UNIVERSITY OF WALES: TRINITY SAINT DAVID - SWANSEA METROPOLITAN

Cartogram Generator for Wales

Implementation and investigation comparing graphical illustration and dry data

by

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A project submitted in partial fulfilment for the degree of B.Sc.(Hons) Software Engineering

in the

School of Applied Computing

Faculty of Architecture, Computing and Engineering

8th January 2017

Declaration of Authorship

I, Hasan Khan declare that I am the sole author of this Project; that all references cited have been consulted; that I have conducted all work of which this is a record, and that the finished work lies within the prescribed word limits.

This work has not previously been accepted as part of any other degree submission.

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Abstract

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The aim of this paper was to report a study investigating the effectiveness and efficiency of graphical illustration with non-contiguous cartogram of Wales, compared to reading dry data. A web based application was developed, black box testing was undertaken for the functions of the application itself, followed by a survey questionnaire for gathering data on user's conciliation.

There was significant differences in people's responses choosing between cartogram and dry data. Overall, the results suggested that the graphical illustration is more appealing then reading the dry data. However the depth testing for the counties during implementation was a little conceded, when a different approach to use CSS transform was taken, implementing a new distorting algorithm in JavaScript.

This issue was identified by the participants, but the cartogram still remained more effective. Better map distortion was recommended using WebGL and addition of features using CSS animations.

Acknowledgements

Tim Bashford, my project supervisor.
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Chapter 1

Introduction

In a production perspective, visualisation is a new form of data representation. Although, the beginning of visualisation can be traced 5000 years ago when mapping was recognised as an important asset in human lives. This technique has been used in producing maps, data plotting for years and this goes back before the birth of Christ, simple sketches on clay tablets by the Babylonian, work by the Egyptians to mark property boundaries, the map of China on silk.

This art of mapping was used by the Greeks and Romans when Claudius Ptolemaeus's written work Geographica, which contained several references of mapping of the world with latitude and longitude lines. This was a revolution for the European geographic rational as it bought in mathematics in the design of maps.

FIGURE 1.1: Claudius Ptolemaeus projection [1]

1.1 History Of Mapping

Ptolemaeus's work [18] continued to be of great importance for the European and Islamic scholars into the Renaissance (1500s).The science of geography and maps progressed in the Arab countries during the middle ages. Around 1154, Al-Idrisi, an Arab scholar [19] composed a number of geographic books and it is believed his work on world maps was extensive for generations of map makers in the Islamic world based on his ideas. All along the Renascence era the Europeans discovery of the Americas resulted in great interest in distant places and migration, public learning and research establishment of institutions such as the French Academy of Science in 1660, all this led to expansion of geography and mapping. In late 1770's a theme started to appear, data were used to log particular occasions like site of illness or floods etc.

Overs the ages, the complexity and accuracy of producing maps has manifold, particularly as understanding of the Earth, mathematics and geography has expanded. Using modern satellite systems and surveying manners, today's cartographers are now able to measure and map with very high fidelity and solidity. Correspondingly, maps have become absolutely critical to most fields of human endeavour. The modern study of visualisation prompted with the idea of computer graphics and this was used for research of scientific problems.Later the attention towards computer aided visualisation was initiated in 1987 from the publication of Scientific Computing. Since than on IEEE computer society and ACM has co-sponsored many workshops and meetings.

1.2 Today's Visualisation

Visualisation is the technology [20] which lets corporate chiefs and many end users see, help understanding the connotation of data by placing it in a visual conditions. Patterns, trends and alternations that might go unexplored in text-based data can be exposed and recognised easier with data visualisation. Today visualisation has come a long way, around 1990s the potential combination of enhanced computer power, inexpensive memory, improved display resolution and quick interaction had lead to development of data visualisation tools and the earliest example of such advanced tool is Dynamic Queries.

FIGURE 1.2: Tree map visualisation [2]

Chapter 2

Literature Review

2.1 Visualisation tools

Visualisation mechanisms governs to a vast latitude of revenues which are accessible for the users which allows to analyse, manipulate and view compound data and information. It is the concept of converting statistical or historical data to graphical observation for the audience. Graphs, charts, maps comes in the form of presenting the tabular information to visuals image, making it easier for the user and the audience by not looking into dense lists of facts and figures which will promote data driven decision making

2.1.1 Data Visualisation

The availability [21] of these mechanisms are costless for the end users which can be to produce nice and admirable graphical delegation of the data that has been inputted. Today's tools go beyond charts and graphs from Excel spreadsheets [22] , use of info graphics spark lines, heat maps, pie/bar charts [23] [24].

2.1.1.1 Pie Chart

Pie chart is divided into sectors where it illustrates the arithmetic depth, the arc width of one sector represents the volume quantity of the whole. They are very much used in the business world and the mass media but, they have been reprehend and experts advise to avoid them, research has shown it is difficult to compare sections of a pie chart, even comparing data with different pie charts.

2.1.1.2 Bar Chart

An alternative to pie charts are bar charts. Bar charts represents data in a graph like charts with rectangles, the length of each rectangle is reciprocal to the value. Bar chart have a diverse range and they usually represent categorical data into several groups, for example, months of the year, age,sizes etc. these categories are usually qualitative.

2.1.1.3 JMOL

JMOL which is an open source viewer for chemical molecular structures in 3D [25], used in Chemistry and Biochemistry. JMOL's graphics engines are written in Java language with no Java3D, OpenGL or any type of hardware acceleration.This graphics engine is special, not a general purpose 3D graphics library. The rendering engine was built especially for exhibit molecules, overall JMOL does a favourable job in outlining spheres and cylinders

2.1.1.4 Gap-Minder

GAP-MINDER is used to present statistical information in dynamic ways. Founded in 2005 by Ola Rosling, Anna Rosling Rnnlund and Hans Rosling [26] to develop a software called the Trendalzyer, which is an information visualisation software to present statistics using animation. The technique used by the software is an interactive bubble chart and uses the bubble and linking techniques for displaying the numeric values of a selected country. Components of the Trendalyzer software, principally the Flash-based motion chart gadget, have become available for public use as part of the Google Visualisations API.

2.1.1.5 Google Earth

GOOGLE EARTH allows the user to view geographical information graphically through several angles and distance. GOOGLE [27] has implemented this tool with the aid of superimposed satellite imagery allows the user to import images which are public and map them geographically. Google Earth displays satellite images of varying resolution of the Earth's surface, allowing users to see things like cities and houses looking perpendicularly down or at an oblique angle, which is also called bird's eye view. The gauge of resolution feasible, is based somewhat on the points of diversion and reputation, but most land is covered in at least 15 meters of resolution.

Overall these visualisation tools gives the audience a better understanding of the raw data. If the blueprint is correct, the graphical production will capture the attention of the audience to certain points, making visualisation tools a powerful force in organisational analysis. Detailed design and coding helps business and organisations to bring more sophisticated insight to each area of the organisation. Now a days most of the software vendors code data visualisation tools in their products helping both the development of visualisation technology and businesses which specialise in visualisation.

2.2 Cartogram as a visualisation tool

2.2.1 History of Cartogram

The sixteenth century Mercator projection is probably the most widely known cartographic projection. Mercator's world map became the standard map projection for its ability to represent lines of constant course, conserve the angles with the meridians. preserving the angles and the shapes of small objects, Mercator's map went unchallenged for the next four hundred years and still used by many till the late half of the twentieth century.

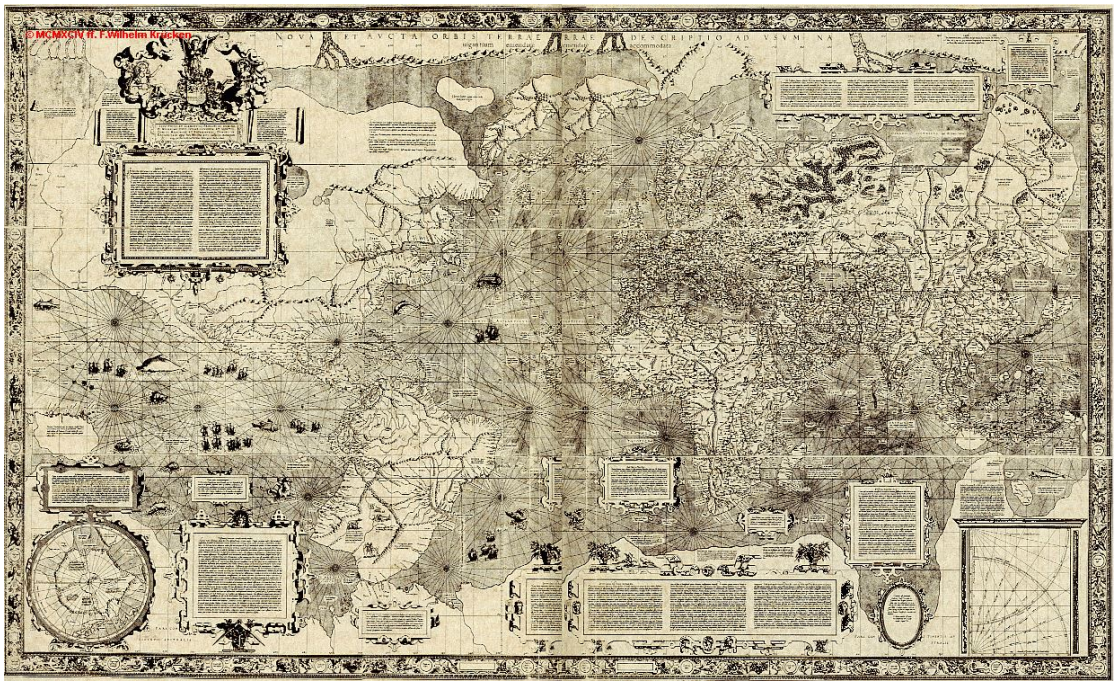


FIGURE 2.1: Mercator's world map of 1569 [3]

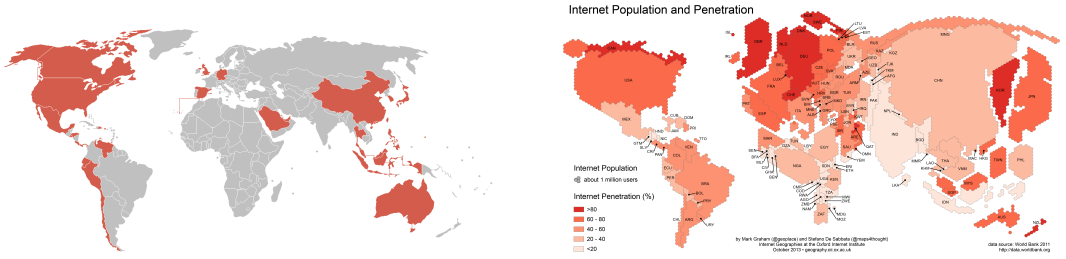
In 1974 Gall or Peter's worldview projection became famous despite not being fully accurate in terms of shapes of territories which caused controversy surrounding political implications of its design and disliking expressed by many cartographers.

2.3 What is Cartogram

Cartograms are maps on which geographic statistical information are projected and is deliberately distorted to give the territories and areas different shapes,sizes or heights to some quality of interest. Ordinary maps are in fact a form of cartogram based on equal land area. Cartograms differ from traditional maps as they use a variable other than area to derive the size of areal units on the map. A cartogram is fundamentally concerned with expressly exemplify a data set and stay true to geographic accuracy.

There are two types [28] of cartograms: Linear cartograms which are known as central-point cartograms and second are Area cartograms. Linear are typically used for show transit times, or direction say routes or cables or even in rivers. The modern London tube first build by Henry Beck in the 1930s which features the subway and straightened links between different routes and are simplifies to accommodate for information for the passengers.

Whereas the area cartogram sometimes referees as *"value by area map"* is a form of visualisation where some spatially extensive variable such as population size, disease etc. is used instead of land area. The figures or the space of the area is distorted or transformed in order to present the information of the variables. Any variation in the values ware represented by varying the size of the region in question.



(A) Normal world map [29] (B) Internet population in the world [30]

FIGURE 2.2: Normal World Map vs Countries colour according to the numbers

2.3.1 Developments of Cartogram

There is a long history to the study of cartograms [31], the Rubber map method by Waldo Tobler in 1973 after working on it for several years, came up with the first algorithm

for cartogram. Due to poor performance, large area error in 1986 Tobler came up with pseudo cartogram which reduced the area error. Since then many different algorithms have been implemented [32] for generating area cartograms. Each one transforms the area in a different way.

His way was proven to be a pre-process a map prior to cartogram construction. But this was rarely used as it produced error for extensive areas.the Density Equalised Map Projection (DEMP) algorithm [33] applies radial transformations from each state boundary and population upon all map vertices's such that the selected region distend or shrinks, leaving the area of all other regions continuing.

It can be seen from Dougeniks work [34] that even a slight alteration to a basic algorithm will produce a very different end cartogram.It can be seen from Dougeniks work that even a slight alteration to a basic algorithm will produce a very different end cartogram.

FIGURE 2.3: Tobler's pseudo cartgoram [4]

Many further attempts have been made to improve Toblers computer algorithm. Gusein-Zade and Tikunovs Line Integral Method [35] applies radial transformations such that the density of a selected cell is made uniform while leaving all other cells unchanged, with the vector sum of transformations applied as a line integral around each of the region boundaries.

Dorlings Cellular Automaton Method (Dorling 1996) is a totally different approach to constructing contiguous cartograms. The cartogram is created by superimposing a grid onto a map. This method is very effective at establishing areas accurately and fixing map

vertices's. The main disadvantage of the method is its inability to preserve shape.Regions on the cartogram tend to lose their unique contours and acquire a simpler shape reflecting the grid

Constraint-based cartogram methods by Kocmoud in 1997 [36] are more successful at preserving the distinctive shapes of nearly all the states, while still achieving a high accuracy in terms of average area error than the DEMP method. Though more area errors are generated by the constraint-based methods than by the line integral method, they are more successful at maintaining region shape and leaving the map recognisable to common users[37] .

2.4 Use of Cartograms

Making of traditional maps using manual method was daunting for anyone [38] who eager-ed to produce a cartogram would takes months. This bought on the computational demands of optimal solutions. By the end of the century led to introduction of algorithms which can cope up with iterative shifting of vertices's. Cartographers intent to produce cartograms for atlases, socio-economic data. Initially cartogram was mainly used for political and economic mapping or even for the discovery of the clustering of disease like malaria in social and enviormental mapping.

The explicit use of cartograms for social and enviormental advancement began with the work of political scientist Michael Kidron, [39] widely known as a revolutionary thinker, cartographer and joint author of the earliest of the State of the World series of atlases, initiated in 1981.Cartograms are produced for various reasons like the London underground map which help people to find their way to destination. Research has shown Cartograms are increasingly used to give and alternative base maps on which other distributions can be drawn, for example, is the disease is particularly spread in a certain area of the map. Cartogram can be used to make conventional maps like areas are coloured different according to the data to show variations.

FIGURE 2.4: Map of London Underground [5]

2.5 Classification of Cartograms

Cartogram can be divided to three types depending on their capability to visualized the variable of the geographical in formations: Non-Contiguous, Contiguous and Semi-contiguous Cartograms. They also can be visualized according to their shapes onto which each unit are distorted according to the variable values: Circular, Squared-based and Irregular.

2.5.1 Non-Contiguous, Contiguous and Semi-contiguous Cartograms

Non-Contiguous are very well known and widely used. One of its features is that the objects do not connect with each other therefore there is more space which allows great flexibility as a results it puts equal stress on every object.

Unlike non-contiguous cartogram [40], contiguous cartograms are connected and it tries to retain the topology as much as possible, thus it can be analysed easily. But, maintaining that contiguity and ensuring the size of the objects are visualised accurately leads to much distortion of the map. Thus this makes the single mist difficult problem for cartographers when constructing contiguous cartogram.

Now Semi-Contiguous cartogram is a sacrifice between keeping the objects connect and to keep their shapes simple as possible. They can maintain the shape of the topology and contiguity by avoiding overlapping between objects. The objects are moved away

a dab from their true location. A bubble chart is a good example for semi contiguous cartogram.

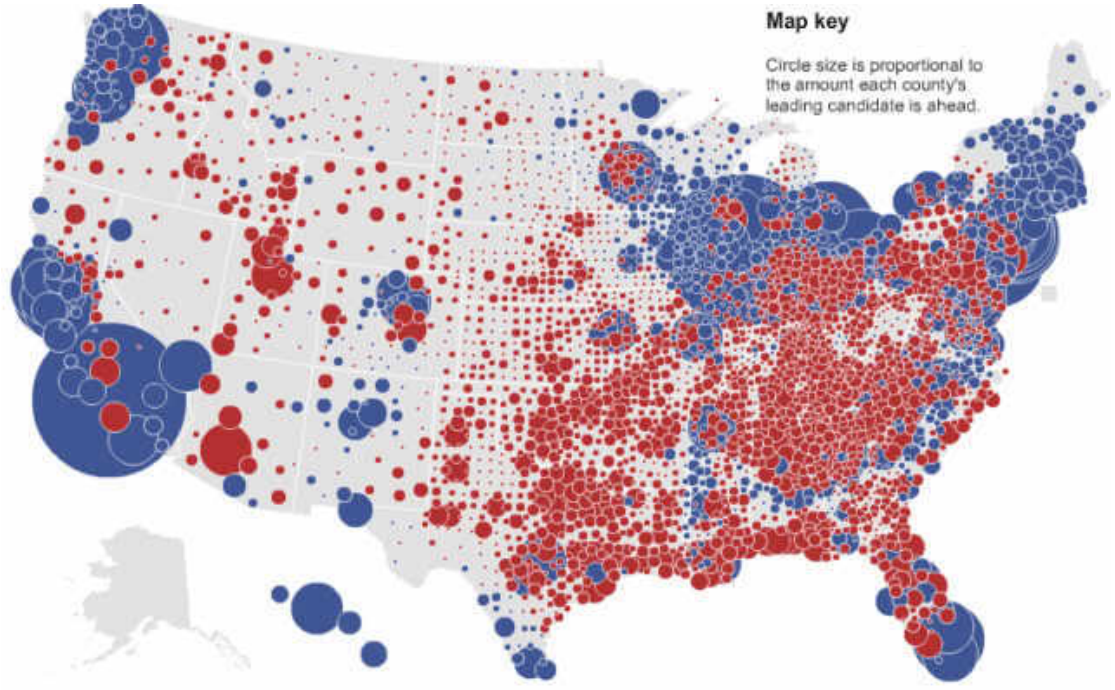


FIGURE 2.5: Bubble chart Cartogram [6]

2.5.2 Circular, Square-based and Multi-variant Cartograms

Circular cartograms are similar to bubble cartograms. One problem with circular cartograms is the gaps between the objects makes it difficult to locate the places in comparison to the traditional map.

Square based cartograms also known as Demer's cartogram [41], he first tried producing cartogram using squares in order to have fewer gaps between the objects. This type of cartograms reduces the distance but, the connection between the objects deviates more and even further from their actual location.

Cartographers will use more than one kind of symbol to produce cartogram. Multi-variant cartogram are the combination of both circle and square to visualise the data. It can be considered as cartogram as they also visualise information about a certain variable. Use of different symbols, can be useful to represent two different variables in the same cartogram. Danger is, the overlapping between the circles and the squares are makes the cartogram confusing.

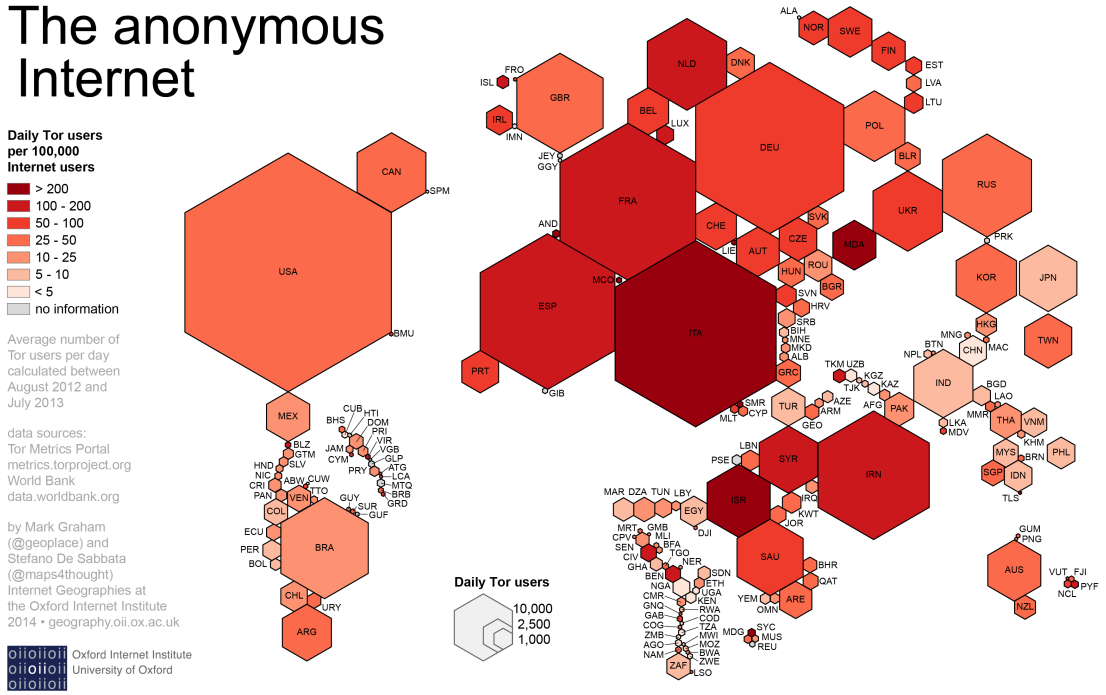


FIGURE 2.6: Hexagon shaped polygons used in a cartogram [7]

2.6 Methods of Cartogram Construction

Cartographers always have to decide how they will distort the shape of the map they have produced to show what the others wish to study from that. A frequent criticism of cartograms is that even cartograms based upon the same variable for the same areas of a country can look very different. Mapping involves making compromises between conflicting goals which result in the variety of views that we have of the world. Inevitably they alter how we see different parts of this world.

There are several methods of building cartograms.In general manual methods are useful when only a few areas are being represented, while computer algorithms have to be used to produce area cartograms of many places. Mechanical methods provided a compromise between these two options in the past.

2.6.1 Drawn by hand

As software use was not profound in the earlier times, cartographers use their hands to visualise the data and produce their maps. More and more cartograms have been drawn of countries in the world, and less detailing was put into them. A world map in which every country has been given almost equal prominence. At first glance this rather

appears to be pointless as it contained less information compare to a conventional map of land areas . However the important use of a cartogram is not to visualise a single statistic. It is often use as a base map upon which several other statistics can be drawn.

2.6.2 Physical Accretion Models

The term "Physical Accretion Models" was first introduced by John Hunter and Jonathan Young [42] in 1964. This was the first approach taken by them to introduce cartograms for British election and the results were published in The Times newspaper in 1964 and 1966. The meaning of this term is to construct cartograms by using wooden tiles and rearranging them by hands.

For old countries like England and Wales [43] a total of 9214 wooden tiles were painted with 62 different colours to produce a cartogram of 2.4 square meters. This took around 16 hours and mostly involved to maintain the shape of the prominent features such as estuaries, contiguity and population proportion. During the construction of this cartogram using wooden tiles and different colour Hunter and Young used to begin their work starting from London

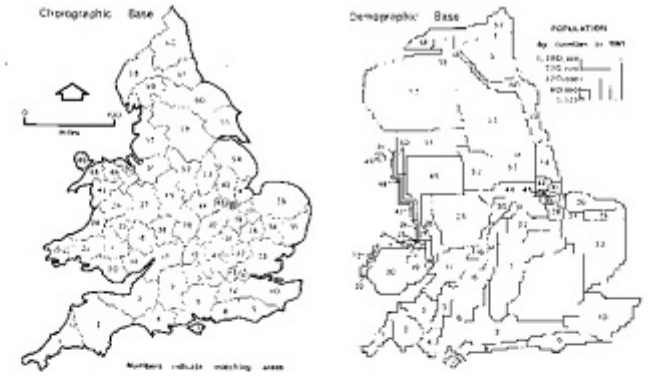


Figure 4c : Map and 1961 population cartogram of England and Wales (Hunter & Young, 1968: 403).

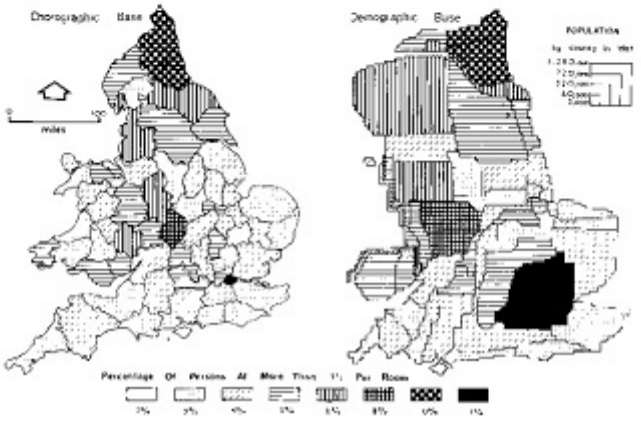


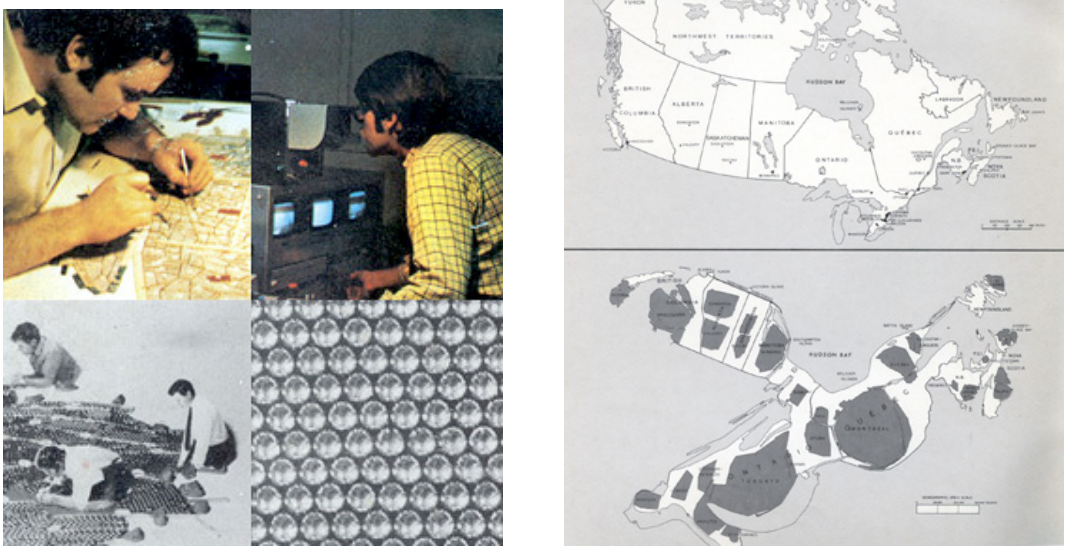
FIGURE 2.7: Hunter and Young projection using Physical Accretion [8]

2.6.3 Mechanical Methods

Only a year after of Hunter and Young's accretion models a paper [44] was published which talks about the method of mechanical cartogram for visualising the population. In 1972, this method was used by Skoda and Roberston in order to produce a map of Canada using the 1966 census divisions with their areas proportion to population.Skoda and Roberston using 265000 steel ball bearings and each with a diameter of one eight of an inch. Each bearing represents 140 people in the map and these bearing were pored into the land areas which were made out of aluminium strips. The ball bearings were weighted rather than counted and the model was put together on several five meter plywood boards surface with fromica.

This method raised much interest in urban geography in the early 1970s. Cartogram radically changed people's views of the world and how it was being exposed in some detail. But only little evidence is there on use of cartograms for social and economic data

visualisation. After five years, Canadian cartographers started to produced cartogram for general elections using equal land area projections.



(A) Skora and Robertson using bearing balls (B) Skoda and Robinson's cartogram

FIGURE 2.8: Mechanical Method [9]

2.7 Computer Algorithms

A good area cartogram will maintain the topology of deformed areas while preserving the regional boundaries so that the map can still read correctly. Attempts of using Algorithms for generation cartograms are now widely preferred and presents anew approach on reformulating the cartogram construction as a constrained optimisation problems.

The production of a cartogram is actually a map deformation problem. The intention of an algorithm to generate cartogram is to equalise density across space with given geometric boundaries and density values associated to spatial partitions delimited by these boundaries. But, there is no individual key to this problem, there are certain stand-alone programs that implement several of these algorithms. These programs are nevertheless limited to only one polygon layer at a time and no real constraints help the user with the deformation control for a given object

2.7.1 Latest techniques and features of Cartograms

The methods discussed above has been used for for a while but several research and developments went on to further improvements and finding new algorithms. Dorling's Universal Data Map and Gastner and Newman diffusion based cartograms are two good examples of modernisation. The former ways are simple and give good results but the latter ones are based on the ideas of diffusion principle and apply distortions which gives a new way if looking at data in cartograms [32].

2.7.2 Universal Data Maps UDM

[43]Population cartograms or also known as Universal Data Maps UDM which is designed by Dorling and Durham for visualising census data using spread sheet. The fundamentals of this design is that the geographical area is represented by a cell in Excel spreadsheet in which each cell is proportional to the size of population of that certain area.

One problem with this method, when the splitting of cells are needed it as almost impossible for building another geography. The cells will be assigned to areas with higher population and this will lead to less accurate representation of real population within the objects. Dorling and Thomas have recently redesigned their methods by using hexagons as a substitute instead of using cells in spreadsheet.

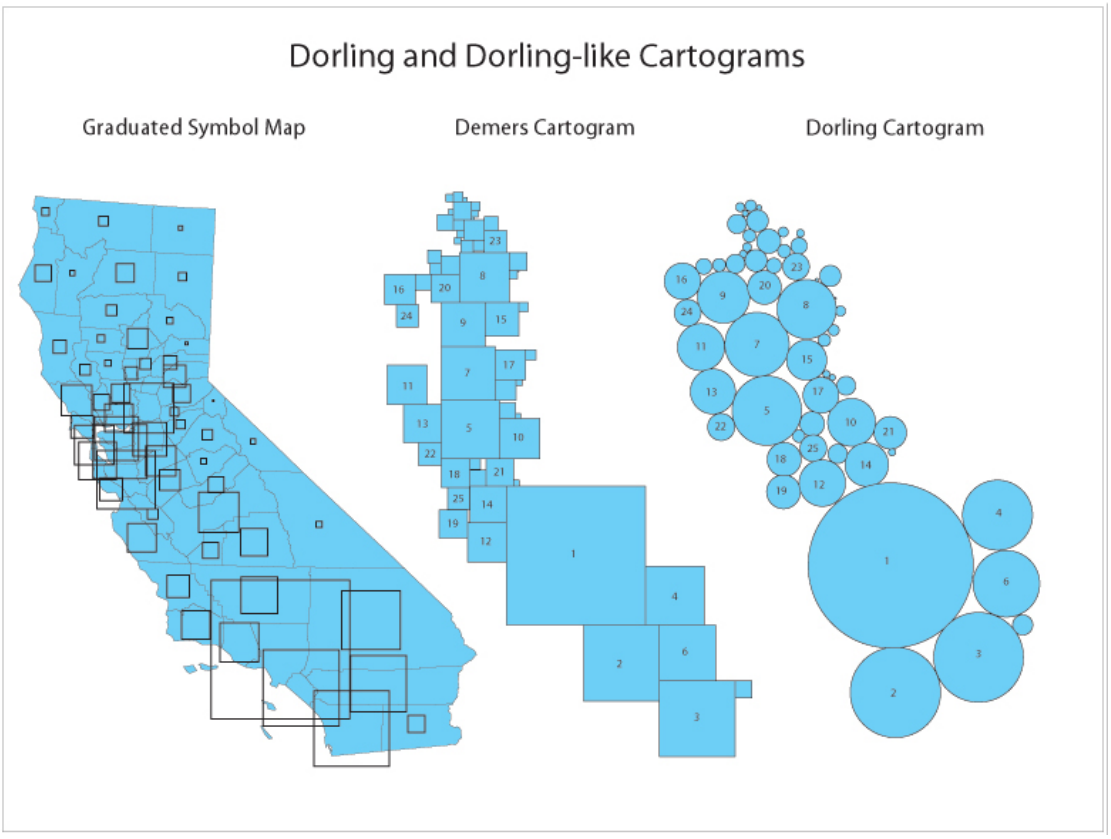


FIGURE 2.9: Dorling like cartograms [10]

2.7.3 Diffusion based Cartograms

The idea of diffusion came up due to a simple observation, population needs to be uniform in a true population cartogram. When the area has been scaled to the proportion to the population of that specific area, the density pf population is the same everywhere. The definition of Diffusion in general is, the movement of particles form a region of higher concentration to a lower of lower concentration.

Diffusion cartograms follows the same principle. Given a particular population density, which is allowed to move from higher density areas to a lower density ares until it is equalised everywhere. The process was achieved by diffusion process.This method of linear diffusion came up by Gastner and Newman in 2004 (which will be discussed in a later section)

One advantage with this process, it gives an accurate visualisation of the variables in a cartogram and looks good graphically. But some of the cartographers don't agree on how Gastner and Newman's diffusion process visualise *(see Appendix B)* the boundaries everywhere. They say, it is most popular because of it is easy to do automatically. Cartograms cannot work if people cannot recognise the geography . If the shapes are

longer/ bigger than the viewers can figure out what is where and how much it is made longer or bigger a place than they expect.

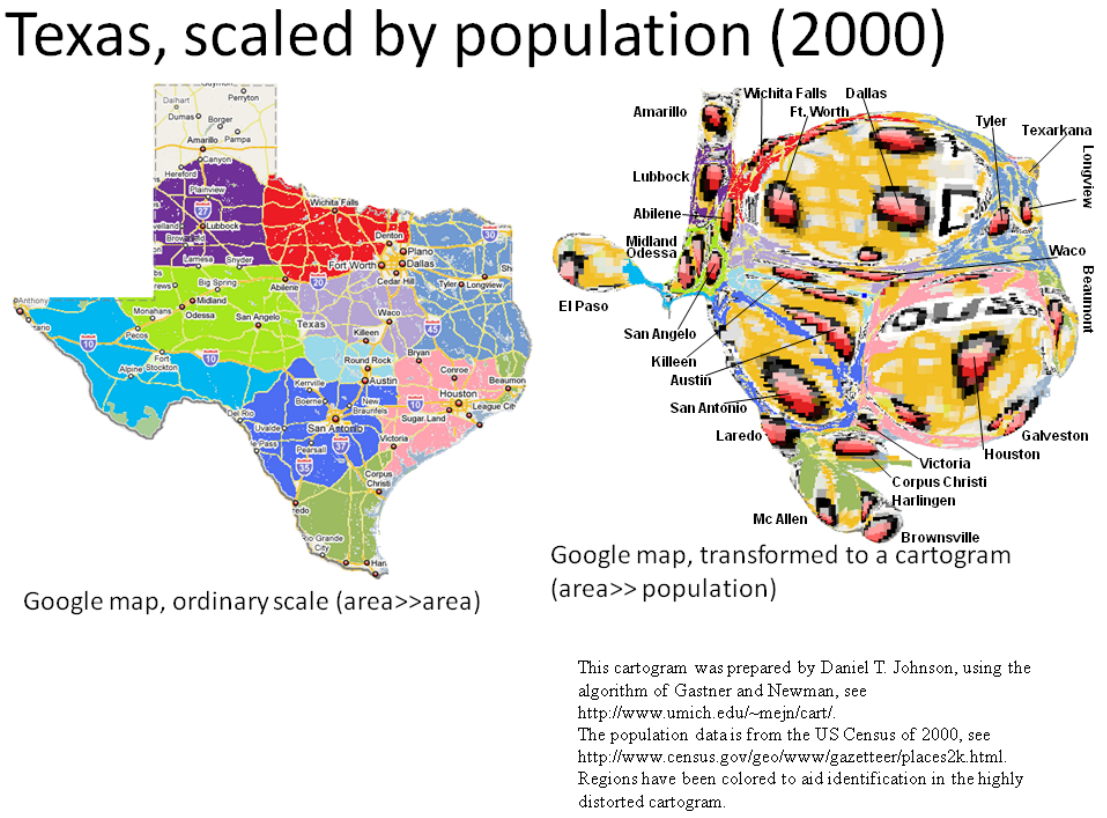


FIGURE 2.10: Diffusion based cartogram [11]

2.7.4 Scan-line based Cartograms

After the introduction of Diffusion based cartogram in 2004 , a successful project [45] also emerged in that year. An algorithm [46] to construct area cartograms which mainly concentrates on keeping the cartogram recognisable for the viewers as it deal with some of the problems which continuous cartograms faces, the restriction of maintaining the area (polygon mesh) topology.

Scan based cartogram was invented by German's CartoDraw project team (Keim 2004). This algorithm uses an iterative relocation of the vertices's based on a modified medial axes transformation of the polygon mesh (which will be discussed in a later section). It is extremely difficult to describe how the computer algorithm acts to make these cartograms form. What really matters is that the Scan-line-based algorithm was designed to preserve the direction and topology of areas in order to keep the map recognisable. Several cartograms were produced using this method and most common ones are based on age, sex, disease variables.

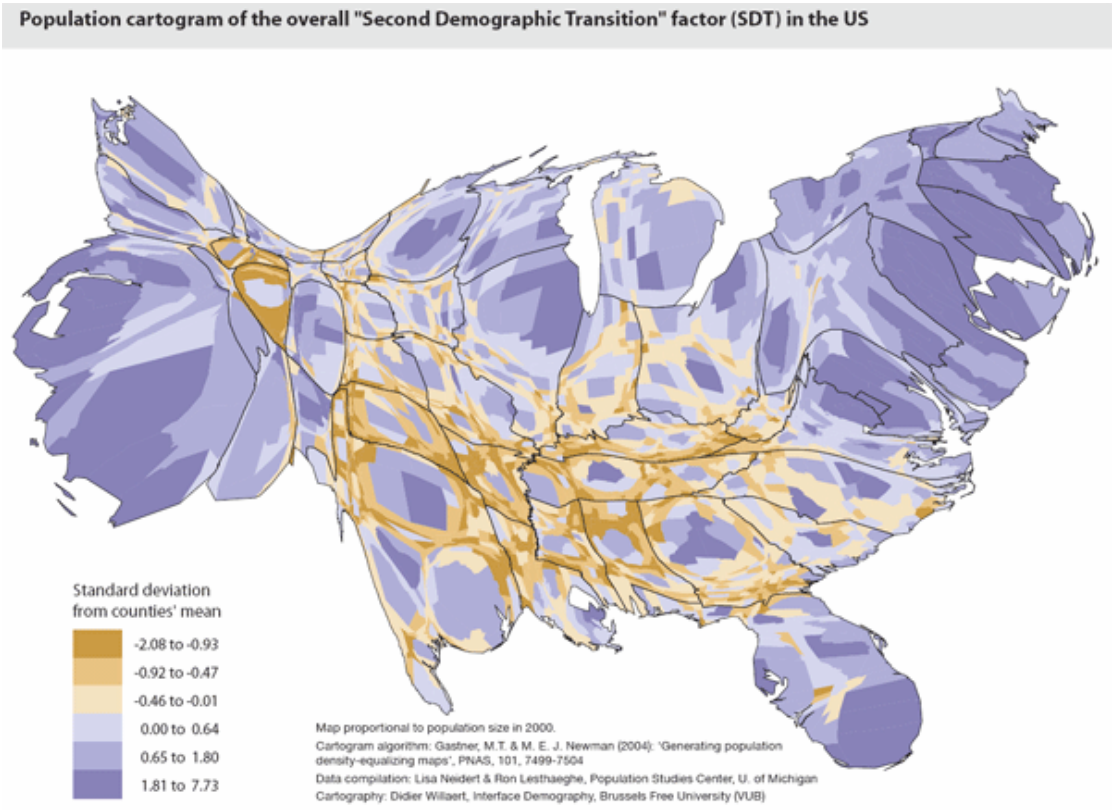


FIGURE 2.11: USA map distortion suing scan-line algorithm [12]

Cartograms dawned as a way of prevailing the constraints of other types of thematic map but their abstract nature causes some difficulties. They are assuredly more surprising which is why, in this age of data visualization they are progressively used. Many Cartographers agrees, the key to a good cartogram is keeping it simple and not trying to make them do redundant visual works. There is a continuance in mapping types that extends from the plain and boring to visually amazing.

2.7.5 The Cartogram Problem

The cartogram problem can be defined as map deformation. The input polygon mesh (the map) P and a set of values X , one for each region. The goal is to deform the map into P′so that the area of each region matches the value inputted to it, doing this in such a way that the overall shape of the regions remain recognisable. Possibly, topology conservation means that the aspects of the injunction mesh must stay the same.

This means the P and P′adjacent edges should stay the same. P and P′mesh should be isomorphic, it may be impossible to simultaneously fulfil this area and shape constraints, but it will also bring out the error of the output cartogram, making the cartogram deformed and unrecognisable.

Several families of cartogram generators described before, they confines from plain non-continuous cartograms to sophisticated solutions that apply computational geometry to distort the map without breaking its topology. None of the methods mentioned so far captures the notion of perfect shape-preservation.

The high complexity of the algorithms restricts their use to static applications with a small number of polygons and vertices's. Second, they have very limited shape preservation.

2.8 3D Distortion

Many researchers has used both filtering and distorting approaches to generate detail in context visualisations. Bifocal display by Spence and Apperley [47], Fisheye view introduced by Furnas[48]. One, two and three dimensional information illustration are very common and a number of tools exists for them. Distortion can be applied along the x,y or z dimensions of the screen display or any combination of the three axis.

However, the information representation and the viewing technique of that information dimensionally do not have to match. As the figure 2.14 shows a 3D distortion applied to 2D surface. This distortion relies on the perspective projection, the first and third images shows that. The first image has a 3D curve from the side, the third image shows distortion applied along the x axis only. But the centre image has got distortion applied to both x and y axis.

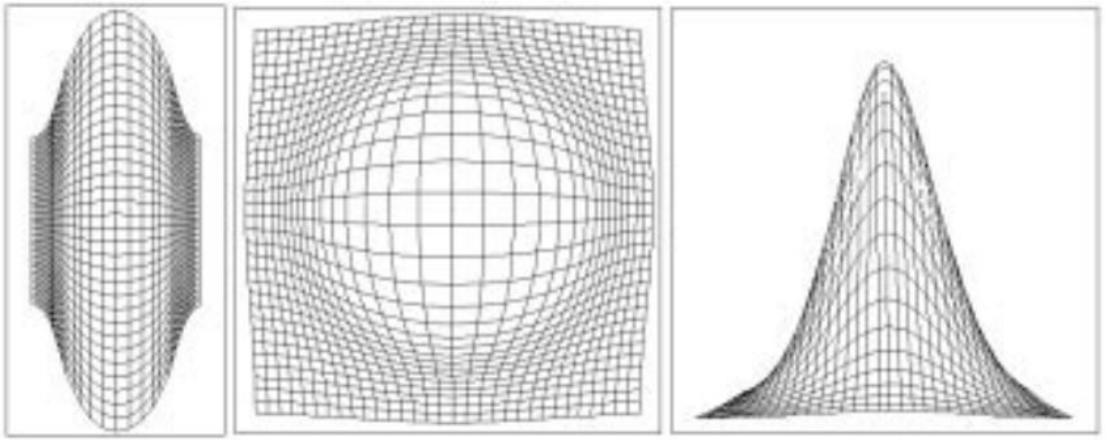


FIGURE 2.12: 3D distortion applied to a 2D surface [13]

Other types of distortion includes the Bifocal display on the third image in figure 2.15, Perspective wall used in the centre image . this distortions are applied on the 1D surface which is the first image since it has width.

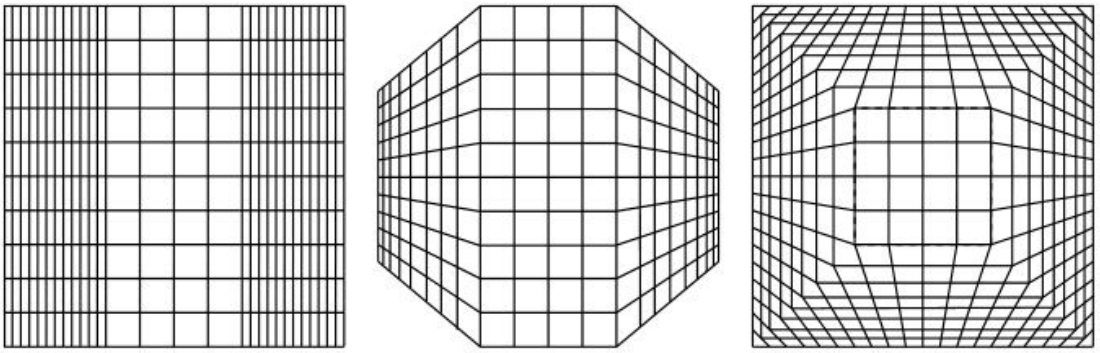


FIGURE 2.13: Bifocal and Perspective wall distortion [14]

Broadly, the underlying manner of 3D distortion is to manipulate the viewing angles (rotation) or the position (navigation). But there are many problems with this approach which has been identified is loss of context, orientation. Using non distortion approach to access the internal details of 3D objects using cutting planes or layer removal and transparency has removed some of the problems. Cutting planes and layer removal solves the loss of context while transparency is a compromise between visibility and maintenance of the context.

2.8.1 CSS 3D Transforms and Animations

It is the second decade of the second millennium, many of the interfaces are still 2D. Apple introduced some applications in OSX 10.7 Lion with some 3D embellishment, Microsoft has their FLIP 3D for a period of time. But the complexity of rendering 3D enviorments has been there for quite some time. For web there are Flash, three.js eventually WebGL. For the front end developers they have their own CSS 3D transforms.

CSS was built to style the HTML documents on the web page, not to develop new web enviorments. However 3D transforms gives the developers plenty of options in between the interface via transitions. For example, the weather app in iphones has got two views: detailed and options. Switching between them is done using 3D flip transition.

2.8.1.1 3D Transforms history

CSS 3D transforms has been out for some time now and most browsers supports the specification. This all started back in 2009 Webkit development team proposed a new extension for CSS which allows the elements to be viewed on a 3D plane. After a year all the browsers supported it and early 2011 for Androids. But development teams other

FIGURE 2.14: Flip transition in iphone app [15]

than WebKit has not shown much enthusiasm for this technique, so it was fairly niche and undersued feature at that time.

2.8.1.2 The Third Dimension - Z axis

In 2D web the elements are moved horizontally and vertically, these directions are the x and y axis. If the top left corner is the origin on the screen, element moving to left is negative x axis and right is positive. The same goes for the y axis up and down. The third dimension is the z axis, developers achieve 3d effects with the web elements by manipulating the z axis. A negative z axis is the element moving away form the viewer and positive movement is towards the viewer.

2.8.1.3 3D transforms functions

Several transformation can be applied in a single CSS transform property.. Developers still use browser prefix as this is still experimental. The 3D transform property accept several properties which are used in 2D transforms in CSS and they are:

1. matix3d. The matrix3d sounds overwhelming, but very complex to implement as this single property takes 16 values.
2. perspective
3. rotateX/Y/Z/3d
4. scaleX/Y/Z/3d
5. translateX/Y/Z/3d

2.8.1.4 Perspective

In order to activate the 3D space, an element needs perspective. This is applied in one of the two ways:

1. Use transform with the perspective as a notation, transform: perspective(500px);
2. Using the perspective property, perspective: 500px;

This give an element a 3D space by manipulating the distance between the Z plane and the viewer. The strength of the effect is determined by the value given. The smaller the value the closer you get from the z plane, more subtle will be the effect. This 3D transforms change the way to design the canvas of web design, it changes the canvas itself trading the flat surface for a voluminous installation.

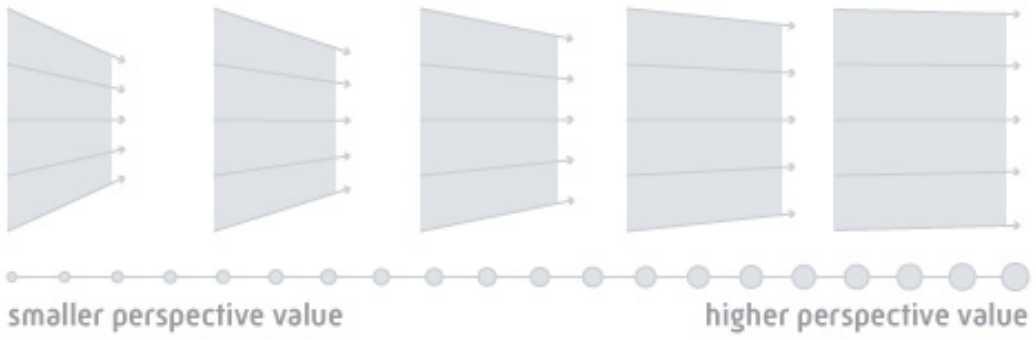


FIGURE 2.15: CSS perspective property [16]

Chapter 3

Research and Development Methodology

3.1 Methodologies

The purpose of this assignment is to research on previous works and studies on the Cartograms, its types and developments and the algorithms used of late, implementation of a cartogram generator software of Wales and carry out appropriate testing to gather conclusion which are open to comprehension

The two purposes of this section are to :

1. **Define the research methodology of this study.**
    - Explain what methods are intended to use when researching and developing the report
    - Indicate how the approach fits the overall research design.
2. **Describe the development methodology.**
    - Provide justification for the selection and procedure
    - Describe any potential limitations

3.1.1 Research Philosophies

For the advancement of the project the developer has cinched to follow with the research onion [49]. This create a good starting point for the right research approach

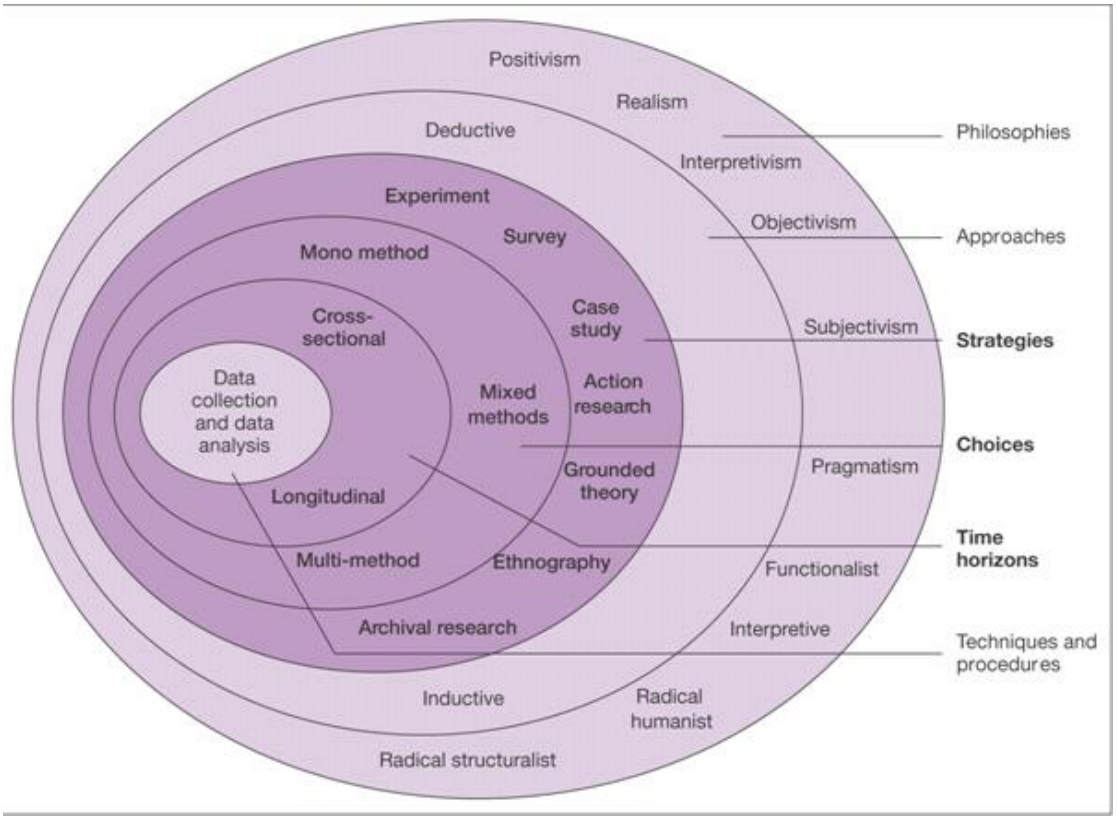


FIGURE 3.1: The Research Onion [17]

A **Positivist** research methodology has been used for this project. Before penning the requirements the developer has collected and research previous works by different authors on the topic of cartograms and its developments. Positivist research gave the developer to find about more about cartograms and algorithms related in its developments, perform reviews on previous literature on the chosen topic and formulate a hypothesis of his own. Based on the research works and the hypothesis, the developer can decide how he is going to progress the whole project.

It is important to keep in mind the nature of knowledge that has been gathered, is related to the project and its hypothesis. In contrast to positivist, phenomenology is a quantitative research methodology. Project or research which is related to a phenomenon and need to know individual experience of people, this method is used. Involves in-depth interviews with the subjects to get full picture.

Deductive research path granted the research to institute a hypothesis by using theory. Sometimes this is informally called a "top-down" approach. Variety of data and information was collected by the developer to confirm or reject the hypothesis to resolve issue.

Various steps of using deductive approach are development of theory, hypothesis, observation through data and confirmation. Based on the general idea it is allied with the positivism philosophy, which comprise hypothesis to prove the expectation. In this kind of approach it is necessary for the researcher to be generic.

Inductive reasoning works the other way, moving from specific observations to broader generalisations and theories. Informally, we sometimes call this a "bottom up" approach. Inductive approach is totally reverse form deductive approach. Observation, pattern, unsettled hypothesis and theory are critical steps of the inductive approach.

The research works for this project was **explanatory**. The developer has formulated a hypothesis based on the research he has undertaken on the topic of cartogram and its developments from previous literature. The researcher had an idea and observed the types and ways of cartogram development, gained more understanding of the algorithms for laying the ground works which will lead to design and implementation phase of the project.

This was a development project as the application will be implemented but it can be classed as **Experiment** and **Survey** strategies. This project is experiment as a question was asked between reading dry table and graphical illustration and to find the answer a survey has been carried out for the second phase of testing.

This project was be based on **mono-method**, adopting a single approach to research, developing a hypothesis, carry out the design , development and testing. Collecting the test results, analyse the outcomes of the survey questions and come to a conclusion about the project.

In contrast, mixed method [50] is more of combining the best of both worlds: the in-depth and more time-consuming insights of qualitative research coupled with the more efficient but, fewer compelling predictive power of quantitative research.

The purpose of the study was to find prevalence of the result of interest. This research takes place at a single point of time , allows the developer to look into numerous things at once. Thus, it was a **Cross-Sectional** research.

3.1.2 Development Methodology

For this project, Rapid Application Development methodology (RAD) also known "hack and fix" will be adopted. This method is an alternative to the waterfall method. Generally RAD approach to application development is to put more attention on the implementation and less in planning on pen and paper.

This project favours rapid development, early prototypes with design and testing of different functions and features of the application is done in parallel due to limited amount if time, RAD suits very well for the Cartogram application implementation.

For this Cartogram application there were no detailed pre-planning. It was doing research work by collecting previous research papers by different authors and try to gain better understating of the application, the tools, algorithms and the programming languages desired for implementing the application.

The developer can plan out the requirements in which ever way he/she think is best. The requirements phase includes penning the project scope , functional and non-functional requirements, and any constraints. If the requirements need any alteration as the project progress due to any new idea or knowledge obtained, it can be implemented on the prototype.

The design phase of RAD was to develop models and prototypes which all include the application's processes input and outputs. As there is limited period of time to develop this application it is best to approach this project by following the design phase rules in RAD. This phase is continuous with the implementation phase where the developers and users participate and suggest changes to the application if required.

As the developer was one of the many users of the application, he will surely continue to come up with his/her own suggestions for any improvements while coding in terms of visibility, features or making it more user friendly for the users to have better visualisation and understanding of the data inputted in the cartogram.

Testing of this application can be carried out during implementation , testing against the requirements, tick off the boxes in the test plan as the developer runs the application going through different functions, inputs and outputs. Also, analyse the survey answers which the users has undertaken after their experience with the application. In RAD, testing phrase is compressed making it less time consuming, putting out the final product for the users sooner.

RAD is overall builds better quality application, as building prototypes and carrying out testing at the same time is done making it less vulnerable to any bugs or error. This project is very time limited,the developer have good understanding of the application requirements and user's feedback will be imminent in testing , the developer can follow the guidelines of RAD for rapid and better application development.

Chapter 4

Requirements and Designs

4.1 Requirements

4.1.1 Introduction

This paper accommodate detailed requirements for the Cartogram Generator for Wales that is being developed for Software Engineering final year 2015. The document should serve as the official basis for any further development of the project.

4.1.2 Purpose

This document is for the use of the developer to have detailed description for implementing a Cartogram for Wales. It will illustrate the purpose and complete declaration for the development of the system. It will also explain any system constraints, interface and interactions with other external applications and users.

4.1.3 Scope

Cartogram generator for Wales is a web based application which helps people to visualise Wales Electoral data based on the users input from the data table detailed to each county. Wales electoral data can be obtained from the BBC wales website, the user can choose to pick the year of election and input the data. This information will act as the bases for the result visualised to the user.

Users from different backgrounds can input their electoral data to visualise the cartogram for their research or any other purposes.This application needs both Internet and electoral

Terms	**Definition**
Must	Minimum level required
Wish	A desirable level of achievement but not mandatory
Should	High priority requirement should be included if possible
Could	Desirable requirement but not necessary
Won't	Requirements that wont be implemented

TABLE 4.1: Table to test captions and labels

data to display the results. All system information which can be accessed only by the admin is located on a web server. Furthermore, after inputting the data a user can visualise the cartogram whichever way he/she prefers, using sliders and rotating the cartogram to any angle and position.

4.1.4 Terms and Definitions

4.1.5 User Characteristics

There are two types of users for the application: Users of the web application and Administrator

The application can be only used to input data and view the cartogram by anyone for free. He/she can use the result of the cartogram for other works. The admin interact with the web server and back-end code, managing the overall system so there are no incorrect information within it.

4.1.6 General Constraints

1. The application is not responsive. So the users might struggle to work with it on other platforms than pcs and laptops
2. The Internet connection is also a constraint for the application. Since its running on a server, it is crucial that there is an Internet connection for the application to function.
3. Some users might experience lag when using the cartogram due to GPU acceleration being disabled in their web browser

4.1.7 Assumptions and Dependencies

1. One assumption with the application is that it will mainly be used on a pc or laptop.

2. The user will input data for at least one county before distortion
3. The platform the application is running is connected to the Internet.
4. The admin will insure the safety and security of the application and will not disclose the time stamp data (if implemented) to any other parties.

4.1.8 User Interfaces

1. The user can read the manual, and the table data.
2. The user can input figures on the table
3. View the cartogram play around with the map using sliders for rotations before or after inputting the electoral data in a web page called Cartogram
4. Change the figures on the table as the user wish.

FIGURE 4.1: Cartogram application prototype

4.1.9 Functional Requirements

This section describes specific features of the software project

4.1.10 Inputs from the Users

1. The user must be able see the table only

2. The users can input electoral data of Wales with year of his/her own choice on the counties
3. The users do not need to input the data for every county but should input at least one county for him/her to see the distortion.
4. The inputs must be numbers of voters for each county
5. The user can alter the figures before or after the distortion.

4.1.11 Outputs

1. 3D distortion of the counties or county (if the user input the data to only one county) based on the user input.
2. The higher the number of voters in a county the bigger its perspective (px).
3. The user can control the viewing angles of the cartogram as he/she likes.

4.1.12 MoSCoW requirements

Must

The user must input data for one party at least in a county of his/her choice.
The input from the user must be a whole number (the number of votes).
The application must distort the counties according to the user's input
The county with the highest total votes will have the largest depth of perspective.
The user must be able to change any figures that was inputted before distortion and the cartogram must again change according to the new figures inputted.

Should

The user should input at least two or three counties to view an adequate distortion.
The application should have sliders for the user to control the viewing angles.
The application should have a transition or filters for the counties after distortion for better depth using the sliders.

Could

The user could choose election results from the link given on the web page or pick his/her own figures
The application could have an animation of some kind for the counties after distortion to give the users a better graphical experience.
The application can change the colour of the counties according to the party's colour with the highest number of votes.

Wont

The application wont accept any decimal figures as user's input.

4.1.13 Security and Maintenance

The admin is responsible for the security in terms of the time-stamp if that is implemented on the application. Otherwise, this application is free to the users. There is no such way to prevent people from looking at the source code for the web pages.

Furthermore, the admin will have the responsibility for maintenance of the application in terms of adding contemporary functions in the future if he/she wishes to do so.

4.2 Design

4.2.1 Use Case Diagrams

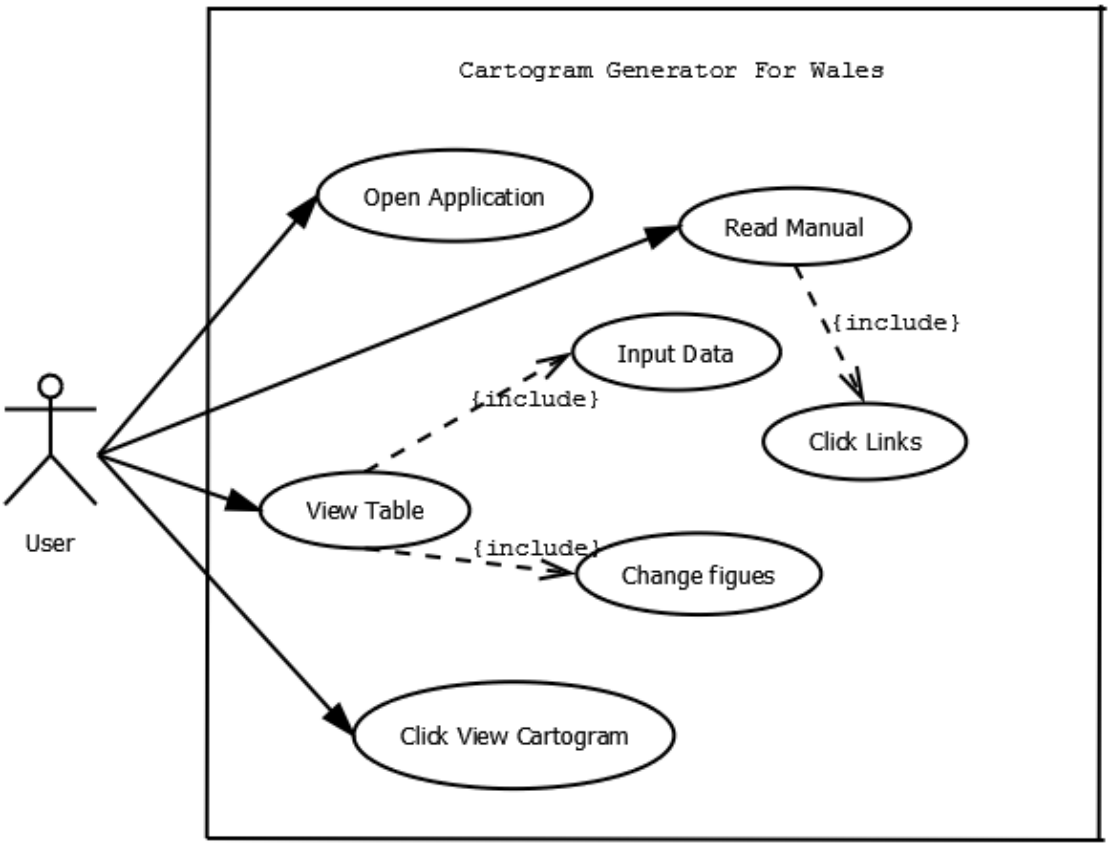


FIGURE 4.2: Use Case diagram 1

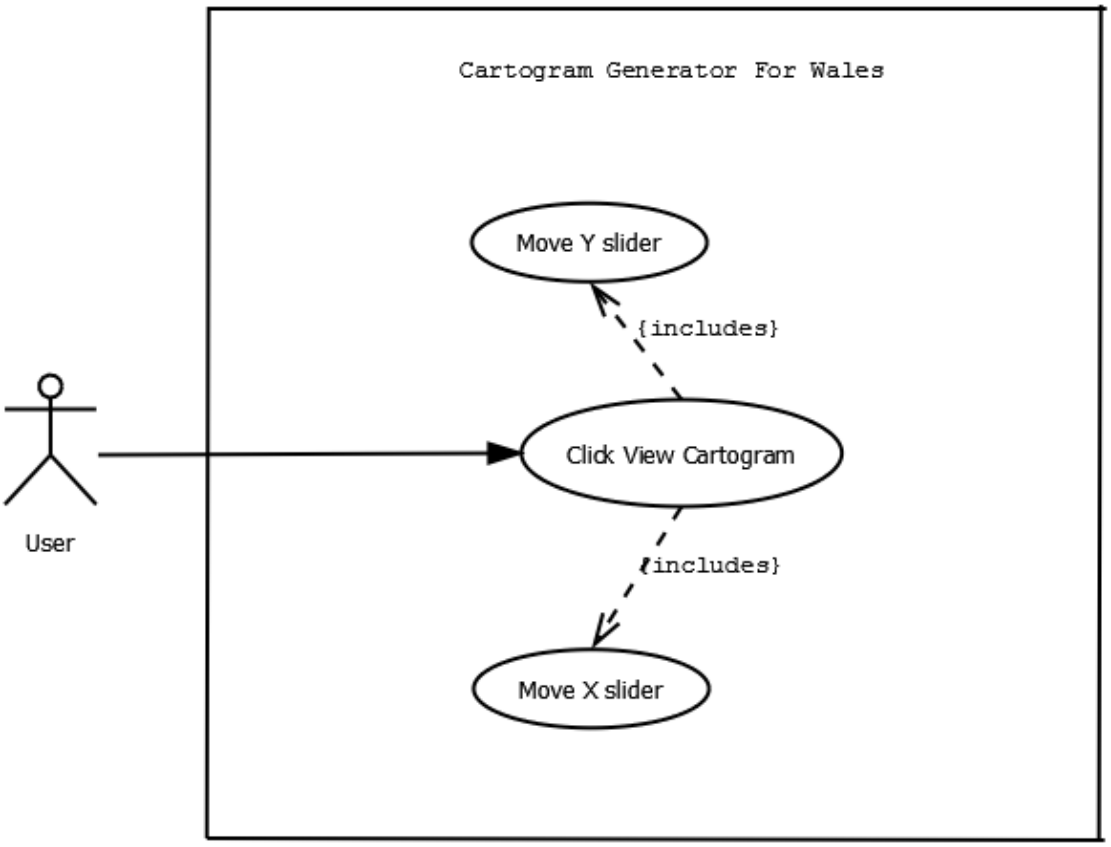


FIGURE 4.3: Use Case diagram 2

4.2.2 Activity Diagrams

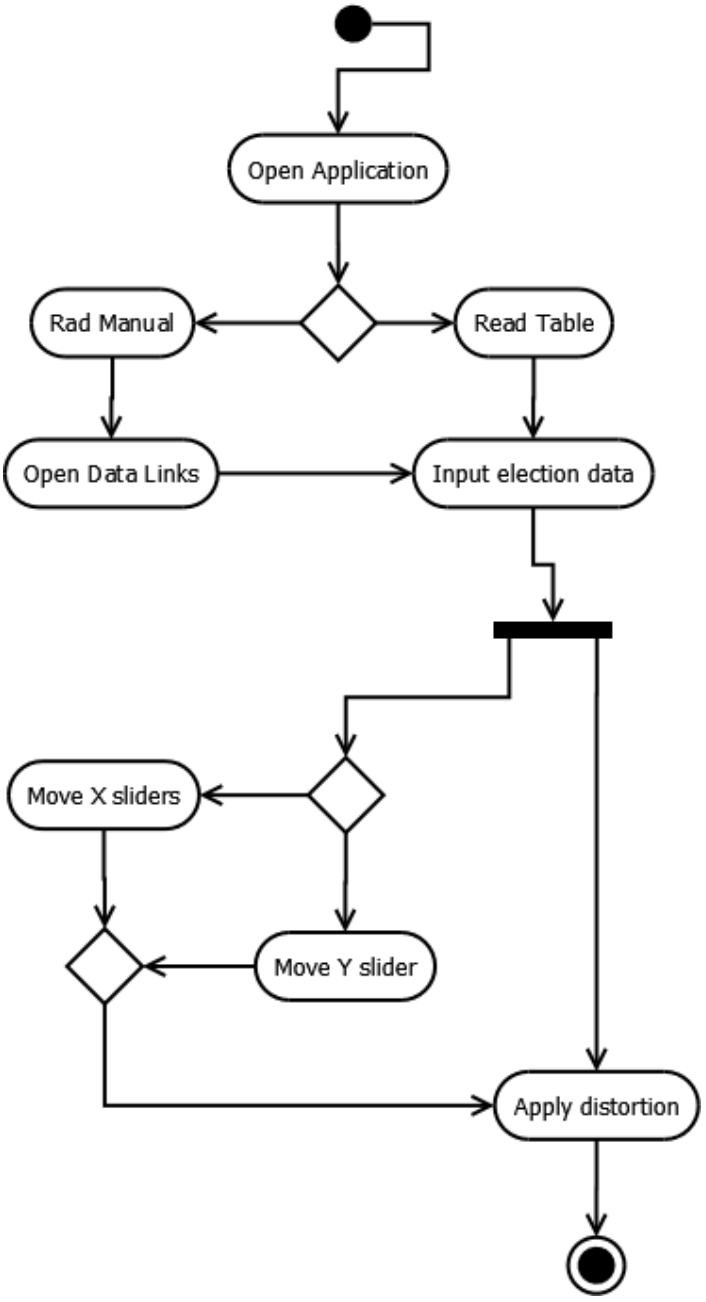


FIGURE 4.4: Activity diagram 1

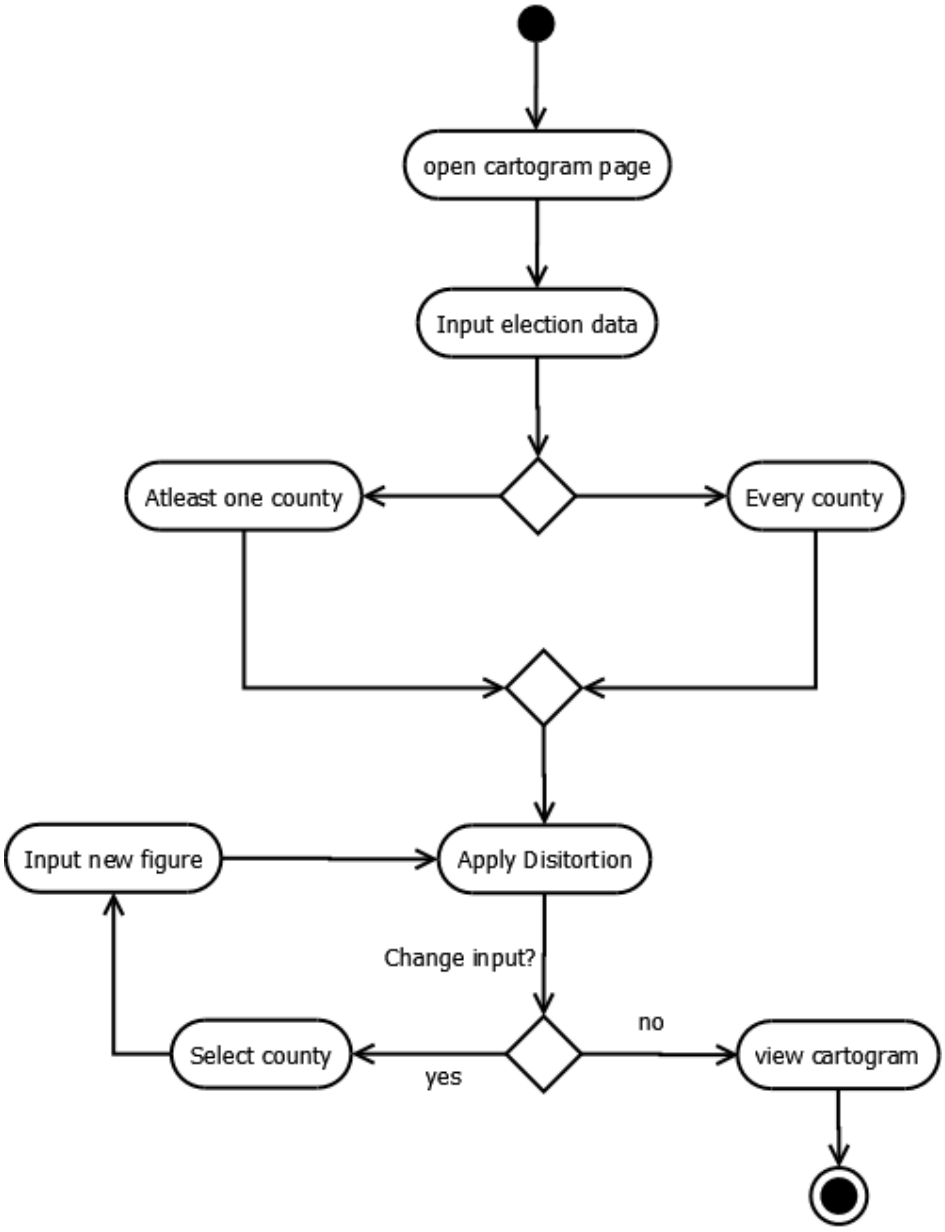


FIGURE 4.5: Activity diagram 2

Chapter 5

Implementation

This document describes the project implementation for developing the cartogram application. Description of the development tools used, the steps of acquiring information and use them for implementation of the application in order to do the major tasks.

5.0.3 Development Tools

For the implementation of this application, the developer used HTML5, CSS 3D transforms, JavaScript and JQuery.The developer also looked into writing some Python scripts for the extraction of polygon coordinates to render in OpenGL but was unsuccessful, which will be discussed in the later section.

The application will be capable of running on all standard browsers, although, the project was designed primarily around Mozilla Firefox. The interface for the application will ultimately provide the users with dynamic mapping resulting a distorted cartogram.

5.0.3.1 Mozilla Firefox

Firefox browser comes with a developer edition with some built in tools for the developers to work across multiple platforms and debug codes. Firefox got a style editor built which enables the developers to view, create new and edit style sheets. Valence (previously known as Firefox Tools Adapter) is an experimental add-on which enables the developers tools to debug a wider variation of browsers.

The developer used JavaScipt and Jquery for this project implementation as mentioned before. Firefox got its own debugger for JavaScript which examines the JS code and help track down any bugs. Debugging can be done locally or remotely. Also, Firebug extension

in Firefox is also a good alternative for HTML, CSS and JS editing and debugging while browsing.

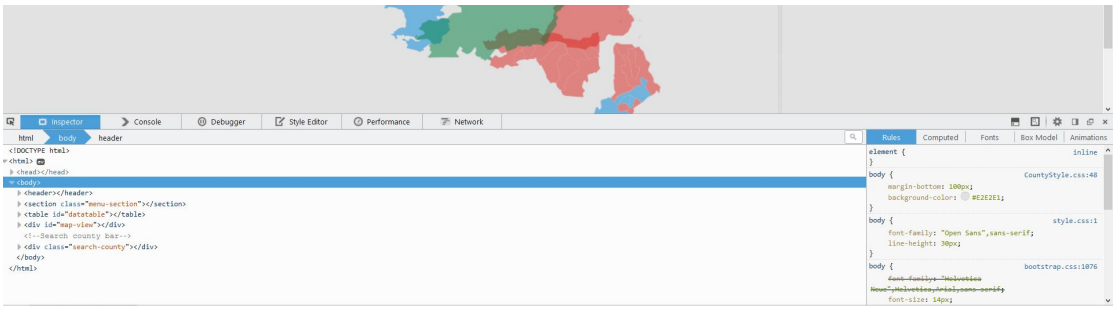


FIGURE 5.1: Development tools in Firefox

5.0.4 Major Tasks

This subsection of the Project Implementation provides the list of the major system implementation tasks:

1. Acquire map of Wales polygon coordinates - SVG image of Wales and extract the coordinates to OpenGL syntax using Python scripting. This process has created some problems while rendering the map specially with the paths for the counties of Wales.
2. Use of Inkscape to separate each of the counties on the map and implement them on a web page using HTML5.
3. Implement the web pages using HTML5 and CSS3 for the layout of the web pages
4. Implement dynamic mapping for the user's input using Javascript and JQuery.
5. Apply 3D distortion on the map using CSS 3D Transforms.
6. Use of CSS filters for better depth between the counties

5.0.5 Wales maps and polygon coordinates

In order to render the map of Wales, the polygon coordinates are needed. The developer looked up on-line for a OpenGL rendering code for map of Wales already written my someone and shared it due to a short time period for the project implementation. Unfortunately, there was to code written, due to lack of time only alternative was to use a .svg format image of the map of Wales.

SVG images can be dynamic and interactive. Time-based modifications to the elements can be programmed in a scripting language (e.g. JavaScript).The developer used the polygons and paths coordinates of a Wales map svg image using a text editor. Moreover, SVG allows styling via CSS [51] which allows the developers to apply CSS transforms.

5.0.6 Python scripting and OpenGL

The generic idea was to acquire the polygon coordinates for the map of Wales and use it for rendering using OpenGL with GLUT utility toolkit. Worst case scenario, draw polygons using straight line edges and have similar resemblance to the map of Wales. The developer collected the coordinates using SVG vector image as mentioned in the previous section.

Write a script for converting the polygon coordinates into OpenGL primitives [52], which is an interpretation of a list of vertices's into a certain shape. In OpenGL, the list of coordinates are specifies for a certain primitive by placing them in a glBegin() and glEnd() block. The library has several primitives to draw certain polygon, but for rendering the map of Wales glpolygon() has been used . It draws a single convex polygon where the vertices's 1 through N define this polygon.

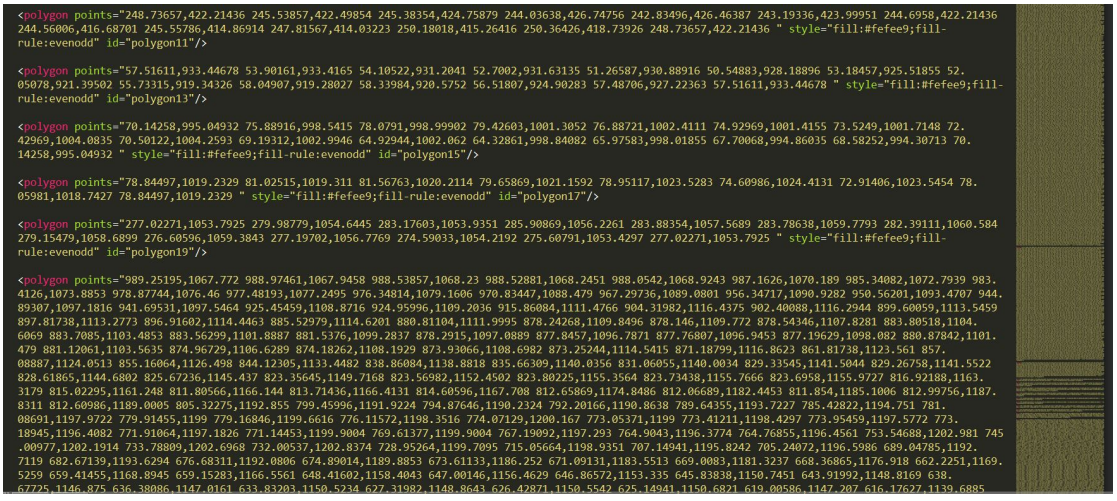


FIGURE 5.2: svg coordinates of Wales in a text editor

Python scripting was used in order to convert the coordinates to OpenGL, the script was to extract the svg polygons using regex. Also called [53] regular expression syntax(or RE) specifies a set of strings that matches. the function let you check if a given regular expression matches a particular string.

```
for match in matches:
    contents = match.split(" ")

    out.write("glBegin(GL_POLYGON);\n")
    h = random.random()
    for point in contents:
        if point == "":
            continue

        x,sep,y = point.partition(",")
        x,y = float(x), float(y)

        out.write("glVertex3f(%s, %s, %s);\n" % ((x/(width/2))-1, (y/(height/2))-1, h))

    out.write("glEnd();\n")

out.write("}")
```

FIGURE 5.3: for loop to write the coordinates in OpenGL format

The result of the script was extracted to a text editor and added to a Wales.cpp file. The code in the main.cpp files was taken from a different source [54], interactive graphics programming module, this code was written by Gordon Dickers which was modified with a doWales() function for the polygon coordinates function for the rendering of the map.

5.0.6.1 InksScape

The main problem was with the paths for the boundary of the counties on the map. The Python script worked only for the whole map but not per county. Inkscape was used to cut out the counties using the path edit, it exported the paths (the boundary lines) instead of polygons (counties). The python script was altered, but could not work with it. It gave negative numbers of the x, y and z coordinates.

The svg map of wales comes with areas of England with was cut down, later all the wales counties was cut separately and saved individually.

5.0.7 HTML5 and CSS 3D transforms

With the counties svg saved individually, The files was implemented on run a browser using HTML5 img element. The basic idea was to implement a web application, in order to do that a material design [55] based theme was coded for the web pages and user input table for the cartogram distortion. The HTML file that was written for all the counties showed overlapping on top of each other.

5.0.7.1 Sliders and 3D transforms

One of the requirements for this application was for the users to control the viewing angles. In order to fulfil that, HTML5 sliders was implemented. This control is very perceptive [56] user interface with a number set within a range. To create the slider, there was option between JavaScript or flash as the solution. But HTML5 saves thousands of byte in the code with the new input type(<input type="range">)

The sliders have input and change event bounds. As the user changes the angles, it makes it possible to detect the change and the CSS files are altered for the map elements to apply transformation.

5.0.8 JavaScript and JQuery for dynamic mapping

Dynamic mapping is a Must requirement for this application. As the application is web based, Javascript has been used to implement the distortion algorithm and user input for dynamic mapping.

Javascript itself is a dynamic programming language. It allows client-side scripts [57] to interact with the user and alter the document content that is displayed.

5.0.8.1 Generate Columns

A JS function generateColumns() was implemented where, the selectors was loop through the array using the push() method adds new items to the end of an array

5.0.8.2 Table data

Two variables input and total, use the find() method for the input element. A variable val, initialise it to a parsefloat function referring it to a val object. Use of isNAN (not a number) built-in function to check the input, than add the total to the val. If the total is greater than highest, highest is equals to total. If lowest is numm or less than total than lowest is equals to the total of the votes, than, total of the data array is equals to the total, than call the render function.

```
input.find("input").each(function(i)
{
    var val = parseFloat($(this).val());
    if (isNaN(val))
        val = 0;

    //data[columns[i]] = val;

    total += val;
});

if (total > highest)
    highest = total;
if (lowest == null || total < lowest)
    lowest = total;
data[county] = total;
```

FIGURE 5.4: Table Implementation

5.0.8.3 Rendering Algorithm

A render function was implemented. A for loop with parameters, for each county in data object. Three variables were create names total which was initialised to an array. Scaled variable, which is for the scaling of the counties and finally val for value where scaled is multiplied by 30 which is the angle of scaling and abs() [58] is a static method of Math object in JavaScipt, use it as Math.abs(), rather than as a method of a Math object.

Variable el initialised with document.getElementById element for the county id. A simple if statement where if el is not null, translate the counties along the z axis.

```
var el = document.getElementById(county);
if (el != null) {
    el.style.transform = 'translateZ('+val+'px)';
}
```

FIGURE 5.5: 3D Transformation on Z axis

5.0.8.4 X and Y sliders

The X and Y sliders are implemented to give the users viewing control of the cartogram as per the requirements. Variables ySlider and yWrapper has initialised with document.getElementById() method to two IDs. The addEventListener() attaches an event handlers to the specified ySlider element with input, change and yFunc as its parameters.

The same procedure is followed for the xSlider but use the rotateY() method this time. The generateColums() function is called. For every counties the .each() iterator function

is used. The .append() method which inserts the figures as the last child of each element and use Math.floor [59] for rounded figures with the random number generator .random() method [60].

```
        $("#"+val+'-data').find("input").each(function() {
            $(this).val(Math.floor(Math.random()*100));
        });
});

$("#datatable input").bind('input change', function() {
    doData();
});

doData();
```

FIGURE 5.6: Random number and Binding

Some parts of the code was commented out due to performance issues. The code was implemented before as shown in he commented code blocks, but there was serious graphics lag without the GPU acceleration enabled in the browser in Windows 8.1 OS. The performance lag was greater when run in Linux Mint distro. The developer had to enabled OpenGL in Firefox, which reduced the performance but did not totally removed it.

Chapter 6

Testing and Results

6.1 Test Hypothesis

6.1.0.5 Definitions

Null hypothesis(H0) is the statement of zero or no change, it contains equality. The researchers, tries to disprove , reject or nullify this hypothesis. The "null" [61] is refers to as the common view of something.

Whereas the **Alternative hypothesis (H1)** is the opposite of null. The researchers attempts to demonstrate in an indirect way. If H0 is rejected than H1 is accepted.

6.1.0.6 Hypothesis

The application will be tested based upon this hypothesis:

Is the graphical illustration better than reading dry data only?

1. *Yes, it is better than reading dry data only, thus it is the alternative hypothesis, H1*
2. *No, this graphical illustration is not better than reading dry data, therefore is the null hypothesis, H0*

6.2 Black-Box Testing

First testing for this application is to examine the functionality based on the requirements. The innate structure of the application is over passed and put the focus solely on the outputs [62] spawned in return to selected inputs and execution conditions

6.2.1 Test Cases

The developer has a series test cases with a set of test data, conventional outcome and post conditions to different test scenarios in order to comply against the functional requirements.The Test cases can be read below

	Project Name	Cartogram Generator For Wales						
	Created by	Hasan Khan						
Test case ID	Test Objective	Precondition	Steps:	Test data	Expected result	Pass/Fail	Post-condition	
TC_01	Read dry table data only	The user need to be connected to the internet and have a updated web browser.	1. The user visits the web page 2. See a table with random numbers generated	Read the table data	The user can see some figures on the table generate randomly.	Pass	The user can read and input his/her own figures ot	
TC_02	Whole number data input only	The user can see the figure table	1. Input some numbers in decimal place 2. Input figures, only whole numbers	There is no change in the counties Distortion is seen in the counties	The users can only see distortion if they input whole numbers only	Pass Pass	The user can see distortion in the counties accordi	
TC_03	Dynamic viewing angles	The user is on the Cartogram page an can view a map of Wales	2. Input data on the table 3.Click view Cartogram 4. Move the x slider 4. Move the y slider	Whole numbers None None None	Distortion is seen in the map The cartogram rotates on the x axis The counties moves in and out according to the y axis	Pass Pass Pass		
TC_04	Dynamic user's input and distortion	The user inputs some data	1. Enter figures 2. click view cartogram 3. move the y slider 4. Change the figures	Wales Election data None None	Distortion in the polygons the higher the slider goes the depth increase for the counties according to the data change in distortion	Pass Pass Pass	The map dsitrotion changes every time the user changes his/her inputs	
TC_05	Colour change in each county	The user input data for every party in a county	Select a county and input all the votes of each parties	Elaction data for each party	The colour of the county changes according to the party's colour with the highest number of votes	Fail	The colour remains the same, no changes is seen.	

6.3 Survey Questionnaire

The second phase of testing was to do data gathering by survey questionnaire. Which was then analysed and interpret the views of a group of people. The survey questionnaire was prepared focusing on the cartogram and the hypothesis. The Survey can be seen in this link *(see Appendix A).*

As it was based on Wales, it was important that the participants of the survey are from Wales or at least knows about the map of Wales and its counties. The questions were structured asking them about there country of residence and the time period of residence. Knowledge about cartogram and Wales, Understanding of the cartogram after distortion and their opinion on this graphical illustration.

6.3.1 Survey Results

This section contains the explanation of the results, a summary of the overall results, who was responsible for the survey questionnaire and data gathering and statistics. The dates, location, definition of the population. Anything that is excluded from the survey and any references related to the survey results.

6.3.1.1 Background Summary

This next section provides an overview of a survey conducted by the developer himself to determine the user's satisfaction of using the application. This satisfaction was assessed by evaluating:

1. The usefulness of the application for better data representation.
2. Overall level of satisfaction compare to dry table.

The evaluation collected from the participants was used to determine weather the goals and objective of the application are achieved and facilitate improvements for the future.

6.3.1.2 Survey Responsibilities

The survey questionnaire was constructed by the developer himself, keeping in mind that the question asked was balanced not biased for all the participants. The language was kept simple and direct. Each question was given with some hints for the participants to

answer with their best knowledge (see Appendix A). The chief researcher of this project was the developer himself.

6.3.1.3 Survey Methodology

The application link was send to a total of 15 people from across Wales, they completed the on-line user survey between April 15 and April 18, 2015, approximately two days after the implementation of the application was finished and black box testing was carried out.

The most common expertise among the participants was from engineering background and all the participants answered in English . As it was a random sample there was no response rate or margin of error calculate for the results.

6.3.1.4 Key Findings

A total of 10 questions was asked to all the participants except one was kept as an optional. The questions were kept short and simple, make it less time consuming to answer them.

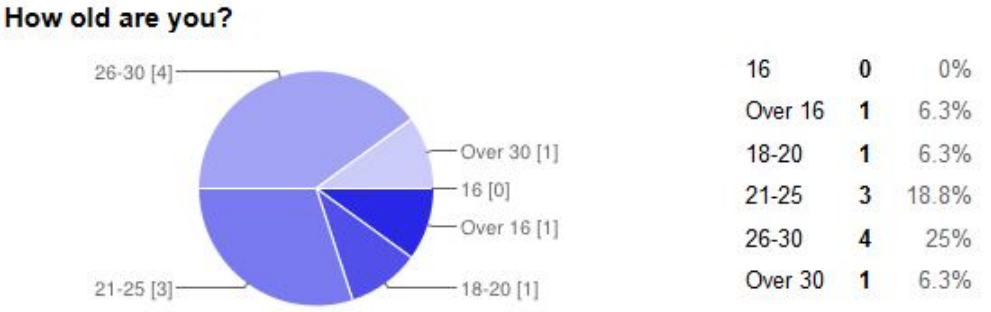


FIGURE 6.1: Question 1 results

- **First question** was asked to all participants. A total of 9 people were asked this question as the age question was added later on the survey. The previous participants who took part in the survey were asked later about their ages.

  All of the 15 participants of the survey was range between over 16 to 30. No was select less than 16 and over 30. All of them are undergraduates in different Welsh universities and as got good basic knowledge of computing.

  The aim of the developer was to question the participants those who are minimum 16 years old to over 30 years old. The reason for the threshold is to have participants, who can give valid response to all the questions with good structured sentences.

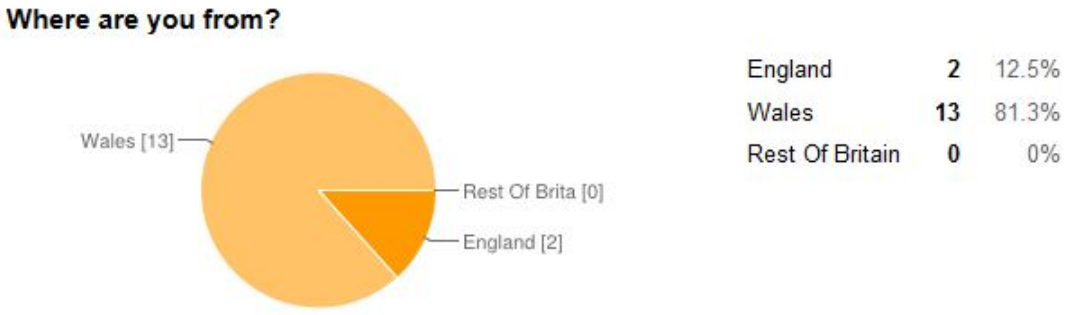


FIGURE 6.2: Question 2 results

- **Second Question** was asked was to all 15 participants, it was valid to ask this question because the cartogram developed is based on Wales. All of the 15 participants answered this question. A total of 13 participants choose Wales and the other two choose England

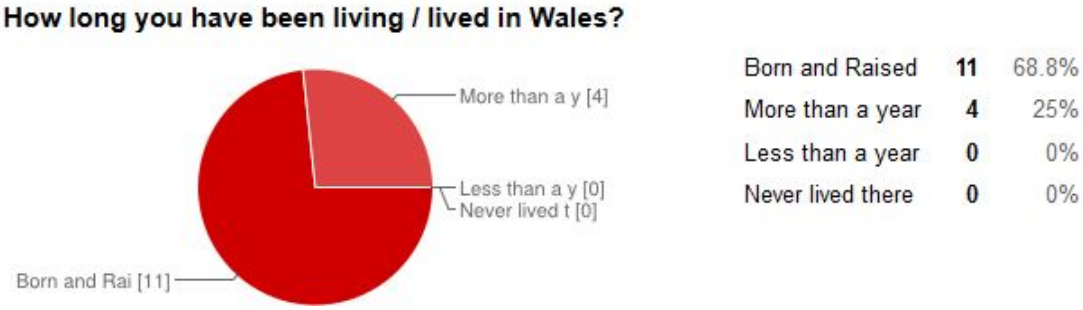


FIGURE 6.3: Question 3 results

- **Third Question** which was asked to all participants. It was asked as a follow up to the previous question. It gave the developer an indication to how they are familiar with the map and major cities/counties of Wales.

  A total of 11 participants out of 15 answered Born and Raised and the other two choose More than a year as their answer. Overall, more than the average participants were from Wales. Only four of them answered they are from England.

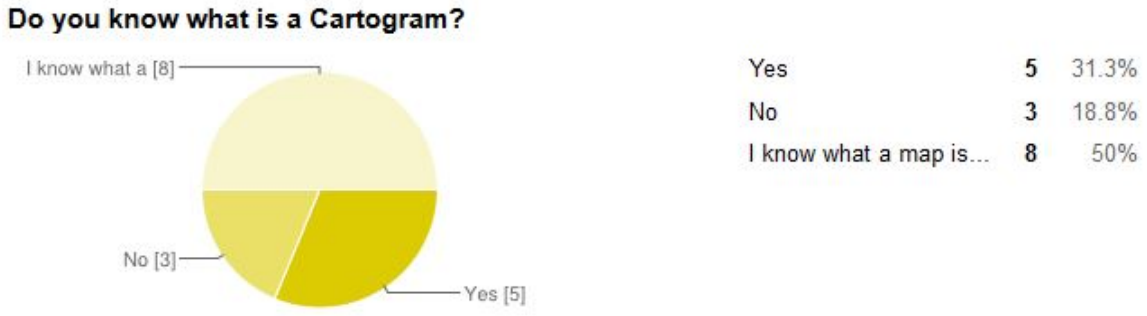


FIGURE 6.4: Question 4 results

- **Fourth Question** was asked to all the participants. Eight people answered they are familiar with a map, four of them said No *(it is assumed that,this answer was rushed while doing the survey)* and four of them answered Yes.

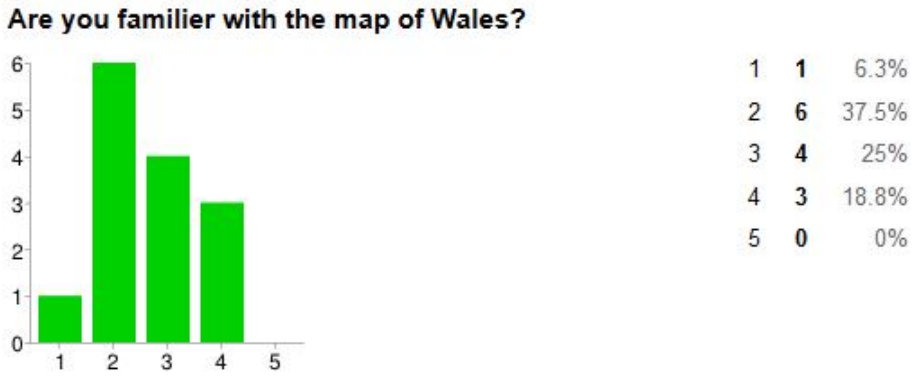


FIGURE 6.5: Question 5 results

- **Fifth question** was asked to all the participants. Seven of them choose 2, four choose 3, three of them choose 4 and only one choose 1 who was actually from Wales, born and raised. The responses for this question was compelling for the developers. Even though most of them are from Wales, they lack the knowledge of most of Wale's counties.

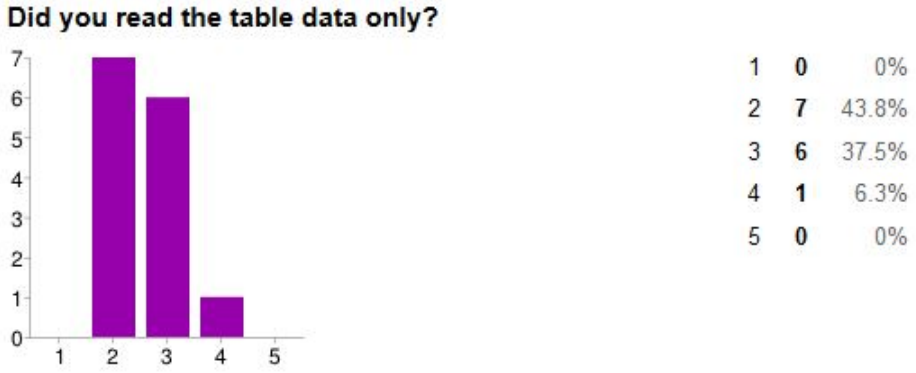


FIGURE 6.6: Question 6 results

- **Sixth Question** was asked to all the participants. Eight of them choose 2, six choose 3 and only one of them choose 4. This question was vital for the conclusion in choosing the hypothesis, the developer did the mean, std deviation and std error on the answers of this question. *(see Appendix A)*

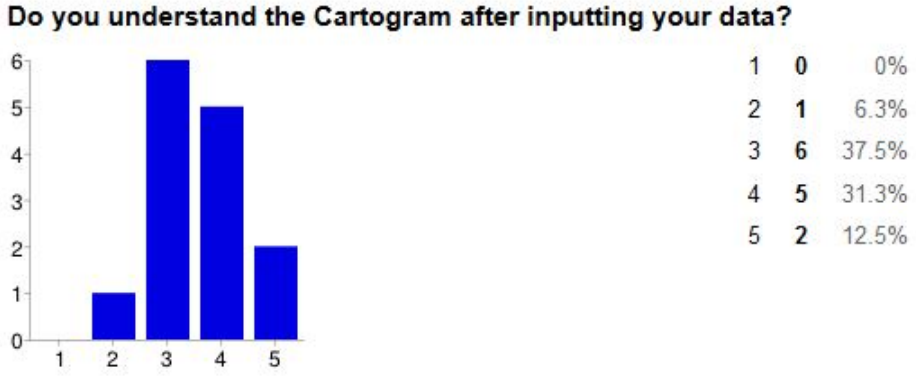


FIGURE 6.7: Question 7 results

- **Seventh Question** was asked to all the participants, seven of them choose 3, five of them choose 4 and the rest choose 5.

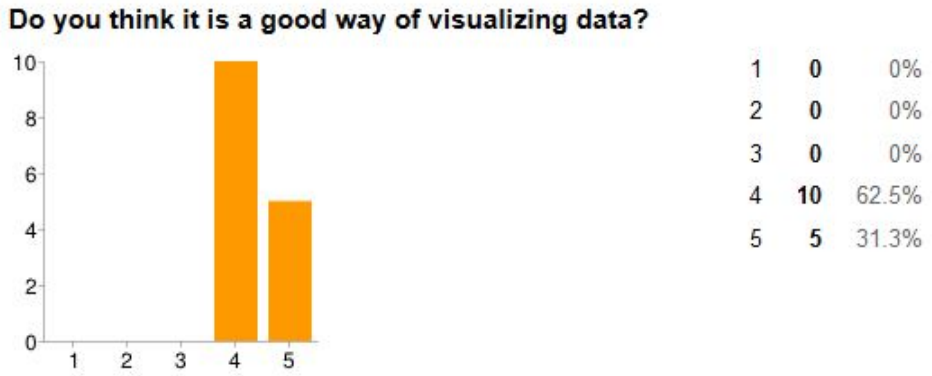


FIGURE 6.8: Question 8 results

- **Eigth question**, Ten people choose 4 and the rest choose 5. This question was asked to the participants to know weather they prefer cartogram as visualisation or any other techniques such as bar or pie chart to represent the figures on the table. *One of them mentioned pie chart which will be discussed further in the future works section.*

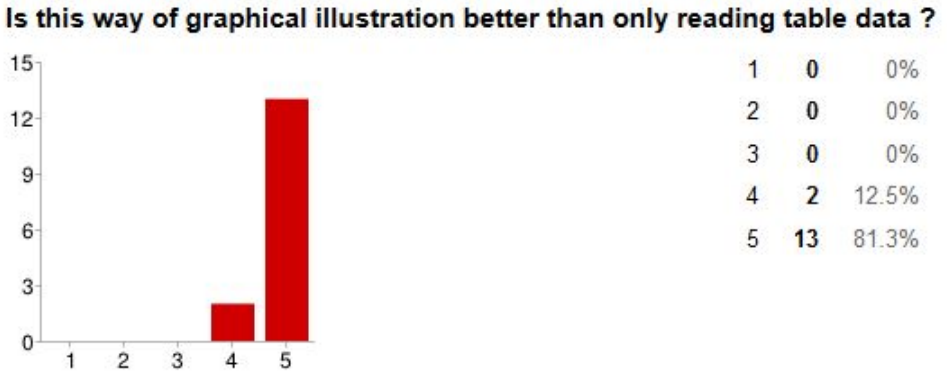


FIGURE 6.9: Question 9 results

- **Ninth Question** was question was vital for the hypothesis test too, the result of this question was used to calculate the p value and based on that one of the hypothesis was chosen.Two people choose 4 and thirteen people choose 5 for their answer. *(see Appendix A)*

6.3.1.5 Statistical Testing

Terms	**Definition**
Statistics	The practice of collecting and analysis of numerical data
Mean μ	the average of the numbers in a column
Standard Deviation σ	Indication of how spread out the numbers are from the mean
Significance Level α	Probability of rejecting the null hypothesis if assumes it is true
P value	Probability of the observed values with evidence against null hypothesis being true

TABLE 6.1: Statistical terms and definitions

The statistical test was carried out comparing the the answers to question number 6 and 9 asked in the survey. The results of the two question are:

With graphical Illustration	Read table data only
4	2
5	3
5	3
5	2
5	2
5	2
5	2
4	4
5	3
5	3
5	3
5	2
5	2
5	2
5	3
4.86666	2.533333333
0.351865775	0.639940473

FIGURE 6.10: Responses for Question 6 (Did you read the table data only?) and Question 9(Is this way of graphical illustration better than only reading table data?) *the headings has been changed for the researchers convenience*

1. From the total of 15 responses the mean μ of question 6 was 2.53 (to 2 decimal places) and the standard deviation σ of 0.64 (rounded).

2. The mean of question 9 was 4.87 (rounded) with a standard deviation of 0.35

So, **H0:** $\mu = 2.53$ **and H1:** $\mu \neq 2.53$

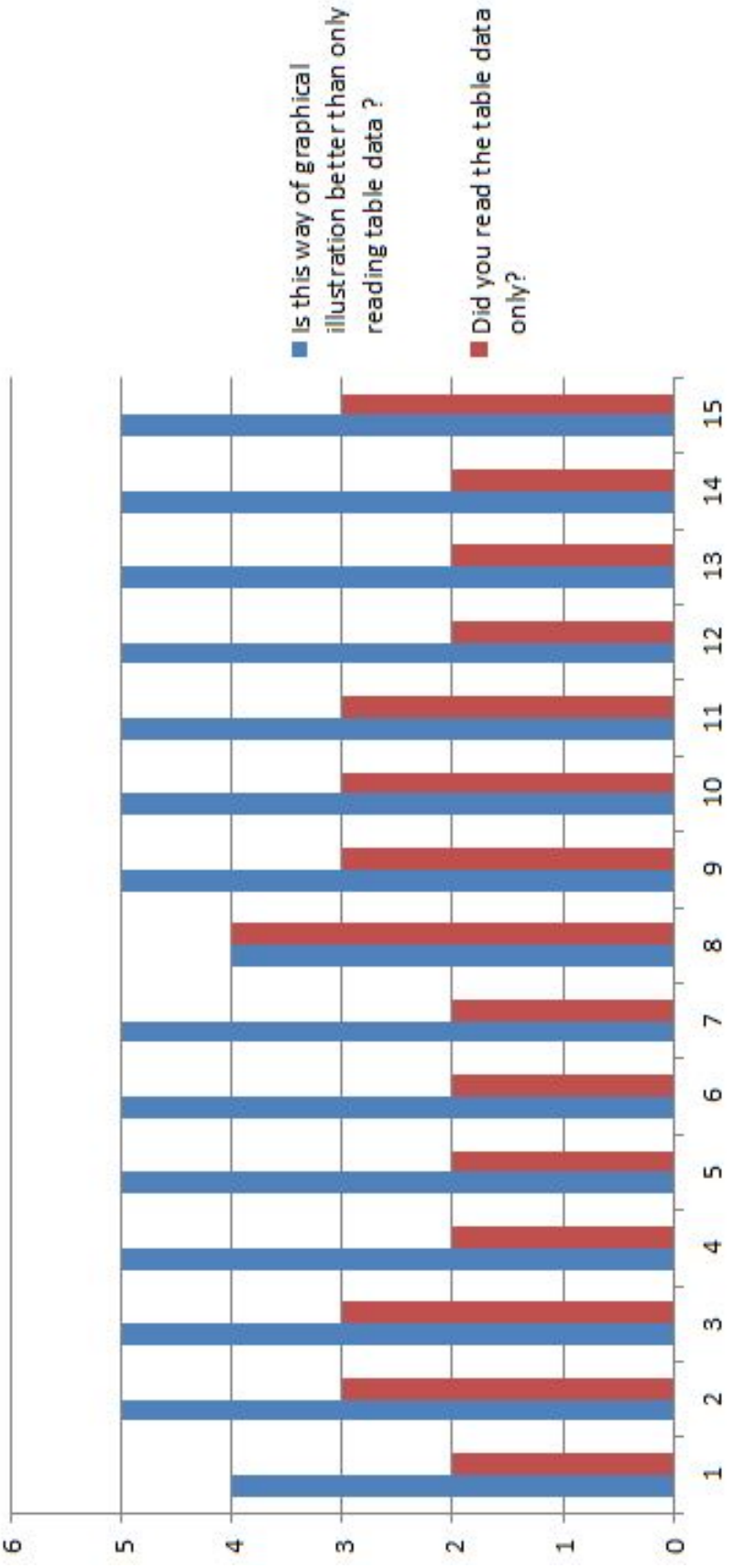


FIGURE 6.11: Bar chart comparing two questions

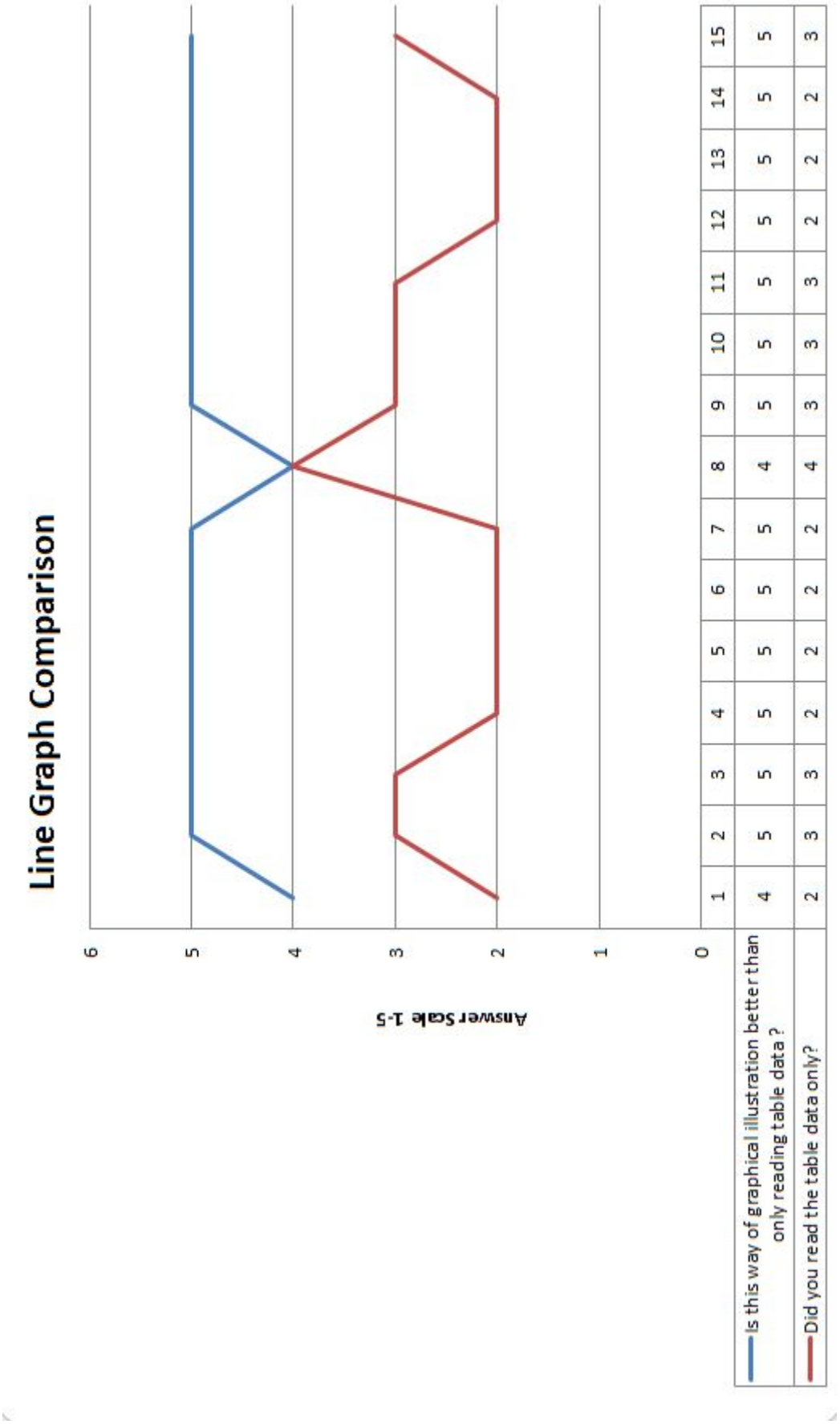


FIGURE 6.12: Line graph comparing responses of question 6 and 9

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.636284763
R Square	0.4048583
Adjusted R Square	0.355263158
Standard Error	0.214598769
Observations	14

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.37593985	0.37593985	8.163265306	0.01443017
Residual	12	0.552631579	0.046052632		
Total	13	0.928571429			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	5.605263158	0.243687621	23.00183793	2.71005E-11
With graphical Illustration	-0.263157895	0.092105263	-2.857142857	0.01443017

FIGURE 6.13: Regression testing summary in MS Excel

6.3.1.6 Significance Level and P value

The significance level α is used as reference probability. The choice for this level is 5% (less than 1 in 20 chance of being wrong), 1% or 0.1% (P <0.05, 0.01 or 0.001) levels can been used. Although these numbers can give a false sense of security.

In ideal world, to define a "perfectly" arbitrary sample, the applicable test and one definitive conclusion cannot be done simply. Most authors refer to statistically significant as P <0.05 and statistically highly significant as P <0.001 (less than one in a thousand chance of being wrong).

Assuming the significance level $\alpha = 0.05$, the P value is 0.014 from the regression testing [63] in MS Excel. There is significant evidence to reject the null hypothesis H0, because, P <0.05

That indicates, only 1.4% of the participants 15 where $\mu = 2.35$, which will produce a mean that provides a very strong evidence to reject H0, as $\alpha \geq$ P is when the null hypothesis is excepted.

P value is just a probability [64], and significance level is for reference. For the hypothesis testing the sample size is very crucial for determining the P value, the greater the sample size the more precise the estimates, the more likely to have evidence against the null hypothesis.

The sample size 15 is a small representative for the test, the bigger the sample size the smaller the P value will be. The P value alone and the estimates does not tell how much difference there is in the target participants. In that case statisticians advice to carry out a confidence interval (CI) test.

95% Confidence Interval					
	with graphical illustration			read table data only	
	Mean	4.866666667		Mean	2.533333333
	Standard Error	0.090851353		Standard Error	0.16523192
	Median	5		Median	2
	Mode	5		Mode	2
	Standard Deviation	0.351865775		Standard Deviation	0.639940473
	Sample Variance	0.123809524		Sample Variance	0.40952381
	Kurtosis	4.349112426		Kurtosis	-0.126679702
	Skewness	-2.40476314		Skewness	0.802288396
	Range	1		Range	2
	Minimum	4		Minimum	2
	Maximum	5		Maximum	4
	Sum	73		Sum	38
	Count	15		Count	15
	Confidence Level(95.0%)	0.194856771		Confidence Level(95.0%)	0.354387222
lower		4.671809896			2.178946111
avg		4.866666667			2.533333333
upper		5.061523438			2.887720555

FIGURE 6.14: 95% confidence interval

6.3.1.7 95% Confidence Interval

CI allows [65] to quantify how confident we can feel a group of data is from its mean value From the table, we are 95% confident the mean value is between 4.67 and 5.06 for question 9. It is, 2.16 (rounded) and 2.89 for question 6. This can be interpreted in a normal distribution graph:

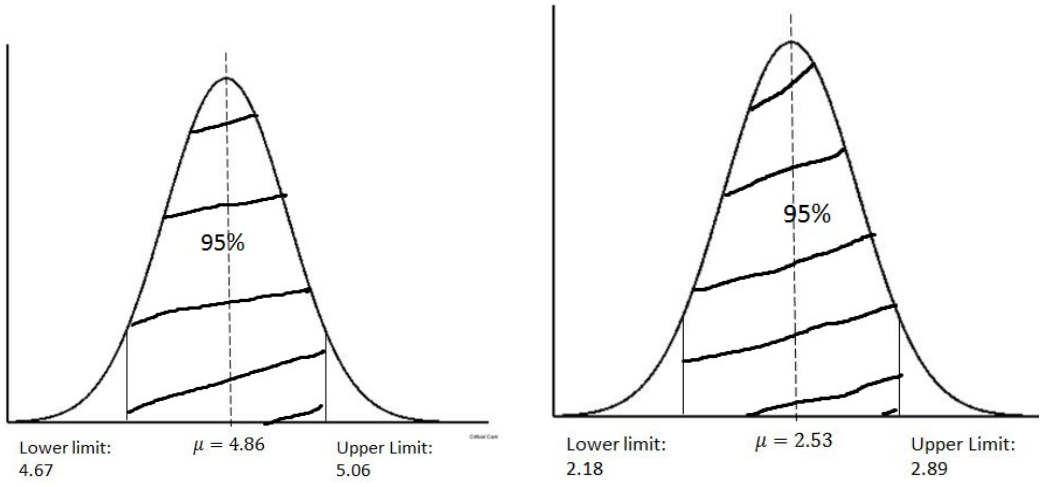


FIGURE 6.15: Distribution graphs for question 6 and 9

Chapter 7

Conclusion and Future works

7.0.2 Test Conclusion

According to the survey responses and test statistic, the developer has rejected the null hypothesis H0. Overall, the participants has stated the graphical illustration is more admirable and engaging in comparison to reading the dry data only. Dynamic mapping and map distortion was quite favourable as they found it more convenient the electoral data for the counties they inputted.

Each participants repeated testing the application at least twice before answering the survey questions. First time they read the table than, inputted the figures to view the cartogram. Second time, they only changed the figures for counties they were interested in.

Although most of the participants was puzzled trying to understand the gist of the distortion. Most of the participants did not care much looking at the figures, as they found it tedious and time consuming. It took some time for each of them to figure out how the map was distorted. The reason for that was assumed, maybe because the participants did not know much about the map of Wales even though 13 of them are from that country.

Furthermore, the x and y sliders was highly praised from the participants, specially, the CSS transforms applied in the ySlider was acknowledged by the participants.

7.0.3 Recommendations

One of the participants mentioned about adding pie charts or something akin for a summary of every county votes. The developer did looked into CSS animation for colour

change to each county with the highest party votes, which can be implemented in the future. Some of the participants questioned the depth of the counties after distortion, better depth can be achieved using WebGL. WebGL handles this [66] by enabling the depth buffer gl.depthfunc() or an alternative to that is blending. The realisation for implementing using WebGL came a while later and time was of the essence for the integration of the project.

Ongoing development of this application will help ensure continued relevance and usefulness to the users in the future. This will include enhancements such as a search bar for every county, which does require a back-end database and needs to be implemented using PHP but CSS hover [67] can be triggered with JavaScript, dynamic pseudo class style with Jquery using an OO approach to model components on a stylesheet, it is possible to view information for each county when hovered or clicked on it.

Development of addition web features, better graphical performance writing better structured code and carrying out code reviews for JavaScript and JQuery and continued monitoring of user feedback.

Chapter 8

Reflection

The undertaking of my third year project involved developing a dynamic mapping application based on Wales. The principal question framing my project was: **"Is this graphical illustration better than reading dry table only?"**. I choose this singular experience because I am fascinated by data visualisation. From the many, Cartogram is an interactive tool which is used to give the viewers better understanding of statistical data on a geographical scale. This realisation has encouraged me to explore and research in the field of Cartogram, its internal mechanisms and a major project was a perfect opportunity to express this desire.

The beginning this project started with collecting different literatures by several authors on cartogram and its developments. It required good judgement on which papers to read as time was limited. This required pre-planning make sure there was valuable point mentioned on my literature review. Designing the layout of my paper using LaTex, thus making it essential for me to familiar with the program .

During the evolution of my project I had pleasure of working with my lecturer Tim Bashford. He and I were able to meet and discuss the progress of my project. when a pressing issue came up that had to be resolved, I would call him and we would discuss the matter. I was excited with the progress, as the research for cartograms was giving me the knowledge to have better understand of its innate structure.

Cartogram developments requires understanding of algorithms and its mathematics which was refreshing as I was very intrigued with mathematics during my time in high school and A-Levels. Although, understanding some mathematical terms mentioned on many papers was vigorous, I was overall happy with the literature review but was adrift with the design and understanding of the implementation. Fortunately, my third year module on graphics programming gave a some light on the project development.

The knowledge of OpenGL gained in my third year and web scripting languages, helped me decided to make my application view on a browser. Implementing the coordinates of Wales in OpenGL, gave me the chance to refresh my familiarity on python scripting. Over the course of my project these past few months, I have acquired new knowledge on CSS3 transforms which gave me more confidence to pen down the design and implementation of the application.

Time was very limited, so I had to be very precise and structured with my time table how i can balance my project work with other assignments.I have previous experience in time managing, I prefer to work methodically, beginning and ending each task before moving on to the next. During the writing and design process, I relished having to formulate ideas which helped me structure my project paper and hone my writing skills.

Throughout the course of this project I came to recognise that I certainly savoured the process of developing a web based application. My project and near future is closely connected as I am interested in pursuing a career in web development.This has allowed me to gain confidence in my ability and assisted my desire to enter that field of work.

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