

## VISUALIZING QUR'ANIC WORDS WITH PARALLEL PLOT

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### ABSTRACT

*Parallel plot is a relatively new type of plot in comparison to scatter plot. The aim of this paper is to find out the effectiveness of parallel plot visualization in comparison to the scatter plot for novice users. Comparison through literature shows that parallel and scatter plot visualization techniques offer similar visualization features. A study was conducted based on the parallel plot in Parallel Coordinate for the Qur'an (PaCQ) interface using a relational model, Goals Operators Methods and Selection Rules (GOMS) analysis and user performance evaluation. Based on the GOMS analysis, the subtasks and operation time involved in exploring data in scatter plot exceeds the subtasks and operation time in parallel plot in relation to the PaCQ interface developed for novice user even though, earlier studies found that scatter plot is easier to use. The GOMS analysis shows that the average time taken to complete tasks for the parallel plot is shorter than the scatter plot. A user performance evaluation shows no significant difference in the scores of interpreting the parallel plot within three levels of educational level of novice users. These findings provide evidences that the parallel plot is more effective for PaCQ designed for novice users.*

**Keywords:** Information Visualization, Parallel plot, Scatter plot, Multidimensional, GOMS analysis

### 1.0 INTRODUCTION

Research in visualization sometimes addresses the issue of expert and novice users. The term novice is sometimes used in an unclear manner. According to Fisher [1] novice users are those without experience in conducting certain tasks. Although, given certain amount of period, experience can be gained by novice user and expertise can be developed in the task involved. There is also the term naïve user, those who lack analytical and critical skills; in particular when using a system without knowing how the system functions. Novice and naïve users may overlap. Therefore in the context of this paper, the terms novice and naïve are both referred to as novice.

The usage of parallel plot visualization technique is usually associated with experts. However, very little research has been conducted on the perceptibility and performance of novice users using parallel coordinate. The perpendicular plots are popular among novice users since this representation is introduced in mathematical classes in secondary school level. The aim of this paper is to find out the effectiveness of parallel plot visualization in comparison to the scatter plot for novice users. It is an extension of work previously completed [2]. In this paper, the advantages and disadvantages of the parallel plot are discussed. A relational model of the parallel plot is outlined based on an interface developed for novice user, called Parallel Coordinate for the Qur'an (PaCQ). PaCQ is an interface developed for learning Qur'anic words in the *Juz Amma* (the 30<sup>th</sup> part of the Qur'an). Goals Operators, Methods and Selection Rules (GOMS) techniques then used to analyze the PaCQ interface based on the relational model. Finally, a user performance evaluation of the novice users interpreting the parallel plot is discussed focusing on the following:

- To evaluate the graphical perceptibility of parallel plot using PaCQ interface.
- To investigate the correlation between the score and the time taken to complete the task related to interpreting the parallel plot.
- To investigate the performance of interpreting the parallel coordinate graph based on the questionnaire given:
  - The performance related to the percentage score of the questions.
  - The performance related to the time taken to complete the task.

## 2.0 PERPENDICULAR PLOT

The perpendicular plots are referred to plots that use the x and y coordinates in a Cartesian system. Scatter plot and a line chart are example of such plots. These plots can be related to two dimensional variables although multidimensional variables are also possible to be displayed with overlapping techniques [3], increasing data representation density for display space efficiency [4] and small multiples techniques [4]. These techniques give rise to new type of charts such as stacked graphs, horizon graphs [4] and vizrank[3].

Interpreting a scatter plot involves identifying correlations, functional dependencies, clusters and other relations [5][6]. Sometimes these could be detected by looking at direction, forms, strength and outliers of the plot. For example, if the scatter plots forms a line with negative or positive slopes, then a negative or positive relation could be implied between the attributes involved. Based from these, relations of the attributes involved could be predicted. However, if the dimensionality increases, the number of different plots to be inspected increases by  $m(m-1)/2$ , where  $m$  is the number of attributes in the set of data [3]. The data can be differentiated via color, symbol or shapes. Values of attributes are represented as points and only the position is effected within the perpendicular x, y axis and not its size, shape and color [3].

The disadvantage of this plot is that only limited number of data items can be visualized in the screen [7] although this could be overcome. Analysis of the scatter plots, for example, can be difficult and time consuming since the x and y projection increases exponentially with the number of attributes [8] [3]. In a larger dataset, the points can overlap and may not be perceived [4] [3] [7]. Bertini and Santucci [9] estimated that a human cannot distinguish between two points in a region smaller than of 14 X 14 virtual pixels. This particular problem is called the occlusion problem, where occlusion is the number of identifiable points relative to any other visible points [9]. In addition, sometimes data need to be compared across multiple charts [4] [10] and this is difficult if the data set is large.

However, these plots have existed for a long time and are popularly utilized [6] by those who have learned how to interpret them easily. The perceptibility of the data characteristic is therefore considered reliable. Heer and et. al [4] refer this as the graphical perception.

There are several operations used with scatter plots, especially to reduce cluttering and to enhance the occlusion percentage. Jittering and distortion can be used to promote occlusion [9]. While jittering displaces the overlapped items around their original position so that they are visible, distortion presents more detail data in less dense region and less detail data in denser region. Other possible operations are zooming (making the display bigger or smaller), panning (scrolling or moving the display to the intended position), filtering and selection detail-on-demand (choosing items to be analyzed), brushing (highlighting) and 3D manipulation [11].

Application of scatter plots, line charts and their families are not surprisingly wide. It had been use in contact of visualization of geographical data (such as NASA earth observation database), molecular biology project [12], financial data (such as stock prices and exchange rates), public policy (such as crime rates) [4], just to mention a few. Many of the targeted users are in the category of experts. Related tools for scatter plots are VisDB [12], VizRank [3], Spotfire [11] and XGobi [13].

## 3.0 PARALLEL PLOT

A simple representation of the parallel concept can be illustrated as follows. Let the Cartesian system plane be represented as  $\mathbb{R}^N$ , where  $N=2$  since it is 2-dimensional and the parallel plane  $\mathbb{P}^2$  represents the  $\mathbb{R}^2$  Cartesian system plane [2]. A point in the  $\mathbb{R}^2$  plane,  $\mathbf{p}_r$  is represented in the  $\mathbb{P}^2$  plane as a line,  $\ell_p$ . This is referred to as the principle of duality. Fig. 1 (a) and 1 (b) illustrate an example, point (3, 0) in  $\mathbb{R}^2$  plane is represented as a line connecting the corresponding points on the x and y axis drawn in parallel to each other. The position of the axis can be interchanged as shown in 1 (c).

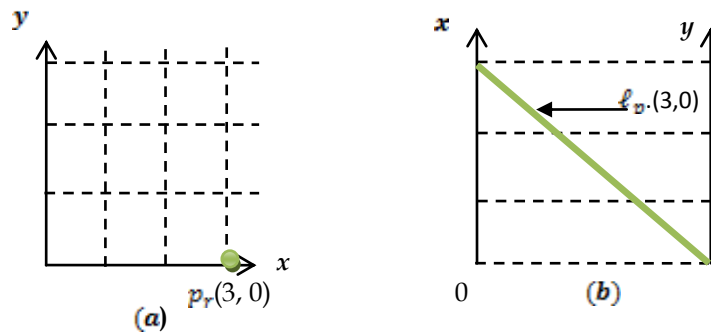


Fig. 1: (a) point (3,0) in the Cartesian  $\mathbb{R}^2$  plane (b) point (3,0) on the line  $l_r$  in the parallel ( $\mathbb{P}^2$ ) plane

Therefore, a line in the  $\mathbb{R}^2$  plane,  $l_r$  can be represented in the  $\mathbb{P}^2$  plane as many lines. Fig. 2 illustrates an example of the parallel plot for a negative slope. Fig. 3 illustrates example of a positive slope.

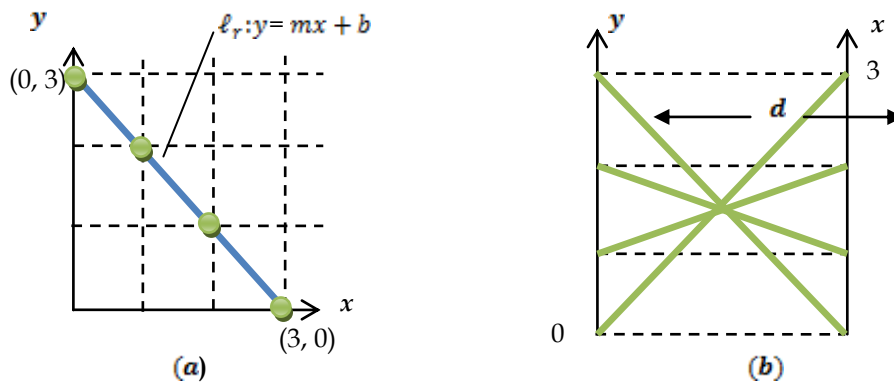


Fig. 2: (a) negative slope line  $l_r$  in the Cartesian  $\mathbb{R}^2$  plane (b) line  $l_r$  in the parallel ( $\mathbb{P}^2$ ) plane

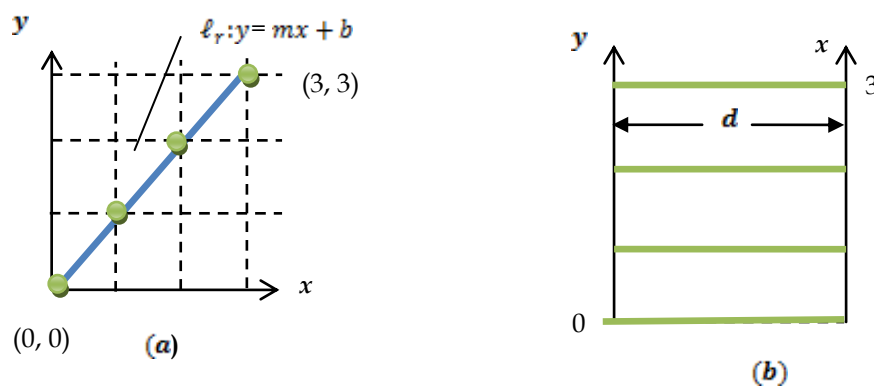


Fig. 3: (a) positive slope line  $l_r$  in the Cartesian  $\mathbb{R}^2$  plane (b) line  $l_r$  in the parallel ( $\mathbb{P}^2$ ) plane

When a third dimension is added in the  $\mathbb{R}^2$  plane, a third line is added in the  $\mathbb{P}^2$  plane as illustrated in Fig. 4 (a) and (b) the point (1, 2, 1).

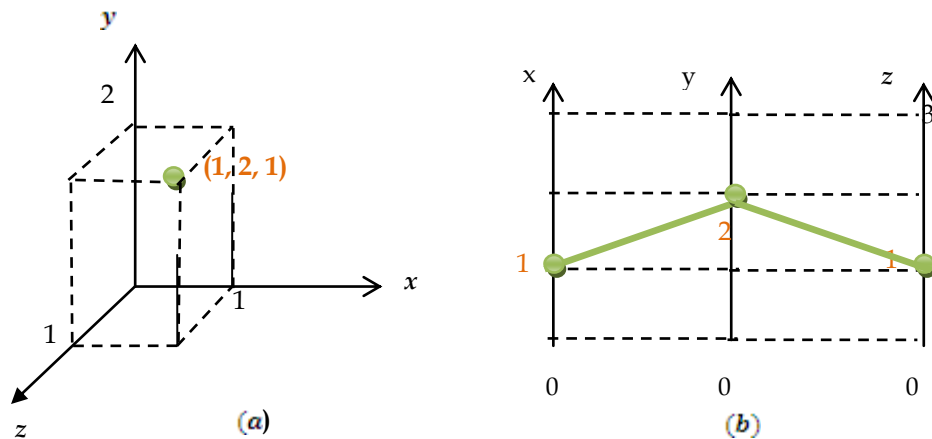


Fig. 4: (a) 3 dimensional lines in the Cartesian  $\mathbb{R}^3$  plane (b) 3 parallel lines represented in the parallel P3 plane

The main disadvantage of parallel plots are that the display is considered cluttered and hard to interpret if there are too many dimensions and set of attributes to be shown, but this would depend on the size of the monitor displaying the data [3, 14, 15, 16]. This problem is related to the occlusion problem, which had been mentioned earlier in perpendicular section. Interpretation of parallel coordinate is harder and requires expert knowledge [14] [17], although there is also evidence showing, that parallel plots are not difficult to manipulate and can result in a more accurate interpretation of data even by novice users [16-18]. Also, parallel coordinate is not suitable for visualizing data sets in the range of hundreds to thousands with relationships among attributes that can only be easily identified for two adjacent axes [19, 20]. Rearranging of the axes can overcome the mentioned problem.

The advantage of this plot is that it uses the display space more effectively, thus increasing the number of data a human can work with at the same time [4]. However, [19] found that 11 axes is the maximum threshold for a human to efficiently analyze the data. Also, N-dimensional properties can be visible from the screen [8].

The operations related to parallel plots are very similar to the scatter plots, i.e., zooming, panning, filtering and selection, detail-on-demand, focus+context, linking+brushing [21, 14, 22] and 3D manipulation. Also, rearranging the axes can improve analysis between two adjacent axes [14, 15]. Some example of real application of parallel plots are in network attacks data [23], land satellite data [24], climate analysis [25], data envelopment analysis [26], fuel injection simulation [13], and many others. The related tools for parallel plots usually include other types of visualization as well for example GGobi [27] and ComVis [22].

#### 4.0 AN ANALYSIS OF PARALLEL PLOT USING A RELATIONAL MODEL

The analysis of the parallel plot is based on a tool developed called the PaCQ interface. The PaCQ interface was developed incorporating parallel plot visualization for supporting the Muslims of non-Arabic speakers to enhance their comprehension of an Arabic document called the Qur'an using the theory of word recognition. The PaCQ interface lets the user go through the Qur'an chapter by chapter (also known as sura). The user can also browse the Qur'an sentence by sentence (also known as ayah). The interface was built using only the last 30th part of the Qur'an, which is also known as *JuzAmma*. The default interface visualizes the frequencies of words [28] in *JuzAmma* and where these words can be found. In browsing through the Qur'an, the user can add up their vocabulary to the list that is stored in the system. The PaCQ interface visualizes the overall percentage of their vocabulary in comparison to each *sura*. Also, the PaCQ interface gives a comparison chart of all words in one *sura* and displays percentages of these words contain in other suras.

In this section, a relational model of the PaCQ interface is described. This is followed with GOMS analysis based on the relational model.

4.1 The PaCQ interface

The PaCQ interface was built using Java language using Eclipse IDE. Fig. 5a) shows the sketch of a scatter plot for two variables, while Fig. 5b) is the same representation in the PaCQ interface. When plotting multi-variable, for example using four variables such as in Fig. 6a), the scatter plot represents these variables within five plots, Fig. 6b) shows the representation of four variables in the parallel plot.

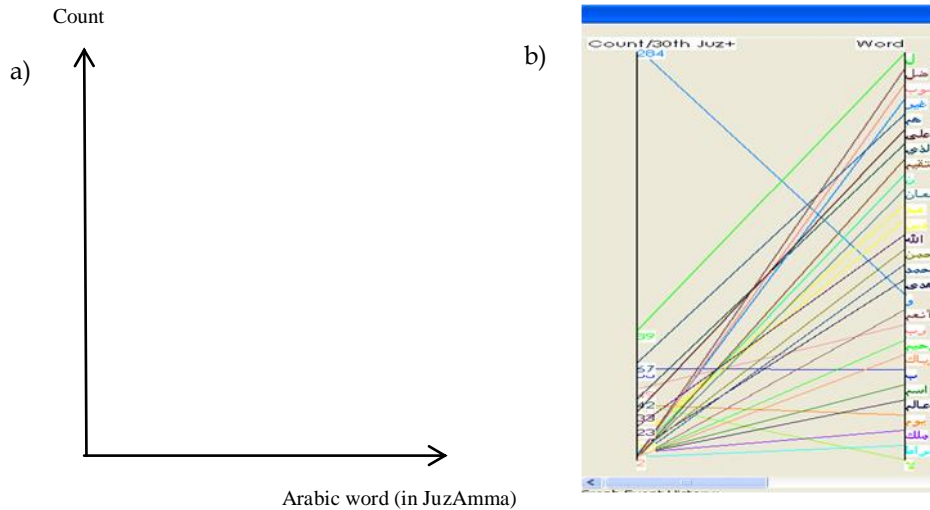


Fig.5: a) shows the sketch of a scatter plot while b) is the same representation in parallel plot of the PaCQ interface

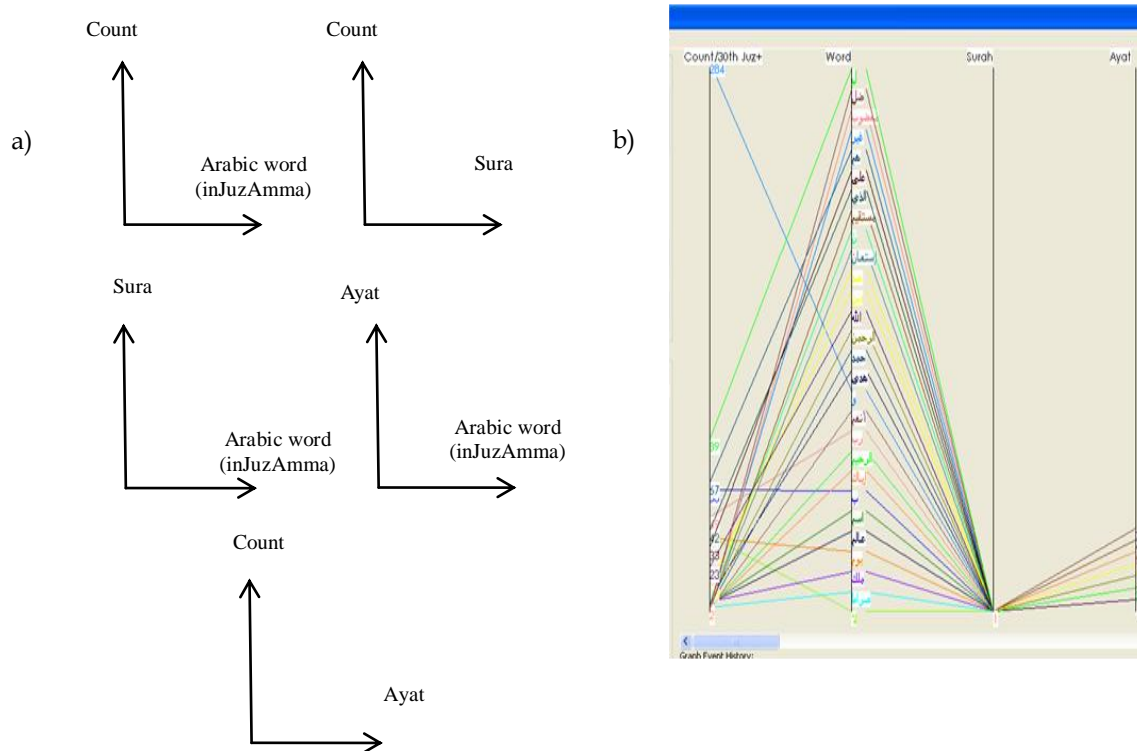


Fig. 6: a) shows the sketch of 5 scatter plots while b) is the same representation in parallel plot of the PaCQ interface

#### 4.2 The PaCQ interface relational model

A relational model can be associated with a database system. The parallel plot is represented as attributes of a table in a database. This can be considered as a simpler approach in explaining the concept to a user. In this study, there are several variables set model for the PaCQ interface:

- The Arabic word, A, where A= all Arabic words in *Sura1(Al-Fatihah)* and *JuzAmma* of the Qur'an.
- The Vocabulary words, V, where  $V \subseteq A$ .
  - Note: the vocabulary for a user in the scope of the study is limited to only the Arabic words in *JuzAmma*.
- The word count, C where  $C = \{c: c \in \mathbf{N}\}$  and  $\mathbf{N}$  is the set of natural numbers.
- The corresponding *Sura*, S where  $S = \{s: s \in \mathbf{N}, s=1 \text{ and } 78 \leq s \leq 114\}$ .
  - Note: *Suras* in *JuzAmma* are from *Sura* number 78 to 114 and the *Sura al-Fatihah* is *sura* 1.
- The corresponding *Ayah*, Y, where  $Y = \{y: y \in \mathbf{N}, y \leq 46\}$ .
  - Note: the maximum number of *Ayah* / verse in *JuzAmma* is 46.
- The percentage of Arabic word, T, where  $T = \{t: t \in \mathbf{N}, t \leq 100\}$

The main relations between these variables can be written as:

- $R_1 = \{(c, a, s, y): \text{There are } c \text{ counts of Arabic words in } \textit{JuzAmma} \text{ and can be found in } \textit{Sura } s \text{ and } \textit{Ayah } y\} \text{ where } c \in C, a \in A, s \in S \text{ and } y \in Y.$
- $R_2 = \{(v, s, t): \text{There is } T \text{ percentage of the vocabulary words } V \text{ in } \textit{Sura } S\} \text{ where } v \in V, s \in S, t \in T.$
- $R_3 = \{(c, s_1, s, t): \text{There is } T \text{ percentages of Arabic words in } \textit{Suras } s_1 \text{ contain in other } \textit{Suras } S \text{ in } \textit{JuzAmma} \text{ and } C \text{ count of Arabic words in the } \textit{Sura } S\} \text{ where } \{s_1: P(s_1)\} \text{ and } P(s_1) \text{ is exactly one } \textit{Sura} \text{ in } \textit{Juz Amma} \text{ and } s \in S, t \in T.$

#### 4.3 The GOMS analysis for perpendicular plot

In this section GOMS [29] analysis is used to predict the time taken for a user to interpret information for the parallel plots. GOMS comprises of a set of techniques on how to model task in terms of Goals, Operators, Methods and Selection Rules while using a graphical user interface. GOMS starts with the goal of the task and decompose these tasks to smaller tasks up to the key-stroke level (e.g. mouse click, pressing a key on the keyboard, finding a target object on the screen, pointing to an object and others). Furthermore, the technique gives an estimated time to accomplish these tasks known as operators. Table 1 shows the tasks involved in relation to the three relations identified for the PaCQ interface.

Table 1: Relations and the corresponding tasks.

Rel.	Scenario/ Goal	Tasks Involved
R <sub>1</sub>	What is the word with the highest count and where can this word be found?	Goal: Find the word with the highest count and where can this word be found
		S1: Find word
		S1.1: Locate/identify count axis/ symbol
		S1.2: Locate the highest count
		S1.3: Locate the corresponding word
		S2: Find where this word can be found
		S2.1: Locate the corresponding <i>s</i>
		S2.1.1: Locate/identify <i>sura</i> axis/symbol
		S2.1.2: Read the corresponding <i>s</i> .
		S2.2: Locate the corresponding <i>y</i>
		S2.2.1: Locate/identify <i>ayat</i> axis/symbol
		S2.2.2: Read the corresponding <i>y</i>
R <sub>2</sub>	What is the sura with the highest percentage based on the vocabulary words in the list?	Goal: Find the <i>s</i> with the percentage of the vocabulary words in the list.
		S1: Find highest percentage
		S1.1: Locate/identify percentage axis/symbol
		S1.2: Locate/identify the highest percentage value
		S2: Find the corresponding <i>s</i>
		S2.1: Locate the <i>s</i> .
R <sub>3</sub>	What is the highest percentage of words in one <i>sura</i> contain in another and what are the <i>suras</i> ?	Goal: Find the highest percentage of words in one <i>s</i> compare to another and the corresponding <i>s</i> .
		S1.1: Locate/identify percentage axis/symbol
		S1.2: Locate the highest percentage value
		S2: Find the corresponding <i>s</i>
		S2.1: Identify the base <i>s</i>
		S2.1.1: Locate/identify the base <i>s</i> axis/symbol
		S2.1.2: Locate/identify the base <i>s</i>
		S2.2: Identify the compared <i>s</i>
S2.2.1: Locate/identify the compared <i>s</i> axis/symbol		

#### 4.3.1 GOMS analysis for relation R1

For relation  $R_1$ , the lowest level tasks involve are 'identify count symbol', 'locate the highest count', 'locate the corresponding word', 'identify *sura* symbol', 'read the corresponding *sura* no.', 'identify *ayat* symbol', 'read the corresponding *ayat* no'. In a parallel plot, these tasks may involve other subtasks:

- The user need to locate the count axis – (1)<sup>1</sup>.
- 'Locate the highest count'; the user may be confronted with a cluttered display. However, there will not be much problem in comparing to the next highest point since the points are display vertically instead of horizontally in the perpendicular view. Therefore, the subtasks involved may be as the following:
  - Select/locate the region with the highest point – (2).
  - Zoom into the region – (3).
  - Read the highest count value – (4).
- Locate the corresponding word; at this point, the words in the parallel plot will also be overlapping with each other. Therefore, the subtask is:
  - Click the highest count value – (5).
- This action can be connected to a filtering function. Once this value is clicked, the system can automatically display the corresponding related attribute, which is the word, the *s*. and the *y*. All other related values can be faded out or temporarily filtered off the display screen, consequently simplifying all subtasks that come after this.
  - View the display word on the word axis.
    - Locate the word axis – (6).
    - Read the word – (7).
- Locate *sura* / *ayat* axis – (8).
- Read the corresponding *s* or *y*. At this point, in the parallel plot, there are many possible *sura* and *ayat* related to the highest word count but it is possible to read all the *s* and *y* – (9).

#### 4.3.2 GOMS analysis for relation R2

In order to achieve the goal for relation  $R_2$ , the lowest level tasks involved are 'identify percentage axis/symbol', 'locate the highest percentage value', 'locate the *s*'.

- Locate percentage symbol – (1).
- Locate the highest percentage value - (2).
- Locate the *sura* no. – (3).

#### 4.3.3 GOMS analysis for relation R3

In order to achieve the goal for relation  $R_3$ , the lowest level tasks involve are 'identify percentage symbol', 'locate the highest percentage value', 'identify the base *sura* symbol', 'identify the base *sura* no.', 'identify the compared *sura* symbol', 'identify the *sura* no. compared'. In the parallel plot, the subtasks involve are as the following:

- Locate the percentage axis – (1).
- Locate the highest percentage value: in this case, since the scale of percentage from 0-100 is at a detectable value, the user can follow the sequence of task as in relation to locate the highest count, which will involve 3 subtasks – (2-4).
- At this point, the user can use a filter function such as clicking on the highest percentage value to display the corresponding attributes (the base *and* compared *sura*). This action automatically reduces the subtasks that come next – (5).
  - Locate the base *sura* axis – (6).
  - Locate the base *sura* no. – (7).
  - Locate the compared *sura* axis – (8).
  - Locate the compared *sura* no. – (9).

<sup>1</sup> Note that the notation number in brackets :“ - (number x)” is referring to task count



## 4.3.4 GOMS analysis estimated time for tasks related to relation R1, R2 and R3

Table 2: GOMS estimated operation duration [23].

Operation	Duration(sec)
Click-mouse-button	0.20
Shift-click-mousebutton	0.48
Cursor movement	1.10
Mental Preparation	1.35
Determine Position	1.20

Table 3: The estimated time for relation, R<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub> for parallel plot

	Lowest Level Tasks	Time/s
R <sub>1</sub>	Locate/identify count axis/ symbol	1.2
	Locate the highest count	1.2 +0.2+ 1.2
	Locate the corresponding word	0.2
	Locate/identify <i>s</i> axis/symbol	1.2
	Read the corresponding <i>s</i> .	1.2
	Locate/identify <i>ayat</i> axis/symbol	1.2
	Read the corresponding <i>y</i>	1.2
	<b>TOTAL</b>	<b>8.8</b>
	R <sub>2</sub>	Locate/identify percentage axis/symbol
Locate/identify the highest percentage value		1.2
Locate the <i>s</i>		1.2
<b>TOTAL</b>		<b>3.6</b>
R <sub>3</sub>	Locate/identify percentage axis/symbol	1.2
	Locate the highest percentage value	1.2 +0.2+ 1.2
	Locate/identify the base <i>s</i> axis/symbol	1.2
	Locate/identify the base <i>s</i>	1.2
	Locate/identify the compared <i>s</i> axis/symbol	1.2+1.2
	<b>TOTAL</b>	<b>8.6</b>

Table 2 shows the GOMS estimated operation time for each low level tasks. The table is used to estimate the time to accomplish relation  $R_1$ ,  $R_2$  and  $R_3$ . Table 3 shows the calculated time to accomplish the tasks using parallel coordinate plots; 8.8s, 3.6s and 8.6s for  $R_1$ ,  $R_2$  and  $R_3$ , respectively. These timing can be considered reasonable.

#### 4.4 The GOMS analysis for scatter plot

GOMS analysis described in section 4.3 with regards to  $R_1$ ,  $R_2$  and  $R_3$  was also carried out for the scatter plot. For relation  $R_1$ , there are 11 tasks involve, for relation  $R_2$ , there are 3 tasks involve and for relation  $R_3$ , there are 19 tasks involve. Referring to Table 4, the time taken to complete tasks related to  $R_1$ ,  $R_2$  and  $R_3$  are 10.05s, 3.6s and 19.65s, respectively.

#### 4.5 Comparing parallel and scatter plot through GOMS analysis

For the parallel plot, 9 tasks are involved to accomplish goals related to  $R_1$ , 3 for  $R_2$  and 9 for  $R_3$ . While in the scatterplot, 11 tasks are involved to accomplish goals related to  $R_1$ , 3 for  $R_2$  and 19 for  $R_3$ . The times taken to accomplish goals related to relations  $R_1$ ,  $R_2$  and  $R_3$  in the parallel plot are 8.8s, 3.6s and 8.6s, respectively, while in the scatter plot, 10.05s, 3.6s and 19.65s, respectively. In terms of the task and time taken to complete relations  $R_1$ ,  $R_2$  and  $R_3$ , the parallel plot is analyzed to be better then the scatter plot. Therefore, the average time taken to complete tasks of relations  $R_1$ ,  $R_2$  and  $R_3$  is 7 for the parallel plot and 11.1 for the scatter plot.

#### 4.6 User performance evaluation

A user study was conducted to evaluate the performance of novice users interpreting the parallel coordinate graph in the PaCQ interface. This section describes the conducted study and the results found.

##### 4.6.1 Evaluation design

Participants were chosen from the Faculty of Science Computer and Information Technology of University of Malaya. 15 participants were involved, with 3 main categories according to their level of education. All of them can be considered as novice users since they do not have experience in interpreting parallel plots. There are five participants in each category:

- High school academic qualification faculty staffs.
- Bachelor degree students.
- Master degree students.

The participants were given a questionnaire with 7 questions based on the parallel coordinate graph in the PaCQ interface. The questions are related to the 3 relations described earlier,  $R_1$  (word count and word position information),  $R_2$  (vocabulary percentage information) and  $R_3$  (comparing percentage of content of words between *sura*). The questions also incorporated instructions on how to interact with the parallel plot.

PaCQ was set at a 1280x800 pixel resolution and highest (32 bit) color quality. Participants interacted with the system using the mouse via a laptop Dell Vostro 1310 or 1210. The session was conducted in various conditions, sometimes simultaneous session with up to a maximum of 5 participants and sometimes individually. The questionnaires were given to the participants and they were told to answer the question as they go through them one by one.

Table 4: The estimated time for relation,  $R_1$ ,  $R_2$  and  $R_3$  for scatter plot

	Lowest Level Tasks	Time/s	
$R_1$	Identify legend of graph	1.2	
	Locate the highest point	1.2	
	Click to zoom into the region	0.2	
	Read the highest count value	1.2	
	Scroll to the other potential highest point	1.1	
	Read the potential highest point	1.2	
	Interpret the comparison	1.35	
	Click/mouse over on the highest point	0.2	
	View the displayed word on the screen	1.2	
	Read legend of the graph	1.2	
	<b>TOTAL</b>	<b>10.05</b>	
	$R_2$	Identify percentage symbol	1.2
		Locate the highest percentage value	1.2
Locate the <i>sura</i> no.		1.2	
<b>TOTAL</b>		<b>3.6</b>	
$R_3$	Identify legend of the graph	1.2	
	Select/locate the region with the highest percentage	1.2	
	Click to zoom into the region above	0.2	
	Read the highest percentage value	1.2	
	Scroll to the other potentially highest percentage	1.1	
	Read the potentially highest percentage	1.2	
	Interpret the comparison	1.35	
	Identify base <i>sura</i> symbol	1.2	
	Select/locate the region of interest	1.2	
	Click to zoom into the region above	0.2	
	Read the region of interest	1.2	
	Scroll to the other interested region	1.1	
	Read the value	1.2	
	Identify the compared <i>sura</i> symbol	1.2	
	Select/locate the <i>sura</i> no.	1.2	
	Click to zoom into the region above	0.2	
	Read the region of interest	1.2	
	Scroll to the other interested region	1.1	
	Read the value	1.2	
	<b>TOTAL</b>	<b>19.65</b>	

#### 4.6.3 Results

##### *The graphical perceptibility:*

The participants were asked to rate what they thought of the parallel plot graph shown to them in the PaCQ interface. The rating was from 1 to 5 with 1 for “very hard to understand” and 5 for very easy to understand. Table 5 shows the detailed description, while Table 6 shows the mean and standard deviation. It can be observed that the mean rating before the test is 1.8 and after the test is 3.2, with standard deviation of 0.68 and 0.86, respectively.

Table 5: Description of rating scale

Rating scale	Description
1	Very hard to understand
2	Hard to understand
3	Average/Neutral
4	Easy to understand
5	Very Easy to understand

Table 6: Graphical Perceptibility of Parallel Coordinate

	Perception of Parallel Coordinate before test	Perception of Parallel plot after test
<b>Mean</b>	<b>1.80</b>	<b>3.20</b>
<b>Std. Deviation</b>	<b>0.676</b>	<b>0.862</b>

##### *The Correlation:*

The Pearson correlation between percentage of the total score and the time taken to complete the tasks were found to be non-significant,  $r(13) = 0.457$ ;  $p > 0.05$ . Table 7 shows this result. The scatter plot from Fig. 2 also shows no linear relation between these two variables.

Table7: Person Correlations

		Percentage of the total score	Time Taken to complete task
Percentage of the total score	Pearson Correlation	1	0.457
	Sig. (2-tailed)		0.087
Time Taken to complete task	Pearson Correlation	0.457	1
	Sig. (2-tailed)	0.087	

##### *The performance related to the percentage score:*

It was found from the one way ANOVA test, that there was no significant difference in the percentage level scores between the three educational level of participants,  $F(2,14) = 0.727$ ,  $p > 0.05$ . Refer to Tables 8 and 9.

In Fig. 2, we can see that 14 out of 15 participants (93%) scored above 70% in interpreting the parallel plot questionnaire.

Table 8: The means and standard deviation of 3 categories of participants for percentage level score

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
High school	5	1.80	.837	.374	.76	2.84
Bachelor Degree	5	2.20	.447	.200	1.64	2.76
Master Degree	5	2.20	.447	.200	1.64	2.76
Total	15	2.07	.594	.153	1.74	2.40

Table 9: One way ANOVA Percentage level score

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.533	2	0.267	0.727	0.503
Within Groups	4.400	12	0.367		
Total	4.933	14			

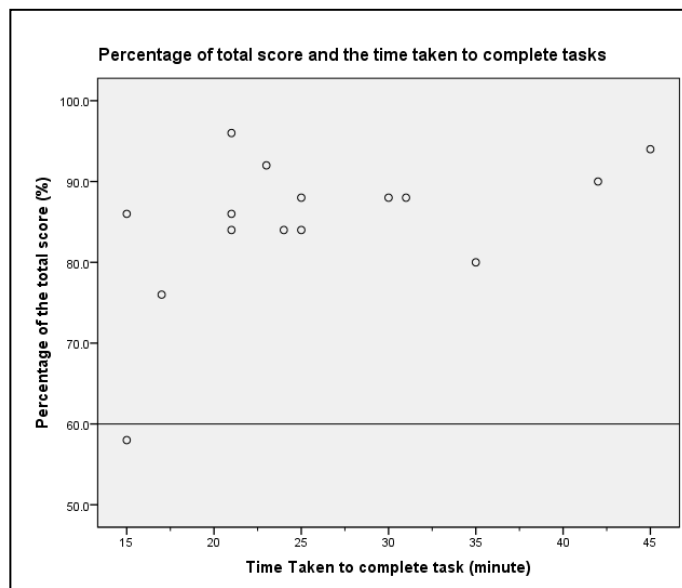


Fig. 2: Percentage of total score and the time taken to complete task

*The performance related to the time taken to complete the task:*

Table 10 shows the means and standard deviation for the time taken to complete the tasks. The means to complete the tasks for high school participants, bachelor degree participants and master degree participants are 18.2, 35.6 and 24.2, respectively. It was found from the one way ANOVA test (see Table 11), that there was significant difference in the time taken to complete the tasks between the three educational level of participants,  $F(2,14) = 12.64, p < 0.05$ . In Table 12, the Scheffe's test shows that the bachelor degree participants took more time to complete the tasks compared to the other two groups. There was no significant difference in the time taken to complete the tasks between the Master degree and the High School group.

Table 10: The means and standard deviation of 3 categories of participants for time taken to complete task

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
High School	5	18.20	3.633	1.625	13.69	22.71
Bachelor Degree	5	35.60	8.112	3.628	25.53	45.67
Master Degree	5	24.20	3.701	1.655	19.60	28.80
Total	15	26.00	9.071	2.342	20.98	31.02

Table 11: One way ANOVA for time taken to complete task

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	781.200	2	390.600	12.64	.001
Within Groups	370.800	12	30.900		
Total	1152.000	14			

Table 12: Comparison of time taken to complete task between participants in the 3 levels of education \*. The mean difference is significant at the 0.05 level.

(I) Education Level	(J) Education Level	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Scheffe High School	Bachelor Degree	-17.400*	3.516	.001	-27.20	-7.60
	Master Degree	-6.000	3.516	.271	-15.80	3.80
Bachelor Degree	High School	17.400*	3.516	.001	7.60	27.20
	Master Degree	11.400*	3.516	.023	1.60	21.20
Master Degree	High School	6.000	3.516	.271	-3.80	15.80
	Bachelor Degree	-11.400*	3.516	.023	-21.20	-1.60

## 5.0 DISCUSSION

The mean for the graphical perceptibility at the beginning was low (1.8). In other words, the participants found that the parallel plot was difficult to understand. This is consistent with the findings of other researches on parallel coordinate [3, 14, 15, 16]. However, at the end of the session, the average rating increases to 3.8, meaning that once the participants know how to interact with the graph, they found that it is much easier than what they have expected. The data shown to the users can be interpreted accurately even by novice users. This was also found by Siirtola & Riih  [16], Siirtola, Laivo, Heimonen, & Raiha [18] and Henley, Hagen, & Bergeron [17].

No significant correlation was found between the time taken to complete the tasks and the percentage score in the parallel plot. However, the mean time taken to complete the tasks between the Bachelor degree group and the other two groups (the High School and the Master level) were significantly different. There was no significant difference in the mean time taken to complete the tasks between the High School and the Master level groups. This indicates that higher education level does not necessarily mean a faster speed of completion the tasks.

The performance related to the percentage of scores between the three levels of education groups was found to be non significant. Again, this indicates that higher education level does not necessarily mean a better performance percentage score. Here, there is evidence showing that novice users can also interpret the parallel coordinate graph accurately, contradicting the arguments of Yuan, Guo, Xiao, Zhou, & Qu [14] and Henley, Hagen, & Bergeron [17], stating that expert users are needed to interpret the graph.

## 6.0 CONCLUSION

A relational model of parallel coordinate was used for the analysis of parallel plot based on an interface called PaCQ. Although it was found that the parallel plot does not score well in graphical perceptibility among users, results show that novice users can interpret parallel plots relatively well. The GOMS analysis of tasks related to the parallel plot also shows that the time taken to complete the tasks related to the parallel plot is well below 10s. The user study among novices with three different levels of education shows no significant difference in the scores of interpreting the parallel plot. These findings provide evidences that that parallel plot is more effective to be used in the PaCQ interface designed for novice users.

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