Selective Hiding for Improved Algorithmic Visualization

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ABSTRACT
In order to benefit most from algorithm visualization (AV) technology students have to be meaningfully involved in the algorithm visualization process. This may imply that they are invited to predict and implement (using an interactive visual learning environment) the operation-sequence of the studied algorithm. In such learning environments users become active players in the AV process. Students are invited to process algorithms (in terms of their high-level operations) created to be processed by computers. The study we have performed reveals latent deficiencies such AV systems might have. Compared to humans, computers are blind in many ways. Visualizing information that has extra meanings for human viewers can obstruct them in following strict computer algorithms. Research results show that wisely applied hiding may result in more effective algorithm visualization due to its higher epistemic fidelity.

Categories and Subject Descriptors
K.3.2 [Computers and Education]: Computer and Information Science Education – computer science education.

Keywords
Algorithm visualization, Interactive learning environments, Constructivist approach, Epistemic fidelity.

1. INTRODUCTION
Computer algorithms are inherently abstract entities. Since they lack any tangible real-world representation it is quite difficult to teach and learn them. As Turing [17] stated: “One’s object is then to have a clear mental picture of the state of the machine at each moment in the computation. This object can only be achieved with a struggle.” Graphical representation of an expert’s “clear mental picture” of the algorithm has become the most common method of illustrating how algorithms work. According to a recent survey “while many good algorithm visualizations are available, the need for more and higher quality visualizations continues” [15,16]. The term ‘algorithm visualization’ (AV) refers to the graphical illustration of computer algorithms in terms of their high-level operations, usually for the purpose of enhancing students’ understanding of the algorithms’ procedural behavior.

Algorithm visualization technology usually includes video or computer-based animations that visually illustrate computer algorithms in action [15,16]. A recent meta-analysis comparing instructional animation with static pictures confirmed the educational effectiveness of representational animations especially when procedural-motor knowledge had to be assimilated [5]. In addition, several studies conclude that AVs foster effective learning when students are actively involved in the visualization instead of passively viewing it [7]. For example, students should be invited to run the animation for several inputs observing the input variant/invariant characteristics of the studied algorithm. A genuinely active involvement may provide learners with the opportunity to have control over the algorithm animation process, even orchestrating it [11]. This implies that learners are invited to play the algorithm processing role of computers.

Compared to humans, computers are blind in many ways. An AV system may visualize information that has extra meanings for learners. In such enriched learning environments learners may find it difficult to follow a strict computer algorithm. For example, sorting algorithm visualisations usually expose the number-sequence to be sorted. Since learners see the numbers, they implicitly realise if two elements are in right order or not, and may skip the explicit comparison operation of the computer algorithm.

In this paper we investigate this phenomenon and suggest solutions to avoid potential side-effects of substituting “blind computers” with “not blind humans” in AV learning environments.

2. THEORETICAL FRAMEWORK
Theories of Epistemic Fidelity and Cognitive Constructivism provide the theoretical framework for this study. Wenger [18] defined the epistemic fidelity of a representation as the degree to which an external representation of a phenomenon reflects the expert’s model of this phenomenon. Epistemic Fidelity theory has its origin in representationalist epistemology [14], which assumes that objects can be represented in the mind by symbolic models, and these “images” are the basis for human reasoning and action (Knowledge representation assumption). According to Hundhausen [6], other assumptions of the epistemic fidelity view are:

- Knowledge flow assumption: (1) Transmitter’s knowledge is encoded in a graphical representation; (2) Graphical representation is decoded by receiver. In terms of AV: knowledge is seen to flow from teacher to AV to student through the conduit of the visual medium.
- Graphical medium effectiveness assumption: Graphical representations are effective tools for presenting mental...