Toward Mobile-Friendly Libraries: The Status Quo

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Abstract. As the number of users accessing web sites from their mobile devices rapidly increases, it becomes increasingly important for libraries to make their homepages "mobile-friendly." However, to our best knowledge, there has been little attempt to *survey* how ready existing libraries are towards this upcoming mobile era and to quantitatively *analyze* the findings via data exploration methods. In this paper, using the W3C's tool, `mobileOK`, we characterize the mobile-friendliness of comprehensive set of more than 400 libraries with respect to locations (e.g., world-wide vs. US vs. EU) and types (e.g., desktop vs. mobile). Based on our findings, we conclude that majority of current libraries (regardless of locations and types) be *not* mobile-friendly at all (with low mobile-friendliness scores of 0.16–0.21). Using mobilization tools, in addition, we demonstrate that the mobile-friendliness of library homepages can be improved significantly (i.e., 67%–82%). As such, much more efforts to make library homepages more mobile-friendly are greatly needed.

1 Introduction

To accommodate today's library users, most libraries currently offer well-designed homepages on the Web where users can find basic information such as opening hours, direction to branches, contact information, etc. Digital libraries in addition offer advanced browsing and searching capabilities on their catalogs, books, and medias. Traditional users have accessed such libraries' homepages from their home desktop machines. However, this trend is changing rapidly. According to Morgan Stanley's forecast in 2009[1], for instance, mobile usage will be at least double that of the desktop/laptop within the next 5 years. Interestingly, recently, Duke university library reported[2] that mobile access to their libraries has tripled from fall 2010 to fall 2011. Therefore, to be able to accommodate such mobile users, libraries have to prepare to make their homepages *mobile-friendly*. First, let us use the following informal definition:

Definition 1 (Mobile-Friendly Web Page) *A web page that can be rendered well in mobile devices is called as the mobile-friendly web page.* □

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[1] `http://www.morganstanley.com/institutional/techresearch/mobile_internet_report122009.html`

[2] `http://prezi.com/a1fmjdk-mjhb/mobile-web-stats-fall-2011/`

Note that the definition of mobile-friendliness is vague and subjective at best. Often, whether a web page is going to be displayed well in a mobile browser or not depends on many factors. W3C's Mobile Web Best Practices [1], for instance, suggests that mobile-friendliness of a page be related with: (1) the types of *content* involved (e.g., narrow image vs. flash-based animation), (2) the *capabilities* of mobile devices and networks used (e.g., basic cellular radio access vs. 4G LTE), and (3) the *context* in which the content is received by the user (e.g., sitting at a desk vs. sitting on a subway). Our focus, in this paper, is more pertinent to "traditional" web browsing of libraries' homepages, excluding other content presentation options or emerging multimodal technologies (e.g., multimedia messaging, and podcasts) on diverse mobile platforms (e.g., iPad).

Regardless of the precise definition of mobile-friendliness, libraries today deal with the issue differently. Some libraries make their homepages (and the whole site) to render well for both desktop and mobile devices. For instance, using feature like CSS3 Media Query [2], one can build a single web page design that renders well across multiple devices. Other libraries make and maintain two separate contents (with separate URLs to such contents): one for desktop and the other for mobile devices. Conventionally, main web site URLs such as "`www.foo.com`" are used for desktop contents, while special URLs such as "`m.foo.com`" or "`foo.com/m/`" are reserved for mobile contents. However, as we will show in this paper, many libraries world wide currently do not have homepages designed for mobile users in mind. Often, a site maintains two separate URLs and contents for desktop and mobile users. To differentiate these two types of homepages, in this paper, we use the following terms:

Definition 2 (Desktop/Mobile Homepage) *When a library homepage is made for user agents from fixed devices (e.g., desktop, laptop, tablet), the homepage, denoted as HP_d, is called a* ***desktop homepage****. Similarly, when made for users from hand-held devices (e.g., cell phone, smartphone, mp3 player), the homepage, denoted as HP_m, is called a* ***mobile homepage****.* □

Despite the importance of mobile-friendliness of library homepages, in general, very little is known about the current status of mobile-ready libraries and their characteristics. In recent years, in library communities, a few attempts to conduct a limited scale of survey have been made (e.g., [3]). However, none of them studied the mobile-friendliness of library pages using measurable metrics in a substantially large scale. In this paper, therefore, we present a comprehensive study to measure various types of library homepages world wide, identify several important characteristics of both desktop and mobile pages of libraries, and their "mobile-friendliness" characteristics in detail.

2 Related Work

Mobile-Friendly Libraries/Museums: One of the recent popular topics in library and museum communities is the migration of existing library and museum sites to support mobile device users. For instance, [4] describes key design and development strategies on how to create mobile-friendly library sites using the case of Oregon State University (OSU) libraries as an example. [5] reviews an array of mobile applications appropriate in museum settings. Unlike ours, their focus is on visitors who visit museum physically (as opposed to visiting web sites). [6] focuses on the issue of mobile learning of nomadic learners in libraries and examines various standards and technologies by IETF or W3C that enable such mobile learning. [7] examines the mobile web landscape such as mobile devices, mobile web apps, mobile library initiatives. It also presents how to create a mobile experience and get started using the mobile Web. Finally, [3] conducts case studies of four selected institutions and university libraries. and concludes that "offering mobile access to digital collections is still a relatively new endeavor for libraries and museums."

Mobile-Friendly Web: There exist tools to check mobile-friendliness of a web page according to common practices (e.g., W3C `mobileOK` Basic Tests 1.0 [8], W3C Mobile Web Best Practices 1.0 [1], mobiReady[3]). Since there are no agreed-upon standards for mobile-friendliness, however, it is not uncommon to have disagreeing result across different tools. More importantly, there is currently no fundamental understanding as to features of web pages affecting their mobile-friendliness. For instance, the Google Mobilizer[4] and the GOMO initiative[5] aim to help generate mobile-friendly version of a web page. While they generate a decent quality output, often, for a page with complex internal structure/graphics, all they do is to strip off textual contents from the page. Therefore, commercial advertisers who want to keep the graphical design aspect of web pages will not find them useful. Using CSS3 Media Query [2], a designer is able to extend a single page design across desktop, tablet, and mobile devices. However, it helps little in rewriting existing mobile-unfriendly web pages into mobile-friendly ones. Commercial tools (e.g., WireNode, Mobify, bMobilized, Onbile) are in abundance to help advertisers create mobile-friendly web sites. However, many of them focus on creating mobile web sites from the scratch (as opposed to rewriting existing ones), or require intensive labor by web designers. Furthermore, none provides an objective measure to indicate how good the rewriting is.

In academic literature, there have been a few attempts to adapt existing web pages for mobile devices (e.g., [9–12]). Although useful, none of them provides quantitative scores w.r.t. how similar a page is (before and after the rewriting). Because of the limitations in mobile handheld devices, including small screen size, narrow network bandwidth, low memory capacity, and limited computing power and resources, researchers explored different methods to improve loading and visualizing large documents on handheld devices. For instance, [13] discussed how to avoid distorting web pages in mobile devices using segmentation of contents and ranking therein. [14] argued that changing the layouts of web pages would simplify or delete contents of the pages, leading to undesired misunderstanding. Instead, the authors designed systems to facilitate users' browsing experience.

[3] `http://ready.mobi/`
[4] `http://www.google.com/gwt/n`
[5] `http://www.howtogomo.com/`

Our Contribution: Compared to aforementioned works, ours is unique in that: (1) Using W3C's `mobileOK`, we quantify the mobile-friendliness of library home pages; (2) Compared to previous surveys of small scales where 10-30 libraries (and their mobile web support) are evaluated qualitatively, we investigate a much substantial number of libraries (> 400) in a systematic fashion; and (3) Using various data exploration methods, we analyze the mobile-friendliness results of those libraries and unearth several interesting findings.

3 Design of the Study

3.1 Testing Mobile-Friendliness with `mobileOK`

The mobile-friendliness of a given web page (i.e., whether or not the page can be rendered well on a mobile device) may change dramatically, depending on the contents, capabilities, and contexts of the evaluation. For instance, the same web page may be displayed well in the latest iPhone with 4G but not so in a barebone cell phone with poor network bandwidth. Therefore, inherently, it is challenging to test whether a given web page is mobile-friendly or not. There are several tools to test mobile-friendliness of web pages or sites (e.g., W3C `mobileOK`, mobiReady, Gomez, iPhoney). In this paper, among these, we decided to use the W3C `mobileOK` checker that supports programmable APIs (as opposed to web interface) and focuses on the mobile-friendliness of basic mobile devices based on several W3C's recommendations. This checker performs various tests defined in the `mobileOK` Basic Tests 1.0 specification [8], which is based upon a limited subset of the Mobile Web Best Practices [1]. The `mobileOK` Basic Tests 1.0 includes 25 tests, each of which in turn includes multiple sub-tests, yielding a total of 100 sub-tests. In our experiments, we use `mobileOK` checker library v 1.4.2. The score returned by `mobileOK` checker is computed based on the number and severity of failures of 25 tests carried out over a web page. Each failure can be diagnosed in a severity level between 1 (low) and 6 (critical). More severe failures will cause more penalty in the score evaluation. Utilizing the scores returned from `mobileOK`, now, we define the following:

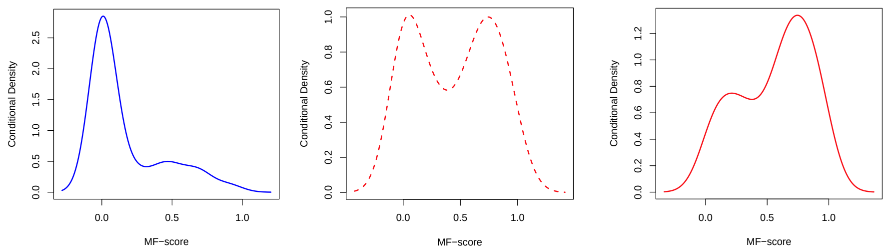
Definition 3 (MF-score) *MF-score (Mobile-Friendliness-score) of a web page p refers to a score that `mobileOK` assigns to p (after scaled down to 0–1 range).*□

If a web page gets an MF-score of 1, it implies that the page is likely to be laid out well in a barebone cell phone. Conversely, the MF-score of 0 means that most mobile devices will not be able to render (part of) the page or will not be able to render the page in a reasonable time frame. It is important to note that the MF-score given by `mobileOK` is not determined linearly. For instance, the MF-score of 0.5 does not imply the passing of half of 25 tests in `mobileOK` nor suggest 100% more mobile-friendly than that of 0.25.

3.2 Setting the Ground Rules

In this section, using the top-500 sites of US from Alexa[6], we attempt to simulate the "ground truth" data set based on *human judges* and *heuristics*, and validate

[6] `http://www.alexa.com/topsites/countries/US`



(a) mobile-unfriendly pages (class = 0) (b) mobile-friendly pages (class = 1) (c) mobile-friendly pages (class = 1 with MF-score > 0)

Fig. 1. Conditional probability distribution.

the effectiveness of `mobileOK` accordingly.

Heuristics-based Ground Truth. First, we accessed the top-500 sites from mobile phone emulators, and identified URLs to their counterpart mobile version by following the re-direction of HTTP responses. At the time of repeated experiments, on average, 465 out of 500 top sites were accessible via HTTP requests, and 44.7% (208 out 465) of top sites turned out to maintain separate URLs/contents for mobile device users. For those 208 top sites with two explicitly made URLs/contents for desktop and mobile users, we consider those homepages made for mobile users (e.g., "`google.com/m`") as the candidate "ground truth" mobile-friendly homepages. The reason is that these homepages are likely to be explicitly designed for mobile device users by human experts or in-house production system in large companies with sufficient resources.

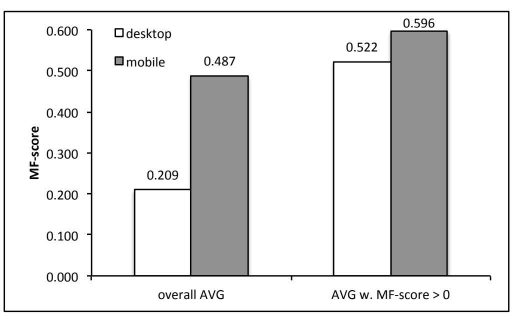


Fig. 2. Average MF-scores of 208 HP_d and HP_m selected from Alexa's top sites.

Figure 2 shows average MF-scores of those 208 top sites. The first two bars show that between two counterpart homepages for the same company, mobile versions have the higher average MF-score than desktop versions have, showing 133% improvement. Considering mobile versions are specifically made for mobile devices, their higher MF-scores are expected. However, on average, overall MF-score of all mobile versions is only 0.487, showing that there exists much room for improvement. That is, although those 208 top sites have made their homepages specially designed for mobile device users, with respect to W3C's mobility standard tests, their overall quality is still rather *poor*. Furthermore, next two bars on the right show the refined average of MF-scores of those sites whose MF-score > 0. As illustrated in Figures 1, the interpretation of the homepage p with MF-score=0 is bimodal (i.e., p is mobile-unfriendly or `mobileOK` incorrectly assigns p's MF-score as 0 even if p is in fact mobile-friendly). Therefore, here, by eliminating those sites that got 0 as MF-score, we tried to mitigate the outlier effect on the calculation of MF-scores. Overall, the average MF-score of mobile homepages rises to 0.596, showing 14% improvement of MF-score from their counterpart desktop homepages.

Human-judged Ground Truth. Second, using only top-200 sites, three human judges visited each site using two mobile phones (i.e., Apple iPhone 4, HTC Inspire 4G, Samsung Galaxy S simulator), and judged the site as either mobile-unfriendly (class=0) or mobile-friendly (class 1). Note that judges did *not* have a prior agreement on the definition of mobile-friendliness, simulating normal users' *ambiguous* perception. Using the majority voting scheme, at the end, a site with at least two "1"s is labeled as class=1 and with at least two "0"s as class=0. Next, after removing those 10 sites that were inaccessible, we obtained a total of 190 data points (i.e., 71 sites in class=0 and 119 sites in class=1). We first measured how much agreement among judges there is on the mobile-friendliness judgements using the Cohen's *Kappa* measure from the social sciences: $Kappa = \frac{P(A)-P(E)}{1-P(E)}$, where $P(A)$ is the proportion of the observed agreement between two judges, and $P(E)$ is the proportion of the times two judges would agree by accident. Since there are three judges, we computed three pair-wise Kappa measures and used their average. In addition, since class (i.e., 0 or 1) distribution is skewed, we used the marginal statistics to calculate $P(E)$, and obtained a final Kappa value of 0.7126. In general, a Kappa value between 0.67 and 0.8 is regarded as fair agreement between judges. Therefore, we can conclude that our human-judged ground truth is in a fair agreement. Figures 1(a) and (b) show kernel density estimators of MF-score distributions using data in class=0 and class=1, respectively. Observe that the high densities around 0 in Figure 1(a) and the bimodal shape around both 0 and 0.75 in Figure 1(b). This implies that when a page p gets a high MF-score, p's probability to be labeled as mobile-friendly by human judges is very high. However, when p's MF-score is close to 0, it could be either of two reasons: (1) MF-score does not well reflect the human perception on mobile-friendliness (since p that human judges viewed as mobile-friendly got the MF-score close to 0), or (2) p is simply poorly designed and mobile-unfriendly. In other words, *the interpretation of cases with MF-score close to 0 should be made with care* (since it could mean one of two reasons). To further validate this implication, we removed 26 "contradicting" data points in class=1 whose MF-score is 0, and got Figure 1(c). Now, observe the unimodal distribution with high densities around 0.75. Figure 1(c) can be considered as an increasing function, implying that a page with a "higher" MF-score be "more" likely to be mobile-friendly.

4 Experimental Results

4.1 Set-Up

For our study, we prepared the URLs of library homepages of various types from the following lists:

- L_{world}: A list of 167 world-wide national libraries (one national library per country)[7].
- L_{us}: A list of top-100 largest (with respect to volumes held) US public libraries[8].
- L_{eu}: A list of 46 European national libraries in "The European Library" project[9].
- L_{mobile}: A list of 105 mobile homepages (HP_m) of world-wide public libraries[10] (e.g., "`m.psu.edu/library/`"). These libraries maintain specially-made homepages for mobile device users exclusively.
- $L_{desktop}$: A list of 105 desktop homepages (HP_d), a counterpart to L_{mobile} (e.g., "`www.libraries.psu.edu`").

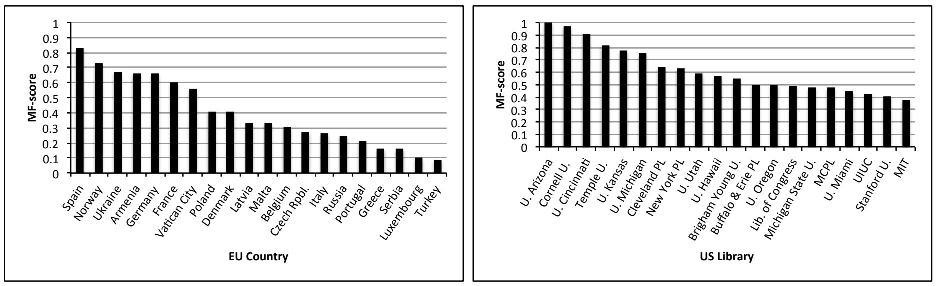
All lists (except L_{mobile}) contain the URLs of conventional library homepages, made mainly for desktop users–i.e., HP_d. Using W3C's `mobileOK` checker library v 1.4.2, we first set our program's user-agent setting as "Mozilla/5.0 (iPhone; U; CPU iPhone OS 4_3_3 like Mac OS X; en-us) AppleWebKit/533.17.9 (KH TML, like Gecko) Version/5.0.2 Mobile/8J2 Safari/6533.18.5" so that the web server of a target library would think that the request comes from a mobile device, iPhone. If the target library detects our user-agent type correctly and forwards the request to their specially-made mobile homepages (HP_m), however, then we treat this mobile homepage as the main URL of the target library and test it accordingly. In obtaining the MF-score of a given library homepage, ideally, one has to fetch all web pages of the library site and use the average MF-score of all pages. However, this approach was abandoned due to the following reasons: (1) The typical number of web pages per library site varies greatly. However, in general, for the large libraries that we investigate in this paper, such number ranges from thousands to tens of thousands, without even including dynamically generated pages. Therefore, we need to reduce the number of pages to experiment; and (2) When a user browses a library's homepage using her mobile device, it is likely that she would bounce back and exit the site immediately if the first encountered URL of the site does not give satisfactory mobile experience. Therefore, in this experiment, we focus on the main URL of the homepage, and ignore all subsequent internally linked pages.

All subsequent experiments have been carried from Nov. 2011 to Feb. 2012. Each target library has been tested for three times, each test two weeks apart, and the average MF-score of three measurements was used for analysis. If the web server of a target library did not respond (within 60 sec) for all three attempts, we removed the library from the analysis.

4.2 Location Based Analysis

First, we compared the MF-scores of three lists (L_{eu}, L_{us}, and L_{world}). In general, substantial percentages of libraries failed a large number of sub-tests of

[7] `http://en.wikipedia.org/wiki/List_of_national_libraries`
[8] `http://www.ala.org/tools/libfactsheets/alalibraryfactsheet22`
[9] `http://www.theeuropeanlibrary.org/`
[10] `http://libsuccess.org/index.php?title=M-Libraries`



(a) Top-20 in L_{eu} (b) Top-20 in L_{us}

Fig. 3. Top-20 MF-scores of homepages of libraries in different regions of the world.

`mobileOK`, yielding the MF-score of 0. At the end, 47.7%, 55.2%, and 44.3% of the lists (L_{eu}, L_{us}, and L_{world}) garnered the MF-score of 0, respectively, indicating that the majority of library homepages are currently "*mobile-unfriendly.*" This is a bit surprising result, considering that libraries in the three lists are either the biggest national library of countries or one of the largest public ones in US (with possibly more sufficient resources for funding and IT than smaller libraries). Top-20 ranks (with respect to MF-score) of two lists are shown in Figure 3. In summary, as shown in Figure 4, all three lists show similar patterns–i.e., rather low MF-scores (with median: 0.31, 0.32, 0.27, mean: 0.185, 0.16, 0.22, and std. dev.: 0.25, 0.25, 0.29 for L_{eu}, L_{us}, and L_{world}, respectively), and similar inter-quartile range (IQR), a bit skewed toward to the left (i.e., low mobile-friendliness).

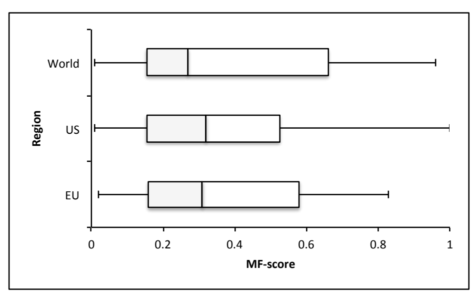
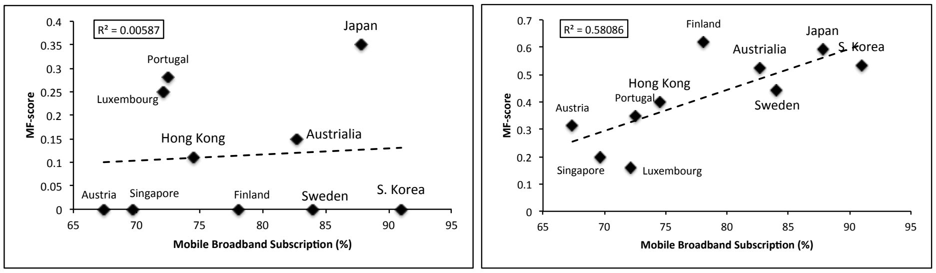


Fig. 4. A box-and-whisker plot of libraries (w. MF-score > 0) using L_{eu}, L_{us}, and L_{world}.

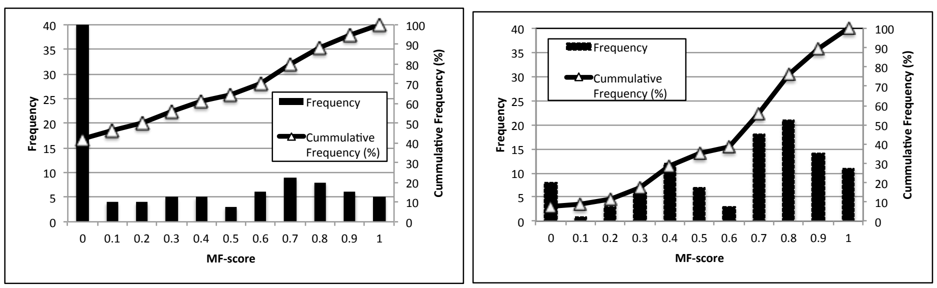
Next, we examined to see if there is any correlation between MF-score of libraries and other factors. However, using L_{us}, first, we found no significant correlation between MF-scores and the ranks of US libraries (with respect to volumes) or state populations where libraries are located, etc. Using L_{world} data, next, we examined the correlation between the MF-score of national libraries and how active people use mobile web with their mobile devices. That is, our conjecture was that if a country has more active mobile web usage, it is more likely that web sites of the country (including library homepages) are designed to be mobile-friendly. From the Global mobile statistics 2012 data set[11], we first obtained top-10 countries with active mobile usages. Then, using Alexa.com's top sites data, we also obtained the top-5 most-visited commercial sites of those 10 countries. When the regression is made

[11] `http://mobithinking.com/mobile-marketing-tools/latest-mobile-stats`



(a) Against national libraries (b) Against top-5 most visited sites

Fig. 5. Linear regression between mobile broadband subscription percentage (X-axis) and MF-scores of 10 countries with most active mobile web access (Y-axis) using: (a) national libraries, and (b) top-5 most visited sites.



(a) MF-score histogram of $L_{desktop}$ (b) MF-score histogram of L_{mobile}

Fig. 6. MF-score frequency histograms of $L_{desktop}$ (i.e., HP_d) and L_{mobile} (i.e., HP_m).

against the MF-score of national library of those top-10 countries, as shown in Figure 5(a), a very low coefficient of determination (i.e., $R^2 = 0.00587$) indicates that X value of the graph (i.e., active mobile web usage of a country) cannot predict well Y value of the graph (i.e., MF-score of its national library). However, when we instead used the average MF-score of top-5 most-visited commercial sites of those 10 countries and correlated it against the mobile broadband subscription percentage, as shown in Figure 5(b), some correlation is found. An R^2 of 0.58086 implies that 58% of the variance in MF-score is predictable from the mobile broadband subscription percentage. In order words, in those countries with heavy mobile web usage, top companies with high traffic are already well aware of and prepared for mobile web browsing. However, unfortunately, this is currently not the case for national libraries in those countries.

4.3 Mobile-Oriented vs. Desktop-Oriented

In this section, we investigated the difference of mobile-friendliness between HP_d and HP_m. The list L_{mobile} contains URLs of homepages that are specially made for mobile device users. Such URLs typically have formats like "`m.foo.com`" or "`www.foo.com/m/`". From these HP_m, we first reverse guessed their original HP_d

such as "`www.foo.com`", and manually corrected any remaining errors. Then, by comparing these HP_d and HP_m w.r.t mobile-fiendliness, we can see the impact of having mobile-friendly library homepages. Overall, the average MF-score of HP_m, 0.586 (std. dev.=0.282), is significantly higher than that of HP_d, 0.318 (std. dev.=0.34). Since HP_m are explicitly designed for mobile browsing, such a result is expected.

In zooming in for more details, Figure 6 shows MF-score frequency histograms and cummulative frequency (%) of both HP_d and HP_m, respectively. In Figure 6(a), note that there are 40 libraries whose MF-score came out as 0, implying poor mobile-friendliness of their homepages. However, in Figure 6(b), this number is reduced to only 7. Furthermore, for those bins of higher MF-score in Figure 6(b), their frequencies are much bigger than those in Figure 6(a), implying that many libraries in L_{mobile} have been designed to be more mobile-friendly.

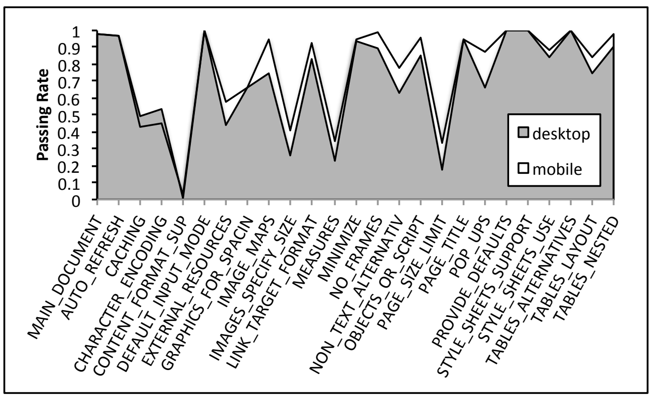


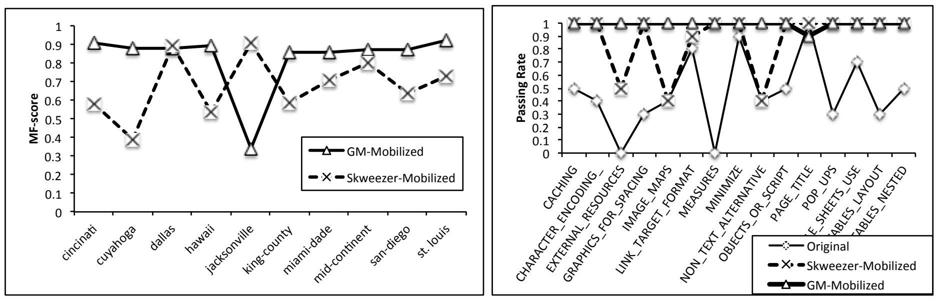
Fig. 7. Comparison of passing rates of 25 sub-tests in `mobileOK` for $L_{desktop}$ and L_{mobile}.

Figure 7 shows a stacked graph of *passing rates* (i.e., the fraction of libraries that passed a particular sub-test in `mobileOK`) for $L_{desktop}$ and L_{mobile} (X axis includes 25 sub-tests of W3C's `mobileOK`). Note that passing rates of L_{mobile} are usually higher than those of $L_{desktop}$. A few sub-tests are noticeable here (e.g., IMAGE_MAPS, IMAGES_SPECIFY_SIZE, NO_FRAMES, OBJECTS_OR_SCRIPT, POP_UPS, PAGE_SIZE_LIMIT, and TABLES_LAYOUT). Homepages of $L_{desktop}$ failed more on sub-tests than those of L_{mobile}. Overall, those poorly designed library homepages suffer from a large page size and loading time (with many embedded resources), a poor layout design, and lack of support for mobile access.

4.4 Mobilizing Library homepages

In this section, we report our small pilot study to see if one can quickly improve the mobile-friendliness of library pages. From the L_{us} list, first, we randomly picked 10 public libraries all of which had the MF-score of 0 and caused a lot of critical/severe violations according to W3C `mobileOK` Basic Tests 1.0 [8] and W3C Mobile Web Best Practices 1.0 [1]. Then, from available tools that can instantly transcode the given web page into mobile-friendly one, we chose two well-known ones: Google Mobilizer[12] and Skweezer[13], and converted main

[12] `http://www.google.com/gwt/n`
[13] `http://www.skweezer.com`



(a) MF-score after mobilization (b) passing rates after mobilization

Fig. 8. Changes of MF-scores and passing rates after mobilization.

homepages of 10 libraries into mobile-optimized ones (i.e., *mobilized*). After the mobilization, we measured the MF-score and passing rates of their homepages. Figure 8(a) shows the much improved MF-score after the mobilization (from the original score of 0). When we look at details of passing rates, in Figure 8(b), it is also clear that mobilized homepages are able to pass more number of sub-tests of `mobileOK` successfully. Although varied in some cases, in our experiments, we note that the mobilization quality (with respect to MF-score) of Google Mobilizer is in general better than that of Skweezer. Note that since existing mobilizer software such as Google Mobilizer and Skweezer largely transcodes pages by stripping off contents from pages, often, the resulting mobilized design contains dull text-based contents and links. Therefore, such a mobilizing software is to be used as a quick-and-dirty way to test the mobile-friendliness of mobilized pages, and more human involvement is likely to be expected in practice.

5 Limitations and Future Plan

We recognize the limitations of the current study and plan to conduct the following research in future: (1) While we validated the effectiveness of `mobileOK` in quantifying the mobile-friendliness of a web page in Section 3.2, a more extensive user study would be able to provide stronger grounding. For instance, using Amazon's Mechanical Turk system, one could do crowd-source based human evaluation of library pages and compare the results with that by `mobileOK`; (2) Current focus of `mobileOK` scoring is on the general "browsing" task of library homepages. Since users often access library homepages with specific tasks in mind (e.g., finding direction to libraries, searching book information), a more fine-grained task-specific study along with mobile-friendliness of homepages would be interesting; and (3) Since "tablets" users are increasing rapidly, we also plan to extend the current study to include tablets as mobile platforms.

6 Conclusion

In this paper, we have analyzed homepages of more than 400 libraries world wide with respect to their mobile-friendliness. From our study, we have found:

(1) W3C's `mobileOK` can be an effective tool to estimate the mobile-friendliness of a web page; (2) According to `mobileOK`, majority of 400+ library homepages (regardless of their locations and types) have very poor MF-scores (in the range of 0.16–0.21); (3) Library homepages explicitly designed for mobile devices (i.e., HP_m from L_{mobile}) have significantly higher MF-scores than those made for desktop viewing (i.e., HP_d from $L_{desktop}$); and (4) Using mobilization tools, the mobile-friendliness of ten US public library homepages can be improved significantly (i.e., 67%–82%).

Acknowledgement and Availability: Author thanks Haibin Liu for providing script codes and Woo-Cheol Kim for helpful discussion on Section 3.2. All final implementation codes and data sets to run the presented experiments are publicly available at: `http://pike.psu.edu/download/tpdl12/`.

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