Big Data Visualization

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***Abstract*—Nowadays, the data is a golden capital for any business organization that wants to improve their business. The big organizations and the most reputed ones do not only think to collect data, but they make continuous efforts to use this data for efficient decision making.**
Data Visualization plays a crucial importance in big data analysis. The existence of various data visualization methods can be confusing forusers to choose the most appropriate.
In this document we give a guide for data visualization methods choosing, and how the traditional methods are improved to meet the big data visualizations need.
The next topic highlights the importance of visual perception in data visualization design and gives some rules for the color choosing.

***Index Terms*—Data visualization; big data visualization, visual analytics; methods of data visualization; color**

I. INTRODUCTION

THE visual human system is very powerful; it can catch information immediately and intuitively. Human beings are innately visual creatures; half of human brain is devoted to visual processing: It processes images 60 000 times more quickly than text. Thus the use of visual perception to interpret and understand complex data is not a new concept; it has deep root.
Data visualization is a graphical representation of information.The abstraction of data allows to the user to pick up the information easier and faster.
The data visualization is practiced in many disciplines. It communicates information clearly and efficiently.
As the authors cited in their paper [1],the purpose of visualization is to improve the clarity and the elegance of the abstract information to allow better understanding of big data and give better interaction and communication
A successful visualization must be [2]
-Informative: Provide access to information and let user gain knowledge.
-Efficient: Access to this information should be as straightforward as possible, without sacrificing any necessary, relevant complexity.
-Aesthetic: The use of graphical construction as axes; layout, shape, colors, lines.. must be harmonic to guide the user, communicate meaning, reveal relationships and highlight conclusions.
Recently, the data visualization became one of the primary interests of data analyses. It can tell many stories that the data cannot tell directly. In their paper [3], the authors show the benefits of data visualization according to the respondent percentages of a survey (Table1).
Data visualization is not new; it has deep roots. The most important data visualizations in history appeared in statistics in 1861 by Charles Minard's [4].

Benefits	Percentages (%)
Improved decision-making	77
Better ad-hoc data analysis	43
Improved collaboration/information sharing	41
Provide self-service capabilities to end users	36
Increased return on investment (ROI)	34
Time savings	20
Reduced burden on IT	15

Table 1: Benefits of data visualization tools [3]

Throughout visualization history, there have been many prominent events; the most important that revolutionize the data visualization is computer development. The figure1 [1] schematizes the evolution of data visualization over the years.

II. OVERVIEW OF DATA VISUALIZATION METHODS

Data Visualization is an analysis tool that enables to users to explore data and find stories that cannot be found with formal statistical tests. The primary step is to know what to look for and what questions to ask based on the available data.
Nathan [6] describes the process to follow for getting a good data visualization (figure2).
Many visualization options exist, it can be hard to figure out what graph or chart suits the data best. The first necessarystep is to understand and learn about the data.
Nathan Yau [5] divides visualization to many areas to make a choice for one particular type of dataeasier.

A. *Visualizing Patterns over Time:*

Data is changed over time; temporal data can be categorized as discrete or continuous recording to the author [5].

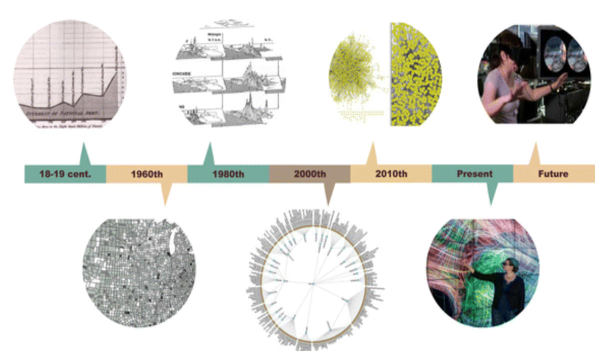


Figure 1: The evolution of visualization methodology [1]

Discrete Points in Time: to show changes over time for several variables, it is possible to use:

- Bars
- Stack the Bars
- Points

Continuous Data: it is similar to the previous case. The difference is that continuous data represents constantly changing phenomena.

- Time Series Chart
- Step Chart

B. Visualizing Proportions:

Many methods that use size or area to show differences or similarities between values or to a whole.

- Pie
- donut:
- Stacked Bar Chart
- Treemap

Proportions over Time:

- Stacked area chart

Point-by-Point

- Line plot

C. Visualizing Relationships

To look for relationship nature between variables: causal or correlative relationship, and prove it graphically it is possible to use:

- Correlations are shown in scatterplots
- Scatterplot Matrix
- Bubbles sized by area
- Bubbles sized by radius
- Distribution

D.*Spotting Differences*

When the user doesn't know what question he shouldask, there are some methods to visualize an overview about the data like:

- Heatmap
- Star Charts
- Parallel coordinates
- Dot plot
- Boxplot

E. Visualizing Spatial Relationships

Nathan [5] explains the maps are a sensitive and delicate type of visualization. The user must be focused on the data as well attentive to the geography dimension

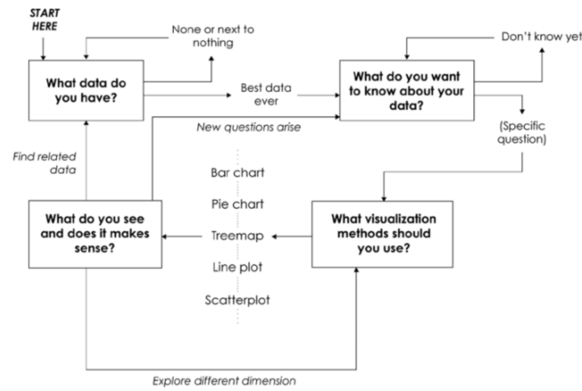


Figure 2: The iterative data exploration process [6]

Spatial data allows many possibilities:

- Map with points
- Map with dot
- Map with colors
- Map with lines
- Map with bubbles
- Choropleth

To wrapping up the previous part, choosing the right charts to tell data story is the most important step in the visualization. The user must pick the best charts to represent the data.

A successful visualization is the one that let data speak for itself and deliver the message hidden in the text or over numbers(Figure 3).

In his survey [1]; the author classified visualization tools based on three factors:

- data types
- visualization technique type
- Interoperability

The data types can be as:

- univariate data
- multi-dimensional data
- texts and hypertexts
- hierarchical and links
- algorithms and programs

Visualization techniques can be elementary (line graphs, charts, bar charts) or complex (based on the mathematical apparatus); Ekaterinalisted in his survey [1] many types as:

- *2D/3D standard figure* (figure 5) as bars, line graphs, various charts, etc
- *Geometric transformations* [8] (figure 6): it represents information as scatter diagram
- *Display icons [9] (figure 7)*: it shows the values of elements of multidimensional data as images, the images can be human faces, arrows,stars…etc.
- *Methods focused on the pixels[10]* (figure 8) for Recursive templates and cyclic segments
- *Hierarchical images [11]* (figure 9) it used for hierarchically structured data.

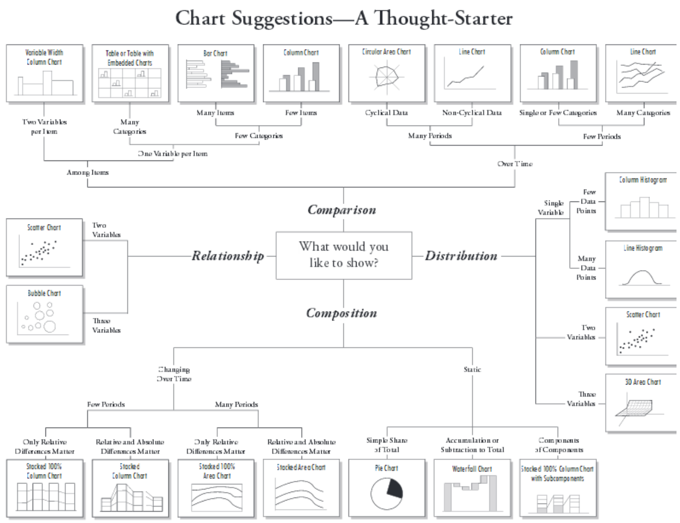


Figure 3:

The interoperability with visual imagery and data analysis techniques is the third factor. Visualization methods should extract the essence of data by the most appropriate visual forms.Diversify visualization angles to allow the user to have different visual points of view that must be considered. In this way; the author enumerated several notions:

- Dynamic projection [12]
- Interactive filtering [13]
- Scaling images [14].
- Interactive distortion [15]
- Interactive combination [16, 17]

III. BIG DATA ANDVISUALIZATION

The first section summarizes the most used data visualizations methods.

In this section, we highlight a trend term that is big data, and we discuss on how the visualization can be helpful to analyze a large amount of data.

A. Big Data Overview

Day after day, the Data in our world grows exponentially; human behavior, astounding information, variety details are captured, collected, and stored to be analyzed. The large volume of data; whether structured or unstructured that inundate the world is the phenomenon of big data. However; the quantity is not the most important; it is what organizations do with data to be developed and enable its success.

According to S.SAGIROGLU and D.SINANC[18], Big data is a term for massive data sets having ample, more varied and complex structure with the difficulties of storing, analyzing and visualizing for further processes or results.

The next part describes some processing methods for big data analysis and the importance of data visualization in data analysis.

B. Big Data Visualization

In his paper [1]; he listed the big data processing methods including applied mathematics, statistics, computer science and economics.According to the authors[1]: “those are the basis for data analysis techniques such as Data Mining, Neural Networks, Machine Learning,”Signal Processing and Visualization Methods Those methods are interconnected and firmly connected to each other as presented in figure 4[1].

The visualization is an important part of Big Data Analytics. Intuitively, the visual representation is more likely to be accepted by a human in comparison with unstructured textual information. However many companies and open source projects see the future of big data analytics via visualization [1].

According to Mordor Intelligence [19], the data visualization applications market “*is currently valued at USD 4.12 billion and is expected to grow at a CAGR of 9.21%, to reach USD 6.99 billion by the end of 2022*”. According to the IDG Research study that listed in the SAS white paper [20] “*98% of the companies that using effective big data use data visualization for analysis*.”

In his book [21], Simon shows that Amazon, Twitter, Apple, Facebook, and Google use data visualization to improve decision into their businesses.

For this reason, it is necessary to develop big data visualization methods to better understand and presentcomplex data.

Face to this undeniable challenge; many reputed groups, designers, are focused on how to improve visualization tools and establishing new interactive platforms .in his paper [22],Husain provides a list of recently developed and powerful visualization tools,platforms, and API.

Many Eyes [23] enables users to upload their multivariate data, generate graphical displays and engage a broader audience.It is an IBM project.

Socrata [24] is an open source project that enables the servicing and sharing of dynamic data from public, government and private organizations.

D3 [25] is a modern JavaScript library ubiquitously used for developing dynamic data visualizations

D3[26] is short for “Data Driven Documents forJavaScript” is an open source library that can render amazing charts out of various data sources usingHTML, SVG, and CSS. This library respondsadvanced visualization need with complex data sets andallows smooth interaction and sharing.

Cytoscape[27] is an open source software platform. It is most commonly used for bioinformatics, but it can be used to visualize and analyze network graphs based on the nodes and edges.Cytoscapeis available as a stand-alone desktop application and a webapplication.

Tableau [28] is commercialdata visualization platform for interrogating complex, structured/unstructured, multi-source data.Tableau[28] offers many advantages as drag and drop and real-time interaction with different types of visualizations (graphs, charts, maps, etc...). It also allows web embedding and team collaboration.

International Business Machines (IBM) Software [29], Microsoft [30], Amazon [31] and Google [32] are commercial Big Data platforms;

As this topic is not a main subject of the paper, this list is not exhaustive.

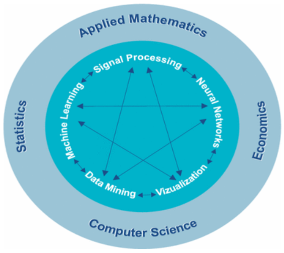


Figure 4: Big Data processing methods interconnection

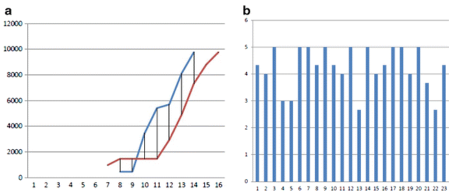


Figure5:An example of the 2D/3D standard figures visualization techniques. (**a**) The simple *line graph* and (**b**) example of a *bar chart*

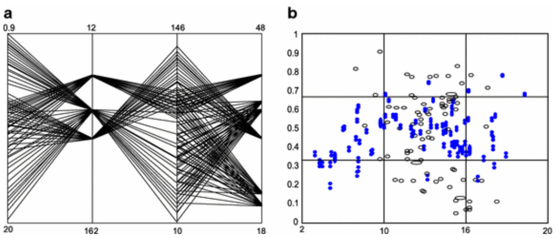


Figure 6: An example of the geometric transformations visualization techniques. (**a**) Example of parallel coordinates and (**b**) the scatter plot

Figure 7: An example of the display icons visualization techniques

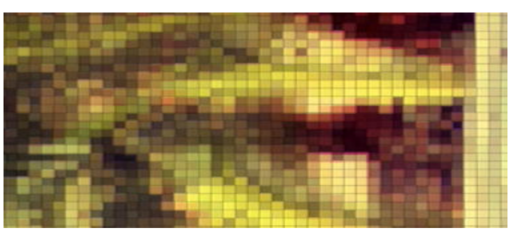


Figure 8: An example of the methods focused on the pixels.

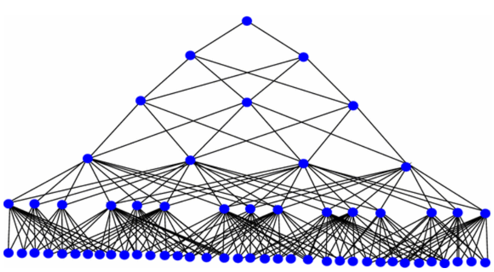


Figure 9: An example of the hierarchical images. Picture illustrates a tree map of data

C. Big data visualization challenges

The graphical representation of a large amount of data is not trivial, in his survey [33]; the author cited some problems that can be meted in Big data visualization:

1) Visual Noise: presenting a whole of data sets that are related to each other can be a mess on the screen, the data visibility can be lost face to this phenomena.

*2) Large Image Perception:*To solve the above problem; an approach of distributingdata above large screen: this generated another problem which is large image perception. The human perception is limited. As seen the graphical representation is not only limited by device screen; but also by the human perception.

3) Information Loss: the data aggregation and filtration areother approaches proposed to reduce the number of visualized points. This waycan be useful to solve the above problem, but it can mislead the user by hiding impressive sets.

*4) High-Performance Requirements:*The listed problems become harder when the visualization is dynamic. Display a whole of data can be Costly in terms of time and resources

5) High Rate of Image Change: the number of data changes and its intensity on display cannot be controlled by the user.

The authors [34] cited more challenges of big data visualization such as perceptual and interactive scalability.

In summary Big Data due to its various properties like volume, velocity, variety, variability, value and complexity put forward many challenges.

D. Big data visualization methods

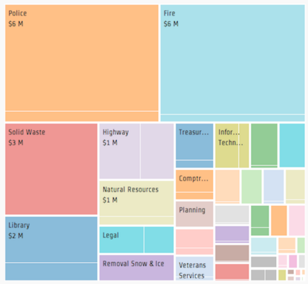
The data amount and complexity are in a continuous increasing, the need to accompany this change also growing: the traditional data visualization methods are inadequate to present big data. The development, improvement, and optimization of the tools and methods that can solve the challenges of the big data visualization can bring enormous benefits to analysts.

Representing data as patterns and forms is of paramount importance for Big Data interpretation, as already discussed the visual perception is more likely to be accepted by a human in comparison with unstructured textual information.However, the perception is limited,especiallywhen it is presented as a significant amount of numerical or text data.

Big data visualizations approaches can be performed through[33]:

- More Than One View per Representation Display
- Dynamical Changes in Number of Factors
-Filtering: such as dynamic query filters, starfield display, and tight coupling.

In this section, we list some big data visualization methods as described and classified in [34] considering the following data criteria: (1) large data volume, (2) data variety, and (3) data dynamics.



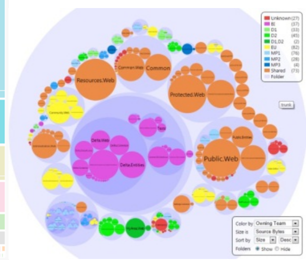


Figure 10: TreeMap exampleFigure 11: Circle Packing example

Figure 12: Sunburst example.

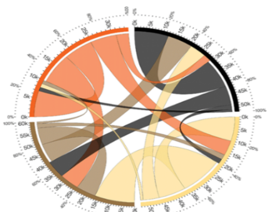


Figure 13: Circular Network Diagram

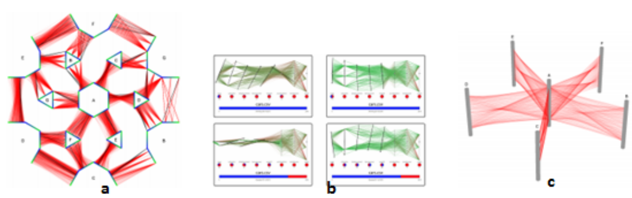


*Figure 14: (**a**) Many-to-many relational coordinates (**b**)Force-directed parallel coordinates (**c**)3D multi-relational parallel coordinates*

TreeMap [35]: is represented by a root rectangle, divided into groups, also represented by the smaller rectangles(figure 10), which correspond to data objects from a set [35].This method of visualization is used for hierarchical data two-dimensional.

The treemap method can be applied to large data volumes; iteratively representing data layers for each level of thehierarchy. This method satisfies the large data volume criterion. However, the method can only show two data dimensions presented by size and color shapes. And the data representation appears at one moment in time. So the criterion data variety and dynamicity are not met in this method.

Circle Packing: it is an alternative to Treemap that uses circles instead of rectangles.

The Primitive shape is a circle; which can include circles as presented in the (figure 11).The most advantage of this method is the possibility to place and percept a lot of objects with many levels of hierarchy. The area of each circle presents an attribute such as quantity. Color may be used to present the second fact. This method looks more beautiful, but it is not as space-efficient as a Treemap, as there is a lot of empty spaceswithin the circles.

Sunburst: This method is a directive of treemap: it converted to apolar coordinate system (figure 12). It is more flexible and allows repaint the whole diagram by changing the radius and arc length. Thanks to this property; this method can quickly show data dynamics using animation. It allowsunderstanding large amounts of data usingefficient and intuitive graphic [36].

Circular Network Diagram (chord diagram visualization) [37]:thischart visualizes the inter-relationships between entities(figure 13). Data object are placed around a circle and linked by curves based on the rate of their relativeness. Color can be used to group the data into different categories, which aids in making comparisons and distinguishing groups.

So, this method directly links several objects and shows how relative it is.It is an elegant and compact way to show networks of relations between items such as products, individuals or groups.

Parallel Coordinates: as defined in the paper [38] "*is a widely used visualization technique for multivariate data and high-dimensional geometry*."It has been a popular visualization technique for multivariate data [39].

This method allows the presentation high-dimensional geometry of data. Thefirst criterion is met.

2D parallel coordinates method only allows the identification of relationships between adjacent axes [40] that is why many approaches have been proposed (figure 14):

Methods that keep 2D parallel coordinates and arrange the axes to show the relationships or to reduce clutter.

Techniques that extend parallel coordinates from 2D to 3D to show many relationshipssimultaneously.

Streamgraph:as defined in[34] is a "*type of a stacked area graph, which is displaced around a central axis, resulting in flowing and organic shape*."

Series of similar events are displayedin thetimeline. The first world war is abstracted using this method by Abi-Haidar[41]. Unstructured text is supported by this method.

This method supports one datadimension,but it can be applied to large data [33].

E. Other Approaches

The new approaches to big data visualization tend towards simplification and improvement in forms of images, diagrams or animation [1]. In this vision, the author presents techniques to better present big data.

1) *Tag cloud*:also called word cloud, this technique is used to visualize text analysis;word, size, color and position indicate characteristics of the word: frequency or prominence:
The perception of the most prominent terms in the text is faster using this method (figure 15).

2) *Clustergram:*this graph is used in cluster analysis for non-hierarchical clustering algorithms like k-means and hierarchical cluster algorithms when the number of observations is large[42].

3) *Motion charts*:It is a dynamic bubble chart which allows active exploration of large and multivariate data and interacts with it (figure 17). These tools:Google [32], amCharts and IBM Many Eyes provide motion chart.

4) *Dashboard* [43]:This technique allows visualizing server logs in real time(figure 18).Log files can be of various formats.The dashboard consists of three layers: data (raw data), analysis (includes formulas and imported data from data layer to tables) and presentation (graphical representation based on the analysis layer).

Figure 15: An example of the tag cloud.

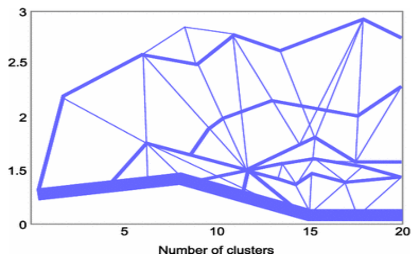


Figure 16: An example of the clustergram

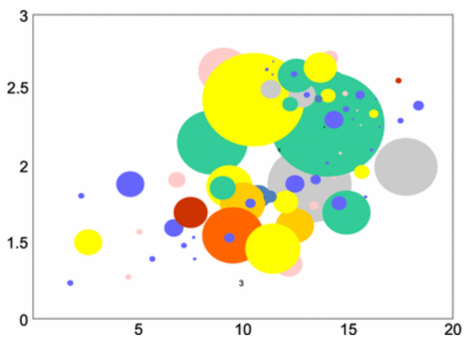


Figure 17: example of the motion chart

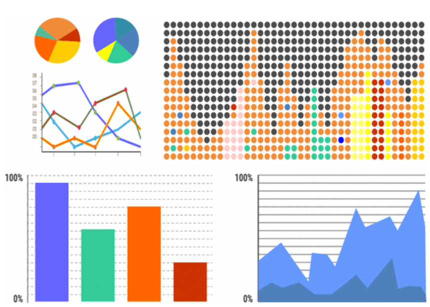


Figure 18: example of the dashboard

IV. Data Visualization Design

The first section provides an overview of Data Visualization and looks at currently used methods for presenting different types of Data. The second section indicates the main challenges and issues in Big Data Visualizationand provides some approaches to master them.

In further section: a brief background of the importance of visual perception is given. Color importance and techniques of choosing color are discussed.

A. Visual Perceptions:

The information is very dependent on the way in which it is presented[44]. Human being tends to comprehend visual information quicker than raw data is very true, but this does not mean that all visualizations are understandable with the same degree [45].

On the other hand, Christopher *g. Healey[46]* explains that we can improve the quality and quantity of displayed information by perception understanding.

Authors in their paper[47] suggest that hard efforts are madein recent years to benefit from human visual perception properties in visualization design.

On the other hand; many research works have shown that "*a limited set of visual properties that are processedpreattentively"*[48].*Preattentive*properties or features offer various benefits with little effort.

Healey[49] cites some advantages ofpreattentive features as

-speed: preattentive tasks can be performed in 200 milliseconds

-independence of the size: time needed to carry out apreattentive task is not dependent on display size.

The following table (Table 2) lists some preattentive features and provides references that describe the tasksthat can be performed using these features [49].

Feature	*Author*
line (blob) orientation	Julész & Bergen (1983); Wolfe (1992)
length	Triesman & Gormican (1988)
width	Julész (1984)
size	Triesman & Gelade (1980)
curvature	Triesman & Gormican (1988)
number	Julész (1985); Trick & Pylyshyn (1994)
terminators	Julész & Bergen (1983)
intersection	Julész & Bergen (1983)
closure	Enns (1986); Triesman & Souther (1986)
color (hue)	Triesman & Gormican (1988); Nagy & Sanchez (1990); D'Zmura (1991)
intensity	Beck et al. (1983); Triesman & Gormican (1988)
flicker	Julész (1971)
direction of motion	Nakayama & Silverman (1986); Driver & McLeod (1992)
binocular lustre	Wolfe & Franzel (1988)
stereoscopic depth	Nakayama & Silverman (1986)
3-D depth cues	Enns (1990)
lighting direction	Enns (1990)

Table 2: Lists of preattentive features and references that describe the tasks that can be carried out using these features.

The next topic discusses a color feature and how it can be used to perform data visualizations shapes.

B. Color: Overview and importance

Color plays asignificant role in the daily life; people make a hard effort to surround their entourage with the colors [50].It impacts emotions and impacts performance [51]

Color enthralls the life:it used in many disciplines like science and engineering not only for aesthetics reasons but also for effectiveness.

In the data visualization; Color is a powerful and often-used visual feature [50].

Color can be an illustrative and informative in data visualization. For this reason, the specialists are quite cognizant of the importance to work on algorithms and rules that orient designer for efficient design [47].

Each method of the data visualization already listed in the previous parts uses colors to become more ready, faster to understand and to memorize.

Netflix [52] is a highly successful organizationwith 48 million subscribers and a market cap of nearly $26 billion. It has utilized color analysis in digital video/ image to catch more and more users (figure 19).

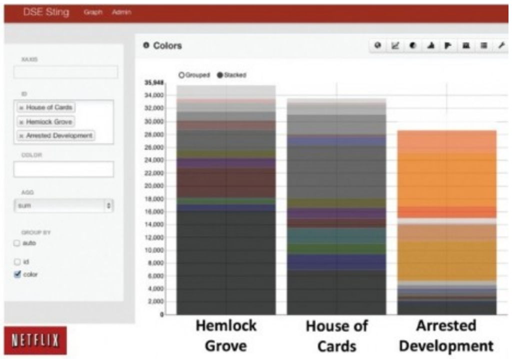


Figure 19: Detailed *Color Comparison of Hemlock Grove, House of Cards, and Arrested Development [53].*

1) Color Design Background

In this section, we define most common terms used in color design.
The color is specified by three dimensions:
Hue: is the color's name, such as red, green or orange. We distinguish three types of colors:primary, secondary, tertiary
Value: is perceived lightness or darkness of the color.
Chroma: describes its colorfulness; High Chroma colors are vivid or saturated, little Chroma colors are grayish or muted [54].
The hue dimension is circular, typically drawn as a hue circle (Figure 20).

Figure 20: Example of hue circle [54]

In color design we distinguish two different terms:
Contrast: contrasting colors are different, and opposites and contrasting hues are on the opposite side of the hue circle.
Analogy:analogous colors are similar; and Analogous hues are close together, most simply variations of the same color name.
According to [54]; Contrast draws attention, analogy groups.
As anexample; the author shows He shows in figure 21 that the red squares catch the attention and stand out from blue-green(analogous field) squares ones.

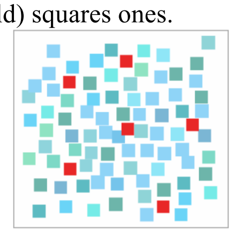


Figure 21: Contrast and analogy. The red squares contrast with the analogous blue-green ones.

On the other hand; the term tint applies to a color that has been lightened and desaturated by mixing it with white. A tone is a color grayed and darkened by mixing it with black.

Complement colors are placed directly opposite each other on this wheel. Two balanced colorscombined will become neutral or gray [55].

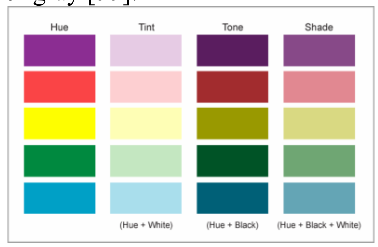


Figure 22:Tints, shades, and tones of five different colors [51]

Another term is involved when we are speaking about data visualization design: the legibility.
Legibility of data visualization is theameliorationofthe quality of being bright enough to read.The issue of legibility comes in data visualization when complex small shapes are used [56]
Many factors impact the legibility in data visualization as a font text,fond contact, and spacing[56].The difference in value between the symbol (text,line, etc..) and its background determines the legibility [54].ThoughHue and Chroma do not contribute in the legibility,whilethe luminancecontrast does.

C. Color selection

1) ColorBrewer

Many color palettes and algorithms for color choosing are developed recently. This topic receives attentionincreasingly because as cited byStone [51]"*A color used well can enhance and clarify a presentation. A color used poorly will obscure, muddle and confuse"*.
To select the right combination of a palette; users refer to many available palettes as *ColorBrewer***.**
ColorBrewer[57] is an online tool that helps users to choosethe appropriate color.It contains 35 colors sets divided into three groups: qualitative, sequential and diverging [57].
Sequential Color Schemes (figure 23-a): it can be presented by one singlehue (6 availableschemes) or multi-hued (12 6 available schemes).
Diverging color schemes (figure 23-b):as explained in his paper [57] this type"*should be used when a critical data class or breakpoint needs to be emphasized.*"Diverging schemes are always multi-hue sequences.
QualitativeColor Schemes (figure 23-c): for a successful presentation of qualitative schemes it must vary hue and keep saturation and lightness constant

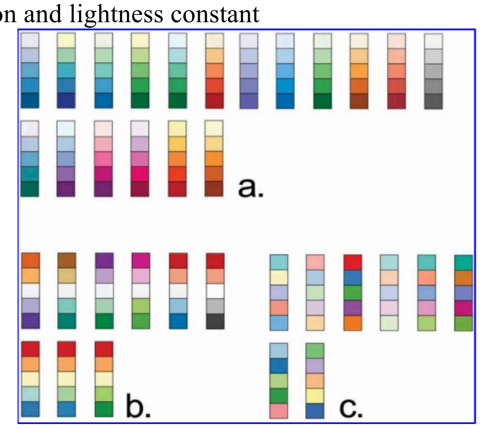


Figure 23: ColorBrewer contains 35 color scheme sets. (a) sequential, (b) diverging and (c) qualitative [57].

2) Color harmony

Cohen [58] defines Color balance as is sets of two or more color relationships that areaesthetically pleasingto theeye.
In 1960, the Art theorist Johannes Itten [58] created a new type of color wheel to construct 26 harmonic colors. The harmonious colorsare described by their relative positions around the color wheel as described in (figure 24).

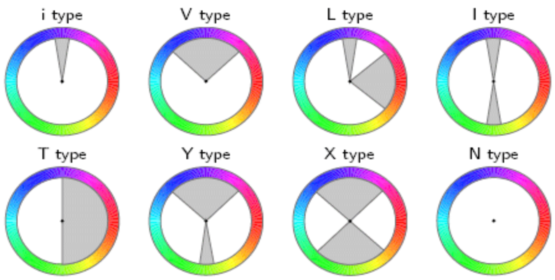


Figure 24:Color Harmonic Templates on the Hue Wheel

V. Conclusion

Data Visualization is an essential tool for making sense of big data. It provides large and bright views to big data than can be obtained from tables and statistics alone.
Improving data visualization methods is the key to the benefit of the richer of big data. The new data visualization methods must go far to let users better understanding and complete view of the data.
In this paper, we have invested to classify the data visualization methods according to many factors.
As we disused many methods are improved, and some others are developed to respond to big data challenges.
Moreover, the study extends to obtain relevant color rules used to improve the big data visualization.
The right choice of these corresponding elements will make a successful visualization.
The purpose of this paper is to prepare a background to develop a datavisualization tool for the XEW [59]platform and extend XEWgraph[60].

Appendix

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