PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
ESCUELA DE INGENIERIA

A BETTER MOBILE BROWSING EXPERIENCE THROUGH PATTERN RECOGNITION AND DYNAMIC RESTRUCTURING OF WEB PAGES

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Thesis submitted to the Office of Research and Graduate Studies in partial fulfillment of the requirements for the Degree of Master of Science in Engineering

Advisor :
JAIME NAVÓN COHEN

Santiago de Chile, (January, 2010)

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To all those who have always been there.

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RESUMEN

El uso de teléfonos móviles ha ido en constante aumento y la masificación de aparatos con soporte 3G como el iPhone y el HTC G1 junto con la oportunidad de contratar planes de Internet ilimitado a bajo costo, potencia enormemente el desarrollo y uso de la Web móvil. Estos dispositivos poseen enormes limitaciones como pantallas muy pequeñas y baja capacidad de procesamiento lo cual produce serios problemas de usabilidad, ya que la gran mayoría de los sitios Web actuales no están diseñados para estos aparatos.

Hoy existen diversas soluciones a este problema. La mayoría se concentra en proveerle al usuario un sistema amigable de zoom con el cual puede navegar de forma más fluida por el sitio. A pesar de este avance, no se logran niveles de usabilidad buenos ni otorgan una alternativa realmente intuitiva.

La siguiente propuesta está orientada a los dispositivos móviles de última generación, reorganizando dinámicamente la estructura de las aplicaciones Web a través de un modelo de reconocimiento de patrones basado en las mejores prácticas de la Web móvil, recomendadas por la W3C. En promedio se lograron niveles de usabilidad 25% superiores a las propuestas nativas de los aparatos probados, destacando principalmente la comodidad y facilidad de uso del sistema, que lograron en promedio una evaluación positiva de un 51%. Todo esto supone un primer paso para lograr avances concretos en la experiencia de uso al navegar por la Web móvil, esperando que en un futuro sea optimizado e integrado a motores de búsqueda que faciliten su utilización.

Palabras Claves: Dispositivos móviles, Adaptación de la Web, Interfaz móvil, Adaptación de la interfaz de usuario, Navegación móvil, Clasificador Bayesiano.

ABSTRACT

The use of smartphones has been steadily increasing and the popularity of devices like the iPhone coupled with affordable unlimited Internet are boosting the interest of both users and developers in the mobile web. These devices however have small screens and relatively low processing power which leads to serious problems of usability when they are used for viewing web sites that were not designed for them. A common solution to this problem is to provide zooming so the user see whole pages at reduced size and zooming on the pieces he is interested in, but this solution is still poor un terms of usability.

In this paper we present a novel approach based on dynamic reorganization of the structure of the Web application. This is done first by the use of a Bayesian model to recognize the components of the original web page and then using the best practice recommendations of the W3C for the mobile Web to rebuild dynamically the contents in the best possible way. We tested our system with a group of 25 real persons and asked them to compare the new system with regular web browsing provided by the device and they gave 25% higher marks to the new system even compared to the best mobile web experiences available today.

Keywords: Small screen device, Content adaptation, Mobile interfaces, User interface adaptation, Mobile browsing, Bayesian Classifier.

1. INTRODUCTION

1.1 Adapting to the Mobile Web

It is a fact that more and more people are increasingly surfing the Web via mobile devices despite the enormous number of limitations they have. In fact, The Mobile Data Association (2009) speaks of growth figures of up to 25% for this segment versus 3% growth of navigation through computers in the UK, reaching 7.3 million of users there only. In the U.S. this figure reaches 40 million users. On the other hand, people are also aware of this change, the same study by The Mobile Data Association (2009) reveals that over 50% of users would substitute their Internet usage on a PC for a mobile device.

Much of this explosive growth is due to the appearance and popularity of new-generation mobile devices like iPhone, Blackberrys, and HTC phones with Android, which offer an enhance of the user experience, providing better support to the existing Web technologies, better connections via Wi-Fi and 3G networks and better visibility for they have higher resolution screens. At the same time, it has been revealed that most Web applications are not designed to be viewed on such devices.

All this has generated enormous interest to investigate different possibilities in order to automatically adapt the existing Web pages to these devices. Some solutions have been proposed, but they keep short of providing a satisfactory experience. This is why one can find either web applications custom made for mobile devices (even one specific device) or special mobile browsers that do a better job than the regular ones.

Many studies have been grouping the different methodologies as they appeared, which has resulted on a set of techniques (Bickmore, Girgensohn and Sullivan, 1999; Paternò, Santoro and Scorcio, 2008) that have been able to define the existing strategies to start studying the problem. Such techniques are "Device-specific authoring" that aims to develop a specific application for each device,

"Multiple-device authoring" which proposes to amend the current web application to fit in mobile devices, "Client-side navigation" which proposes that each mobile device fit the Web applications to it's specifications, "Automatic re-authoring" which seeks to automatically change every website and "Page filtering" which proposes to remove irrelevant content to the final user like ads, whitespace, etc. Table 1-1 summarizes the advantages and disadvantages of this techniques.

Table 1-1: Important points to consider on existing techniques.

	Where	**Advantages**	**Disadvantages**
Specific-device authoring	Server	Excellent usability and user experience.	It is extremely expensive and requires the creation of a new version of the existing Web site.
Multiple-device authoring	Server	The Web application will be adapted easily to each platform.	The implementation is expensive and requires changing the structure of all existing Web sites.
Client-side navigation	Client	It works well in the specific device.	It requires downloading the entire page to your device, demanding unnecessary bandwidth and memory.
Automatic re-authoring	Server, Proxy Server or Client	Can be standardized for multiple Web sites and requires no extra work from the original developers.	It is very difficult to standardize the structure of the entire Web, so it's most likely to get bad results with some applications.
Page filtering	Server, Proxy Server or Client	Increase access speed and reduced memory consumption of the mobile device. Sort and clean the application.	It can delete valuable content to the user.

As can be seen, the first two techniques proposed to completely rebuild the current Web, which becomes virtually impossible in medium term, because it would increase costs and development time. The third one suggests delivering all the processing of information to the mobile device, but it requires a lot of unnecessary memory in addition to bandwidth and processing power. Those characteristics are not common on mobile devices so we need to find another solution. Finally, both the fourth and fifth technique are seen as feasible alternatives, but have a high error probability if you want to do complex standardizations.

Taking all pros and cons of each technique discussed above into account, this work is based on Automatic re-authoring and Page filtering proposals to process Web content and deliver it dynamically adapted to the end user. This provides the more generic possible scenario, covering most of Web applications and mobile devices without requiring high production costs.

1.2 Related Work

As discussed above, there is an enormous interest in finding a solution to the problem of adapting the Web applications to mobile devices. You may see this interest reflected in the investigations made so far, which can be grouped into four categories depending on the approach each of them takes to solve the problem: resizing, reducing to single column, restructuring and others.

1.2.1 Resizing

The first group of proposed systems relies on giving the end users the ability to zoom in or out to achieve a more comfortable movement flow and facilitate the navigation through it.

Many popular mobile browsers (Opera Mobile, Safari Mobile and Android WebKit) have zooming capabilities as a way to improve the mobile Web experience, in addition to giving direct access to this capability through a special key or some special moves when you have a touch screen.

Summary Thumbnails (Lam and Baudisch, 2005) also proposes zooming, but it goes a little further. It suggests displaying the entire Web application in one view with summarized texts and enlarged font size to recognize what is being read. Then, when zooming in on what you're interested, the system shows the user the original text. All this is done by adjusting the size of the screen that holds the device so as to maximize all available space.

Mini Map (Roto et al., 2006) attempts to improve navigation redefining the widths of the text boxes and creating a single column, matching the width of the device and making the font size smaller so that it is more readable, thus partly eliminating horizontal scrolling. Then, without restructuring the basic layout of the page, it can display a smaller version of the complete Web application on one corner of the screen in order to navigate through the content in a more agile way.

These proposals greatly improved user experience, but are still far from offering the ideal solution because they generate a lot of horizontal scrolling and often causes disorientation to the user.

1.2.2 Single column

The second group proposes to eliminate one of the weakest points of the previous group, horizontal scrolling. These solutions take the entire contents of the Web applications and present them in a one big column.

The SmartView project (Milic-Frayling and Sommerer, 2002) is one of the ideas that go into this category because they simply propose to reduce the content to a single column through a system that recognizes the original structure and define the order in which the final content will be shown.

As mentioned before, MiniMap (Roto et al., 2006) also goes into this category because it also reduces the sizes of the columns of the page to a width that does not require horizontal scrolling. The difference between MiniMap and SmartView, is that the first one does not restructure the entire contents in one great column, but it redefines the width of each column of the site to adjust it to the screen size, keeping the original layout.

Finally, Power Browser (Buyukkokten et al., 2000) proposes a system that group and hide the contents through sets of links, in order to create navigation trees that will expand vertically, taking advantage of the width offered by the device.
It is worth noting at this point that although the elimination of the need for horizontal scrolling could cause an extremely extensive vertical scrolling.

1.2.3 Restructuring

A different strategy to the problem involves restructuring the HTML of the selected web page, according to certain patterns to provide a better experience to the mobile user.
Digester (Bickmore et al., 1999), for example, performs automatic re-authoring from a proxy server that acts as a bridge between Web applications and the mobile devices using the automatic re-authoring technique. The most interesting aspects of this proposal are the grouping of contents based on the title, the possibility to create an abstract of a text allowing full reading when clicking on it, the reorganizing of rows and columns on the tables according to certain studied design patterns and the adjustment of images according to the size and capacity of the equipment. The major weakness of this system is that it was designed for old mobile phones, which have changed a lot since they proposed it; therefore, this excellent idea needs to be reinvented.
Semantic Transformer (Paternò et al., 2008) also proposes a dynamic system based on automatic re-authoring techniques from a proxy server. It analyzes the HTML document tree to create groups of elements and assigning them costs depending on their content. Then, depending on these costs, the system separates the content on different pages that are connected via links within the text.

1.2.4 Others

Finally, there are other solutions that do not fit into any of the categories described above. For example, Blekas, Garofalakis and Stefanis (2006) propose a system that, as if they were using the Page Filtering technique, takes advantage of RSS to

present Web contents in a smarter way. As RSS feeds are XML documents with well defined semantic structure, the proposed system corroborates its existence and gives users the possibility to read it instead entering the page. The big limitation of this proposal is that the RSS feeds only refer limited content from the Web application and sometimes only current issues instead of what the user is looking for, leaving other relevant information aside.

We propose a novel dynamic restructuring approach that works for most web pages and provides a much better usability to the mobile surfers.

1.3 Hypothesis

The working hypothesis is that a system that can detect the main components of most web pages and according to this it can perform a dynamic restructuring of the contents before it is delivered to the user would provide to the mobile user a much better experience even compared to the best browser/device combinations existing today.

1.4 Overall objective

The overall objective of this thesis is to design and build a system that can detect and dynamically reorganize the most common elements present in any Web application so that it will be able to provide greater usability to users of mobile devices.

1.5 Specific objectives

The specific objectives are:

a) To identify design patterns of the most common web pages and applications
b) To build a recognition algorithm and system to detect the important components of the page
c) To build and implement a system that can act between client and the server
d) To test the system with real users so they can rate the web browsing experience it provides

2. A BETTER MOBILE BROWSING EXPERIENCE

2.1 Adapting to the Mobile Web

The ability of a mobile device to adapt a web application, in spite of its limitations, has captured the attention of many people. The increase use of these devices for surfing the internet (The Mobile Data Association, 2009; Arellano y Benavente, 2006) triggered by the popularity of the latest 3G equipped devices has made us realize a simple truth: most web sites and web applications were not designed for these wonderful phones.

It is then important to find ways to improve the user experience when browsing in the mobile Web. Some solutions have been proposed, but they keep short of providing a satisfactory experience. This is why one can find either web applications custom made for mobile devices (even one specific device) or special mobile browsers that do a better job than the regular ones.

There are a number of techniques (Bickmore, Girgensohn and Sullivan, 1999; Paternò, Santoro and Scorcio, 2008) that help to create automatic adjustments to Web applications. They can be summarized as follows:

- Device-specific authoring: This consists in creating a new version of the Web application that is completely designed to be use on a mobile device. This requires a lot of extra work from the development team of every existing Web software, which translates into high production costs and a lot of time. A clear example of this is what Amazon did with his mobile version.
- Multiple-device authoring: This involves creating a version of the Web application with specific pieces for each platform (mobile or desktop). For example, you can create an application that detects if the connection comes from a mobile device or not in order to determine which version of the CSS files need to be used. This requires an exhaustive software engineering and web application design that, multiplied by the number of applications that requires changing, translates into very high production costs and development time.

- Client-side navigation: This implies that the mobile device provides some tools to facilitate Web browsing. For example the Opera mobile browser, which allow easy zooming to facilitate navigation through Web applications. In order to develop an advanced system using this technique you need a lot of processing power, memory capacity and bandwidth of the device, limited features of current mobile devices.
- Automatic re-authoring: The purpose of this technique is to create a system that takes an arbitrary web document and automatically transform it into one that correctly fits the specific device. The implementation of this technique can be performed from the server, the client or an intermediate proxy server depending on the need and proposed requirements. An example of this would be the Opera Mini system that offers to adjust the width of the Web text to screen size.
- Page filtering: This suggests the dynamic detection of various elements of the Web application to show the end user only what matters to him, discarding any nuisance like advertising, etc. Like Automatic re-authoring, this technique can also be deployed on a server, a client or a proxy server without major complications. The mayor risk of using this technique is that some contents relevant to the end user could be discarded.

Our solution falls into the automatic re-authoring and page filtering categories. Web contents is processed dynamically and delivered in a already adapted form to the end user. This provides the more generic possible scenario, covering most of Web applications and mobile devices without requiring high production costs.

2.2 Related Work

Researchers in this area have proposed solutions and systems that can be grouped into different categories depending on the approach each of them takes to solve the problem: resizing, reducing to single column, restructuring and others.

The first group of proposed systems relies on giving the end users the ability to zoom in or out to achieve a more comfortable movement flow and facilitate the navigation through it. MiniMap (Roto et al., 2006), for instance, presents Web

contents in columns, eliminating horizontal scrolling. It can also display a small version of the complete Web application on one corner of the screen in order to navigate through the content in a more agile way. Summary Thumbnails (Lam and Baudisch, 2005) and many popular mobile browsers (Opera Mobile, Safari Mobile and Android WebKit) have zooming capabilities as a way to improve the mobile Web experience. The SmartView project (Milic-Frayling and Sommerer, 2002) reduces the content to a single column whereas Power Browser (Buyukkokten et al., 2000) eliminates horizontal scrolling through link navigation trees. It is worth noting at this point that although the elimination of the need for horizontal scrolling could cause an extremely extensive vertical scrolling.

A different strategy to the problem involves restructuring the HTML of the selected web page according to certain patterns to provide a better experience to the mobile user. Digester (Bickmore et al., 1999) performs automatic re-authoring from a proxy server that acts as a bridge between Web applications and the mobile devices. The most interesting aspects of this proposal are the grouping of contents based on the title, the possibility to create an abstract of a text allowing full reading when clicking on it, the reorganizing of rows and columns on the tables according to certain studied design patterns and the adjustment of images according to the size and capacity of the equipment. Semantic Transformer (Paternò et al., 2008) also proposes a dynamic system based on automatic re-authoring techniques from a proxy server, but it analyzes the HTML document tree to create groups of elements and assigning them costs depending on their content.

Finally, Blekas, Garofalakis and Stefanis (2006) propose a system that takes advantage of RSS to present Web contents in a smarter way. As RSS feeds are XML documents with well defined semantic structure, the proposed system corroborates its existence and gives users the possibility to read it instead entering the page. The big limitation of this proposal is that the RSS feeds only refer limited content from the Web application and sometimes only current issues instead of what the user is looking for, leaving other relevant information aside.

We propose a novel dynamic restructuring approach that works for most web pages and provides a much better usability to the mobile surfers.

2.3 A few assumptions

We consider the present most advanced generation of smartphones (iPhone, HTC G1) as the target both in terms of screen size and processing power. Moreover, we assume that the device has a reasonable bandwidth connection through 3G or WiFi. Finally, we assume that future mobile browsers will have full support of Web technologies that exist today for desktop computers (AJAX, JavaScript, HTML, CSS) Support of these technologies is not complete today (Koch, 2009), but it has improved considerably over time and is expected to remain so.

2.4 Recognizing the structure

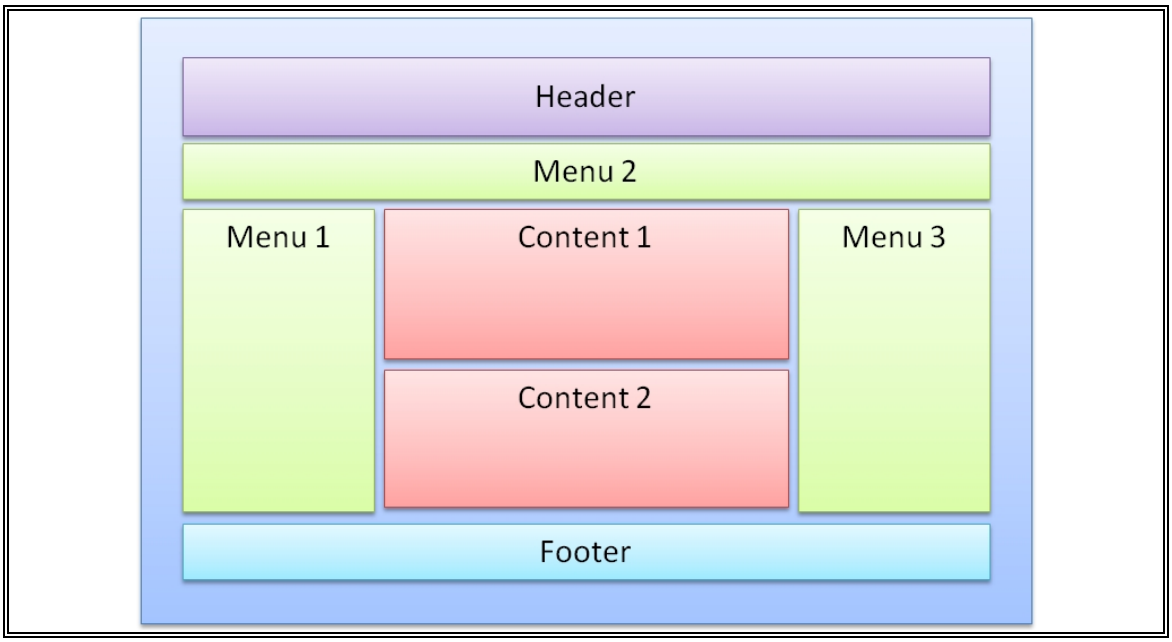

Figure 2-1: Structure of a common Web application

We wanted to dynamically adapt the existing web to mobile devices through restructuring and content selection. To achieve it, we looked at the basic patterns

present on Web applications so the system could recognize and transform them for presentation in the mobile device.

A typical Web application presents a pattern similar to Figure 2-1: a header, one to three menus, a certain amount of content and a foot page. Some forms and links to many RSS news feeds may appear as well.

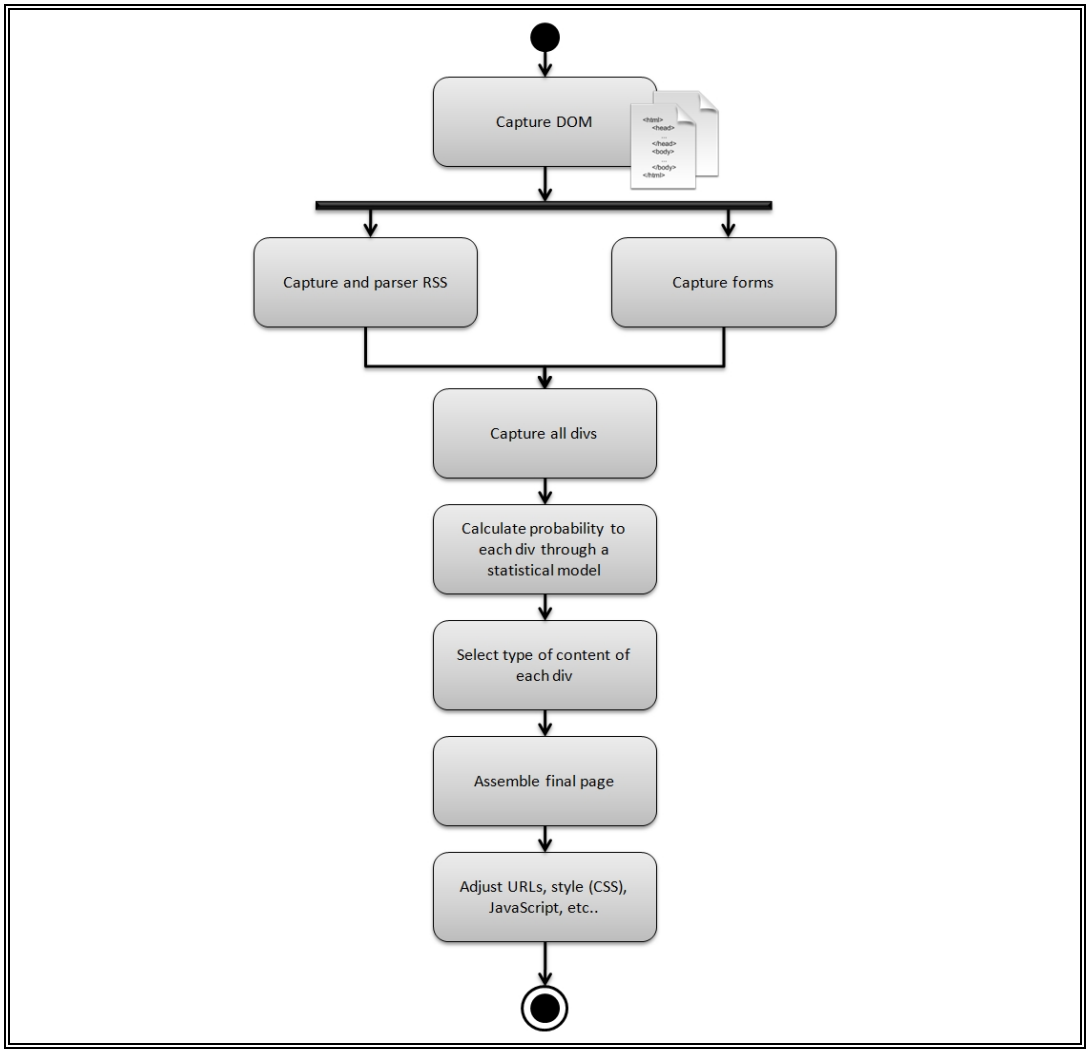

Figure 2-2: Flowchart of the sections recognition diagram

Since Forms and RSS feeds can be relatively easy to identify due to its structure at HTML code level but the other sections may be harder to recognize we introduced in our design a pattern detection mechanism based on a Bayesian classification model.

The recognition process of the sections is described in Figure 2-2. To get the HTML tree the system proceed to capture the DOM tree starting with the URL of the page.

To capture RSS feeds and forms, after the DOM is complete, all tags <form> are captured and kept separately in a hidden tag especially created for this purpose. Then all tags <a>, equivalent to the links of the page are caught, and those tags that within the text or the attribute "title" have the words "feed" or "rss" are analyzed.

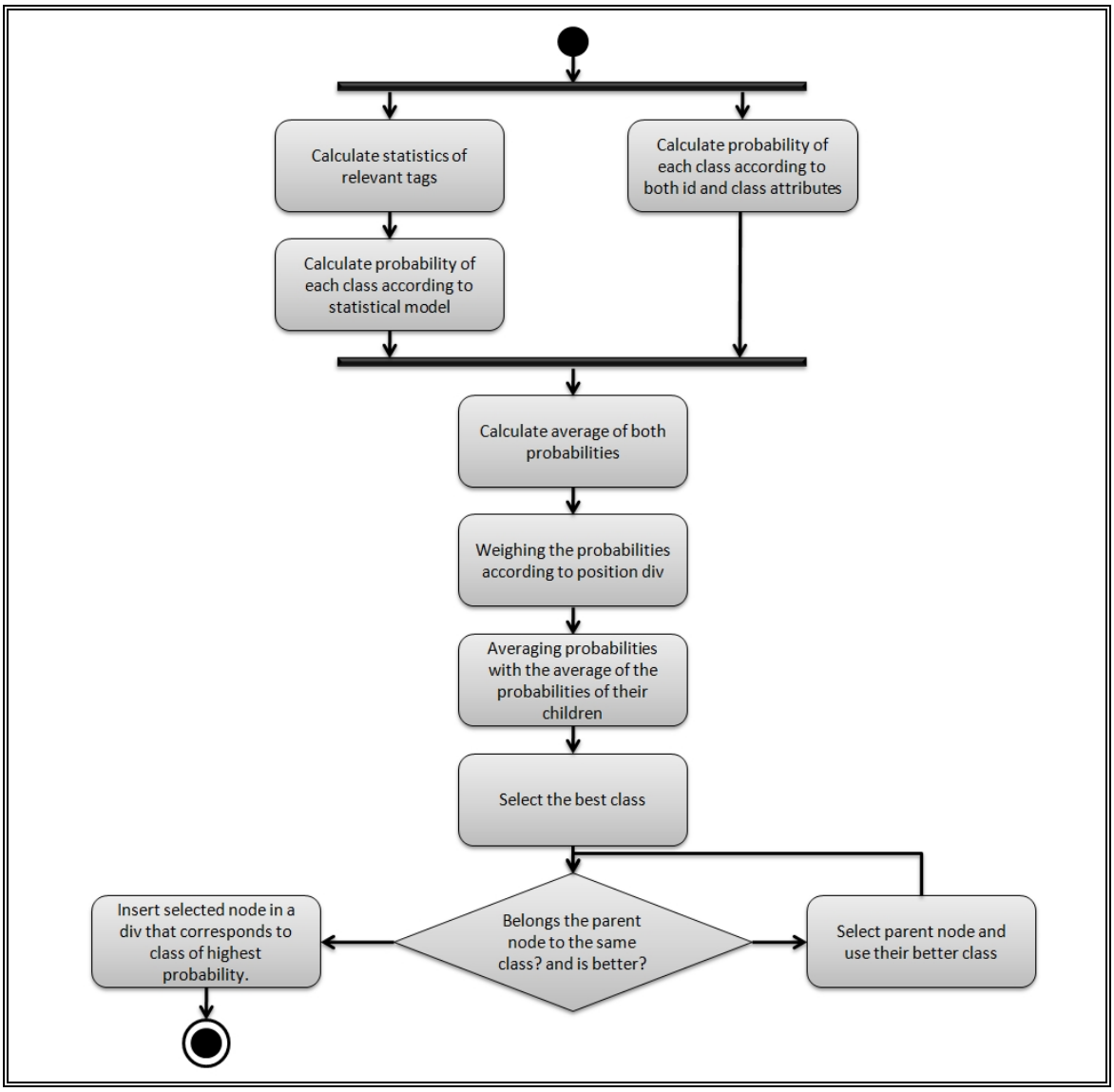

Figure 2-3: Flow diagram of tag probabilities calculation

Then when with the first of those links is found, the RSS's DOM tree is captured through the same method used before. Once this code captured, it looks for the <rss> tag. If found, the XML code is parsed and the result is stored in another tag especially created for this purpose.

To capture all the divisors (tags), we calculate their probabilities and group them according to the kind of content that should be. Figure 2-3 shows how the probabilities of each selected divisor are calculated. The system first captures the statistics of the divisor and then calculates the probabilities based on the pattern recognition model. Independently, the system calculates the probability of their belonging to each class according to the id attributes and class that they have. These two probabilities are averaged and weighted by the relative positions that the divisor in the DOM tree have. Then, the probabilities are averaged with the average of the probabilities from the selected children divisors nodes, and finally we check between parent nodes if any of them have or not a better probability. The selected nodes are stored in special divisors for each category depending on their probability.

To get the final page, the previously obtained divisors are attached to a new HTML tree structure. The navigation through these divisors will be controlled from the mobile client by basic JavaScript functions. Final adjustments of the URLs, style (CSS), JavaScript and other minor adjustments such as changing destination addresses of links and images so it doesn't lose consistency, or eliminating any CSS style and JavaScript code from the original site, in order to avoid possible errors.

The implementation of the Bayesian classification model needs a pre-training. For this, a representative sample of the current Web was used. To this end we consider the three most popular CMS (Wordpress, Drupal and Joomla) and 400 HTML templates were selected for each one of them. Another group of about 600 average pieces of HTML code, belonging to each category to analyze (menu, content, header and footer) was added to the sample. Then, the average and

standard deviation of the data was calculated to get the best differentiators for the classifier, which were:

- Frequency of div tag.
- Frequency of p tag.
- Frequency of ul tag.
- Number of characters present in the code.
- Number of characters present in the content of the code (without tags).
- Ratio between the number of characters present in the contents of the code versus the number of tags (referring to the number of links present in the code).

It may be surprising that the statistics of the id attributes and class for the Bayesian classifier have not been taken into account. This decision was taken because that information gave such good results that it was worked independently.

The probability function used for the classifier was based on the frequency ranges.

2.5 Reorganizing the Contents

Once the elements have been captured, the new page needs to be built. The criteria we use to produce a "better" page is based on the best practices guide for mobile Web of the W3C (Rabin and McCathieNevile, 2008). According to this, the points that had a greater connotation for model development are:

- Navbar: Keep a basic menu with a single line at the top of the page. This gives the user a neat and clear navigation. To achieve this, a top menu that allows a smooth navigation between the subpages was added.
- Balance: Having too many links on the page increases the need to scroll through the content of interest, whereas having few links triggers the need to make many clicks to find what you want. Concentrating all the menus of the original application and leaving them only a click away eliminating unwanted movement and arranging navigation without causing excessive delays.
- Navigation: Keep a consistent navigation system throughout the site. This detail helps the user to always know how to move inside the application. The proposed design has a simple and well defined structure.

- Page size usable: Suggests dividing the page into several pieces that have a limited content with high usage. To accomplish this, the most important elements of the site were grouped and pooled before being independently submitted, focusing on the real use for the user.
- Scrolling: Limit the scrolling to one direction unless maintaining both orientations it is strictly necessary. Thus, the width of the screen was redefined to avoid the horizontal scrolling at all costs.

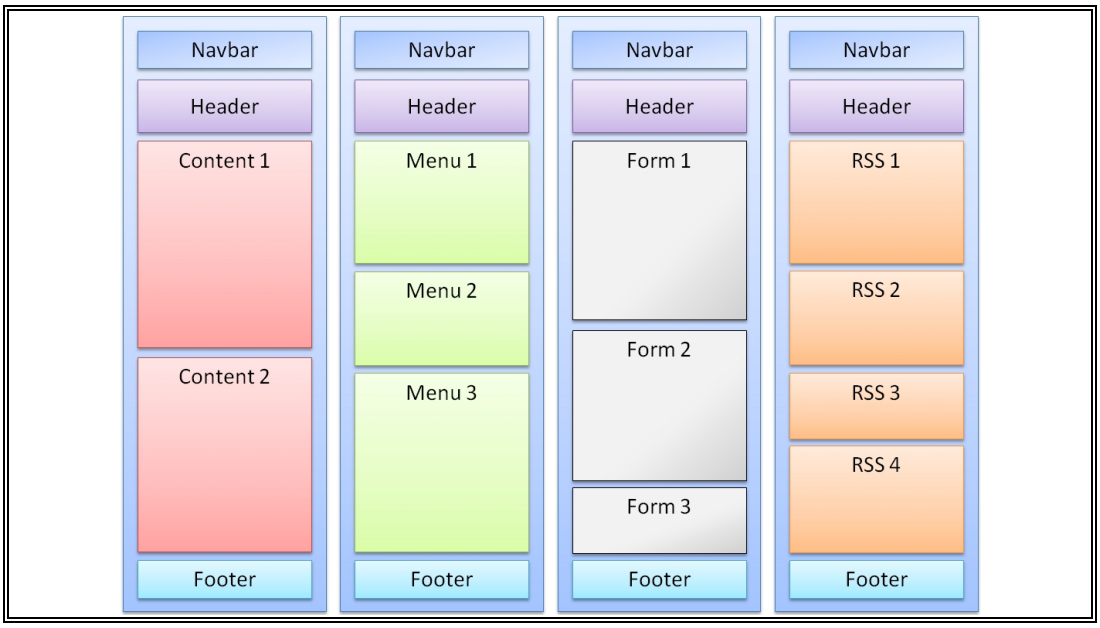

Figure 2-4: Restructuring designed for mobile device.

- Central meaning: Stresses the importance of maintaining the main content of the page above the rest. As mentioned before, the proposed restructuration brings together the various elements of the submitted pages, shows them independently and arranges them on the screen according to their importance level.

The page is therefore restructured according to the templates shown in figure 2-4 with a navigation bar at the top and keeping the original content and structure but presenting it to the user in a more suitable way. To achieve smoother movement

between the subpages, the system incorporates a series of JavaScript functions to be executed on the mobile client through the upper menu.

The results can be seen in figures 2-5 to 2-7. Figure 2-5 shows a sample page viewed through a desktop computer browser with a resolution of 1440x900 pixels. Figure 2-6 presents the view of the same page, but through an emulator of HTC Magic device running the Android WebKit. The page doesn't look very well because of the menus and a large scrolls both vertical and horizontal. Finally, in Figure 2-7 the same page as presented by our system. The ease of navigation and the elimination of any horizontal scrolling together with a menu that is only a click away, giving the option of a quick view of all forms and RSS pages produces a much better usability.

Figure 2-5: This example page is clearly designed to be viewed through high resolutions screen.

Figure 2-6: The view through the Android WebKit

Figure 2-7: The proposed system eliminates horizontal scrolling and organizes all the page information

2.6 Architecture

The system runs on a proxy server, since it should be transparent to the application and also should not add extra processing load to the mobile device. Furthermore, this makes it easy to capture and collect statistical information. Figure 2-8 show how it works: the client, connected to the Internet from a mobile device, starts browsing through a form that asks him for the URL of the page that he wants to visit. After entering the URL and sending the form, the user activates the restructuration of the HTML code of the selected Web application for the system to give him a first view of the page and save the changes in a cache to avoid future processing of a Web page already processed.

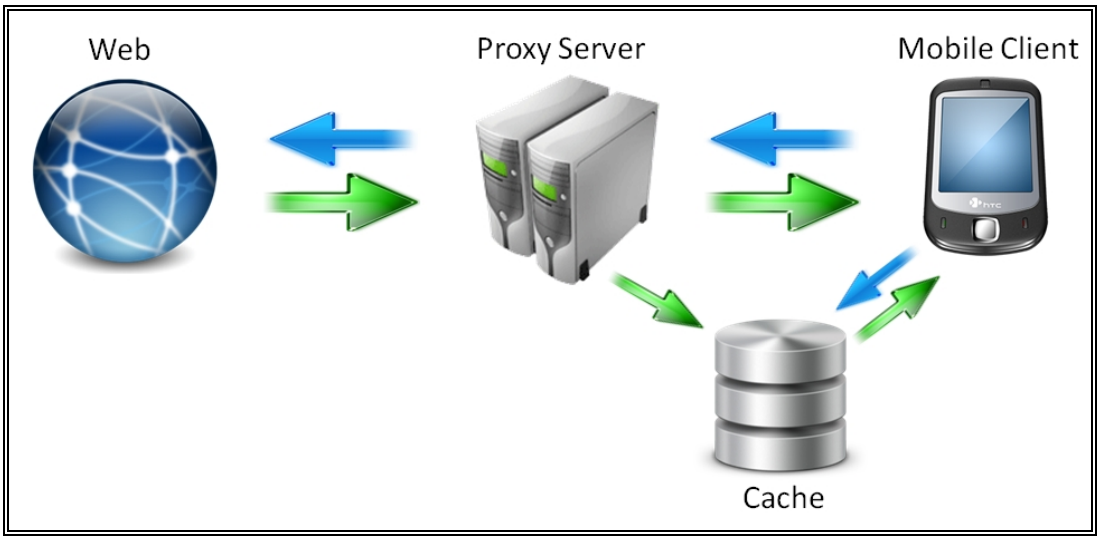

Figure 2-8: Information Flow Chart

2.7 Testing the usability of the system

We tested the usability of the system with a group of 25 persons aged between 20 and 60 years old and very different levels of technological expertise. We conducted surveys to measure the following:

- The feeling of quality and correctness of the system.
- The feeling of the user's comfort.
- The feeling of easiness when performing a task.

- The feeling of agility that the system offers.
- The feeling of quality that the graphic presentation has.

The study was made independently by each of these people at different times of the day and immersed in the following environments:

- Home: The user's house.
- Office: The user's workplace.
- Outdoor public place: Green areas inside the university campus..

Each person was given a mobile device (iPhone 3G or iPod Touch) connected to a WLAN (wireless) and he was asked to navigate the Web using both ours, and the default system of the device. Once the test complete, he was requested to complete a short survey consisting on 10 questions inquiring about different aspects related to the usability of the system, plus a final question about what system would he/she prefer in the future. The results are presented on Table 2-1 and Figure 2-9.

Table 2-1: The proposed system was evaluated with scores above 5.5 (scale 1 to 7)

	Questions	**Native system**	**Proposed system**	**Difference**	**Difference %**
quality and correctness	1, 6	5.0	5.6	0.5	10%
user's comfort	2, 7	4.1	6.2	2.1	51%
easy to carry out a task	4, 8	5.0	6.0	0.9	18%
agility	3, 10	4.7	5.7	0.9	19%
quality of graphics	5	4.4	5.7	1.2	28%

The results show improvements in all aspects reaching an impressive 51%, in user comfort. It is noteworthy that although the system takes slightly longer to load, users considered that the proposed system is in general more agile. This could be

attributed to the smooth effects of JavaScript used for the transfer through the different sections.

Another interesting aspect is the good marks the aesthetic quality (graphic) of the system gets even after we eliminate almost all CSS styles. They tend to give more value to structural details such as font size and limiting the maximum width than to style elements like colors. In this sense, the users preferred functional graphics that avoided the need for horizontal scrolling and zoom.

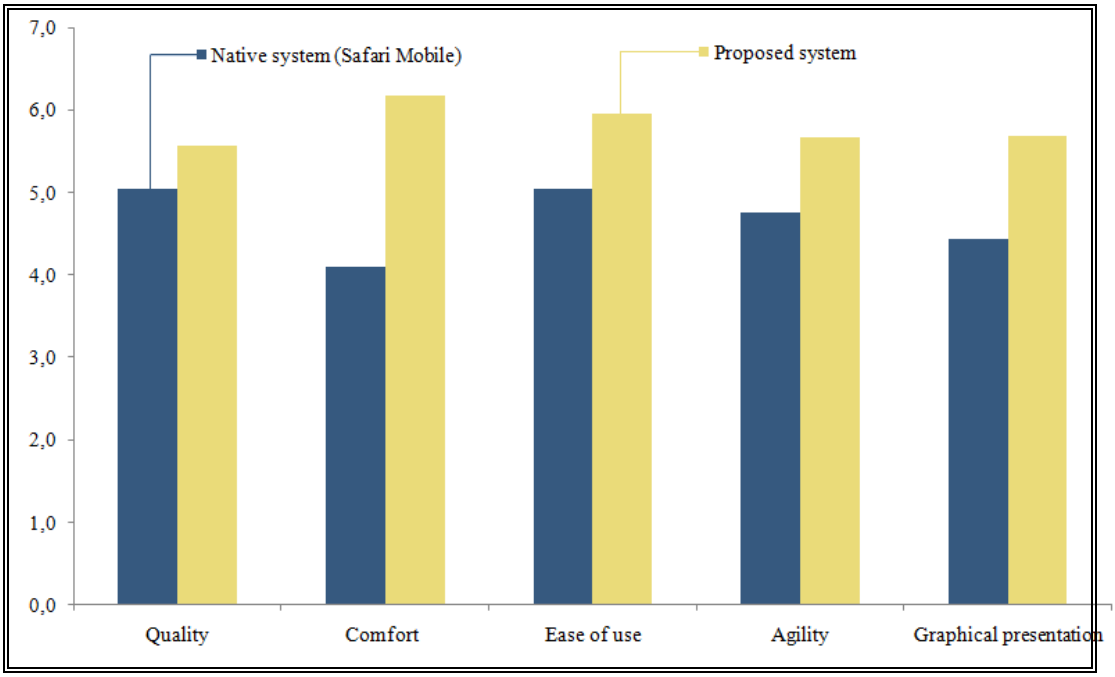

Figure 2-9: The proposed system achieves higher assessments in all aspects of usability.

Finally, according to the more emotional last question, 92% of the users surveyed said they preferred the new system instead of the default system from the device. We realize that careful more rigorous usability testing is needed but the results are quite encouraging.

2.8 Conclusion

We presented a novel solution and built a system based on a dynamic restructuring to the problem of presentation of Web pages on mobile devices. The system uses

a Bayesian pattern recognition model to recognize the components of the original web page and then uses a strategy based on W3C best practices to restructure the same contents in the best way for a mobile device.

More than one thousand HTML templates corresponding to the most typical web page designs were used as input to the Bayesian model so it can be able to identify the most basic elements of a web page: header, menu, content, forms, RSS feeds and footer.

The whole process runs in a proxy server so neither the server nor the client are affected in any form and the performance is not degraded.

We tested our system against the best web experiences on mobile devices existing today (Safari on the iPhone) asking a number of real users of diverse ages what they think. Although this cannot be considered a conclusive usability test and much more rigorous testing is needed, the results were quite encouraging. The people gave better marks to the new system in every aspect we asked including a 51% improvement in one dimension. Furthermore, asked directly about which one they would choose an astounding 92% opted for the new one.

Our findings tell us that dynamic restructuring of web pages before they are served to mobile devices could improve the usability of the application giving the user a much better experience than any mobile web browser could do. There is of course a lot of room for system improvement. For example we plan to examine in the near future one or more of the following:

- detecting native mobile pages
- integrating a mobile Web search engine.
- capturing structure through table rows (tags <td>).
- automatic shortening of long texts.
- caching CSS and JavaScript.
- HTML5
- allocating buttons for specific functionalities
- testing other pattern recognition models (neural networks)

3. CONCLUSIONS AND FUTURE WORK

This work was inspired after the fact that in spite of the dramatic advances in mobile devices we have witnessed in the last few years (especially after the iPhone) most web pages and web applications were originally designed for the desktop. This translates in a poor web experience when the user loads those same web pages into its mobile device.

We decided that among all the different strategies to tackle the problem that had been used, a transparent dynamic restructuring carried out by a proxy server that sits between the server and the mobile device was the most promissory. We made then another key strategic decision: instead of trying to build a completely general restructuring scheme that can work on any page or application we thought that a much better job could be done if we assume that most web pages these days look quite similar. Thus, researching the design of existing Web applications, we can conclude that the vast majority of these websites follows a similar structure defined by a top header which has the role of placing the user within a context, some menus (one to three) are designed to provide accessibility to the rest of the site, a body with all the core content, to give the user all the important information and a footer that provides all secondary information such as copyright, contact addresses, and so on.

Moreover, researching on how websites are built, we realized the great insight that the Content Management Systems (CMS) have on the Web, especially open source ones such as Joomla, Drupal and Wordpress. We decided to make further investigations and realized that using predesigned templates was a common practice, either for using it as it is, with no change, or making some modifications to keep it as a basis. All this research on CMS reaffirmed our theories of design. After analyzing about 1200 Joomla, Drupal and Wordpress templates (400 of each CMS), the numbers surrendered an average of 1 top header, 2 menus, 3.5 contents and 1 footer. All the research took into account these patterns of Web design and statistical analysis of web templates.

We conceived our system as composed of two subsystems: a recognizer and a builder. The first one is the responsible of analyzing the original webpage to detect the key components whereas the second is the one that needs to restructure these components into the new page that will go to the mobile device.

To build the recognizer two options were essentially studied: neural networks and Bayesian classifiers. Reading Victor Fresno's (2006) research on Bayesian classifiers, we concluded that it was a very effective system in pattern recognition and easy to implement. This way and using the CMS templates previously studied as learning sample, we decided to implement this model.

During the development of Bayesian classifier another point of analysis was discovered: which probability function to choose. Victor Fresno's study (2006) found that the best probability function for pattern recognition of HTML content on the model of Bayesian classifier was the multinomial function. This was implemented with bad results. For this reason, other probability functions were evaluated and we concluded that the appropriate function was the one based on rank because it got the best result. This function was created through lines of probability that were captured in the statistics of frequency and limits given by the data.

That was how, after the system was trained with a sample of some over 1,000 pieces of HTML code and under all the specifications described above, it proved to be very effective, achieving an excellent 80% of the sample effective analysis recognition. Despite the good results, we believe that there is still a lot to improve in this area.

As the recognizer, a part of the builder was based on the conclusions obtained in the analysis stage of the current web, ie taking into consideration the role and importance of each of the sections described, and reordering them as if they were a necessary good. Thus, it was considered that the role that the header and footer have cannot be ignored, therefore remained unaltered. Furthermore, the roles played by menus and content are two things that, despite the fact that they go hand by hand, they are rarely needed at the same time. Thus, it was decided to separate

them, favoring the contents and putting the menus a click away. Moreover, taking into consideration the recommendations of the W3C (Rabin & McCathieNevile, 2008) on the mobile Web applications, we decided not to put aside important issues for the next generation of mobile devices such as navbar, balance, navigation, page size usable, scrolling and the organization of the contents of greater significance (central meaning).

We believe that a key decision on the successful completion of the system was developed only with open source technologies, because they gave us great flexibility, in addition to having full backing of big communities behind. The working environment was mounted on a Linux (Ubuntu 9.04) with Aptana Jaxer on Apache2 and MySQL database. Definitely the mix of these technologies amply demonstrated the strength necessary to permit completion of this project, Linux with Apache and Mysql are mature technologies and have huge communities around the world.

After conducting a series of internal tests on the correctness, fluency and functionality of the system proposed through the two best mobile Webkits today (mobile Safari browser of Apple and Google's Android WebKit), we asked a group of ordinary people to prove the system via iPhone or iPod Touch connected to a wireless network. To cover a wide spectrum of users, the tests were made to persons with an age range between 20 and 60, all with varying degrees of technology domain expertise. In addition, tests were conducted under different environments, so as to broaden the possibilities of social context in which it is used. We are aware that a simple survey cannot be considered as a conclusive usability test, therefore, it would be highly relevant to conduct more rigorous tests that measured more specific effects of usability as the number of clicks that a user must perform to accomplish a specific task, the actual time it takes to load a Web application, the time it takes to reach the information he/she is looking for, etc.. Even though a much more rigorous testing is needed, the results were quite encouraging. Outcomes were superior in absolutely every aspect measured and evaluations were very positive. The proposed system was about 5.5 assessments in

all areas (on a scale of 1 to 7), always emphasizing the comfort of the user who obtained a 6.2 grade-point average, 51% higher than the native system. Furthermore, asked directly about which one they would choose an astounding 92% opted for the new one.

Our findings tell us that dynamic restructuring of web pages before they are served to mobile devices could improve the usability of the application giving the user a much better experience than any mobile web browser could do.

Anyway, there is a lot of room for system improvement. For example we plan to examine in the near future one or more of the following:

Detecting native mobile pages: Many Web applications have their native version for mobile devices. It could be detected automatically, to be redirected to these versions, instead of trying to change the original page.

Integrating a mobile Web search engine: The current mode provided by the system to browse the Web is a simple form where the user delivers the URL of the page to visit. Instead, the system could integrate the results of a search engine site (like Google Mobile or similar) to make the system work transparently.

Capturing structure through table rows (tags <td>): Currently, the proposed system only scans the div tags ( ) and thereby makes the selection of sections within the analysis of patterns in the HTML codes from the different sites studied. We also found that many of the sections were defined by rows of tables (tags <td>), so implementing the revision of these tag should improve the system performance.

Automatic shortening of long texts: Currently, the proposed system shows all the texts found, although many of them are useless to the end user. Thus, it could be convenient summarizing lengthy paragraphs in a few lines and give the option to read more if desired.

Caching CSS and JavaScript: To avoid possible errors, the developed system removes all of the CSS style and JavaScript code that comes along with the captured Web page. Thus, the system would be greatly enhanced if it could integrate such codes.

HTML5: This new version of HTML includes special tags to define the headers, menus, footer and contents of websites, thus, the implementation of the recognition of this Hyper Text Markup Language, would greatly facilitate pattern recognition work, as we previously reviewed.

Allocating buttons for specific functionalities: Within the guide of the best practices for mobile Web offered by the W3C (Rabin and McCathieNevile, 2008) we find that it proposes direct access buttons that provides a specific functionality of the system, in order to speed up navigation. How was the system designed for mobile devices without a keyboard? Like the iphone? This was not implemented but would be interesting to have.

Testing other pattern recognition models (neural networks): It is possible to discuss the real effectiveness and quality of results that the Bayes networks model could deliver. Thus, it would be interesting to evaluate other models of pattern recognition such as neural networks.

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APPENDIX

APPENDIX A: STATISTICS OF HTML TAGS

Tag <a>

Type	Total	Min	Max	Avg	Std
1	943	0	844	13.3404029692470838	28.5639620216930259
2	654	0	173	14.7079510703363914	17.3703563056269009
3	389	0	9	1.6426735218508997	1.8341910345939241
4	391	0	17	2.9104859335038363	2.3181928238158641

Tag <abbr>

Type	Total	Min	Max	Avg	Std
1	943	0	5	0.13891834570519618240	0.60148586074119014346
2	654	0	9	0.54587155963302752294	1.0384077907961937
3	389	0	1	0.01799485861182519280	0.13310367238496456481
4	391	0	3	0.03836317135549872123	0.26996938302033113012

Tag <acronym>

Type	Total	Min	Max	Avg	Std
1	943	0	1	0.00212089077412513256	0.04602867907858620648
2	654	0	2	0.49847094801223241590	0.86580298568876731315
3	389	0	0	0.00000000000000000000	0
4	391	0	1	0.00511508951406649616	0.07142810301224486614

Tag <address>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	7	0.02752293577981651376	0.39426320131107872388
3	389	0	0	0.00000000000000000000	0
4	391	0	1	0.01023017902813299233	0.10075457976340926648

Tag <applet>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <area>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <b>

Type	Total	Min	Max	Avg	Std
1	943	0	8	0.14422057264050901379	0.46122011421761237356
2	654	0	21	0.21865443425076452599	1.0772123969250615
3	389	0	0	0.00000000000000000000	0
4	391	0	4	0.08951406649616368286	0.54506411684158131051

Tag <base >

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <basefont>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <bdo>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <big>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <blockquote>

Type	Total	Min	Max	Avg	Std
1	943	0	3	0.00318133616118769883	0.09769344135387542228
2	654	0	1	0.25076452599388379205	0.43378496895463017082
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

**Tag
**

Type	Total	Min	Max	Avg	Std
1	943	0	17	3.1601272534464475	3.8253846488983512
2	654	0	59	6.5581039755351682	9.4916173259552107
3	389	0	4	0.09254498714652956298	0.41451866404551023139
4	391	0	8	0.48081841432225063939	0.93040677360925957496

Tag <button>

Type	Total	Min	Max	Avg	Std
1	943	0	1	0.00212089077412513256	0.04602867907858620648
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <caption>

Type	Total	Min	Max	Avg	Std
1	943	0	1	0.02226935312831389183	0.14763652354050728043
2	654	0	1	0.00152905198776758410	0.03910309435028875180
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

**Tag **

Type	Total	Min	Max	Avg	Std
1	943	0	1	0.00318133616118769883	0.05634342669709342243
2	654	0	1	0.00917431192660550459	0.09541522161176702968
3	389	0	1	0.00514138817480719794	0.07161101294044557732
4	391	0	1	0.00255754475703324808	0.05057217374241736190

Tag <cite>

Type	Total	Min	Max	Avg	Std
1	943	0	3	0.0042417815482502651 1	0.10294512830342533387
2	654	0	1	0.36085626911314984709	0.48061650124603455462
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <code>

Type	Total	Min	Max	Avg	Std
1	943	0	1	0.00106044538706256628	0.03256448045129180746
2	654	0	2	0.11620795107033639144	0.32545926019070530713
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <col >

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <colgroup>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <dd>

Type	Total	Min	Max	Avg	Std
1	943	0	18	0.0381760339342523860	0.8285162234145517163
2	654	0	1	0.2492354740061162079	0.4329014928443836565
3	389	0	0	0.0000000000000000000	0
4	391	0	0	0.0000000000000000000	0

Tag <del>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.0000000000000000000	0
2	654	0	0	0.0000000000000000000	0
3	389	0	1	0.0051413881748071979	0.0716110129404455773
4	391	0	0	0.0000000000000000000	0

Tag <dfn>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.0000000000000000000	0
2	654	0	0	0.0000000000000000000	0
3	389	0	0	0.0000000000000000000	0
4	391	0	0	0.0000000000000000000	0

Tag <dir>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.0000000000000000000	0
2	654	0	0	0.0000000000000000000	0
3	389	0	0	0.0000000000000000000	0
4	391	0	0	0.0000000000000000000	0

**Tag **

Type	Total	Min	Max	Avg	Std
1	943	0	83	6.4835630965005302	7.7895280040920820
2	654	0	130	16.3807339449541284	18.6578033323301976
3	389	0	17	3.3316195372750643	2.3143551793344419
4	391	0	10	1.7851662404092072	1.4587964517635353

Tag <dl>

Type	Total	Min	Max	Avg	Std
1	943	0	5	0.01060445387062566278	0.23014339539293103234
2	654	0	1	0.24923547400611620795	0.43290149284438365658
3	389	0	1	0.00514138817480719794	0.07161101294044557732
4	391	0	0	0.00000000000000000000	0

Tag <dt>

Type	Total	Min	Max	Avg	Std
1	943	0	7	0.01484623541887592789	0.32220075355010344527
2	654	0	1	0.24923547400611620795	0.43290149284438365658
3	389	0	2	0.01028277634961439589	0.14322202588089115460
4	391	0	0	0.00000000000000000000	0

**Tag **

Type	Total	Min	Max	Avg	Std
1	943	0	2	0.01908801696712619300	0.18902031393823143114
2	654	0	7	0.39296636085626911315	0.60877660220599352778
3	389	0	0	0.00000000000000000000	0
4	391	0	2	0.04092071611253196931	0.24466234472986773279

Tag <fieldset>

Type	Total	Min	Max	Avg	Std
1	943	0	1	0.0084835630965005302	0.09176340096760933604
2	654	0	1	0.25382262996941896024	0.43553041613283439745
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <font>

Type	Total	Min	Max	Avg	Std
1	943	0	1	0.00530222693531283139	0.07266162791498894928
2	654	0	3	0.00458715596330275229	0.11730928305086625530
3	389	0	1	0.00257069408740359897	0.05070201265633938293
4	391	0	1	0.01023017902813299233	0.10075457976340926648

Tag <form>

Type	Total	Min	Max	Avg	Std
1	943	0	3	0.41569459172852598091	0.55775532083691257026
2	654	0	2	0.34556574923547400612	0.50404510826722719825
3	389	0	2	0.27763496143958868895	0.47083886578895977571
4	391	0	2	0.02046035805626598465	0.17421116817470269148

Tag <frame>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <frameset>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <h1>

Type	Total	Min	Max	Avg	Std
1	943	0	6	0.04878048780487804878	0.39064987169019582914
2	654	0	12	0.54281345565749235474	1.4100390571858538
3	389	0	2	0.71208226221079691517	0.49677623976066478263
4	391	0	1	0.00511508951406649616	0.07142810301224486614

Tag <h2>

Type	Total	Min	Max	Avg	Std
1	943	0	13	1.2979851537645811	1.9568775151044025
2	654	0	21	4.0489296636085627	5.6447178483689091
3	389	0	2	0.42159383033419023136	0.49963546460155359410
4	391	0	4	0.07416879795396419437	0.42622103588888290118

Tag <h3>

Type	Total	Min	Max	Avg	Std
1	943	0	7	0.53340402969247083775	1.2763976033723083
2	654	0	50	1.6085626911314985	2.9637400445989977
3	389	0	1	0.02827763496143958869	0.16597840201863680387
4	391	0	2	0.01790281329923273657	0.16698441741291826332

Tag <h4>

Type	Total	Min	Max	Avg	Std
1	943	0	7	0.05302226935312831389	0.49127081462669251568
2	654	0	13	0.39449541284403669725	1.1464174061155804
3	389	0	1	0.00771208226221079692	0.08759183330002400897
4	391	0	1	0.02557544757033248082	0.15806721650644082544

Tag <h5>

Type	Total	Min	Max	Avg	Std
1	943	0	3	0.01590668080593849417	0.20284965563124418376
2	654	0	3	0.25840978593272171254	0.44845958258112423539
3	389	0	0	0.00000000000000000000	0
4	391	0	1	0.01023017902813299233	0.10075457976340926648

Tag <h6>

Type	Total	Min	Max	Avg	Std
1	943	0	1	0.00106044538706256628	0.03256448045129180746
2	654	0	1	0.25382262996941896024	0.43553041613283439745
3	389	0	0	0.00000000000000000000	0
4	391	0	1	0.00511508951406649616	0.07142810301224486614

Tag <hr>

Type	Total	Min	Max	Avg	Std
1	943	0	2	0.00318133616118769883	0.07278546546187312375
2	654	0	13	1.5642201834862385	2.6784840494017905
3	389	0	0	0.00000000000000000000	0
4	391	0	2	0.01278772378516624041	0.15137033361986811850

Tag <i>

Type	Total	Min	Max	Avg	Std
1	943	0	8	0.01484623541887592789	0.27219355995471953857
2	654	0	2	0.38837920489296636086	0.79175661213493977649
3	389	0	0	0.00000000000000000000	0
4	391	0	1	0.00511508951406649616	0.07142810301224486614

Tag <iframe>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	2	0.00458715596330275229	0.08738360039115006475
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <img>

Type	Total	Min	Max	Avg	Std
1	943	0	56	1.1633085896076352	3.0621396147763439
2	654	0	15	1.2140672782874618	2.1448433766411052
3	389	0	6	0.44473007712082262211	0.89968736932385036441
4	391	0	4	0.07416879795396419437	0.35391258104782880945

Tag <input>

Type	Total	Min	Max	Avg	Std
1	943	0	24	3.1007423117709438	4.9980282184669688
2	654	0	14	3.5382262996941896	5.1424641697709194
3	389	0	7	0.75835475578406169666	1.3270435972022623
4	391	0	6	0.04859335038363171355	0.46430738697192279889

Tag <ins>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <isindex>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <kbd>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <label>

Type	Total	Min	Max	Avg	Std
1	943	0	10	0.87698833510074231177	1.6587062486119657
2	654	0	7	2.1238532110091743	3.1503829198960606
3	389	0	2	0.02313624678663239075	0.19525144889650975922
4	391	0	0	0.00000000000000000000	0

Tag <legend>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	1	0.25382262996941896024	0.43553041613283439745
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

**Tag **

Type	Total	Min	Max	Avg	Std
1	943	0	842	4.64899257688229	17.3508605025929
2	654	0	65	5.06727828746177	7.44536958542422
3	389	0	7	0.29305912596401028278	1.01862963793452207576
4	391	0	13	0.44757033248081841432	1.5196787715693758

Tag <link>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <map>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <menu>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <meta>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <noframes>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <noscript>

Type	Total	Min	Max	Avg	Std
1	943	0	2	0.12831389183457051962	0.33777405966127782954
2	654	0	1	0.00611620795107033639	0.07802633521137065540
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <object>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	1	0.00152905198776758410	0.03910309435028875180
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

**Tag **

Type	Total	Min	Max	Avg	Std
1	943	0	5	0.00848356309650053022	0.17219739911639229416
2	654	0	6	1.5489296636085627	2.5851307207638945
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <optgroup>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	2	0.49847094801223241590	0.86580298568876731315
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <option>

Type	Total	Min	Max	Avg	Std
1	943	0	11	0.03393425238600212089	0.55572116448611200305
2	654	0	6	1.4954128440366972	2.5974089570663019
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <p>

Type	Total	Min	Max	Avg	Std
1	943	0	14	0. 0843054082714736	0.55347315073185
2	654	0	58	6.17966360856267	8.8793605071720
3	389	0	1	0.0874035989717223	0.282199551400445
4	391	0	7	0.255754475703324	0.619263350410854

Tag <param>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	7	0.01070336391437308869	0.27372166045202126239
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <pre>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	1	0.24923547400611620795	0.43290149284438365658
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <q>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <s>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <samp>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <script>

Type	Total	Min	Max	Avg	Std
1	943	0	8	1.0010604453870626	2.5168221587391501
2	654	0	6	0.12844036697247706422	0.57674564790751849010
3	389	0	1	0.00514138817480719794	0.07161101294044557732
4	391	0	2	0.08184143222506393862	0.29256195560720587730

Tag <select>

Type	Total	Min	Max	Avg	Std
1	943	0	1	0.00424178154825026511	0.06502516966387974808
2	654	0	1	0.24923547400611620795	0.43290149284438365658
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <small>

Type	Total	Min	Max	Avg	Std
1	943	0	8	0.01484623541887592789	0.29466623081718782760
2	654	0	13	2.1850152905198777	4.1137377045403191
3	389	0	0	0.00000000000000000000	0
4	391	0	1	0.03580562659846547315	0.18604328988665502894

**Tag **

Type	Total	Min	Max	Avg	Std
1	943	0	41	0.53870625662778366914	2.6606229060162092
2	654	0	40	3.6681957186544343	6.0382900826667703
3	389	0	3	0.29820051413881748072	0.59510187198577362011
4	391	0	5	0.42966751918158567775	0.93892444847404591257

Tag <strike>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

**Tag **

Type	Total	Min	Max	Avg	Std
1	943	0	10	0.02863202545068928950	0.37181333254726884971
2	654	0	14	0.50611620795107033639	1.1472555541536016
3	389	0	1	0.02313624678663239075	0.15052976705759285201
4	391	0	2	0.06393861892583120205	0.26506668017812394600

Tag <style>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <sub>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	1	0.24923547400611620795	0.43290149284438365658
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <sup>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	1	0.25076452599388379205	0.43378496895463017082
3	389	0	1	0.00257069408740359897	0.05070201265633938293
4	391	0	0	0.00000000000000000000	0

Tag <table>

Type	Total	Min	Max	Avg	Std
1	943	0	8	0.93955461293743372216	1.6373930048632781
2	654	0	15	2.3470948012232416	3.6513878458470943
3	389	0	4	0.23393316195372750643	0.66136394963112202555
4	391	0	1	0.01023017902813299233	0.10075457976340926648

Tag <tbody>

Type	Total	Min	Max	Avg	Std
1	943	0	5	0.07953340402969247084	0.51622814898289580072
2	654	0	9	0.06422018348623853211	0.67474997047409358963
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <td>

Type	Total	Min	Max	Avg	Std
1	943	0	61	4.1208907741251326	7.6215012126444974
2	654	0	42	6.1941896024464832	7.2922306429240676
3	389	0	4	0.24935732647814910026	0.70858567447499556010
4	391	0	3	0.03580562659846547315	0.23478698052632831240

Tag <textarea>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	1	0.25382262996941896024	0.43553041613283439745
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <tfoot>

Type	Total	Min	Max	Avg	Std
1	943	0	1	0.02120890774125132556	0.14415660659219630171
2	654	0	1	0.00152905198776758410	0.03910309435028875180
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <th>

Type	Total	Min	Max	Avg	Std
1	943	0	7	0.51219512195121951220	1.2675978904972840
2	654	0	7	0.4701834862385320	1.03629783604940
3	389	0	2	0.03341902313624678663	0.19375263682428393057
4	391	0	0	0.00000000000000000000	0

Tag <thead>

Type	Total	Min	Max	Avg	Std
1	943	0	1	0.04347826086956521739	0.20403933497472920278
2	654	0	1	0.05810397553516819572	0.23411901571997533718
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <tr>

Type	Total	Min	Max	Avg	Std
1	943	0	20	3.5376458112407211	6.0972665879632619
2	654	0	30	4.4969418960244648	6.2305739614758774
3	389	0	6	0.27506426735218508997	0.83042673695317109846
4	391	0	1	0.01278772378516624041	0.11250141174127514028

Tag <tt>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

Tag <u>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	3	0.03836317135549872123	0.31388611534982539801

**Tag **

Type	Total	Min	Max	Avg	Std
1	943	0	17	1.8441145281018028	2.3742436130724795
2	654	0	50	2.3134556574923547	4.4647233228370999
3	389	0	3	0.16195372750642673522	0.42716071472439198424
4	391	0	5	0.24808184143222506394	0.72489797934902035462

Tag <var>

Type	Total	Min	Max	Avg	Std
1	943	0	0	0.00000000000000000000	0
2	654	0	0	0.00000000000000000000	0
3	389	0	0	0.00000000000000000000	0
4	391	0	0	0.00000000000000000000	0

APPENDIX B: LOWER AND HIGHER FREQUENCY

class	variable	floor	top
1	Total tags	38	163
2	Total tags	104	307
3	Total tags	12	25
4	Total tags	9	21
1	a	0	27
2	a	7	23
3	a	1	2
4	a	2	4
1	abbr	0	0
2	abbr	1	1
3	abbr	0	0
4	abbr	0	0
1	acronym	0	0
2	acronym	1	0
3	acronym	0	0
4	acronym	0	0
1	address	0	0
2	address	0	0
3	address	0	0
4	address	0	0
1	b	0	0
2	b	0	0
3	b	0	0
4	b	0	0
1	blockquote	0	0
2	blockquote	1	0
3	blockquote	0	0
4	blockquote	0	0
1	br	2	5
2	br	2	11
3	br	0	0
4	br	1	0
1	button	0	0
2	button	0	0
3	button	0	0
4	button	0	0
1	caption	0	0
2	caption	0	0
3	caption	0	0
4	caption	0	0

1	center	0	0
2	center	0	0
3	center	0	0
4	center	0	0
1	cite	0	0
2	cite	1	0
3	cite	0	0
4	cite	0	0
1	code	0	0
2	code	0	0
3	code	0	0
4	code	0	0
1	dd	0	0
2	dd	1	0
3	dd	0	0
4	dd	0	0
1	del	0	0
2	del	0	0
3	del	0	0
4	del	0	0
1	div	3	10
2	div	8	25
3	div	3	4
4	div	2	2
1	dl	0	0
2	dl	1	0
3	dl	0	0
4	dl	0	0
1	dt	0	0
2	dt	1	0
3	dt	0	0
4	dt	0	0
1	em	0	0
2	em	1	0
3	em	0	0
4	em	0	0
1	fieldset	0	0
2	fieldset	1	0
3	fieldset	0	0
4	fieldset	0	0
1	font	0	0
2	font	0	0
3	font	0	0
4	font	0	0

1	form	1	0
2	form	1	0
3	form	1	0
4	form	0	0
1	h1	0	0
2	h1	0	1
3	h1	1	0
4	h1	0	0
1	h2	1	2
2	h2	2	6
3	h2	1	0
4	h2	0	0
1	h3	0	1
2	h3	1	3
3	h3	0	0
4	h3	0	0
1	h4	0	0
2	h4	0	0
3	h4	0	0
4	h4	0	0
1	h5	0	0
2	h5	1	0
3	h5	0	0
4	h5	0	0
1	h6	0	0
2	h6	1	0
3	h6	0	0
4	h6	0	0
1	hr	0	0
2	hr	1	2
3	hr	0	0
4	hr	0	0
1	i	0	0
2	i	0	0
3	i	0	0
4	i	0	0
1	iframe	0	0
2	iframe	0	0
3	iframe	0	0
4	iframe	0	0
1	img	0	2
2	img	1	2
3	img	0	0
4	img	0	0

1	input	1	5
2	input	1	6
3	input	1	1
4	input	0	0
1	label	1	1
2	label	1	3
3	label	0	0
4	label	0	0
1	Code length	968	5876
2	Code length	3459	10459
3	Code length	363	912
4	Code length	341	763
1	Content length	15	816
2	Content length	1320	5043
3	Content length	59	190
4	Content length	69	168
1	Content length VS Links	0	91
2	Content length VS Links	68	749
3	Content length VS Links	12	116
4	Content length VS Links	21	43
1	legend	0	0
2	legend	1	0
3	legend	0	0
4	legend	0	0
1	li	0	13
2	li	1	8
3	li	0	0
4	li	0	1
1	noscript	0	0
2	noscript	0	0
3	noscript	0	0
4	noscript	0	0
1	object	0	0
2	object	0	0
3	object	0	0
4	object	0	0
1	ol	0	0
2	ol	1	2
3	ol	0	0
4	ol	0	0

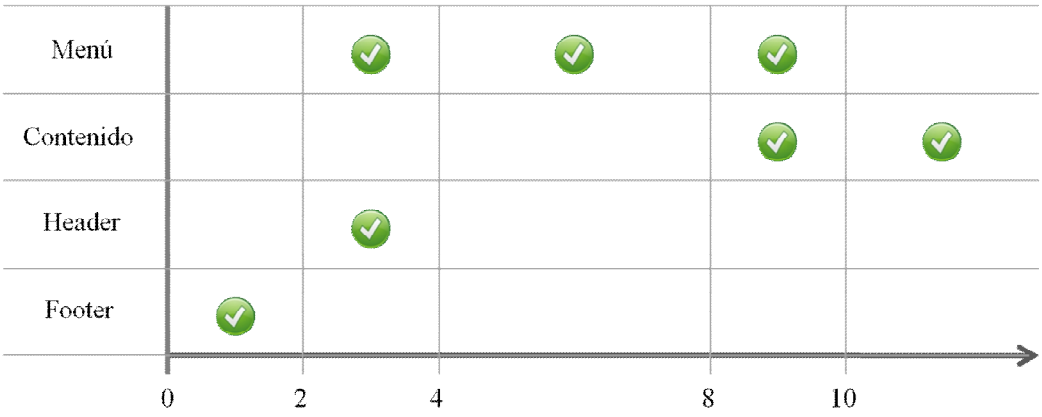
1	optgroup	0	0
2	optgroup	1	0
3	optgroup	0	0
4	optgroup	0	0
1	option	0	0
2	option	1	2
3	option	0	0
4	option	0	0
1	p	0	0
2	p	1	10
3	p	0	0
4	p	0	0
1	param	0	0
2	param	0	0
3	param	0	0
4	param	0	0
1	pre	0	0
2	pre	1	0
3	pre	0	0
4	pre	0	0
1	script	0	2
2	script	0	0
3	script	0	0
4	script	0	0
1	select	0	0
2	select	1	0
3	select	0	0
4	select	0	0
1	small	0	0
2	small	1	4
3	small	0	0
4	small	0	0
1	span	0	1
2	span	1	6
3	span	1	0
4	span	0	0
1	strong	0	0
2	strong	0	1
3	strong	0	0
4	strong	0	0
1	sub	0	0
2	sub	1	0
3	sub	0	0
4	sub	0	0

1	sup	0	0
2	sup	1	0
3	sup	0	0
4	sup	0	0
1	table	1	1
2	table	1	4
3	table	0	0
4	table	0	0
1	tbody	0	0
2	tbody	0	0
3	tbody	0	0
4	tbody	0	0
1	td	1	7
2	td	3	9
3	td	0	0
4	td	0	0
1	textarea	0	0
2	textarea	1	0
3	textarea	0	0
4	textarea	0	0
1	tfoot	0	0
2	tfoot	0	0
3	tfoot	0	0
4	tfoot	0	0
1	th	0	1
2	th	0	0
3	th	0	0
4	th	0	0
1	thead	0	0
2	thead	0	0
3	thead	0	0
4	thead	0	0
1	tr	1	6
2	tr	2	7
3	tr	0	0
4	tr	0	0
1	u	0	0
2	u	0	0
3	u	0	0
4	u	0	0
1	ul	1	3
2	ul	1	4
3	ul	0	0
4	ul	0	0

APPENDIX C: THE PROBABILITY FUNCTION BASED ON THE FREQUENCY RANGES

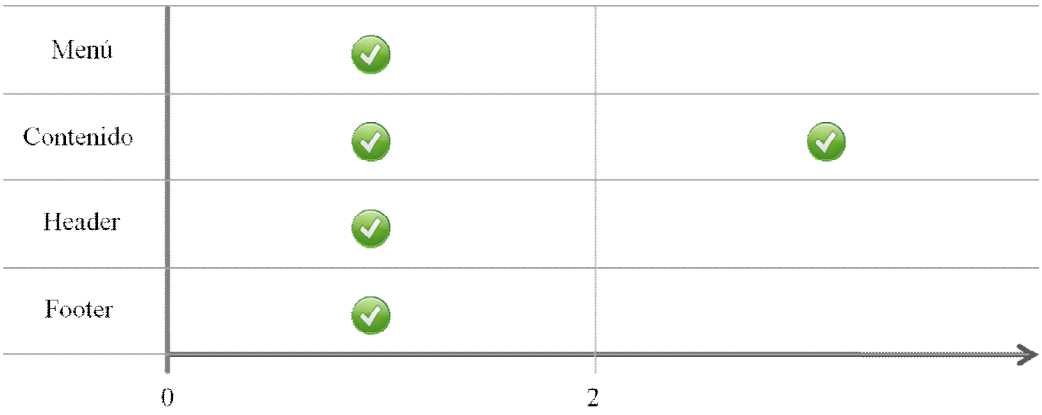
Tag

Floor	Top	P(menu)	P(content)	P(header)	P(footer)
0	2	0	0	0	1
2	4	0,5	0	0,5	0
4	8	1	0	0	0
8	10	0,5	0,5	0	0
10	-	0	1	0	0



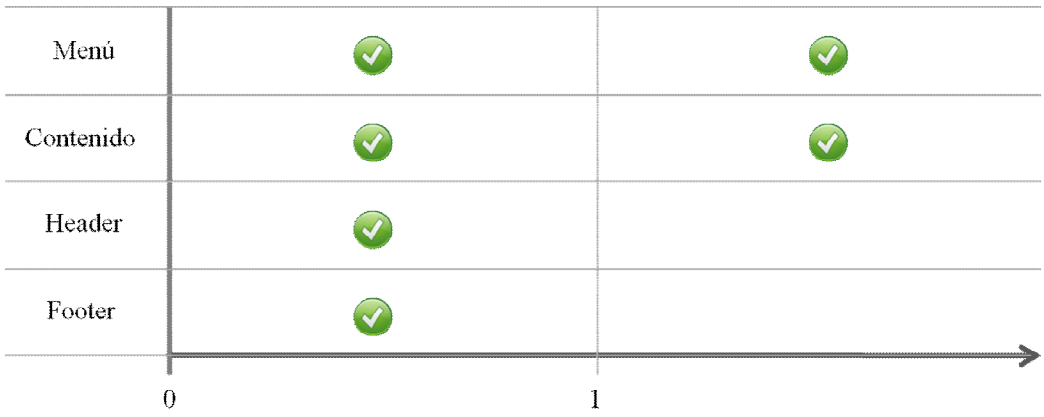
Tag <p>

Floor	Top	P(menu)	P(content)	P(header)	P(footer)
0	2	0,25	0,25	0,25	0,25
2	-	0	1	0	0



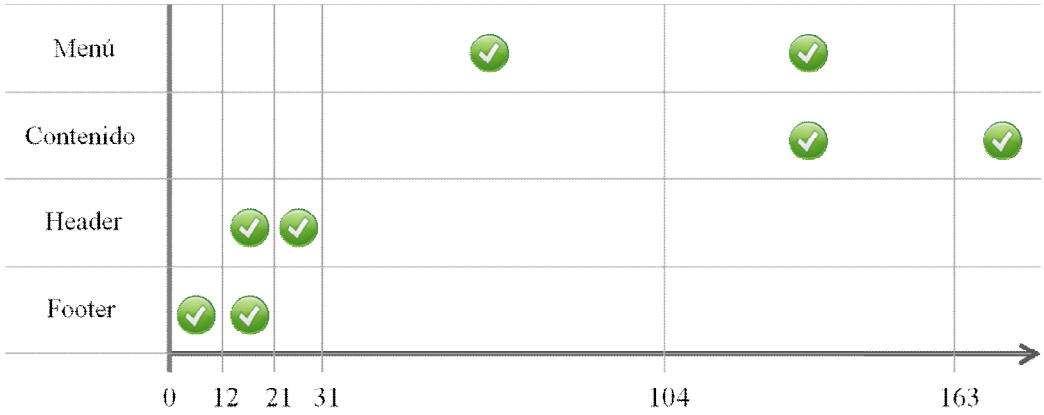
Tag

Floor	Top	P(menu)	P(content)	P(header)	P(footer)
0	1	0,25	0,25	0,25	0,25
1	-	0,5	0,5	0	0



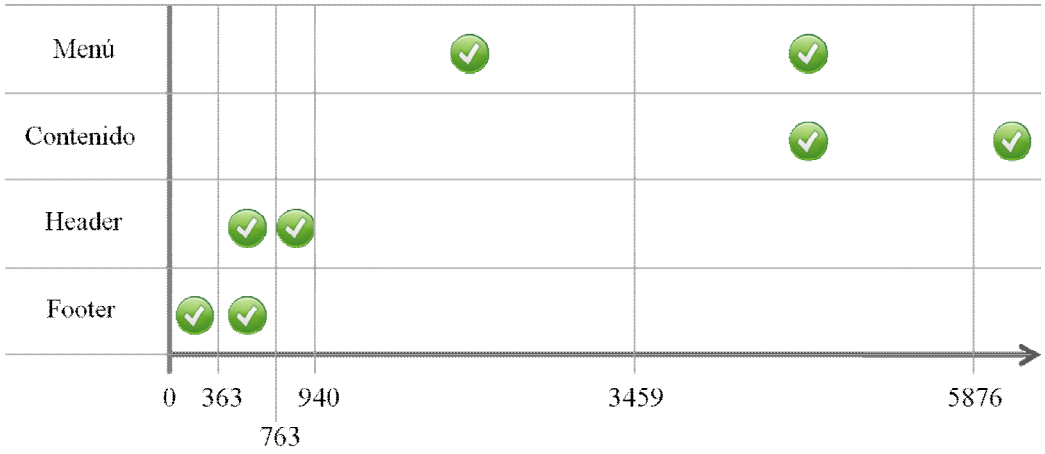
Total tags

Floor	Top	P(menu)	P(content)	P(header)	P(footer)
0	12	0	0	0	1
12	21	0	0	0,5	0,5
21	31	0	0	1	0
31	104	1	0	0	0
104	163	0,5	0,5	0	0
163	-	0	1	0	0



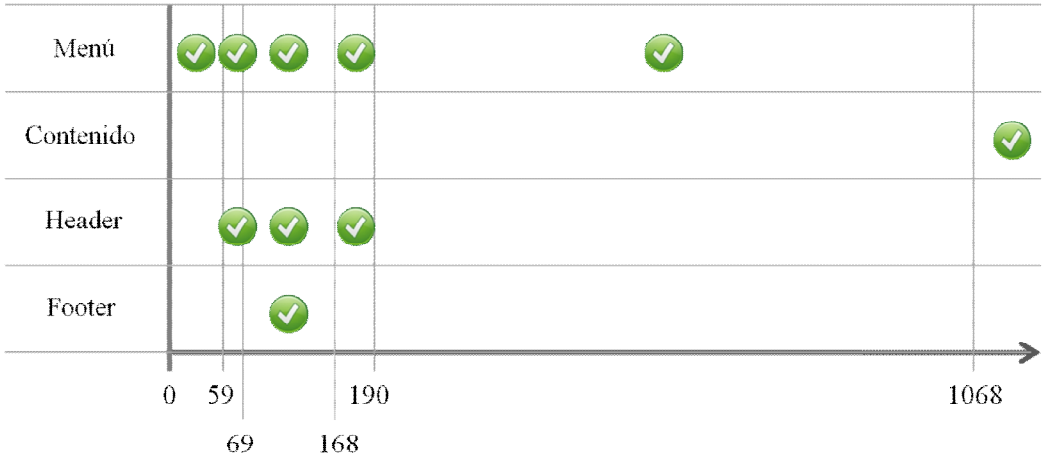
Code length

Floor	Top	P(menu)	P(content)	P(header)	P(footer)
0	363	0	0	0	1
363	763	0	0	0,5	0,5
763	940	0	0	1	0
940	3459	1	0	0	0
3459	5876	0,5	0,5	0	0
5876	-	0	1	0	0



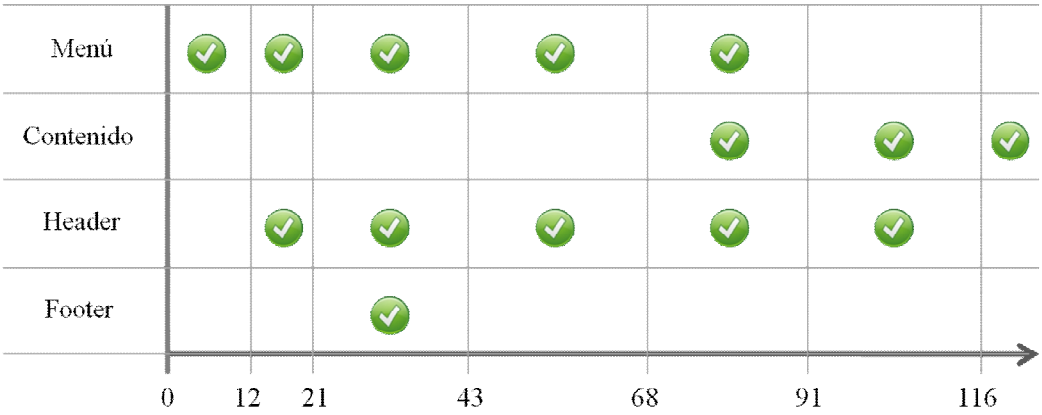
Content length (without tags)

Floor	Top	P(menu)	P(content)	P(header)	P(footer)
0	59	1	0	0	0
59	69	0,5	0	0,5	0
69	168	0,33	0	0,33	0,33
168	190	0,5	0	0,5	0
190	1068	1	0	0	0
1068	-	0	1	0	0



Content length vs links

Floor	Top	P(menu)	P(content)	P(header)	P(footer)
0	12	1	0	0	0
12	21	0,5	0	0,5	0
21	43	0,33	0	0,33	0,33
43	68	0,5	0	0,5	0
68	91	0,33	0,33	0,33	0
91	116	0	0,5	0,5	0
116	0	0	1	0	0



APPENDIX D: USABILITY SURVEY

Póngale nota a cada característica del sistema.

		Muy mal						Excelente
	Sistema	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. Ausencia de fallas	Nativo							
	Propuesto							
2. Facilidad de uso	Nativo							
	Propuesto							
3. Fluidez en la navegación	Nativo							
	Propuesto							
4. Precisión en la navegación	Nativo							
	Propuesto							
5. Diseño y formato de las páginas visitadas	Nativo							
	Propuesto							
6. Calidad general del sistema	Nativo							
	Propuesto							
7. Comodidad de uso	Nativo							
	Propuesto							
8. Asimilación intuitiva del sistema	Nativo							
	Propuesto							
9. Tiempo de respuesta del sistema	Nativo							
	Propuesto							
10. Agilidad del sistema	Nativo							
	Propuesto							

¿Qué sistema preferiría? Nativo ___ Propuesto ___

Observaciones:

_____

_____

_____

_____

APPENDIX E: SURVEY RESULTS

	Sistema\Pregunta	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Elección
Eval1	**Nativo**	6	5	5	6	4	5	4	6	6	4	Propuesto
	Propuesto	5	7	6	5	6	6	7	6	6	6	
Eval2	**Nativo**	6	2	2	1	2	2	2	7	2	3	Propuesto
	Propuesto	5	4	5	6	4	5	5	3	4	5	
Eval3	**Nativo**	4	6	5	6	4	6	6	7	6	5	Propuesto
	Propuesto	5	7	5	7	6	7	6	7	6	6	
Eval4	**Nativo**	6	4	4	7	2	5	2	5	5	5	Propuesto
	Propuesto	7	7	7	7	7	6	7	7	5	5	
Eval5	**Nativo**	3	2	7	2	4	3	2	7	7	7	Propuesto
	Propuesto	6	7	7	7	6	7	7	5	7	7	
Eval6	**Nativo**	4	4	5	5	4	4	5	5	5	5	Propuesto
	Propuesto	7	7	7	7	7	7	7	7	7	7	
Eval7	**Nativo**	3	3	3	3	3	3	3	3	3	3	Propuesto
	Propuesto	6	6	6	6	7	6	6	7	6	7	
Eval8	**Nativo**	6	7	7	6	7	7	7	7	7	7	Propuesto
	Propuesto	7	7	7	6	7	7	7	7	7	7	
Eval9	**Nativo**	6	3	4	6	3	3	3	3	4	3	Propuesto
	Propuesto	6	6	7	6	6	6	6	6	6	6	
Eval10	**Nativo**	4	5	3	4	5	4	4	4	4	3	Propuesto
	Propuesto	7	7	7	6	7	6	7	6	7	6	
Eval11	**Nativo**	3	1	3	2	3	5	2	3	4	4	Propuesto
	Propuesto	6	6	5	6	5	5	4	6	4	4	
Eval12	**Nativo**	3	5	5	6	4	5	3	6	4	6	Propuesto
	Propuesto	7	7	7	7	6	7	7	7	6	7	
Eval13	**Nativo**	3	5	5	6	4	5	3	6	4	6	Propuesto
	Propuesto	7	7	7	7	6	7	7	7	6	7	
Eval14	**Nativo**	4	5	4	5	3	4	5	4	5	5	Propuesto
	Propuesto	6	6	6	6	5	6	6	6	6	7	
Eval15	**Nativo**	6	3	5	5	7	3	2	6	4	3	Propuesto
	Propuesto	4	6	5	4	5	4	4	5	5	4	
Eval16	**Nativo**	6	7	5	5	6	6	5	7	5	6	Propuesto
	Propuesto	3	7	6	6	4	6	6	6	5	6	
Eval17	**Nativo**	6	6	6	6	6	6	5	6	6	6	Nativo
	Propuesto	4	5	6	6	4	5	6	6	6	6	
Eval18	**Nativo**	7	5	5	5	4	6	7	6	4	6	Propuesto
	Propuesto	5	6	6	5	7	6	5	6	6	6	
Eval19	**Nativo**	7	4	5	3	4	5	5	6	5	6	Propuesto
	Propuesto	7	6	6	7	6	6	7	6	6	7	
Eval20	**Nativo**	6	4	3	5	6	4	3	5	5	6	Propuesto
	Propuesto	4	5	5	4	5	5	5	5	5	4	
Eval21	**Nativo**	7	5	4	4	4	7	4	5	6	6	Propuesto
	Propuesto	4	6	5	6	5	4	7	5	5	5	
Eval22	**Nativo**	7	4	3	5	7	7	5	5	5	5	Nativo
	Propuesto	2	4	3	4	5	4	7	5	3	3	
Eval23	**Nativo**	5	4	4	5	4	5	4	5	5	5	Propuesto
	Propuesto	5	6	6	6	6	6	6	6	5	5	
Eval24	**Nativo**	7	3	5	6	6	5	3	5	4	4	Propuesto
	Propuesto	4	6	6	6	5	5	7	6	3	4	
Eval25	**Nativo**	7	4	5	4	5	5	5	5	5	5	Propuesto
	Propuesto	4	6	5	5	5	6	6	7	4	4	