion, accelerated motion separated in two seperate laboworks).

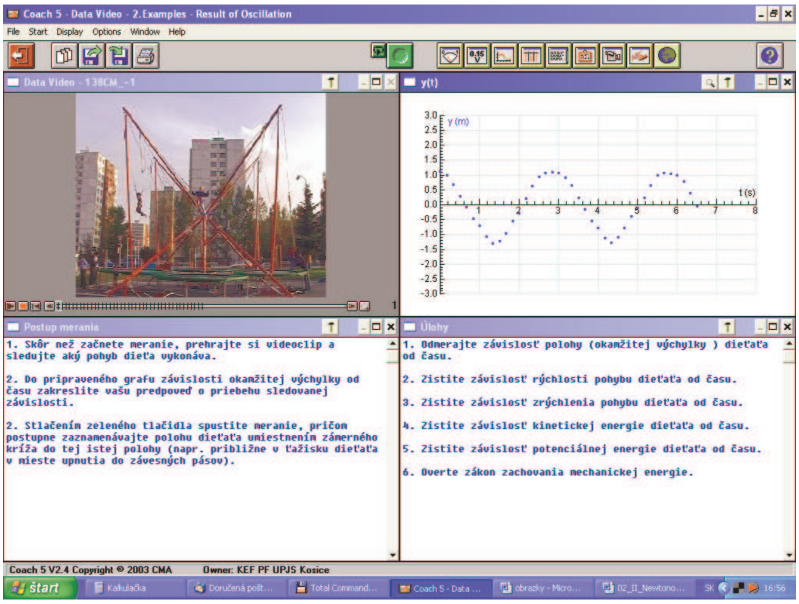

Fig. 2 Example of a videomeasurement of oscillations on elastic bends

5 CONCLUSION AND FUTURE PERSPECTIVE

Videomeasurement provides a significant pedagogical tool for the physics teacher. On the other hand, teachers are not prepared yet for this technique. We have to help them to be able to handle it. There is a set of videomeasurements prepared and verified available for use at schools. In the next year project first teachers come for a training where we let them know about the technique and the methods used and then they realize the videomeasurement on their own with their students, either in our computer-based lab or at their own school, if there is the appropriate technical equipment (computers, software) available.

LITERATURE

Molnar, M., Creating video clips for instruction, Physics Teacher 33, 1995, 158-159

Benenson, W. and Bauer, W. Frame grabbing techniques in undergraduate physics education, American Journal of physics 61, 1993, 848-851

Beichner, R., J., Video-based Labs for Introductory Physics Courses, Journal of College Science Teaching, 29 (2), 1999, 101-104

Zollman, A., D., Teaching and Learning Physics with Interactive video, in http://perg.phys.ksu.edu/dvi/pt/intvideo.html

Bryan , J.: Video Analysis Software and the investigation of the Conservation of Mechanical Energy, Contemporary Issues in Technology and Teacher Education, 4(3), 284-298

M.G.C. Peiris and K. Tennakone, “Rate of rise of a liquid in capillary tube”, Am. J. Phys. 48, 415 (1980)

A.A. Duarte, D.E. Strier, and D.H.Zanette, “The rise of a liquid in a capillary tube reviseted: A hydrodynamical approach”, Am. J. Phys. 64, 412-418 (1996)