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Perspectives of Mobile Learning in Optics and Photonics

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ABSTRACT

Mobile learning (m-learning) can be considered as a new paradigm of e-learning. The developed solution enables the presentation of animations and 3D virtual reality (VR) on mobile devices and is well suited for mobile learning. Difficult relations in physics as well as intricate experiments in optics can be visualised on mobile devices without need for a personal computer. By outsourcing the computational power to a server, the coverage is worldwide.

Key words: 000.2060 Education, Mobile Learning, e-Learning

1 INTRODUCTION

Recent developments in the area of mobile communications open up new perspectives in e-learning. Technologies like GPRS, UMTS and LTE permit broadband internet access in the same way new devices offer much more intuitive user interfaces. At the same time the computational power and storage capacity of mobile devices have increased significantly over the last years. Nowadays mobile devices are widespread in daily live for organization and communication purposes. These are the reasons to investigate mobile devices as a means for e-learning. Mobile learning makes learning more flexible and more context-related.
Because mobile devices are typically "always switched on" no lengthy booting procedures must be performed in advance. Combined with highly developed touch screens and different input/output facilities like cameras, mobile devices are best suited to assist the learning process in classrooms situations, on the move, but also at external sites. Additionally mobile learning is very attractive for younger people for whom mobile devices are part of their natural living conditions.
A very critical issue for successful integration of mobile devices into the learning process is the adaptation of content to the actual learning conditions and settings as well as to the individual functionality of the device, its display and the provided data formats for text, sound, animations, videos and virtual reality (VR).

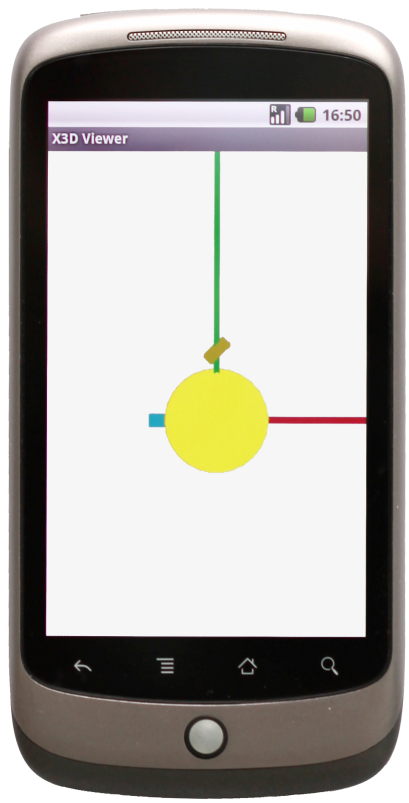

Fig. 1: Virtual reality on an Android OS

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Our approach is based on three particular ideas: (i) the shift of computationally intensive calculations to the server, (ii) the automated adaptation of the media format and VR description to the mobile device (iii) the definition of learning scenarios best fitted to mobility.

In earlier papers we presented our method for implementing three-dimensional virtual reality applications on mobile devices. In this paper we focus on the applications of such a method in e-learning and mobile learning for optics and photonics.

Dynamic physical processes can be rigorously described by equations. But being a student to understand and learn topics like optics and photonics, figures, animations, 3D virtual reality are very important. Due to recent improvements in the hardware of mobile devices, in programming environments, in data formats and transmission properties lecturers and scientists are given new perspectives. All the tools for development of high quality applications for learning purpose are available. Examples of technologies are MIDlets, Java FX, Flash light, SVG, X3D, etc. (Fig. 1)

Especially animations and 3D virtual reality allow for an observation, understanding and anticipation of the evolution of a state of a physical process. If a simulation tool is integrated into the learning setting, interactivity and constructivist learning will be possible. The learner can influence the dynamics of the simulated process by changing simulation parameters interactively and thus s/he can update the visualization result. This kind of "challenge-response" chain opens up a new channel for information transfer in mobile learning.

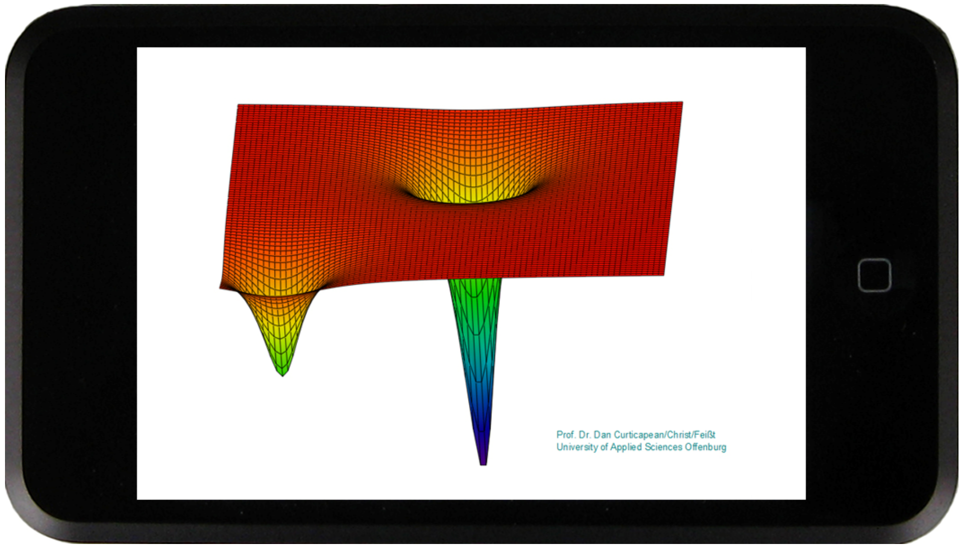

Figure 2a: Performed simulation from the theory of relativity on a mobile device

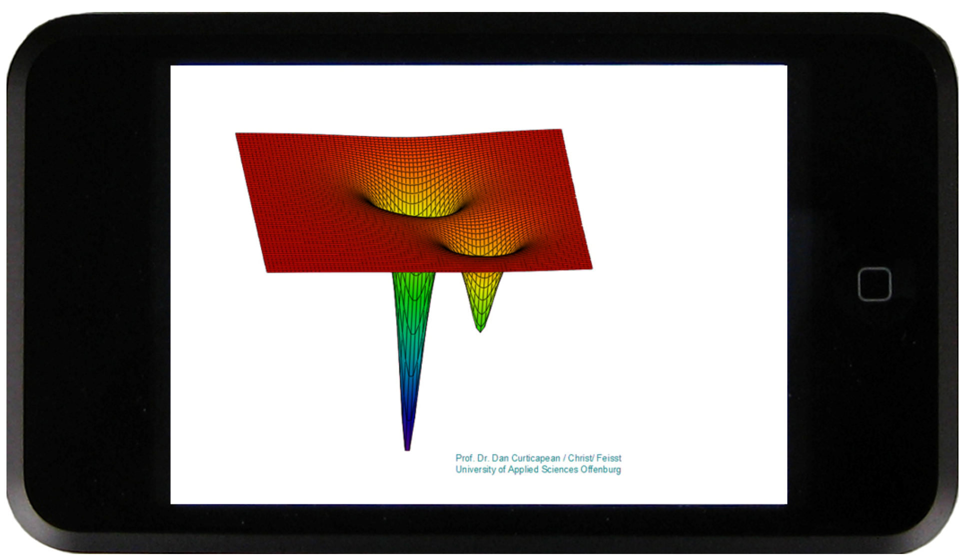

Figure 2b: The same simulation like in Fig. 2a but after time

Those applications are typically split and are partly performed on the server side as well as on the client side, that is the mobile device. Both of the following scenarios are possible: (i) pre-calculation of a large variety of complex settings and storage on server side, (ii) dynamically interactive simulations by directly tuning parameters on client side and performing the calculations on the server side on the fly. In order not to distract from the learning content, both user interface and navigation have to be designed to be as easy as possible and highly intuitive.

Under these conditions complex interrelationships can be visualized easily and impressively by means of virtual-reality simulations and 3D animations. Terms, definitions and scientific regulations will be memorized and understood more easily by association with given visual representations. It is the task of the learning setting to combine mobile learning, face-to-face meetings, (a)synchronous communication and e-learning content presentation in an optimal way.
Optics and photonics provide a large variety of such examples, for instance the optical path through lenses, the visualization of electromagnetic fields, and the Fourier transformation.
An example for such a computationally intensive calculation originating from the theory of relativity is depicted in Figure 2a and Figure 2b.

2 CONCEPT AND SYSTEM ARCHITECTURE

This concept is based on the client-server architecture for device-independent mobile learning [1]. The overall system architecture is illustrated in simplified form in Figure 3.

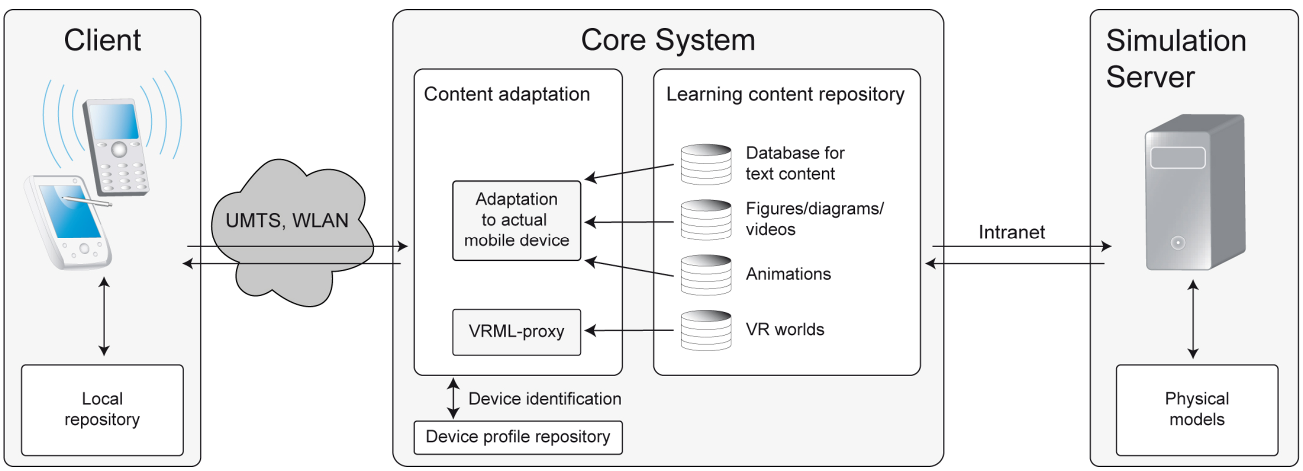

Figure 3: Overall client-server system architecture

The content for the users (e.g. text, illustrations, animation, diagrams, etc.) is pre-generated by authors as well as generated on-demand by the simulation server as results of the simulation of physical models (e.g. diagrams, animations, VR scenes), whereby the simulation model is controlled by the users input. The on-demand generated results can, in addition to the transfer to the users' device, be stored in the "*learning content repository*". In order to make content in this repository accessible to all kinds of devices, the content is stored in a generalised form in this database. In order to optimise the device presentation, the generalised content will be adapted to the device according to its capabilities.
In case of VR data, a copy of the actual world is also stored at server side at the VRML proxy and a bidirectional connection for communication is established. This guarantees that those parts of the VR world which are necessary at the client for presentation are delivered just in time.

3 NEW HORIZONS AND PERSPECTIVES

3.1 Shift of computationally intensive calculations to the server

Nowadays, the capabilities of mobile devices like computing power and the amount of storage memory are rapidly increasing. New input and output capabilities are developed, e.g. high resolution displays and touch screen and flexible keyboards. This tremendous improvement of hard- and software allows for more complex programs, but still, these devices are too weak to perform the calculations of a large physical simulation or render these results as 2D or 3D animations. Therefore it is still beneficial to shift these computationally challenging processes to a high end server. Often intensive calculations have to be done only once, e.g. performing simulations and rendering their results as 2D- or 3D-animations.

For more advanced learning-by-doing simulations and equation solving, inputs sent by the learner via his mobile device have to be processed on the server side. The server sends back results as tables, diagrams, animations and/or VR worlds.

Because of emerging displaying technologies on client side combined with high bandwidth and short latency times below one second for 3G and 3G-LTE/IMT-advanced mobile networks those features will no longer be restricted to PCs or laptops.

3.2 Automated adaptation of the media format and virtual reality description to the mobile

The large diversity of mobile device functionality has, in contrast to PC based applications, a bigger influence and consequences. This fact is quite obvious for display resolution and display size [2]. For the best presentation of figures and animations their resolution has to be adapted and a proper data format has to be selected. In some cases it is possible to produce the results of a simulation process directly as video or animation (e.g. in MathCad or matlab). Often a conversion of the simulation result has to be performed. The reason for this is that there are no possibilities for direct output within the simulation environment to a standard image format and the fact that most mobile devices are unable to handle the formats of these simulation environments. The result of such a conversion process can be an image, an animation, a video or a VR scene. While images and videos are widely supported by most modern mobile devices, this is not valid for VR.

For best presentation of 3D VR onto displays of mobile devices, this scene has to be adapted to the actual device carefully (Fig. 4). It is impossible to perform this conversion in advance because there are too many different devices. A single "master VR world" is defined or generated and stored at server side. Dependent on the capabilities of the connected mobile device, the VR worlds have to be calculated on demand. X3D, as a XML-like description language for VR, allows to reconstruct the delivered VR world on the basis of an overall master VR world at server side while taking the limited functionality of the mobile output device into account. A proxy system manages individual copies of the VR, optimises them and transfers only adapted data. This procedure reduces the transfer bandwidth and computing power on client side [3] – [4]. This proxy system internally uses Java3D like the mobile client does. With this system architecture there is no longer a necessity for different file sets for different resolutions and one master VR world can be maintained on the content server for all devices. This is important for multi-user mobile learning settings.

Generating the simulation results as 3D VR worlds has several advantages. One of the biggest advantages is that the users can interact with these resulting VR worlds. The users can rotate, move, and zoom in/out and can have a look at the simulation results from any perspective and therefore obtain a better understanding. The additional 3D impression will help to understand in particular complex physical processes (e.g. electromagnetic waves). Another advantage is caused by the X3D format itself. The fact that all visible objects can be represented as software objects enables the proxy system to manipulate and interact with these objects. Therefore the proxy system can re-arrange the order of the objects according to visual criteria, i.e. the biggest visual objects will be first, smaller objects will be sent out to the client later. This way, a kind of "streamed" VR scene can be realised. Figure 4 illustrates the client-server communication via the VRML-proxy system [3].

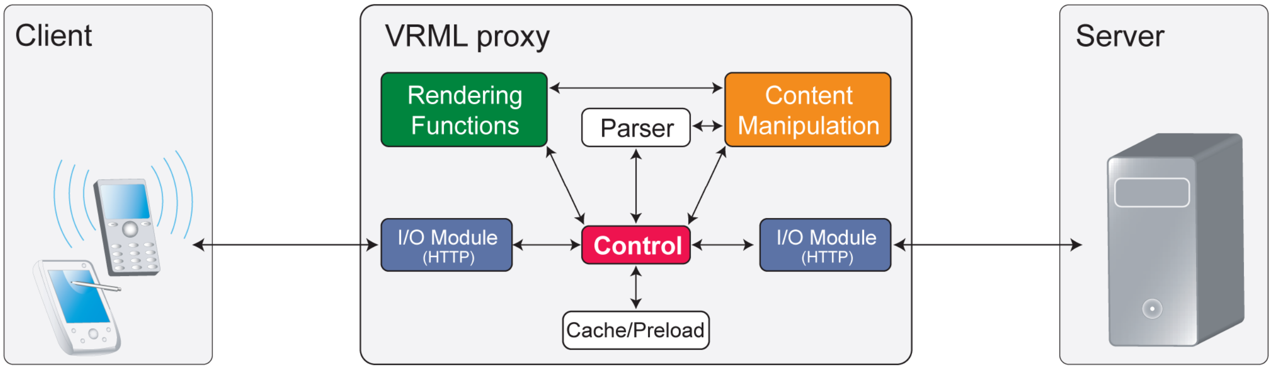

Fig. 4: Client-server communication with VRML-proxy core components

The communication between the mobile device client and the VRML-proxy system is a standard HTTP communication which is performed by the *I/O module*. After the VRML-proxy system has analysed the client's request, this information is handed over and handled by the *Control module*. In case this module recognises that the specific request is available in the *Cache module* it will use this version, otherwise it will be requested from the server repository. In case the VR data was loaded from the repository, this data has to be parsed (*Parser module*) to gain the internal Java3D representation which is handled by the *Content manipulation module*. This step can be skipped in case the data is loaded from the *Cache*. With the help of the *Content manipulation module*, the order of the objects is manipulated according to visual properties and written to an X3D file. Data exchanged by the VRML-proxy system and the clients is stored as X3D. The conversion from X3D to the internal Java3D and back to X3D may look contra-productive because of the additional processing overhead, but the resulting advantages of interacting and manipulating content outweighs the processing overhead. The fact to implement the VRML-proxy system to client communication as X3D gives the possibility to use a client without VRML-proxy system as well as using the VRML-proxy system with any other X3D client. The *Control module* interacts with the clients and the content located on the VRML-proxy system to provide streaming VR content. The system additionally allows the preloading of additional information from the VRML-proxy system and post-loading at the mobile device side. In case data are post-loaded at the mobile device client side, only the objects closest to the virtual viewer's perspective are loaded onto the mobile device. The information on the client side is updated according to the movement of the virtual users' view.

Figure 5: Mobile phone running 3D VR performed simulation

Based on X3D data the client will generate the stereoscopic view with respect to internal or external output devices if appropriate. Anaglyph images can be generated by state of the art colour displays of mobile devices. A prototype running on a Sony Ericsson P1i with a 240*320 dot display (Nokia N95 240*320) proved that one obtains a realistic 3D impression already with medium sized displays. The first prototype of an Android system (Google Nexus One) with its state-of-the-art hardware shows an intuitive multi touch input version of the VR viewer software.

According to our opinion, in the near future mobile devices will have lenticular lenses or build in three-dimensional screens which will be commercially available. For professional purpose in future head mounted devices or two video projector systems could be connected to mobile devices. The mobile device is delivering the X3D VR world description and the connected external device calculates and displays the VR world.

3.3 Definition of learning scenarios best fitted to mobility

Mobile learning is an emerging area of application for mobile devices. In order to realise successful mobile learning applications, an optimal fit of learning scenarios to the advantages of mobile devices is essential. At the same time keeping its restrictions in mind is important. Mobile devices are optimised for communication, information, and organizational purpose, modern devices include as well internet and social networks applications. This includes speech, SMS/MMS, internet search, database access, calendar functionality, all of these are often required for instant and situation specific needs. Other important features are sound, photos, videos and its peer-to-peer interchange as well as high interactivity (e.g. games). On the other hand mobile devices are not developed and designed for long term reading or permanent concentrated working, as one is used to with PCs and laptops in an office, a business meeting or a conference environment.

Our aim is to design learning scenarios which include graphically rich but text-reduced presentations with a high rate of interactivity and communication purpose within groups of learners. Meaningful interactivity with advanced learning objects as well as communication and collaboration with other learners, tutors and teachers are means for constructing knowledge and collaborative learning [5]. Both are important issues if one apply the ideas of constructivism.

The system discussed in this paper will take care that the learning process can be easily segmented into short periods and can be interrupted by unexpected events by a third party. Therefore, if short interactive 2D/3D-animations, VR worlds, graphical representations of simulations results from a server are included into the learning process, this fits best to the requirements of the mentioned scenarios. According to our opinion such a system will increase learning and understanding significantly [6].

4 EXAMPLES OF ANIMATIONS

In the context of science, a picture represents an image of a state at a given moment in time. This interpretation may be well suited for time-invariant states, e.g. in the case of the well-known state of matter diagram originating from thermodynamics. A similar success can be achieved when depicting time-invariant states originating from the theory of electricity, e.g. the distribution of streamlines of the field. However, most of the occurring states and processes in nature are dynamic, i.e. they develop over time, so that a momentary still-frame alone is not sufficient to capture their evolution over time. The influence that passive components in an alternating current have on voltage can be visualised well and unambiguously by animating the current or power distributions. For instance, the sense of complex formulas like Fourier-approximations given by the relations (1) - (3) [7] – [13]

$$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} \left[a_n \cdot \cos(n \cdot x) + b_n \cdot \sin(n \cdot x) \right] \qquad (1)$$

$$a_0 = \frac{1}{\pi} \cdot \int_0^{2\pi} f(x)dx \qquad (2)$$

$$a_n = \frac{1}{\pi} \cdot \int_0^{2\pi} f(x) \cdot \cos(n \cdot x)dx$$

$$n \in N \qquad (3)$$

$$b_n = \frac{1}{\pi} \cdot \int_0^{2\pi} f(x) \cdot \sin(n \cdot x)dx$$

can be visualised very easily by animations. To solve this task, image sequences have to be generated with the necessary temporal resolution and have to be furthermore well-ordered. The 20th frame of the performed animation that corresponds the Fourier approximation with n = 20 is presented on a mobile device (Fig. 5). The animation is performed by the sequence of 33 frames computed for n = 0 to n = 32. Figure 6a to 6e present frames integrated in the Fourier-Animation with an increasing number n.

Modern techniques allow for an efficient computation of such image sequences and their subsequent viewing: This way scientific animations and Virtual Realities in 3D can be created.

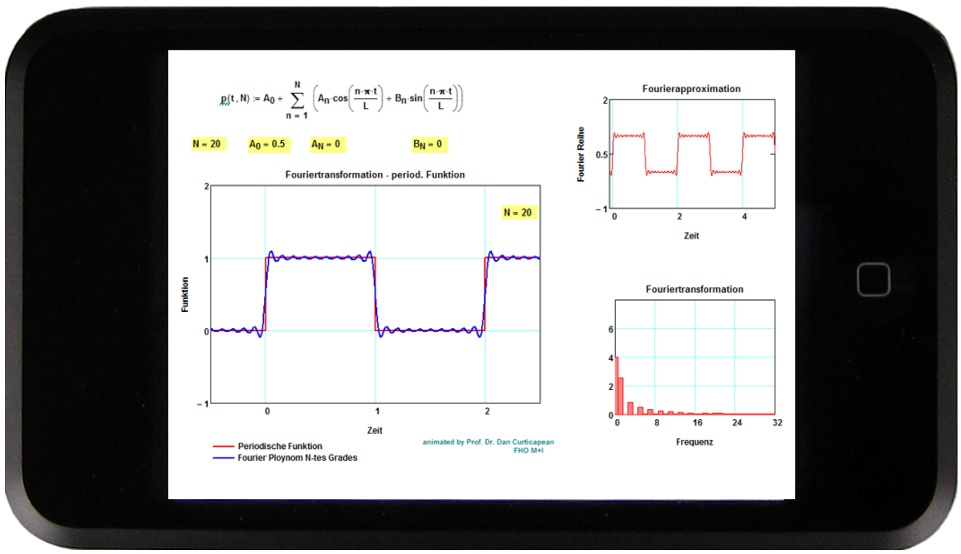

Figure 5: Fourier series of a periodic function animated

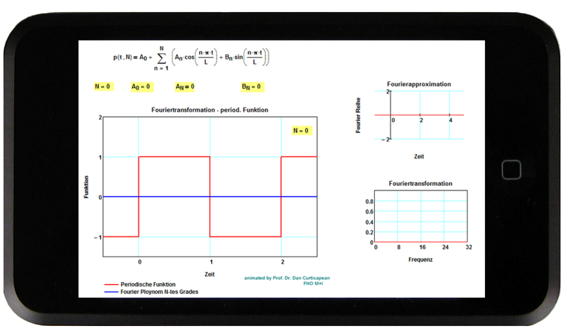

Fig. 6.a: n = 0

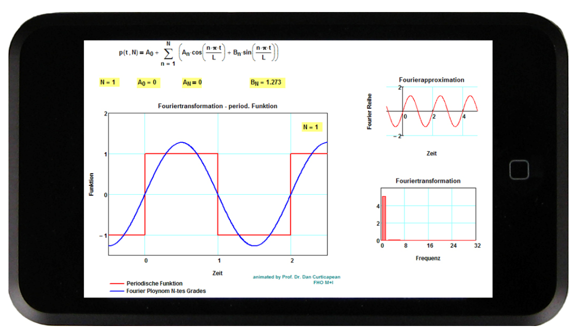

Fig. 6.b: n = 1

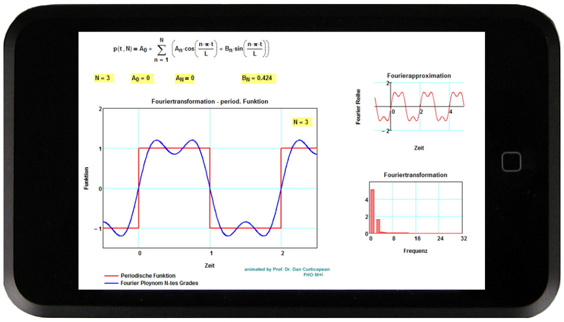

Fig. 6.c: n = 3

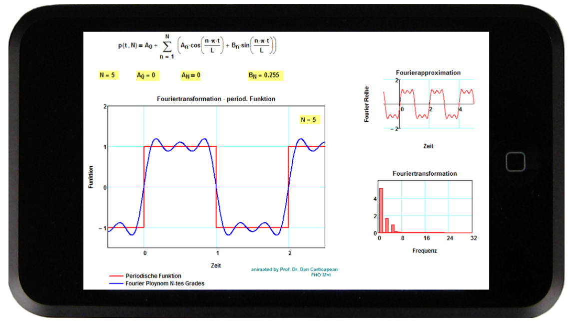

Fig. 6.d: n = 5

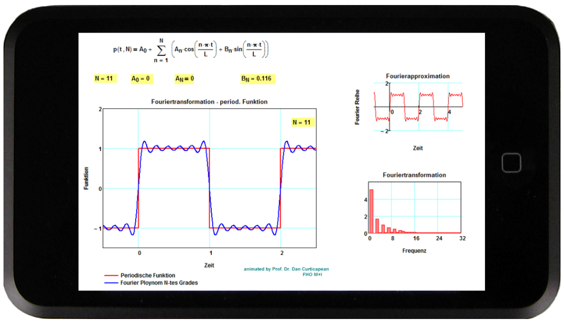

Fig. 6.e: n = 10

Fig. 6: Computed frames integrated in the Fourier-Animation

As previously described, very complex concepts such as the gravitation can be summarized in animations by means of e.g. MathCAD. Thanks to these animations the curvature of space by mass as described in the theory of relativity can be understood unmistakably, as presented in a frame of the animation reproduced in Figure 2. Figure 2.a and Figure 2.b show two still frames taken from the animation that are ordered chronologically according to the evolution of the system. Each frame corresponds to a single state (central field captures a planetoid).

Another sensible application of animations occurs in optics. Figure 7 shows the final frame of a ray-tracing animation. The depicted light rays illuminate the symmetry axis of the optical fiber orthogonally. This way the core of the single mode optical fiber becomes visible

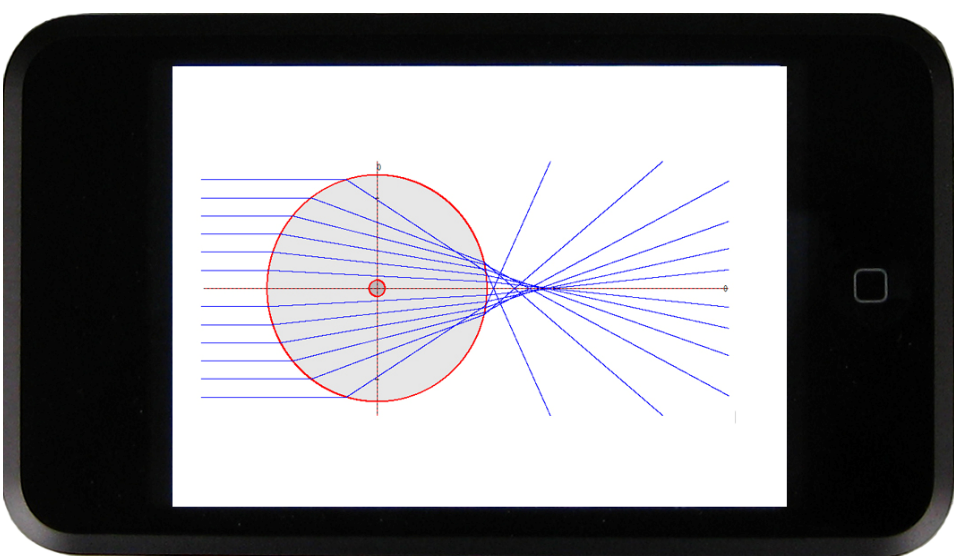

Figure 7: Light rays tracing through a single mode optical fibre

To perform the simulation presented in Fig. 7 that describes the light ray passing an optical core, nine matrices have to be multiplied.

Figure 8 shows the simulation of angular intensity distribution through a diffraction grid. By means of animations one can show both the influence of the grid constant to the interference image and the emerging of an interference image by changes of the intensity. The well-known formula of the normalized intensity [14] – [15] is given by relation (5).

$$I_{Norm} = \frac{I_\alpha}{I_{max}} = \frac{\sin^2\left(\frac{\pi \cdot b}{\lambda} \cdot \sin\alpha\right)}{\left(\frac{\pi \cdot b}{\lambda} \cdot \sin\alpha\right)^2} \cdot \frac{\sin^2\left(p \cdot \frac{\pi \cdot g}{\lambda} \cdot \sin\alpha\right)}{\sin^2\left(\frac{\pi \cdot g}{\lambda} \cdot \sin\alpha\right)} \tag{5}$$

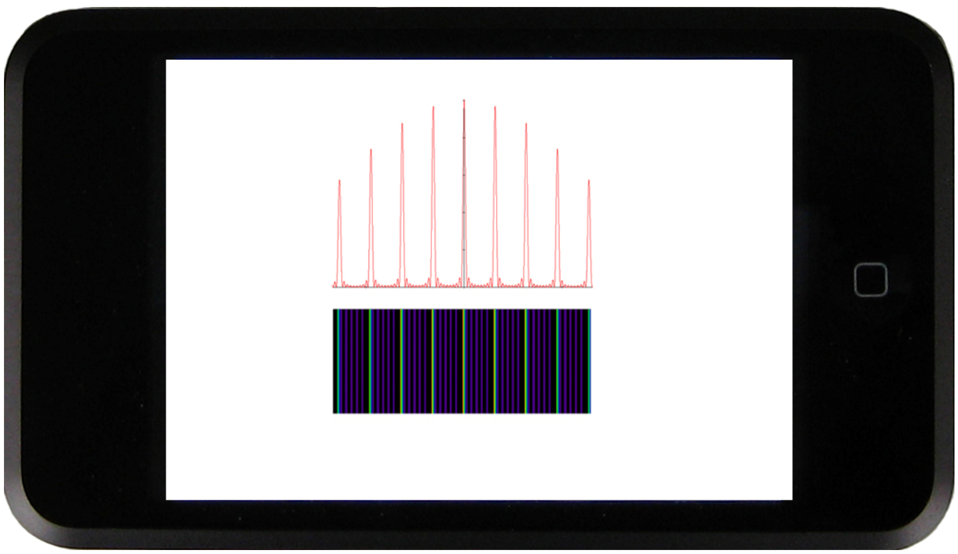

Figure 8: Simulation of angular intensity distribution through a diffraction grating

Nowadays the technical feasibility of creating didactically valuable animations is given. The remaining task is to develop multi-media contents that are both didactically valuable and attractive for learners when used in a mobile learning platform. And last but not least, the learner should have fun while learning.

5 CONCLUSIONS

New technologies influence the learning behaviour, especially if the new technology is commonly used and fits to the requirements of recent learning theories, including communication, cooperation and collaboration within teams.

Regarding abstract theories (e.g. optics, theory of relativity), complex systems (e.g. communications) and/or not visible matters (e.g. electromagnetic waves), the understanding can be improved by adequate diagrams, figures, animations or 3D VR. Especially in physics it is of high advantage for a learner to have such visualisations besides mathematical and textual explanations. In combination with recent developments in advanced display technologies, in computational performance and in mobile network infrastructure mobile learning can be applied very well to these high challenging physical topics.

An overall system architecture has been presented. It shifts computationally intensive calculations to the server and adapts content presentation to individual mobile devices. As a result, interactive animations and 3D VR can be included into the learning content delivery to a great extent. We are convinced that such a system fits to the lifeworld especially of younger people and increases learning and understanding significantly. Prototype like examples show that this is no longer a goal for the far future but can be applied in nowadays arrangements.

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