ADAPTING WEB PAGE TABLES ON MOBILE WEB BROWSERS:

RESULTS FROM TWO CONTROLLED EMPIRICAL STUDIES

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

Displaying web page content in mobile screens is a challenging task and users often face difficulty retrieving the relevant data. It can force them to adopt a time-consuming hunt-and-peck strategy. Application of design principles can improve the view of the webpage data content and reduce the time consumption in viewing it. This is especially true with HTML tabular data content. This thesis discusses the background and applications of the gestalt design principle techniques to HTML tabular data content. An empirical study was performed to investigate the usability of two types of the adaptive styles namely, single and multi-layout. This thesis also compared the adaptive styles that use gestalt principles with simple HTML tabular data on mobile screens. A controlled study which involved university students was performed showed that the adaptive layout styles improved the efficiency of finding information in the website by gestalt principles usage and eliminating horizontal scroll.

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1. INTRODUCTION

Small screen devices like PDA's and Mobile Devices are commonly used for the communication purpose in today's world. These devices are increasingly being used for accessing the information by browsing the web. Consumers of Smartphones are using their devices to browse the internet several times per day. The competition for the smart phones industry is increasing rapidly as the customers usage of web browsing is increasing day by day. According to Bango, a company that offers a tool for tracking traffic from mobile users, reports a 600% growth in traffic to mobile websites [18]. These results were gathered from a range of mobile sites over a period of last twelve months and showed that the customers are using their smart phones for browsing more frequently and over longer periods of time.

The results from the Bango study also revealed that ten out of the twenty most trafficked PC-based Web sites did not work well on leading mobile phones. This is not surprising considering the smaller screen size of the mobile devices as compared to the personal computers. Users often get confuse while viewing the relevant data on mobile web browsers, which can force them to adopt a time-consuming hunt-and-peck strategy. To address this problem, researchers have focused a lot of attention on adapting the web content from PC-based web sites to mobile web browsers in order to improve the browsing efficiency of mobile users [2]. Considerable effort has been devoted to identifying methods and tools to adapt the web content from PC-based web contents in order to reduce the horizontal and vertical scrolling while viewing the web page contents in small screen devices. A few representative examples of previous research work are described below.

In order to provide an efficient web browsing experience for PDAs and mobile device users, researchers at the Stanford's digital library developed a special browser (i.e., Power

Browser [3]). The Power Browser displays the link description of a web page which are generated from anchor text, URL or ALT tags and when the links are clicked its appropriate content in the web page is displayed. This idea of implementing the links that point to the corresponding content reduces the navigation time as well as the scrolling. Similar to the concept used in the power browser, Ahmadi et al., introduced the Hybrid Method [5] that divides the layout of a webpage into different panes (i.e., left pane, right pane, center pane, top pane, and bottom pane). The hybrid method integrates the structural analysis and visual detection as each individual section of the Web page is dealt with the grid to organize and display the contents independently in a new Web page. This method provides the flexibility of dealing with the automatic adaptation of the desktop representation of Web page to a small screen representation. Likewise, the Web page segmentation [6] technique divides the small screen region into sub-regions by dividing the Web page into different (coherent) parts and each of them is organized independently through the tree structure. In the Web page segmentation approach, a Web page is divided into nine segments that can be accessed directly. This approach focuses on a particular section of the Web page by pressing a single key without scrolling. These approaches have been empirically evaluated through controlled experiments and case studies and have shown to improve the experience of mobile web browsers (e.g., [5]).

Other researchers have developed approaches to improve Web browsing experience on small-screen devices that are similar to web-page segmentation. For example, comparative browsing by Z. Hua and H. Lu [7] uses an interface to facilitate browsing on small-screen devices which presents an index overview on the master device with links pointing to the detailed block content. Similarly, in layout-based mobile browsing approach by Virpi Roto [19]), the content is shown in the order it appears on the markup file, and all content is typically scaled to fit the screen width.

The usability testing on the above approaches have shown that adapting "general" webpage content on small-screen devices have met with considerable success. Following up on the success, researchers like Kärkkäinen and Laarni have analyze the main characteristics of PDAs and have provided guidelines in designing Web pages for small screen devices [20].

However, there are still some limitations when adapting Web page contents to the small-screen. The biggest problem is that when wide data Tables that contain detailed information are scaled to fit the screen; the details in the image cannot be seen without extensive scrolling or zooming. Even when using the segmentation approach with data tables, the problem is that when a row does not fit onto the screen, it flows to the next row, and it is hard for users to interpret which data goes together. Also the order of the content in different segments causes difficulties for end users. It is hard to foresee at which point of the layout, the wanted information is located, so one constantly needs to spot some keywords or items in the content on the screen while scrolling.

While there are several research efforts on adapting general web page content, a little effort has focused on improving the adaptation of web page tabular data in mobile devices. An HTML table that requires a little horizontal or vertical scrolling on a desktop may need much more scrolling on a mobile device with a small screen. The results from a recent study on usability of Mobile vs. Desktop Web browsing experience of HTML tabular data [9] showed that the mobile device users' performance was poor due to the problems in locating the desired content in the Web page table on small screens without extensive back and forth scrolling. The results also highlighted the problem that users find it hard to differentiate the main headers and the related data content present in tabular data form on mobile web browsers.

To address the above problem, a study [9] developed three prototype systems as examples of three general techniques for the display of tables on small screens: Default View, Linear View, and Overview. The Default View, simply displays the original table without transformations (i.e. table is not modified in any way) using the Internet Explorer browser. In Linear View Prototype, they used linear algorithm which created sub lists, where each sub list contained the data of one row of the original table. The Overview Prototype, which is written in Java, mimics features found in the Pocket PC version of Excel. The font size of the data in the new table is reduced and zoom-in and zoom-out functionalities are provided for the user. The table columns are elapsed to fit the width of the small screen. This works reasonably well up to 11 columns and 15 rows. If the table is bigger than 11X15, the table appears to be largely empty. The user can adjust column widths as needed and mouse-over pop-ups can be used to show the contents of individual cells. They conducted experiments to compare each of them with the same Web page tables on the PDA device to find the better technique among the three. In this study, the researchers considered test cases to measure efficiency by counting the number of actions, button clicks or scrolling actions, taken by the user to complete each task. They measured accuracy as the number of correct results of each task. In addition, they surveyed the users to determine their perception of ease of use and preferences they may have. The results showed that the Overview technique performed best and the remaining two techniques exhibited irregular patterns related to the test cases.

To address the limitations, research work done at North Dakota State University by Yaswanth Potla [23] tries to improve the adaptation of web page tables on small screen devices.

The underlying theme of his research solution is that, by decreasing the amount of horizontal and vertical scrolling of HTML tabular data on mobile browsers, we can improve the browsing efficiency of end users. To accomplish this, his research approach involves placing the main headers together in one place and its related data content together in a different place. His approach adapts an HTML table into a hierarchical structure based on the row-column headers, which are also used as an overview that provides navigation links to different sections in a table. He provided with two adaptive layouts, and the user has the choice of selecting the one that he/she wishes to use, depending upon their personal preferences. The first layout displays all information of a table in a single narrow page to avoid horizontal scrolling and the second layout distributes information to different sub-pages, each of which approximately occupies the mobile screen, and thus eliminates scrolling. In the first adaptive style, all the information in an HTML table is accessed within one single page. When the user clicks on a hyperlink, the corresponding data is displayed in the same page. In the second adaptive style, the information in a table is presented in different pages that are connected through navigational links. Since the information displayed in each page approximately occupies one screen, this style can minimize the scrolling.

With his approach done, we had previously conducted a controlled experiment [22] to investigate the usability of these two types of adaptive styles (i.e., single narrow and multi-page) in comparison to browsing simple HTML tabular data on mobile Web browsers. A controlled study with university students was performed to determine if students using adaptive layout styles were more efficient (i.e., spent less time finding information) than the students using HTML web page layout while browsing the information contained in different types of HTML web page tables. The results showed that (1) the adaptive layout styles (both single narrow and multi-page) improves the browsing efficiency for individual subjects as compared to HTML web page style, (2) the single narrow adaptive layout resulted in the improved browsing efficiency compared to the multi-page adaptive layout for one-dimensional HTML web page tables, and (3) the multi-page adaptive layout was more efficient than the single narrow adaptive layout for multi-dimensional HTML tables. While the results were promising, the feedback from the subjects suggested that their browsing efficiency can be further improved if the parts of the visualization between the parts of information and the organization of these parts (and the whole they belong to) can be improved. This motivated to our further investigate ways to improve the perceptual organization (how smaller objects are grouped to form larger ones) in order to present the content in a better way and further reducing the navigational time to access the data. To achieve our goal, we applied psychology-based principles (called gestalt principles) and applied them to our single and multi-layout adaptive applications.

As mentioned above, motivated by the initial results and feedback from the first experiment, we investigated the use of Gestalt Principles to improve the adaptation of HTML web page tables on mobile-devices. Gestalt (meaning ‘Shape’ or ‘Form’) principles were coined in the early 1920s to describe a design’s wholeness [10, 15]. According to Gestalt psychology, the whole is different than the sum of its parts. Based upon this belief, Gestalt psychologists developed a set of principles to explain perceptual organization, or how smaller objects are grouped to form larger ones. These principles are often referred to as the "laws of perceptual organization". Gestalt laws like Similarity, Proximity, Continuity, Unity, Focal Point, Figure-to-ground-relationship, Closure, Balance, Good Form, etc. are among those laws that help in making better visualization and each law has its own importance. The detail explanation of these gestalt laws will be explained in the section 2.2. For a small screen device, it is important to present the content clearly and get the content quickly. It is clear that, for small screen devices like PDA's and mobile devices scrolling horizontally and vertically to get the relevant information is a difficult task if the information of the web page is present with a whole lot of information. Gestalt principles help in resolving this issue.

Our research utilized these principles to minimize the scrolling effects without having any ambiguity in user's selections on screen. By applying these gestalt principles on our HTML web page table adaptation, the visual of the screen was improved in both single and multi-layout applications. For both the applications all the headers, sub headers, and the related data content are placed together accordingly, thereby helping the user to easily identify the links and data. By placing the sub headers of a header together will help in getting which sub headers belongs to which headers this also helps in easily differentiating the sub headers and the headers. Different colors are used for headers and sub headers in order to identify easily. Upward scrolling button is placed at the right bottom corner of the screen in order to minimize the vertical scrolling effect. The selected link will appear in the brighter color knowing which sub header is selected to the user. More details of these features are presented in Section 3.

This thesis presents our experiment approach and describes empirical study that were conducted to investigate the usability of these two types of adaptive styles (single and multi-layout) in comparison to browsing simple HTML tabular data on mobile Web browsers after application of the gestalt principles. A controlled study with university students was performed to determine if students using adaptive layout styles after applying gestalt principles were more efficient (i.e., spent less time finding information) than the students using HTML web page layout while browsing the information contained in different types of HTML web page tables. A total of ten different gestalt principles were applied to both single and multi-layout applications, data analysis and results of these applications after application these gestalt principles will be discussed in section 5.

This thesis is organized as follows. Section 2 discusses Related Work. Section 3 presents Adapting HTML Tabular Data. Section 4 presents Adapting HTML Tabular Data by applying Gestalt Principles. Section 5 illustrates a comprehensive User Study on our approach. Section 6 presents Data Analysis and Results, followed by Conclusion and Future Work in Section 7.

2. RELATED WORK

This section details the related work on Adapting Web-Page Tables and Gestalt Principles. Section 2.1. addresses the background research on Adapting Web-Page Tables. Sections 2.2. and 2.3. introduce the Gestalt principles and previous work on use of the Gestalt Principles in Software Engineering.

2.1. Background on Research in Adapting Web-Page Tables

Displaying the Web pages on small screen devices such as PDAs and mobile devices has been discussed and analyzed through different methodologies and approaches [1, 2, 3, 4]. In each case, the goal is to effectively manage and organize the Web pages for displaying the content on the small screen devices. These adaptation methods use a special browser for summarizing the Web pages [1]. Previous research approaches for viewing and summarizing Web pages and HTML forms on small devices include the Power browser, End-game browsing, and tree structures [2, 4]. The special browser developed at the Stanford's digital library (also called as power browser) is used to access the Web pages from PDAs and mobile devices [3]. Similarly, the Hybrid method [5] divides the layout of a webpage into different panes as discussed in section1.

The Web page segmentation [6] technique divides the small screen region into sub-regions and each of them is organized independently through the tree structure. In the Web page segmentation approach, a Web page is divided into nine segments that can be accessed directly by clicking on it. This approach focuses on a particular section of the Web page which is selected by user among the nine segments available. To improve Web browsing on small-screen devices, a two-level browsing approach has been developed i.e., within-page collaborative browsing, and between-page comparative browsing. The collaborative scheme [7] uses an interface to facilitate browsing on small-screen devices which presents an index overview on the master device with links pointing to the detailed block content. Clicking the link directly points to the display update of detailed block content on slave devices. The comparative scheme [7] uses a different approach which acquires the comparative pages according to the page that the user is viewing on the master device and displays these pages on slave devices.

Minimap [8] is another Web page visualization method that shows the pages in a modified original layout. Some of the Mobile phones are having stylus but most of the Mobile phones are provided with an input device that allows 5-way (joystick) functionality to access the Web page in horizontal and vertical directions along with the select button with a press option. Minimap addresses the issue of viewing the particular contents of the Web page with zoom-in and zoom-out options.

A study [9] on the techniques like Default View, Linear View, and Overview are being conducted to compare each of them with the same Web page tables on the PDA device to find the better technique among the three. In this study, the researchers considered some test cases to measure the efficiency of each technique. The Overview technique resulted better among the three and the remaining two techniques exhibited irregular patterns related to the test cases. These test cases include Simple Lookup, Scroll Lookup, Complex Grid, Complex Column, and Complex Compare. These test cases were used to compare the three techniques against a 2-D table.

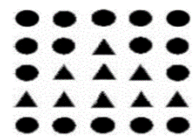
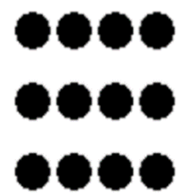
2.2. Background on the Gestalt Principles

Gestalt (meaning ‘Shape’ or ‘Form’) principles were coined in the early 1920s to describe a design’s wholeness. In the 1930s and 1940s Gestalt psychology was applied to visual perception, by Max Wertheimer, Wolfgang Köhler, and Kurt Koffka who founded these so-called gestalt approaches to form perception. Their aim was to investigate the global and holistic processes involved in perceiving structure in the environment. More specifically, they tried to explain human perception of groups of objects and how we perceive parts of objects and form whole objects on the basis of these. The investigations in this subject crystallized into “the gestalt laws of perceptual organization." While by some counts there are over 114 laws of Gestalten, with many of them applying directly to visual forms, historically artists and designers have focused on a handful of perceptual laws to improve their two dimensional works, such as paintings, photographs, posters, book covers, and so on [15]. Some of these laws, which are often cited in the software engineering and interaction design community include: Similarity, Proximity, Figure-to-ground relationship, Closure, Continuation, Symmetry, Isomorphic Correspondence, Unity, Simplicity, Good Form, and Focal Point [17].

A designer can apply these principles of perception to organize information and make sure that users will quickly make sense of the elements on-screen, understand what functionality or data they represent, and make informed decisions about their actions. Many of the laws are very closely related or overlap, and it is often very hard to distinguish between them. These principles have been applied to improve the comprehension of the software engineering diagrams [13], and visual screen design in context of instruction media [12]. This research tries to use these principles to improve the adaptation of webpage HTML tables on small screen devices. By applying these principles, we can make the small screen design user friendly and easy to access.

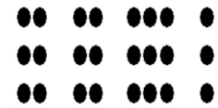
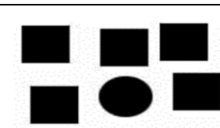
To begin, Table 1 defines the eleven gestalt principles that are most commonly used for the interface design [10]. For each principle, a brief description is facilitated with the figure (visual representation of the gestalt principle) to clearly describe the use of the gestalt principles in improving the interactive design of web pages. In Section 3, we will discuss the application of these principles in adapting web page HTML tables on small screen devices.

Table 1. Gestalt principles

Principle	Description	Example
Similarity	*Similarity* is grouping principle, which states that those elements that share qualities (of color, size, or shape, for example) will be perceived as part of the same form. An example of similarity principle shows that a triangle is resided inside the square. The viewer can recognize a triangle inside the square, because these elements look similar and thus part of the same form	
Proximity	*Proximity* is a grouping principle of perceptual organization. It states that, all else being equal, we tend to perceive elements to be associated when they are close together. An example of proximity shows that every row has the same property as they are placed together. Viewers will mentally organize closer elements into a coherent object, because they assume that closely spaced elements are related and those further apart are unrelated. In the Figure, we mentally arrange the dots into three horizontal rows, because the dots in the rows are closer together than in the columns	
Figure-to-ground relationship	*Figure/ground* principle states that we tend to perceive some visual elements as the figure, with a definite shape and border, while other elements appear as the ground, further away and behind the main focus of the figure. Associated figure explains that we can see two figures. You can see vase when the background is white (i.e. vase is viewed as a figure here) and you see two faces when the background is black (i.e. the two faces are viewed as a figure here).	
Closure	We tend to enclose spaces by completing contours and ignoring gaps in figures. It follows from good continuity and allows us to group elements together or to interpret forms as complete though parts may be missing. Example figure explains that the letter is closure as some parts of the letters were missing	
Continuation	We prefer to perceive smooth, continuous contours rather than abrupt changes in direction. Elements that continue a pattern tend to be grouped together. Included example explains us that our eyes follow from bottom to the top of the picture instead from top to bottom. So, the continuation flow here is from bottom to top.	

(continues)

Table 1. Gestalt principles (continued)

Principle	Description	Example
Symmetry / Balance	A visual object will appear as incomplete if the visual object is not balanced or symmetrical. A psychological sense of equilibrium, or balance, is usually achieved when visual 'weight' is placed evenly on each side of an axis. Here the left side of the figure tells us that the visual object is balanced together as each column has definite number of row sets i.e. symmetrically placed whereas the right side of figure doesn't.	
Isomorphic Correspondence	All visuals do not have the same meaning to us, because we interpret their meanings based on our experiences. The included example figure explains us that, we would interpret its meaning as a help or question icon, even if we could not understand the Finnish word "Apua," because we associate a question mark with 'help' based on past experience	
Simplicity	When learners are presented with visuals, there is an unconscious effort to simplify what is perceived into what the viewer can understand. For explaining the southern cross, left side figure is better than the right side figure.	
Unity	Unity implies that a congruity or arrangement exists among the elements in a design they look as though they belong together. As an example, left side of figure is lacking in the unity whereas right-side figure can be seen as united as the letters are arranged together.	
Good form	Good form is a simple design or a symmetrical layout. In the shown example of good form, straight white bars together formed as the logo IBM.	
Focal Point	Every visual presentation needs a focal point, called the center of interest or point of emphasis. This focal point catches the viewer's attention and persuades the viewer to follow the visual message further. The example shows the main focus of a person goes to the circle which is surrounded by squares. So here circle is the focal point.	

2.3. Background on the Use of Gestalt-Principles in Software Engineering and Human-Computer Interaction

Gestalt Principles have previously been utilized for improving the screen display of a web page on big sized screen devices like desktops and personal computers [12]. Basic idea behind using the gestalt principles for better visualization is that they suggest how static visual elements should be presented in order to achieve effective visual results. Usually Human minds are accustomed to visualize things as a whole rather than visualizing as parts, for example when we look at peoples face we look as a whole, not as two eyes a nose, and a mouth. In the same way Gestalt laws attempts to understand psychological phenomena by viewing them as organized and structured wholes rather than the sum of their constituent parts. These laws help us to create good structure and a sense of togetherness on web pages. These laws also help in giving suggestions on how to draw attention to elements that are important or how to create a balanced and stabled web page when adapting them to small devices. This section talks about some of the previous work (in chronological order) that has successfully applied the gestalt theories to improve the visual screen design.

Patrick Moore and Chad Fitz [11] investigated the gestalt theory to evaluate if the application of gestalt principle improves the visual screen design in context of instruction media. The researchers applied six different gestalt principles to a badly designed instruction page to show what improvements result when Gestalt theory is utilized in instructional design. The authors basically redesigned the instruction page and showed that the gestalt laws were useful in improving the visual screen design in context of instruction media.

Karen Smith-Gratto, Mercedes M.Fisher [12] did a similar empirical study regarding the application of gestalt principles to user interface design. In this study, the researchers demonstrated how the laws of perception can be applied to improve the screen design. The researchers took an instruction screen design and basically redesigned the instruction screen design by applying the gestalt laws. The results showed that it is beneficial to apply the gestalt laws to the instructional design of the screen because the learner perceives the information faster and it aids their ability to learn. Dempsey Chang et al., [10] used the gestalt literature to distil the most relevant Gestalt laws for educational visual screen design. They applied 11 important gestalt principles to test the usefulness of these principles in visual screen design to the redesign of an instructional multimedia application 'WoundCare' that was originally developed to teach nursing students wound management. The basic text based screens in the original WoundCare application were replaced with new interactive graphical design of WoundCare application by applying the gestalt laws. The new screen design of the WoundCare application was then evaluated by the nursing students asking them to rate the new and original WoundCare applications. The results showed that the new screen design was strongly supported by the students which helped them in learning.

Krystle Lemon et al., [13] also demonstrated the application of a handful of gestalt principles for software UML diagram understandability. The researchers conducted an empirical study that compared the software diagrams, one with gestalt laws applied and the other without any gestalt law applied. The study examined the bad version of diagrams and applied gestalt laws to it. By using Proximity, Similarity, and Continuity, the authors showed that the Gestalt principles positively affected the comprehension in the complex diagrams.

Lisa Graham [15] further investigated the application of the gestalt laws in interactive media design. Artists and designers have long used gestalt visual principles in their two-dimensional works such as paintings, posters, and magazine layouts to improve composition, organize information, and enhance visual communications. While gestalt visual laws are present in all visual designs, whether two-dimensional or interactive, there are significant gaps in the research applying gestalt theory to interactive media designs. This thesis examined crucial gestalt visual laws within the context of interactive media design. The results showed that understanding gestalt visual laws within the framework of interactive media design can provide educators and students with a scientific structure by which they can analyze and visually improve their interactive designs. Skillful application of gestalt can result in web and multimedia designs with stronger compositions that facilitate communication.

These results are promising, and motivated us to investigate the use of gestalt principles in adapting web page HTML tables on small scale device. However, most of the work on the application of gestalt principles have focused on big size screen devices (e.g., desktops) [12], or have focused on improving the comprehension of software engineering UML diagrams [13]. To our knowledge, no research results have been reported on the application of gestalt principles to the small screen devices like mobiles and PDA's. The most relevant background research (during our literature review) to our work was a proposal in the Nokia mobile company forum to use the gestalt principles for the small screen sized mobiles [16]. The author emphasized the importance of gestalt laws and its usefulness to small screen sized mobiles. They also hypothesized that these gestalt principles are used to organize information and makes sure that users will quickly make sense of the elements on-small screen sized mobiles, understand what functionality or data they represent, and make informed decisions about their actions. The author mainly explains how

Similarity, Proximity, Repetition, Figure-to-ground relationship, Closure, and Continuation gestalt laws can be useful in mobile screen user interface design and can be helpful in achieving a better visual user interface design. This further motivated us to apply and empirically evaluate these laws in our research work for better user interface design for small screen sized mobile and PDA devices when viewing the HTML web page tables.

In our research work, we have analyzed these gestalt principles and application of the relevant principles to improve the web-page table adaptation on small-screen devices. The most common principles that we utilized for our research work include: Similarity, Figure-Ground Relationship, Good Form, Focal Point, Continuation, Simplicity, Symmetry/Balance, Unity, Isomorphic Correspondence and Proximity are used in our research work, and are discussed in section 4.

3. ADAPTING OF HTML TABULAR DATA

The adaptation process of HTML tabular data proceeds in two steps which are done at North Dakota State University by Yaswanth Potla [23]. First, his approach retrieves information from the original HTML table and records the information in a hierarchy. Then, an adaptive layout (either in a single narrow style or a multi-page style) is generated based on the retrieved information. Static Structure of the approach is shown in below Figure 1. All the rectangular boxes here define the different classes which are used in the application to generate hyperlinks and contents of a tabular data. Main classes like HTML Utility, HeaderLinks, TableManager and RandomStringGenerator are performed in generating the creation of header links, sub header links and the contents of a HTML tabular data. Main functions of those classes are

- The HTMLUtility Class is designed to construct adaptive HTML files with the generated hyperlinks and contents.
- The HeaderLinks Class contains the details of each hyperlink and the position of those links within the div tag.
- The TableManager Class retrieves the attributes of <TH> and <TD> tags and calls the RandomStringGenerator class to generate a unique ID for each navigation links.

3.1. Information Extraction

This approach takes the HTML Web page table as input, and uses the SAX Parser to retrieve the actual tabular data based on <th> and <td> tags. When the information enclosed in an HTML table is parsed, two tree map objects are created, one for the <th> tag and the other for the <td> tag. For each <th> or <td> tag, a TableManager object is created to store the details of "rowspan", "colspan" and "anchorid".

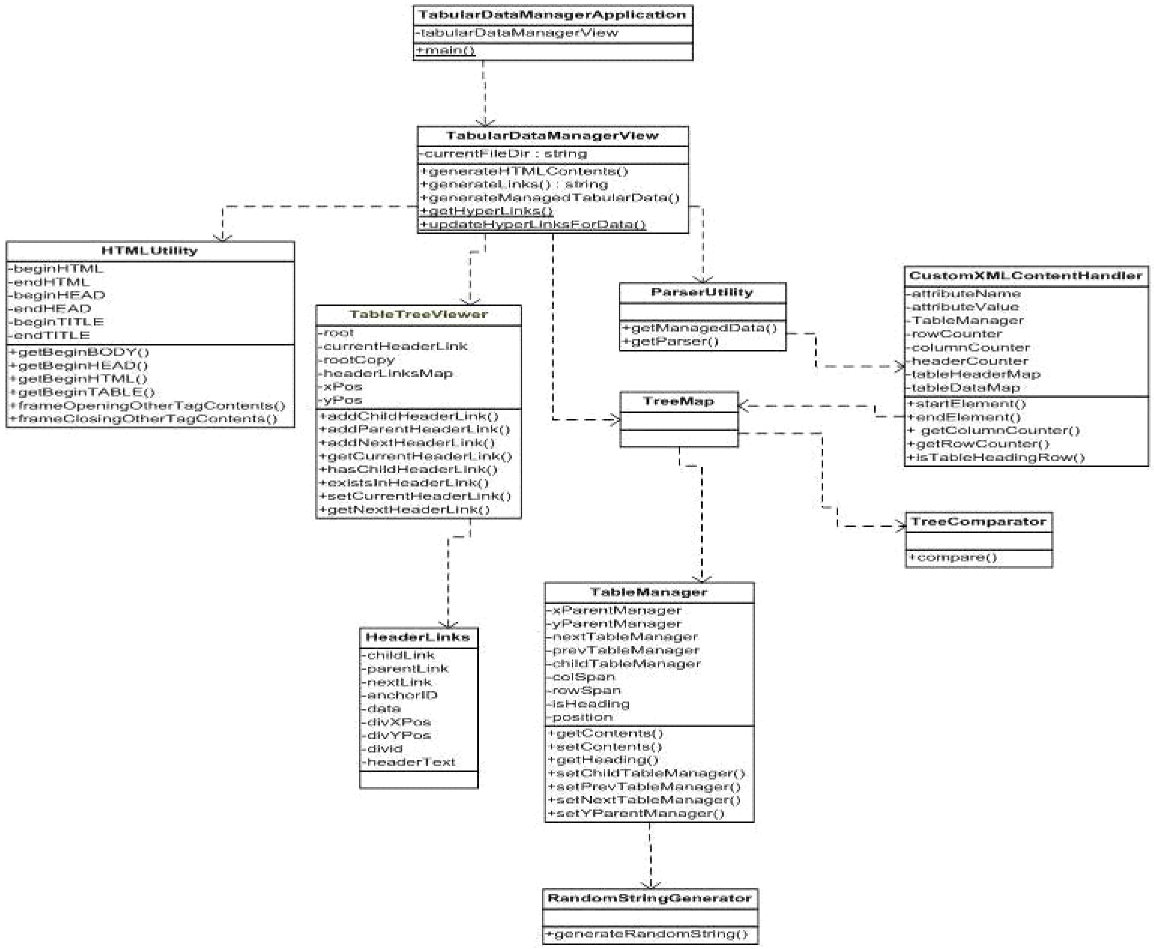


Figure 1. The static structure [23]

After creation of the TableManger objects for the HTML tabular data, the objects will be added to the corresponding tree maps based on <th> or <td> tags where all the header information will be stored in <th> tree map and detailed contents will be stored in <td> tree map.

Based on the TableManager objects present in the tree map for <td> tags, the tree map for <th> tags is iterated to form a meaningful hyperlink for each <td> tag. In case of a table with a single column/row header, there is only one hyperlink generated for the entire column or row. For multi-dimensional tables, the table manager objects in the tree map for <th> are iterated to create HeaderLink objects and a relationship is established between the HeaderLink objects based on the position of the <th> tag in the source HTML table.

In a one-dimensional HTML table, we use the column/row headers as the navigational links but in multi-dimensional HTML tables, the navigational links are organized into two levels (row headers, column herders) depending on the user's personal preferences.

3.2. Layout Adaptation

The extracted information in an HTML table is adapted to either a single narrow layout or a multi-page layout.

In both the layouts the HTMLUtility class is responsible for providing the hyperlinks for the data content by utilizing the header links.

For a single dimensional HTML table, the hyperlinks are generated based on the row header or column header. For a multi-dimensional HTML table the hyperlinks are generated by combining the row headers and column headers. Based on the layout style, the generated hyperlink navigates within the same page (i.e. in a single narrow layout) or to a new page (i.e. in a multi-page layout). In order to uniquely represent each navigation link, we use randomly generated alphanumeric strings with 6 characters to identify different links.

3.2.1. Single Narrow Layout

In the single narrow layout, both the navigational hyperlinks and the detailed data contents of the HTML tabular data are present in the same page. The navigational links acts as a table of contents for that Web page and are positioned at the top most of the page, the data contents are then placed below the navigational links in the same page. In order to achieve this, each topic (i.e. headers information) in an HTML table is provided with a hyperlink to navigate to it. In this single layout structure, the random strings are used in two places: (1) in each detailed section to act like a bookmark, and (2) in hyperlink anchor tags to navigate to the bookmarked detailed section. Random strings that are generated for both the places will be same for achieving correct navigation. Once the hyperlinks are achieved, the approach generates an adaptive HTML web page using <DIV> (which represents position of the hyperlink) and <a> anchor tags (actual links for navigation).

For example consider the One-Dimensional HTML Web table in Figure 2. Figure 2 depicts the resultant single narrow layout Web page. The header information from the table in Figure 2 (‘Subject’, ‘Instructor’, and ‘Room Number’) generates three random strings using the random string generator (For illustration purposes, we simply use ‘randomstring1’, ‘randomstring2’, and ‘randomstring3’ in Figure 2 to refer to those random strings). These three random strings are used as bookmarks for three detailed sections and the hyperlinks use them as the anchor reference, referring to a particular bookmarked detailed section (i.e. Mathematics, Science or XYZ).

Subjects	Instructor	Room Number
Math	ABC	100
Science	XYZ	200

↓

```
HTML>

<BODY>

<div><a href="#randomstring1">Subject</a></div>

<div><a href="#randomstring2">Instructor</a></div>

<div><a href="#randomstring3">Room Number</a></div>

<a name="#randomstring1">Maths</a>
<a>Science</a>

<a name="#randomstring2">ABC</a>
<a>XYZ</a>

<a name="#randomstring3">100</a>
<a>200</a>

</HTML>

</BODY>
```

Figure 2. Restructured HTML web page body in the first adaptive layout [23]

3.2.2. The Multi Page Layout

In the multi-page layout, a hyperlink is generated for each <td> tag with the corresponding row header or column header or both (for multi-dimensional tables), which navigates to a new HTML Web page. This approach generates different new HTML web pages for all the different tags that are present. The column header tags or the row header tags with an empty <td> tag are excluded from the final display/output to avoid an empty page.

To illustrate with an example, Figure 3 depicts the result of table with the multi-page layout. The contents of each header are restructured and displayed in a new Web page. From the below Figure 3, the header “Subject” is restructured and its contents are displayed in a new Web page with an anchor id reference as “RandomString1.html”. “Mathematics” and “Science” are the contents of the header “Mathematics”, displayed as the HTML data in the new Web page with the name “RandomString1.html”. In the similar manner different new HTML pages will be generated for different random strings.

The “Div” container is used to generate the tree structure of the hyperlinks, depending upon the dimension of the table. Figure 3 depicts the usage of the second adaptive layout, where an entry HTML file (i.e. displaying table of contents) is created along with the three other HTML files (i.e. displaying detailed information).

EXAMPLE:

In order to illustrate the approach, this sub-section presents a one-dimensional table and adapts it to a multi-page layout. Consider the below shown HTML table as the input shown in Figure 4 that is then processed in two steps.

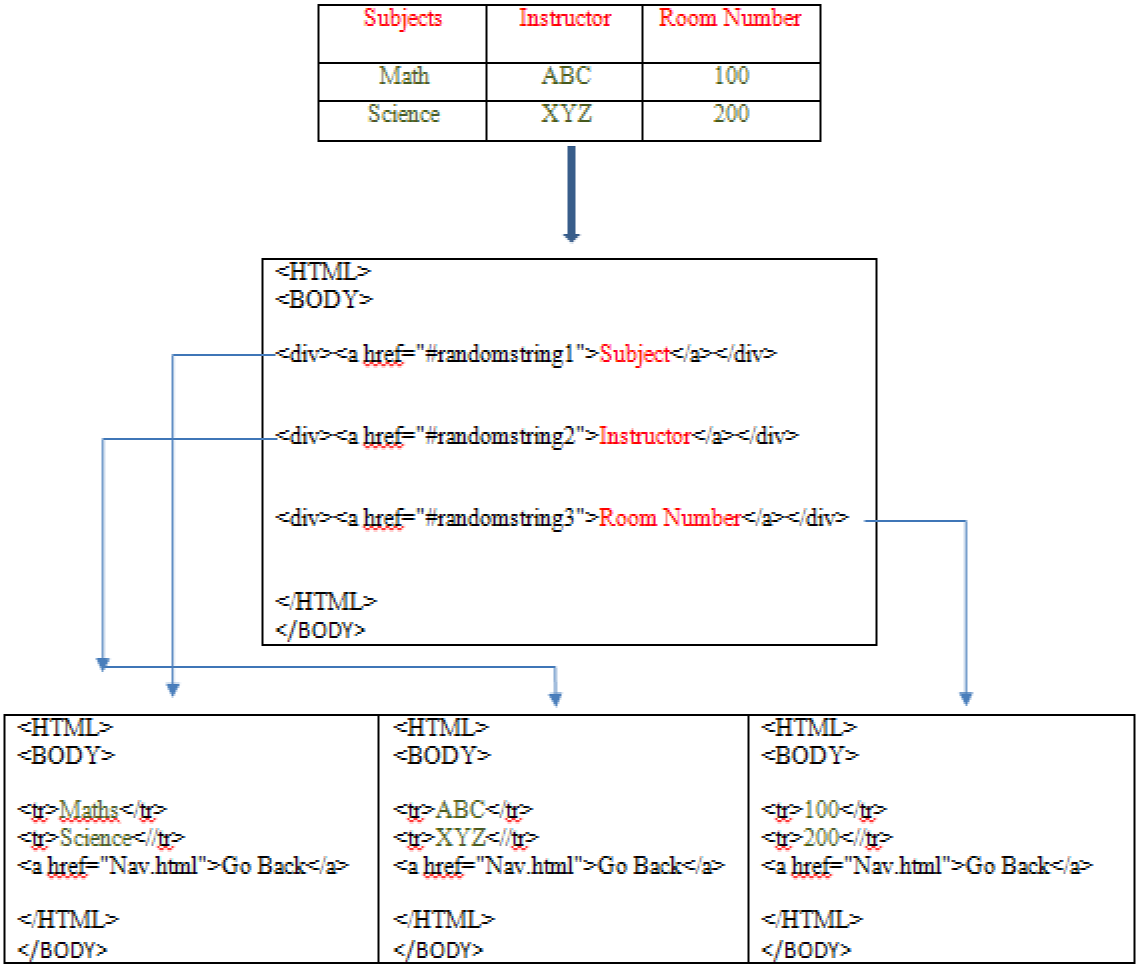


Figure 3. Restructured HTML web page body in the second adaptive layout [23]

The two main steps are:

Parsing the table and stores <td> and <th> tags data.

Creating navigational links for the parsed tags data.

In the first step, the SAX software parses the table data and records the information enclosed in the table. The first row of the table are headers which are represented with the table header cell (1, 1), cell (1, 2), and cell (1, 3). The rest of the table contains the data cells. All the information in these table row/column cells is stored in the two separate Tree maps, one for the <td> tag data and the other for the <th> tag data.

Wednesday,May 20	Thursday,March 21	Friday,May 22
8:30to10:30 a.m. Opening Ceremony: General Chair; Keynote Address: Steve McConnell	8:45to10:30 a.m. Conference Update: General Chair Keynote Address: Carlo Ghezzi	8:45to10:30 a.m. Conference Update: General Chair; Keynote Address: Pamela Zave
10:30to11:00 a.m. Break	10:30 AM to 11:00 a.m. Break	10:30to11:00 a.m. Break
11:00 a.m.to12:30 p.m. Salon A: Research: Collaborative Development (Salon A) Research: Software Quality and Metrics (MacKenzie) Research: Debugging (Salon F) SEIP: Complex Systems (Salon B) Formal Research Demonstrations: Software Development Assistance (Seymour)	11:00 a.m.to12:30 p.m. Research: Modeling (Salon A) Research: Maintenance (Salon B) Formal Research Demonstrations: Program Comprehension (Seymour) Technical Briefing (Salon C) SEIP: Testing Telecom (MacKenzie) SEIP: Testing Medical (Salon F)	11:00 a.m.to12:30 p.m. Research: Testing I (Salon A) Research: Concurrency (Salon B) Formal Research Demonstrations: From Requirements to Architecture (Salon C) 11:00 a.m.to12:30 p.m. SCORE wrap up session (Salon F)
11:00 a.m.to 12:30 p.m. New Ideas and Emerging Results (Salon C)		
12:30 p.m.to2:00 p.m. Lunch BOF Meetings	12:30to2:00 p.m. Lunch BOF Meetings	12:30to2:00 p.m. Lunch BOF meetings
2:00 p.m.to3:30 p.m. Technical Briefing (Salon C) Research: Dynamic Adaptation (Salon A) Research: Components (Salon F) Research: Program Analysis (Seymour) SCORE presentations by student team finalists (MacKenzie) SEIP: Refactoring and Tools (Salon B)	2:00to3:30 p.m. Research: Code Generation and Transformation (Salon A) Research: Program Comprehension (MacKenzie) TSE-TOSEM (Salon F) Special Green Session (Salon C) SEIP: Predicting Defects and SEIP Keynote on Video Game Industry (Salon B) Formal Research Demonstrations: Web Services (Seymour)	2:00to3:30 p.m. Research: Testing II (Salon A) Research: Model Synthesis (Salon B) Technical Briefing (Salon C) Formal Research Demonstrations: Differences and Similarities (Salon F)
3:30 p.m.to 4:00 p.m. Break	3:30 to 4:00 p.m. Break	3:30to4:00 p.m. Break
4:00 p.m.to 5:30 p.m. Research: Web Applications (Salon A) Research: Development Tools (Salon F) SCORE presentations by student team finalists (MacKenzie) New Ideas and Emerging Results (Salon C) 4:00 p.m.to5:30 p.m. SEIP: Agile and Process (Salon B) Formal Research Demonstrations: Testing and Fault Localization (Seymour)	4:00 to 5:30 p.m. Awards Plenary	4:00to5:30 p.m. Research: Development Paradigms and Software Process (Salon A) Research: Program Analysis II (Salon B) Formal Research Demonstrations: Concurrency and Debugging (Salon C) Formal Research Demonstrations: Components and Features (Salon F)
Wednesday Evening SIGSOFT Town hall (Marine) Conference Reception (Currents) (Front of Salon A)	Thursday Evening SIGSOFT Town hall (Marine) Conference Reception (Currents) (Front of Salon A)	5:45to6:30 p.m. Closing Plenary: General Chair

Figure 4. One dimensional table [23]

In the second step, this approach re-organizes information and creates navigational links. In order to access the information enclosed in each <td> tag, the navigational links are organized in a hierarchy, and each link uniquely refers to the information enclosed in a specific <td> tag. For example, for the information which is indexed with the row header Wednesday, May 20 (i.e. cell (1, 1)) a link will be created and by clicking this link opens a new Web page where the corresponding actual data along with the actual navigational path will be displayed. (i.e. the information from the cells (2,1), (3, 1), (4, 1), (5, 1), (6, 1), (7, 1), (8, 1), (9, 1), (10, 1))This navigational path helps the user to know where he/she is and what exactly he/she is accessing from the table.

3.2.3. User Study 1 Experiment and Results

The major goal of our 1st study was to evaluate the usability and efficiency of adaptive layout techniques for browsing of HTML tabular data on handheld devices [22]. This study investigated whether using the single narrow and multi-page adaptive layouts reduces the browsing time (due to lack of scrolling) when accessing the information contained in an HTML web page table on a mobile device. The main goals of the experiment are to analyzing web browsing efficiency in both adaptive layouts and HTML pages, analyzing web browsing efficiency in both adaptive layouts (i.e. single narrow and multi-page layout.), and analyzing the effect of independent (browsing method) and dependent variables (time spent) for the purpose of improving the mobile browsing experience of individual's participants using the adaptive layouts with respect to reducing their browsing and navigation.

After having set with our goals the experimental design for this experiment is as fallows. This experiment was a factorial design in which ninety six (96) participating subjects browsed the information contained in the following three forms:

a) Standard HTML web page tables,

b) The tables adapted to a single narrow layout, and

c) The tables adapted to a multi-page layout.

The experiment was a classic pretest posttest control group design in which participants browsed HTML tabular data using three different browsing methods (simple HTML layout, single narrow layout and multi-page adaptive layout).

The subjects were asked to browse through different HTML tables, and answer questions based on the information contained in them. The subjects kept a log of the time it took them to answer each question as well as the total time spent to answer all the questions. The mobile browsing efficiency of standard web HTML tables and their corresponding adaptation using both layout styles were then evaluated based on the total time spent on browsing the information. The allocation of subjects to different treatment methods is shown in Figure 5.

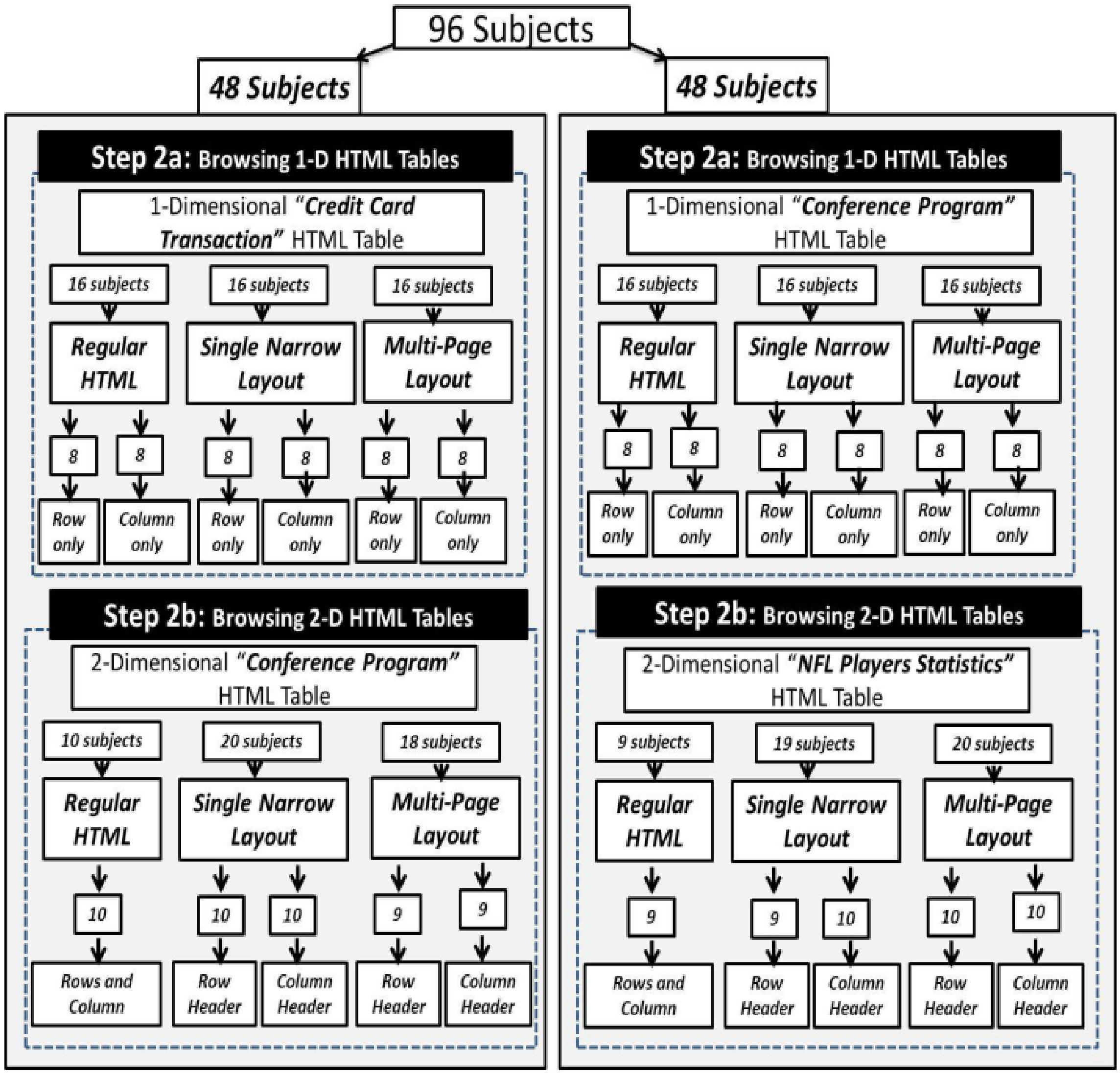


Figure 5. User Study 1 – Treatment groups and experiment steps [23]

For the analysis on browsing efficiency in both adaptive layouts and HTML pages, the results from this study showed that the single narrow layout always improved the browsing efficiency and resulted in reduced in browsing effect as compared to standard HTML web page layout. However, this improvement was not always statistically significant. The same result was true for the multi-page adaptive layout as it improved the browsing efficiency for all the times except in one case when the subjects using the standard HTML web page layout were more efficient. Therefore, the reduced browsing efficiency is not always helpful and is significant for the adaptive layouts when compared to standard HTML web page layout.

For the analysis on browsing efficiency in both adaptive layouts (i.e. single narrow and multi-page layout.), the results from this study showed that for one-dimensional HTML pages single narrow adaptive layout showed better result than multi page adaptive layout but for multi-dimensional HTML pages it is completely opposite multi page adaptive layout showed better result. However, in all of the cases, the difference in the browsing efficiency of single narrow and multi-page adaptive layout was insignificant.

For the analysis on browsing efficiency for independent variables, major conclusions are:

The subjects who use their handheld devices very frequently will be more efficient when using the adaptive layout treatments.

The subjects who are highly comfortable with browsing on their handheld devices are also more efficient when using the multi-page adaptive layout.

We ran a one-way ANOVA test and Tukey HSD test (for post-ANOVA comparisons) to see whether the individual subjects using a single narrow adaptive layout or a multi-page adaptive layout took significantly less time to browse the information contained in the HTML web page tables as compared to the individual subjects using standard HTML web page tables. The results for one-dimensional and multi-dimensional tabular data are shown in Figure 6 (with the significant results highlighted).

The main objective of the thesis is to reduce horizontal and vertical scrolling and if possible eliminate them completely. The HTML table was restructured and addressed in the tree format. These objectives were addressed successfully with the help of two adaptive layout

1-D Credit Card (Rows Only Tables)		
	Single narrow layout	Multi-page layout
Simple HTML layout	P < 0.01	P < 0.05
Single narrow layout		Non-significant

1-D Credit Card (Columns Only Tables)		
	Single narrow layout	Multi-page layout
Simple HTML layout	Non-significant	Non-significant
Single narrow layout		P < 0.05

1-D Conference Program (Rows Only Tables)		
	Single narrow layout	Multi-page layout
Simple HTML layout	Non-significant	Non-significant
Single narrow layout		Non-significant

1-D Conference Program (Columns Only Tables)		
	Single narrow layout	Multi-page layout
Simple HTML layout	P < 0.01	P < 0.05
Single narrow layout		Non-significant

2-D Conference Program (Sorted by Row Headers)		
	Single narrow layout	Multi-page layout
Simple HTML layout	P < 0.01	P < 0.01
Single narrow layout		Non-significant

2-D Conference Program (Sorted by Column Headers)		
	Single narrow layout	Multi-page layout
Simple HTML layout	P < 0.01	P < 0.01
Single narrow layout		Non-significant

2-D NFL Player Statistics (Sorted by Row Headers)		
	Single narrow layout	Multi-page layout
Simple HTML layout	Non-significant	Non-significant
Single narrow layout		Non-significant

2-D NFL Player Statistics (Sorted by Column Headers)		
	Single narrow layout	Multi-page layout
Simple HTML layout	Non-significant	Non-significant
Single narrow layout		Non-significant

Figure 6. User study 1 – statistical results using ANOVA and Turkey HSD [22]

Applications, by displaying the HTML Web page table data within the same page as well as displaying in a new Web page while using the small screen devices such as PDAs and Mobile devices. The navigational time to access the data in the Web page table will be reduced by using these two applications. This experiment motivated us to still make reduction of the scrolling effects, even eliminate vertical scrolling completely. This motivated us to come up with gestalt principles usage to the application which helped in scrolling reduction and also made to present the information that need to be accessed in no time of scrolling with better design view in small screen devices. We enhanced the adaption of the HTML tables by applying Gestalt Principles and subsequently evaluated the usefulness of these principles through the second user study. Details of the application of gestalt principles are explained in below Section 4.

4. ADAPTING HTML TABULAR DATA BY APPLYING GESTALT PRINCIPLES

We have shown (in Section 3) the process of information extraction and the layout representation for our application. In this section, we will explain the application of the gestalt principles of perception to further enhance our application (both single and multi-page layout applications).

In our research, we have applied ten different gestalt principles to enhance the visual perception for our applications. The ten different applications that we used are: similarity, proximity, focal point, good form, simplicity, unity, symmetry/balance, continuation, figure-background, and isomorphic correspondence. In the rest of this section, we will explain the application of each of these ten aforementioned principles. To provide a high-level overview, the original HTML Table is shown in Figure 7 along with the single layout and multi-page layout (Figure 8 and Figure 9 respectively) as a result of the application of gestalt principles. More details on how each of these principles was applied follows.

Similarity: Similarity is a grouping principle, which states that elements that share qualities (of color, size, or shape, for example) will be perceived as part of the same form. As we know that tables contains headers, sub-headers and data contents. Therefore, by grouping all the headers and sub-headers together would enable the formation of a similar structure which will make it simple for users to understand and differentiate the levels of tabular data content. Similarity is applied for both the application1 and application2 by differentiating and grouping together headers, sub-headers and data content. We hypothesize that the principle of similarity makes our application much easy to perceive and understand where the different levels of HTML tabular data content is present. All the headers, sub-headers and data contents are of different forms, colors, and shapes as show in the below Figure 10 can explain the principle of similarity.

Day and Time		Room Number						
		Ballromm Hall	A	B	C	D	E	
Day 1	9:00 to 9:05	Welcome						
	9:05 to 10:35	Opening Ceremony: General Chair Keynote Address: Steve McConnell 10 Most Powerful Ideas in Software Engineering						
	10:35 to 11:00	Break	Break	Break	Break	Break	Break	Break
	11:00 to 12:30	Taming Coincidental Correctness: Coverage Refinement with Context Patterns to Improve Fault Localization X. Wang, S.C. Cheung, W.K. Chan, Z. Zhang	Predicting Build Failures Using Social Network Analysis on Developer Communication T. Wolf, A. Schroter, D. Damian, T. Nguyen	How Tagging Helps Bridge the Gap between Social and Technical Aspects in Software Development C. Treude, M. Storey	Tesseract: Interactive Visual Exploration of Socio Technical Relationships in Software Development A. Sarma, L. Maccherone, P. Wagstrom, J. Herbsleb	Succession: Measuring Transfer of Code and Developer Productivity A. Mockus	Predicting Faults Using the Complexity of Code Changes A.E. Hassan	A Case stu an Automa Software E Measurem Analysis S Industrial I I.D. Comai Succi
	12:30 to 14:00	Lightweight Fault Localization Using Multiple Coverage Types R. Santelices, J.A. Jones, Y. Yu, M.J.Harrold	Model Checking Flight Control Systems: The Airbus Experience T. Bochot, P. Virelizier, H. Waeselynck, V. Wiels	Extracting, Specifying, and Predicting Software System Properties in Component Based Real Time Embedded Software Development J.E. Kim, O. Rogalla, S. Kramer, A. Haman	Experience with Modularity in an Advanced Teleconferencing Service Deployment E. Cheung, T.M. Smith	UEMan: A Tool to Manage User Evaluation in Development Environments S.R. Humayoun, Y. Dubinsky, T. Catarci	TranStrL: An Automatic Need to Translate String Locator for Software Internationalization X. Wang, L. Zhang, T. Xie, H. Mei, J. Sun	SmartTuto Based Inte Tutorials v Replay Y. Huang, N.
	14:00 to 16:00	Creating and Evolving Software by Searching, Selecting and Synthesizing Relevant Source Code D. Poshyvanyk, M. Grechanik	Detecting Inefficient API Usage D. Kawrykow, M. Robillard	Mining Recurrent Activities: Fourier Analysis of Change Events A. Hindle, M.W. Godfrey, R.C. Holt	Toward a Framework for Law Compliant Software Requirements A. Siena, J. Mylopoulos, A. Perini, A. Susi	How Do System Architectures Affect Software Requirements. J. Miller, R. Ferrari, N.H. Madhavji	The Marketplace of User Interface Real Estate L. Troiano, G. Canfora	SecondWA Workspace Tool Basec Virtual Wo Neiman, H Liu
		Improving Bug Tracking		Using Quantitative	Model Evolution by	Taming Dynamically	[illegible]	Modular S

Figure 7. Original HTML page layout screenshot

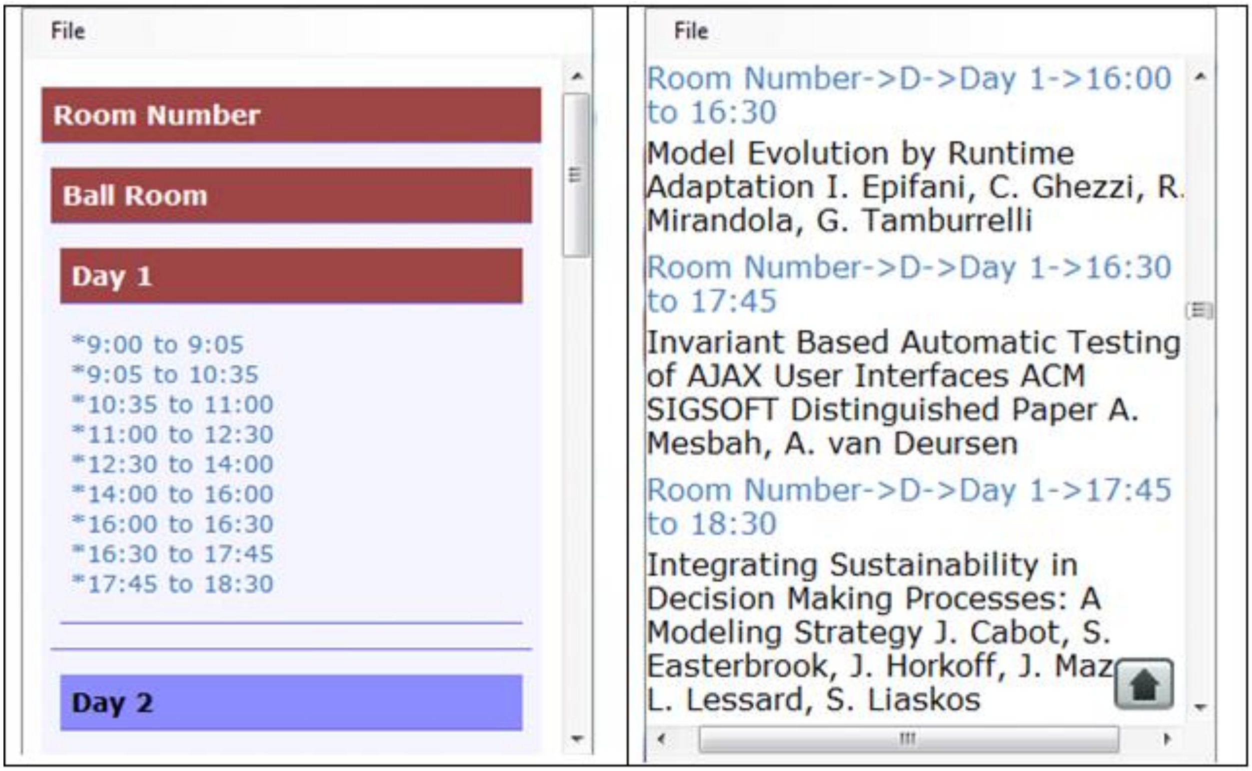


Figure 8. Single page layout application

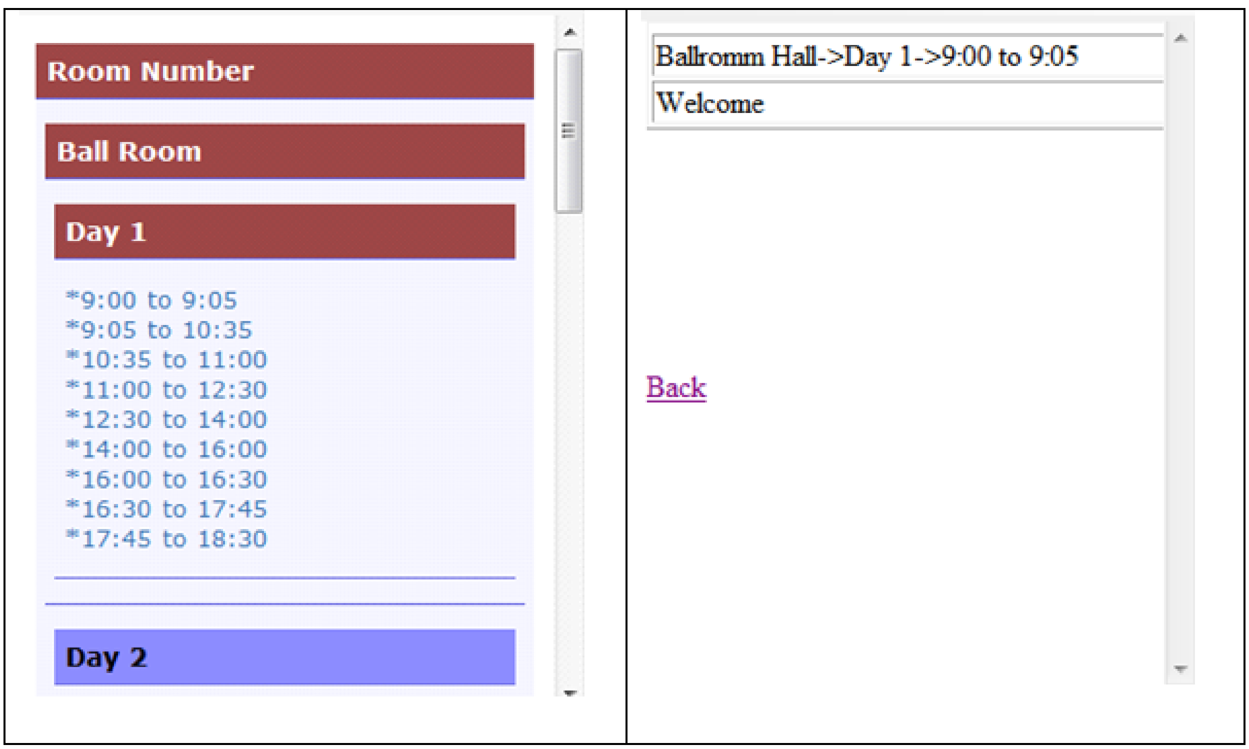


Figure 9. Multi page layout application

Proximity: Proximity is another grouping principle of perceptual organization. It states that, all else being equal, we tend to perceive elements to be associated when they are close together. Again, grouping all the headers, sub-headers, and data contents of an HTML tabular data together follows the principle of proximity. For both the applications, we first display only headers of the HTML tabular data where all the headers grouped together will form a similar group. When the user clicks on any header, all the related sub-headers will be displayed together which will again form a similar sub-header group. In this way, we had applied the grouping principle of perceptual organization to headers and sub headers.

Focal Point: Focal Point allows the information to be focused at a given time and also catches the viewer's attention and persuades the viewer to follow the visual message. In our applications 1 and 2, instead of showing all the headers, sub headers and data contents altogether in a disorder manner, we only show the main headers first which makes user to focus only on it excluding all the sub-headers and data content and when a click operation on any of the header is performed, the corresponding sub headers appear which allows user to focus on the sub-headers. Finally, clicking on any of the sub-header link brings down to the corresponding data content. The different levels of focusing the data content of an HTML tabular data into headers, its corresponding sub-headers and its relevant data content makes the use of principle Focal Point.

Good Form: A good form is nothing but just showing the right information that is needed with a simple design for users. Here for our applications 1 and 2, we make use of showing only headers first which makes the application look as a simple design and when a header is clicked we only show the corresponding sub headers instead of showing every sub-header which makes the application look so simple. By using simple colors and font in the application also made our application look simple and in a good form.

Continuation: Continuing the design feel of our applications makes use of the principle continuation. Here in Single layout, it has no other external link pages and the content is present in just single page. Whenever the user clicks on a header or its corresponding sub header the data content is shown which is presented below the headers and sub headers. So feel of the design is like all the headers and sub headers are displayed first and its data content below it. In multi layout, whenever user clicks on a link it takes to a new page where the data is shown and when back button is clicked it takes to the headers and sub headers section. In both the layouts, grouping of the headers, sub-headers and data content altogether makes the flow continuous and simple. The flow of the data in both the applications is continuous and simple. This is how the simple continuity is used in our applications.

Simplicity: We should not make any user to get distracted from what he wants to focus on. By applying simple color effects with simple design flow makes our application look simple and great. With the use of other gestalt principles also made our application a very simple and easy to use.

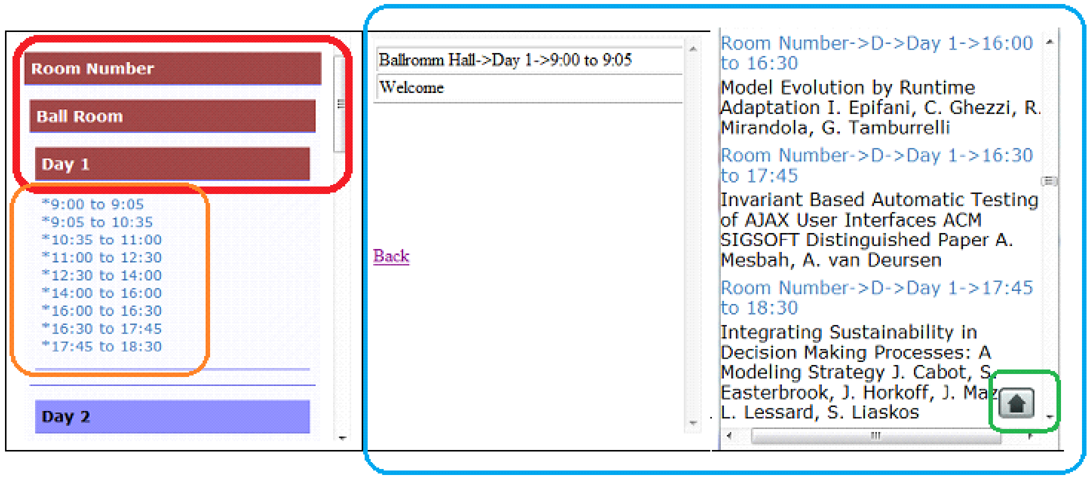
Unity: Unity explains us about the togetherness of similar groups at a place. By placing all the headers, sub headers and data content together makes a good unity for the application. Here for our application we placed all the headers together with their corresponding sub-headers together and also placing data content together for those headers and sub-headers.

Symmetry/Balance: Symmetry/balance tells us about a good balanced design. By separating each and every section and placing the content together which belongs to the same group makes our application a balanced design. Here for our applications 1 and 2, we separated the header and sub-headers section with the data section. This kind of balance will help user to easily understand and identify the content quickly.

Figure-Background: As we know the application has different headers and its corresponding sub headers figure-background come into picture when user clicks on any of the headers its corresponding sub headers are displayed which makes users to easily find which header he has clicked.

Isomorphic Correspondence: Showing functionality with an image in the application makes the use of the principle Isomorphic Correspondence. Image like home button, arrows for the direction of the page, a help button and etc., are used in many of the web pages and applications which leads to the use of isomorphic correspondence. With the images and use of Isomorphic correspondence we interpret their meanings based on our experiences and their universal language. Here in our applications 1 and 2, we used an up arrow function which makes user to go top of the page without applying any vertical scrolling.

The below Figure 10 explains the use of gestalt principles for an HTML Tabular Data for our application. The red and orange borders indicate headers and sub-headers. Sky blue bordered color indicates the data content for those headers and sub-headers.



- **Red** and **Orange** indicates **Headers** and **Sub-Headers**
- **Sky-blue** indicates **Data Content** for application1 to the left and application2 to the right.
- **Green** indicates an **Up Arrow Image** (Isomorphic Correspondence usage)

Figure 10. Different levels of abstraction of an HTML tabular data explaining the use of Gestalt principles

5. USER STUDY 2: EVALUATING THE USEFULNESS OF GESTALT PRINCIPLES

The major goal of this study is to evaluate the usability and efficiency of adaptive layout techniques for browsing of HTML tabular data on handheld devices by using Gestalt Principles of Perception. This study investigates whether using the single narrow and multi-page adaptive layouts reduces the browsing time (due to lack of scrolling) when accessing the information contained in an HTML web page table on a mobile device where gestalt principles were applied to those tables. This study also compares these two layouts single and multi-page with the standard html web page.

This experiment is a factorial design in which participating subjects browsed the information contained in the following three forms:

a) Standard HTML web page tables,

b) The tables adapted to a single narrow layout, and

c) The tables adapted to a multi-page layout.

The subjects were asked to browse through different HTML tables, and answer questions based on the information contained in them. The subjects kept a log of the time it took them to answer each question as well as the total time spent to answer all the questions. The mobile browsing efficiency of standard web HTML tables and their corresponding adaptation using both layout styles were then evaluated based on the total time spent on browsing the information. The details of the study are provided in the following subsections and the data analysis and results will follow in the next section.

5.1. Research Question and Hypotheses

Using the Goal Question Metric (GQM) approach to define the goals for this study, we obtained the following goals and hypotheses:

Goal 1: Analyze adaptive layouts and standard HTML web page tables for the purpose of their evaluation with respect to their web browsing efficiency on mobile devices for individuals.

Hypothesis 1: Individual participants using adaptive layouts (either a single narrow or a multi-page layout) were more efficient (with respect to their browsing time) than individuals using standard HTML web page tables.

Goal 2: Analyze both adaptive layouts styles (i.e., single narrow and multi-page layout) for the purpose of their evaluation with respect to their web browsing efficiency on mobile devices for individuals.

Hypothesis 2: Individual participants using a multi-page adaptive layout were more efficient (with respect to their browsing time) than individuals using a single narrow layout adaptation of HTML web page tables.

Goal 3: Analyze the effect of independent variables for the purpose of improving the mobile browsing experience of individual's participants using the adaptive layouts with respect to reducing their browsing and navigation time.

Hypothesis 3: Other independent variables (comprehension skills, user interface development and browsing experience, and comfort level with browsing on mobile devices) affect the individual performance during the mobile browsing of HTML tables adapted to a single narrow layout and a multi-page layout.

5.2. Independent and Dependent Variables

This experiment manipulated the following independent variables:

1. The browsing method: Subjects browsed the tabular data using standard HTML web page table or using the adaptive layout techniques (either a single narrow layout or a multi-page narrow layout).

2. The background experience of subjects: Though subjects were all undergraduate students, they had varied levels of background experience in terms of their reading comprehension, user-interface development and web browsing experience for hand-held devices.

We also measured the following dependent variable.

The time spent: the total time spent (in minutes) by each subject while browsing through the information contained in the HTML web page tables.

The browsing method is the treatment variable of our experiment. Details of the allocation of subjects to different treatment variables are described in Section. The other variables allow us to access several potential threats to the experiment's internal validity. Hypothesis 3 investigates the effect of these other independent variables on the dependent variables. Table 2 provides a detailed definition of these variables.

5.3. Experiment Design

5.3.1. Participating Subject

There were total of 64 students who took participation in our research work. These 64 students were divided into three different groups of 22(Simple HTML), 21(Application1) and 21(Application2) by random selection of students. Here each of the group is again sub divided into two groups and further subdivided into two more groups except the first group which consists of 22(Simple HTML). The design approach is clearly shown in the below Figure 11.

Table 2. Other independent variables

Variable	Definition
Reading Comprehension	Measures subjects reading comprehension skills on a scale of 1 (needs considerable improvement) to 5 (very high)
Development experience	Measures subjects previous experience with user-interface development for mobile devices
Browsing experience	Measures subjects experience with browsing on handheld devices on a scale of 1 (none/rarely used) to 5 (very frequently used)
Average Time spent	Measures the average number of hours (per day) spent by subjects while browsing on their handheld devices
Comfort level	Measures the subjects degree of comfort level on a scale of 1 (very low) to 5 (very high) while browsing on mobile devices

Each group is given a different research input data sets (Simple HTML, Application1, and Application2).

The first group which is of 22 subjects was sub divided into 2 groups of 11 each and first 11 students were given (Row and Row + Column) data sets and the other 11 students were given (Column and Column +Row) data sets.

The second group which uses Application1 of 21 subjects was again sub divided into 2 groups of 11 and 10 students, first 11 students were again sub divided into 5 and 6, first 5 students were given (Row and Row Header) data sets and other 6 students were given (Row and Column Header) data sets and the other 10 students were again sub divided into 5 each, first 5 students were given (Column and Row Header) data sets and other 5 students were given (Column and Column Header) data sets.

The third group which uses Application2 of 21 subjects was again sub divided into 2 groups of 10 and 11 students, first 10 students were again sub divided into 5 each, first 5 students were given (Row and Row Header) data sets and other 5 students were given (Row and Column Header) data sets. And the other 11 students were again sub divided into 6 and 5, first 6 students were given (Column and Row Header) data sets and other 5 students were given (Column and Column Header) data sets.

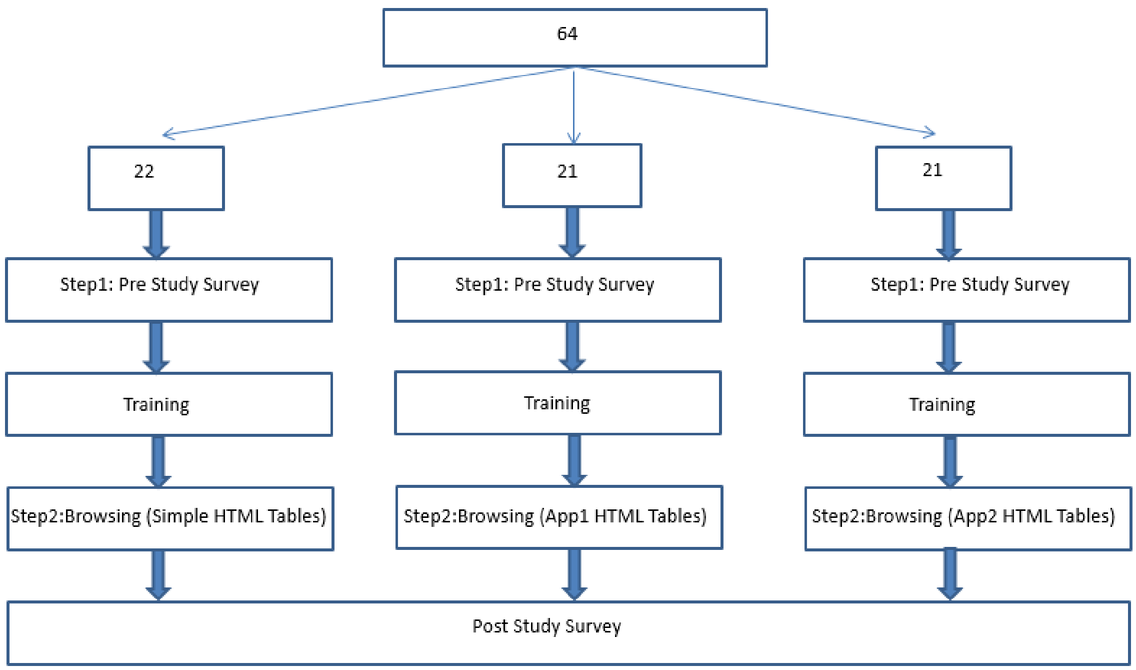


Figure 11. High level view of experimental steps

5.3.2. Html Tabular Data

A brief description of the one-dimensional and multi-dimensional HTML web page tables used in this study is provided as follows:

One-dimensional tabular data set used in this study concerned the credit card transaction data.

Multi-dimensional tabular data set used in this study concerned the conference program data.

For a one-dimensional HTML table adaptation to either a single narrow or multi-page layout, the hyperlinks are generated based on the row header or column header. Therefore, for each one-dimensional HTML data (e.g., Credit Card Transaction Data), we had two sets of HTML tables (rows only HTML table and columns only HTML table). Further, we had two sets of HTML tables adapted to both a single narrow layout (i.e., row only HTML table and column only HTML table adapted to a single narrow layout). Also, we had two more set of HTML tables adapted to multi-page layout (i.e., row only HTML table and column only HTML table adapted to a multi-page layout). Therefore, for each one-dimensional tabular data, we had 6 set of input data as:

1. Simple HTML columns only,
2. Simple HTML rows only,
3. Single narrow layout columns only,
4. Single narrow layout rows only,
5. Multi-page layout columns only, and
6. Multi-page layout rows only.

For each multi-dimensional HTML data (e.g., conference program Data), we had only one set of HTML table (HTML table with rows and columns). For multi-dimensional HTML table the hyperlinks are generated by combining the row headers and column headers. Therefore, for each multi-dimensional HTML table, we also had two sets of input data each (one indexed by row headers, and other indexed by column header) for both a single narrow layout and multi-page layout. Therefore, for each multi-dimensional tabular data, we had developed 5 set of input data as: 1. Simple HTML rows and column data, 2. Single narrow layout indexed by rows headers, 4. Single narrow layout indexed by column headers, 5. Multi-page layout indexed by row headers, and 6. Multi-page layout indexed by column headers. The allocation of subjects to these different data sets and experiment operation of this study are discussed below (and shown in Table 3).

5.3.3. Experiment Operation

The experimental design includes three steps and one training session. Figure-11 provided an overview of experiment steps. The details of each step are provided in the following subsections.

Table 3. (Allocation of subjects to different treatment groups) R-Row, C-Column, RH-RowHeader, CH-ColumnHeader

	64 Students (Subjects)									
	22(Simple HTML)		21(Application1)				21(Application2)			
	11	11	11		10		10		11	
	11	11	5	6	5	5	5	5	6	5
Dataset 1	R	C	R	R	C	C	R	R	C	C
Dataset 2	R+C	R+C	RH	CH	RH	CH	RH	CH	RH	CH

1. ***Step 1: Pre-Study Survey***: The first step was to collect the background information from the participating subjects regarding their reading comprehension skills, their previous experience in designing user interfaces for hand held devices, their web browsing experience and their experience with web browsing on mobile devices. The information during the pre-study was used to gain additional insights into the individual performance of subjects while browsing the tabular data using different browsing methods.

2. ***Training Session***: During this short session, the participating subjects were trained by showing video on how to use the mobile simulator to access different input data sets by teaching them on example input data sets. They were instructed on how to use their allocated browsing

methods, how to use the excel sheet to answer the questions based on the information contained in the input data and how to record time taken to answer the questions.

3. ***Step 2: Browsing HTML Web Pages***: After the training was done, the subjects used the mobile simulator to open and browse their allocated input data files and answer the questions based on the information contained in them. As shown in Figure 11 , each subject at Step 2 browses through a one-dimensional input HTML data set, answers the question, and keeps a record of time spent answering those questions. Then, that subject browses through a multi-dimensional input HTML data set, answers the question, and keeps a record of time spent answering them.

4. ***Post-Study Survey***: The subjects were then given a questionnaire to provide feedback about the different mobile browsing methods used by them during the study, and the problems faced when browsing through the information contained in HTML web page tables.

6. DATA ANALYSIS AND RESULTS

This section compares the browsing efficiency of three treatment groups. The subjects in each treatment group reported the time they spent answering the questions while browsing the information contained in different HTML web page tables.

Similar to the first study, the subjects applied three treatment methods on one-dimensional and multi-dimensional table. Regarding the one-dimensional HTML tables, we compared the median browsing efficiency (time spent in minutes) of three different groups - (i.e., a regular HTML layout, or a single narrow layout, or a multi-page layout).

Based on the comparison of the median values on One-Dimensional HTML data set, the results showed that the subjects using the Application 1 (i.e., single narrow adaptive layout) spent least time (a median value of 4.25 minutes) as compared to the Application 2 (i.e., multi-page layout) that yielded a median value of 5.15 minutes which in turn was more efficient than the simple HTML table (a median value of 8.5 minutes). This result shows that, Application 1 and Application 2 were more efficient in browsing the information contained in one-dimensional HTML tabular data as compared to browsing the standard HTML table.

The Figure shown below Figure 12 explains the data analysis for one-dimensional data. The Figure compares the three treatment methods (Application1, Application2 and HTML) with the median time spent. Median time spent on both the applications application 1(4.25 minutes) and application2 (5.15 minutes) are lesser to the median time spent on HTML data (8.5 minutes) and the results was statistically significant at $p<0.05$.

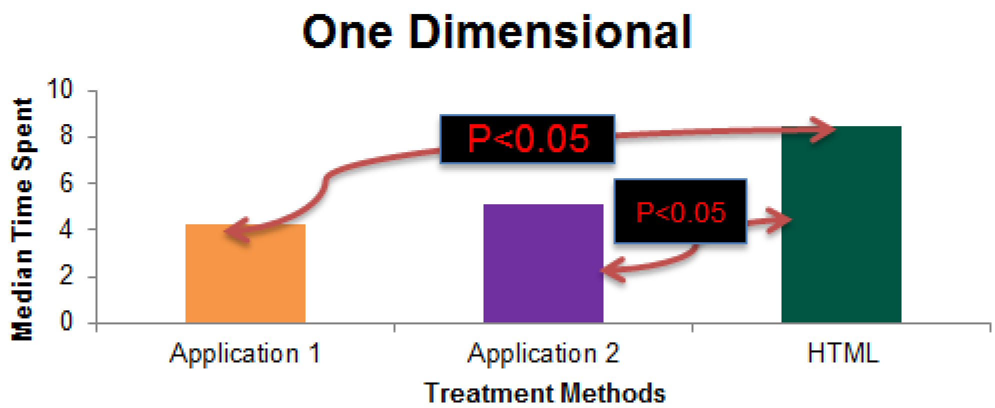


Figure 12. Data analysis for one-dimensional data

Similar analysis was performed on the second data set (i.e., multi-dimensional HTML data set). The median values were again tallied and compared across the three treatment groups. The results again showed that the single narrow adaptive layout was more efficient than the multi-page layout which in turn was more efficient than the simple HTML table. Regarding the median values, the subjects using Application 1 spent a median of 6.2 minutes as compared to the median value of 8 minutes for Application 2 and a median value of 13 minutes for simple HTML table. This result again verifies that the subjects using the Application 1 and Application 2 were more efficient at browsing the information contained in HTML tables as compared to the standard HTML tabular data.

The Figure shown below Figure 13 explains the data analysis for multi-dimensional data. The Figure compares the three treatment methods (Application1, Application2 and HTML) with the median time spent. Median time spent on both the applications application 1(6.2 minutes) and application2 (8.0 minutes) are lesser to the median time spent on HTML data (13.0 minutes) and the results was statistically significant at $p<0.05$.

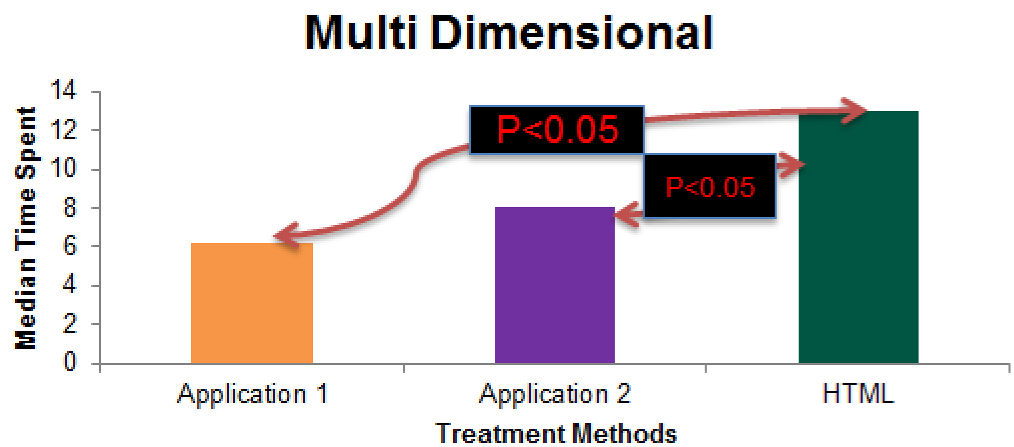


Figure 13. Data analysis for multi-dimensional data

The results from One-Way ANOVA and Tukey HSD test showed that for the data sets (One-Dimensional and Multi-Dimensional), the subjects using the Application 1 (vs. Simple HTML tables) and the subjects using the Application 2 (vs. Simple HTML tables) were significantly more efficient at browsing the information contained in the data sets. The results was statistically significant at $p<0.05$.

The results from the post study questionnaire showed that the subjects using the Application1 and Application 2 rated the user interface better than the standard HTML tables. Each subject participating in this study employed a different browsing method. Each participant evaluated the browsing method that they used during the experiment run on four distinct characteristics: a) *ease of accessing the desired information*, b) *ability to minimize the scrolling (horizontal and/or vertical)*, c) *clarity of interaction design*, and d) *practical usefulness*.

The subjects evaluated the browsing methods using a 5-point scale (very low-low-medium-high-very high). A total of 22 subjects evaluated the regular HTML web page tables. Similarly, 21 subjects evaluated the single narrow adaptive layout interface and another 21 subjects evaluated the multi-page adaptive layout interface. We conducted the non-parametric binomial test conducted to determine whether the mean response for each characteristic was significantly greater than medium (the midpoint of the scale) for each of the three browsing methods. The results show that three out of four characteristics were rated significantly positive for Application 1 and/or Application 2: a) *ease of accessing the desired information*, b) ability to minimize scrolling for multi-page layout, and c) practical usefulness of single narrow layout. Overall the participants had a positive impression of the adaptive layout browsing methods.

7. CONCLUSION AND FUTURE WORK

The main objective of the thesis is to reduce horizontal and vertical scrolling and if possible eliminate them completely by applying the gestalt principles. The HTML table was restructured and addressed in the tree format. These objectives were addressed successfully with the help of two adaptive layout applications, by displaying the HTML web page table within the same page as well as displaying in a new web page while using the small screen devices such as PDAs and Mobile devices (i.e. single layout and multi layout application). The navigational time and ease of accessing the data in the web page table will be reduced by using these two applications.

Due to very limited screen size and huge volumes of data, the limitation of minimum scrolling was not completely eliminated. Viewing the data in different ways by eliminating the scrolling effect is one of the main future works that comes into play. In this thesis as we showed the minimization of scrolling effects for accessing the data in two different ways i.e. single and multi-dimensional view, this can be extended to combine into one single application. Apart from these two main views we can still make available of the original HTML data to be viewed in the same single application combining altogether three different views in a single bundled application. This approach can give user a flexibility of choosing different views at the same time for the same tabular data which may at times ease the accessing the data in no time. An example of this is shown in below Figure 14.

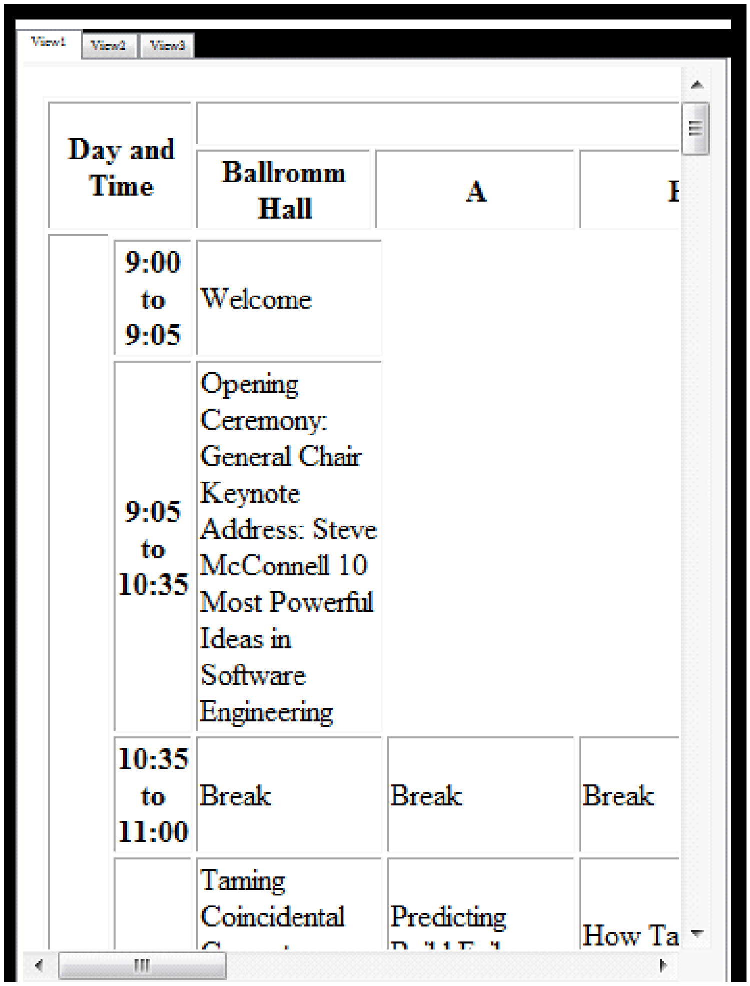


Figure 14. Three different views in portrait mode

One of the other future works that can be done is showing the data is in landscape view mode. In this thesis we see that our experiments were done only in portrait mode by leaving landscape mode. Data can be viewed using this approach in a wide range screen, which will be helpful in viewing the information. It is important sometimes to get the information viewed in landscape mode for better user interface experience and viewing the information in no time. By this approach we can also eliminate the scrolling effect further as the screen size to view is larger. An example of this is shown in the below Figure 15.

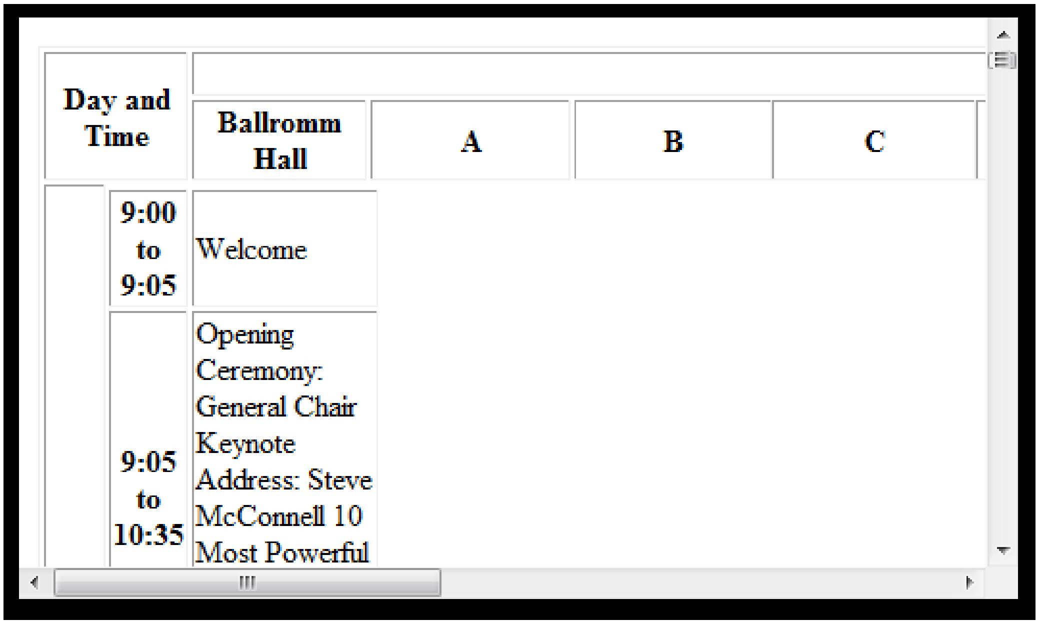


Figure 15. Landscape mode view

We can also provide the HTML tabular data to show up only the meta-data content and display. User can select the appropriate meta-data content which is displayed and can view the whole data information pertain to that meta-data content by clicking on it. This will improve in viewing the whole tabular data structure at the same time provided with meta- data information. Scrolling to view the data will be effected since the tabular size decreases with the display of meta-data content.

The participating subjects also provided feedback regarding the improvements to both adaptive layout styles based on their experience during this study. We plan to consider the suggestions and make improvements to the existing layout styles and plan future studies to empirically evaluate the usefulness of these adaptive layout styles for mobile browsing efficiency of end users.

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