Automated Repair of Asymmetric Web Pages during Resolution of Mobile Friendly Problems

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Keywords: Mobile Friendly Problems, Symmetric Structure, Web Application.

Abstract: In software development, software usability is an important aspect to ensure the end-user does not strain or encounter problems with the use of a product or website's user interface. Mobile friendly problem (MFP) causes the low quality of the website visibility and has a potential risk to decrease usability for a mobile user. The existing solutions to mobile friendly problems do not address symmetrical structure of web pages. To address this limitation, we have proposed an automatic repair technique that generates symmetric mobile friendly patches by tuning the symmetric criteria of a web page. The empirical evaluation shows that this approach gets better structure on the basis of symmetry in 90.7% of the evaluated websites. Moreover, A survey based evaluation shows that 88%, out of 54 websites, have been considered as more preferable than the previous version by the users.

1 INTRODUCTION

The web is being accessed more and more on mobile devices. Mobiles have become a common medium of accessing the internet. Designing websites to be mobile friendly ensures that the pages of that website is readable and usable on all devices (Mob, 2020). The websites which are developed for desktop viewport might be difficult to view and use on a mobile device. Alternatively, the mobile-friendly version is readable and immediately usable. Google has updated its ranking criteria and included mobile-friendliness as a criteria while returning search results for mobile devices in April 2015 (Mul, 2020). This concludes that if a website is not mobile friendly, the probability of getting higher rank in the search results will be less.

The main problem of existing approaches is the violation of symmetric structure of the website. Symmetrical design relies on proportion to create a style with mirroring sides. Symmetry happens when the composition of design is distributed evenly around a central point or axis of a website (Yang and Shi, 2009). Symmetry is considered one of the most important predictors for visual appeal according to the gestalt law which describes how human perceives patterns. (Bauerly and Liu, 2008). Gestalt theory is a psychology theory to describe the perspective process of human (Wertheimer, 1938). Lavie and Tractinsky have also argued that symmetry is also an important factor in the aesthetic perception of websites (Lavie and Tractinsky, 2004). In Zheng et al.'s evaluation, symmetry significantly correlated with participants' subjective ratings on aesthetics (Zheng et al., 2009). Symmetry happens when the composition of web elements, contents and design is evenly distributed around a center point of axis. The work involved in making a symmetric mobile-friendly site can depend on developer resources, business model, and expertise. There is no automatic way to ensure symmetry of a website. The developers have to implement the symmetric design manually. So this is time consuming and costly.

The existing approaches of repairing a mobile friendly websites do not ensure the symmetry of the web page. There are some existing approaches to fix presentation issues of websites. For example, one approach repairs layout cross browser issues caused by the inconsistencies in different browsers' rendering of a same web page (Mahajan et al., 2017). The other solution shows a framework of repairing faulty CSS of a web application but it does not address mobile friendly problems (Walsh et al., 2015). Elsewhere. PhpRepair (Samimi et al., 2012) solves HTML syntax problems in web application. Moreover, Wang et al. (Wang et al., 2012) proposed an approach to fix presentation issues using static and dynamic analysis. However, none of these techniques identify mobile friendly problem and provide repairs for them. Maha-

Azmain, M. and Ganguly, K.
Automated Repair of Asymmetric Web Pages during Resolution of Mobile Friendly Problems.
DOI: 10.5220/0010500504610468
In *Proceedings of the 16th International Conference on Evaluation of Novel Approaches to Software Engineering (ENASE 2021)*, pages 461-468
ISBN: 978-989-758-508-1

jan et al. (Mahajan et al., 2018) proposed an approach to produce CSS patches automatically that can fix the mobile friendly problems of a web page (Mahajan et al., 2018). To distinguish the best fix proficiently, this methodology evaluates metrics identified by layout distortion and mobile friendly score to achieve the solution. None of the existing approaches ensures symmetry during resolution of mobile friendly problem.

The goal of this research is to deliver a technique to improve symmetric structure of a website during resolution of mobile friendly problems. This proposed method has been compared with the existing works. This methodology helps to develop mobile friendly websites with a symmetric structure. Moreover, this approach has decreased development time and cost as it automatically fixes a web page according to the viewports of the mobile devices.

With this aim, this study answers the following Research Questions (RQs):

1. **How to improve symmetric structure during resolution of mobile friendly problems?** By answering the following sub-questions this question can be answered.
   (a) **How to identify CSS properties and values of the HTML elements that cause asymmetry of a web page?** By answering this question, we will get a solution to find some problematic HTML elements that cause asymmetry.
   (b) **How to improve symmetric structure of a website in different viewports?** By answering the question, a patch will be generated automatically that will modify some CSS properties like position, height, width, padding etc. so that the whole page will be symmetrically structured.

To answer these questions, a search based technique has been proposed that uses balance score and proportion score to address an optimal solution to get symmetric mobile friendly CSS patch. This technique first applies patches to fix mobile friendly problems of the target patch. Then, the approach evaluates symmetric structure of the web page on the basis of symmetry based metrics named proportion score and balance score. It also finds the faulty HTML elements that cause asymmetry. After that, the approach generates patches that modifies some CSS properties like position, height, width, padding etc. so that the whole page can be symmetrically structured. Therefore, the approach generates patches that maintain trade-off between symmetry and layout distortion. The approach repositions the segments to maintain symmetry by updating CSS values of the HTML elements. The solution can be applied to any types of viewports because the size parameters are configurable in the media query according to the accessed device viewport size.

To evaluate this solution, the proposed solution has been validated using both metrics and survey-based evaluation. The repaired version has achieved better score in terms of balance score and proportional score. This symmetric mobile friendly approach gets 90.7% better balance score and 96.2% better proportion score than the existing mobile friendly approach. It confirms that the repaired versions have more symmetric structure than the existing mobile friendly technique. A survey based evaluation has been conducted on 25 professional software engineers of Bangladesh. This survey shows that 88% websites, out of 54, have been considered as more preferable than the previous version by the users. On average, the rating (out of ten) of updated symmetric mobile friendly version had a 21% improvement than the mobile friendly version.

2 METHODOLOGY

This section contains the core parts of the technique which are later described in details throughout this chapter. The following points are the main constitutes of the proposed approach.

First, the approach parses the document object model (DOM) tree of the target web page to identify the segments. After that, the approach incorporates the existing mobile friendly fix (Mahajan et al., 2018). This applies patches to fix mobile friendly problems of the target patch. This step uses two metrics named mobile friendly score and layout distortion for evaluation.

Then, the approach evaluates symmetric structure of the web page based on symmetry based metrics. It also finds the faulty HTML elements that cause asymmetry. Moreover, the CSS attributes and the values of the elements is identified. For example, an image containing absolute positioning, fixed height and fixed length can cause asymmetry. To detect the asymmetry, the approach checks the balance between the two sides of a web page according to the centralized vertical axis. The approach identifies all these problematic properties and values that cause asymmetry.

After that, the approach generates patches that modifies some CSS properties like position, height, width, padding etc. so that the whole page can be symmetrically structured. However, improving symmetry can cause layout distortion. Layout distortion means overlapping of the segments of a web-

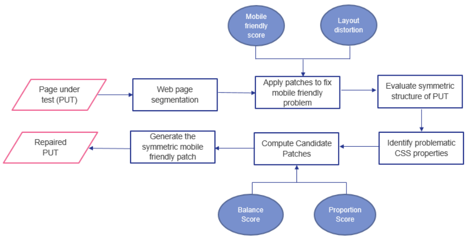


Figure 1: Overview of the solution approach.

Figure 2: Example of Web Page Segmentation.

site. Therefore, the approach generates patches that maintains trade-off between symmetry and layout distortion. The approach updates the position property value (static, relative or sticky) to achieve the most symmetric structure possible for that web page. However, the updated element can overlap on other elements that cause segment overlapping. To resolve this, the approach repositions the overlapped segments maintaining symmetry. The overview of the solution approach is shown in Figure 1. This step uses two metrics named proportion score and balance score to generate the symmetry mobile friendly patch. New values are made into CSS style declarations by converting it into a CSS selector. A CSS media query is formed by these updated CSS style values.

2.1 Segmentation of the Web Page

The primary stage analyzes the structure of the page to recognize fragments - sets of HTML components whose properties should be balanced together to preserve the visual consistency of the repaired page. An illustration of a segment may be a arrangement of text-based links in a navigation bar where on the off chance that the text style measure of any interface within the section is little, at that point all of the nav links ought to be balanced by the same amount to preserve the links' visual consistency. To maintain consistency, the fix value of a target element has to be close to the related elements.

The document object model (DOM) tree of the target web page needs to parsed to identify the desired segments from a web page. There are several types of segmentation process, such as Block-o-matic (Sanoja and Gançarski, 2014), clustering based partitioning (Chakrabarti et al., 2008), correlation clustering(Bansal et al., 2004). We have chosen to use visual representation based segmentation process called VIPS (Cai et al., 2003). In the VIPS algorithm, the vision-based content structure of a page is deduced by combining the DOM structure and the visual cues. First, DOM structure and visual information, such as position, background color, font size, font weight, etc., are obtained from a web browser. Then, from the root node, the visual block extraction process is started to extract visual blocks of the current level from the DOM tree based on visual cues. Every DOM node is checked to judge whether it forms a single block or not. If not, its children will be processed in the same way. When all blocks of the current level are extracted, they are put into a pool. Visual separators among these blocks are identified and the weight of a separator is set based on properties of its neighboring blocks. After constructing the layout hierarchy of the current level, each newly produced visual blocks is checked to see whether or not it meets the granularity requirement. If not, this block will be further partitioned. After all blocks are processed, the final vision-based content structure for the web page is outputted. Below we introduce the visual block extraction, separator detection and content structure construction phases respectively. The steps of VIPS is shown in Figure 2. We can see that, the segments are the header content, multiple content pane and the footer. The blue blocks are the separators of the segments. The red blocks are intermediate segments and the black blocks are the final segments of the web page.

2.2 Applying Mobile Friendly Fix

After segmentation, this approach incorporates the existing mobile friendly fix (Mahajan et al., 2018). The overview of the process is given below:

1. Identifying Problematic Segments. To detect mobile friendly problems in a web page, google mobile friendly test (GMFT) is used. The GMFT tool identifies the problems with the faulty elements and their CSS properties. Then it is easy to determine which segments have faulty elements by analyzing the CSS properties. This approach applies a update to the segments to recognize which ones may be tricky with regard to that mobile friendly issue. The issue with the CSS properties is, they inherit styles from their parent HTML elements. Therefore, this approach introduce Property Dependence Graph (PDG). This graph repre-

sents style relationships among all of the HTML elements of a web segment based on CSS inheritance. This approach defines three type of PDG: font, content size and tap target PDG.

2. Repair. The repair step uses two metrics named mobile friendliness and layout distortion. The Google mobile friendliness test scores each web page on the basis of mobile friendliness. This score has a range of 0 to 100. The measure of update in a layout can be controlled by building models that express the relative visual positioning among and inside the parts of a page. To decide the edge marks, the methodology registers the Minimum Bounding Rectangles (MBRs) of each section (Chaudhuri and Samal, 2007). This is done by finding the largest and smallest X and Y coordinate values of the components, which can be obtained by analyzing the DOM of the page.
3. Computing Candidate Patches. The best CSS patch balances between the mobile friendliness and layout distortion. It irritates adjustment factors as to find the appropriate fix that vary a little from the original web page. This approach finds that the mean and standard deviation values are the best in context of Gaussian distribution. Finally, this approach included an amendment factor to permit the way to get the optimal solution.
4. Generating Final Patch: The method creats a set of fixes. The CSS properties are updated according to the fix result for all nodes in the PDG. A CSS media query is formed by these updated CSS style values. When an user access the page, this media query cause it to be rendered.

2.3 Evaluation of Symmetry Structure

In this stage, the approach finds the faulty HTML elements that cause asymmetry. Moreover, the CSS properties and the values of the target elements will be identified. For example, an image containing absolute positioning, fixed height and fixed length can cause asymmetry. To detect the asymmetry, the approach will check the balance between the two sides of a web page according to the centralized vertical axis. The method has to identify all these problematic properties and values that may cause asymmetry.

After getting all the HTML elements along with the CSS properties, the approach detects the faulty elements that cause asymmetry to the web page. This detection is done separately for each segments of the web page. The symmetric evaluation of the HTML elements is concluded by two metrics. They are:

(a) Balance Score. The equal distribution of visual weight in a design is defined as balance. Visual balance occurs around a vertical axis. Our eyes require the visual weight to be equal on the two sides of the axis. Balance score is a metric for measuring equilibrium along a vertical axis in the layout. It is calculated by the summation of symmetrical balance, vertical balance and horizontal balance. The balance score of an individual element, $B_i = (N_i, H_i, C_i, E_i)$ is defined as follows:

(i) N_i The number of elements in each segments on both sides.

(ii) H_i The distance from the closest headline and sub-headline on both sides or not.

(iii) C_i The distance from the closest call to action button according to the center.

(iv) E_i The number of elements under the heading on both sides

The total balance score is the summation of each balance score of the targeted web page. If the the total balance score for a page p is $B(p)$ and total number of elements in that page is n, then

$$B(p) = \frac{(n*100) - \sum_{i=1}^{n}(N_i, H_i, C_i, E_i)}{n*100}$$

(b) Proportion Score. It is the ratio between the dimensions of elements. The ratio is calculated by dividing the height of any element by its length. The proportion of every elements in a web page needs to be similar to maintain symmetric structure. The proportion score of a web page is calculated by the difference of individual mean proportion score of each mirror side of that web page. The solution is looking for a proportion score close to zero. If the height of an HTML element e is H_e and width is W_e, the proportion score of that element is P_e.

$$P_e = \frac{H_e}{W_e}$$

The web page needs to divided into two sides on the basis of vertical axis. Then the elements will be separated into two sets such as left set and right set. The elements, which are overlapped on the vertical axis, are the common members of the two sets. If the proportion score of left set is P_Ls and right set is P_Rs,

$$P_Ls = \frac{\sum_{i=1}^{n_l} P_e}{n_L}$$

where the number of elements in left side is n_L and

$$P_Rs = \frac{\sum_{i=1}^{n_R} P_e}{n_R}$$

where the number of elements in left side is n_R. Therefore, the final proportion score of a page W is P_W,

$$P_W = P_Ls - P_Rs$$

These two metrics are used to detect the faulty elements in that web site which cause the distortion of symmetry. Moreover, the approach gets the faulty segments by analysing the faulty HTML element's segment.

2.4 Generate Symmetric Mobile Friendly Patch

The idea behind the solution is to achieve optimal solution efficiently. Search based technique has been used to generate candidate patches to get symmetric mobile friendly web page. The value of balance score and proportion score has been changed dynamically to gain highest balance score (close to 1) and lowest proportion score (close to 0). Search-based strategies start by choosing a sample set from the solution space. For this, the method iterates over each of the elements in the site. For every component, it repeats over every node of the PDG, beginning with the root node, and updates value that will be referred to CSS property. When new property estimations have been completed for all nodes in the PDG, the method creates a bunch of fixes. The values have been updated according to achieve the highest balance score and lowest proportion score.

New values are made into CSS style declarations by converting it into a CSS selector. A CSS media query is formed by these updated CSS style values. When an user access the page in a mobile viewport, this media query cause it to be rendered with the updated CSS patch.

3 EXPERIMENTATION AND FINDINGS

This section contains the implementation details, experiments, result discussion of the proposed approach. The discussion of the results to explain some important insights are also presented. This section also describes the subjects, tools that is used in the implementation, environment setup and evaluation questions.

3.1 Implementation Details

The proposed methodology was implemented in Java using Eclipse Photon 4.8 Integrated Development Environment (IDE) (Ecl, 2020). Moreover, We used python 3 using virtual studio code to develop the analyzer tool named UIAnalyzer. An Object Oriented Programming language such as Java provides extensive support for polymorphism, inheritance and encapsulation which are necessary for reusability. This is why it was used to implements the approach.

We have used Google mobile friendly test api to identify the mobile friendly problems in a web application.Mobile Friendly Test is a tool that allows to easily carry out a mobile site test telling about a website's score in terms of mobile responsiveness. To render the document object model of a webpage and to get information about XPath of the HTML elements, an emulated Chrome browser v65.5 has been used for mobile experience. Selenium Webderiver is used to get all the HTML elements parsed. We have used jStyleParser for detecting defined CSS properties for every HTML nodes in a web page.

3.2 Subjects

For result analysis, 54 websites were selected from the most popular websites list across all categories listed by MOZ top 500 websites (The, 2020). We selected MOZ website list as the source because it gives the popularity based ranking and a mix of different layouts. We have used HTTrack (HTT, 2020) to download all the HTML files, images, CSS and javascript files from the website.

3.3 User based Case Study

A user based case study has been conducted by doing a survey. The purpose of this survey is to evaluate the visual appeal of the updated web page that is incorporated with symmetric mobile friendly patch. The participants were asked to compare the previous and updated versions of the subjects in that survey. For each subject, the survey included a screenshot of the original and updated pages when viewed in a viewport of the mobile device. The questions of the survey were:

1. Which version between two screenshots (One is mobile friendly, other one is symmetric mobile friendly) is more visually attractive?
2. Which version they would prefer more to use in a mobile device?
3. Rate the each version of the target page on a scale of 10.

We used Google Form service to do this survey. For the survey, we had 25 participants who are currently

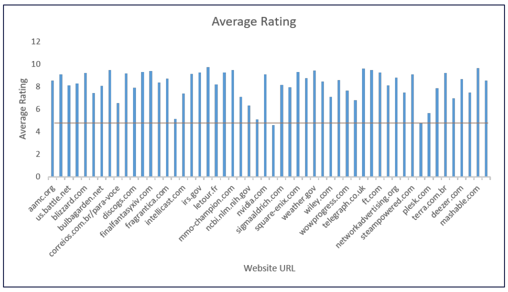
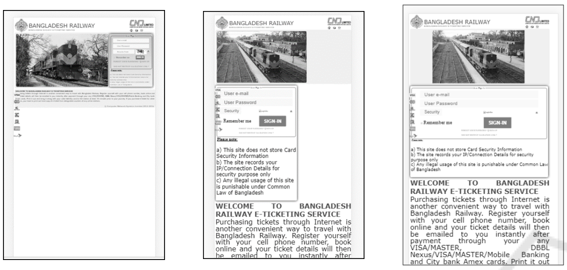


Figure 3: Average Rating of symmetric mobile friendly versions of 54 subjects.



(a) Website with mobile friendly problems

(b) Website after applying mobile friendly solution

(c) Improved symmetric structure

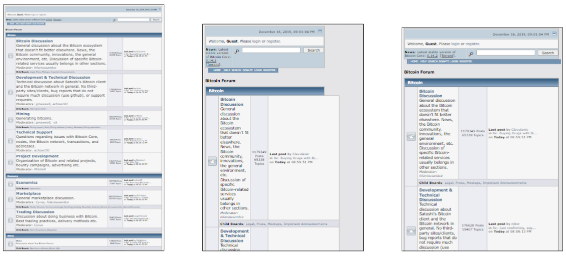
Figure 4: Screenshots of the outcome - 1.

working as software developers in different multinational software companies of Bangladesh. Based on the result of the survey, the participants preferred using symmetric version 48 out of 54 subjects. Only 6 subjects had a negative preference for using the symmetric version. On average, the rating of updated symmetric mobile friendly version had a 21% improvement than the mobile friendly version. Figure 3 shows the average ratings of symmetric mobile friendly versions of all 54 subjects given by the participants. It shows that 53 of them have a rating of more than 5.

There are some screenshots (4) given. 4a shows a website with various mobile friendly problems. After applying the solution for mobile friendly problems, the website has asymmetric structure (4b). 4c is the final result that shows how the website looks after fixing the structural problem. Figure 5 shows one more example of the symmetric mobile friendly solution.

4 RESULT ANALYSIS

The effectiveness of the approach is dependent on two metrics such as balance score and proportion score of a web page. The range of two metrics is 0 to 1. If the balance score is close to 1 and the proportion score is close to 0, it is evaluated as more effective. First, these



(a) Website with mobile friendly problems

(b) Website after applying mobile friendly solution

(c) Improved symmetric structure

Figure 5: Screenshots of the outcome - 2.

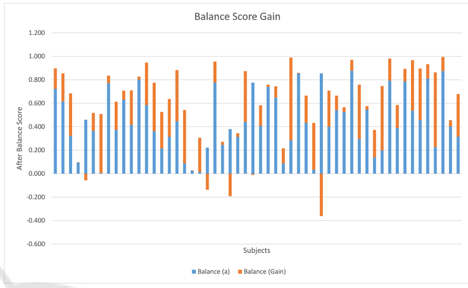


Figure 6: Distribution of Balance Score Gain.

metrics have been calculated for the version with mobile friendly patch. Then, these metrics have been calculated for the updated version of the website with symmetric mobile friendly patch. As we are targeting to increase the balance score and decrease the proportion score, it is easy to evaluate the effectiveness of the approach by analyzing the difference of the two versions of the subjects.

The balance score and proportion score of the mobile friendly versions and symmetric mobile friendly versions for 54 websites can be found in this link[1]. 49 out of 54 subjects have gained balance score. Therefore, the effectiveness of the approach on the basis of balance is 90.7%. Moreover, 52 out of 54 subjects have lost proportion value. The effectiveness on the basis of proportion score is 96.2%. The figures 6 and 7 show the distribution of balance score and proportion score. The blue portion indicates the proportion score and balance score of the mobile friendly version. The orange portion indicates the improvement of proportion score and balance score of the symmetric mobile friendly version. It shows that the symmetric mobile friendly version generates better patch than the mobile friendly patch in terms of symmetry.

Table 1 shows that the mean value of balance gain is 0.20 and the mean value of proportion loss is 0.25 which are greater that 0. It confirms that the repaired versions have performed better than the previous mo-

[1]https://doi.org/10.6084/m9.figshare.14184635

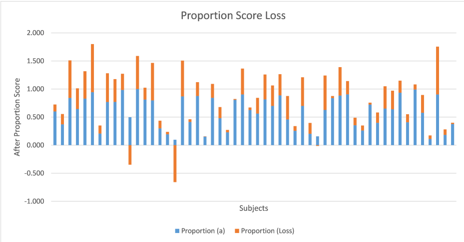


Figure 7: Distribution of Proportion Score Loss.

bile friendly technique.

Table 1: Summary of Evaluation Metrics.

	Max	**Min**	**Average**
Balance Gain	0.705	-0.361	0.202
Proportion Loss	0.858	-0.658	0.253

5 RELATED WORK

In this section, the existing mobile friendly problem solving approaches will be discussed. In the literature, most of them have proposed the detection and resolving process of presentation failure of web applications (Walsh et al., 2015; Panchekha and Torlak, 2016; Mahajan et al., 2017; Alameer et al., 2016; Wang et al., 2012). A few have proposed the resolution process of mobile friendly problems in web pages (Mahajan et al., 2018). Some of them have shown the significance of visual symmetry as an important factor in the aesthetic perception of websites (Bauerly and Liu, 2008; Lavie and Tractinsky, 2004; Zheng et al., 2009).

Walsh et al. (Walsh et al., 2015) proposed an automated method for detecting potential faults in the layout of responsively designed pages. This approach models the layout of a responsive web page across a series of viewport widths, explicitly taking account of the key aspects of responsive layout, namely the changing visibility, width, and relative alignment of web page elements. This approach can not detect mobile friendly problems. Moreover, new HTML elements namely header, footer, section etc have been introduced recently. This approach does not work properly with these elements.

Alameer et al. (Alameer et al., 2016) proposed an automated technique for detecting when a web page's interface has been distorted due to internationalization efforts and identifying the HTML elements or text responsible for the mentioned problem. This solution is too specific to generalize to the broader domain.

The continually expanding number of internet browsers with which clients can get to a site has presented new difficulties in controlling visual issues. Differences in the appearance of a site across various web browsers are known as Cross Browser Issues (XBIs) (Mahajan et al., 2017). It is caused by the contrasts in how different programs render HTML and CSS rules. The XFix technique repairs layout Cross Browser Issues (XBIs) — presentation failures. In this domain, the “correct” presentation of the page is available through one of the browsers, the layout of which must be mimicked in another. Mobile friendly problems entail a different approach, in which the presentation of a page must be changed to correct a series of identified issues. There is no correct reference rendering available to the repair process, which must also maintain as much of the original aesthetics of the page as possible.

Mahajan et al. (Mahajan et al., 2018) proposed an automated approach for solving mobile friendly problems in web application. They proposed a way to dynamically create CSS patches that can improve the mobile friendliness of a site. To effectively get the best fix, this methodology checks different aspects of the problem to evaluate metrics identified by layout distortion and the calculation of the solution. The approach is divided into 3 phases - segmentation, localization and repair. The repair phase computes a repair CSS set for the web page. It identifies a patch that improves the web page's mobile friendliness score. It also ensures that the generated patch does not significantly distorts the layout of the web page. They analyzed 38 real-world subjects collected from the best 50 most visited websites over all seventeen categories reported by Alexa. The results for effectiveness were that 95% (36 out of 38) of the subjects passed the GMFT after Applying MFix's proposed CSS repair fix. In terms of the measuring metric, the repaired version was evaluated to have improved visual value as it were 38% of the time. This approach solves mobile friendly problems of a website but it can not maintain the original symmetric structure. Therefore, the repaired version has a lower attractiveness. According to their evaluation, the repaired version had a lower attractiveness 62% of the time.

The existing solutions of asymmetry and mobile friendly problems are limited in manual development. These approaches are time consuming and costly. One approach repairs layout cross browser issues caused by the inconsistencies in different browsers' rendering of a same web page. The other solution shows a framework of repairing faulty CSS of a web application but it does not address mobile friendly problems. An other approach fixes presentation issues using static and dynamic analysis. There is an approach to produce CSS patches automatically that can fix the mobile friendly problems of a web page. However, none of these techniques solve both asymmetry and mobile friendly problem, which provides the scope for a major contribution in this domain.

6 CONCLUSION

This paper proposes an automated repair technique that incorporate mobile friendly solutions and symmetric structure of web application. For this, a search based approach has been devised that considers coordination between mobile friendly problem and symmetry problem. This approach depends on offline version of a website because this can not handle the dynamic changes in rendering. Our future work is to handle the dynamic changes along with the symmetric mobile friendliness of a web page. This solution needs to introduce fixing the online version of a web site. Another possible future work is to analyze the relation between symmetry, mobile friendliness and complexity of a web page to quantify this relation. As the complexity of a web page depends on the elements, contents and layout, symmetry analysis on different types of website can extract valuable insights. Moreover, new HTML elements have been introduced in modern web pages. The modification of these elements needs different approach in the context of symmetric mobile friendly solution. In addition to that, different types of new viewports are being introduced day by day. These new viewports may need updated solution to incorporate.

REFERENCES

(2020). Eclipse photon — the eclipse foundation. https://www.eclipse.org/photon/. (Accessed on 09/30/2020).

(2020). Httrack website copier - free software offline browser (gnu gpl). https://www.httrack.com/. (Accessed on 09/30/2020).

(2020). Mobile-friendly test – google search console. https://search.google.com/test/mobile-friendly. (Accessed on 09/28/2020).

(2020). Multi-screen overview - adsense help. https://support.google.com/adsense/answer/6051803?hl=en&visit_id=637368306470692014-1946767540&rd=1. (Accessed on 09/28/2020).

(2020). The top 500 most popular websites - moz. https://moz.com/top500. (Accessed on 09/30/2020).

Alameer, A., Mahajan, S., and Halfond, W. G. (2016). Detecting and localizing internationalization presentation failures in web applications. In *2016 IEEE International Conference on Software Testing, Verification and Validation (ICST)*, pages 202–212. IEEE.

Bansal, N., Blum, A., and Chawla, S. (2004). Correlation clustering. *Machine learning*, 56(1-3):89–113.

Bauerly, M. and Liu, Y. (2008). Effects of symmetry and number of compositional elements on interface and design aesthetics. *Intl. Journal of Human–Computer Interaction*, 24(3):275–287.

Cai, D., Yu, S., Wen, J.-R., and Ma, W.-Y. (2003). Vips: a vision-based page segmentation algorithm.

Chakrabarti, D., Kumar, R., and Punera, K. (2008). A graph-theoretic approach to webpage segmentation. In *Proceedings of the 17th international conference on World Wide Web*, pages 377–386.

Chaudhuri, D. and Samal, A. (2007). A simple method for fitting of bounding rectangle to closed regions. *Pattern recognition*, 40(7):1981–1989.

Lavie, T. and Tractinsky, N. (2004). Assessing dimensions of perceived visual aesthetics of web sites. *International journal of human-computer studies*, 60(3):269–298.

Mahajan, S., Abolhassani, N., McMinn, P., and Halfond, W. G. (2018). Automated repair of mobile friendly problems in web pages. In *Proceedings of the 40th International Conference on Software Engineering*, pages 140–150. ACM.

Mahajan, S., Alameer, A., McMinn, P., and Halfond, W. G. (2017). Automated repair of layout cross browser issues using search-based techniques. In *Proceedings of the 26th ACM SIGSOFT International Symposium on Software Testing and Analysis*, pages 249–260. ACM.

Panchekha, P. and Torlak, E. (2016). Automated reasoning for web page layout. *ACM SIGPLAN Notices*, 51(10):181–194.

Samimi, H., Schäfer, M., Artzi, S., Millstein, T., Tip, F., and Hendren, L. (2012). Automated repair of html generation errors in php applications using string constraint solving. In *2012 34th International Conference on Software Engineering (ICSE)*, pages 277–287. IEEE.

Sanoja, A. and Gançarski, S. (2014). Block-o-matic: A web page segmentation framework. In *2014 international conference on multimedia computing and systems (ICMCS)*, pages 595–600. IEEE.

Walsh, T. A., McMinn, P., and Kapfhammer, G. M. (2015). Automatic detection of potential layout faults following changes to responsive web pages (n). In *2015 30th IEEE/ACM International Conference on Automated Software Engineering (ASE)*, pages 709–714. IEEE.

Wang, X., Zhang, L., Xie, T., Xiong, Y., and Mei, H. (2012). Automating presentation changes in dynamic web applications via collaborative hybrid analysis. In *Proceedings of the ACM SIGSOFT 20th International Symposium on the Foundations of Software Engineering*, page 16. ACM.

Wertheimer, M. (1938). Gestalt theory.

Yang, X. and Shi, Y. (2009). Enhanced gestalt theory guided web page segmentation for mobile browsing. In *2009 IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology*, volume 3, pages 46–49. IEEE.

Zheng, X. S., Chakraborty, I., Lin, J. J.-W., and Rauschenberger, R. (2009). Correlating low-level image statistics with users-rapid aesthetic and affective judgments of web pages. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1–10. ACM.