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Visualizations and Animations in Learning Systems

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Synonyms

Visualization and animation tools; Educational use of visualization and animation

Definition

The topic *visualizations and animations in learning systems* focuses mainly on the usage of visualization/animation techniques in educational systems to support the learning process in some way. There are several definitions of visualization in the literature. Sometimes, visualization is defined as a simple process that creates a drawing, a diagram, or an image based on specific data or information. In fact, it is a cognitive process that produces a mental model in the human brain with the hope that this model supports better understanding or insight. In light of this background, other definitions were developed and one which is often applied is the following: *visualization* is the use of computer-supported, interactive, visual representations of data to amplify cognition. Note the word "interactive" in this context. If the content of a concrete learning system is related to complex (time-dependent) processes, then animations could be used to support the learner in a better understanding of those issues. *Animations* can be defined as simulations of movements created by series of pictures (frames) or by a so-called animation framework that allows smooth movements of graphical objects on the screen.

Theoretical Background

Surely, we could assume that visualizations and animations are related to *multimedia*. In general, multimedia covers much more aspects, such as images, video, text, but also different sensory modalities of the learners. Here, we regard visualizations and animations as defined above. One important difference between visualization and multimedia research is the understanding of the term *interaction*. In multimedia, interaction is often associated with direct access to different media supported by a learning system or with controlling the playback of videos using a VCR metaphor. In context of visualization and animation, the learner should have influence on the content visualized, for example, in order to filter out uninteresting details, to reduce the complexity, to choose another visual representation, or to focus on an interesting graphical element.

From a technical perspective, visualization and animation are research areas in computer science with a long history. Many fundamental techniques were developed in the past decades to provide the basis of complex visualizations and visualization tools used in nearly all sciences (cf. for example Spence 2007). Thus, the step applying them within learning systems was straightforward, especially in computer science, natural science or engineering education. All those fields have in common that many study contents can hardly be described with words or static diagrams. Examples are computational models in computer science, motion sequences in sport sciences, or the functionality of metabolic networks in biology. In consequence, visualizations based on the mentioned standard techniques were developed to support the learner in a better understanding of the inherent structure of large sets of relevant data or of complex relationships within the learning content. Typically, the choice of a suitable visual representation and interaction technique is—among other things—highly dependent on the content that is to be visualized.

Often, such study contents also have a time factor, which has to be considered. This can be done in two different ways. Firstly, time can be interpreted as an additional dimension or attribute and is visually represented in the same way as any other attribute, e.g., in form of an additional axis within a coordinate system. The second possibility is to use time in its original sense and to produce a "dynamic visualization" or animation. Additionally, animations can represent causal relationships or can simply be used to concentrate the viewer's attention on a specific area of the display. Park and Hopkins extended these ideas and identified six different didactical functions of animations in learning systems (Park & Hopkins 1994):

- "demonstrating sequential actions in a procedural task,
- simulating causal models of complex system behaviours,
- explicitly representing invisible system functions and behaviours,
- illustrating a task which is difficult to describe verbally,
- providing a visual analogy for an abstract and symbolic concept, and
- obtaining attention focused on specific tasks or presentation displays."

From a learning perspective, it is interesting to understand which aspects of visualizations and animations could support learning and to what extend. The literature is somewhat contradictory in that matter. This can be reasoned by the difficulty to evaluate complex visualizations, because different components of a visualization can play an important role, such as the chosen visual representation, interaction metaphor or even aesthetical issues. One example is the development and use of algorithm animations in computer science education. Algorithms are abstract, well-defined lists of instructions for completing a specific task, and they are one of the fundamental concepts in computer science and related fields. Often, algorithms are hard to explain as well as to understand by students. Many algorithm animations were developed (mostly based on complex algorithm animation frameworks) and subsequently evaluated, using various methods. The learners mostly advocated them, but the evaluation results do not corroborate final conclusions regarding their usefulness or effectiveness (Moreno 2007). Some authors analyzed the role of visualization and engagement in this context and presented a framework for experimental studies of visualization effectiveness (Naps et al. 2003). Perhaps, the most effective way to use such tools is to encourage the learner to build his/her own animations with the help of an algorithm animation framework (active learning).

A related interesting aspect is the level of influence on the visualization/animation taken by a student. Some research projects explored how the automatic generation of visualizations and animations can be used in educational software for computer science and related fields (Kerren 2004). The main idea was to let the learner as much freedom to act as possible, but not to require a deeper knowledge in graphics: in a first step, he/she specifies a (computational) model more or less formally. Then, a special visualization system automatically generates an interactive visualization, which is based on that model specification. Finally, the generated visualization can be used for complex simulations of the underlying model together with arbitrary input data. In consequence, the learner can deepen his/her knowledge of those models, try out different hypotheses and check them with the help of the visualization.

A further observation is that visualizations and animations are often relatively independent from the learning system itself, i.e., they exist side-by-side and are not really embedded into the learning system, see Figure 1 for instance. This fact leads to interesting research challenges that are discussed, amongst others, in the next section.

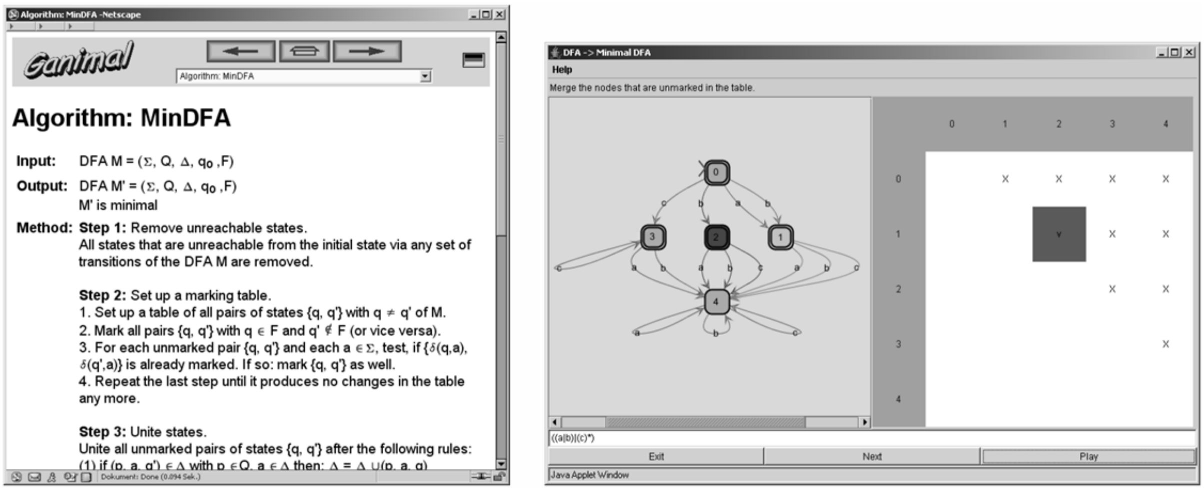

Fig. 1: HTML-based, textual description of an algorithm on the left and corresponding interactive animation on the right; taken from (Kerren 2004).

Important Scientific Research and Open Questions

If interactive visualizations and animations are used in educational systems, we can easily identify a list with interesting open questions and research challenges:

- One of the most important open questions is the expected value of interactive visualizations in learning systems. Visualizations and animations will have to be seriously evaluated in the future. Special evaluation strategies and standards are desirable, also in order to be able to compare different visualizations.
- As already mentioned, a critical point is the integration of visualizations/animations into learning systems, such as hypertext books or course management systems. On the one hand, this is a technical problem and several solutions are possible depending on both the technologies used for the visualization and for the learning system. On the other hand, developers must keep didactical aspects in mind, such as learner/teacher support, learning strategies, etc. (Rößling et al. 2006).
- A connatural problem is the measurement of the learning progress during the exploration of a visualization by the learner. This information could be communicated back to the learning system by the visualization itself and could be used for adjustments and/or automatic assessments.
- The combination of visualization/animation with explaining text or speech is challenging too. This depends on the learning mantra and leads to concrete problems, for example, synchronization issues or interactive help provided by the system.
- Strategies to support different learning styles should be created. So far, visualizations are usually based on the ideas and understanding of visualization developers and not on the students' needs. Top-down and bottom-up learning strategies could also be realized in complex visualizations.
- Mobile learning emerged as an important research field and visualizations play an important role in this area. As the use of (GPS-enabled) mobile devices is heavily increasing, interesting learning situations become possible, for instance, biology lessons in fields and forests or the like. Visualization techniques must be adapted to fulfil new requirements, especially for small displays.

Cross-References

→ Active learning
→ Blended learning
→ Computer-based learning tools
→ Constructivist learning
→ E-learning tools
→ Human-computer interaction and learning
→ Multimedia learning
→ Virtual learning environments

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