

# Web-Based Visualization Tools Of Data Structure & Algorithm – A Review Of Experience

<sup>A</sup>Noor Fadzilah Ab Rahman, <sup>B</sup>Nurkaliza Khalid, <sup>C</sup>Farhana Abdullah  
Ashuhaimi

<sup>a,b,c</sup>*Kolej Universiti Islam Antarabangsa Selangor (KUIS),  
Selangor, Malaysia*

*noorfadzilah@kuis.edu.my*

**Abstract.** Data structure is a fundamental subject for undergraduate computer science students. However, students have encountered difficulties while learning this subject due to its abstract and complex nature. Basically, data structure is a subject which enables students to learn how to organize and manipulate data in a variety of ways. Prior studies have explored and used visualization tools as an approach to address students' difficulties in learning data structure. These studies have shown that the application of visualization tools in learning and teaching could help to assist students' understanding while increasing their motivation and interest in the learning process. The aim of this paper is to review the authors' personal experience of using two web-based visualization tools.

**Keywords:** visualization tool, algorithm, data structure

## INTRODUCTION

Data structure is a subject to teach undergraduate computer science students to organize and manipulate data in a variety ways. However, student encountered difficulties while trying to understand the basic concepts embedded in the subject such as array, stack, linked list, queue, tree and graph. Subsequently, operations such as insertion, deletion, and searching and the algorithms involved in data structure also caused problems to these students. The main reason is the complex and abstract nature of the subject. This means that some level of abstract thinking is required to understand the embedded concepts of data structure. In addition, students need to also understand how the algorithms and various operations were being executed. Thus, the application of traditional teaching methods to learn data structure presented a challenge to both instructors and students.

Prior studies(such as [1], [6] and [7]) have explored and used visualization tools as an approach to address the mentioned difficulties. These researches have concluded that the application of visualization tools, its helped to assist students' understanding, and increase their motivation and interest in their learning process. According to [6], the concept of data structure are commonly illustrated using images. M. Esponda-Arguero[6] further mentioned that visualization coupled with oral explanation are used to clarify the dynamic of algorithm. Therefore, the traditional teaching method could be improved while increasing and also increased the interaction between instructors and students.

Junaid Akram & Luping Fang [4] mentioned visualization as an interface between mind, perceptions, ideas, learning and the way to understand. Their finding showed that the use of visualization tools could enhance students' cognitive level and provide a better learning experience. This is because visualization tools could graphically represent data in either static or dynamic 2D or 3D format [9]. Furthermore, these tools also embedded elements such as animation, visual hints, sound and interactivity to cater the students' different learning styles [5].

Consequently, determining the appropriate practices, aspects and use of visualization software as learning tool is important in the field of software visualization [2]. Currently, there are many visualization tools to be used as learning tools in teaching and learning data structures. However, not all these visualization tools were available for free. Therefore, in this paper, the authors explored and reviewed two visualization tools; Data Structure Visualization and VisuAlgo that are freely available on the Internet based on their personal experience while using the tools. The reviews were focused on the aspects of development and usage of the visualization tools.

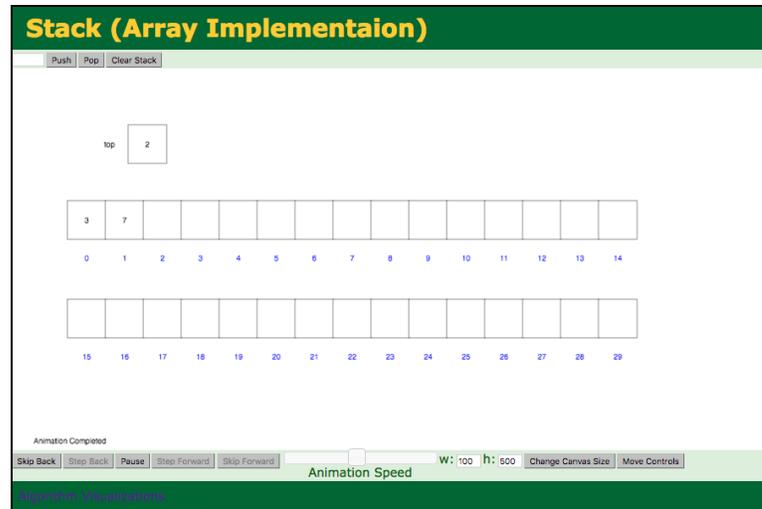
## **REVIEW OF EXPERIENCES IN USING WEB-BASED VISUALIZATION TOOLS**

Data Structure Visualization (DSV) is a free visualization tool which allows users to visualize algorithm and understand complex data structures [3]. The tool could be obtained [www.cs.usfca.edu](http://www.cs.usfca.edu). DSV provide numerous interactive animations for a variety of data structures and algorithms. This visualization tool is written in javascript using the HTML5, and could be run in any web browser and also on iOS devices like the iPhone and iPad.

The DSV provide visualizations for common data structure and algorithm such as Stack, Queues, Recursion, Sorting, Heap and Graph. This visualization tool used the concept of self-explanatory through the use of an algorithm known as Algorithm Specific Control. This control provided algorithm operation that will change depending upon the type of algorithm being visualized. As such, push and pop operations for stack structure were visualized just by pushing several buttons.

Figure1 shows how students can push or pop an element in the stack by entering text in the appropriate field either by pressing return or clicking the relevant button. Array implementation is used to visualize the concept and basic operations of stack. In general, push and pop operations occurred at the top of a stack. The top value of a stack is based on the reference index of an array. Once a new element and push command is given, the visualization will begin to insert the new element into the array according to the current top index value. After the push animation is completed, the top value will automatically change and points to the next index value of the array.

In order to learn and visualize the pop operation, students will need to click the pop button. The pop animation will illustrate how the element is popped out from the array structure according to the top value. Students could also empty a stack by clicking the clear stack button. In order to simplify the visualization of the operation, buttons controlling all general animation appears at the bottom of the screen.



**FIGURE 1:** A snapshot of stack animation in Array Implementation

The general animation controls allow students to do actions such as *skip back* or undo the previous command that has been given. Other actions were *Play/Pause Toggle* in between play mode in which the algorithm runs free until it completes and paused mode where students need to press the *Step Forward* or *Step Back* button to advance the animation. Students could change the speed of the animation by using *Animation speed(sliding)*. They were also given the opportunity to change the canvas size and moves the general controls from being at the top to the bottom of the webpage.

The second free web-based visualization tool explored was VisuAlgo. The URL of website for this tool is <http://visualgo.net>. According to [8], VisuAlgo was conceptualised in 2011 as a visualizations and animations tool to help students to understand well-known data structures and algorithms typically taught in the computer science curriculum by allowing them to learn the basics on their own and at their own pace. However, unlike DSV, VisuAlgo was not designed to work well on small touch screens (e.g. smartphones). This is due to the requirement to cater the complex algorithm visualizations that required lots of pixels and also click-and-drag gestures for interaction. Therefore, the minimum screen resolution for a respectable user experience is 1024x768. Only the landing page is relatively mobile-friendly.

VisuAlgo is an ongoing project and more complex visualizations are still being developed. The VisuAlgo is a tool that contains many visualized advanced algorithms. One important component of VisuAlgo is the Online Quiz which consists of an automated question generator and also answer verifier that allows students to test their knowledge of basic data structures and algorithms. This Online Quiz system provides more than 12 visualization modules to assist students in learning data structures and algorithms. A snapshot of the portal page of VisuAlgo is shown in Figure 2.



**FIGURE 2:** A snapshot of the portal page of VisuAlgo

The VisuAlgo's Online Quiz System generated the questions by using well-defined grammatical rules. The questions were randomly generated. Each visualization module also has a Tutorial Mode that is accessible from that page's top right corner to explain the data structure and/or algorithm being visualized as shown in Figure 3.

The tutorial mode is automatically shown to first time users to showcase the range of capabilities of each visualization page. Figure 3 showed a description of hash table which is displayed at page's top right corner of the visualization page with a list of basic operations that are available at the right corner of bottom page. We can also control the *Play/Pause Toggle* and change the speed of the animation by using the speed/slider that are provided at the bottom of page. The visualization page also provide an e-Lecture mode at the page's left corner for more exploration about the hash table.

Public user can only use the training mode to access this online quiz system as shown as in Figure 4. In order to do this, first, students need to choose the topic. Users are allowed to choose the level of question difficulty (easy, medium or hard). Another possibility that is provided in this system is the numerous questions (up to 20 for each modules). Finally, the time limit to answer the online quiz is up to 40 minutes.

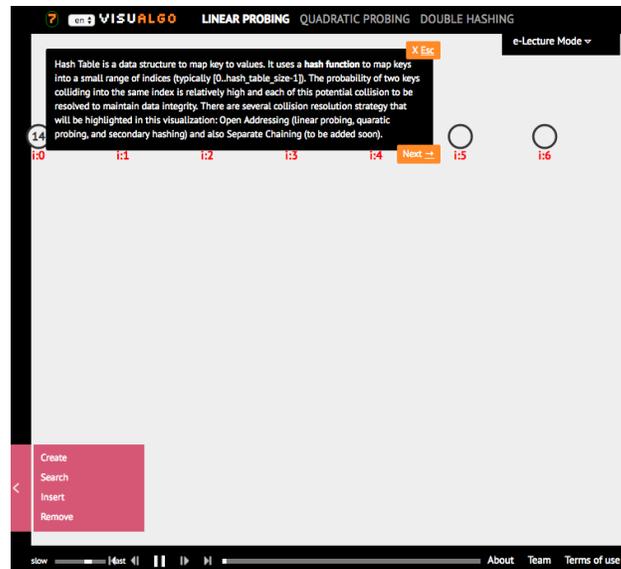


FIGURE 3: A snapshot of Tutorial Mode of Hash Table visualization page

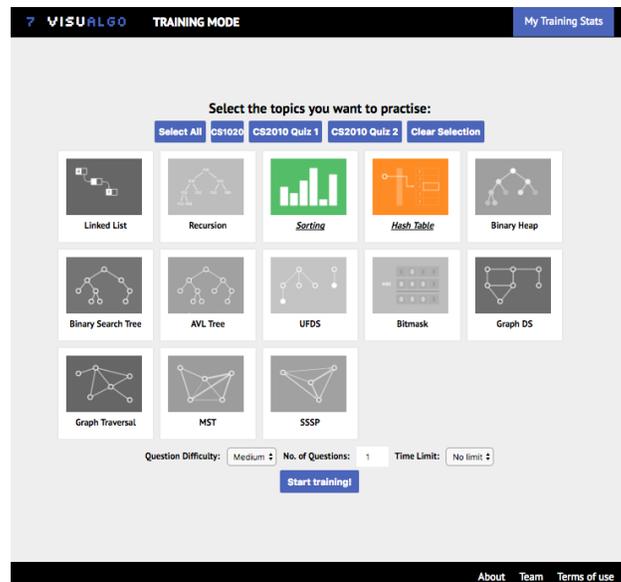


FIGURE 4: A snapshot of training mode for public mod

Then, students can allowed to start answer the questions through on this online quiz. Figure 5 showed a page of selection sort question with a provided choices of answers. Students can choose and enter their answer for the question by selecting one of the given answers in vertex/edge symbol. There are various input methods are provided for students to enter their answers in this online quiz system either in traditional multiple choice question (MCQ) style, selecting one vertex/edge, selecting a subset or a sequence of vertices/edges, enter a number in input box, and draw the answer graph. To proceed to answer the next questions, students need to go the next page that provided at the bottom of page. After all questions are answered, then student need to submit the quiz by clicking the submit quiz button at the page's left corner.

Subsequently, every each students' answers are then evaluated and graded instantly. Figure 6 showed that students would able know the feedback on their answers. The VisuAlgo's Online Quiz System will displayed the answered questions and give the correct answer if their answers are wrongly. Furthermore, the visualization algorithm of each question also provided for better understanding and further learning to students.

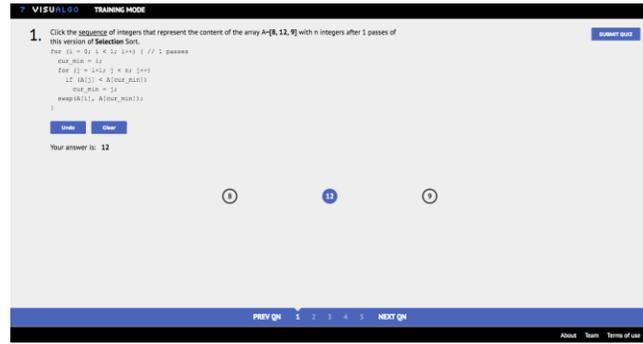


FIGURE 5: A snapshot of online quiz for selection sort topic



FIGURE 6: A snapshot of online quiz answer

## CONCLUSION

In this paper, we have explored and reviewed on the aspects of development and how to use the visualization tool such as DSV and VisuAlgo for teaching and students' self-learning. Based on our review to the related works, we found that the visualization tool of data structures are useful and would be very helpful in self-learning and to see how the execution of the algorithm is animated.

These web-based visualization tool that we reviewed are emphasize on exploration environment, in which students can learn through experimentation of the algorithm's behavior at their own time. These tool can be used to animate user-defined algorithms and also as an effective additional tool to the traditional classroom education.

## REFERENCES

1. Cetin, I., & Andrews-Larson, C. (2016). Learning sorting algorithms through visualization construction. *Computer Science Education*, 26(1), 27-43.
2. Fadzilah et al., (2015). Using Software Visualization In Learning Introductory Programming: A Review. E-proceeding : International Conference on Information Technology & Society .
3. Galles David, 2011, Data Structure Visualization Tool (DSV). <http://www.cs.usfca.edu>
4. Junaid Akram & Luping Fang, 2015. Cognitive Effects of Visualization on Learning Data Structure and algorithms, Proceeding of the 3<sup>rd</sup> International Conference on Digital Enterprose and Information Systems, Shenzhen, China, 2015, ISBN:978-1-941968-10-9
5. Kasurinen, J., Purmonen, M., & Nikula, U. (2008). A study of visualization in introductory programming. In *Proc. 20th annual Meeting of Psychology of Programming Interest Group, Lancaster, UK*.
6. M. Esponda-Arguero, 2010, Techniques for visualizing data stryctures in algorithmc animation, *Journal of Information Visualization* vol 9, 31-46
7. S Roy, “AlgoVis: A Tool for Visualizing and Simulation of Data Structure Algorithm”, International Conf. on Computer, Communication, Control & IT , MacMillan Adv. Research Series, ISBN 023-063-759-0, pp 63-68, India, 2009. Retrieved on: 04 April 2016
8. Steven Halim, Zi Chun Koh, Victor Bo Huai Loh, Felix Halim, 2012, Learning Algorithms with Unified and Interactive Web-Based Visualization, *Olympiads in Informatics*, 2012, Vol. 6, 53–68 . (<http://visualgo.net>)
9. Urvashi Pathania, Aman Singh, 2014, Visualization Tools of Data Structures Algorithms – A Survey, *International Journal of Advanced Research in Computer Science and Software Engineering*, Volume 4, Issue 3, March 2014