SURVEY OF AI VISUALIZATIONS IN EDUCATION

Paul Juell
Department of Computer Science and Operation Research
North Dakota State University
Fargo, ND, 58102, USA
Paul.juell@ndsu.nodak.edu

Vijayakumar Shanmugasundaram*
Department of Math and Computer Science
234 C Ivers, 901 8th St S
Concordia College
Moorhead, MN, 56562
shanmuga@cord.edu

ABSTRACT

Visualizations are increasingly being used in teaching and as student aids for learning Artificial Intelligence. We are interested in the strengths of the various visualizations and the maturity of the field. In this we are addressing the ways the visualizations are presented to students and the types of options presented to the students. We surveyed a number of commonly available visualizations and classified them on a number of bases. This study helps characterize the area and allows us to suggest some good practices for developing AI visualization.

Keywords: Survey, Artificial Intelligence, Visualizations, Evaluation, and Features.

*** Contact Author**

INTRODUCTION

Visualization is increasingly becoming more important in Artificial Intelligence. Many instructors in teaching Artificial Intelligence provide visualizations as supplemental learning resources. For example, these are used to help explain the more abstract processes involved in Blocks world, Hill climbing search, Genetic Algorithms, State search, and Neural networks. Creating and using these visualizations are time consuming for both teachers and students. Anecdotal evidences [3] suggest that these visualizations are useful. We surveyed these visualizations and analyzed them to find out the various features of these visualizations that played crucial role in providing the usefulness. More over, we wanted to look for ways for improvement and suggest some more features. We addressed this by identifying the features, briefly explaining these features and the need for evaluating the visualizations using these features, evaluating the visualizations using these features on a numeric scale, classifying these features based on their importance, then providing some good principles/guidelines for either creating new visualizations or improving the existing visualizations.

IDENTIFICATION OF IMPORTANT FEATURES

When we surveyed AI visualizations, we could identify some of the important features in different AI visualizations. We listed the most important features we observed from these AI visualizations: 1. Clarity 2. Precision 3. Efficiency 4. Text and Visualization 5. Reload every time 6. Mapping from pictures to abstract Description 7. Aesthetics 8. System Availability 9. Easy use 10. Interactivity. But we also listed some other significant features we thought would improve these surveyed visualizations: 1.Speed control 2. Stop and Start 3. Step Back 4. Caution 5. Source code 6. Independency 7. Learner's training 8. Annotations 9. Different views.

BRIEF EXPLANATION OF IMPORTANT FEATURES

Clarity: The visualizations should be clearly visible to the naked eye. *Precision:* The visualizations should be accurate in conveying the idea. *Efficiency:* They should be efficient in conveying the message. *Speed control:* They can be run with different speeds as students with different capacity are expected to view them. *Stop and Start:* They should be able to be stopped and started at any time. *Step Back:* One should be able to step back and see what happened. *Text and Visualization:* Both explanation text about the visualization and the visualization should be present. *Caution:* A clear warning should be displayed that the code corresponding to the creation of visualization is different from the algorithm and students need not try to understand the internal of visualization. *Source code:* The code needed for creating the visualization should be available along with the visualization –this would help anyone who wants to improve the visualization for his or her use. *Reload every time:* The visualizations need not be reloaded every time when the user wants to rerun it. *Independency:* The visualization should stand on its own. *Mapping from pictures to abstract Description:* The visual1zation should match the abstract description about the concept. *Aesthetics:* Visualizations should be pleasing to the eye and mind. *System Availability:* Maintenance should be carried out regularly so that the visualizations are easily accessible and available at any time. *Learners training:* Provision for prior easy training for using the visualization should be provided. *Easy use:* Te users should be able to obtain the visualization easily without any complicated procedure for obtaining it. *Annotations:* Comments should be displayed with each step of the visualization. *Interactivity:* They should interact with the user with different parameters. *Different Views:* The visualizations should provide ways for seeing the visualizations in different views.

NEED FOR EVULATING THE VISUALIZATIONS

The lack of knowledge about human-computer interaction makes it more difficult to find the fact that visualization aids student learning. J. T. Stasko, and A. Lawrence [5] estimate that in the last two decades more than hundred and fifty software visualization prototypes and systems have been built. Only few attempts are made to systematically evaluate them. He observes that there is no proper procedure for empirical evaluation of software visualization systems. He laments that if the systems are not evaluated and shown to be effective, what is the point of building them. E. R. Tufte [6] explains with examples and statistics of a scholarly compiled list how basic principles and guidelines followed for centuries in maps and statistical graphics are often missing in the colorful images emanating from computer visualizations. Largely researchers in visualization have concentrated on particular visualization techniques and applications. But they have made very few efforts in evaluating the features, creating proper principles, guidelines as guidance to develop visualizations.

EVUALATING VISUALIZATIONS

We have surveyed, used, and then evaluated AI visualizations using these features. Grades were given for each feature - maximum possible for each feature is10. The total can be out of maximum possible of 180. We compiled the list of AI Visualizations based on these classification: At least two visualizations for the following topics: 1. Hill Climbing 2. GA 3. Blocks world 4. Neural Network 5. Depth First 6. Breadth First 7. Crossing. We selected these AI visualizations available on the web for our study. It is very hard to find out the true goals of these visualizations. We have chosen only those visualizations, which are meant for teaching, learning, and research. We have to rely on the descriptions provided along with the visualizations by the authors to assume the goals of these visualizations. We are also not sure whether they are still in use by the authors, students, and researchers.

CLASSIFICATION OF FEATURES

The list of features that various authors have used to evaluate visualizations is a large list. We want to select some of these features, classify and group these features. We hope this list will help authors of visualizations to self-evaluate and improve their work using these features. We propose the following six features: 1. CPE (Clarity, Precision, Efficiency) feature 2. VCR (Speed Control, stop and start, step back, reload) feature 3. ANNOTATIONS feature 4. INTERACTION feature 5. MAPPING feature 6. INDEPENDENCY feature. We plan to share 100 points among these features: CPE feature = 15, VCR feature =15, ANNOTATIONS feature =20, INTERACTION feature =20, MAPPING feature =10, INDEPENDENCY feature =20. The authors can award points to their visualizations based on these features and self evaluate them. If the total points are less than 80, they should reconsider their design and try to improve the visualization by addressing these features.

GUIDELINES FOR CREATING VISUALIZATIONS FOR EDUCATION

CLARITY

E. R. Tufte [6] stresses the importance clarity by giving an example of ear diagram with thick pointer lines. The lines generate noise and clutter in the diagram. He suggests that visualization creators should make all visual distinctions as subtle as possible, but still clear and effective.

PRECISION

Visualizations authors should take care to ensure that their visualizations should convey the point. The idea conveyed by the visualization should be precise. The basic principle of visualization is to help students learn the concepts. The authors should take care that no harm is done to the student community by providing imprecise information.

EFFICIENCY

Visualizations authors should not be roundabout in conveying their ideas. The way they convey the message should be efficient. Students if required to do some work for getting the visualization should be able to do relatively easy work. It should not be time consuming for them.

SPEED CONTROL, STOP AND START, STEP BACK

E. R. Tufte [6] explains in detail how disinformation design techniques help the magician to perform his tricks successfully by hiding information. The reverse of these techniques hold true for the visualization creators. For example, Magicians should never tell their audience beforehand what they are going to do and should never perform the same trick twice on the same evening to be successful. But visualization creators should do the opposite of this. The features speed control; stop and start, step back help the visualization creators to achieve that. These factors also help the students to repeatedly see and understand what is being conveyed. One of the lists of the comments given by their [5] student users of the visualization: absence of a way to step the through animation a frame at a time, the inability to rewind or replay the animation, not to able to step back and see.

TEXT AND VISUALIZATION

J. T. Stasko, and A. Lawrence [5] stress the importance of the presence of text about the visualization and the visualization being together and explain that the animation is fundamentally a visual mapping of the data objects and operations. The student has to understand the visual mapping to gain benefit out of it. Since the student does not understand its data and objects and is initially trying to learn the algorithm, does not have the basis to comprehend the visual mapping. A student cannot translate the graphical actions to the represented algorithm, as the student cannot "get" what the picture is all about. Our own experience concurs with this. The best way to solve this is ensure that the visualization itself is thoroughly explained and described initially before showing the visualization.

CAUTION, SOURCE CODE, AND RELOAD EVERYTIME

The factor 'caution' is very essential as the students are prone to get confused with the code meant for creating the visualization and the program code for which the visualization is created. It is very important that visualization authors include a caution notice warning the students that they need not understand the internals of the visualization in order to view the visualization. We have come across situations where the students get confused with the internals of visualizations and the concepts for which visualizations are created [3]. The availability of source code will make it easy for various students/ teachers to improve on the existing visualization and help them to understand or teach the concepts well. Making the students to reload the page every time they want to change the parameters may irate the students and force them to abandon altogether.

INDEPENDENCY

Can visualization stand alone? No, it is very hard to make visualization stand alone. A picture is worth thousand words – Old proverb. But thousand words may be needed to make the visualization convey the actual idea it meant to convey. When the visualization creator creates visualization, he may have planned one particular idea to reach all the users uniformly. In reality different users may interpret the visualization in many different ways [2]. For example, we did a small experiment by showing a plain picture (Hand with cards and a cover – page 56) [6], without any descriptions and details to five persons, requesting them to provide explanation as what the picture conveys to them. All the five came up with different ideas and none of their ideas matched. A visualization creator should take care so that the visualization along with other helping factors like annotations, mapping, text explanation should be able to stand on its own.

MAPPING FROM PICTURES TO ABSTRACT DESCRIPTION

E.R. Tufte [6] displays in his book the drawing of Robert Willis and the redrawing of Sir David Brewster about the documentation of a theory of concealed workings of the Automation Chess Player. He points out how inefficient their efforts to provide legends. Their legends required the readers to cross-reference many times between the legends, text, and drawings. In addition these were isolated on different pages of their books. It is significant that the visualizations should be provided with proper text at appropriately laid out and mapping from visualizations to abstract description should be done carefully.

AESTHETICS

This is an important guideline as it plays crucial role in pleasing the eyes of the user. No one would even give a first glance to the visualization if it were not pleasing to the eye. But at the same time the authors should not go to any length for providing the pleasing effect.

SYSTEM AVAILABILITY

J. T. Stasko, and A. Lawrence [5] point out that the system availability aids in providing the visualization to the students outside the class room setting to reinforce concepts learned in class.

LEARNERS TRAINING AND EASY USE

There should be a possibility for the students to get trained in using the visualization before they start using the actual product. This will ease the pressure on the students for easy use of the visualization in their study.

ANNOTATIONS

Annotations are essential part of visualization. E. R. Tufte [6], while trying to explain the layers of visualization, points out the importance of annotation as important part of visualization, "Another layer of content comes from the annotation, which accents the visual separations by pointing to various levels." He also quotes the example of techniques of magician tricks not to tell the audience in advance as what they are going to do so that their attention is not drawn to their actions. But the reverse of this example is true for Visualization creators. Providing annotations help creators to make the students to pay attention to what is going to happen next, thereby improving their comprehension. No one would dispute the importance of writing comments for a computer program. What comments do to computer programs is done by the annotations to the visualizations. Annotations create the effect of story telling. A. Badre, and J. Allen [1] found a superior performance for the textual notation among the novice subjects compared to the performance of the experienced learners, which emphasizes the importance of providing Annotations. J. T. Stasko, and A. Lawrence [5] list the comments given by their student users of the visualization: lack of textual explanations of what was occurring at that moment in the animation.

INTERACTIVITY

J. T. Stasko, and A. Lawrence [5] list the comments given by his student users of the visualization: lack of multiway tree view. Interaction enhances data exploration. D. A. Keim [4] explains that connecting multiple visualizations through interactive techniques provides more information than considering the component visualizations independently.

DISCUSSION OF RESULTS

The results of the survey are tabulated in the Table 1. None of the AI visualizations surveyed have all the features. Some of them have only 70% of the features. From our survey, it is clear that 100 % of the authors evaluated have tried to address the following features Clarity, Precision, Efficiency, Aesthetics, System Availability, Easy use, and to some extent succeeded in their efforts with their average score of 8.5. Please note that more than 15 visualizations don't work apart from the evaluated list. That means that 50% of the visualizations are not even available. 84% of the authors could provide interface so that the users need not reload every time successfully with an average of 8. 76% have provided both Text and Visualization along with their visualizations with an average of only 7 – which need slight improvement on the part of authors. 68% of the authors have attempted to provide Mapping from pictures to abstract Description. They scored only an average 6. Some more improvements are required. 60% of the visualizations are interactive with an average score of 6 only. Some more improvements are required.

52% of them are provided with facilities for some Learners training with an average of 5. More attention is required. 40% of them are provided with Caution with 4-point bad average. 44% of them are Independent with poor score of 3. This shows clearly the efforts for attaining independency are very less and even their independency is not that great. Only 36% of the visualizations are displayed with the Source code for others to use. Some of them add a sentence that they can be approached through email for source code. Only 0-16% of them tries to provide Speed control, Stop and Start, Step Back, Annotations have very bad average of 0-2. This is the area where more care should be taken.

Out of large number of visualizations surveyed 50% of them are not working. Creating visualization is very expensive. Maintaining it is more expensive. That could be one of the reasons that only 50 % of them are working. While surveying these visualizations, one cannot help the feeling that the enthusiasm for creating the visualization is not sustained by the authors for maintaining them. The authors seem to be overwhelmed by the complexity of the idea to be conveyed in the process they forget about the usefulness of some of the some important features which would have gone in long way to improve the performance of their work.

TABLE 1. Results

Features	% of Visualizations	Average score	Remarks
Clarity	100	8.5	OK
Precision	100	8.5	OK
Efficiency	100	8.5	OK
Speed control	16	2	More Improvement needed
Stop and Start	16	2	More Improvement needed
Step Back	16	2	More Improvement needed
Text and Visualization	76	7	Slight Improvement needed
Caution	40	4	More Improvement needed
Source code	36	4	More Improvement needed
Reload every time	84	8	OK
Independency	44	3	More Improvement needed
Mapping from Pictures to abstract Description	68	6	Slight Improvement needed
Aesthetics	100	8.5	OK
System Availability	100	8.5	OK
Learners training	52	5	More Improvement needed
Easy use	100	8.5	OK
Annotations	16	2	More Improvement needed
Interactivity	60	6	Slight Improvement needed

We understand from our survey that the authors of visualizations are content with the creation of visualizations to convey their ideas but not interested in maintaining them for educational purpose as most of the visualizations don't work. Large number of authors is not keen in paying attention to the above-mentioned features, which are crucial for improving the visualization. The reason for not providing user-friendly interfaces like VCR controls, and annotations could be attributed to the fact that providing them is expensive. But they are very important from the user's perspective. Providing guidelines for creating and then evaluating will help the authors of visualizations to create a better visualization.

FUTURE WORK

We plan to create new visualizations or improve our own existing visualizations based on these guidelines, get them evaluated, get them tested for their effectiveness. If the effectiveness is not statistically significant, then we may have to reevaluate the guidelines. We want to extend our survey to other areas of visualizations – Software visualization, Algorithm animation, scientific visualization, Information visualization.

CONCLUSION

We have crossed a stage where if some one created visualization, it was appreciated without going into merits of the visualization. Now is the high time that we should start pay attention to guidelines, features for improving the visualization. Instead of concentrating on the guidelines and features, there is no point in trying to find out the effectiveness of visualization.

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BIOGRAPHY OF AUTHORS

Paul Juell received his Ph.D. in Computer and Information Science from Ohio State University in 1982. He is an Associate Professor in the Department of Computer Science and Operation Research at North Dakota State University at Fargo. His current research interests include; Artificial Intelligence techniques, distance education and visualizations for teaching. He is a member of the ACM and ACM SIGART.

Vijayakumar Shanmugasundaram is currently working as an Instructor in the Mathematics and Computer Science Department of Concordia College, Moorhead, Minnesota. He received double MS in Engineering and Computer Science from North Dakota State University. He is working on his PhD program in Computer Science under Dr. Paul Juell in North Dakota State University. His research interests include program visualization in teaching, scientific visualization, network and Web based learning. He is a member of the ACM, an affiliate of IEEE, Computer Society, a member of ISCA, and a member of CUR.