International Journal of Pure and Applied Mathematics
Volume 118 No. 24 2018
ISSN: 1314-3395 (on-line version)
url: http://www.acadpubl.eu/hub/
Special Issue
http://www.acadpubl.eu/hub/

Algorithm Visualization Design Guidelines for Mobile Leaning

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April 1, 2018

Abstract

This study is about the algorithm visualization design guidelines for mobile platform, to teach students data structures and algorithm (DSA) subject effectively. The previous analytical review report that AV design guidelines on mobile platform are still lacking. Generally, the previous AV guidelines are prepared for website and desktop platform. In reality, many evidences displayed that mobile learning could improve engagement in learning environments, and consequently effect student's acquisition. Researchers highlighted that UI design and Interactivity are significant elements in designing AV system effectively. Nonetheless, these two facets in previous AV design guidelines are separated and not elaborated comprehensively. The UI design in our guidelines is about the recommendation of user interface arrangement, such as AV features (visualization, pseudo-code, buttons, text, etc.) in mobile screen device, while interactivity discusses the features that can engage students in learning-by-doing paradigm. Consequently, this study primarily proposes the design guidelines of AV mobile learning that integrates those two aspects. The guidelines are established through systematic activities: analytical review from various related fields. The guidelines are useful for AV designers in constructing AV mobile learning.

Key Words:data structure and algorithm, algorithm visualization, DSA, mobile learning and AV design guidelines.

1 Introduction

In the computer science to teach and learn DSA subject are considered as the most challenging duty (1, 2). DSA is an imperative subject for IT students but has abstract nature and hard to learn (3). In general, to portray the sequential process in an algorithm is the difficult one.

Patel (4) listed four difficulties of delivering and understanding DSA course: firstly, the motivation of students looking at this subject is still very low. Second, this subject is so abstract and sometimes so tricky to describe. Third, to do the task together among students is still low too. Forth, students still find it complicated to project the DSA concept into real-life setting as implementation.

Previously, this subject was taught by using text book and power point (conventional approach). Specifically, the lecturers or tutors utilize static images in explaining the sequential processes of each algorithm and its transition. However, representing those logics with static images is considerably not effective (5). Mainly, this happens because students have difficulty to keep up with the movement of static images that represent the complicated processes with many variables and pointers. Also, it is possible for tutors to teach this subject so fast, while students still digest the previous stage of logic (6). Another way is by drawing one by one-by-one picture on white board; this way is considered as clearer and easier to grasp by student, but takes a lot of times.

Therefore, algorithm visualization (AV) has been highly recommended by the researchers in this field to make things clearer and simpler (7). AV is purposely created to visualize or anime the processes sequentially of algorithms, so that students can clearly see the logic behind pseudocode. The AV was in movie animation, which means the students can watch the AV passively. Afterward, many studies (8-11) showed that watching animation only will not yield significant learning performance; an active learning atmosphere must be created. This means interactivity in AV system should be included as to create experiences of active learning system.

In doing so, Naps et al. (12) mentioned six engagement taxonomies as to create active learning in software visualization, which are: no viewing, viewing, responding, changing, constructing, and presenting. No viewing (plain description without animation) is acknowledged as the lowest engagement level, where by presenting (showing proficiency in constructing AV in front of other students) is the highest engagement level.

From their experimental studies, the researchers (13, 14) really suggested to use varied engagement level, due to it will motivate and engage students better in understanding DSA concept. The forms, such as, viewing activity (step-by-step watching animation), responding (quiz form), constructing visualization exercises, etc. In addition, according to Lee and Rling (15) and (16) to design and create AV system effectively, another aspect called user interface (UI) is also prominent to be considered. UI design is about the arrangement symbol system, such as image, text, animation, graphic, placement, sound, icon, decorations, etc. These all elements must be designed carefully; otherwise the poor UI design can lead to low effectiveness of learning (16)(Cooper et al., 2014).

In consort with designing AV system effectively, the researchers (13, 15, 17, 18) in this field also proposed several design guidelines. Nevertheless, the previous review (19) towards these guidelines displayed that AV design guidelines prepared on mobile platform are still lacking. Most of guidelines is for web platform (13, 20) and desktop platform (3). Meanwhile, only two AV studies focused on mobile learning. (17, 21). Additionally, the discussions of interactivity and UI design are separated and still not comprehensive in previous design guidelines. Consequently, this paper takes initiative to propose the AV design guidelines on mobile platform.

2 Literature Review

Many reasons and motivations proved that mobile platform is better than desktop or website platform in term of improving students' learning performance. Duin, et al. (22) stated that mobile learning has been showing a noteworthy increment as a predominant technology, demonstrating distinguished prospective as learning aid.

Mobile learning nowadays is so advantageous, ubiquitous, and irreplaceable that generates the rising of it is rapid. The advantageous of mobile platform are like portability, accessibility, flexibility (23), cross content learning, interactivity, network accommodation (24). Additionally, encouraging the students to work peer to peer and collaborative learning in sharing knowledge without obstructed by time and space (25).

A study by Dahlstrom et al. (26) stated the student that students of university are so passionate to always utilize mobile devices in the class as learning aid. Another by Ciampa (27), the 6th grade students have bigger motivation when the teacher started to explain them through mobile learning. This also has been reviewed from 7 well-known publication journals of Social Science Citation Index (SSCI) by (28) that mobile learning could enhance motivation, students' interest, and learning acquisition. Through post-test and post-test of mobile learning, many researchers (29-31) stated that performance of students is considerably improving.

However, as regards to mobile learning, Ramli & Habib (32) conducted a survey (quantitative analysis) about learning aid, from 19 public Malaysian universities at computer science faculty, namely, UTM, USM, UUM, IIUM, UM, UTeM, UniMAP, UNIMAS, USIM, UniSZA, UPSI, UITM, UPM, UMS, UKM, UPNM, UMP, UTHM, and UMT. They found out PowerPoint is the most used as learning aid with 94.1%, the second highest is through exercises or problem-solving activities (92.2%), and the third is using textbook (90.2).

Hence, this study is motivated to implement AV system into computer science faculty in Malaysia particularly, by starting from developing AV design guidelines on mobile platform as the fundamental of AV studies. As stated before, The AV itself can visualize sequential processes of an algorithm, depicting the motion of pointers, variables, data, operations, etc. (33). The First AV was in 1984, the name was BALSA. Since then, many researchers participated until now to produce their AV, and now there are more than hundreds AV tool across the internet. Each has created with different use case (algorithm types) (34). It is believed that AV is better than Text-Book and PowerPoint in improving students test results.

Meanwhile, this study is purposely prepared to focus more on design guidelines of making effective AV system on mobile learning, which contains two important aspects, namely Interactivity aspect and UI design aspect. The AV designers could adapt these guidelines to any cases of their desired algorithm types; the guidelines proposed will help them to manage or select what they should design, avoid, and add in their AV mobile learning.

3 Methodology/Materials

This research method used for this study is Design Science Research Methodology (DSRM) (35, 36). This methodology has stages and its activities in which the researcher could perform iteratively through stages in fulfilling the research objectives. Figure 3 displays that this study only focuses on the third stage of DSRM which is developing design guidelines. Meanwhile, the other stages will be conducted in the future. The first stage is to identify the research gap, problem statement and research motivation. Then, from its extracted problem of previous stage, it continues to the second stage, which is defining objective of the study. Thus, it is the main artifact is to develop AV design guidelines on mobile platform as the third stage. In doing so, the authors perform content and comparative analysis towards related theories and studies of this field, namely UI design guidelines, mobile development design guidelines, gestalt theory, cognitive load theory, constructivism theory, engagement taxonomies, etc. These activities are responsible to select the appropriate recommendation to be applied in the guidelines.

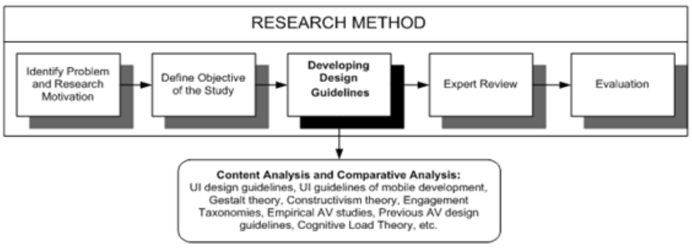

Figure 1. Research Methodology

4 AV Design Guidelines for Mobile Learning

As aforementioned above, the proposed design guidelines comprise two different aspects, which are UI design and interactivity. The guidelines are research-based form in which each has justification (37), extracted from comparative and content analysis results.

5 Aspect of UI Design

i) Avoid horizontal and vertical scrolling the mobile learning studies Fuglerud & Rssvoll (38) and (39) showed learning performance of students is decreasing when they use horizontal scrolling; this is due to the eyes' movement are distracted. Thus, the researchers, such as (21) and (37) strongly suggested to apply tabs or swipe gestures instead, decreasing the probability of distraction in mobile learning. Similarly, scrolling vertically should be removed, due to it also leads to split attention effect (40). This is in line with empirical study by (41) that students' understanding is affected to be slower once they do reading and scrolling simultaneously.

ii) Choose suitable color (Guarantying readability and clarity) Selecting appropriate colors is really important for AV system, displaying or highlighting imperative UI elements, such as, state of visualization (pseudo-code line), animation state or current animation progress, background color, etc (17, 42). If the wrong color is choosen, it will hamper students to grasp the logic and concept of an algorithm (42). Thus, we adapt the list of safe colors in which these colors can be applied to represent information or text on mobile and desktop platform, namely red, green, yellow, blue, black, white, pink, cyan, gray, orange, brown, and purple.

iii) The visualization and pseudo-code have to be adjacent The placement of AV and pseudo-code has to be close each other in one area. If the components are placed in different area or separated with big white space, the split attention effect will happen and influence the focus of learning process. This is similar to the recommendation by cognitive load theory (43). Specifically, it is mentioned in his spatial contiguity principles that the correspondent picture and text have to be put closely as it will enhance the students' understanding.

iv) Show textual explanation During the presentation of AV step-by-step process, the textual explanation for each state will help student understanding the concept of an algorithm (44, 45). This textual explanation responds towards current algorithm visualization step in viewing activity.

v) Use sound/aural explanation To strengthen the learners' perception, the aural explanation is really suggested as additional explanation, clarifying textual explanation (13, 15). This is due to rehashing information could be avoid using this approach. The students can understand the explanation in the proper manner, decreasing the misunderstanding or having wrong interpretation. A study by Alhosban and Hamad (13) exhibited that students' response time and learning acquisition are gradually improving after using additional aural instruction. Nonetheless, the other types of sound, such as music background could sometime divert students during learning environment (46).

vi) Select the relevant and important content: AV designers should be careful in choosing information or content to be placed on AV system, excluding irrelevant information, otherwise it will affect the effective learning of students. The designers should remove the arbitrary animation, explanation, screen background (47). This is also underscored in coherence principle by Mayer (48) that stated the better learning will be gained, if the irrelevant or unnecessary contents are eliminated. This happens because sometimes designers like to put more designs (background), additional sound and text which are not related with the learning material itself. Therefore, simple, concise and direct will help much better for learners to comprehend the course. vii) Design visual hierarchy on AV system This section recommends making appropriate visual hierarchy, namely, proximity, alignment, contrast, and repetition (Williams, 2005) (49). Contrast means designer should create such appealing variation on visual elements. The things like size, shape, space, etc. Repetition means to create rhyme for the similar visual elements, showing the unify region and duplication style to the same elements (Graham, 2008) (50). Alignment is about creating connection towards visual elements, can be along the curvilinear or linear path. Proximity is about placing the related elements nearby one another. Finally, the expanded/hidden menu or information on mobile platform is effective to characterize hierarchical presentation.

viii) Choose appropriate orientation This must be chosen in appropriate manner; the designer can select either orientations (portrait or landscape) or fix to use one orientation style only (51). Even though, some studies (41) suggested that landscape orientation give more effects on students' learning performance and students' user experiences than portrait orientation.

viii) Text size and visualization should be responsive: The elements such as, text size, animation, and others should be responsive with the phone resolution size, meaning they can respond to be smaller and bigger size depending on phone screen size. In addition, according to study by (41), they reported that regarding small screen size, the smaller text is preferable compared to bigger size, due to it will decrease the risk of expanding that need learner to do scrolling action.

6 Aspect of Interactivity

i) Customize environment: The learners have control to adjust the environment of AV system based on preferences. For example, they can adjust the background color, speed of visualization, and magnification so that they will be more comfortable and enjoy the learning (Halim, Koh, Loh, & Halim, 2012b) (6).

ii) Support database that can save points This feature enables AV system to store the points of students' answer as they will learn through their mistakes(52). Points are used usually in exercises activity. The point is also able to encourage students' motivation and challenge them more to have better results.

iii) Allow students to have viewing AV activity As it is listed in engagement taxonomy by Naps et al., (12), viewing is the lowest engagement level in AV system. Viewing is the fundamental feature so that students can watch the step-by-step process of visualization by pressing several control buttons, such as next, prev, play, etc. The next button allows student to go to the succeeding processes and the prev one is used to get back to the previous line once they lose of the track. While play button only let the student watch the animation from the beginning until the end. Myller et al. (53) added that the viewing control is categorized as controlling viewing engagement.

iv) Use structural view in AV Another feature during viewing activity is to have structural view in AV, making thing easier for learners to jump further to the other steps since they already master the previous logic before (54). This feature enables students to jump to particular steps without have to back to the whole processes from the beginning.

v) Allow responding activity Responding level is the second of engagements taxonomy in which students are mandatory to answer some relevant questions or also asking predictive question during viewing activity. The studies by (55, 56) showed that the transition activity from viewing then continue to do responding activity are able to increase the comprehension of students. Two ways on how to implement responding level. Firstly, the designer could integrate responding activity during viewing activity, which means while students watching AV, the question can pop-up to ask them what will be the answer for the next line, reflecting either they understand the continuation of the logic or not. Secondly, the responding activity is placed in different area as it shows the relevant questions (quiz-form) to be fulfilled. In addition, to support responding activity, additional clues are useful as feedbacks of students' answer to guide what to do or respond. Lastly, the answer is presented later.

vi) Allow changing activity The third engagement level of taxonomy is changing level. This means the students can insert or change the variable value so that they can see the different behavior of AV. This helps student to learn and understand better when they can see the different example of AV (57). This level is represented together with viewing activity in which student can custom their input before and continues to perform viewing activity.

vii) Allow constructing activity Constructing is the fourth engagement level of taxonomy; this is presented in form of exercises activity. The students can play or simulate the AV itself, following the instruction provided by clicking interface of AV element, for instance array, number to be further swapping, selecting, connecting, etc. Malmi, et al. (52). In exercises activity, immediate feedback is really recommended to increase learning effectiveness (Urquiza-Fuentes & Velzquez-Iturbide, 2009) (58), informing the learners about the clue, instruction, confirmation, information about wrong or right answer, etc.

viii) Allow presenting activity This level is the fifth and the highest engagement level. This level is related to the proficiency of students, presenting their simulation (constructing activity) in front the class. This also can be done by explaining using viewing feature.

7 Conclusion

This study proposed the AV design guidelines on mobile platform, providing what should the designers do in two different aspects, namely: UI design and interactivity. These guidelines are created based on research-based, which mean each guideline is created based on its justification from the DSRM third stage. The guidelines are helpful for AV designers and lectures in designing AV learning on mobile platform effectively. The UI aspect is for designing user interface of AV, arranging and select appropriate AV elements. Meanwhile, interactivity is about recommendations towards what kind of features that should be applied on AV to guarantying the active learning environment. In the future study, the authors will go to the next stage, which are conducting expert review (reviewing the guidelines) and validating (doing prototyping) as user evaluation stage.

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