Visualisation Techniques to Facilitate Argument Exploration

Dana Khartabil

School of Computing

Edinburgh Napier University

A thesis submitted in partial fulfilment of the requirements for the degree Doctor of Philosophy

June 2020

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and acknowledgements.

Dana Khartabil
June 2020

Acknowledgements

My greatest appreciation goes to my supervisors Professor Jessie Kennedy and Dr Simon Wells for the guidance, encouragement, and the support they gave for accomplishing this work. Your constructive feedback has helped me in my endeavour. Thank you very much for giving me this opportunity to work with you both and learn from your experiences. Also I want to thank Dr Christopher Collins and Dr Benjamin Bach for their valuable feedback and their guidance.

I also wish to convey my heartfelt gratitude and appreciation to my parents, Fayzah and Shahir. My siblings, Rania, Dima, Raghda and Yousef for their ultimate support and love. You represent the true treasure in my life.

Last but not least, I would like to thank my husband, Ammar, and my son, Joud. Thank you for supporting me at the end of a long journey. Thank you for your unconditional love that you give for me. All this could have never happened without you both.

“By visualizing information, we turn it into a landscape that you can explore with your eyes, a sort of information map. And when you’re lost in information, an information map is kind of useful.”

David McCandless

Abstract

Visualisation is a graphical representation that is used to aid understanding and gain insight into information. Similarly, visualising arguments can help people to explore argument structure and comprehend knowledge associated with tough problems.

In this thesis, we focus on representing arguments, especially when data size increase, which causes difficulty in exploring and understanding arguments. A fundamental problem from an argument perspective is that understanding argument requires users to understand the overview, read the content of arguments, and recognise how the arguments support, compete, and conflict with each other. Applying information visualisation techniques or combination between them in an argumentation domain can improve the navigation and exploration in argument data.

The main contribution of this thesis is proposing various visualisation approaches for gaining insights on argument data and helping experts to understand arguments. Based on collected user requirements, the work presents several prototypes that provide an overview of arguments while giving users the ability to read the argument text. To compare and evaluate our proposed techniques and tools, a controlled user study and interviews with argument experts are conducted. The collected qualitative and quantitative results are thoroughly analysed using relevant statistical tests.

Contents

List of Figures

List of Tables

List of Abbreviations

AIF	Argument Interchange Format
ArgVis	Argument Visualisation
AVERs	Argument Visualization for Evidential Reasoning based on stories
CSAV	Computer-Supported Argument Visualisation
CSS	Cascading Style Sheets
CVD	Colour Vision Deficiency
DOM	Document Object Model
F+C	Focus and Context
IBIS	Issue-Based Information Systems
InfoVis	Information Visualisation
OVA	Online Visualisation of Arguments
SEAS	Structured Evidential Argumentation System
SVG	Scalable Vector Graphics
UI	User Interaction

Chapter 1

Introduction

Argumentation is a process in which the arguer seeks to justify or refute a standpoint by providing reasons for or against a position. Arguments are statements that include a conclusion, often referred to as a claim, and a collection of premises that work together to support or oppose the conclusion [1]. Arguments are a common human activity, and their use is studied in many domains, such as in education to improve critical thinking, in social media to understand people's thinking, in law to better understand cases, in politics to deliver opinions on new issues to voters, and in business to attract and satisfy customers.

Argument mapping is used to diagram the structure of argument and move from a purely linguistic expression to visualisation. This commonly occurs in the form of box and arrow diagrams [2]. Argument analysis tools implement argument mapping and aim to make the structure of the argument being studied more apparent to the viewer. Whilst traditionally a manual human activity, argument analysis is increasingly being automated using computers, a process is known as 'Argument Mining'.

Argument visualisation (ArgVis) is used to explore relations between argument elements (premises and conclusion) and help in reading their contents. Different visualisation approaches are used in argumentation, some to help experts/analysts find relevant information and share ideas, and others to track the relationships between arguments and detect patterns within their structure. ArgVis techniques and tools present arguments utilising a combination of text, symbols, and boxes. Figure 1.1 illustrates the steps of argument analysis from the original text through to ArgVis. Compared with the text that the arguments originated in, ArgVis provides the reader with a general view of the topics raised and shows the relations between the argument elements. Also, it helps people to explore and understand these datasets so they can make a decision regarding the topic of the argument. For example, healthcare professionals and policymakers in 2015 tried to understand the factors behinds the increase in obesity rates in the UK [3]. They were overwhelmed by the amount of the collected data they needed to study and analyse. They used an ArgVis tool called DebateGraph [4] to help unravel the complexity of the data and find solutions to tackle the obesity pandemic. Using DebateGraph assisted them in presenting the data related to the obesity issues and exploring the relations between the argument elements. Another example is the investigation of the ethical aspects of deploying and researching into climate engineering [5]. ArgVis was used to present an overview of moral reasons in favour of or oppose taking certain action or policies related to climate engineering.

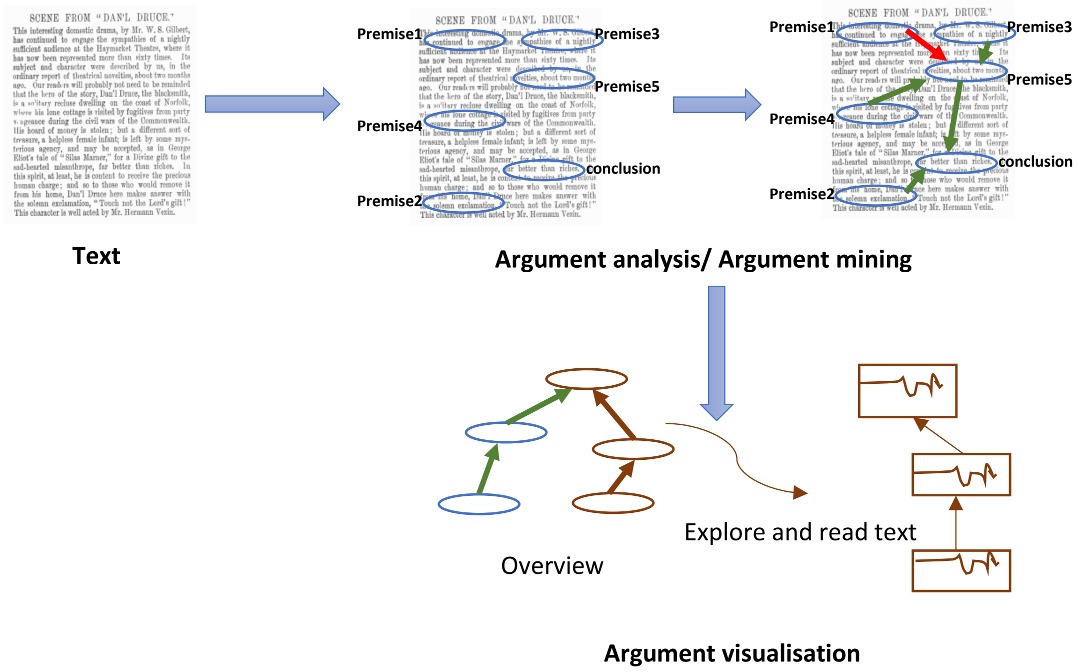


Figure 1.1 The steps for extracting and discovering the arguments from text (argument mining or argument analysis), followed by ArgVis to present the structure and explore arguments.

The structure of this Chapter is as follows. First, the research aims are elaborated, followed by an outline of the research questions. Second, the contributions of this research are presented. Finally, this Chapter concludes with an overview of the thesis structure.

1.1 Research Aim and Questions

These datasets are related to various domains and issues that are increasingly crucial and important in our lives, such as obesity and climate change. Understanding these datasets requires exploring how argument elements are connected to each other, reading the content, and recognising how the argument elements support and oppose others. Satisfying these requirements create challenges in ArgVis, particularly as the size of datasets, is increasing. With the advent of argumentation mining technologies and an increased focus on argumentative analysis, datasets can easily exceed a hundred argument elements. Whilst these are not "big datasets" in absolute terms, the argumentative structure has specific features that mean that the complexity of the dataset does not appear to scale linearly with size. The increasing demand for tools that help to investigate argument data in different domains is a driving force to develop ArgVis techniques and tools [6].

This research focuses on ArgVis to help experts understand arguments by achieving a balance between presenting an overview of the argument structure and providing legible text for the details of the argument elements when the number of argument elements exceeds a hundred. From that, our research questions are:

Q1 Which visualisation techniques should be deployed to provide an overview of arguments structure?

Q2 How can visualisation techniques help to provide legible text for reading argument contents while still providing an overview of structure?

To address these research questions, novel techniques are investigated, developed, and evaluated to help in reading the argument contents. Additionally, tools are implemented to accomplish the balance between the overview of argument structure, and legible text can be accomplished.

1.2 Contributions

This research aims to help argument experts explore and understand arguments. The focus of this research is the visualisation of arguments, in particular, how an effective overview of arguments structure can be provided while simultaneously providing legible text for reading the details of the arguments when the argument dataset exceeds a hundred elements.

The main contribution of this research is a hybrid novel tool called Argument Visualisation Tool *AVT*. This tool aims to help argument experts to understand and explore arguments by providing an overview of arguments structure with a technique to quickly navigate the text in one view while allowing the experts to read the argument content in another coordinated view. As part of this research, the following techniques and tools are developed and evaluated.

(a) *StackedBoxes* tool: a coordinated view between a novel *stacked-boxes* technique and a sunburst layout. Stacked-boxes focus on the text with features for fast navigation, while the miniature sunburst provides an overview.

(b) *Sunburst Pop-Up* tool: an integrated view between the sunburst layout that shows the overview of arguments structure while a novel *stacked-labels* technique helps in reading and navigating a text. When users hover over the sunburst, the *stacked-labels* shows the nodes from the root to the hovered node, allowing users to read the argument contents.

(c) *Icicle F+C* tool: an integrated view between the icicle plot that visualises the structure of arguments and focus and context (F+C) technique that helps to read a text by enlarging the parents of the focused node, as well as all the focused node's children.

1.3 Overview of the Thesis

The rest of this thesis is organised as follows:

Chapter 2 introduces argumentation and highlights the importance of arguments in different domains, like law and education. Then, argument structures are discussed, followed by a review of widely used argument models, supported by an example.

Chapter 3 presents a review of the literature related to various aspects of this thesis. First, information visualisation (InfoVis) is defined, and the visual representation techniques for graphs are discussed. The layouts and visual techniques used to present long text and help to improve legibility are described. After that, a review of user interaction techniques that can help in providing both details and overview of argument data is provided. Finally, a review of the limitations in existing ArgVis tools and the challenges to be addressed are presented.

Chapter 4 presents the designing of argument visualisation tools and techniques. To understand the domain problem(s), argument experts are interviewed. During the interviews, the difficulties and obstacles the experts faced upon using existing ArgVis tools are discussed, along with their main requirements. To satisfy these requirements, a *Sunburst Node-Link* tool is proposed. Reflecting on the pros and cons of this tool, three novel tools for presenting argument data are designed and implemented; namely, *StackedBoxes*, *Sunburst Pop-Up*, and *Icicle F+C*.

Chapter 5 presents an evaluation of the proposed tools in two stages. The first evaluation is a controlled user study to collect quantitative data, i.e. time and errors, and qualitative data about the tools. The second evaluation is an expert review. A hybrid tool (*AVT*) is deployed to satisfy experts' feedback.

Chapter 6 summarises the contributions of this thesis, discusses the limitations of the work, and outlines several promising directions for future work.

Chapter 2

Argumentation Background

Argumentation is a valuable skill in life, which aims to justify or refute the standpoint of someone by providing strong reasons for or against a position. People convince others to agree with their views by offering justification and reasoning [7].

In this Chapter, the use of arguments in various domains is introduced, and argument structure and commonly used argument data models are reviewed. Finally, tools that are widely used in the literature to analyse and map arguments are surveyed.

2.1 Argumentation

In this section, the differences between argument in monologues and dialogues are introduced. Then, the importance of arguments in diverse domains such as education, law, and social media are reviewed.

Arguments are a structure of many statements called premises that offer the reasons for a conclusion or a claim. The study of argumentation not only attempts to identify these parts of an argument, but also the relationships between premises and conclusion [1]. Arguments can be found in both monologues and dialogues. A monologue is a speech that a person delivers to express inner thoughts. The monologue aims to change the beliefs of the listener or evoke feelings in the audience [8]. An example of a monologue would be, Mary tried to justify her choices by saying:

"I am going to marry Sean. He is handsome, brilliant and incredibly rich" [9].

Dialogue is a communication between two or more persons such as discussion, debate, or quarrels [10]. The example below is a discussion between two persons [10]:

(1) Allen: *"The Evanston City Council should make it illegal to tear down the city's old warehouses."*

(2) Beth: *"What's the justification for preserving them?"*

(3) Allen: *"The warehouses are valuable architecturally."*

(4) Beth: *"Why are they so valuable?"*

(5) Allen: *"The older buildings lend the town its distinctive character."*

There are similar features between monologues and dialogues, such as argument structure and the dominance of listener beliefs in guiding the presentation of information [11]. O'Keefe highlighted the difference between monologue and dialogue as the former is structured to support a case, while the latter is structured to cause active dispute [10].

Arguments are applied in different domains to achieve various objectives. For example, in learning and education, students try to be logical and reasonable; they strive to improve their skills in arguing to convince others of their opinions and ideas. Students think critically and independently about essential issues and contest values by using arguments. Argumentation in education and science is a collaborative discussion between two or more parties to find agreement or solve an issue [12], [13, Chapter 3]. Argumentation helps learners think deeply, provide reasoning for their thoughts, develop their collaborative ability, and share their ideas. In law, criminals and prosecutors argue to prove who is guilty. Using argument supports criminal investigators and lawyers to express their reasoning about the case and provide evidence [14]. Finally, arguments are used in social media where users can debate, express their opinion, vote on issues shared between them, and convince others with their ideas and viewpoints [15], such as in Climate CoLab[1] and CreateDebate [2]. Humanity faces many problems that concern people such as climate change, famine, and war where discussion and collaboration can help lead to solutions to the problem [16], [13, Chapter 3]. In addition,

[1] http://climatecolab.org/

[2] http://www.createdebate.com/

argumentation plays a role in research such as artificial intelligence and automation reasoning where arguments are used for handling conflicting information, viewpoints, or opinions.

2.2 Argument Structure

An argument consists of a claim or conclusion (C) and a set of premises (Ps) that support or oppose that conclusion. The way that premises and conclusions are connected with each other to form the argument is called the argument structure [17]. In this section, the argument structure that describes how an argument elements can be connected to each other is introduced.

There are three ways in which premises can be connected to a conclusion and each has a standard diagrammatic representation; i) *convergent*, ii) *linked*, and iii) *divergent* arguments. In convergent arguments, the premises are connected to the conclusion with each premise independently supporting the conclusion, as shown in Figure 2.1 (similar to a logical `OR`). In linked arguments, as illustrated in Figure 2.2, the premises work only together to jointly support the conclusion (similar to the logical `AND`). In divergent arguments, a premise supports multiple different conclusions, as shown in Figure 2.3. Note that in the case of both convergent and divergent arguments, the argument can be split into individual arguments [1]. Individual arguments may also be chained together, with the conclusion of one argument acting as the premise of another, yielding large and complex structure of arguments.

2.3 Models of Argument Structure

To understand arguments, their elements and the relations between them, several models have been developed that structure the arguments using maps. In the following, popular models in the literature are reviewed, i.e. Standard, Wigmore, Toulmin, Issue-Based Information Systems (IBIS), and Argument Interchange Format (AIF). An example is presented here and interpreted into all of the models to help understand the difference between them. Some models use labels near argument elements to distinguish between them.

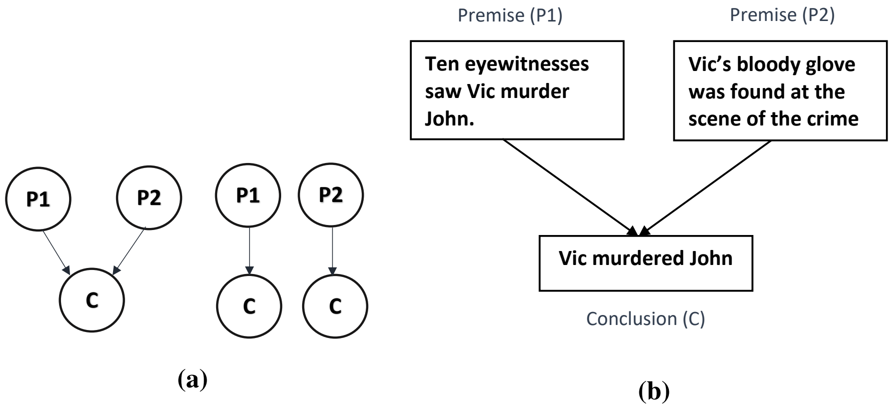

P1
P2
C
P1
P2
C
C
(a)
Premise (P1)
Premise (P2)
Ten eyewitnesses saw Vic murder John.
Vic's bloody glove was found at the scene of the crime
Vic murdered John
Conclusion (C)
(b)

Figure 2.1 Standard argument structures: (a) two forms of convergent argument; on the left, the premises "P1" and "P2" are connected to the conclusion "C" with each premise independently supports the conclusion "C". As converging argument can be considered independently, the convergent argument can be treated as two separate arguments as shown in the right-hand portion of (a); (b) an example of a convergent argument.

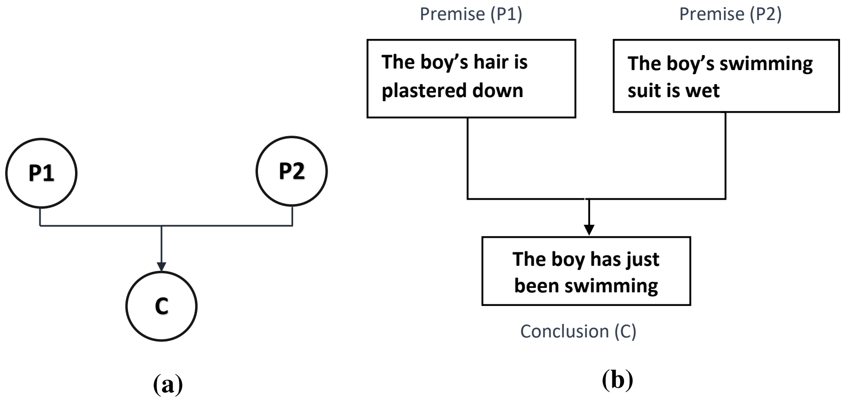

P1
P2
C
(a)
Premise (P1)
Premise (P2)
The boy's hair is plastered down
The boy's swimming suit is wet
The boy has just been swimming
Conclusion (C)
(b)

Figure 2.2 Standard argument structures: (a) linked argument where the premises "P1" and "P2" work together to support the conclusion "C"; (b) an example of linked argument.

2.3.1 Standard Model

The Standard model is a simple argument model [18], which is a combination of the basic argument structures mentioned in section 2.2. This model is used in philosophy and critical thinking [1]. Figure 2.4 shows an example of the Standard model where the conclusion is located at the top of the map while the other nodes are the premises [18]. The linked arguments, illustrated in Figure 2.4, are related to each other by a horizontal line and converge to an arrow to another box. Rebuttals are premises that attack the conclusion. An example of a rebuttal is drawn in Figure 2.4 using the grey box on the left.

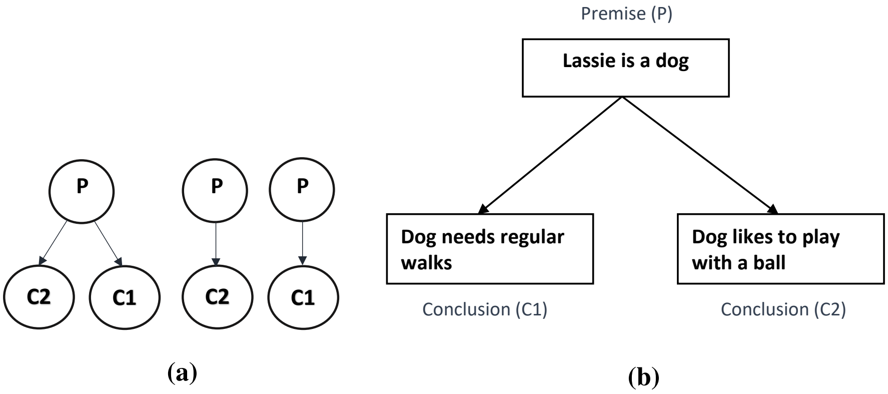


Figure 2.3 Standard argument structures: (a) two forms of divergent argument, on the left a premise "P" supports multiple different conclusions "C1" and "C2" or argument can be split into individual arguments as on the right ; (b) an example of divergent argument.

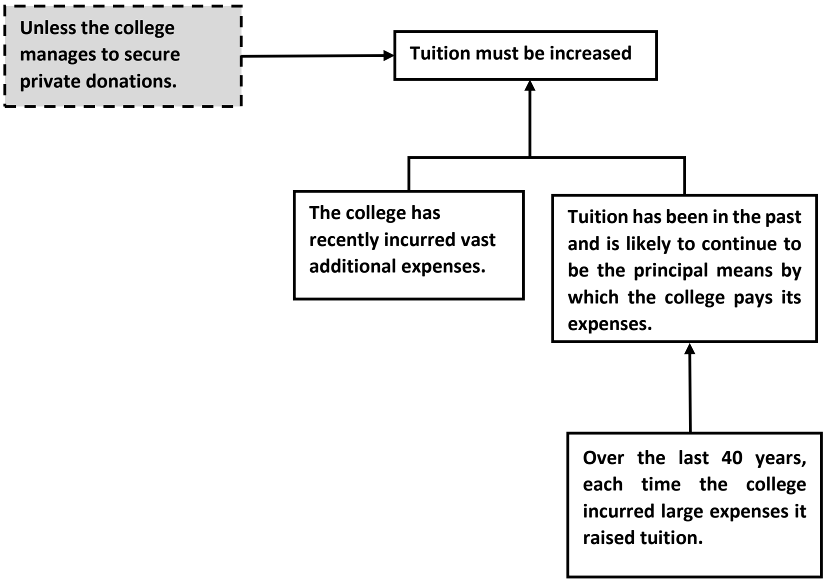

Unless the college manages to secure private donations.
Tuition must be increased
The college has recently incurred vast additional expenses.
Tuition has been in the past and is likely to continue to be the principal means by which the college pays its expenses.
Over the last 40 years, each time the college incurred large expenses it raised tuition.

Figure 2.4 An example of the Standard model. The conclusion is at the top of the model, and all the other nodes are premises. The linked arguments are linked to each other by a horizontal line and converge to an arrow to conclusion.

2.3.2 Wigmore Chart

The Wigmore chart is a unique and complex model that consists of many shapes, symbols, numbers and lines [19]. Lines represent the relations between arguments, while shapes display the facts or evidence which is drawn as a tree. It is used to visualise and model legal evidence arguments [20]. Evidence in the Wigmore chart is offered from the prosecution or defence and can be classified into the following types [19]:

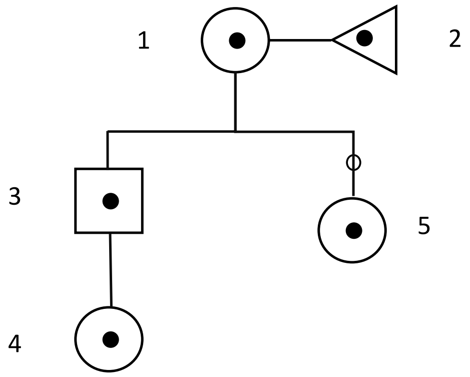
- Testimonials where square shapes represent the facts provided by the witnesses.

- Circles denote circumstantial evidence that represents all other facts.

- Corroborative evidence is presented as a triangle that supports testimonial or circumstantial evidence.

Figure 2.5 illustrates an example of a Wigmore chart which is translated from the same example shown in Figure 2.4. The rebuttal in Wigmore is presented with a node that has a small circle on the connected line [21].

The Wigmore chart is a rich model that includes a lot of shapes and symbols, and every chart comes with a "key list" that explains each box and number. However, the Wigmore chart is complicated and using it effectively requires learning its shapes and symbols. Consequently, it is a significant investment for experts and can be too complicated for amateur users [22].



1. Tuition must be increased.
2. The college has recently incurred vast additional expenses.
3. Tuition has been in the past, and is likely to continue to be, the principal means by which the college pays its expenses.
4. Over the last 40 years, each time the college incurred large expenses it raised tuition.
5. Unless the college manages to secure private donations.

Figure 2.5 An example of the Wigmore chart with a list to clarify the statements associated with the number in the chart.

2.3.3 Toulmin Model

The Toulmin model expresses the structure of an argument based on Data, Claim, and Warrant [23]. The Data (premise) is the statement that expresses the evidence or the fact. The Claim (conclusion) is the statement that people are arguing about. The statement that supports the bridge between the Data and the Claim is called a Warrant (premise). When the Warrant is not supportive enough, another statement called Backing (premise) can be provided. A Rebuttal (premise) attacks the Claim, while the qualifier is a set of words or a phrase expressing how certain the author/speaker is concerning the Claim. The same example above is represented in the Toulmin model [21], as shown in Figure 2.6.

The Toulmin model provides a useful collection of elements to describe the aspect of argumentative practice. According to Eemeren *et al.* [24], it is difficult to distinguish between Data and Warrant as both support the Claim with no hint to recognise between them.

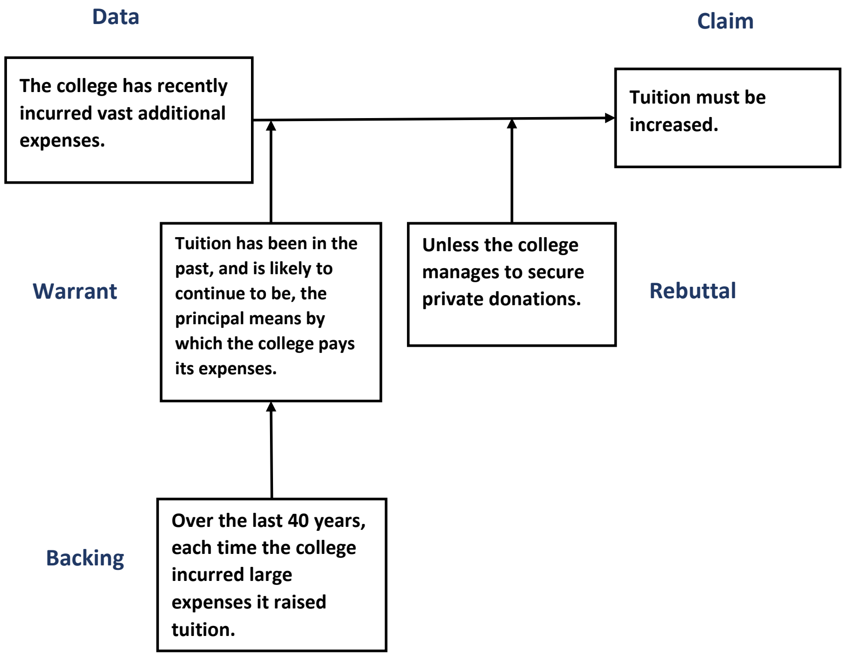

Data
Claim
The college has recently incurred vast additional expenses.
Tuition must be increased.
Warrant
Tuition has been in the past, and is likely to continue to be, the principal means by which the college pays its expenses.
Unless the college manages to secure private donations.
Rebuttal
Backing
Over the last 40 years, each time the college incurred large expenses it raised tuition.

Figure 2.6 illustrates and integrates the elements of argument identified by Toulmin [23]. These include Claim, Data, Warrant, Rebuttal and Backing.

2.3.4 IBIS

IBIS is used to identify ill-defined problems and help users discuss various issues related to these problems to reach a better solution [25]. The IBIS model consists of three elements. First, issues that reflect a problem or a question that needs to be answered. Second, positions or ideas that express the solution. Third, arguments which support or oppose the ideas. Figure 2.7 depicts the same example used in the previous models. IBIS may seem simple, and it has a structural coherence to reflect the problem-solving discussion [26]. However, IBIS is hard to learn as it over-splits ideas, sometimes resulting in the big picture being lost in a morass of issues, ideas and arguments [27]. In addition, it does not show linked arguments.

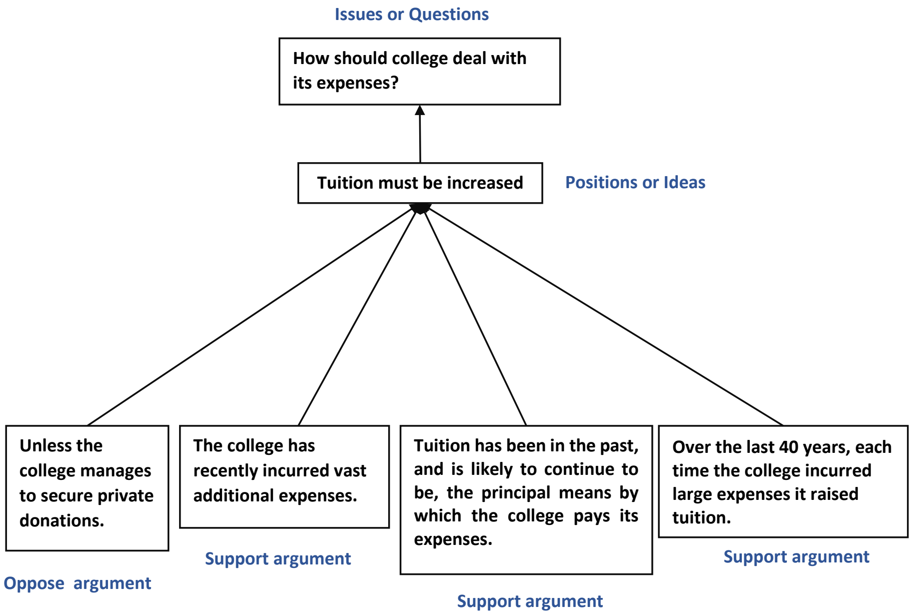

Issues or Questions
How should college deal with its expenses?
Tuition must be increased
Positions or Ideas
Unless the college manages to secure private donations.
The college has recently incurred vast additional expenses.
Tuition has been in the past, and is likely to continue to be, the principal means by which the college pays its expenses.
Over the last 40 years, each time the college incurred large expenses it raised tuition.
Oppose argument
Support argument
Support argument
Support argument

Figure 2.7 An example of the IBIS model with the main elements of the model which are the question, position to answer the question, and support or oppose arguments.

2.3.5 AIF

AIF is an international argument format that allows an exchange of arguments resources between argument tools. It consists of three main concepts [28]. The first explains the ontology of the argument entities and the relations between them. The second is about the ontology of the communication protocol. The third is the ontology of an environment where the argument takes place. AIF uses nodes and edges to present the entities of the arguments, and the nodes have two types, information and schema. Information nodes, also called I-nodes, present argument elements such as conclusion and premises. Schema nodes, i.e. S-nodes, reflect the pattern of reasoning and have three types; inference schema (RA-node), preference schema (PA-node), and conflict schema (CA-node) [29]. AIF accounts for only monological arguments. However, it has been extended to include a dialogue between two or more users in AIF+ [30].

All the nodes in the previous example (Figure 2.4) are presented as I-nodes in AIF using boxes [31] while S-nodes, denoted as diamonds, reflect the relations (support/oppose) between the I-nodes as shown in Figure 2.8.

Translating between the models is not always an easy process; each model has its own elements and its method of connecting these elements to each other. Thus, many interpretations from one model to another can be found [21], [32]. AIF is designed in a way that can be extended to capture a variety of argumentation models. For example, Carneades [33] is an argument tool for legal reasoning that has a data model called Carneades Argument Graphs (CAG). CAG translates into AIF, which allows users to interchange with any system that is compatible with AIF, like Araucaria [34] and Rationale [35]. These exchanges break down the barriers between argument domains. Other examples of mapping arguments from argumentation models into AIF and vice versa can be found in Oren *et al.* [32]. AIF provides a flexible, rich model for manipulation and representing argumentation structure [36], and thus, is adopted in this research to describe the data structure.

2.4 Argument Analysis and Mapping

Argument mapping is a way of diagramming the structure of arguments [37], that is used to enhance users' reasoning skills. Gelder studied the effect of using argument maps, and the results showed improvement in argument reasoning and thinking skills [38]. Dwyer *et al.* [39] compared graphical argumentation tools (argument map) with textual tools and found that students who used graphical tools could better recall argument elements than those who employed textual ones. Furthermore, Dwyer *et al.* [40] found that the students who used

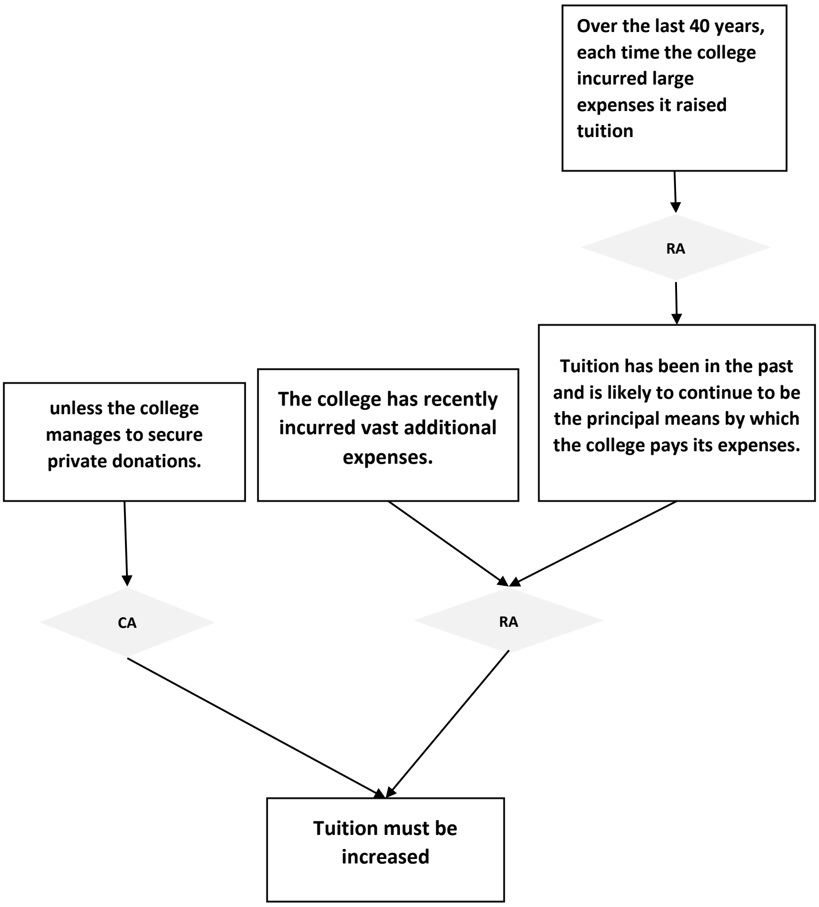

Over the last 40 years, each time the college incurred large expenses it raised tuition
RA
unless the college manages to secure private donations.
The college has recently incurred vast additional expenses.
Tuition has been in the past and is likely to continue to be the principal means by which the college pays its expenses.
CA
RA
Tuition must be increased

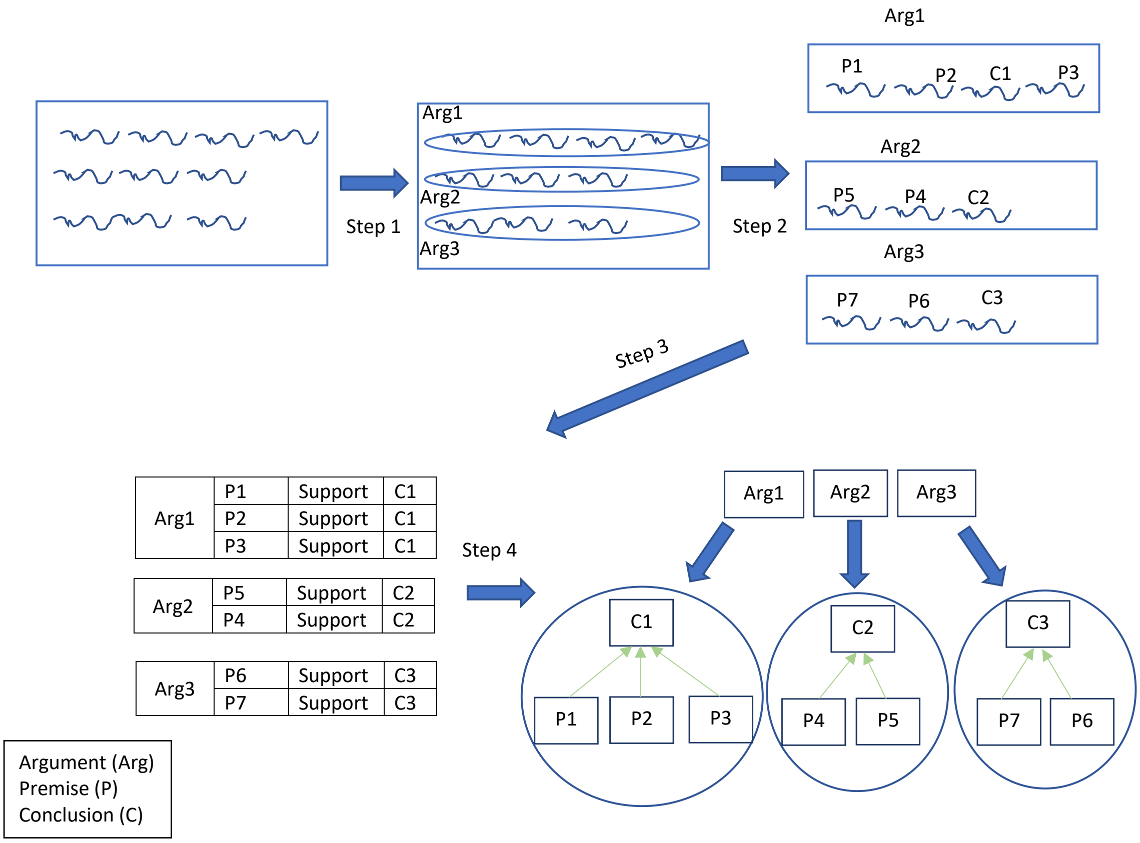
Figure 2.8 An example of the AIF model. The information nodes (argument elements) are presented using the rectangles, and the schema nodes (relations between the information nodes) are displayed using diamonds.

argument mapping scored higher in their critical thinking post-test than pre-test. Ortiz [41] found that students who took critical thinking courses and used argument maps improved their ability in critical thinking. Argument mapping is also used to support analysis. For example, Betz and Cacean [5] used argument maps to analyse the moral reasons for climate change; these argument maps provide an overview of the data and help to structure complex debates.

Argument analysis extracts the arguments and makes the relations between argument elements explicit. It takes text as an input, extracts debate and arguments, and determines how the arguments of different proponents relate to each other. The process of extracting arguments from text can be summarised, as shown in Figure 2.9, into the following steps [42]:

1. Identify individual arguments
2. Distinguish premises and a conclusion
3. Determine the structure of the argument
4. Represent arguments

Extracting arguments from text is a complicated process as in many situations, the premises and conclusion do not follow each other but are spread across multiple lines, which makes it challenging to identify them in the text. Also, it is difficult to determine the relations between them as they do not have a special linguistic mark in most arguments [43]. Another difficulty is incomplete arguments, where the premises or conclusion are implicit, which can only be solved by supplying the premises or a conclusion.



Arg1	P1	Support	C1
	P2	Support	C1
	P3	Support	C1
Arg2	P5	Support	C2
	P4	Support	C2
Arg3	P6	Support	C3
	P7	Support	C3

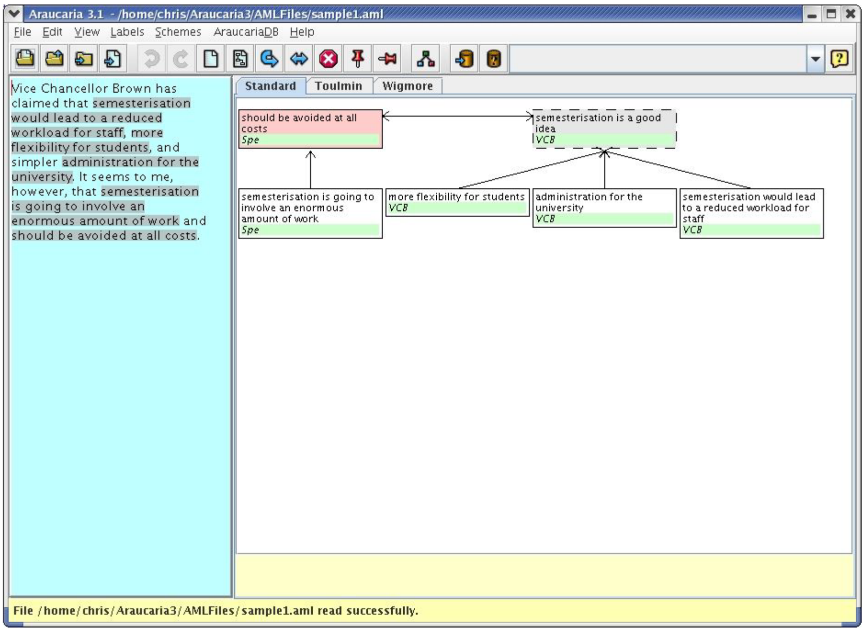
Figure 2.9 Argument analysis steps. Step 1, all the arguments in the text are recognised. Step 2, different argument elements, premises and conclusions, are distinguished. Step 3, the relationships between the argument elements are defined. Step 4, argument elements are visualised and connected.

Argument analysis tools help users to analyse arguments from text such as Araucaria [34], an open-source tool. Users can structure and represent the arguments using Standard, Wigmore and Toulmin models that are embedded in Araucaria. Users can then select a specific part of the text, which is located on the left of the interface, as illustrated in Figure 2.10. Upon selecting the text, users can create nodes and links between them to shape the argument map. Araucaria version 4 allows the user to create and edit an AIF model [44]. Other examples for argument analysis tools are Online Visualisation of Argument (OVA) and MonkeyPuzzle. The former is similar to Araucaria except that it is designed to extract arguments from web pages [45]. MonkeyPuzzle is a new tool with a similar user interface to Araucaria as both have the text and visualisation panels, but MonkeyPuzzle adds the possibility to annotate and analyse arguments from multiple sources [46].

Most argumentation tools use maps to visualise argument structure and help analysts to understand how argument elements are connected with each other. Nowadays, argument analysis and argument mining tools are automated to handle large volumes of text [47], [48]. Different techniques and layouts [49], [50] are designed to visualise argument datasets. Understanding arguments requires first to have a macro-structure, i.e. to see the overview of the whole argument. Second is a micro-structure that involves exploring the internal structure of argument elements [42]. Third is the ability to read the text of the argument elements [51]. These requirements create challenges in ArgVis, which will be discussed in the following Chapter by reviewing ArgVis tools and highlighting the pitfalls with respect to achieving these requirements.

2.5 Summary

In this Chapter, arguments in monologues and dialogues were defined, and the importance of arguments in different domains, like law and education, was introduced. Argument structures were reviewed to understand the way that premises and conclusion connect, and widely used argument models were introduced supported by examples. The reviewed models were the Standard that uses a linked, divergent and convergent argument structure, Wigmore chart (legal domain), Toulmin (critical thinking), IBIS (ill-defined problems), and AIF. Argument analysis tools, tools that use argument maps to help experts present an argument structure


Araucaria 3.1 - /home/chris/Araucaria3/AMLFiles/sample1.aml
File Edit View Labels Schemes AraucariaDB Help
Standard Toulmin Wigmore
should be avoided at all costs
Spe
semesterisation is a good idea
VCB
semesterisation is going to involve an enormous amount of work
Spe
more flexibility for students
VCB
administration for the university
VCB
semesterisation would lead to a reduced workload for staff
VCB

Vice Chancellor Brown has claimed that semesterisation would lead to a reduced workload for staff, more flexibility for students, and simpler administration for the university. It seems to me, however, that semesterisation is going to involve an enormous amount of work and should be avoided at all costs.

File /home/chris/Araucaria3/AMLFiles/sample1.aml read successfully.

Figure 2.10 Araucaria user interface: the text panel is on the left side of the interface, and the visualisation panel is on the right [34]. The presented nodes in visualisation are highlighted in the text panel.

and make it explicit, were reviewed. The requirements of understanding arguments were discussed.

In the following Chapter, InfoVis is introduced with a focus on the visual representation of trees and networks, and the pros and cons of each layout. Then, existing ArgVis tools are surveyed, and their layouts are categorised into the indentation, node-link, nested, matrix, and hybrid ones summarising their advantages and limitations. After that, the challenges in ArgVis are highlighted. Finally, the design and validation methods are reviewed to help in designing and improving ArgVis tools.

Chapter 3

Information Visualisation and Argument

Visualisation makes argument structure easier to interpret compared to textual representations and reduces the cognitive load required to recognise instances of a certain element [52]. Visual representations offer a better understanding of arguments. Therefore, visualisation layouts for graphs are reviewed to investigate promising layouts that can be used to visualise the arguments. Moreover, using interactivity in visualisation tools allows users to explore and check further details about the visualised data. The key requirements for understanding arguments that should be considered in designing ArgVis tools, as discussed in section 2.4, are:

K1 having an overview of the argument dataset to understand how premises and conclusions connect with each other.

K2 recognise the patterns of relationships between argument elements, e.g. support and oppose relationships.

K3 reading the text of argument elements.

Interaction techniques for overview and exploring fine details, e.g. overview and zoom, focus and context, details on demand, are surveyed to investigate which techniques are better to achieve **K1** and **K2**. Besides, the methods used to explore the text and read argument contents in the literature, e.g. labelling, are discussed (**K3**).

3.1 Information Visualisation

Using computer systems allows us to store and collect massive amounts of data that are difficult to manage and interpret manually. Therefore, the demand for computer tools that enable users to manage data effectively has grown rapidly in recent decades. Visualisation provides users with an interactive representation that makes complex data readable and understandable. Information visualisation (InfoVis) can be defined as “the use of computer-supported, interactive, visual representations of data to amplify cognition” [52, p. 6]. InfoVis helps users obtain knowledge about the internal structure of the data and the embedded relationships [53].

In the following sections, different graphical representations for trees and networks are reviewed. Then, techniques for visualising long text, e.g. email and conversation, in the literature are explored [54]. Furthermore, user interaction techniques that help in achieving a balance between overview and details are investigated.

3.1.1 Visual Representation of graphs

A graph consists of two elements, nodes and edges, where nodes are connected by edges, i.e. links [55], and a path is a sequence of links that connect the nodes. Edges with a specific direction define a directed graph; otherwise, the graph is undirected. A graph can be cyclic if it contains a closed path between the nodes, i.e. a path starts and ends with the same node. Both nodes and edges can have attributes; a node has a degree that measures the number of links connected to it, and an edge can have a numerical value, weight, that refers to the distance between two nodes. A network is a directed graph, while a graph without a cycle is called a tree [56]. Different representations for tree and network layouts are discussed below and illustrated in Figure 3.1.

There are three visual representations for networks, namely, node-link, matrix, and hybrid [57]. In node-link, nodes are presented as point marks and links are drawn as line marks, as illustrated in Figure 3.2a [58], [59]. Node-link layouts are familiar to users, but they can suffer from edge-crossings [60] and scalability in large graphs [61]. Matrix layouts can mitigate these two problems [62]. In a matrix, all nodes are positioned along the horizontal rows and vertical columns of the matrix layout while links occupy the squares that relate

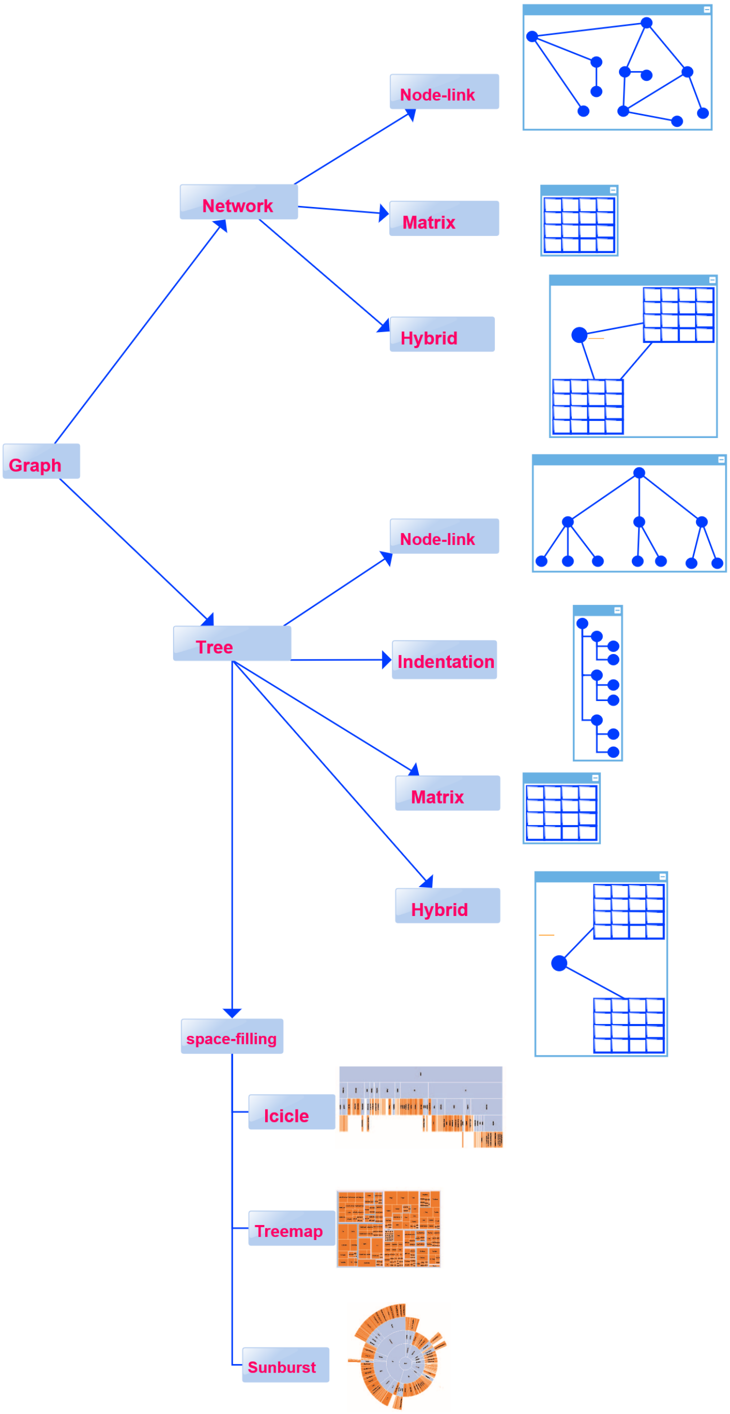
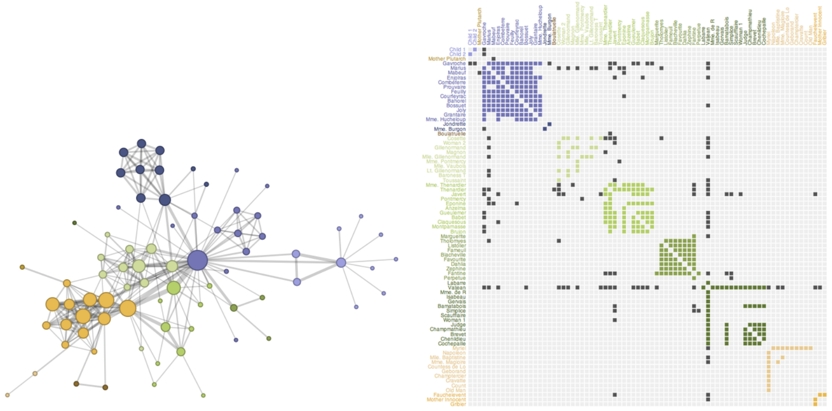


Figure 3.1 Networks and tree layouts. Three visual representations for networks, namely, node-link, matrix, and hybrid. Tree representations can be categorised into non-space-filling techniques (node-link, matrix and indentation), and space-filling techniques (icicle, treemap, sunburst).

the nodes to each other, as illustrated in Figure 3.2b [55]. Matrix representations suit dense graphs, but it lacks familiarity to most users [63]. The combination between matrix and node-link layouts, known as a hybrid layout, aims to overcome the limitations of both approaches and focus on their strengths [64].



(a) **(b)**

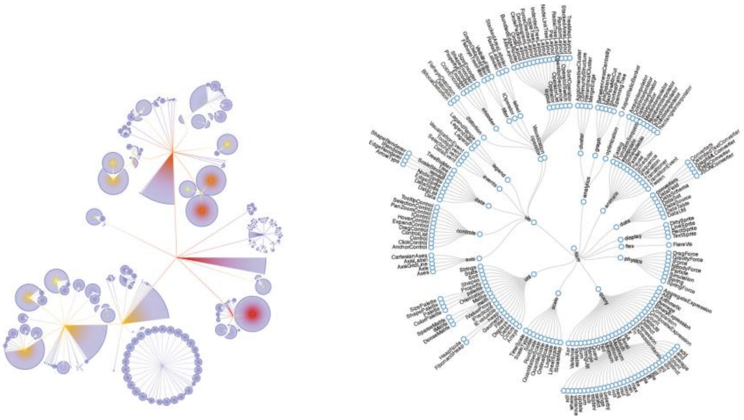
Figure 3.2 Network representations: (a) node-link layout; (b) matrix layout [58].

A tree layout is a simple graph with a hierarchy structure, i.e. parent-child relations between nodes where each node has one parent. Tree representations can be categorised into non-space-filling techniques, e.g. node-link, matrix and indentation, and space-filling techniques, e.g. treemap [65], sunburst [66], [67] and icicle [68].

Node-link layouts are the most common representations of non-space-filling tree layouts [69]. Based on node-link layouts, several tree-drawing algorithms have been proposed, such as the radial tree and bubble tree [60]. In the radial tree, nodes are located on circles that surround the parent node, and node locations depend on the depth of the tree. In the bubble tree, each parent with its children forms a full circle. Examples of the bubble and radial trees are shown in Figure 3.3 (a) and 3.3 (b), respectively.

In matrix layouts, each column and row of the matrix is related to a node. The edge from node (i) to node (j) is symbolised by cell (i, j). It is difficult for users to follow edge paths in matrix layouts [69].

In indentation layouts, nodes are listed linearly based on their depth in the tree [69]. Indentation layouts are widely used to help users navigate and read the text [70], [71]. This layout is familiar to users due to its similarity to file browsers [72]. The text is presented inside the visualised nodes without overlapping, as shown in Figure 3.4. However, the

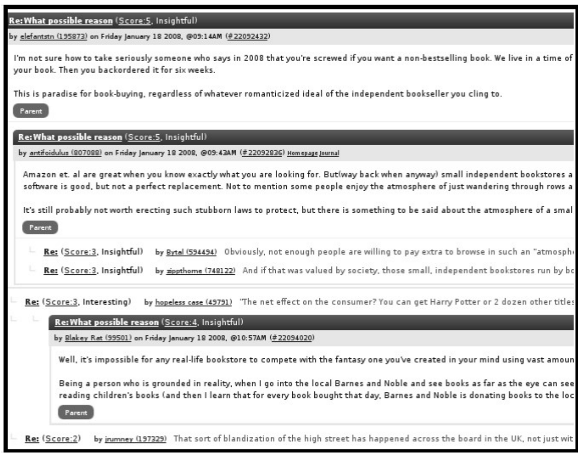


(a)

(b)

Figure 3.3 Examples of node-link layouts: (a) Bubble tree (b) Radial tree [55].

overview of the whole data is lost with large data as it can only show a small amount of data at once [72], [73].



Re: What possible reason (Score:5, Insightful)
by elefantstn (195873) on Friday January 18 2008, @09:14AM (#22092432)

I'm not sure how to take seriously someone who says in 2008 that you're screwed if you want a non-bestselling book. We live in a time of
your book. Then you backordered it for six weeks.

This is paradise for book-buying, regardless of whatever romanticized ideal of the independent bookseller you cling to.

Re: What possible reason (Score:5, Insightful)
by antifoidulus (807088) on Friday January 18 2008, @09:43AM (#22092836) Homepage Journal

Amazon et. al are great when you know exactly what you are looking for. But(way back when anyway) small independent bookstores a
software is good, but not a perfect replacement. Not to mention some people enjoy the atmosphere of just wandering through rows a

It's still probably not worth erecting such stubborn laws to protect, but there is something to be said about the atmosphere of a smal

Re: (Score:3, Insightful) by Bytal (594494) Obviously, not enough people are willing to pay extra to browse in such an "atmosph
Re: (Score:3, Insightful) by zippthorne (748122) And if that was valued by society, those small, independent bookstores run by bc

Re: (Score:3, Interesting) by hopeless case (49791) "The net effect on the consumer? You can get Harry Potter or 2 dozen other titles

Re: What possible reason (Score:4, Insightful)
by Blakey Rat (99501) on Friday January 18 2008, @10:57AM (#22094020)

Well, it's impossible for any real-life bookstore to compete with the fantasy one you've created in your mind using vast amoun

Being a person who is grounded in reality, when I go into the local Barnes and Noble and see books as far as the eye can see
reading children's books (and then I learn that for every book bought that day, Barnes and Noble is donating books to the loc

Re: (Score:2) by jrumney (197329) That sort of blandization of the high street has happened across the board in the UK, not just wit

Figure 3.4 Example of indentation layout with long labels inside the nodes [70].

In space-filling techniques, juxtaposition is used to express the relations between the nodes instead of links to save space and condense the overview. These techniques can be rectangular like treemap (Figure 3.5) and icicle plots (Figure 3.6), or circular such as sunburst layouts (Figure 3.7). Each parent in the treemap (nested layout), enfolds its children on its boundaries [74]. In the icicle plot, child nodes are adjacent to the parent's border [68]. Sunburst layouts rely on a circular or radial display to represent a hierarchy. The root is represented in centre, and each level of the tree forms a ring that surrounds the root.

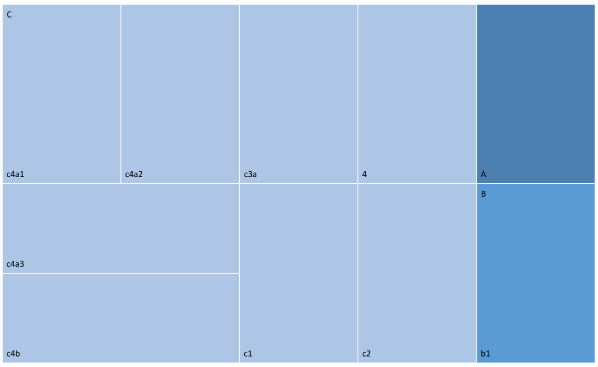


Figure 3.5 Example of the nested treemap layout.

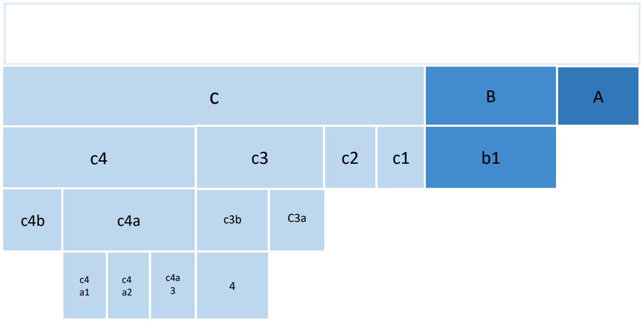


Figure 3.6 Example of the icicle layout.

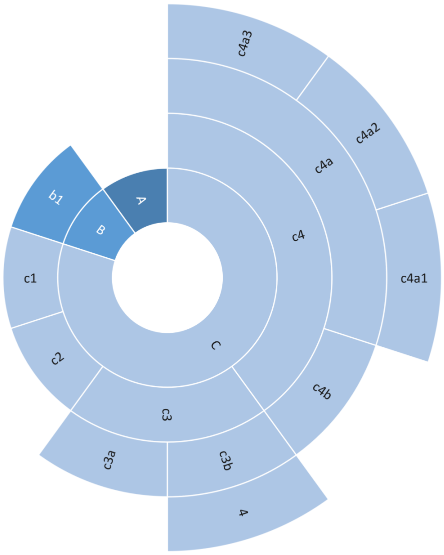


Figure 3.7 Example of the sunburst layout.

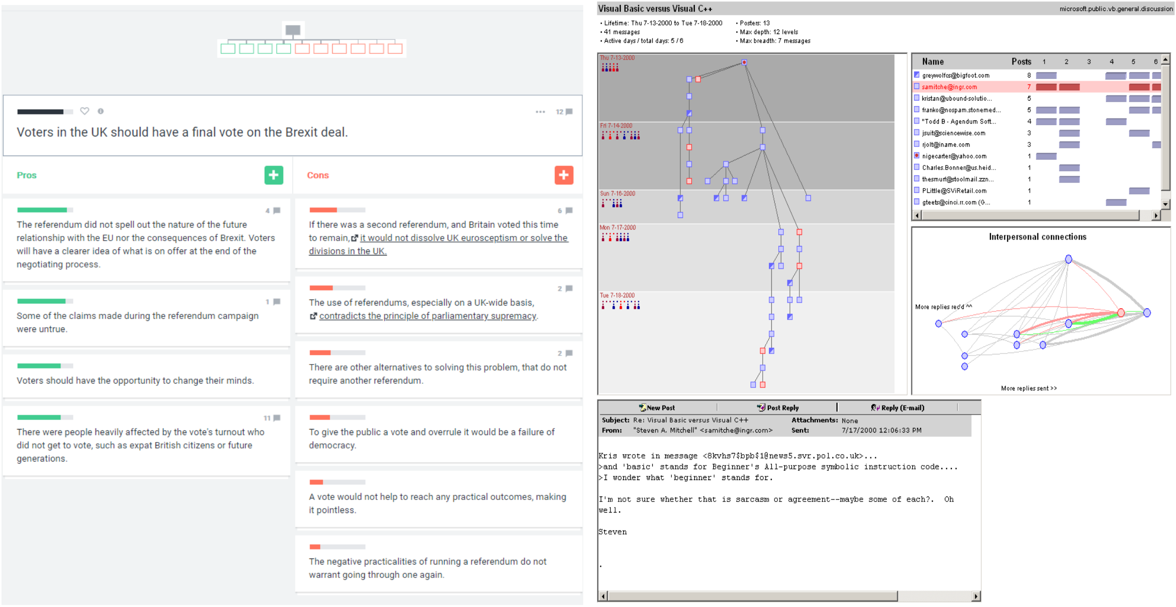
Stasko *et al.* [66] compared and evaluated two space-filling techniques, treemap and sunburst, concerning their capabilities for standard file-management tasks by conducting two comprehensive studies. The participants preferred the sunburst as it has a more explicit structure compared with the treemap [66]. Cawthon *et al.* [75] measured the aesthetic, effectiveness and efficiency of 11 different tree visualisations. The survey addressed aesthetic ranking and task performance. The results showed that sunburst ranked the highest in aesthetic. Furthermore, icicle and sunburst layouts had the highest percentage of correct responses. Icicle and sunburst are more suitable layouts for providing an overview than treemaps [74], [76]. The structure in the treemap is not as clear as in the classical tree [77]. Therefore, icicle and sunburst layouts can be promising solutions for providing an overview of arguments.

A hybrid approach is a combination of layouts, such as node-link and treemap layouts, that takes advantage of layouts with clear structure and space efficiency [61]. Additionally, user interaction designers take advantage of the strength of each visualisation by coordinating them in multiple views. The multiple views technique uses two or more distinct views to support the investigation of a single entity [78], [79]. There are common types of coordination, such as overview + details, drill down, brushing and linking and synchronised scrolling [80]. Some studies prove that coordinated views improve navigation and exploration [81], [82].

Many visualisation techniques have been developed in the literature to present messages, blogs, emails, and conversations and show the relations between their elements [83]. Kim *et al.* used a node-link layout where nodes and links are presented as tag clouds [84]. Gil and Ratnakar used indentation layout to show the structure and allow users to read the text at the same time [71]. To better utilise the visualisation area, Yee and Hearst applied space-efficient layouts, e.g. treemap layouts, to visualise both text content and structure [85].

The two coordinated views are used for ease of exploring and understanding visualised information; one to show the overview and another to navigate and read the text. For example, two coordinated views using node-link layouts to represent the structure, with an indentation layout to help explore the text, are proposed in several studies [86], [73], [87], [88]. Kialo [89], a tool for critical thinking and serious discussion, uses a sunburst layout to show the overview of the data. When the user clicks on any threads, it transforms into another window with the node-link layout to reflect the structure of the focused chain, with a linked table to present the text of the parent and all the children in the first level (Figure 3.8a).

Multiple-coordinated views are used for structure navigation and reading the discussion. Smith and Fiore [90] proposed a dashboard that includes: a) a tree to display the structure of the selected thread, b) a message view to present the contents of a selected message, and c) a node-link network which shows the interpersonal connection as shown in Figure 3.8b. Wattenberg *et al.* [91] used user interactions, i.e. focus and context technique, to help users navigate through the discussion overview while individual messages are displayed in the detailed view.



Voters in the UK should have a final vote on the Brexit deal.

4 The referendum did not spell out the nature of the future relationship with the EU nor the consequences of Brexit. Voters will have a clearer idea of what is on offer at the end of the negotiating process.

1 Some of the claims made during the referendum campaign were untrue.

Voters should have the opportunity to change their minds.

11 There were people heavily affected by the vote's turnout who did not get to vote, such as expat British citizens or future generations.

6 If there was a second referendum, and Britain voted this time to remain, it would not dissolve UK euroscepticism or solve the divisions in the UK.

2 The use of referendums, especially on a UK-wide basis, contradicts the principle of parliamentary supremacy.

2 There are other alternatives to solving this problem, that do not require another referendum.

To give the public a vote and overrule it would be a failure of democracy.

A vote would not help to reach any practical outcomes, making it pointless.

The negative practicalities of running a referendum do not warrant going through one again.

(a)

Visual Basic versus Visual C++ microsoft.public.vb.general.discussion

- Lifetime: Thu 7-13-2000 to Tue 7-18-2000
- 41 messages
- Active days / total days: 5 / 6
- Posters: 13
- Max depth: 12 levels
- Max breadth: 7 messages

Name	Posts
greywolfcs@bigfoot.com	8
samitche@ingr.com	7
kristan@ubound-solutio...	5
franko@nospam.stonemed...	5
"Todd B - Agendum Soft...	4
jsuit@sciencewise.com	3
rjolt@iname.com	3
nigecarter@yahoo.com	1
Charles.Bonner@us.heid...	1
thesmurf@stoolmail.zzn...	1
PLittle@SVIRetail.com	1
gteets@cinci.rr.com (G...	1

Subject: Re: Visual Basic versus Visual C++ Attachments: None
From: "Steven A. Mitchell" <samitche@ingr.com> Sent: 7/17/2000 12:06:33 PM

```
Kris wrote in message <8kvhs7$bpb$1@news5.svr.pol.co.uk>...
>and 'basic' stands for Beginner's All-purpose symbolic instruction code....
>I wonder what 'beginner' stands for.

I'm not sure whether that is sarcasm or agreement--maybe some of each?.  Oh
well.

Steven


.
```

(b)

Figure 3.8 Examples of context layout (a) A snapshot of the Kialo tool illustrates the node-link layouts to present the argument structure with a table to show the linked text; (b) The Netscan dashboard that combines multiple views to display the structure, text and connection between the persons who participate in a discussion [90].

In the following sections, interaction techniques that help to make sense of overview and details, one of the key requirements to understand an argument, are reviewed.

3.1.2 User Interaction

User interaction (UI) is an action carried out by users to help them better understand the visualised information [92]. No layout can overcome the problems raised by the large size of data occurring in a visualisation without UI [60]. Shneiderman summarised essential interactive characteristics introduced by InfoVis into seven features; overview, zoom, filter, relate, details on demand, history, and extract [93]. The following paragraphs focus on the UI that provide the overview and details (**K1** + **K2**).

3.1.2.1 Overview and Zoom

The overview provides users with a view of the entire graph and the structure of the data. Zooming helps users reduce the complexity of the data visualisation by focusing on and increasing the size of relevant information [94]. **Zooming and panning** allow users to navigate and move from one point of the zoom level to another. The drawback of this technique is that if the focused view is not what users needs, they must zoom-out and adjust the view again [95]. The **overview + details** technique is a promising solution to this problem, as the overview is embedded with a detailed view in the same display area, each with a distinctive presentation [95], e.g., Google Earth. In Google Earth, a small space is allocated in the displayed area to present the overview of the whole data, which is controlled by users to choose the focused point, as shown in Figure 3.9.

Focus and context (F+C) removes the spatial and temporal separation between the two views by displaying the focus within the context in a single view. F+C is used to expand the viewing area of the sections currently being viewed while compressing the remaining sections. When the user moves the cursor to another part of the view, the display changes dynamically making the new focus larger and shrinking the rest of the view [96]. Figure 3.10 illustrates the increase in the size of information at the central lens area by using a magnification lens (fisheye) [97], [98]. F+C is used in many visualisation systems to solve problems in real-world applications, such as the Perspective Wall [99] and DocumentLens [100] that distort contextual views to show the interested region but remain in context. F+C has been used with space-filling adjacency layouts to help users explore and read the text [101].

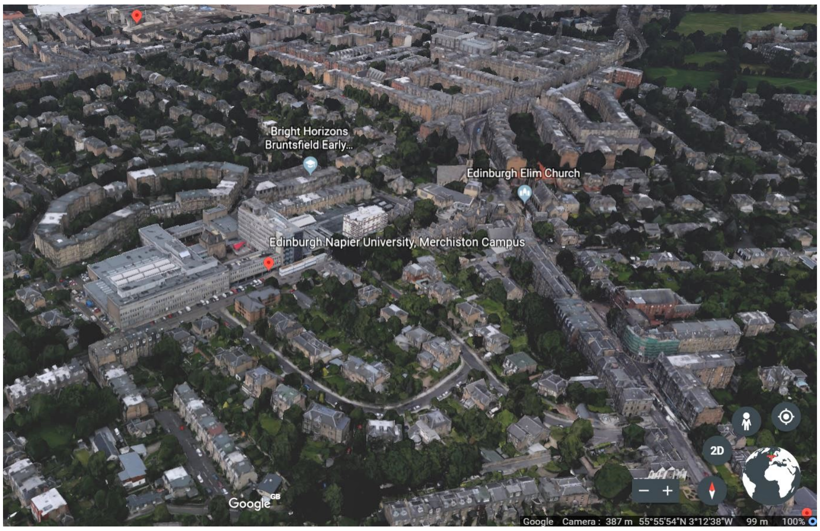

Bright Horizons
Bruntsfield Early...
Edinburgh Elim Church
Edinburgh Napier University, Merchiston Campus
2D
Google
Google Camera : 387 m 55°55'54"N 3°12'38"W 99 m 100%

Figure 3.9 Example of overview and details techniques on Google earth. The overview of the earth is represented on the right bottom corner, and is based on users' choice. The details are displayed on the detail view.

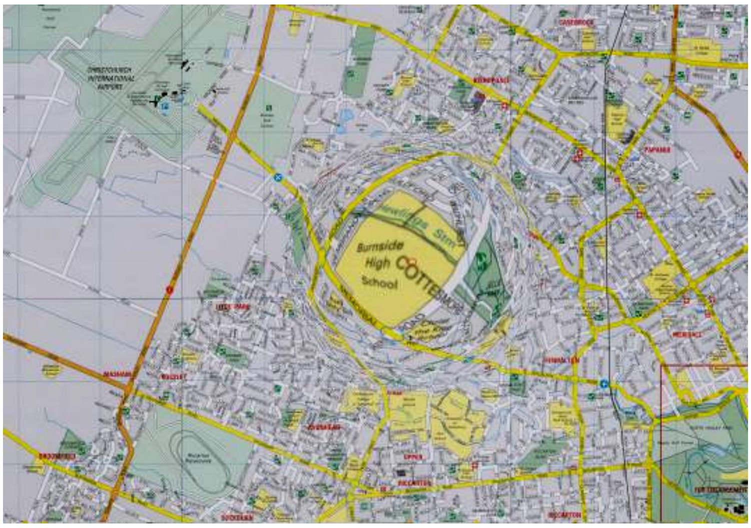


Figure 3.10 A fisheye view where the size of information at the central lens is increased at the focused point [98].

3.1.2.2 Details-on-Demand

Due to the limitation of display screen size, it is difficult to provide all the details in visualisation, especially for large datasets where the graph becomes complicated. Details-on-demand is a technique that allows users to obtain more information about focused items (**K3**), such as with pop-up information, i.e. a label that appears when users hover over these items [93]. One of the benefits of this technique is to explore more details quickly without changing the representation, e.g., OpinionBlocks that provides an aspect-based sentiment overview for customer reviews. It uses labelling to allow users to read and navigate customer reviews [102].

Labelling in InfoVis reflects the relations between visual objects and textual elements. Based on the location of a label relative to the visual object, labels can be classified into internal and external ones. Internal labels are located inside the visual object [103] and this way of labelling is explicit, readable and points immediately to the visual object. However, one of its pitfalls is overlapping between long labels due to lack of space [104]. External labels are located outside the visual object and connected to it using a leader line [105]. Many algorithms are designed to optimise the location and alignment of external labels [106].

Boundary labelling is a type of external labelling designed for long labels, where a rectangle is used to frame the label(s), a leader connects each label to the object, and one or more labels can be placed in one rectangle [107]. Excentric labelling is a dynamic technique of boundary labelling, revealing labels of items near a point of interest [108]. Labels are placed in the same order of the corresponding area, which may result in crossed leaders when the labelling is dense. Therefore, the technique has been improved by allowing users to scroll between the labels and inherit the visual features of the object like colour and font [106], [109].

Features such as readability and aesthetics should be considered when labels are designed [104], and we should avoid labels overlapping with each other or with the related structure. These problems are increased when the number of labels rises, or the labels are long [110].

3.2 Argument Visualisation

Argument visualisation (ArgVis) is any non-verbal technique used to present arguments in which the relationships among arguments are made explicit [111], [112], [38]. Kirschner *et al.* discussed in [51] the importance of ArgVis in making sense of information and presenting the disagreements and evidence in a way that helps to understand arguments. Loll *et al.* surveyed 97 argumentation experts from various domains and showed that the argument representation helps in understanding arguments and organising ideas across all domains surveyed [113]. The main aims of ArgVis are to clarify the arguments elements and the relationships between them, to allow users to gain a quick overview, and to show more or less details of interesting arguments to focus on relevant parts [51], [6]. Difficulty in understanding argument structures stems from a tension between needing an overview of the whole structure to explore how arguments elements are connected to each other while also investigating the details [114], [42].

The following example will demonstrate how ArgVis can bring various facts of an argument to the surface in different ways. The argument is “Fayetteville, North Carolina is a great place to live. The city has many great restaurants and movie theatres, the schools are good, but the weather is bad". First, the argument elements need to distinguished. The argument consists of the conclusion “Fayetteville, North Carolina is a great place to live" which has two supporting statements (premises): “The city has many great restaurants" and “the schools are good", and one opposing statement (premise) “the weather is bad". To present the argument, the following indentation layout can be used.

(1) Fayetteville, North Carolina is a great place to live:

(1.1) The city has many great restaurants.

(1.2) The schools are good.

(1.3) The weather is bad.

From this example, it is known that three statements are connected to the conclusion. However, the relations between the premises and conclusion are unknown before reading the statements. The relations can support or oppose the conclusion. Colours can be used to distinguish between different types of statements and thus make the relationships more explicit, for example:

(1) Fayetteville, North Carolina is a great place to live:

(1.1) The city has many great restaurants.

(1.2) The schools are good.

(1.3) The weather is bad.

Instead, argument elements can be denoted by nodes, i.e. boxes and incorporate links to express the relationships between these argument elements with colour encoding to reflect the type of relationships, as in Figure 3.11. ArgVis uses boxes or circles and arrows or lines to represent the arguments, where the boxes or circles represent the claims, position, ideas, statements. Arrows or lines reflect the relationships [115].

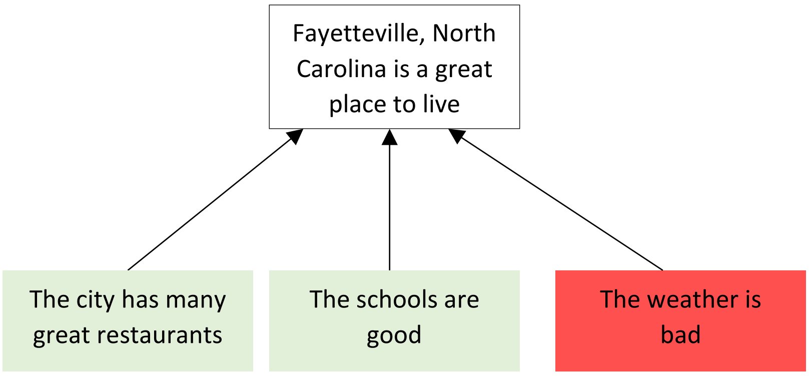

Fayetteville, North Carolina is a great place to live
The city has many great restaurants
The schools are good
The weather is bad

Figure 3.11 Use of boxes and links to represent an argument[s].

Most of the ArgVis tools use a tree or network to present the argument [116], while others use a table or matrix. Details of existing ArgVis tools in CSAV are introduced in the following sections.

3.2.1 Argument Visualisation Layouts

In these sections, existing ArgVis tools are reviewed, categorised based on their layouts [117], by describing their visual techniques and highlighting their limitations.

3.2.1.1 Indentation Layout

Indentation layouts reveal the hierarchical argument structure by placing the arguments (nodes), with the text inside, vertically at varying levels of indentation depending on the depth of the nodes in the structure. To improve collaborative deliberations, Collaboratorium [118] used an indentation layout to organise discussions based on various types of statements such as issue, and idea. To distinguish between the types, relevant icons near each node are displayed. DebateGraph [4], Hermes [119], ARGUMED [120], AcademicTalk [121], LEGALESE [122] and Evidence Hub [123] are other examples of tools that have used an indentation layout to present the arguments. LEGALESE employs a title to recognise diverse types of statements, as represented in Figure 3.12a. DebateGraph uses red for opposing statements and green for supporting ones, as shown in Figure 3.12b.

To provide users with more details about the arguments, some tools used two or more views such as Hermes. The latter has two views, one to display the arguments and the relationships between them, and another to show information (metadata) about the selected node, as illustrated in Figure 3.12c.

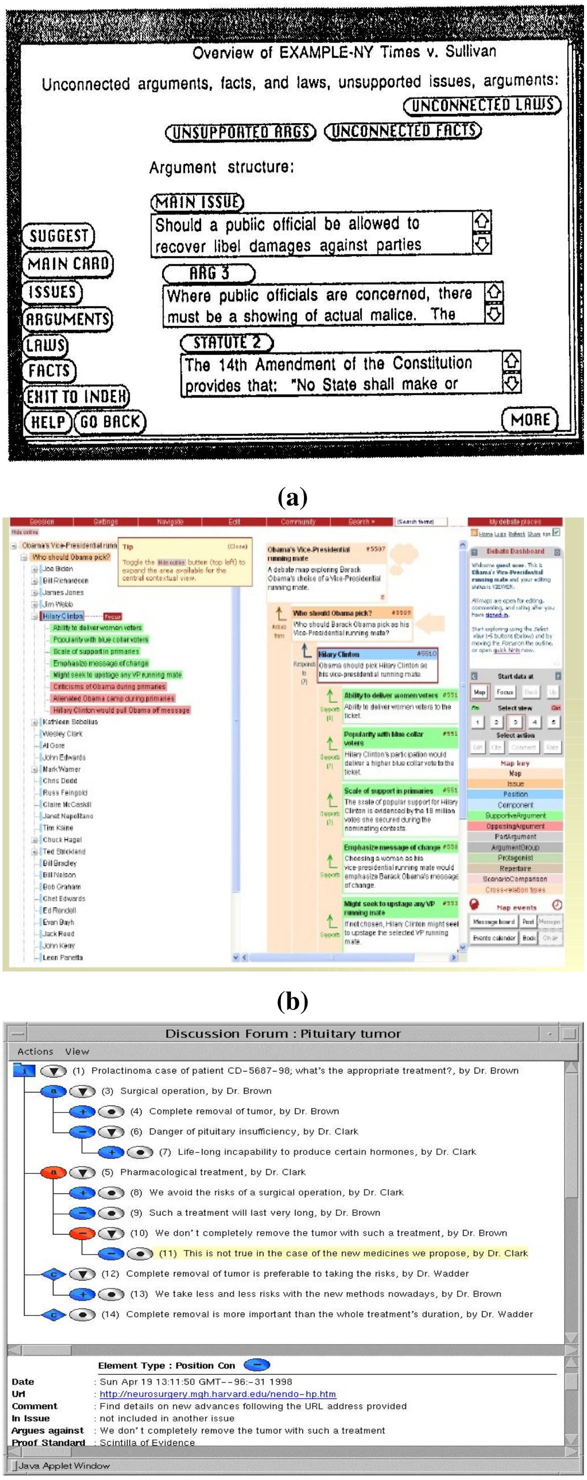
Indentation layouts are familiar to users due to their similarity to file browsers. In these layouts, text can occupy nodes without crossing. However, they fail to provide an overview of the structure in large arguments due to the limitation of the window size. Also, indentation layouts can be overwhelming due to the number of expanders needed to get to specific data [124].

3.2.1.2 Node-link Layout

Node-link layouts use nodes to present the argument elements and links to express relations between them. Depending on the argument structure model of the argument tools, some tools present the argument using tree layouts such as Rationale [125], Carneades [33], Structured Evidential Argumentation System (SEAS) [126], Argvis [127] and Reason!Able [128]. Others visualise the argument using network layouts, e.g. Argument Visualization for Evidential Reasoning based on stories (AVERs) (Figure 3.13) [14], Metafora [129], Cohere [130], bCisive [49], LASAD [131], and LARGO [132]. Some tools remove the cycle, which is a closed path between nodes, by duplicating statements and present the arguments as a tree [33], since network layouts are more complicated than tree layouts, and trees are relatively stable [133].

Argument nodes in the node-link layout have various colours and shapes. The shapes help to present argument elements. Colours are used to recognise different types of relations. For example, green, red and blue are used to show support, oppose and neutral relationships, respectively, as shown in (Figure 3.13).

DebateGraph uses a node-link layout with various views [4]. The first one is a simple triangular vertical tree with the root on the top and child nodes on the bottom, as clarified in Figure 3.14. The second is a radial tree where the root is located in the centre, and children



Overview of EXAMPLE-NY Times v. Sullivan

Unconnected arguments, facts, and laws, unsupported issues, arguments:

Argument structure:

MAIN ISSUE

Should a public official be allowed to recover libel damages against parties

ARG 3

Where public officials are concerned, there must be a showing of actual malice. The

STATUTE 2

The 14th Amendment of the Constitution provides that: "No State shall make or

(a)

Obama's Vice-Presidential runn
Who should Obama pick?
Joe Biden
Bill Richardson
James Jones
Jim Webb
Hilary Clinton
Ability to deliver women voters
Popularity with blue collar voters
Scale of support in primaries
Emphasize message of change
Might seek to upstage any VP running mate
Criticisms of Obama during primaries
Alienated Obama camp during primaries
Hillary Clinton would pull Obama of message
Kathleen Sebelius
Wesley Clark
Al Gore
John Edwards
Mark Warner
Chris Dodd
Russ Feingold
Claire McCaskill
Janet Napolitano
Tim Kaine
Chuck Hagel
Ted Strickland
Bill Bradley
Bill Nelson
Bob Graham
Chet Edwards
Ed Rendell
Evan Bayh
Jack Reed
John Kerry
Leon Panetta

Tip

Toggle the Hide outline button (top left) to expand the area available for the central contextual view.

Obama's Vice-Presidential running mate #5507

A debate map exploring Barack Obama's choice of a Vice-Presidential running mate.

Arises from

Who should Obama pick? #5509

Who should Barack Obama pick as his Vice-Presidential running mate?

Responds to (7)

Hilary Clinton #5510

Obama should pick Hilary Clinton as his vice-presidential running mate.

Supports (8)

Ability to deliver women voters #551

Ability to deliver women voters to the ticket.

Supports (7)

Popularity with blue collar voters #551

Hilary Clinton's participation would deliver a higher blue collar vote to the ticket.

Supports (7)

Scale of support in primaries #551

The scale of popular support for Hilary Clinton is evidenced by the 18 million votes she secured during the nominating contests.

Supports

Emphasize message of change #558

Choosing a woman as his vice-presidential running mate would emphasize Barack Obama's message of change.

Supports

Might seek to upstage any VP running mate #333

If not chosen, Hilary Clinton might seek to upstage the selected VP running mate.

Debate Dashboard

Welcome **guest user**. This is **Obama's Vice-Presidential running mate** and your editing status is VIEWER.

All maps are open for editing, commenting, and rating after you have signed-in.

Start exploring using the *Select view* 1-5 buttons (below) and by moving the Focus on the outline, or open quick hints now.

(b)

Discussion Forum : Pituitary tumor

(1) Prolactinoma case of patient CD−5687−98; what's the appropriate treatment?, by Dr. Brown
(3) Surgical operation, by Dr. Brown
(4) Complete removal of tumor, by Dr. Brown
(6) Danger of pituitary insufficiency, by Dr. Clark
(7) Life−long incapability to produce certain hormones, by Dr. Clark
(5) Pharmacological treatment, by Dr. Clark
(8) We avoid the risks of a surgical operation, by Dr. Clark
(9) Such a treatment will last very long, by Dr. Brown
(10) We don' t completely remove the tumor with such a treatment, by Dr. Brown
(11) This is not true in the case of the new medicines we propose, by Dr. Clark
(12) Complete removal of tumor is preferable to taking the risks, by Dr. Wadder
(13) We take less and less risks with the new methods nowadays, by Dr. Brown
(14) Complete removal is more important than the whole treatment's duration, by Dr. Wadder

Element Type : Position Con

Date	: Sun Apr 19 13:11:50 GMT−−96:−31 1998
Url	: http://neurosurgery.mgh.harvard.edu/nendo−hp.htm
Comment	: Find details on new advances following the URL address provided
In Issue	: not included in another issue
Argues against	: We don' t completely remove the tumor with such a treatment
Proof Standard	: Scintilla of Evidence

Java Applet Window

(c)

Figure 3.12 Three examples of indentation layouts: (a) LEGALESE [122] uses titles to distinguish between different types of argument statements; (b) DebateGraph [4] applies green and red colours to reflect support/oppose relationships, respectively; (c) Hermes [119] uses one view to display the arguments graph with different colour encoding and varied symbols to distinguish the argument elements, and another view to illustrate the metadata.

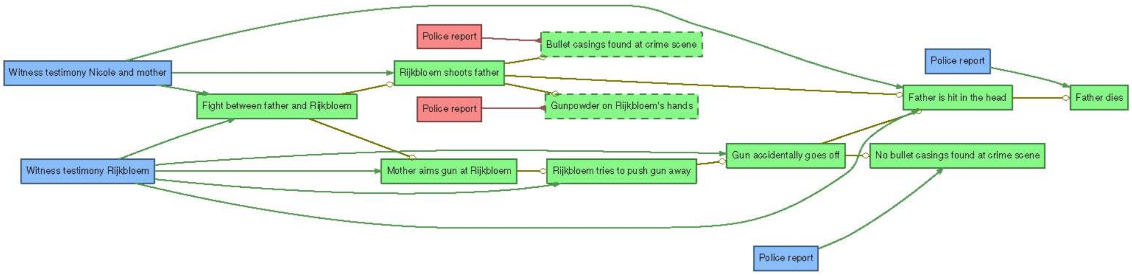

Police report
Bullet casings found at crime scene
Witness testimony Nicole and mother
Rijkbloem shoots father
Police report
Fight between father and Rijkbloem
Police report
Gunpowder on Rijkbloem's hands
Father is hit in the head
Father dies
Witness testimony Rijkbloem
Mother aims gun at Rijkbloem
Rijkbloem tries to push gun away
Gun accidentally goes off
No bullet casings found at crime scene
Police report

Figure 3.13 AVERs is an example of node-link layout [14].

are placed on circles surrounding the root according to their depth in the tree, as shown in Figure 3.15.

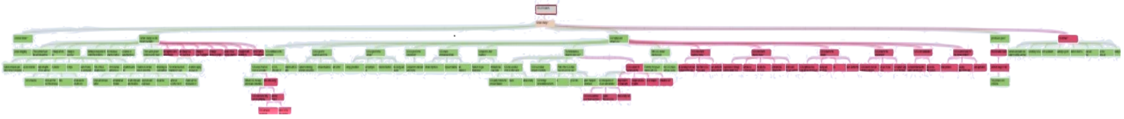


Figure 3.14 Tree node-link view of DebateGraph to illustrate the argument structure [4].

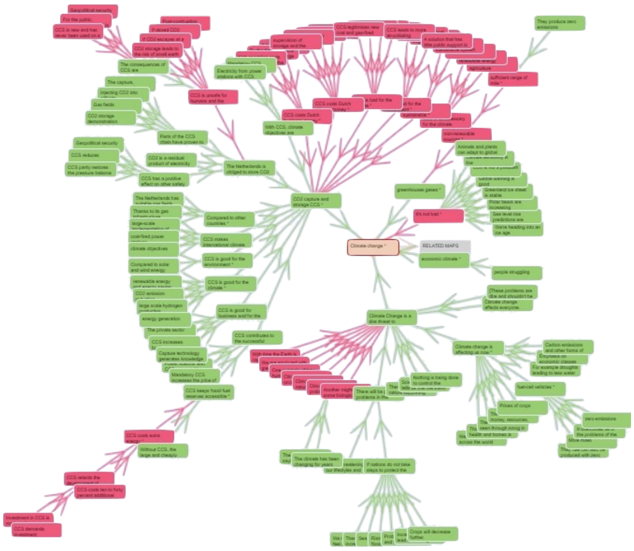
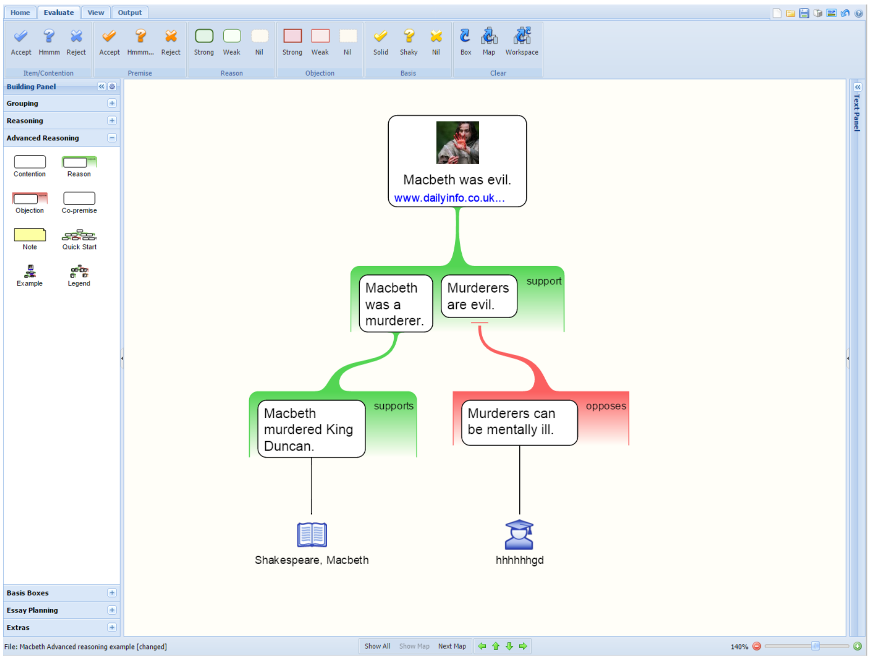


Figure 3.15 Radial node-link view of DebateGraph to present the structure of arguments [4].

Rationale [125] proposed a new tree structure called hi-tree. The key novelty in this representation is to allow statements that are linked together and at the same level to be grouped into "compound nodes" instead of using links to save space, as illustrated in Figure 3.16.

Node-link layouts are useful in presenting an argument structure and showing relations between arguments in a simple way. However, when the number of nodes with long text increases, the graph becomes space-inefficient. Consequently, the overview is lost [124].



Macbeth was evil.
www.dailyinfo.co.uk...

Macbeth was a murderer.

Murderers are evil.

Macbeth murdered King Duncan.

Murderers can be mentally ill.

Shakespeare, Macbeth

hhhhhhgd

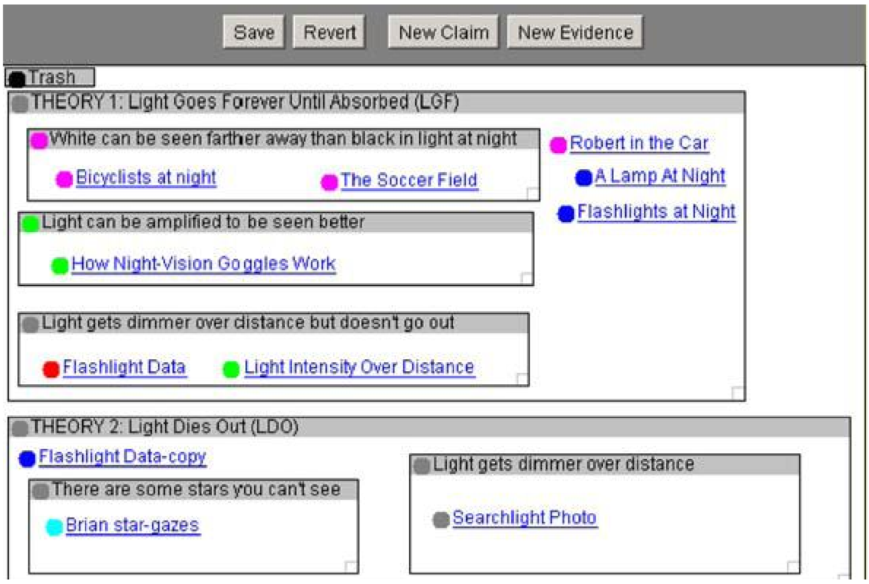
File: Macbeth Advanced reasoning example [changed]

Figure 3.16 Rationale representation with oppose and support premises; two premises linked to each other to support the conclusion (linked argument) [125].

3.2.1.3 Nested Layout

Nested layouts are one of the space-filling techniques, which use space to express relations between nodes instead of links to save space and condense the overview. For example, SenseMaker [134] uses a box-based Venn diagram to visualise small hierarchy data [135]. It displays the conclusion in a frame with the evidence denoted by dots located in the related frame, as shown in Figure 3.17.

Issue Maps uses a treemap layout to solve the problem of readability in large-scale arguments [6]. The main elements of Issue Maps are issues and arguments. Treemaps are used to allow users to get an overview of the vast amount of information. Different sizes of



THEORY 1: Light Goes Forever Until Absorbed (LGF)

White can be seen farther away than black in light at night

Bicyclists at night

The Soccer Field

Robert in the Car

A Lamp At Night

Flashlights at Night

Light can be amplified to be seen better

How Night-Vision Goggles Work

Light gets dimmer over distance but doesn't go out

Flashlight Data

Light Intensity Over Distance

THEORY 2: Light Dies Out (LDO)

Flashlight Data-copy

There are some stars you can't see

Brian star-gazes

Light gets dimmer over distance

Searchlight Photo

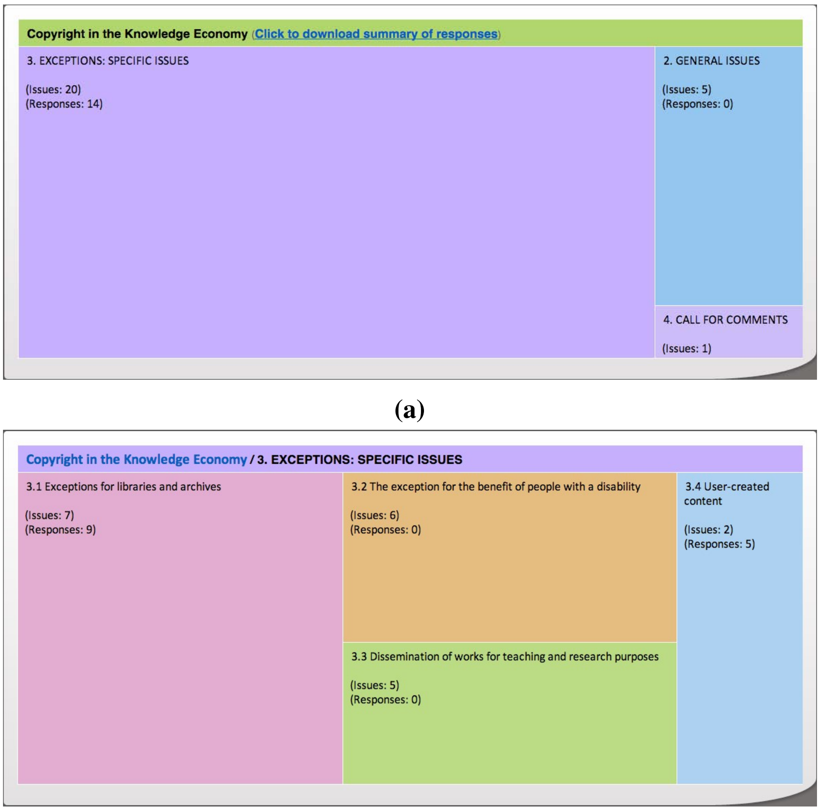
Figure 3.17 The nested layout (one of the space-filling techniques) of SenseMaker tool [134].

rectangles indicate the comparative number of arguments associated with each issue. Instead of displaying the children inside their parents as rectangles, Issue Maps displays the number of children as depicted in Figure 3.18a. Overview and details on demand has been used so users can click on any rectangle to see the arguments raised in that particular one as illustrated in Figure 3.18b. Also, pop-up text are provided to read the text.

Nested layouts overcome the problem of space and scalability. However, ArgVis tools that have used the nested layout did not take full advantage of it. For example, SenseMaker leaves blank spaces between the child nodes, and thus, does not utilise the entire display area. Likewise, Issue Maps only presents the number of children inside their parent which makes it hard to understand the type of relationships between the nodes.

3.2.1.4 Matrix Layout

Matrix layouts are used to make the relations in arguments explicit. The matrix, i.e. the tabular, layout uses rows and columns to denote argument elements and cells to represent the relations between these elements. Belvedere [136] applied a matrix layout to help users explore the argument relations. Belvedere uses a green plus sign to show support relations and a red minus sign to represent oppose ones



Copyright in the Knowledge Economy (Click to download summary of responses)

3. EXCEPTIONS: SPECIFIC ISSUES

(Issues: 20)
(Responses: 14)

2. GENERAL ISSUES

(Issues: 5)
(Responses: 0)

4. CALL FOR COMMENTS

(Issues: 1)

(a)

Copyright in the Knowledge Economy / 3. EXCEPTIONS: SPECIFIC ISSUES

3.1 Exceptions for libraries and archives

(Issues: 7)
(Responses: 9)

3.2 The exception for the benefit of people with a disability

(Issues: 6)
(Responses: 0)

3.3 Dissemination of works for teaching and research purposes

(Issues: 5)
(Responses: 0)

3.4 User-created content

(Issues: 2)
(Responses: 5)

(b)

Figure 3.18 Overview and details techniques in Issue Maps: (a) Overview map of debate showing main topics; (b) View of one of the sub-topics, i.e. the big purple rectangle in (a), showing the arguments inside this sub-topic [6].

Competing Hypotheses uses a matrix layout to define the evidence and arguments [137, p. 95]. The advantages of using a matrix layout are scalability for large arguments and the lack of occlusion due to link crossing. The pitfalls are the difficulty in following a specific path [50] and its unfamiliarity to users [55].

3.2.1.5 Hybrid Layout

Horn is one of few argument visualisation tools that provides users with an overview of the arguments so users can explore the structure and decide where to start reading [49]. Horn uses nested and node-link representations to present arguments as a large tree with many boxes [138], as illustrated in Figure 3.19. Each box is called a claim box, which may contain a claim, a rebuttal, or a counter-rebuttal. The boxes are connected to each other using links; arrows with labels that show the type of relations, i.e. support or oppose.

Other tools use two layouts as coordinated views, to provide an overview and allow the user to read text such as DebateGraph. It uses a node-link layout to represent the structure and an indentation layout for user navigation and reading the text. Belvedere applied a matrix layout with node-link layout as another type of presentation [136]. The matrix layout helps to discover the missing relations between nodes (Figure 3.20).

Following this review of existing ArgVis tools and categorising their layout into five groups, Table 3.1 summarises the advantages and disadvantages of each ArgVis layout.

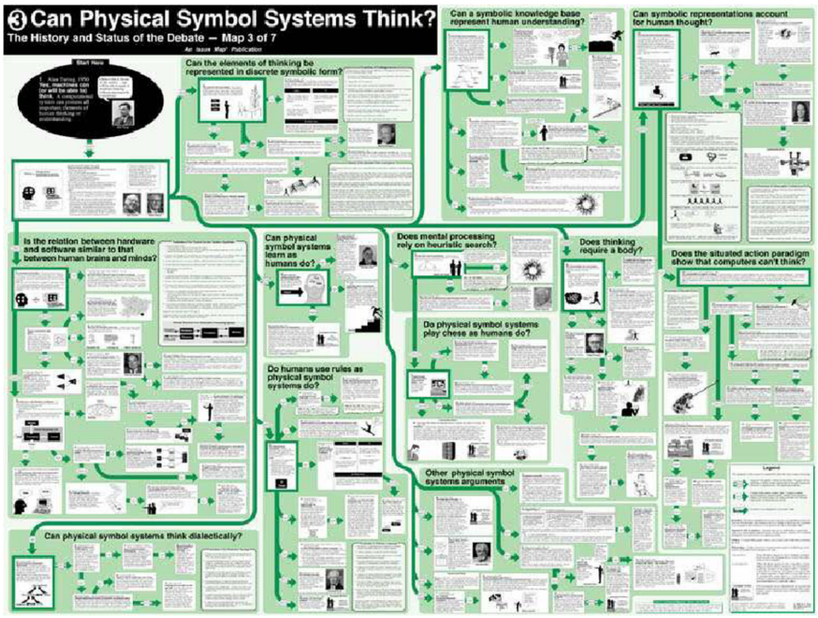
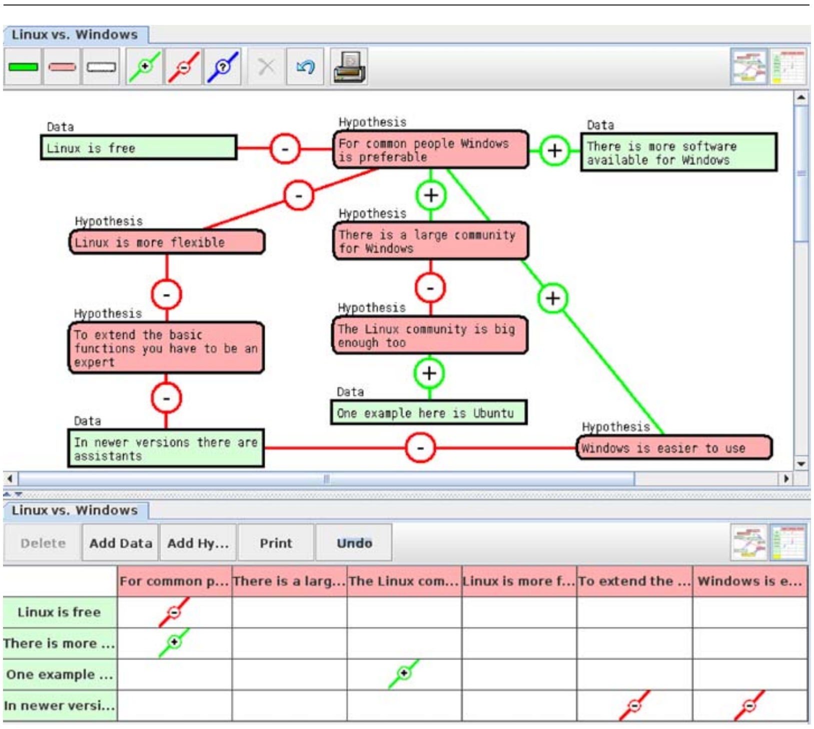

3 Can Physical Symbol Systems Think?
The History and Status of the Debate — Map 3 of 7
Start Here
Can a symbolic knowledge base represent human understanding?
Can symbolic representations account for human thought?
Can the elements of thinking be represented in discrete symbolic form?
Is the relation between hardware and software similar to that between human brains and minds?
Can physical symbol systems learn as humans do?
Does mental processing rely on heuristic search?
Does thinking require a body?
Does the situated action paradigm show that computers can't think?
Do physical symbol systems play chess as humans do?
Do humans use rules as physical symbol systems do?
Other physical symbol systems arguments
Can physical symbol systems think dialectically?
Legend

Figure 3.19 Horns-argument-map, which is a tree layout of boxes and link. The box contains claim, rebuttal, and counter-rebuttal [138].

Table 3.1 Advantages and disadvantages of argument visualisation layouts.

	Advantage	**Disadvantage**
Indentation layouts	- Present text without crossing. - Familiar to the users.	- Lack provision overview for large arguments.
Node-link layouts	- Present the arguments' structure and show relationships in a simple way. - Present tree and network structure.	- Space-inefficient when the number of nodes with long labels increase. - Lose the overview with large arguments.
Nested Layouts	- Provide overview.	- ArgVis tools that have used the nested layout did not take full advantage of provided space.
Matrix Layouts	- Explicit arguments relationships. - Lack of occlusion, e.g., link crossing.	- Unfamiliar to the user. - Challenging to follow a specific argument path.
Hybrid layouts	- Inherit the advantages of combined layouts. - Compact visualisation and easy correlation.	- Inherit the disadvantages of combined layouts. - It can be complex for users to understand.


Linux vs. Windows
Data
Linux is free
Hypothesis
For common people Windows is preferable
Data
There is more software available for Windows
Hypothesis
Linux is more flexible
Hypothesis
There is a large community for Windows
Hypothesis
To extend the basic functions you have to be an expert
Hypothesis
The Linux community is big enough too
Data
One example here is Ubuntu
Data
In newer versions there are assistants
Hypothesis
Windows is easier to use
+
-
Linux vs. Windows
Delete
Add Data
Add Hy...
Print
Undo

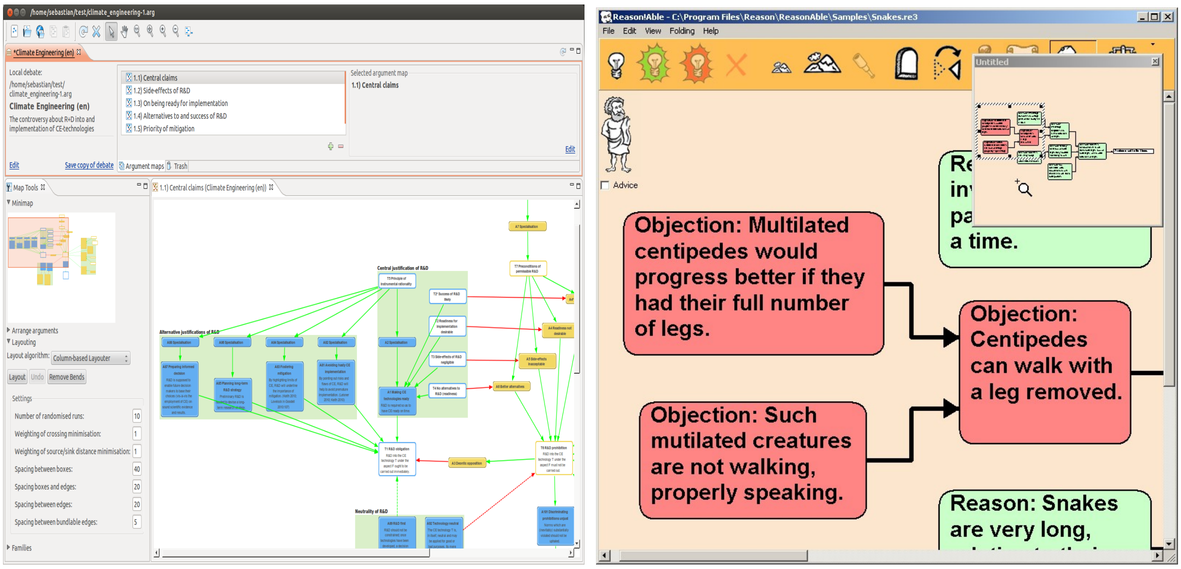
	For common p...	There is a larg...	The Linux com...	Linux is more f...	To extend the ...	Windows is e...
Linux is free	−					
There is more ...	+					
One example ...			+			
In newer versi...					−	−

Figure 3.20 Belvedere tool uses the node-link in top frame and the matrix (rows and columns) in bottom. It uses a green plus sign to show support relations and a red minus sign to represent oppose ones [136].

3.2.2 Interaction in ArgVis Tools

The zoom and pan technique is used in ArgVis tools to increase the size of the focused point and navigate from one focused point to another. Example of tools have used an overview and details technique, where detailed information is displayed beside an overview of the entire view in a small rectangle at the corner of the same window, as in OVA [15] and Argunet (Figure 3.21a) [139]. The small view of the overview is separated from the details view in the Reason!Able as clarified in Figure 3.21b [128]. While using this technique helps the user to understand more information about the data, sharing the display area can cause memory issues for users [55]. Rationale provides users with two techniques, overview and details and collapses and expands the sub argument [140].

DebateGraph uses a technique for supporting interactive exploration developed by Yee [141]. The layout of the tree animates into a new layout, and the focused node is located in the centre (Figure 3.22). However, this technique changes the geometry between the views, which may confuse users and make it difficult for them to understand the relations



/home/sebastian/test/climate_engineering-1.arg

*Climate Engineering (en)

Local debate:
/home/sebastian/test/climate_engineering-1.arg
Climate Engineering (en)
The controversy about R+D into and implementation of CE-technologies

- 1.1) Central claims
- 1.2) Side-effects of R&D
- 1.3) On being ready for implementation
- 1.4) Alternatives to and success of R&D
- 1.5) Priority of mitigation

Selected argument map
1.1) Central claims

Layout algorithm: Column-based Layouter

Settings

Number of randomised runs:	10
Weighting of crossing minimisation:	1
Weighting of source/sink distance minimisation:	1
Spacing between boxes:	40
Spacing boxes and edges:	20
Spacing between edges:	20
Spacing between bundlable edges:	5

Edit
Save copy of debate
Argument maps
Trash
Map Tools
Minimap
Arrange arguments
Layouting
Layout
Undo
Remove Bends
Families
1.1) Central claims (Climate Engineering (en))
Central justification of R&D
Alternative justifications of R&D
Neutrality of R&D
A7 Specialisation
T7 Preconditions of permissible R&D
T5 Principle of instrumental rationality

Reason!Able - C:\Program Files\Reason\ReasonAble\Samples\Snakes.re3

Objection: Multilated centipedes would progress better if they had their full number of legs.

Objection: Centipedes can walk with a leg removed.

Objection: Such mutilated creatures are not walking, properly speaking.

Reason: Snakes are very long,

(a) **(b)**

Figure 3.21 Examples of overview and details techniques (a) Overview and details in same window in the Argunet [139]; (b) Separated overview and details windows the Reason!Able [128].

between the views. Table 3.2 gives an example of the user interactions that apply in the argument visualisation tools.

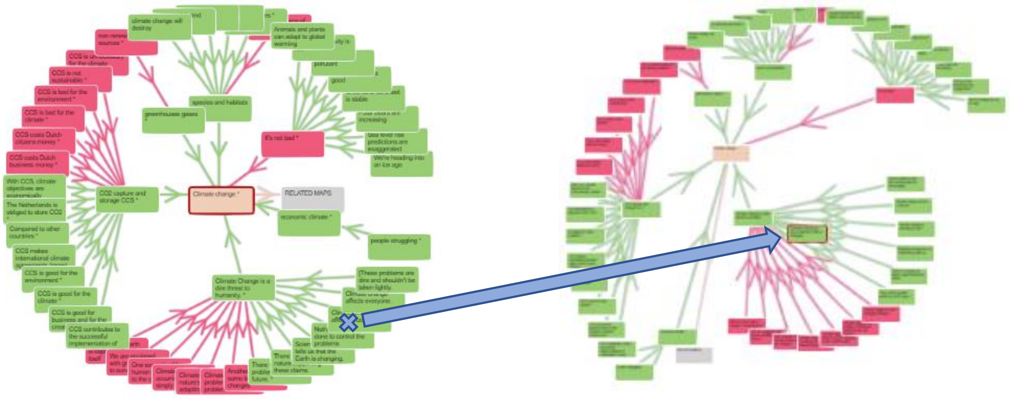


Figure 3.22 Animation technique in DebateGraph: (a) overview in DebateGraph radial layout, (b) The radial layout in DebateGraph is changed and the focused node, the one with the red border, is allocated in the centre of layout [4].

Table 3.2 Example of argument visualisation tools and user interactions.

ArgVis tools	Overview	Zoom	Extract	Filter	Detail on demand
CompendiumLD	Y	Y	Y	N	N
Belvedere	N	N	Y	N	N
Rational	Y	Y	Y	N	Y
Reason!Able	Y	Y	Y	N	N
Digalo	Y	Y	Y	Y	Y
AcademicTalk	N	N	Y	N	N
InterLoc	N	N	Y	N	N
Debategraph	Y	Y	Y	Y	Y
Convince ME	N	N	N	N	N
SenseMaker	N	N	Y	Y	N
ArguMed	N	N	N	N	N
LEGALESE	N	N	N	N	N
TruthMapping	N	N	N	N	N
Argunet	Y	Y	Y	N	Y
Evidence Hub	Y	Y	Y	Y	Y
OVA	Y	N	Y	N	N
SEAS	Y	Y	Y	Y	/
ArgVis	Y	Y	Y	N	/
bCisive	Y	Y	Y	Y	/
Metafora	Y	Y	Y	Y	/
Carneades	Y	Y	N	Y	Y
LASAD	N	N	Y	Y	N

3.2.3 Argumentation Visualisation Challenges

Many ArgVis tools have been proposed to help people in understanding arguments, exploring their structure and visually mapping the flow of inferences. However, the increasing use of online argument capture and rising demand for argument mining techniques to automatically recognise argumentative inferences in text creates the requirement to improve tools for visually exploring these datasets.

One of the challenges that faces ArgVis is visualising large arguments [49], i.e. when the number of nodes exceeds a hundred (or less in some cases) [140], [142]. To mitigate this problem, a big screen with high resolution has been used to present arguments [115]. However, this does not solve the problem of space inefficiency. Besides, a big screen is not available to all people, so it is not an efficient solution.

The number of nodes may not sound large, but it can be problematic in argumentation datasets as they are textual by nature. The challenge arises from users requesting to have a sense of the details and a vision of the whole [143]. Furthermore, ArgVis should allow users to read the argument text regardless of its length to help them understand the arguments, therefore the text associated with nodes must be legible. For example, Figure 3.23 shows a large argument graph about Decartes Meditationes using Argunet tool [139]. The graph illustrated all arguments unfolded, which resulted in a poster with a size of 2.5m x 4m [144].

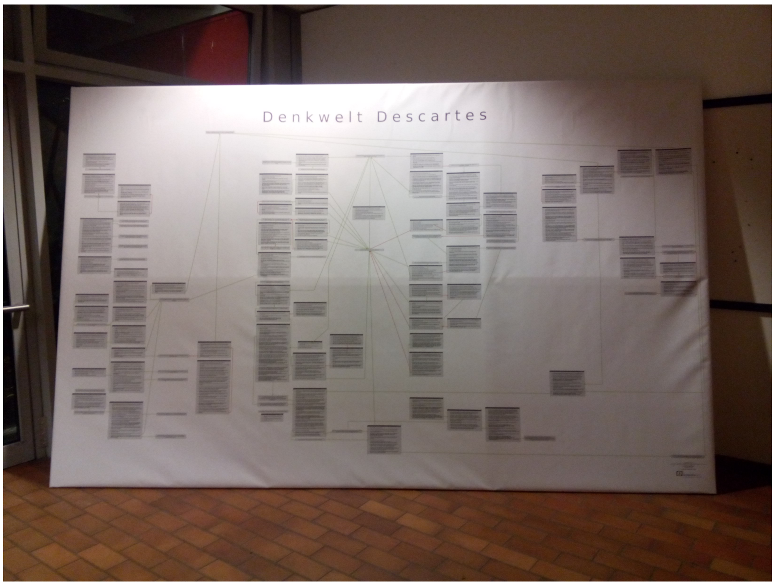


Figure 3.23 Argument graph presented at the conference of the Gesellschaft für Analytische Philosophy as a poster [144].

The challenges of ArgVis, where the number of nodes exceeds one hundred, can be summarised as, first, scalability. How can a large-argument dataset be presented, that allows the user to develop a sense of the whole data and explore the details? Second is readability; how can the user be assisted in reading the argument content?

The text requires a lot of space to visualise, especially when the number of nodes increases. Besides, ignoring user interaction can complicate the problem raised by the large size of the graphs. Improving the interaction in ArgVis can help users to explore and navigate arguments. ArgVis tools have tried to address these challenges using the following approaches:

(1) To focus the visualisation design on the structure and only show the texts on demand [127]. The large size of data and constraint of the screen size limits the amount of presented information. For this reason, users are provided with the required information without changing the visualisation view.

(2) To focus on the text but reduce information displayed in the structure [118]. The focal point is the text so the users can read it, meanwhile keeping the structure to assist in the analysis.

(3) To provide both–text and structure–simultaneously and embed the text into the graph, resulting in a very large visualisation [115].

3.3 Visualisation Design and Validation

Several models for designing visualisation tools have been proposed in the literature [52], [145], [146]. These models concentrate on the InfoVis pipeline, starting with processing raw data, transferring it into relations or sets that make it easy to visualise and then mapping the transformed data to a visual structure. After that, different views are created, and interaction techniques are added to help users understand and explore data [147]. However, these models do not give guidance on how to evaluate these systems or validate every stage. On the other hand, many evaluation systems have failed to present detailed guidance for users of where to carry out the evaluation [148], [149]. One of the most popular models is the nested model. The nested model provides a full framework for designing visualisation tools by dividing the visualisation design into levels [150]. It also suggests validation methods with guidelines for users to undertake at each level. The nested model can be applied in many visualisation approaches such as problem-driven, and technique-driven; therefore, it is adopted as the core method approach throughout this research. The nested model consists of four levels, as illustrated in Figure 3.24 and listed below:

(1) The first level is to understand the domain problem and data structure. The designer should be fully aware of the tasks that users are expecting from the designed visualisation system. The designers need to understand the users' requirements to make the visualisation useful and usable for them. However, involving users in the design process is time-consuming to collect and analyse the data. Besides, users often do not know precisely what they want [151]. The substantial problem at this level is the gap and potential misunderstanding between the designer and users. It is essential that the designer avoids making assumptions and gets back to users to understand their requirements deeply. Holding interviews or observing the target users are promising solutions to prevent such problems.

(2) The second level is to operate and abstract a data type. On this level, the designer tries to format the collected data from the specific domain into a vocabulary for InfoVis. There are many suggestions to validate this level, such as to let the target users try the tool or to write documents about how the target audience uses the deployed system.

(3) The third level is to encode and add interactions. This level focuses on translating the data to the visual elements. Expert review, user study, and qualitative discussion are used to validate the results at this level.

(4) The fourth level is to check the algorithm design where the designer has to deal with technical issues, e.g. measure the algorithm speed.

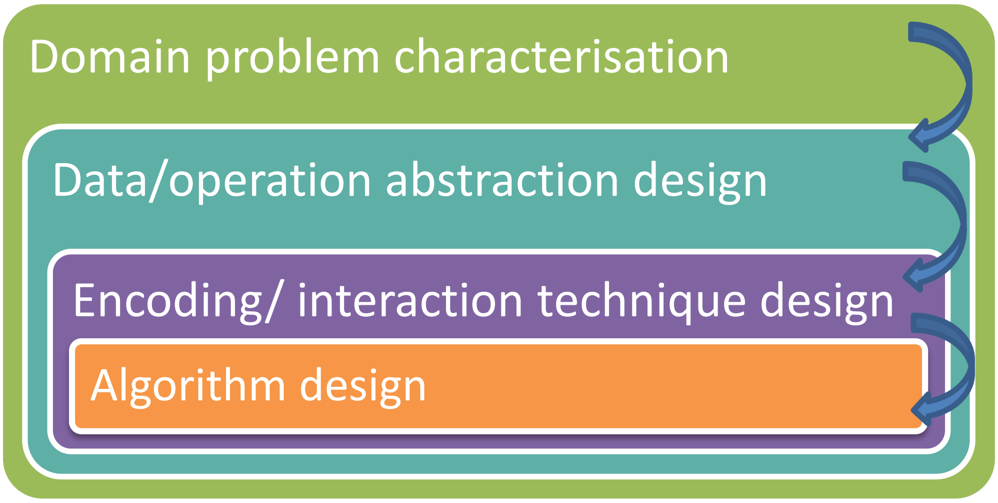

Domain problem characterisation
Data/operation abstraction design
Encoding/ interaction technique design
Algorithm design

Figure 3.24 The four levels of the nested model [150].

The nested model provides methodological underpinnings throughout this research. The major points of intersections are summarised as follows.

(1) The first step in the nested model is to understand the user's requirements and domain problems. The existing work on argument domains are reviewed to build an understanding of argumentation. Also, interviews with experts are conducted to understand the issues with existing approaches and their requirements for improved argumentation tools as will be shown in details in Chapter 4. The experts are chosen from various argumentation domains, who have used or been involved in designing one of the existing ArgVis tools. During the interviews, the experts were asked to answer a few questions about the ArgVis tools they use, such as the reasons for choosing specific tools to present the arguments, the problems encountered upon using these tools and which features were missing, the difficulty of using these tools and the experts' level of satisfaction of the obtained outcomes.

(2) The second step of the nested model is to map the data collected from the interviews into InfoVis vocabularies. Arguments have a graph structure consist of nodes (argument elements) and the relations between them. The discussion about the graph layouts are presented in Chapter 4.

(3) The third step in the nested model is encoding and interaction. Argument elements (premises and conclusion) are presented as nodes in sunburst and icicle. The colour encoding of the nodes reflects the relationships between them, with **red** nodes *opposing* their conclusion and **green** nodes *supporting* their conclusion. *Stacked-labels* and *StackedBoxes* are used to navigate the text. More details about the user interaction and visual techniques to achieve the requirements are proposed in Chapter 4. To validate the second and the third steps in this model, experts were contacted to test the tools and give feedback.

(4) The fourth step is algorithm design and implementation, which is explained in detail in Chapter 4. The time of the running algorithm is monitored to check the speed of the algorithm. Also, a usability study with 21 participants and experts review are conducted to evaluate the proposed visualisation tools.

The nested model is a flexible framework that proposes various methods of validation to help designers make decisions based on domain problems. It is an inter-disciplinary framework that can be applied in different domains by introducing methods of communication between the visualisation designers and the users, i.e. analysts or experts from other domains, to gather the users' needs.

Evaluation and validation in InfoVis have many forms such as interviews, experts' reviews, focus groups, survey, and controlled experiments. The data are collected from these different evaluations are either qualitative or quantitative [152].

3.3.1 Quantitative Approaches

Quantitative evaluation collects performance measurements like time, accuracy, mouse clicks and error. Controlled experiments are one approach which is used to collect results about the usability issues of the prototypes or compare between the various visualisation and interaction techniques [153]. These experiments require the user to perform the specific tasks that are representative of the experiment hypothesis, measure the dependent variable and observation. Analysis of this data is then often performed using statistical methods that allow probabilistic statements to be made. The main difficulties in this approach are deciding the sample of participants, designing visual tasks, and asking the right questions [154].

3.3.2 Qualitative Approaches

Qualitative data can be collected from users or experts by conducting observations, interviews, or long-term case studies. The observation can be conducted in both laboratories and specific fields. Designers can take notes while they observe participants deal with systems/tools, which gives a chance for the participants to ask or discuss their ideas and thoughts while they are carrying out tasks [155]. In an interview, designer (s) and participant (s) can interchange their ideas and opinions to develop usages of the proposed visualisation systems [61]. The designer can record or take notes during the interviews. In a long-term case study, designers deploy the visualisation system and participants use it in their actual work for a considerable length of time. Designers collect notes, diaries, and videos that are used to study the effectiveness of the system [146].

Qualitative approaches face several challenges, such as the collected data is subjective as it depends on the experience of the participants. Also, it is challenging to decide the sample size of participants, as there is no guideline to determine how many are needed. The number of participants may grow until the designers do not gain any new insights from the qualitative evaluation [153]. These two approaches (qualitative and quantitative) can be used together to enhance the understanding of users behaviour and system performances for real-world analysis tasks.

3.4 Summary

In this Chapter, InfoVis was introduced and a review undertaken of visual representations of graphs, highlighting the advantages and disadvantages of each layout. Following that, the techniques used to visualise the text were described, i.e. logs, conversation, and UI methods were discussed. Then, existing ArgVis tools were reviewed and their layouts were categorised into five groups. First, the indentation layout where argument elements can fit inside the nodes without crossing. However, this layout cannot show an overview of the whole data. Second, the node-link layout that can provide a clear structure, but it is unscalable when the size of argument datasets increase. Third, the nested layout that overcomes the problem of space and scalability, but the ArgVis tools that have used this layout did not take full advantage of the available space. Fourth, the matrix layout that is used to make argument relations explicit. The main drawback of this layout is the difficulty of following a specific path between the nodes to understand the relations between the arguments. Fifth, the hybrid layout which combines two layouts. All ArgVis tools that have used the hybrid layout in the literature adopted node-link as one of the combined layouts, and thus inherited its drawbacks. Furthermore, ArgVis tools have neglected UI that allows users to understand and explore data better, especially in large datasets, and only a few of the argument visualisation tools have evaluated the techniques they have used. This Chapter concluded by considering visualisation design approaches and the nested model is seen as the most appropriate to follow for designing any new technique and tool.

In the upcoming Chapter, argumentation experts were interviewed to collect user requirements and three novel tools are proposed to visualise text and argument structures. The first tool puts the text first, indicating connected and related argument elements through visual cues (*StackedBoxes*), while a sunburst layout provides an overview linked to the main *stacked-boxes* layout. The second tool overlays text on demand on a sunburst visualisation (*Sunburst Pop-Up*). The third tool is an adaption of an icicle plot to visualise structure with F+C to help with reading the text (*Icicle F+C*).

Chapter 4

Argument Visualisation Techniques and Tools

ArgVis is a presentation of reasoning in which the relationships among argument elements are made explicit using graphical or other non-verbal techniques [111]. It is used to help users understand and explore the argument and make relations between the premises and the conclusion explicit.

In this Chapter, argument experts are interviewed to collect the user' requirements and to discuss the gaps found in existing ArgVis tools. To address the defined requirements, several tools are proposed for visualising text and argument structure. The first tool (*StackedBoxes*) focuses on the text, indicating connected and related argument elements through visual cues called *stacked-boxes*, with a linked miniature sunburst providing a structural overview. Each layer in *stacked-boxes* was treated as a navigable strip of siblings which present the focused node highlighted, parents (stacked above), and the first child of each level in the tree below the focused node, with the siblings scrollable for all levels. The second tool (*Sunburst Pop-Up*) focuses on the structure using a sunburst layout adapted to suit argument criteria and overlays text on demand using a modified labelling technique called *stacked-labels*. The *stacked-labels*, i.e. boxes, are similar to those used in *stacked-boxes* but are limited to only showing the parents of the focused node (no children or siblings). The third tool (*Icicle F+C*) is an adaption of an icicle plot to visualise the structure while using F+C to enlarge the premises in a focused node chain.

4.1 Exploratory Analysis Requirements

User requirement analysis is a process to identify users' demands and become familiar with how they use different techniques and tools [156]. Discussing with experts domain problem and data structure, which is the first step of the nested model, helps to understand the domain unique vocabularies and its specialised tasks. In addition, it saves the designer's time [154] and helps to focus and prioritise effort. There are no guidelines or a specific number of experts that should be interviewed. The sample size can be decided when designers fully understand the experts' requirements [157]. A number of argument experts from the academic group Argumentation Theory and authors of ArgVis tools published papers were contacted to volunteer in the study. Seven experts agreed to volunteer in the current research to further investigate the domain problems and the requirements. These experts were researchers, senior researchers, and associate professors who have worked in different areas of argumentation, e.g. argument mining, problem-solving, and ArgVis. Details about the experts are presented in Table 4.1.

The interviews aimed to understand the applications of ArgVis tools, the role of visualisation in argumentation, and the obstacles the experts faced when they used these tools. Also, they aimed to identify the size of data the experts dealt with and to collect the requirements. The interview questions were divided into three parts as listed in Table 4.2. The first part covered the use of previous argument tools and the purpose(s) of using them (Q1-Q3). The next set of questions aimed to identify the limitations of the tools that the experts have used (Q4-Q7). The second part focused on the size of the data the experts dealt with (Q8) and the difficulty in presenting this size of data (if any) (Q9-Q11). The third section aimed to identify ways that the experts read and understand arguments (Q12-Q13) and to collect the users' requirements of the new ArgVis tools (Q14-Q17).

The interviews were one-to-one and lasted between 30 and 45 minutes. Experts were asked to fill in the ethical form presented in Appendix A. Each interview started with explaining the aim of the study, followed by asking the interviewees about their experience in ArgVis tools. Then, the interview questions were completed, and the session finished by asking the experts if they had any requirements for new ArgVis tools or any further comments.

Table 4.1 A summary of information relating to the study participants.

	Country	City	Current Job Description	Experience
E1	**UK**	**Dundee**	He works as a research assistant in argumentation since 2009. He is working now in argument mining. He has developed a range of widely used tools for argument analysis, visualisation, and storage.	10 years
E2	**UK**	**Swansea**	He is an Associate Professor in Law and Computer Science Legal Studies and works in argument mining.	10 years
E3	**USA**	**Illinois**	She is an Assistant Professor in argumentation and evidence. She is developing Linked Data (ontologies, metadata, Semantic Web) approaches to managing scientific evidence.	6 years
E4	**UK**	**Leeds**	He is a research assistant. He works in the areas of analytic aesthetics and moral psychology.	3 years
E5	**UK**	**Leeds**	She is an academic fellow. Her research interests are transporting governance, sustainable travel behaviours, persuasive technology, and transport geography.	4 years
E6	**UK**	**Edinburgh**	He worked as a retired researcher in philosophy. He worked in the project about investigated the relevance of argument visualisation techniques to political debates.	4 years
E7	**UK**	**London**	She is a research associate. She is interested in network-centric, modelling and visualising ideas and arguments as networks of nodes which can be analysed for topographical and semantic patterns.	13 years

Table 4.2 Interviews questions, divided into three parts; uses of ArgVis, size of the data, and understanding the arguments.

	Questions
Use of argument visualisation	Q1- Do you use any argument visualisation tools? Q2- What kind of things are you looking for by using this tool ? Q3- What techniques do you use to present the arguments ? Q4- Are there any limitations in this tool? Q5- What are the actions that you want to do with your data but you cannot by using this tool ? Q6- Can you see all the information you want? If not, what is missing? Q7- Why are these things (in the previous question) essential for argumentation?
Data size and obstacles	Q8- What is the size of the dataset that you have used ? Q9- Did you find it difficult to present this data? Why? Q10- How do you break down a large argument to understand it? Q11- What information do you like to present or see on the argument?
Reading and understanding the argument	Q12- Is there a specific flow that you want to read the arguments through ? Q13- When you explore the arguments, what are the things you are looking for? Q14- Is it important to you to know the number of nodes that support/ attack the main conclusion? Or what is information that you like to know about this diagram? Q15- What are the features that you would like the tool to provide to help you understand the argument? Querying? Exploring? Searching? Q16- Why is it important to check the overview of the whole data before starting to explore one argument? Q17- How is it important to present the different type of arguments (linked/ convergent)?

During the interviews, the experts mentioned limitations of the previous ArgVis tools and the four main limitations are listed below:

(L1) “Most of the tools use nodes and arrows, which are brilliant when you have a small number of arguments but when the number increases to 20-30 nodes, the graph becomes very dense, making exploration very tough.”

(L2) “The tools which used node-link have become dense and impenetrable. Arguments can not just be made into pretty pictures because we’re also interested in the content."

(L3) “The tools we have designed are only for small scale arguments; I would like to have tools that handle a large number of arguments.”

(L4) “The biggest challenge of presenting the large-scale arguments is that we want to see the whole picture and see the details of what’s going on using the same tool which we miss in most of the current argument tools”.

4.1.1 Requirements

The second step in the nested model is formatting the interviews data into vocabulary for InfoVis. The interviews were analysed using NVivo; software used for qualitative and mixed-methods research [158]. It helps to organise interview contents and explore different possibilities of data analysis and interpretation. Based on the aim and the questions of the interviews, categories were identified that help to analyse the interview data, such as Data Size, Obstacles, Read Argument, Usage of ArgVis, Understand Arguments, and Requirements. The defined categories were then used to categories the answer provided by the experts. Finally, all the answers in each category were checked to identify the user requirements. It can be concluded that the ability to provide a quick summary of the overall data and read the text are key priorities. The user requirements are illustrated as follows:

(R1) **Show arguments overview:** present the entire arguments, all at once, in order to know how they are connected to the main topic and with each other. Also, explore the logic flow of the argument in the proper order making the reasoning structure explicit.

(R2) **Read the text of the argument:** the ability to read the text of premises and conclusion to help understand the argument. At the same time, the text must not take up a large space on the graph.

(R3) **Provide navigation:** support experts to keep track of where they are relative to the overall argument structure and allow them to focus on one chain of the argument (from conclusion to all the related premises).

(R4) **Zoom in and out:** the ability to make the graph larger and smaller.

(R5) Collapse unneeded arguments to focus on the important ones

(R6) Provide a summary of argument relations types

(R7) Enable users to compare arguments

The requirements mentioned above represent a consensus across the experts. It is also worth mentioning that requirements R1, R3, and R4 fit with the ones proposed by Shneiderman [159]. There are a few additional requirements that are either for specific domains or only applicable for particular projects. These requirements are related to dialogue analysis, dialogue visualisation and argument evaluation. They are excluded from this research as the focus of this thesis is on achieving a balance between the overview and details of an argument, and reading argument text for understanding the argument rather than analysing it. In future work, more features and requirements will be considered. Those requirements are listed below but are out of the scope of this research.

(R8) Obtain some information about the participants in the argument/debate

(R9) Search through the data, for instance, can it succinctly show the number and type of contributions made by any individual

(R10) Know the missing parts in the graph

(R11) Modify the layout by rearranging the connection between the elements

4.2 Argument Visualisation Techniques and Tools

To achieve the users' requirements, several tools and techniques were implemented using a JavaScript library Data-Driven Document (D3) [160]. This was done in order to address steps 3 and 4 of the nested model, i.e. encoding, interactions and algorithm implementation. D3 is a dynamic, interactive, online data visualisation framework used in modern browsers [161]. It was developed by the Stanford Visualization Group. It allows binding any kind of data to the Document Object Model (DOM). For example, you can use D3 to generate an HTML table from an array of numbers or use the same data to create a bar chart with smooth transitions and interaction. With D3, users can develop high-performance data dashboards and sophisticated data visualisations. Users can reuse D3 code and add specific functions and features. D3 is a combination of many web technologies, such as Hypertext Markup Language (HTML) for page content, Cascading Style Sheets (CSS) for aesthetics, JavaScript for interaction, and Scalable Vector Graphics (SVG) for two-dimensional graphics with support for interactivity and animation. The D3 website provides users with proper documentation, multiple examples, and various visualisation options [162]. D3 was chosen for this research because it is a free, open-source library with reusable components that supports popular browsers.

4.2.1 Design and Implementation

The next sections describe the iterative design of these tools and techniques and highlight the advantages and limitations of each one.

4.2.1.1 *Sunburst Node-Link*- Sunburst with node-link

Showing data structure is an indispensable requirement to understand arguments (R1). Space-filling techniques are promising solutions to present the argument structure by displaying an overview of the whole data. For example, the sunburst layout is one of the best performing visualisation techniques for tree structures in terms of efficiency and effectiveness [75].

Therefore, the first prototype was based on the sunburst layout, where the main conclusion of the argument is placed in the centre of the sunburst (the root node); the premises surround it. Each level of argument statements is connected with the previous level by the support or oppose relations. The sunburst helps to provide an overview by showing the complete structure of arguments, to build a mental map and explore the most opposing/supporting statements. The colour encoding of the arguments in the sunburst reflects the relationships between them. The colour encoding adopted in this research is widely used in existing ArgVis tools, where red colour denotes opposing relationships, and green indicates supporting ones.

Linked arguments are two premises that are connected to support or oppose the conclusion (section 2.2). To present the linked arguments in the sunburst, two layers are proposed as illustrated in Figure 4.1; one big layer to display the argument statements, and a thin layer to reflect the relationships between these statements. The thin layer is coloured with red/green depending on the relations as shown in Figure 4.2.

Reading the textual content of conclusion and premises is crucial to understand the arguments (R2), thus argument statements are presented inside the sunburst nodes. The text is truncated and wrapped, and the font size is changed based on the size of the containing node. Despite showing the argument structure efficiently, the size of the sunburst nodes

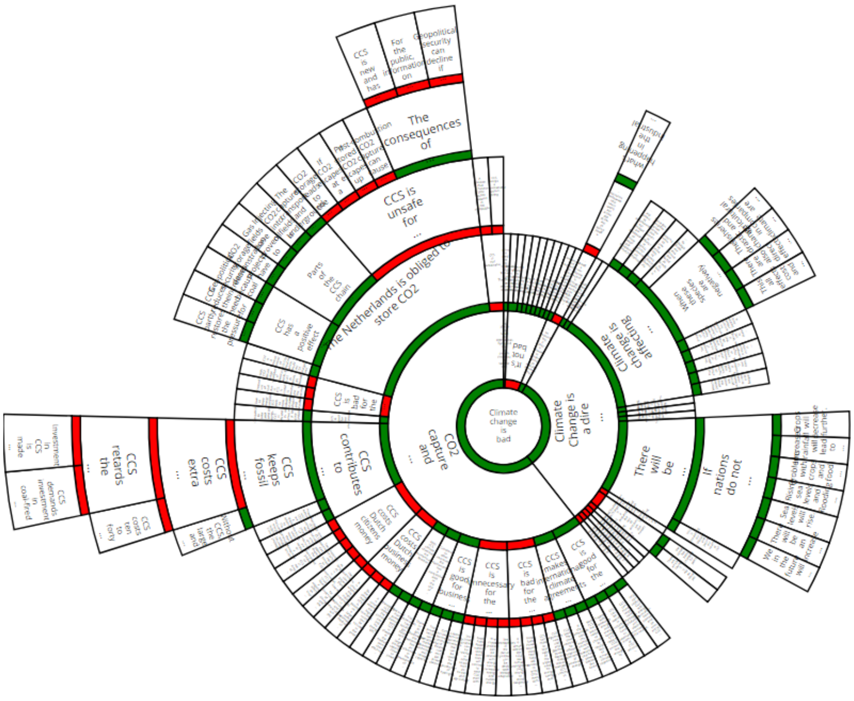

Climate change is bad
CO2 capture and
Climate Change is a dire ...
Climate change is affecting ...
The Netherlands is obliged to store CO2
CCS is unsafe for ...
The consequences of
CCS is new and has
For the public, information on
Geopolitical security can decline if
Parts of the CCS chain
CCS has a positive effect
CCS is bad for the
CCS contributes to
CCS keeps fossil
CCS costs extra ...
CCS retards the
Investment in CCS is made
CCS demands investment in coal-fired
CCS costs ten to forty
There will be ...
If nations do not ...
When species are negatively
CCS costs Dutch citizens money
CCS costs Dutch businesses money
CCS is good for business
CCS is unnecessary for the
CCS is bad for the
CCS makes international climate agreements
CCS is good for the

Figure 4.1 The sunburst with two layers, the big layer is the arguments' statements and the narrow layer reflects the relations between statements.

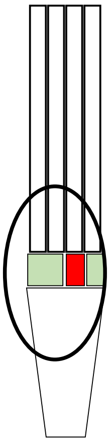


Figure 4.2 Linked arguments in the sunburst which connect with each other by a thin layer.

does not allow the presentation of long labels, especially when moving away from the centre where sunburst nodes get narrower. Therefore, another technique is needed for reading the text. Node-link layouts can present the text of all children of a focused node, and thus helps the users to navigate the argument elements quickly. Consequently, a coordinated view is proposed consisting of a sunburst layout to present the overview with a node-link layout to help navigate through the text (Figure 4.3). When the users click on any node in the sunburst layout, the node-link layout is displayed in the coordinated view to reflect the chain from the clicked node to all its children as in Figure 4.4. The argument chain in the sunburst is highlighted to reflect the node-link view (R3). The users can change the size of the node-link view to make it bigger at the expense of the sunburst layout view. Also, for quick navigation through the nodes and reading the text, the entire label of the node, i.e. full-length statement, will pop-up when hovering over the nodes in the sunburst.

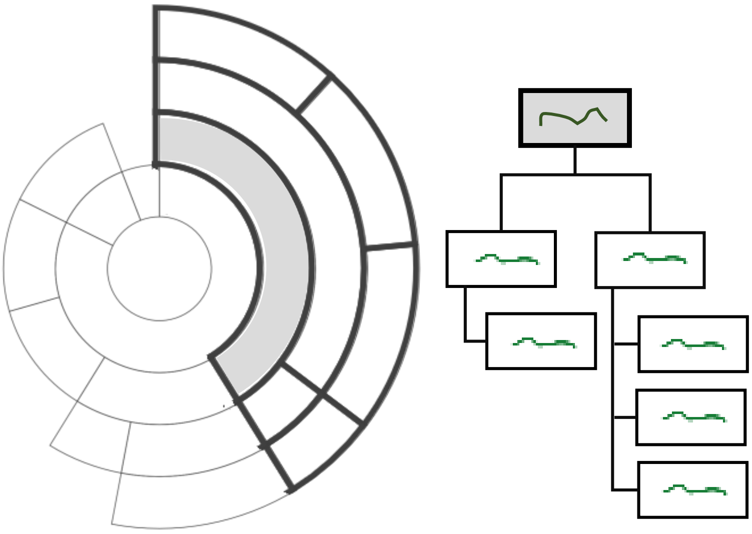


Figure 4.3 The sketch of *Sunburst Node-Link*; the sunburst to present the overview of argument, and node-link layout to help reading and navigate the text.

The linked arguments are presented in both the sunburst and the node-link, as illustrated in Figure 4.4 and Figure 4.5. An example of linked arguments, as shown in the layout, is demonstrated through the following statements: **“It is dire to species of plants and animals that are being affected by the warming of the earth"** and **“When these species are negatively affected, we are negatively affected"**. The statements mentioned above are linked together to give reasoning and to support the statement “climate change is affecting us now". This design was presented as a poster in the “European Conference on Argumentation", June 2017, Fribourg, Switzerland [163]. The feedback from argumentation experts was

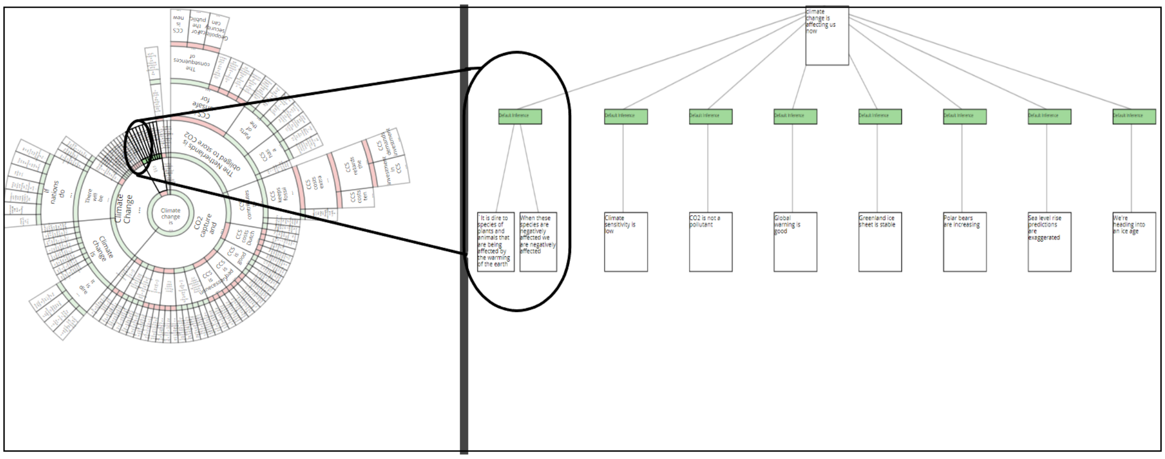

Climate change is
Climate Change
CO2 Capture and
climate change is affecting us now
Default Inference
` It is dire to species of plants and animals that are being affected by the warming of the earth
When these species are negatively affected we are negatively affected
Climate sensitivity is low
CO2 is not a pollutant
Global warming is good
Greenland ice sheet is stable
Polar bears are increasing
Sea level rise predictions are exaggerated
We're heading into an ice age

Figure 4.4 The coordinated view, the sunburst layout on the left and node-link layout on the right. Also the linked arguments are illustrated in both layouts.

positive. One of those experts found that using the space-filling sunburst technique to present arguments is a promising way to provide an overview.

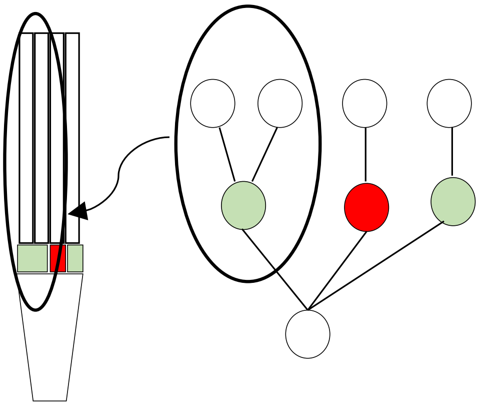


Figure 4.5 The linked arguments in both the node-link layout (right) and the sunburst layout (left).

The node-link view in this tool inherited the limitation of the node-link layout in terms of space-efficiency, and it was challenging to show the focused node's children while keeping the labels readable, especially when the number of nodes grows, i.e. exceeds 40 nodes (Figure 4.6). Besides, the thin layer in the sunburst is unnoticeable when data grows, especially as nodes in the sunburst located far away from the centre become very tight. The pop-up label in the sunburst allows the users to read the text, but it is limited to showing the text of the hovered node only. Therefore, going through an argument's chain requires a lot of navigation from the user. To overcome the problems in the previous prototype and give users the flexibility to read all the statements until the conclusion, the pop-up label was extended and offered a new layout, called *stacked-boxes*, in a fixed view rather than the space-inefficient node-link layout for reading and navigating the text (R1, R2, R3). More details about this tool are presented in the following section.

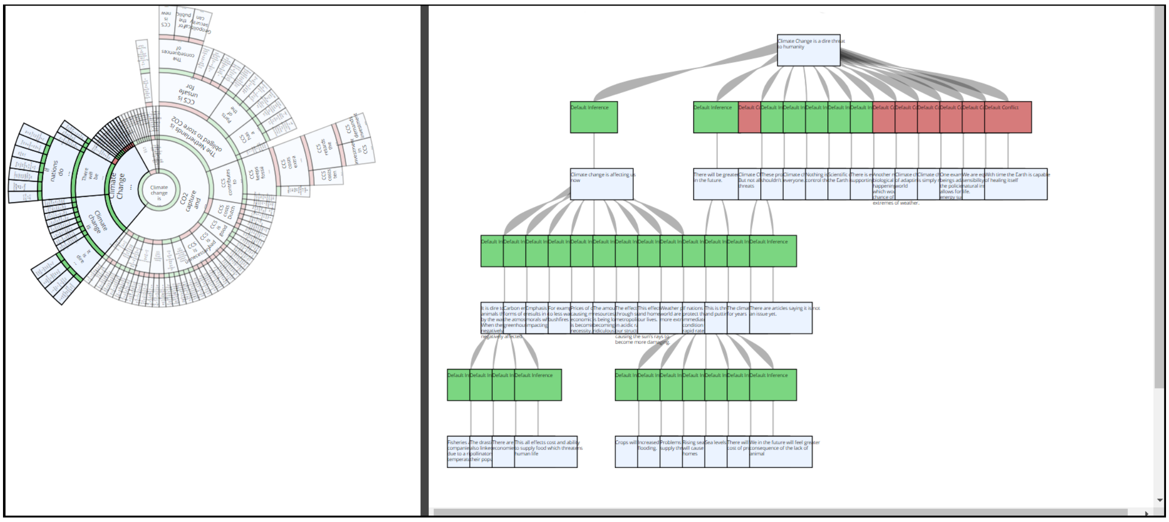

Climate change is
Climate Change
Climate Change is a dire threat to humanity
Default Inference
Default Conflict
Climate change is affecting us now

Figure 4.6 The coordinated view of sunburst with node-link layout that reflects the problem of space-efficiency to show the nodes and text in the node-link.

4.2.1.2 *StackedBoxes*–Sunburst with stacked boxes

StackedBoxes relies on the coordinated view between a sunburst to provide the structure and *stacked-boxes* for reading and navigation of text. As the thin layer is not easy to see in the sunburst, colour encoding of the argument's statements was used to reflect these relationships. To distinguish the linked arguments from the rest, a small bridge that connects these argument together is presented as part of the nodes, as clarified in Figure 4.7.

The *stacked-boxes* layout underwent five cycles of design development as shown in Figure 4.8. Our first version represents the list of argument statements (Figure 4.8a) from the root until the focused (selected) node, in a fixed view (Figure 4.9). This version helps users to read the argument text quickly from the focused node to the root conclusion, but it does not enable reading the content of the focused node's children or sibling nodes. Also, it is difficult to read the text in one view and navigate in the other.

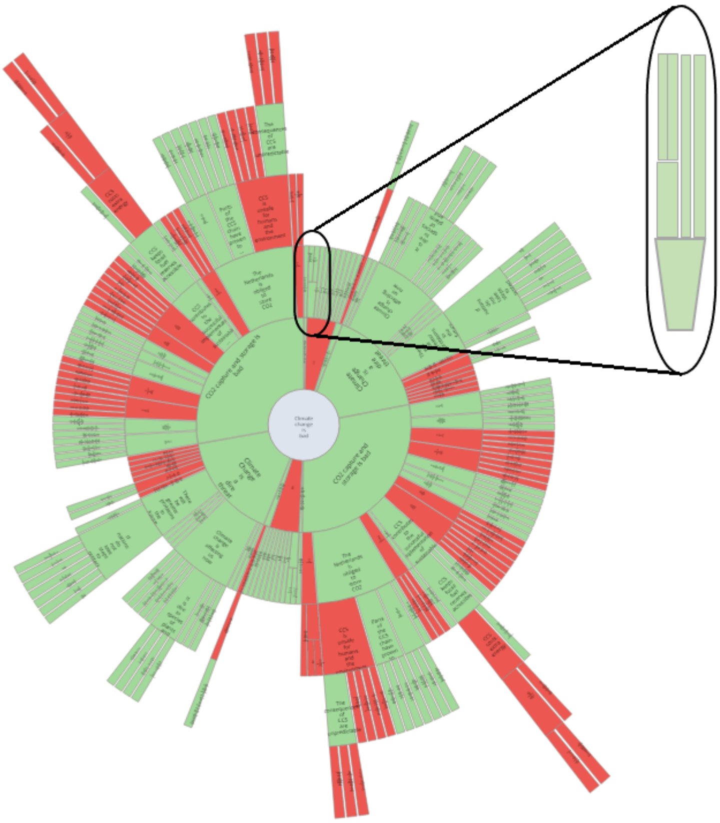


Figure 4.7 The sunburst with colour encoding and a small bridge is presented to connect the linked arguments to each other.

The layout was improved in the second version (Figure 4.8b) to offer quick navigation and reading the text of the sibling nodes. This version displays the focused node, its parents, and all the children in its sub-tree, as in Figure 4.10. The siblings of the focused node are presented at a fixed width on either side. This version provides intuitive scrolling through the siblings, so the selected node is given focus. However, this version highlighted mainly the structure of the child nodes rather than helping the users to read the text.

Thus, the layout was further improved in a third version to reveal the text of the focused node, its parents, and all its first level children, as shown in Figure 4.8c. The children are portrayed in a vertical layout, as opposed to horizontal, to use the available space, as illustrated in Figure 4.11. However, this version resulted in a mixed visual metaphor which could be confusing for the user as the layout stacks nodes vertically from the root down to

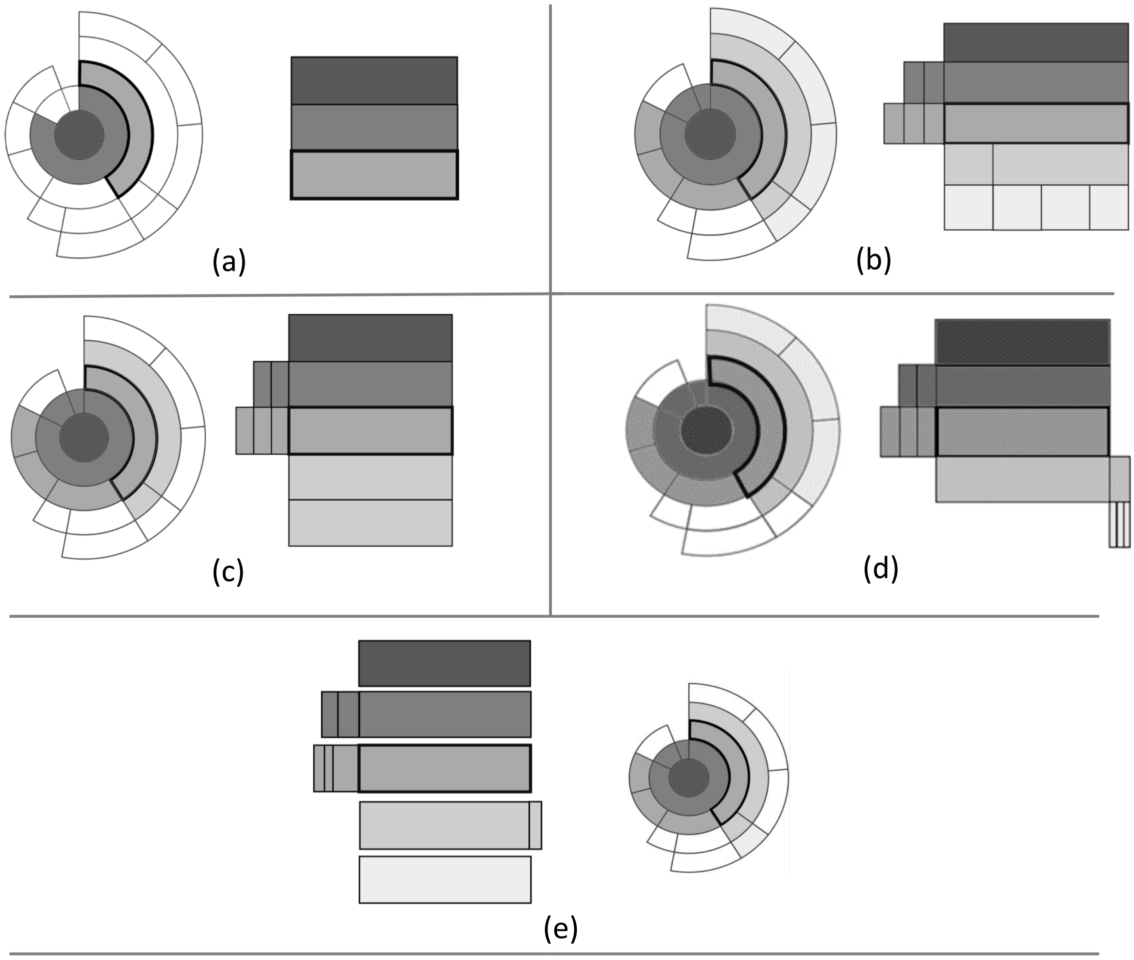


Figure 4.8 The iterative design sketches of the *StackedBoxes*. The grey scheme reflects the hierarchy structure, i.e. the root is coloured with a dark grey that shades lighter by level towards the leaf nodes. The coloured nodes in the sunburst show the nodes in the coordinated *stacked-boxes* and demonstrate the difference between the versions.

the focused node (as per the tree), while below the focused node the vertical stack represents the first level children of the focused node (a horizontal layer in the tree).

Consequently, the layout was changed to show the text of the first child of the selected node and the structure under its siblings in a fourth version, as illustrated in Figure 4.12. This design presented inconsistencies in the way nodes are connected as the children of the focused node are not displayed in the *StackedBoxes* (Figure 4.8d).

Therefore, in the final fifth version of development, each layer of the boxes was treated as a navigable strip of siblings which present the focused node highlighted, parents (stacked above), and the first child of each level in the tree below the focused node, with the siblings

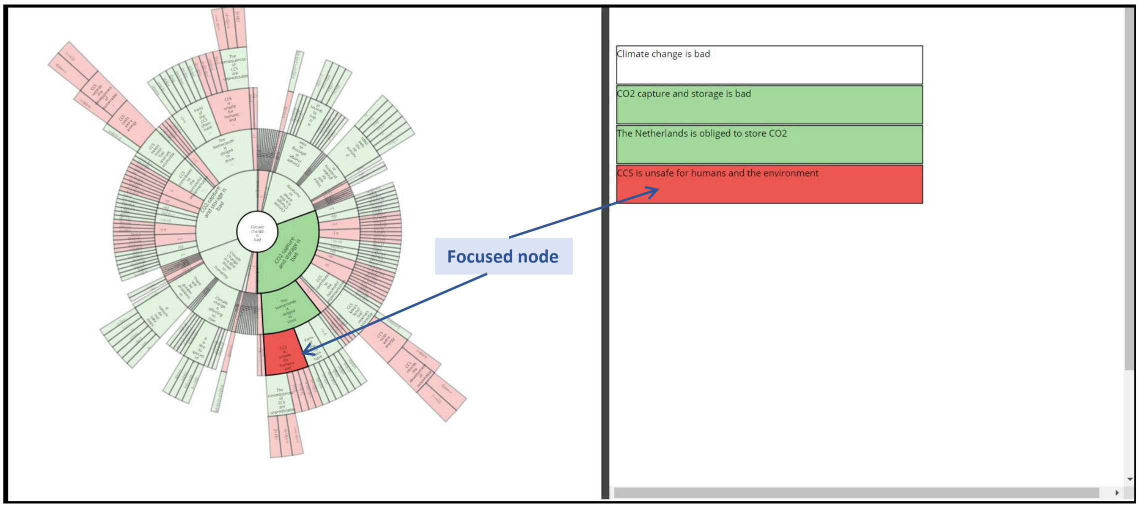

Climate change is bad
CO2 capture and storage is bad
The Netherlands is obliged to store CO2
CCS is unsafe for humans and the environment
Focused node

Figure 4.9 The first version of the *StackedBoxes* represents the list of arguments' statements from the root until the focused node on the right with the sunburst on the left to show the overview.

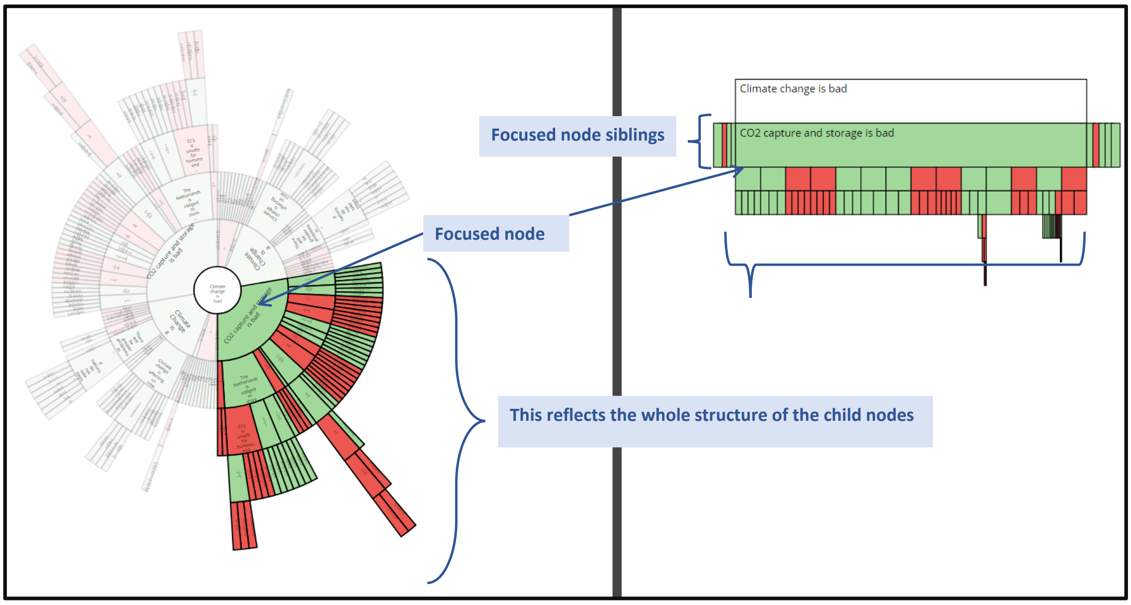
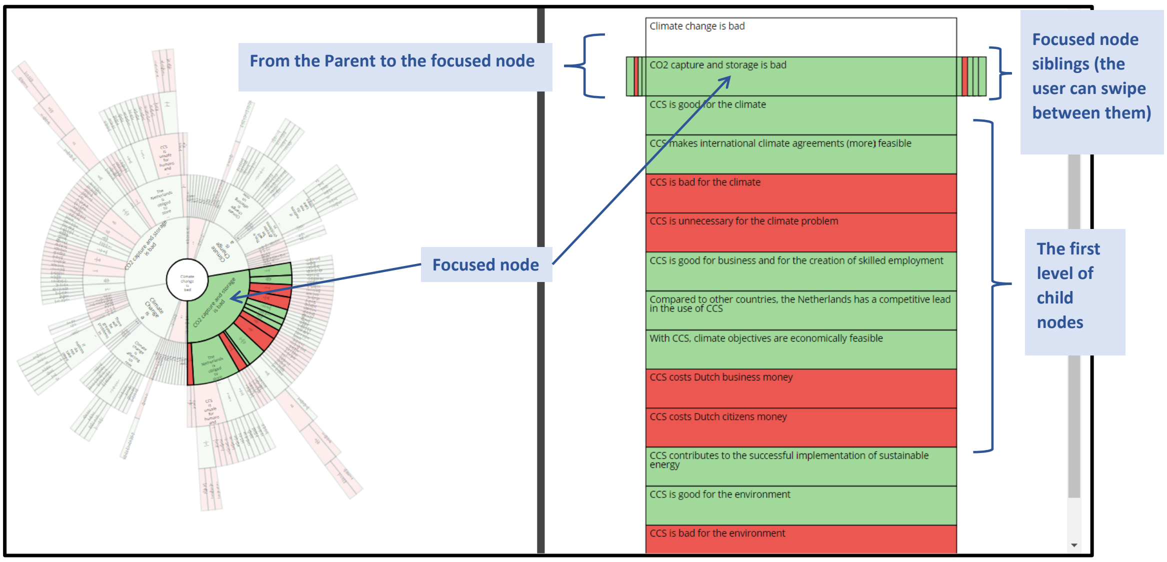

Climate change is bad
CO2 capture and storage is bad
Focused node siblings
Focused node
This reflects the whole structure of the child nodes

Figure 4.10 The second version of the *StackedBoxes* displays the focused node, its parent, its siblings, and all the children on the right and the sunburst on the left.

scrollable for all levels, as illustrated in Figure 4.8e. When the user scrolls through the sibling nodes, the selected node becomes the focused node with no changes on the upper level, while underneath, the focused node changes to reflect the chain of this node. A small space



From the Parent to the focused node

Focused node

Focused node siblings (the user can swipe between them)

The first level of child nodes

Climate change is bad

CO2 capture and storage is bad

CCS is good for the climate

CCS makes international climate agreements (more) feasible

CCS is bad for the climate

CCS is unnecessary for the climate problem

CCS is good for business and for the creation of skilled employment

Compared to other countries, the Netherlands has a competitive lead in the use of CCS

With CCS, climate objectives are economically feasible

CCS costs Dutch business money

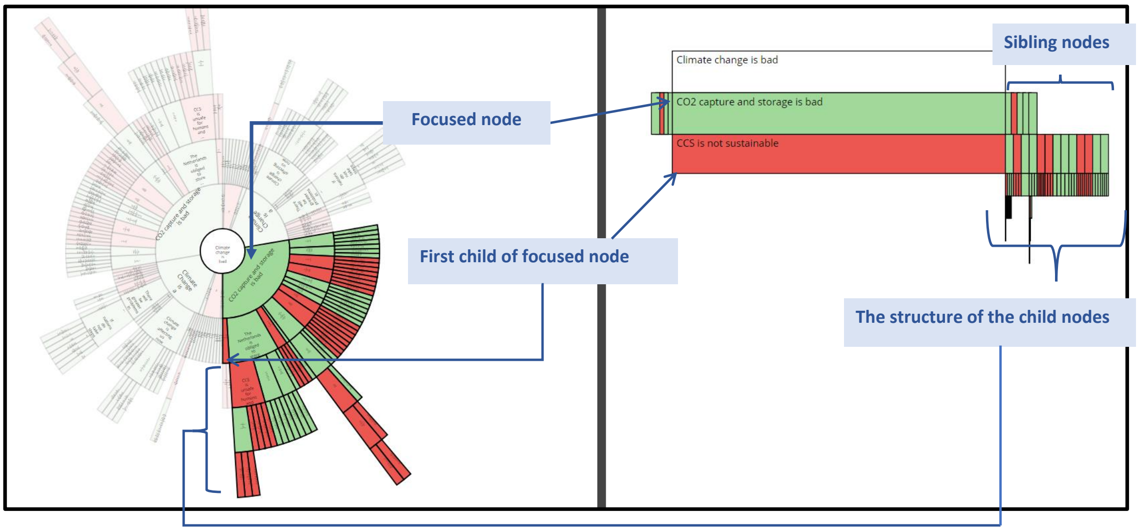
CCS costs Dutch citizens money

CCS contributes to the successful implementation of sustainable energy

CCS is good for the environment

CCS is bad for the environment

Figure 4.11 The third version of the *StackedBoxes* shows parents, focused node, and all the first level of children for the focused node on the right and the sunburst on the left.



Focused node

First child of focused node

Sibling nodes

The structure of the child nodes

Climate change is bad

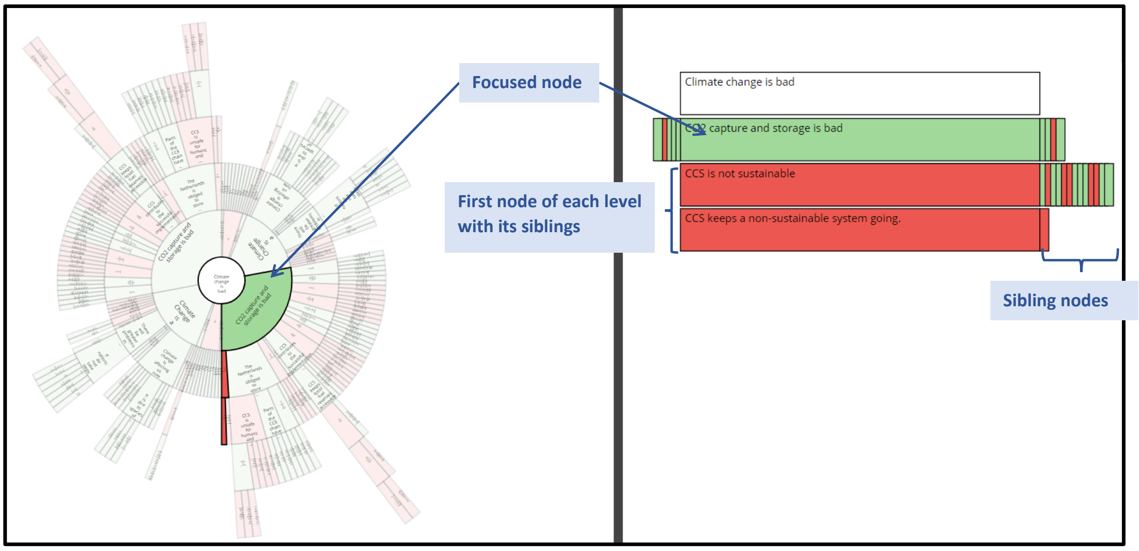
CO2 capture and storage is bad

CCS is not sustainable

Figure 4.12 The fourth version of the *StackedBoxes* show the text of the parents, focused node, first child node and the structure under its siblings on the right and the sunburst on the left.

between the levels is created in the *stacked-boxes* to show that each level is not connected with the level above or below as in Figure 4.13.

The users can navigate by clicking on any node of the *stacked-boxes* or any node in the sunburst. The branch of the clicked node is reflected immediately in the *stacked-boxes*. The sunburst view is rotated to show arguments in the same direction as in the *stacked-boxes*



Climate change is bad

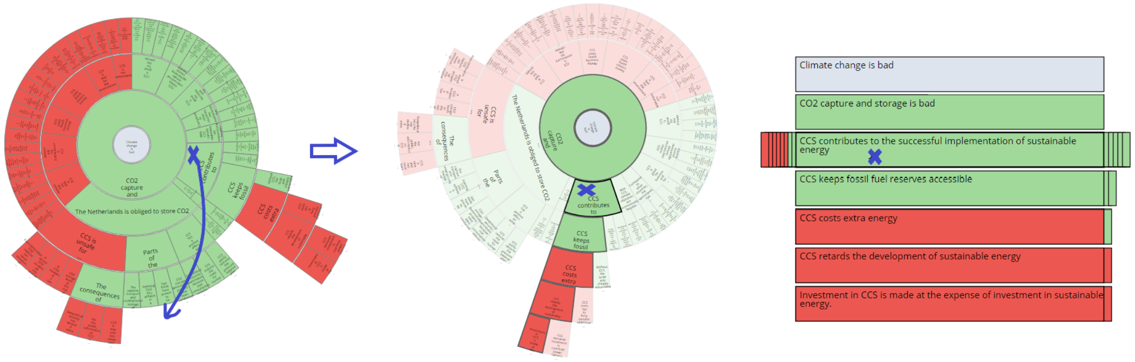
CO2 capture and storage is bad

CCS is not sustainable

CCS keeps a non-sustainable system going.

Figure 4.13 The fifth version of the *StackedBoxes* show the text of parents, focused node, first child node in each level, and siblings on the right and the sunburst on the left.

(Figure 4.14). By using the keyboard cursor keys, the users can navigate the *stacked-boxes* in all directions, i.e. up/down and left/right, which allows fast and accurate navigation of the argument structure (R3).



Climate change is bad

CO2 capture and storage is bad

CCS contributes to the successful implementation of sustainable energy

CCS keeps fossil fuel reserves accessible

CCS costs extra energy

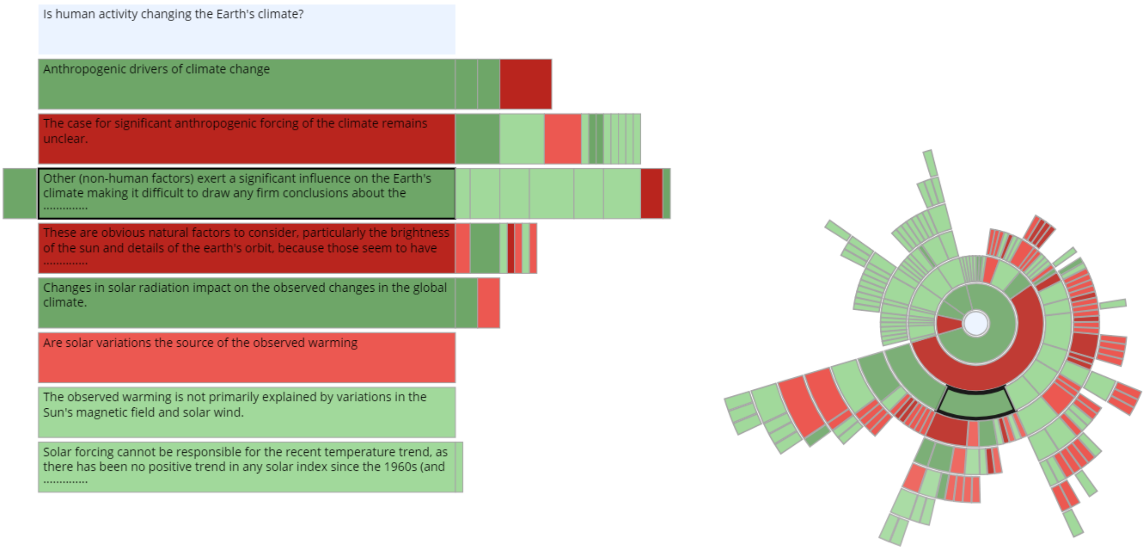
CCS retards the development of sustainable energy

Investment in CCS is made at the expense of investment in sustainable energy.

Figure 4.14 Rotate feature in the sunburst layout. When the user clicks on the focused node the argument's chain is reflected immediately in the *StackedBoxes*. The sunburst view is rotated to show arguments in the same direction as in the *StackedBoxes*

As the *stacked-boxes* became the focus view for reading the text, the layout was changed to make the *stacked-boxes* the main view on the left with the sunburst reduced to a small overview figure on the right for viewing and navigating the overall structure. The *stacked-boxes* list was displayed when users click on any node in the sunburst. To avoid having an empty view in the *stacked-boxes* view when the tool starts up, the node with the longest chain was presented as a focused node at the start.

Furthermore, a search bar is available for users to search for specific words. Search results will be highlighted using a darker shade of the original colour of the nodes as illustrated in Figure 4.15. The idea behind keeping the colours was to allow the users to identify the highlighted nodes as supporting or opposing. Because the layout of the *stacked-boxes* does not display the full argument structure, some search results may not appear in the *stacked-boxes*. Thus, a shortcut (Alt + S) was provided to help users navigate through all the search results and pull all search results into the layout as the results are cycled through.



Is human activity changing the Earth's climate?

Anthropogenic drivers of climate change

The case for significant anthropogenic forcing of the climate remains unclear.

Other (non-human factors) exert a significant influence on the Earth's climate making it difficult to draw any firm conclusions about the ....

These are obvious natural factors to consider, particularly the brightness of the sun and details of the earth's orbit, because those seem to have ....

Changes in solar radiation impact on the observed changes in the global climate.

Are solar variations the source of the observed warming

The observed warming is not primarily explained by variations in the Sun's magnetic field and solar wind.

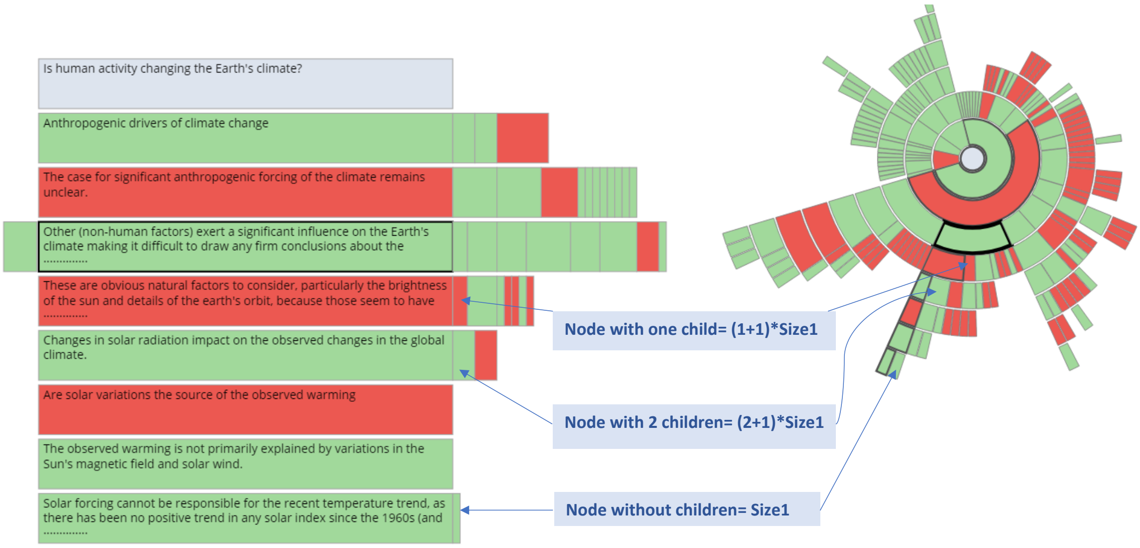
Solar forcing cannot be responsible for the recent temperature trend, as there has been no positive trend in any solar index since the 1960s (and ....

Figure 4.15 Search results in the *stacked-boxes* and the sunburst. The results are highlighted using a darker shade of the original colour of the nodes.

The width (size) of siblings was updated to reflect the number of children in the whole sub-tree instead of using a fixed width. However, this could occupy a lot of space due to the potential number of children, therefore the width was again changed to reflect the number of children only on the next level, as shown in Figure 4.16. The size (width) is calculated as follows:

Nodes with no children have a fixed size equal to *Size*. Nodes with *N* children have the $SizeN = (N \times Size + Size) = (N+1) \times Size$.

Linked arguments are presented in the *stacked-boxes* as sibling nodes. As it is important to the user to read the texts of the linked arguments together, they are displayed in a single



Is human activity changing the Earth's climate?

Anthropogenic drivers of climate change

The case for significant anthropogenic forcing of the climate remains unclear.

Other (non-human factors) exert a significant influence on the Earth's climate making it difficult to draw any firm conclusions about the ....

These are obvious natural factors to consider, particularly the brightness of the sun and details of the earth's orbit, because those seem to have ....

Changes in solar radiation impact on the observed changes in the global climate.

Are solar variations the source of the observed warming

The observed warming is not primarily explained by variations in the Sun's magnetic field and solar wind.

Solar forcing cannot be responsible for the recent temperature trend, as there has been no positive trend in any solar index since the 1960s (and ....

Node with one child= (1+1)*Size1
Node with 2 children= (2+1)*Size1
Node without children= Size1

Figure 4.16 The sibling's size in *stacked-boxes* with coordinated sunburst. The size reflects the first level of the children.

node separated by a dashed line, as illustrated in Figure 4.17. The linked argument of interest is placed at the bottom, so its children (if any) are displayed underneath it. Users can zoom in and out (R4) to make the sunburst bigger or smaller.

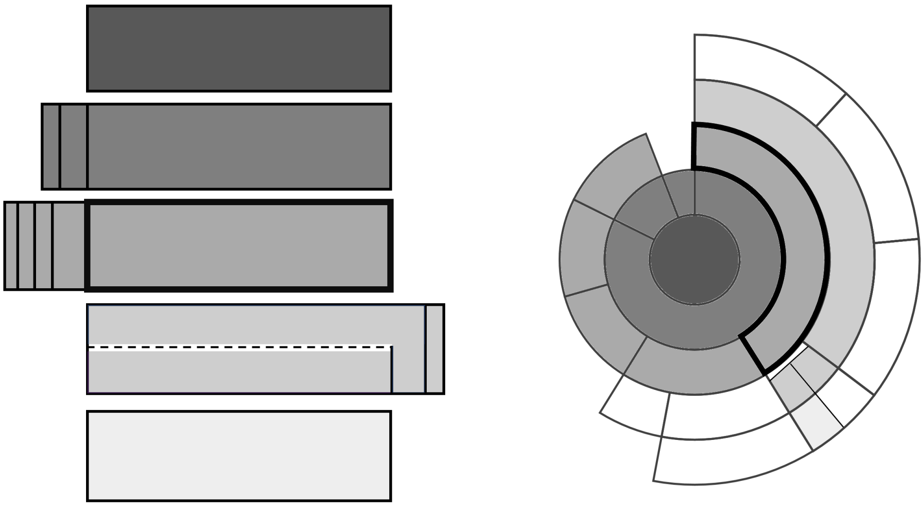
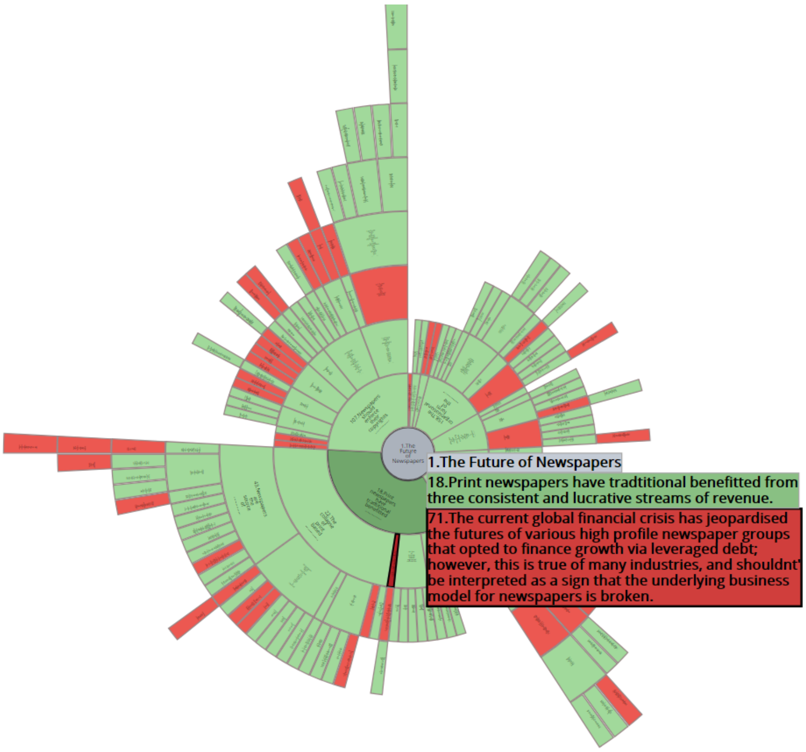


Figure 4.17 The sketch of linked argument in *StackedBoxes*.

The *StackedBoxes* offers quick and fast navigation through the sibling nodes and children. However, it could be challenging to navigate the structure through the sunburst while reading the text in the coordinated view. Therefore, the initial sunburst prototype was adopted and the pop-up label was extended to become a *stacked-labels* or list of labels; more details are presented in the next section.

4.2.1.3 *Sunburst Pop-Up*—Sunburst with pop-up labels

Due to its effectiveness in presenting an overview, the aim of this prototype was to enhance the readability of text in the sunburst, without the need for a coordinated view for reading the text. To reduce the amount of navigation required when reading the text on sunburst 4.2.1.1, an integrated approach, and the simple node pop-up label were enhanced with stacked pop-up labels called *stacked-labels*. The *stacked-labels*, i.e. boxes, are similar to those used in stacked boxes, but are limited to only showing the parents of the focused node (no children or siblings). The width and height of each box in the *stacked-labels* has the dimensions of the wrapped text. The colours of the boxes are the same as the nodes in the sunburst, as clarified in Figure 4.18. The chain on the sunburst is highlighted to reflect the *stacked-labels*. Also, the border of the hovered node is coloured with black to distinguish it from the other nodes.



1.The Future of Newspapers

18.Print newspapers have tradtitional benefitted from three consistent and lucrative streams of revenue.

71.The current global financial crisis has jeopardised the futures of various high profile newspaper groups that opted to finance growth via leveraged debt; however, this is true of many industries, and shouldnt' be interpreted as a sign that the underlying business model for newspapers is broken.

Figure 4.18 The *Sunburst Pop-Up* with *stacked-labels* showing all the highlighted premises until the conclusion.

The linked arguments are displayed in this technique with a bridge node which joins linked nodes at the same level, as in *Sunburst Node-Link*. In the *stacked-labels*, linked nodes are shown side-by-side on the same level (Figure 4.19).

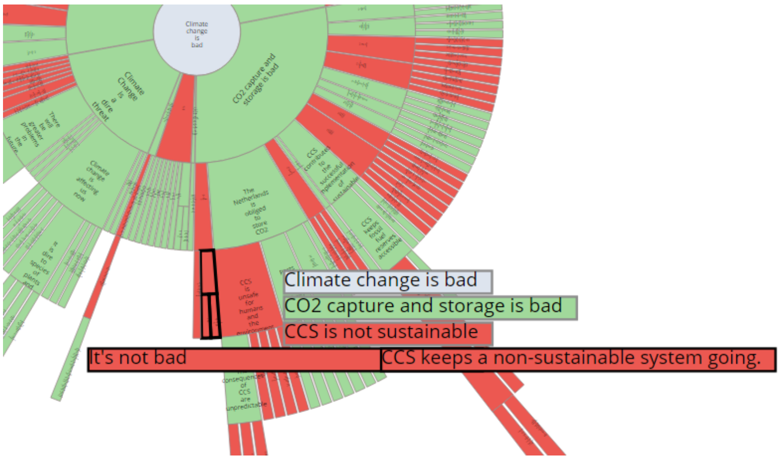

Climate change is bad
CO2 capture and storage is bad
Climate Change is dire threat
The Netherlands is obliged to store CO2
Climate change is bad
CO2 capture and storage is bad
CCS is not sustainable
It's not bad
CCS keeps a non-sustainable system going.
Consequences of CCS are unpredictable

Figure 4.19 A linked argument is presented in *Sunburst Pop-Up*with a bridge node connecting the linked nodes together.

Regarding the position of the *stacked-labels*, some issues were taken into consideration while designing them such as minimising the area of sunburst structure hidden by the *stacked-labels* and maintaining consistent logic of where they will appear (avoiding unexpected jumping around the window). The following four options for *stacked-labels* positions were proposed, as illustrated in Figure 4.20:

Upon implementing these four options, the list could go outside the window border in **Stacked-Label-2** and **Stacked-Label-3**. Also, in **Stacked-Label-1** the location of the *stacked-labels* is presented far from the hovered node, especially when the node is far from the centre of the sunburst. Also, changing the reading order can be confusing for the users (changing between top-down and bottom-up reading of the *stacked-labels*) as in **Stacked-Label-2** and **Stacked-Label-1**. For this reason, **Stacked-Label-4** was chosen where the *stacked-labels* list is located inside the window.

The nested model [150] recommends getting a feedback from the end user to validate the design. Therefore, the argument experts who were involved in the interviews of the users' requirements were contacted, with respect to the *StackedBoxes* and the *Sunburst Pop-Up*, and one expert accepted to volunteer. She tried both of the tools, and provided her feedback that is listed below:

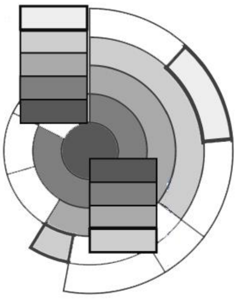
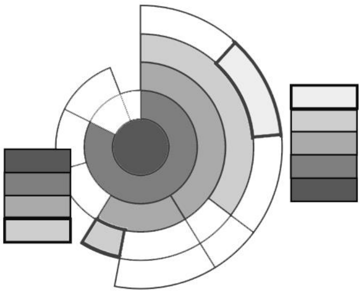
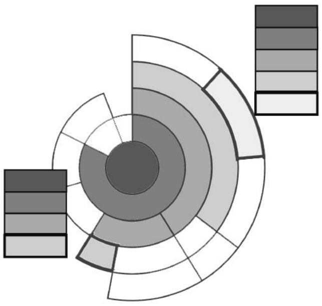
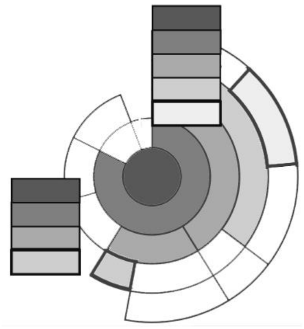
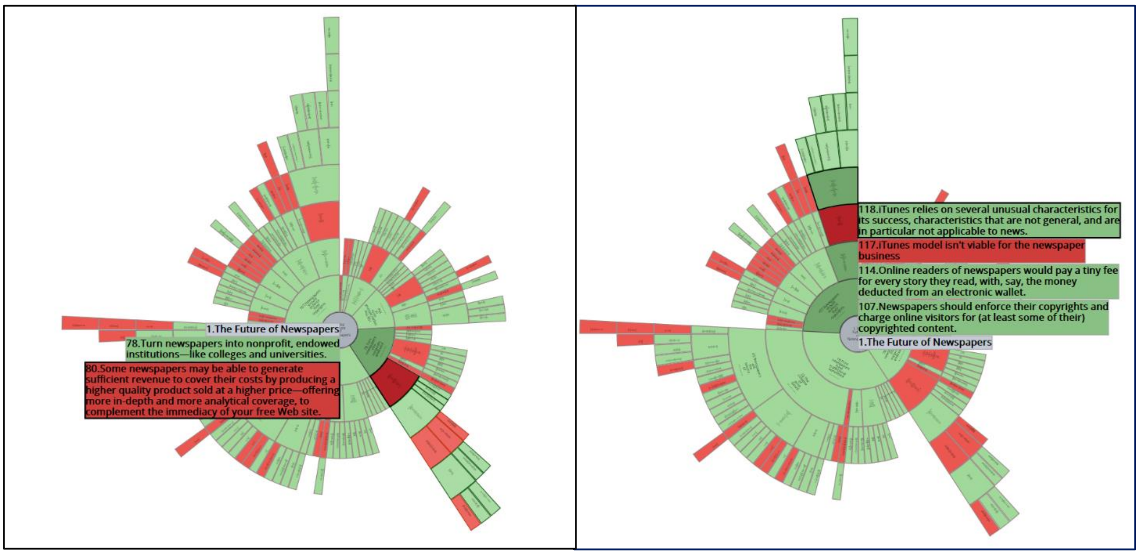
	**Stacked-Label-1:** has a fixed position close to the centre of the sunburst on the opposite side of window to where the mouse is positioned. It lists the labels in the same order as the arguments are visualised in the sunburst. The *stacked-labels* always present the nodes from the root to the hovered node, which means the list can flip between the top and bottom halves of the circle (Figure 4.21) but is always located inside the available window space.
	**Stacked-Label-2:** shows the *stacked-labels* close to the hovered node, and in the same order as arguments are visualised in the sunburst, i.e. top-down or bottom-up (Figure 4.22).
	**Stacked-Label-3:** always displays the arguments from the root down to the hovered node, while the *stacked-labels* are placed outside the sunburst and close to the hovered node (Figure 4.23).
	**Stacked-Label-4:** shows the argument from top-down to the hovered node. Based on the mouse position in the window and the size of the *stacked-labels*, the list is displayed in a location inside the window (Figure 4.24). The position of the *stacked-labels* is dynamic depending on whether the hovered node is close to or far from the centre as follows. First, the position of the hovered node is identified. Second, the width and height of the *stacked-labels* are calculated. Third, if the *stacked-labels* extend outside the window, a new position of the *stacked-labels* is calculated to keep it inside the window depending on the width/height of the window and the size of the list.

Figure 4.20 The iterative design sketches of the *Sunburst Pop-Up*, each with two examples of hovered nodes and *stacked-labels* to show the label placement strategies. The grey scheme reflects the hierarchy structure, i.e. the root is coloured with a dark grey that shades lighter by level towards the leaf nodes. The coloured nodes in the sunburst show the nodes in the coordinated *stacked-labels*.



1.The Future of Newspapers

78.Turn newspapers into nonprofit, endowed institutions—like colleges and universities.

80.Some newspapers may be able to generate sufficient revenue to cover their costs by producing a higher quality product sold at a higher price—offering more in-depth and more analytical coverage, to complement the immediacy of your free Web site.

118.iTunes relies on several unusual characteristics for its success, characteristics that are not general, and are in particular not applicable to news.

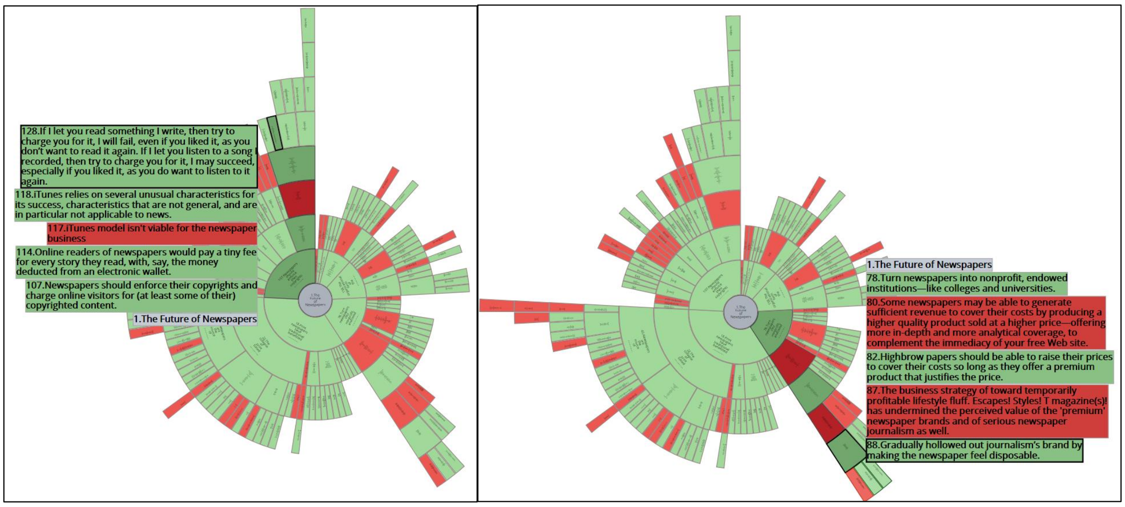
117.iTunes model isn't viable for the newspaper business

114.Online readers of newspapers would pay a tiny fee for every story they read, with, say, the money deducted from an electronic wallet.

107.Newspapers should enforce their copyrights and charge online visitors for (at least some of their) copyrighted content.

1.The Future of Newspapers

Figure 4.21 List-1 shows the list in the same order as the arguments, near the center of the sunburst on the opposite side of window of the hovered node. The left and right figures show different list positions depending on the hovered node.



128.If I let you read something I write, then try to charge you for it, I will fail, even if you liked it, as you don’t want to read it again. If I let you listen to a song I recorded, then try to charge you for it, I may succeed, especially if you liked it, as you do want to listen to it again.

118.iTunes relies on several unusual characteristics for its success, characteristics that are not general, and are in particular not applicable to news.

117.iTunes model isn't viable for the newspaper business

114.Online readers of newspapers would pay a tiny fee for every story they read, with, say, the money deducted from an electronic wallet.

107.Newspapers should enforce their copyrights and charge online visitors for (at least some of their) copyrighted content.

1.The Future of Newspapers

1.The Future of Newspapers

78.Turn newspapers into nonprofit, endowed institutions—like colleges and universities.

80.Some newspapers may be able to generate sufficient revenue to cover their costs by producing a higher quality product sold at a higher price—offering more in-depth and more analytical coverage, to complement the immediacy of your free Web site.

82.Highbrow papers should be able to raise their prices to cover their costs so long as they offer a premium product that justifies the price.

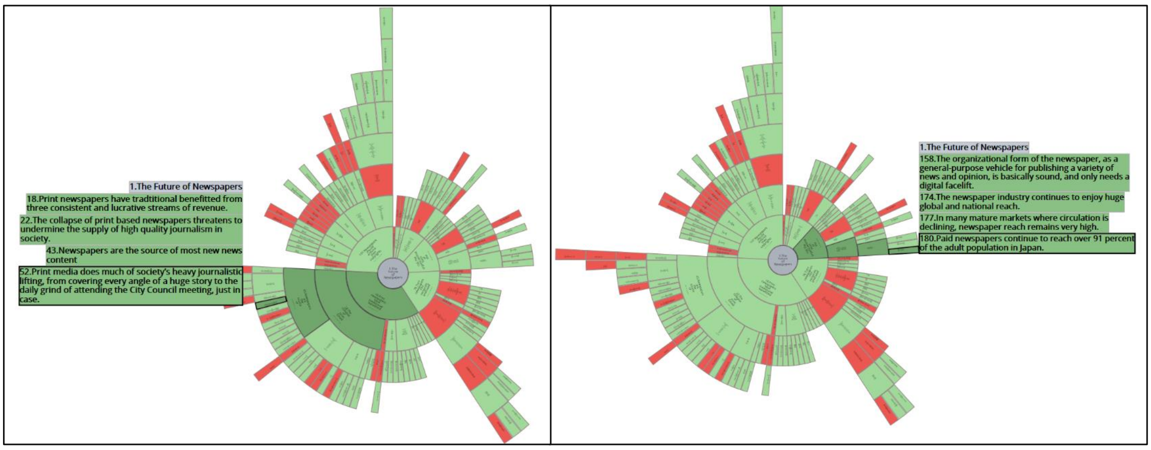
87.The business strategy of toward temporarily profitable lifestyle fluff. Escapes! Styles! T magazine(s)! has undermined the perceived value of the 'premium' newspaper brands and of serious newspaper journalism as well.

88.Gradually hollowed out journalism’s brand by making the newspaper feel disposable.

Figure 4.22 List-2 shows the list near the hovered node and in the same order as arguments. The left and right figures show different list positions depending on the hovered node.

(a) “I think overall this is a very helpful visualisation for quickly getting a sense of the argument tree and the most significant topics.”

(b) “I can easily distinguish the pros and cons.”



1.The Future of Newspapers

18.Print newspapers have tradtitional benefitted from three consistent and lucrative streams of revenue.

22.The collapse of print based newspapers threatens to undermine the supply of high quality journalism in society.

43.Newspapers are the source of most new news content

52.Print media does much of society's heavy journalistic lifting, from covering every angle of a huge story to the daily grind of attending the City Council meeting, just in case.

1.The Future of Newspapers

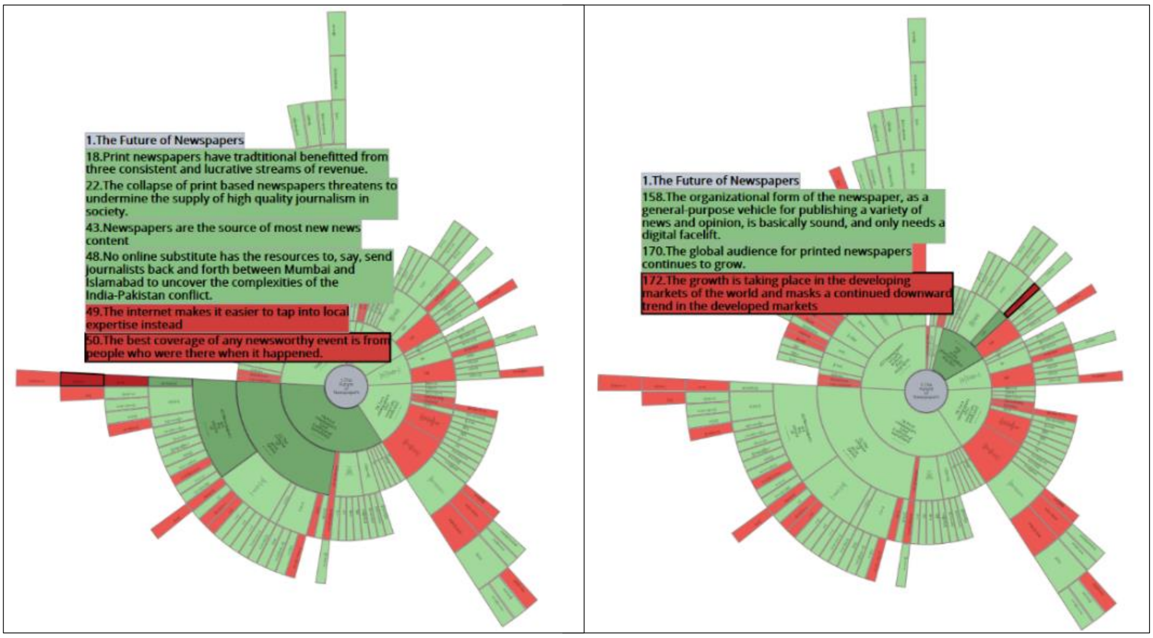
158.The organizational form of the newspaper, as a general-purpose vehicle for publishing a variety of news and opinion, is basically sound, and only needs a digital facelift.

174.The newspaper industry continues to enjoy huge global and national reach.

177.In many mature markets where circulation is declining, newspaper reach remains very high.

180.Paid newspapers continue to reach over 91 percent of the adult population in Japan.

Figure 4.23 List-3 shows the list of labels from the top down to the hovered node and it is placed near the hovered node. The left and right figures show different list positions depending on the hovered node.



1.The Future of Newspapers

18.Print newspapers have tradtitional benefitted from three consistent and lucrative streams of revenue.

22.The collapse of print based newspapers threatens to undermine the supply of high quality journalism in society.

43.Newspapers are the source of most new news content

48.No online substitute has the resources to, say, send journalists back and forth between Mumbai and Islamabad to uncover the complexities of the India-Pakistan conflict.

49.The internet makes it easier to tap into local expertise instead

50.The best coverage of any newsworthy event is from people who were there when it happened.

1.The Future of Newspapers

158.The organizational form of the newspaper, as a general-purpose vehicle for publishing a variety of news and opinion, is basically sound, and only needs a digital facelift.

170.The global audience for printed newspapers continues to grow.

172.The growth is taking place in the developing markets of the world and masks a continued downward trend in the developed markets

Figure 4.24 List-4 shows the list of the argument from the top down to the hovered node. The list is always allocated inside the window. The left and right figures show different list positions depending on the hovered node.

(c) "It's great that you outline the part of the diagram that the comments apply to in the left panel."

(d) "I like the text list (*stacked-boxes*), and the navigation using the keyboard is fast and easy."

The *stacked-labels* list provides quick navigation and fast hovering to read the text. However, the list only pops-up when hovering over the sunburst. One of the development stages of the *stacked-boxes* (Figure 4.10) is reminiscent of an icicle plot; therefore, as an alternative design, the icicle plot with a focus and context (F+C) technique was adapted to enhance reading the text while providing an overview of the whole structure.

4.2.1.4 *Icicle F+C*—Icicle plot with focus and context

This technique is an adaption of an icicle plot to visualise the structure of the argument while using F+C to read the text and focus on one argument chain (R5). The root node is on the left-hand side, while the child nodes stretch towards the right. This orientation of the icicle plot was chosen to present the text horizontally, which is more natural for reading and also gives more space for the text. Furthermore, the columnar presentation keeps sibling nodes in the same column which could also help in reading and navigating as illustrated in Figure 4.25a and Figure 4.25b.

The text is truncated, wrapped and had a font size that changed based on the size of the containing node. To allow the users to read the chain of the argument, the F+C technique was applied which works when users click in any node of the icicle plot, as shown in Figure 4.25c. It enlarges all parent arguments (to the left) and children. Also, it scales all expanded argument boxes up to a size that fully shows the contained argument text. At the same time, the text of the sibling nodes of the clicked nodes are displayed and enlarged, allowing users to navigate through the siblings quickly. The text of all the other nodes are removed as there is no space to present them, and they would to be unreadable, as shown in Figure 4.26.

The colour of the nodes in the *Icicle F+C* is the same as the other tools. If arguments are linked, an additional box is introduced that bridges the boxes of these linked arguments (Figure 4.27).

The algorithm of the F+C is presented in Figure 4.28 and described as follows.

1. Resize the sibling nodes of the parent's chain to a fixed size.

2. Calculate the size of all the parent's chain as (previous parent size – (size of sibling * number of siblings)).

3. Calculate an (x, y) of the siblings and parents and move them.

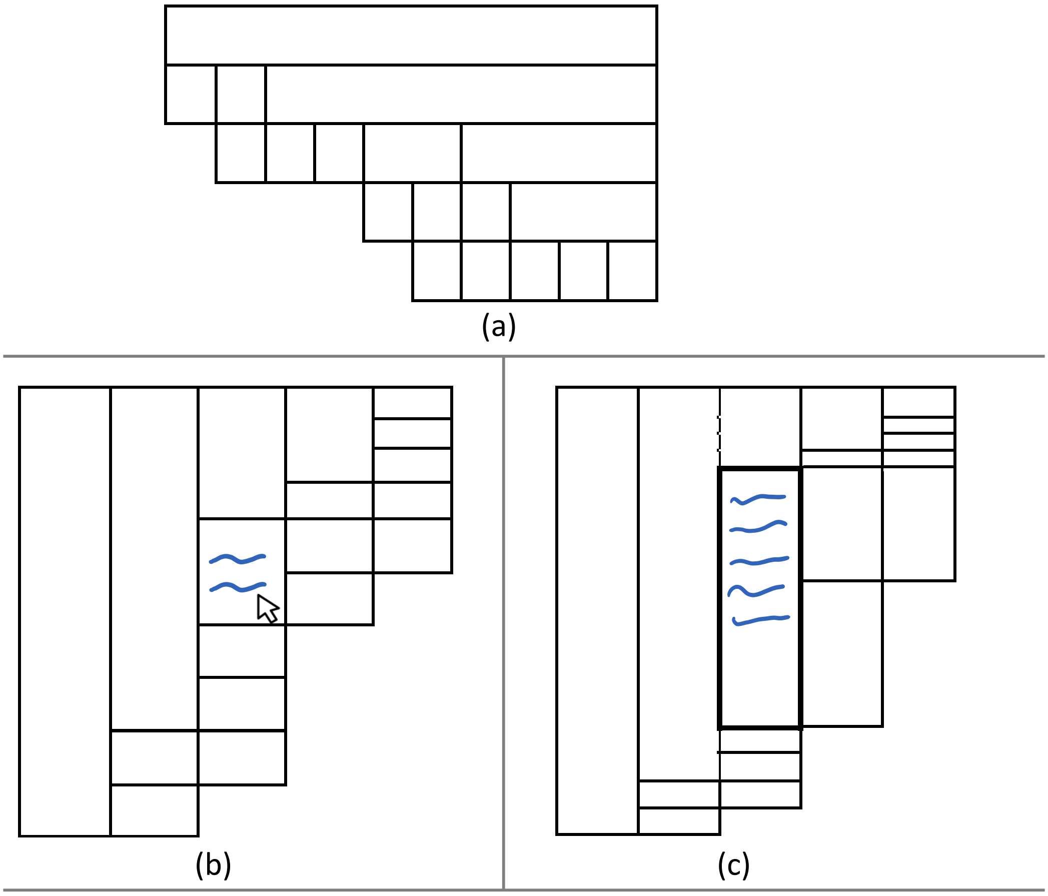


Figure 4.25 The iterative design sketches of *Icicle F+C*: (a) first prototype shows the icicle plot in vertical position; (b) second prototype with horizontal position to give more space for the text; (c) icicle plot with F+C technique.

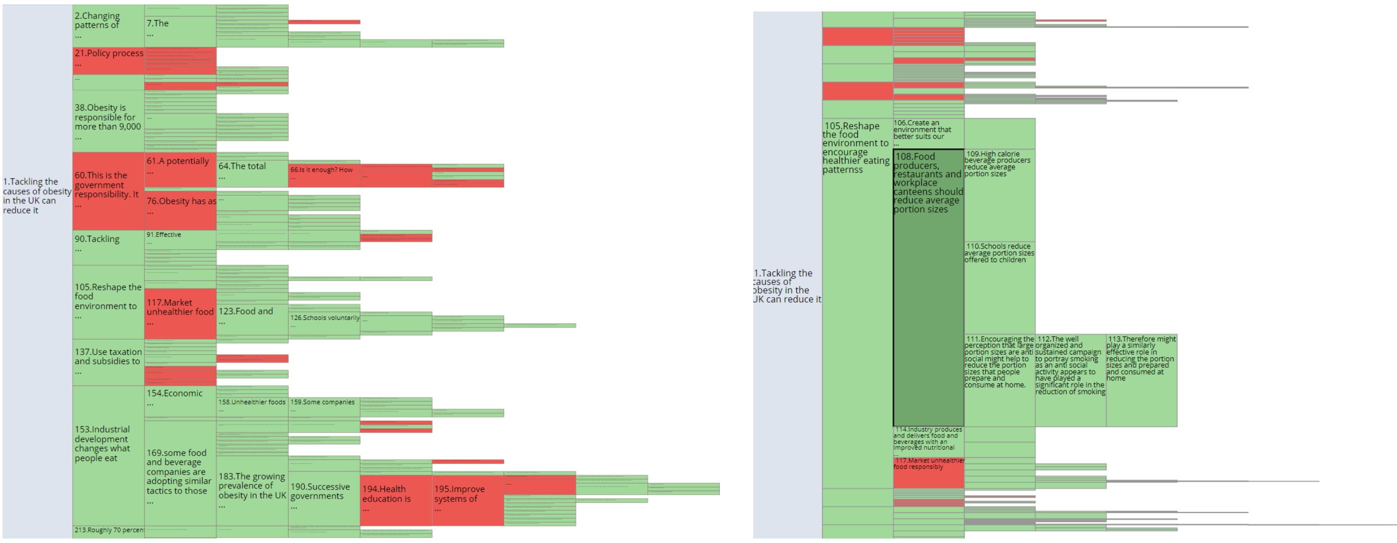
4. Calculate the clicked node size as 2*(clicked node parent size /number of children+1).

5. Calculate the clicked node siblings size as (clicked node parent size-clicked node size)/number of children-1).

6. Calculate the clicked node children size as (clicked node size/ number of children of the clicked node).

7. Enlarge the children of the clicked node.

8. Change font size for the clicked node chain based on the size of the containing node.


1.Tackling the causes of obesity in the UK can reduce it
2.Changing patterns of ...
7.The ...
21.Policy process ...
38.Obesity is responsible for more than 9,000 ...
60.This is the government responsibility. It ...
61.A potentially ...
64.The total ...
66.Is it enough? How ...
76.Obesity has as ...
90.Tackling ...
91.Effective ...
105.Reshape the food environment to ...
117.Market unhealthier food ...
123.Food and ...
126.Schools voluntarily ...
137.Use taxation and subsidies to ...
153.Industrial development changes what people eat
154.Economic ...
158.Unhealthier foods ...
159.Some companies ...
169.some food and beverage companies are adopting similar tactics to those ...
183.The growing prevalence of obesity in the UK ...
190.Successive governments ...
194.Health education is ...
195.Improve systems of ...
213.Roughly 70 percent
1.Tackling the causes of obesity in the UK can reduce it
105.Reshape the food environment to encourage healthier eating patternss
106.Create an environment that better suits our ...
108.Food producers, restaurants and workplace canteens should reduce average portion sizes
109.High calorie beverage producers reduce average portion sizes
110.Schools reduce average portion sizes offered to children
111.Encouraging the perception that large portion sizes are anti social might help to reduce the portion sizes that people prepare and consume at home.
112.The well organized and sustained campaign to portray smoking as an anti social activity appears to have played a significant role in the reduction of smoking
113.Therefore might play a similarly effective role in reducing the portion sizes and prepared and consumed at home
114.Industry produces and delivers food and beverages with an improved nutritional ...
117.Market unhealthier food responsibly

(a) **(b)**

Figure 4.26 (a) The overview of the icicle plot; (b) shows collapsing unimportant parts of the argument to allow the user to focus on the bit they are interested in while keeping the context of that part in the whole argument.

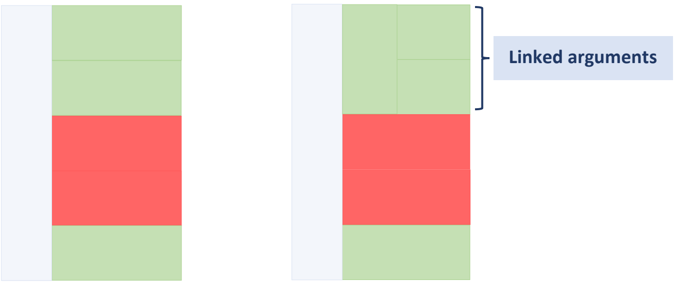


Figure 4.27 Linked arguments in *Icicle F+C*with additional bridge to connect the linked nodes together.

The *Sunburst Pop-Up*, *StackedBoxes*, and *Icicle F+C* help in satisfying the requirements (R1, R2, R3, R4, R5). **R6** in the users' requirement emphasises the importance of providing the user with the number of support/oppose relations. To satisfy this requirement, a pie chart was used that shows the number of support/oppose nodes on a focused chain throughout all the tools. When the tool starts up the pie chart reflects the whole number of supporting and opposing relations. The number is updated when users hover through the graph or click on a specific node (Figure 4.29). Table 4.3 illustrates how the requirements in the tools were achieved.

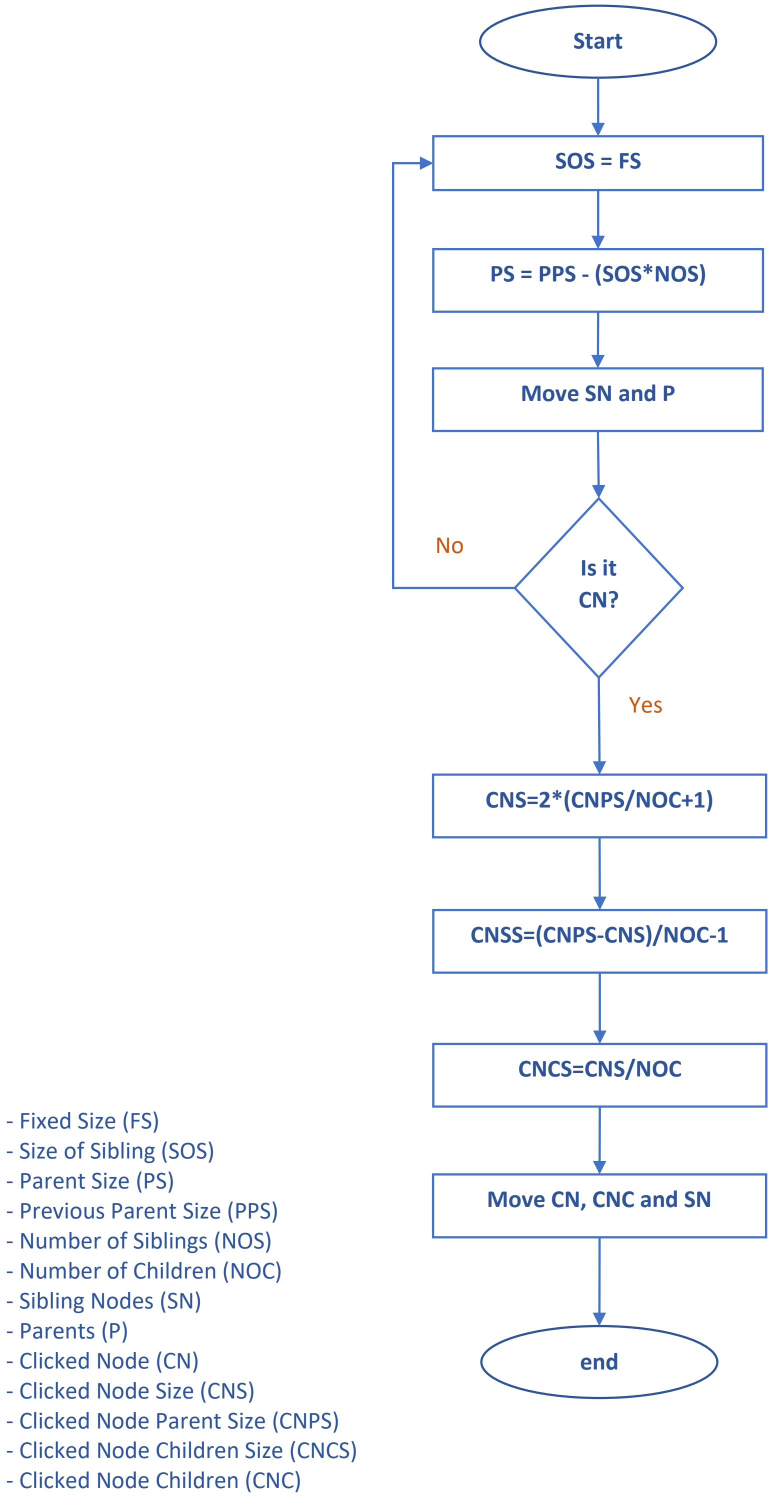


Figure 4.28 F+C algorithm chart.

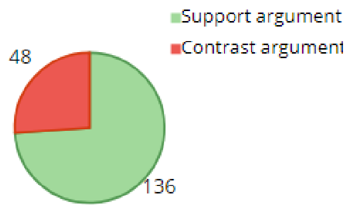


Figure 4.29 A pie chart reflects the number of nodes in a graph.

Table 4.3 The accomplished requirements in the tools.

Requirements	Implementations
R1	Sunburst layout in StackedBoxes and Sunburst Pop-Up tools. Icicle plot in Icicle F+C tool.
R2	Stacked-labels in Sunburst Pop-Up tool. F+C in Icicle F+C tool. Stacked-boxes in StackedBoxes tool.
R3	Use highlighting for argument chain and dark border for focused node.
R4	Users can zoom in and out to make the layout bigger or smaller.
R5	Uses F+C technique in the icicle plot.
R6	Uses a pie chart that shows the number of support/oppose nodes.

Having followed the nested model [150] and as part of the user-centred design, involving the user in the design is an important part of validation. For this reason, the experts were contacted for validation and feedback. Consequently, one of the experts agreed to be involved in the validation process. The three tools and all the features were explained to the expert, then she tried the tools and provided her informal feedback:

"I liked the StackedBoxes in the way that you present the whole chain of the argument, and at the same time, it allows us to go through the content of the children in an easy way. The technique you used in Icicle F+C is good that it presented all the content of the clicked node, but I lost the overview in the layout. In my opinion, combining between two views of visualisation, one for structure and one for the content is a promising solution to solve the problem of the large arguments. For the content, I like the linear layout which is almost similar to your stacked-boxes". During the interview, the advantages and disadvantages of each tool were discussed. Consequently, ideas about the evaluation process and tasks were considered.

Red and green colours were used for support and oppose statements in the argumentation community, respectively. This scheme is based upon an established colour encoding that is widely used in existing ArgVis tools, but it is not accessible for users with a Colour Vision Deficiency (CVD). In Figure 4.30, the Colour Blindness Simulator[1] was used to show how people with CVD will see the red and green colours of our proposed prototype.

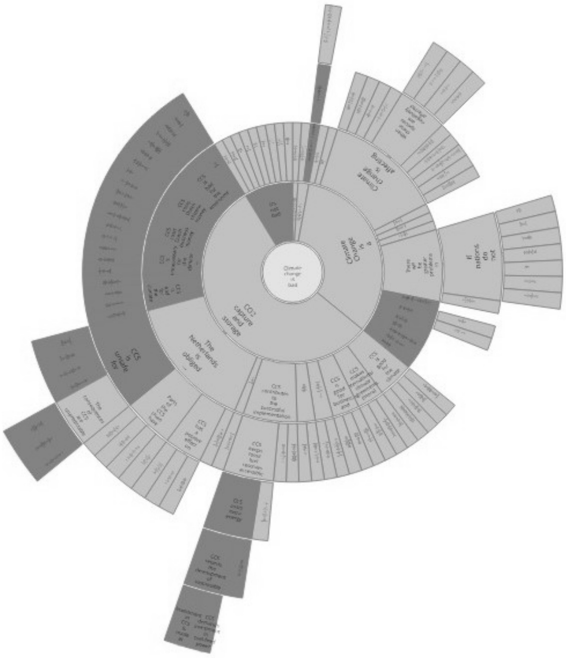


Figure 4.30 The red and green colours for people who suffer from CVD.

In later prototypes, the Color Brewer palettes[2] was used. It offers option to choose the colours for colorblind safe [164]. Blue and orange were applied for support and oppose relations, respectively [165]. These colours were applied to all the tools by simply changing the colour variable in CSS, as shown in Figure 4.31, Figure 4.32, and Figure 4.33.

4.3 Summary

Having identified a set of requirements, based primarily on interactions with experts, several tools were designed and constructed. To understand the domain problem, which was done by interviewing seven argumentation experts. During the interviews, the difficulties and the

[1] https://www.color-blindness.com/coblis-color-blindness-simulator/
[2] http://colorbrewer2.org/

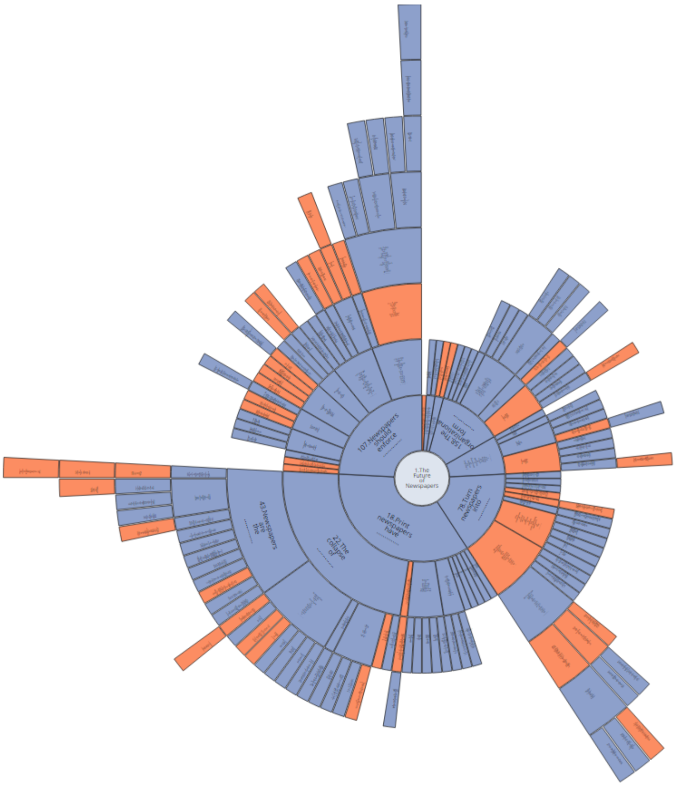
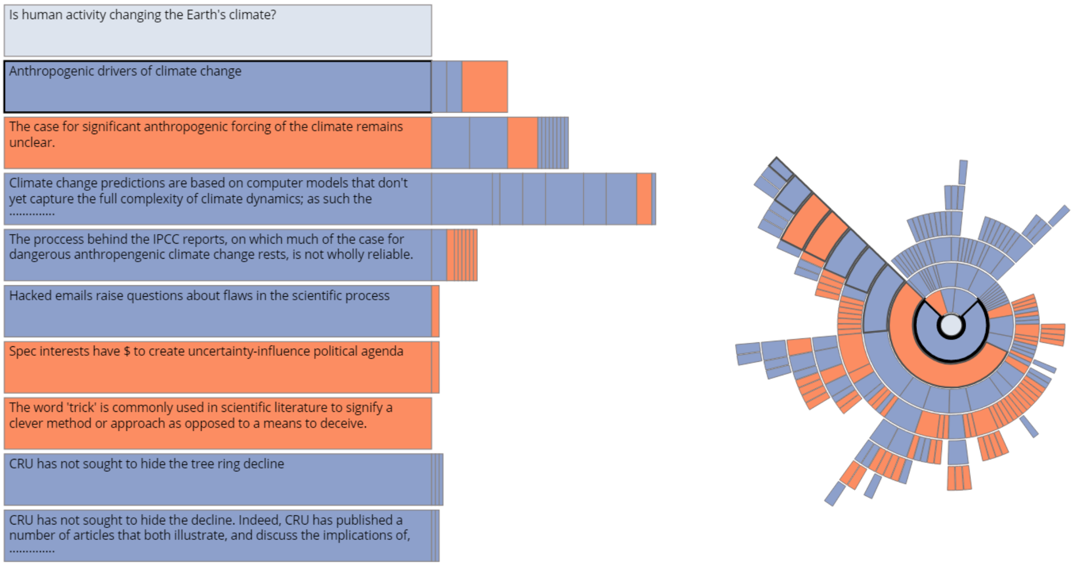


Figure 4.31 The *Sunburst Pop-Up* with blue and orange colours.


Is human activity changing the Earth's climate?

Anthropogenic drivers of climate change

The case for significant anthropogenic forcing of the climate remains unclear.

Climate change predictions are based on computer models that don't yet capture the full complexity of climate dynamics; as such the ....

The proccess behind the IPCC reports, on which much of the case for dangerous anthropengenic climate change rests, is not wholly reliable.

Hacked emails raise questions about flaws in the scientific process

Spec interests have $ to create uncertainty-influence political agenda

The word 'trick' is commonly used in scientific literature to signify a clever method or approach as opposed to a means to deceive.

CRU has not sought to hide the tree ring decline

CRU has not sought to hide the decline. Indeed, CRU has published a number of articles that both illustrate, and discuss the implications of, ...

Figure 4.32 The *StackedBoxes* with blue and orange colours.

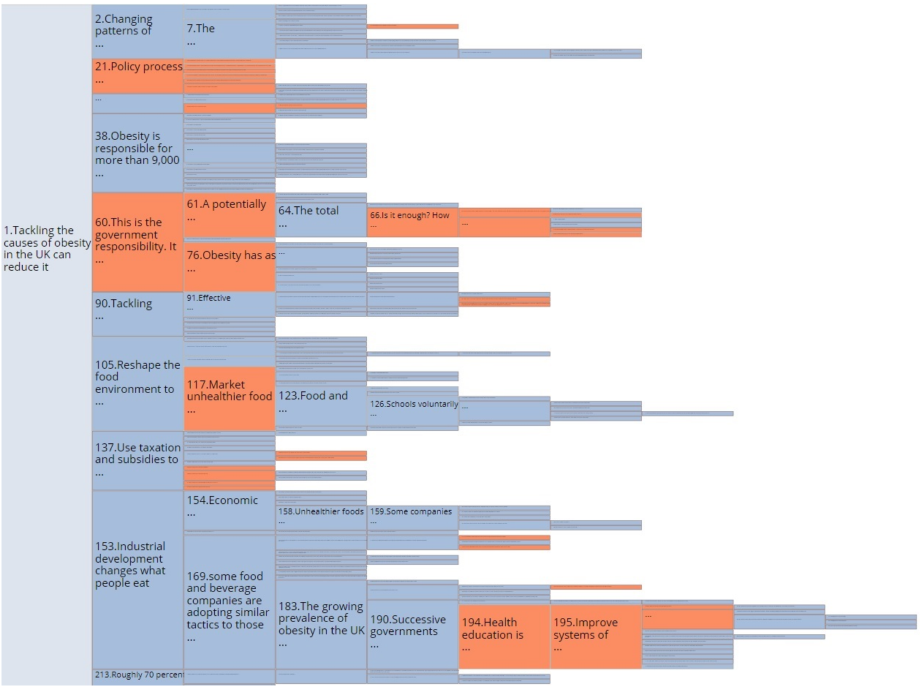

1.Tackling the causes of obesity in the UK can reduce it
2.Changing patterns of ...
7.The ...
21.Policy process ...
38.Obesity is responsible for more than 9,000 ...
60.This is the government responsibility. It ...
61.A potentially ...
64.The total ...
66.Is it enough? How ...
76.Obesity has as ...
90.Tackling ...
91.Effective ...
105.Reshape the food environment to ...
117.Market unhealthier food ...
123.Food and ...
126.Schools voluntarily ...
137.Use taxation and subsidies to ...
153.Industrial development changes what people eat
154.Economic ...
158.Unhealthier foods ...
159.Some companies ...
169.some food and beverage companies are adopting similar tactics to those ...
183.The growing prevalence of obesity in the UK ...
190.Successive governments ...
194.Health education is ...
195.Improve systems of ...
213.Roughly 70 percent

Figure 4.33 The *Icicle F+C* with blue and orange colours.

obstacles the experts faced when using existing ArgVis tools were discussed. To satisfy these requirements, the *Sunburst Node-Link* tool was proposed. Reflecting on the pros and cons of this tool, three other tools for presenting argument data were designed; a novel tool called *StackedBoxes*, *Sunburst Pop-Up*, and *Icicle F+C*. The first tool was a coordinated view that links a new design called *stacked-boxes* with the sunburst. The aim of *stacked-boxes* was to read and navigate the arguments. *stacked-boxes* passed many cycles of design development until the final version that allows users to read the text and easily navigate through the structure. The second tool (*Sunburst Pop-Up*) was the sunburst with the *stacked-labels* displayed when the user hovers over the sunburst. This *stacked-labels* list reflected the argument chain from the root to the hovered node. The third tool (*Icicle F+C*) used the icicle plot with the F+C to help read the text. The F+C enlarged all the parents of the focused node at the expense of the other parents, which made the text in the whole chain of the focused node readable.

To summarise, several techniques and tools for ArgVis were proposed. Three of those prototypes, namely *StackedBoxes*, *Sunburst Pop-Up*, and *Icicle F+C*, satisfy the main user requirements especially when the number of the argument elements arises into a hundred;

providing the overview of the structure (R1), reading the text of argument statements (R2), and providing user interactions with the arguments (R3, R4, R5, R6). To evaluate these prototypes, a user study is carried out, and quantitative and qualitative data is collected and thoroughly analysed in the next Chapter.

Chapter 5

Evaluation of Argument Visualisation Tools

In order to comprehensively assess the techniques and tools proposed in Chapter 4, two evaluation studies were undertaken: a controlled user study and an expert review [152]. Two evaluation studies are conducted due to the difficulty in finding a good number of experts to evaluate our tools. The non-expert feedback would provide useful information about the three tools, which could be used to improve the prototypes before the final testing with experts whose time is valuable. The first study, i.e. a controlled user study, is performed in order to collect quantitative measurements of time and errors, and qualitative feedback about each of the three tools. Three different datasets were chosen from the argument visualisation website, DebateGraph [4]. The second study, i.e. an expert review, is conducted with a small number of experts to obtain performance results from the perspective of those who are actively working the argumentation domain [152]. The results of both evaluation methods are analysed and discussed in this Chapter. Improvements in the proposed tools as a result of the evaluations are also presented.

5.1 Controlled User Study

Evaluation in InfoVis is challenging because of the difficulty in identifying the right evaluation technique, choosing the most relevant tasks for evaluating the system, selecting the correct number of participants and analysing the collected data [153]. Lam *et al.* presented seven evaluation scenarios in InfoVis [154] as follows:

- Draw out the requirements of the design by understanding the problem domain and work practices, e.g., field observation, interviews and laboratory observation.
- Evaluate the visual data analysis like a case study.
- Evaluate how visualisation can help in communication which can be achieved using field observations and interviews.
- Evaluate decision making using InfoVis, like heuristic evaluation.
- Measure the performance of the visualisation design, such as a controlled experiment, and this evaluation is used to check the performance and interaction of people with specific visualisation. Additionally, it can be used to compare novel techniques with others.
- Evaluate the performance of the visualisation algorithm.
- Get feedback from the users about the proposed visualisation, like an informal evaluation and laboratory questionnaire.

Measuring the performance of the visualisation design was chosen for our evaluation, as the three tools (*StackedBoxes*, *Sunburst Pop-Up*, *Icicle F+C*) were compared to check which one seems to help the users perform better in specific tasks. There are four main steps in this study; a) define the hypothesis, b) determine the independent variable, c) measure the dependent variables, and d) apply relevant statistical tests to the results [153]. To verify the user requirements that the proposed tools have satisfied, and explore their advantages and shortcomings, a usability study was run to seek answers to the following questions:

Q1: Which layouts better support the overview in arguments datasets?

Q2: Which techniques better support reading the text?

Q3: Does coordinated view (*StackedBoxes*) improve or degrade the performance (time and error) compared with the integrated views (*Sunburst Pop-Up* and *Icicle F+C*)?

In addition, information about each tools' performance, usability, and interactive features was collected based on one-to-one sessions.

5.1.1 Hypothesis

To answer the aforementioned questions, the hypotheses for this study are:

H1: Sunburst layout (*StackedBoxes*, *Sunburst Pop-Up*) performs better (time and error) than an icicle layout (*Icicle F+C*) in showing argument structure. The sunburst layout in the *Sunburst Pop-Up* and the *StackedBoxes* is one of the top performing visualisation techniques [75].

H2: *Icicle F+C* is better (time and error) than the *Sunburst Pop-Up* in reading the text; *Icicle F+C* provides a better technique for reading the text than *Sunburst Pop-Up* as the position of the *stacked-labels* is not fixed.

H3: The coordinated view (*StackedBoxes*) is more accurate (time and error) than the other two tools; it allows the user to read the text carefully and navigate through the siblings, whereas, the sunburst shows the overall structure of the arguments.

5.1.2 Tasks

By analysing the interviews which discussed in Chapter 4, three representative tasks were generated, and each aims to test different aspects of argument understanding. The tasks focus on some of the requirements listed in subsection 4.1.1, which are overview and details, showing the argument elements, and navigation as shown in Table 5.1. One of the experts involved in the user requirements was contacted and our tasks were discussed with him/her. Each task has a corresponding question in the study. In Table 5.1, the steps that the participants should take to answer each question were illustrated and the relations between the tasks and the requirements were clarified.

- **Content and Structure (CS):** In this task, which is related to R1 (seeing the overview), R2 (reading the text), and R3 (navigating) of the user requirements, the participants were asked to find the reasons or explanations that support or oppose a given statement based on the topic. The user needs to look for a specific premise and read the reasons connected with this argument to find the answer (content). There are two questions for this task: one question related to the node near the centre and the second question associated to node far away from the centre. These two questions explore the difficulty of navigating nodes in the sunburst and the icicle layouts when nodes are far away from the centre.

- **Content (C):** Here, the participants were asked to look for all those statements which include a specific word, e.g., 'energy'. The user has to use the search feature and read the argument text to find the given word. This task is connected to R2 (reading the text) and R3 (navigating) of the user requirements.
- **Structure (S):** In this task, which addresses (R1) (logic flow of the argument) of the user requirements, the participants were asked about the structure of the arguments. The participants should survey the whole structure and check the relations between the argument elements to find the correct answer. To examine that the structure is clear, the participants were asked not to count the nodes on the graph.

Table 5.1 The relations between the tasks and user requirements and the steps of answering the survey questions.

Tasks	Procedure to answer the survey questions	Requirements		
		R1	R2	R3
CS	Look for a specific argument. Navigate through all the reasons.	X	X	X
C	Search for a specific word. Read all the search results to find the answers.		X	X
S	Check the argument structure	X		

5.1.3 Participants and Setting

Isenberg *et al.* [166] surveyed 581 papers from IEEE visualisation conferences to review the types of evaluation these papers have used and the number of participants. Many evaluation studies used 1-5 participants, while (11 - 20) participants is a large number in the user experience and performance study. For this study, in the first stage of evaluation there were 21 participants (13 males, 8 females), aged 25–37. They all had normal or corrected-to-normal vision without any colour impairment. 12 of the participants were PhD students in computing or engineering, and 9 were working as researchers. All of the participants did not have any background in ArgVis. The study was run on the Intel Core i7 and 15-inch flat screen with a resolution of 1920 x 1080 pixels. The participants were asked to fill in the ethical form, presented in the Appendix B, which was the agreement of free participation in this study, and the freedom to withdraw at any time the participants like.

5.1.4 Dataset

It was challenging to get a dataset where the number of nodes exceeds 100 on an interesting and useful subject. Having a single dataset can influence the participants' performance in favour of the tool that comes last in the study. Thus three different datasets were selected to evaluate the three proposed tools. Three common and understandable topics, which did not require prior knowledge, were chosen in order to understand the argument and answer the questions: climate change, the future of printed newspapers, and obesity. The datasets were collected from DebateGraph [4], which was chosen as it has datasets with diverse topics. David Price, the co-founder of DebateGraph, provided his consent to use those datasets.

Our data included 202 nodes and 201 relations for climate change, 200 nodes and 199 relations for the future of printed newspapers, and 221 nodes and 220 relations for obesity. The relations have two types, opposing and supporting ones between the statements in the hierarchy structure. The statements can be convergent or linked as in section 2.2.

5.1.5 Procedure

Three pilot studies with three different volunteers were undertaken to check the time and difficulty of the study, before the evaluation with the participants was started. All of them did not have any background in ArgVis. Upon completing these three studies, some changes to the study's questions were performed to clarify them. In addition, a printed copy of the instructions was provided for participants to help them during the study.

Each session in the evaluation lasted between 30 and 60 minutes and started with an explanation of the aim of the study and clarification of how each tool works. Three trial questions, one for each tool, were given before starting the study to allow the participants to become familiar with the tools and raise questions. The printed instructions regarding the three tools were provided to the participants which they can keep during the study

(Appendix C). The study consisted of three blocks; each block presented a tool with four task questions representative to our tasks CS, C, and S as shown in Table 5.2, followed by three questions about the subjective usability of the tool as illustrated in Table 5.3. To minimise the impact of the tools' order and datasets on the study and participants performance, all possible combinations of tool-topic were covered and assigned to participants randomly.

Before seeing the visualisations and answering the questions, participants were first prompted with the question. After having understood the question, participants pressed a button and could access the visualisation. Pressing the button would activate a timer to measure how long it took participants to find an answer. Not all people have the same speed ability to type on the keyboard. To avoid letting this affect our time analysis, the participants needed to right-click on any node, and the answer was transferred immediately to the answer box.

Response time and accuracy were stored in the database for all the questions. Also, the entirety of each session was recorded using an audio recorder. At the end of the session, participants were asked to order the tools based on their preference and provide the reason(s) for their selection and additionally to provide general comments or feedback.

Table 5.2 Questions about each dataset, related to the tasks CS, C, and S for the different datasets.

Dataset	Questions	CS	C	S
Obesity	Please provide any two statements which detail actions that help to tackle obesity and reduce it.	X		
	Which statement explains why some companies use fructose instead of cane sugar?	X		
	Which statements mention the term eating?		X	
	Which statement has the most immediate supporting statements (without opposing statements)?			X
Climate Change	Please provide two statements which explain the role of fossil fuels in climate change.	X		
	Please provide any two statements which mention the relation between climate change and water vapour.	X		
	Which statements mention the term energy?		X	
	Which statement has the most immediate opposing statements (without supporting statements)?			X
Newspapers	Please provide any two statements which explain how newspapers should enforce their copyright.	X		
	Please provide one statement which mentions who provides the best coverage of any newsworthy event.	X		
	Which statements mention the term source?		X	
	Which statement has the longest argument chain (excluding the parent node)?			X

Table 5.3 The three 5-point Likert scale subjective usability questions about participants' experience on using the relevant tool.

Tool	Questions	Reading	Search	Layout
StackedBoxes	How did you find the pop-up list of labelling when browsing for reading the text?	X		
	How easy was it to see the result of a search on the argument map?		X	
	How easy was it to explore the structure of the argument map?			X
Sunburst Pop-Up	How did you find the pop-up list when browsing for reading the text?	X		
	How easy was it to see the result of a search on the argument map?		X	
	How easy was it to explore the structure of the argument map?			X
Icicle F+C	How did you find the F+C functionality of the Icicle layout?	X		
	How easy was it to see the result of a search on the argument map?		X	
	How easy was it to explore the structure of the argument map?			X

5.1.6 Results

5.1.6.1 Variables:

There are two types of variables in our results; the first are the independent variables which are the three tools. The second are the dependent variables which could be influenced by the independent variables. In our case, they are the time, error and accuracy.

To decide which statistical test needs to be implemented, the selection process illustrated in Figure 5.1 was applied. There are two hypotheses for the statistical test, first is a null hypothesis where there is no difference between the two or more samples. The second hypothesis is the opposite, where there is a difference between them. The time and the error for each task were checked if they follow a normal distribution or not by applying the Shapiro-Wilk test as the number of samples in our study is 21, that is less than 2000 elements. If $p < 0.05$, data do not follow a normal distribution. Also, the samples were checked if they are paired using the "Two-Related-Sample" test, i.e. if there are any differences in the mean or not. If $p < 0.05$, the samples are paired. As the three tools were compared, the p-value was adjusted by using Holm's Sequential Bonferroni correction [167]. The simple Bonferroni correction rejects only null hypotheses with the p-value less than (0.05/m), where m is the number of comparison pairs. If the result of the statistical test shows that there is a significant difference between the three tools, then another statistical test was applied between the two tools to determine whether they are significantly different, which is called Pairwise Comparisons.

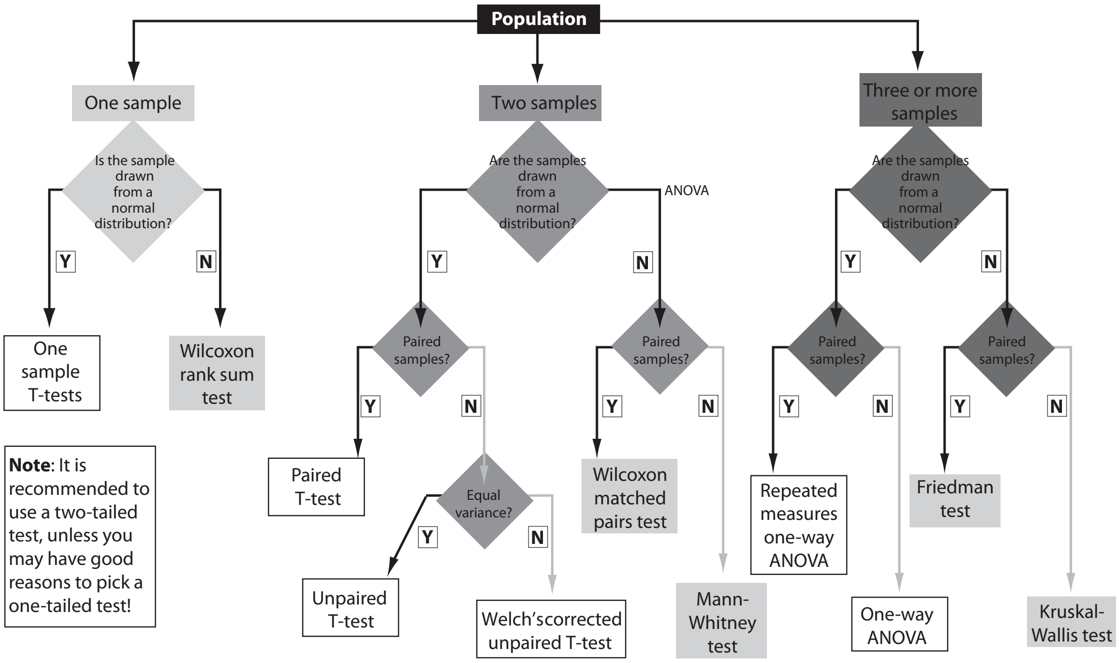
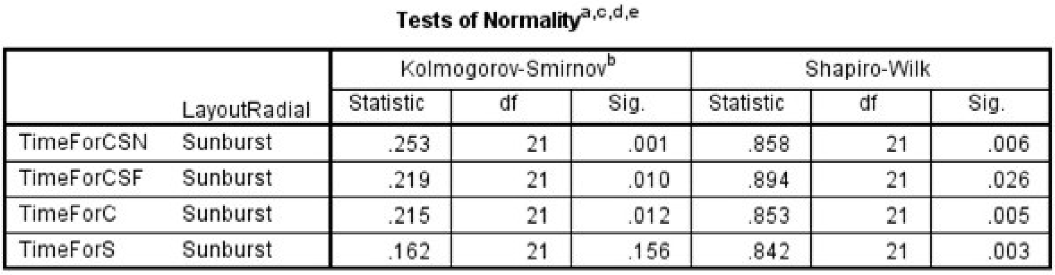

Population
One sample
Two samples
Three or more samples
Is the sample drawn from a normal distribution?
Are the samples drawn from a normal distribution?
ANOVA
Are the samples drawn from a normal distribution?
Y
N
Y
N
Y
N
One sample T-tests
Wilcoxon rank sum test
Paired samples?
Paired samples?
Paired samples?
Paired samples?
Y
N
Y
N
Y
N
Y
N
Note: It is recommended to use a two-tailed test, unless you may have good reasons to pick a one-tailed test!
Paired T-test
Equal variance?
Y
N
Wilcoxon matched pairs test
Repeated measures one-way ANOVA
Friedman test
Unpaired T-test
Welch'scorrected unpaired T-test
Mann-Whitney test
One-way ANOVA
Kruskal-Wallis test

Figure 5.1 The selection process for the right statistical test [168].

5.1.6.2 Time

The time spent by the users to complete the tasks of *Sunburst Pop-Up*, *Icicle F+C*, and *StackedBoxes* significantly deviated from a normal distribution as the p $<$ 0.05 of the Shapiro-Wilk test illustrated in Figure 5.2, Figure 5.3, and Figure 5.4 shows respectively.

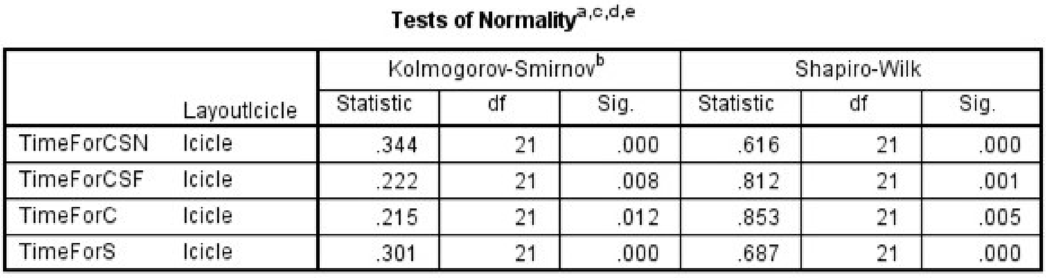


Tests of Normality^{a,c,d,e}

		Kolmogorov-Smirnov^{b}			Shapiro-Wilk		
	LayoutRadial	Statistic	df	Sig.	Statistic	df	Sig.
TimeForCSN	Sunburst	.253	21	.001	.858	21	.006
TimeForCSF	Sunburst	.219	21	.010	.894	21	.026
TimeForC	Sunburst	.215	21	.012	.853	21	.005
TimeForS	Sunburst	.162	21	.156	.842	21	.003

Figure 5.2 The time result of the normality of *Sunburst Pop-Up* tool.

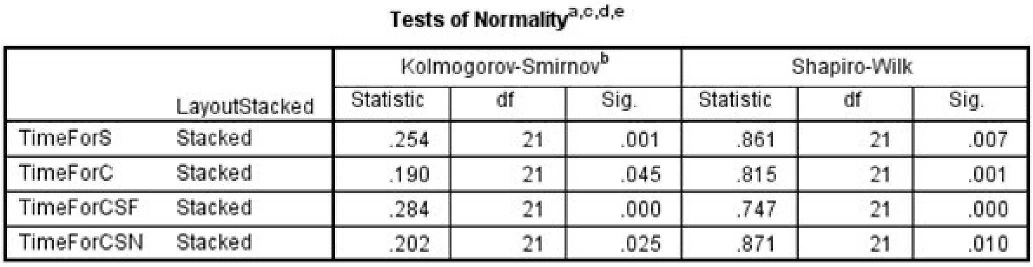
After that, the“Two-Related-Samples" test was applied, and the result showed that the samples were not paired (p $>$ 0.05). Regarding Figure 5.1, the Kruskal-Wallis test was applied for comparing the result of the three tools. The most important values that should be considered in the Kruskal-Wallis test tables are [169]:



Tests of Normality[a,c,d,e]

		Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	LayoutIcicle	Statistic	df	Sig.	Statistic	df	Sig.
TimeForCSN	Icicle	.344	21	.000	.616	21	.000
TimeForCSF	Icicle	.222	21	.008	.812	21	.001
TimeForC	Icicle	.215	21	.012	.853	21	.005
TimeForS	Icicle	.301	21	.000	.687	21	.000

Figure 5.3 The time result of the normality of *Icicle F+C* tool.



Tests of Normality[a,c,d,e]

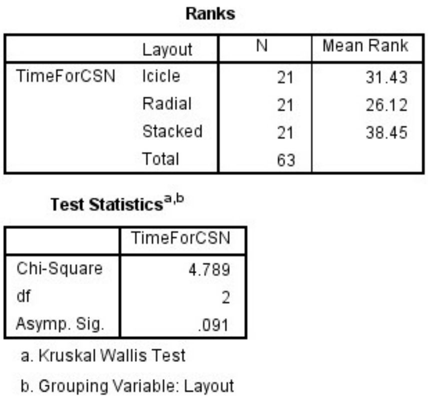
		Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	LayoutStacked	Statistic	df	Sig.	Statistic	df	Sig.
TimeForS	Stacked	.254	21	.001	.861	21	.007
TimeForC	Stacked	.190	21	.045	.815	21	.001
TimeForCSF	Stacked	.284	21	.000	.747	21	.000
TimeForCSN	Stacked	.202	21	.025	.871	21	.010

Figure 5.4 The time result of the normality of *StackedBoxes* tool.

Chi-Square: a larger value indicates larger differences between the samples.

Asymp.Sig: the (p-value). If p $>$ 0.01, the differences between the samples are not statistically significant.

The results in Figure 5.5, Figure 5.6, Figure 5.7, and Figure 5.8 show no significant difference between the three tools with respect to the time taken to answer the questions in all the tasks. The p-value is higher than 0.01 in all the Kruskal-Wallis tests for the tasks; CSN (p = 0.91 $>$ 0.01), CSF (p = 0.027 $>$ 0.01), C (p = 0.850 $>$ 0.01), S (p = 0.246 $>$ 0.01).



Ranks

	Layout	N	Mean Rank
TimeForCSN	Icicle	21	31.43
	Radial	21	26.12
	Stacked	21	38.45
	Total	63	

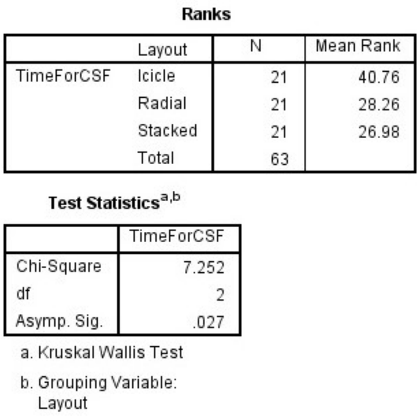
Test Statistics[a,b]

	TimeForCSN
Chi-Square	4.789
df	2
Asymp. Sig.	.091

a. Kruskal Wallis Test

b. Grouping Variable: Layout

Figure 5.5 The result of Kruskal-Wallis test for the CSN task.



Ranks

	Layout	N	Mean Rank
TimeForCSF	Icicle	21	40.76
	Radial	21	28.26
	Stacked	21	26.98
	Total	63	

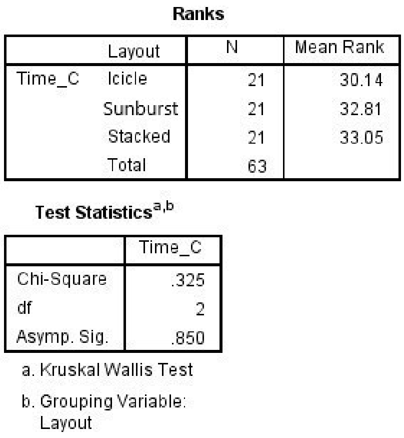
Test Statistics[a,b]

	TimeForCSF
Chi-Square	7.252
df	2
Asymp. Sig.	.027

a. Kruskal Wallis Test

b. Grouping Variable: Layout

Figure 5.6 The result of Kruskal-Wallis test for the CSF task.



Ranks

	Layout	N	Mean Rank
Time_C	Icicle	21	30.14
	Sunburst	21	32.81
	Stacked	21	33.05
	Total	63	

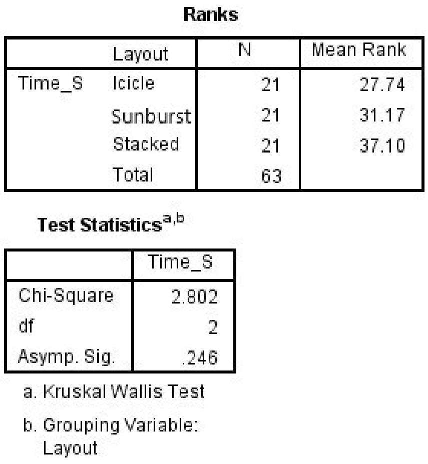
Test Statistics[a,b]

	Time_C
Chi-Square	.325
df	2
Asymp. Sig.	.850

a. Kruskal Wallis Test

b. Grouping Variable: Layout

Figure 5.7 The result of Kruskal-Wallis test for the C task.



Ranks

	Layout	N	Mean Rank
Time_S	Icicle	21	27.74
	Sunburst	21	31.17
	Stacked	21	37.10
	Total	63	

Test Statistics[a,b]

	Time_S
Chi-Square	2.802
df	2
Asymp. Sig.	.246

a. Kruskal Wallis Test

b. Grouping Variable: Layout

Figure 5.8 The result of Kruskal-Wallis test for the S task.

The average time, in minutes, for each tool is illustrated in Figure 5.9. The participants have spent the least amount of time, 6.1 minutes, to answer the questions in *Sunburst Pop-Up* compared with the *Icicle F+C* questions which recorded the highest at 7.7 minutes, with the *StackedBoxes* questions taking 7.5 minutes.

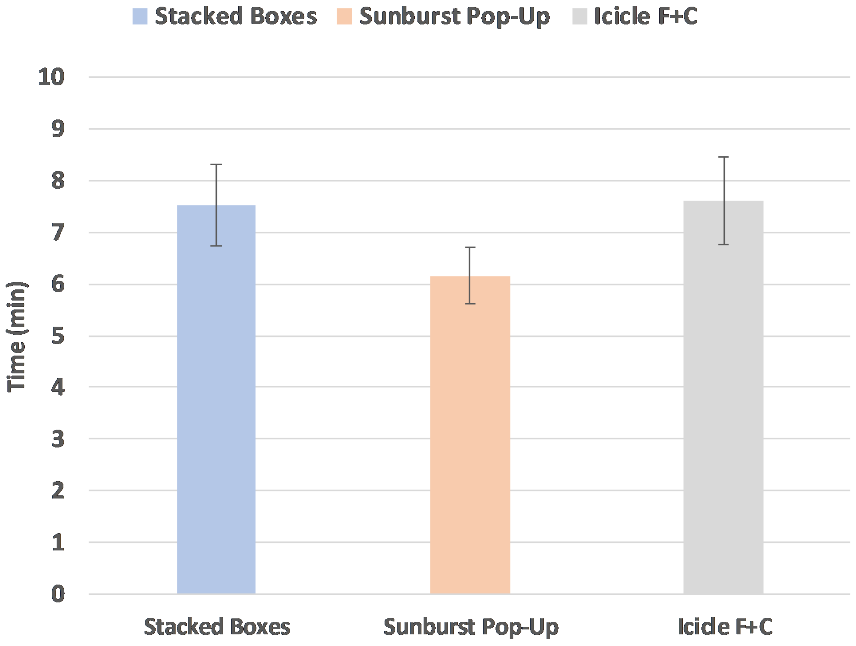


Figure 5.9 The average time, in minutes, for each tool.

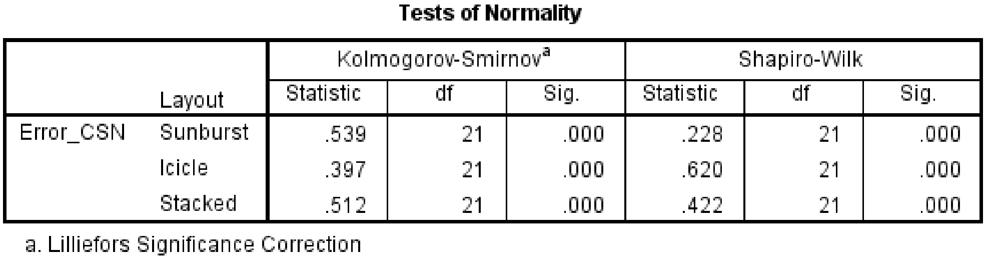
5.1.6.3 Error

To analyse the error in the *CS* task, the node near the centre (CSN) and far from the centre (CSF) were considered in our analysis.

The error in the CSN was found not to follow a normal distribution as p < 0.05, as in Figure 5.10, for all tools. Also, the data were not paired samples. As a result of implementing the process shown in Figure 5.1, the Kruskal-Wallis test was applied for significance testing. The result showed a significant difference (p = 0.007 < 0.01) between the tools, as shown in Figure 5.11.

For pairwise comparison, the Mann-Whitney test was employed. The most important values that should be considered in the Mann-Whitney test tables are [169]:

Mann-Whitney U and Wilcoxon W: they summarise the difference in mean rank numbers.

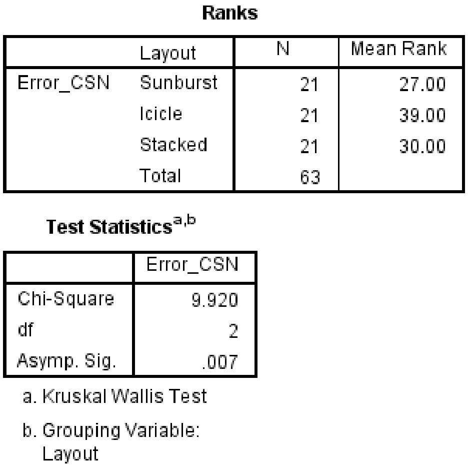


Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Layout	Statistic	df	Sig.	Statistic	df	Sig.
Error_CSN	Sunburst	.539	21	.000	.228	21	.000
	Icicle	.397	21	.000	.620	21	.000
	Stacked	.512	21	.000	.422	21	.000

a. Lilliefors Significance Correction

Figure 5.10 The result of normality for CSN.



Ranks

	Layout	N	Mean Rank
Error_CSN	Sunburst	21	27.00
	Icicle	21	39.00
	Stacked	21	30.00
	Total	63	

Test Statistics[a,b]

	Error_CSN
Chi-Square	9.920
df	2
Asymp. Sig.	.007

a. Kruskal Wallis Test

b. Grouping Variable: Layout

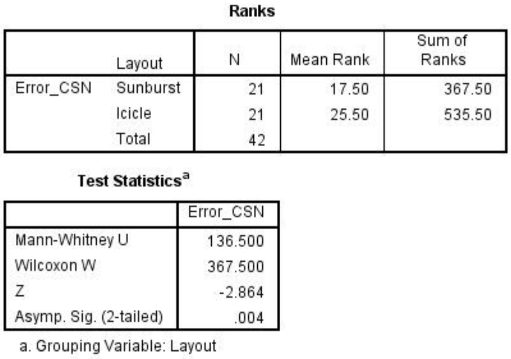
Figure 5.11 The result of Kruskal-Wallis test for CSN.

Asymp Sig: the (p-value). If $p > 0.01$, the differences between the samples are not statistically significant.

The results of the tests are illustrated in Figure 5.12, Figure 5.13, and Figure 5.14. The $p = 0.004 < 0.01$ between *Sunburst Pop-Up* and *Icicle F+C*, so *Sunburst Pop-Up*, with average error of 5% as in Figure 5.15, performed better in the CSN task than *Icicle F+C*, with average error of 43%. There were no other differences can be found in these results.

The error in the CSF task was also found not to follow a normal distribution (Figure 5.16) and it was not paired samples as well. The Kruskal-Wallis test was applied for significance testing and the result in Figure 5.17 shows that there is a difference between the tools ($p = 0.009 < 0.01$).

For pairwise comparison, the Mann-Whitney test was employed. The results of the tests are illustrated in Figure 5.18, Figure 5.19, and Figure 5.20. The $p = 0.009 < 0.01$



Ranks

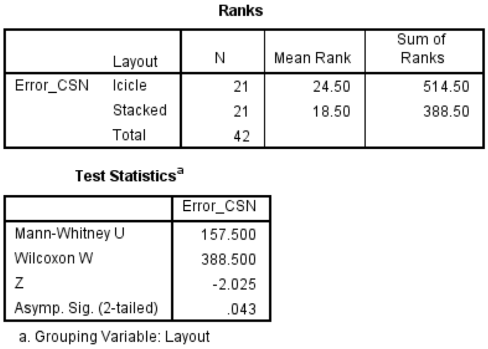
	Layout	N	Mean Rank	Sum of Ranks
Error_CSN	Sunburst	21	17.50	367.50
	Icicle	21	25.50	535.50
	Total	42		

Test Statistics[a]

	Error_CSN
Mann-Whitney U	136.500
Wilcoxon W	367.500
Z	-2.864
Asymp. Sig. (2-tailed)	.004

a. Grouping Variable: Layout

Figure 5.12 The results of the Mann-Whitney test between *Sunburst Pop-Up* and *Icicle F+C* in the CSN task.



Ranks

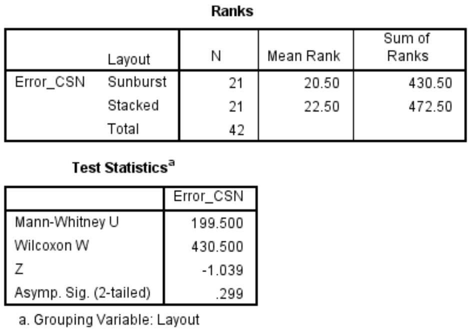
	Layout	N	Mean Rank	Sum of Ranks
Error_CSN	Icicle	21	24.50	514.50
	Stacked	21	18.50	388.50
	Total	42		

Test Statistics[a]

	Error_CSN
Mann-Whitney U	157.500
Wilcoxon W	388.500
Z	-2.025
Asymp. Sig. (2-tailed)	.043

a. Grouping Variable: Layout

Figure 5.13 The results of the Mann-Whitney test between *Icicle F+C* and *StackedBoxes* in the CSN task.



Ranks

	Layout	N	Mean Rank	Sum of Ranks
Error_CSN	Sunburst	21	20.50	430.50
	Stacked	21	22.50	472.50
	Total	42		

Test Statistics[a]

	Error_CSN
Mann-Whitney U	199.500
Wilcoxon W	430.500
Z	-1.039
Asymp. Sig. (2-tailed)	.299

a. Grouping Variable: Layout

Figure 5.14 The results of the Mann-Whitney test between *Sunburst Pop-Up* and *StackedBoxes* in the CSN task.

between *Sunburst Pop-Up* and *Icicle F+C*, so *Sunburst Pop-Up*, with average error of 14% as in Figure 5.21, performed better in the CSF task than *Icicle F+C*, with average error of 52%. There were no other differences can be found in these results.

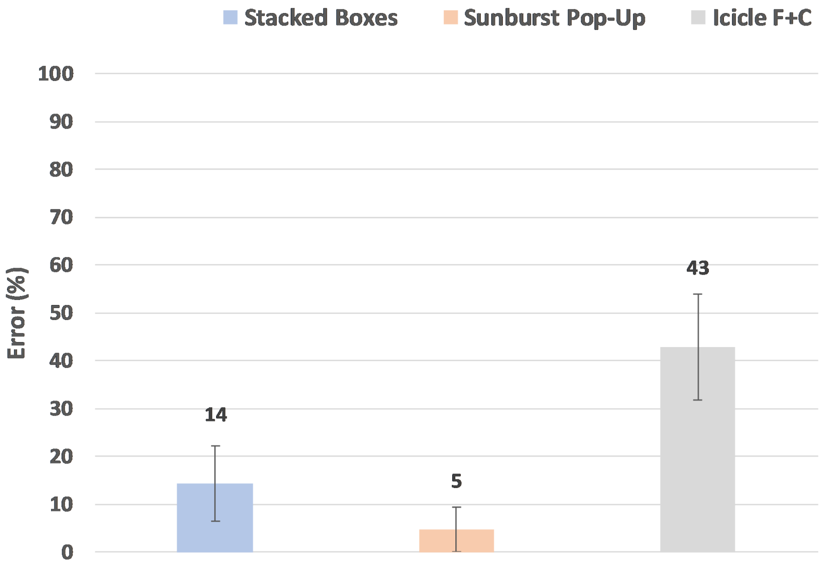
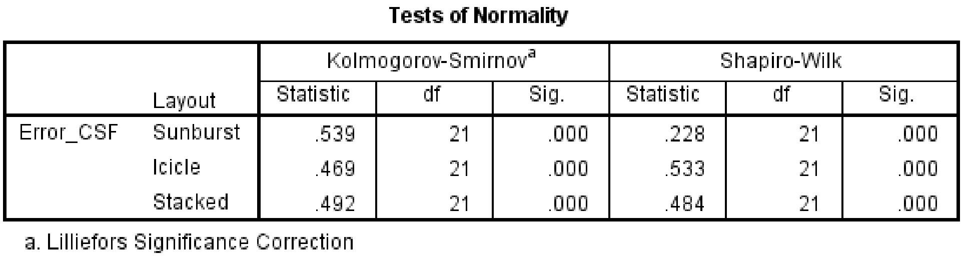


Figure 5.15 Average error for CSN by tool.



Tests of Normality

	Layout	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Error_CSF	Sunburst	.539	21	.000	.228	21	.000
	Icicle	.469	21	.000	.533	21	.000
	Stacked	.492	21	.000	.484	21	.000

a. Lilliefors Significance Correction

Figure 5.16 The result of normality for CSF.

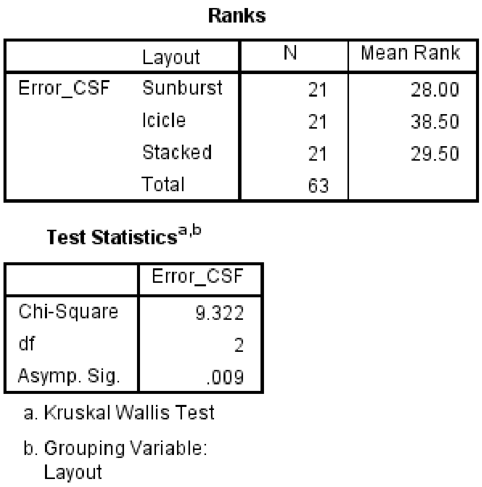
Error for C was found not to follow a normal distribution ($p < 0.05$), as illustrated in Figure 5.22. Following Figure 5.1, the Friedman test was chosen as the data is not normally distributed and it is paired sample.

The most important values that should be considered in Friedman test tables are [169]:

The mean ranks: if the original variables have similar distributions, then the mean ranks should be roughly equal.

Asymp Sig: is our significance level (p). If $p > 0.01$, the differences between samples are not statistically significant.

The result (Figure 5.23) showed that $p = 0.004 < 0.01$, so there is a significant difference between the tools. For pairwise comparison, the Wilcoxon signed rank test was applied



Ranks

	Layout	N	Mean Rank
Error_CSF	Sunburst	21	28.00
	Icicle	21	38.50
	Stacked	21	29.50
	Total	63	

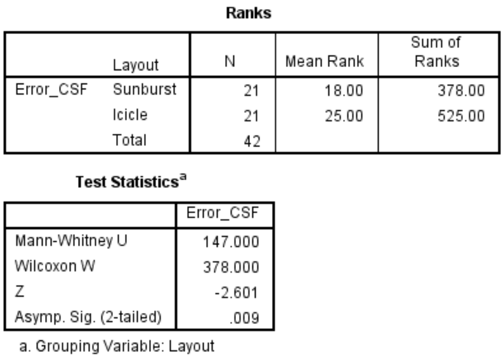
Test Statistics^{a,b}

	Error_CSF
Chi-Square	9.322
df	2
Asymp. Sig.	.009

a. Kruskal Wallis Test

b. Grouping Variable: Layout

Figure 5.17 The results of the Kruskal-Wallis test for CSF.



Ranks

	Layout	N	Mean Rank	Sum of Ranks
Error_CSF	Sunburst	21	18.00	378.00
	Icicle	21	25.00	525.00
	Total	42		

Test Statistics^{a}

	Error_CSF
Mann-Whitney U	147.000
Wilcoxon W	378.000
Z	-2.601
Asymp. Sig. (2-tailed)	.009

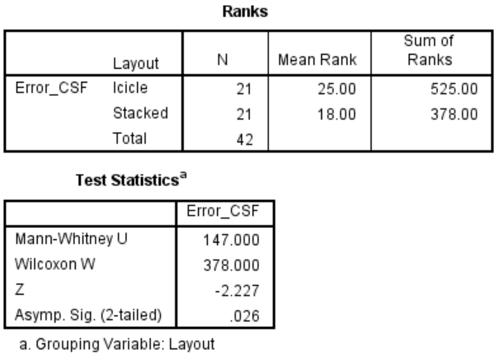
a. Grouping Variable: Layout

Figure 5.18 The results of the Mann-Whitney test between *Sunburst Pop-Up* and *Icicle F+C* in the CSF task.

between each pair of the tools. The most important value that should be considered in Wilcoxon signed rank test tables are [169]:

Asymp Sig: the p-value. If p $>$ 0.01, the differences between the samples are not statistically significant.

The outcomes showed that *Sunburst Pop-Up* (average error 19%) performed better in the C task than *Icicle F+C* (average error 71%, p = 0.002), as clarified in Figure 5.24 and Figure 5.25. There were no other differences can be found between the results.



Ranks

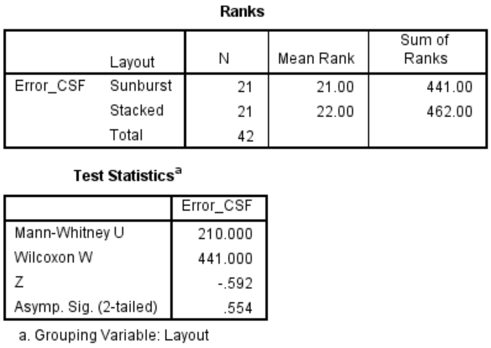
	Layout	N	Mean Rank	Sum of Ranks
Error_CSF	Icicle	21	25.00	525.00
	Stacked	21	18.00	378.00
	Total	42		

Test Statistics[a]

	Error_CSF
Mann-Whitney U	147.000
Wilcoxon W	378.000
Z	-2.227
Asymp. Sig. (2-tailed)	.026

a. Grouping Variable: Layout

Figure 5.19 The results of the Mann-Whitney test between *Icicle F+C* and *StackedBoxes* in the CSF task.



Ranks

	Layout	N	Mean Rank	Sum of Ranks
Error_CSF	Sunburst	21	21.00	441.00
	Stacked	21	22.00	462.00
	Total	42		

Test Statistics[a]

	Error_CSF
Mann-Whitney U	210.000
Wilcoxon W	441.000
Z	-.592
Asymp. Sig. (2-tailed)	.554

a. Grouping Variable: Layout

Figure 5.20 The results of the Mann-Whitney test between *Sunburst Pop-Up* and *StackedBoxes* in the CSF task.

For the **S task**, it was found not to follow a normal distribution ($p < 0.05$), as illustrated in Figure 5.26. They were not paired samples so the Kruskal-Wallis test was applied. The result showed that $p = 0.357 > 0.01$, so no other differences can be found, as in Figure 5.27. The average error is higher for *Icicle F+C* than the two other tools (*StackedBoxes*= 24%, *Sunburst Pop-Up*= 19%, *Icicle F+C*= 38%), as demonstrated in Figure 5.28.

5.1.6.4 Subjective Ratings

The participants were asked to provide feedback about their experience of each tool during the evaluation. They rated each of the three tools across three satisfaction questions covering the search, reading the text, and exploring the structure of the argument using the layout. Responses were on a 1-5 Likert scale, where 1 = Very easy and 5 = Very difficult.

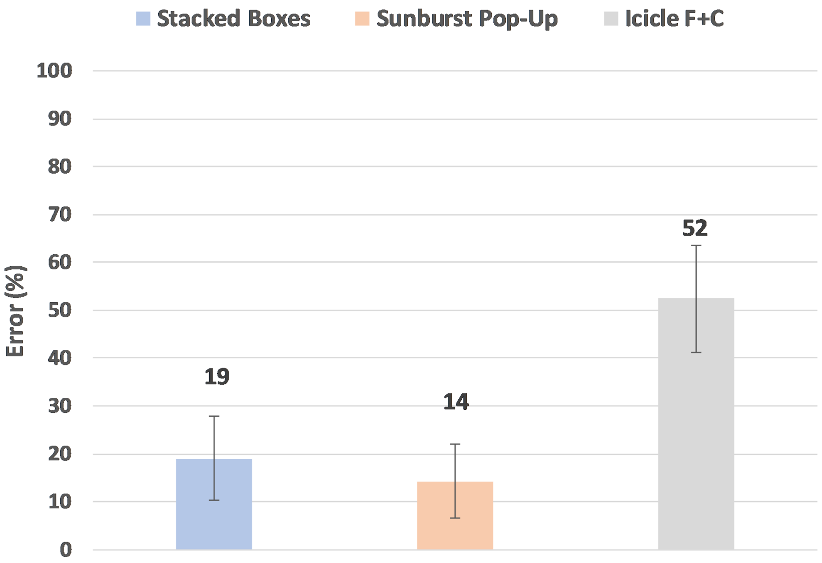
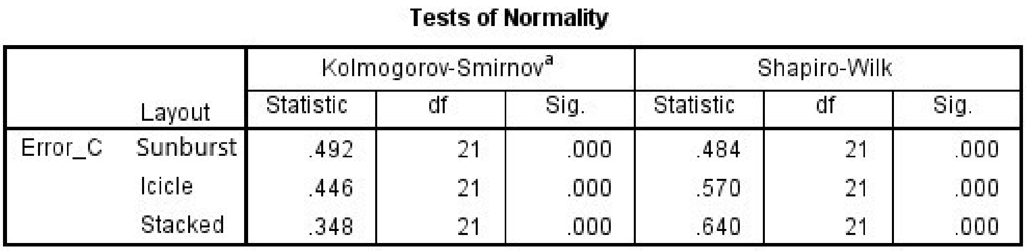


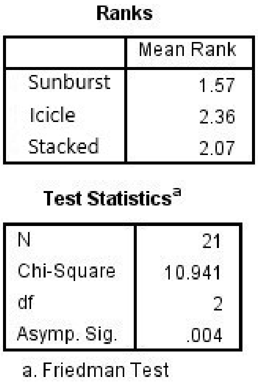
Figure 5.21 Average error for CSF by tool.



Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Layout	Statistic	df	Sig.	Statistic	df	Sig.
Error_C	Sunburst	.492	21	.000	.484	21	.000
	Icicle	.446	21	.000	.570	21	.000
	Stacked	.348	21	.000	.640	21	.000

Figure 5.22 The result of the error normality of the C task.



Ranks

	Mean Rank
Sunburst	1.57
Icicle	2.36
Stacked	2.07

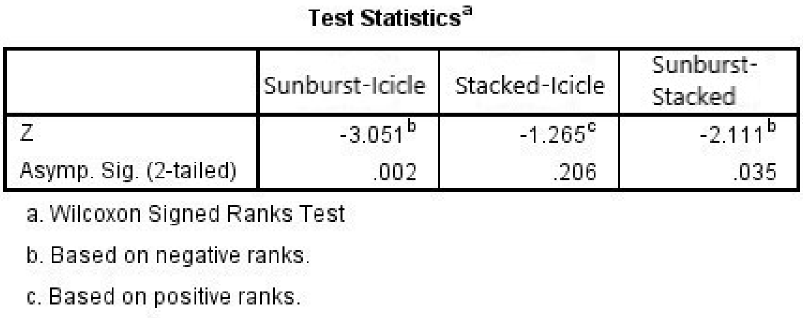
Test Statistics[a]

N	21
Chi-Square	10.941
df	2
Asymp. Sig.	.004

a. Friedman Test

Figure 5.23 The C result of the Friedman test.

For **search results**, were found not to follow a normal distribution (p < 0.05) in all tools, as shown in Figure 5.29. The samples were not paired.



Test Statistics[a]

	Sunburst-Icicle	Stacked-Icicle	Sunburst-Stacked
Z	-3.051[b]	-1.265[c]	-2.111[b]
Asymp. Sig. (2-tailed)	.002	.206	.035

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Figure 5.24 The result of the Wilcoxon test for C.

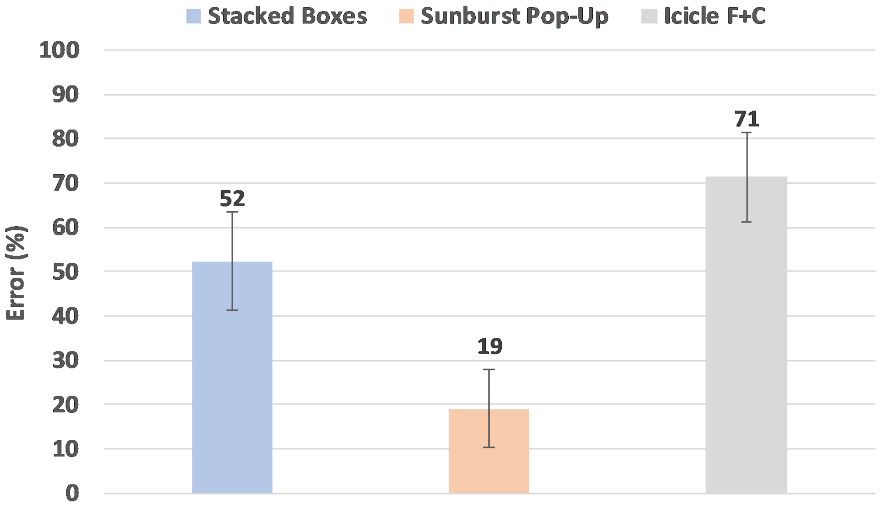
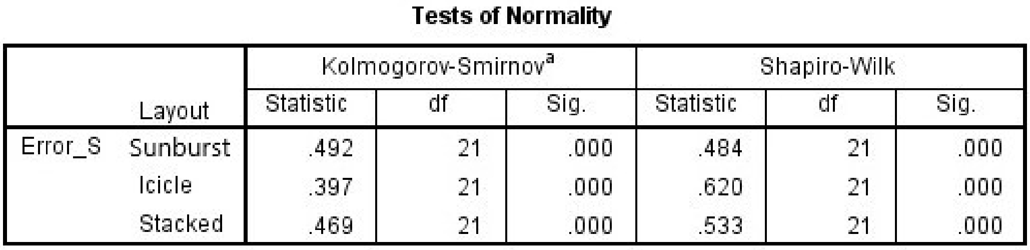


Figure 5.25 Average error for C by tool. Bars represent Stacked Boxes, Sunburst Pop-Up, and Icicle F+C.

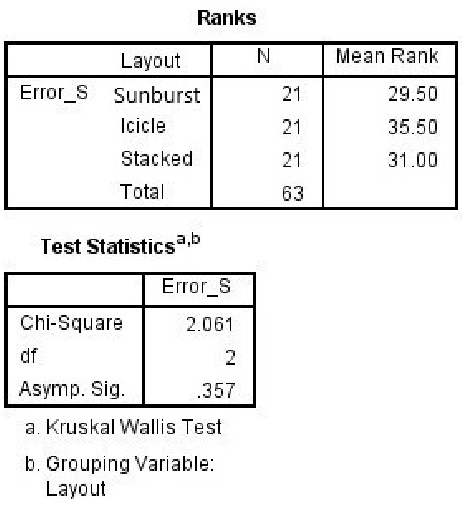


Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Layout	Statistic	df	Sig.	Statistic	df	Sig.
Error_S	Sunburst	.492	21	.000	.484	21	.000
	Icicle	.397	21	.000	.620	21	.000
	Stacked	.469	21	.000	.533	21	.000

Figure 5.26 The result of the error normality for S.

The Kruskal-Wallis test was applied to compare the three tools. The test showed that there was no difference between the three tools (p = 0.097 > 0.01), as depicted in Figure 5.30. Figure 5.31 clarified that the user found that *Sunburst Pop-Up* and *StackedBoxes* were the



Ranks

	Layout	N	Mean Rank
Error_S	Sunburst	21	29.50
	Icicle	21	35.50
	Stacked	21	31.00
	Total	63	

Test Statistics[a,b]

	Error_S
Chi-Square	2.061
df	2
Asymp. Sig.	.357

a. Kruskal Wallis Test

b. Grouping Variable: Layout

Figure 5.27 The result of the Kruskal Wallis test for S.

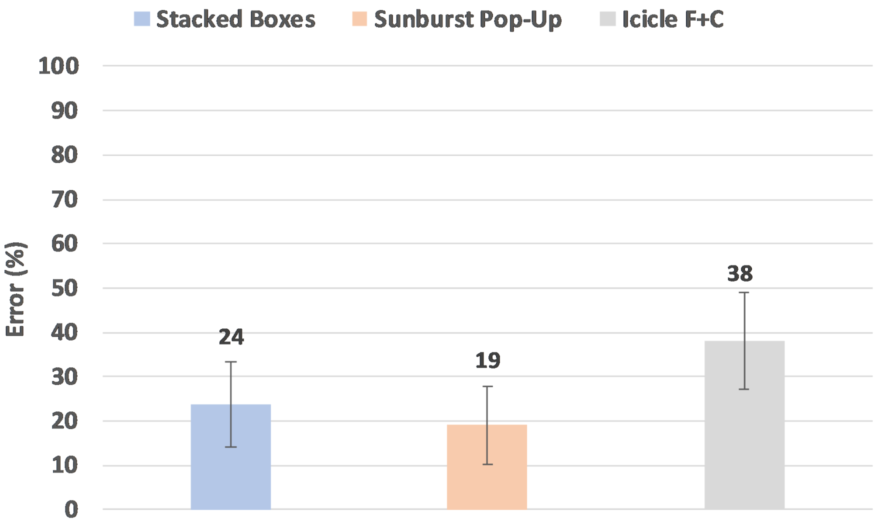
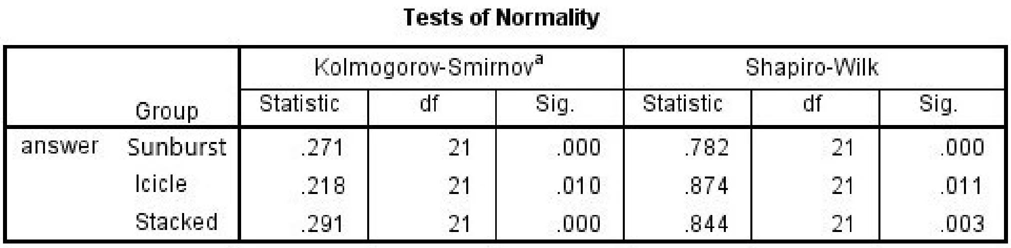


Figure 5.28 Average error for S by tool.

easiest compared with *Icicle F+C* in finding the search results, which scored the highest number in difficulty (33%).

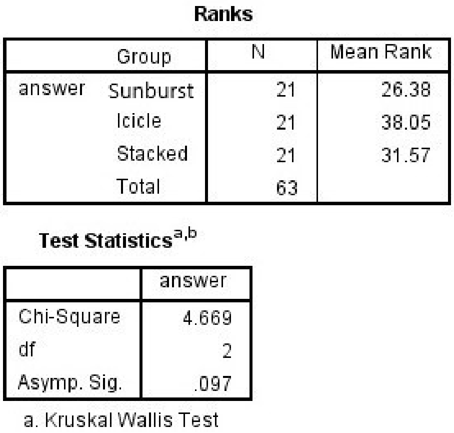
For **text reading**, it was found not to follow a normal distribution ($p < 0.05$), as shown in Figure 5.32 and the samples were paired. For this reason, Friedman's ANOVA was applied and it showed a significant difference between tools ($p < 0.01$), as illustrated in Figure 5.33. A Wilcoxon signed rank test for pairwise comparison showed that the F+C technique in *Icicle F+C* was the difficult technique with $p < 0.01$ between *Sunburst Pop-Up* and *Icicle F+C* and p



Tests of Normality

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
answer	Sunburst	.271	21	.000	.782	21	.000
	Icicle	.218	21	.010	.874	21	.011
	Stacked	.291	21	.000	.844	21	.003

Figure 5.29 The result of normality for search.



Ranks

	Group	N	Mean Rank
answer	Sunburst	21	26.38
	Icicle	21	38.05
	Stacked	21	31.57
	Total	63	

Test Statistics[a,b]

	answer
Chi-Square	4.669
df	2
Asymp. Sig.	.097

a. Kruskal Wallis Test

Figure 5.30 The result of Kruskal Wallis test for search.

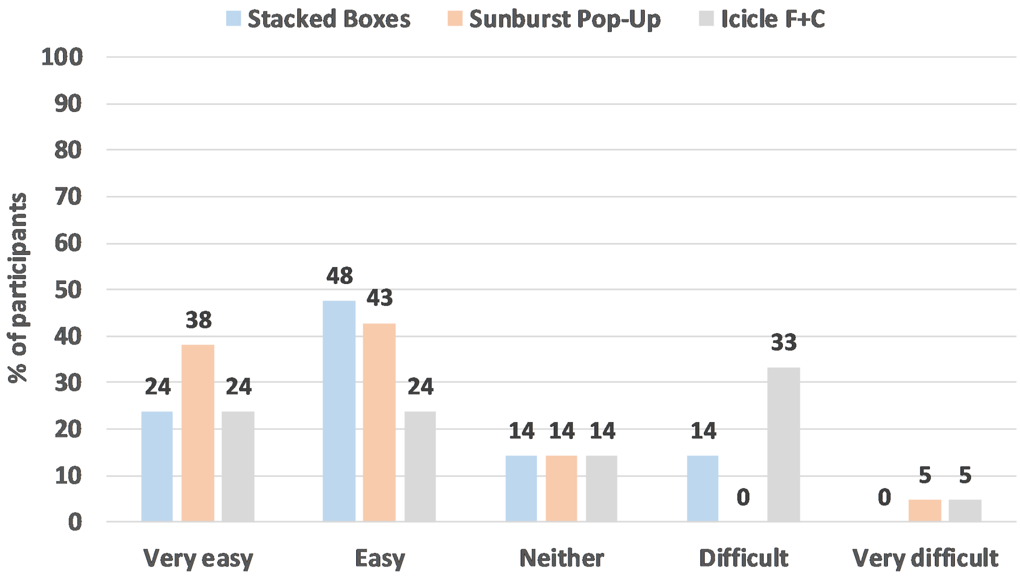
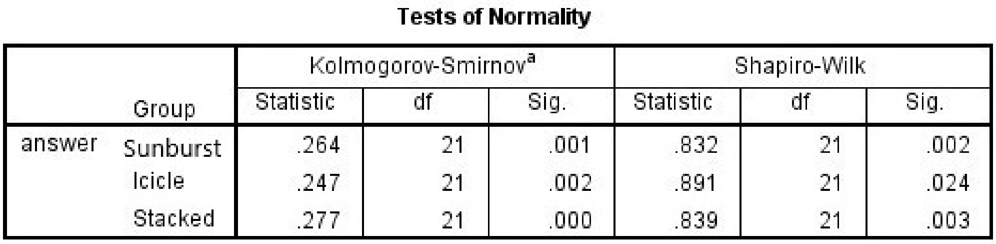


Figure 5.31 The percentage of search results by tool.

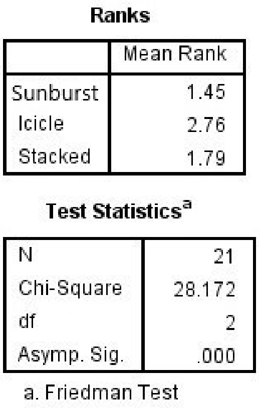
= 0.001 < 0.01 between *StackedBoxes* and *Icicle F+C*, as shown in Figure 5.34. Additionally, the results in Figure 5.35 clarified that the *Sunburst Pop-Up* (33%) and *StackedBoxes* (33%) were the easiest techniques compared with *Icicle F+C* (10%).



Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
answer	Sunburst	.264	21	.001	.832	21	.002
	Icicle	.247	21	.002	.891	21	.024
	Stacked	.277	21	.000	.839	21	.003

Figure 5.32 The result of normality for reading text.



Ranks

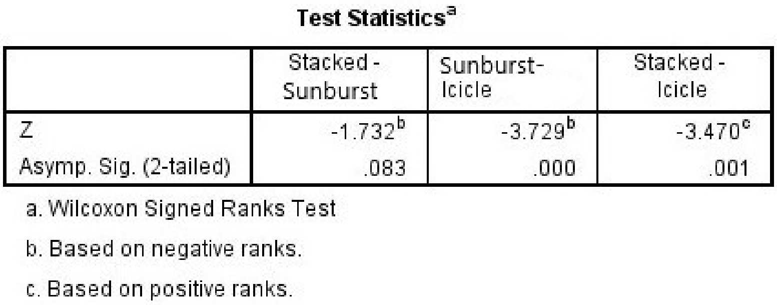
	Mean Rank
Sunburst	1.45
Icicle	2.76
Stacked	1.79

Test Statistics[a]

N	21
Chi-Square	28.172
df	2
Asymp. Sig.	.000

a. Friedman Test

Figure 5.33 The result of the Friedman test for reading text.



Test Statistics[a]

	Stacked - Sunburst	Sunburst-Icicle	Stacked - Icicle
Z	-1.732[b]	-3.729[b]	-3.470[c]
Asymp. Sig. (2-tailed)	.083	.000	.001

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Figure 5.34 The result of the Wilcoxon test for reading text.

For **using tool**, it was found not to follow a normal distribution ($p < 0.05$), as in Figure 5.36 and they were paired samples.

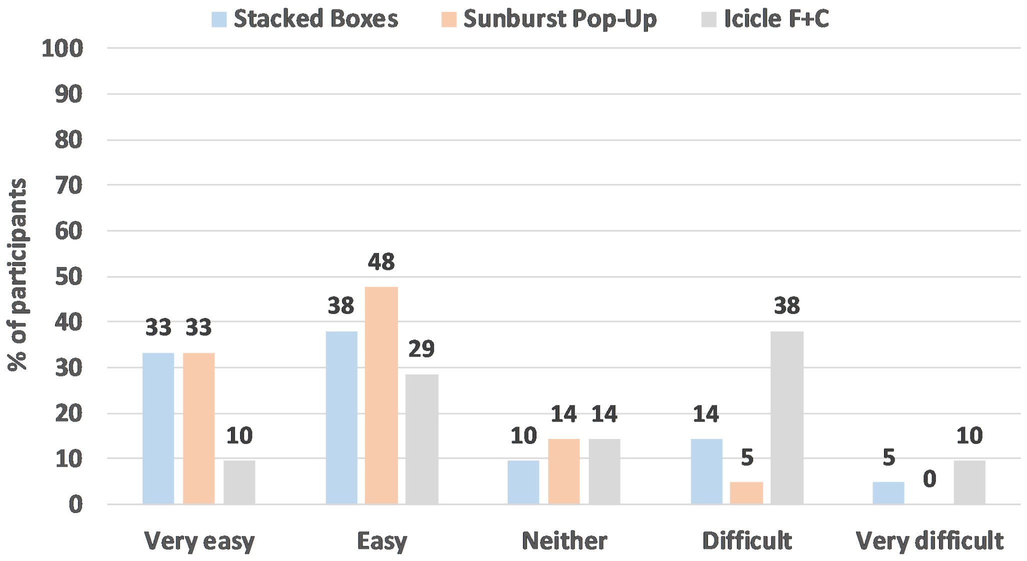
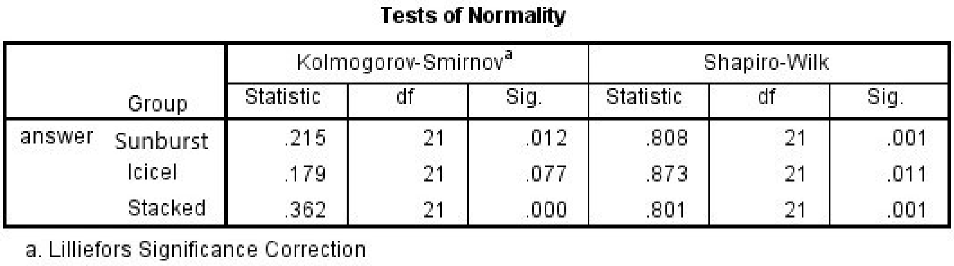


Figure 5.35 The percentage of reading text results by tool.

Friedman's ANOVA test was applied, and the result showed a significant difference ($p < 0.01$) between the tools (Figure 5.37). A Wilcoxon signed rank test for pairwise comparison showed that *Sunburst Pop-Up* is preferred over *Icicle F+C* and *StackedBoxes* (Figure 5.38). The results in Figure 5.39 clarified that the *Sunburst Pop-Up* (38% of participants found it very easy) and *StackedBoxes* (57% found it easy) were the most straightforward tools compared with *Icicle F+C* (29% found it difficult).



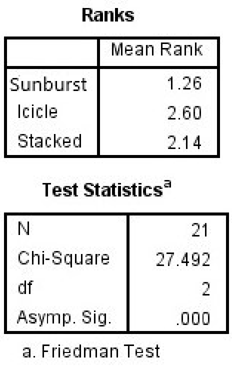
Tests of Normality

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
answer	Sunburst	.215	21	.012	.808	21	.001
	Icicel	.179	21	.077	.873	21	.011
	Stacked	.362	21	.000	.801	21	.001

a. Lilliefors Significance Correction

Figure 5.36 The result of normality for using tools

At the end of the study, the participants were asked to rank the tools from the most preferred to the least, as shown in Figure 5.40. The *Sunburst Pop-Up* was the most preferred



Ranks

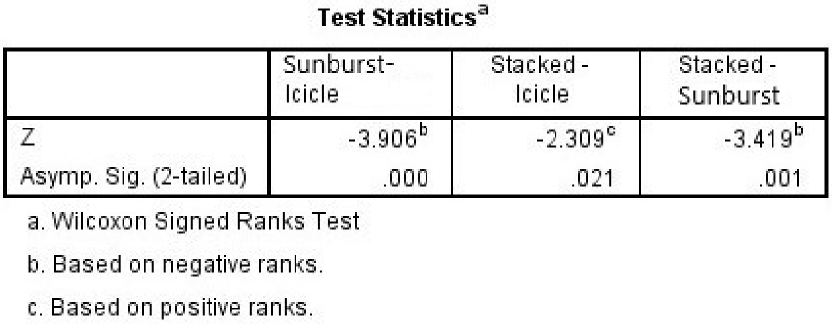
	Mean Rank
Sunburst	1.26
Icicle	2.60
Stacked	2.14

Test Statistics[a]

N	21
Chi-Square	27.492
df	2
Asymp. Sig.	.000

a. Friedman Test

Figure 5.37 The result of the Friedman test for usability.



Test Statistics[a]

	Sunburst-Icicle	Stacked - Icicle	Stacked - Sunburst
Z	-3.906[b]	-2.309[c]	-3.419[b]
Asymp. Sig. (2-tailed)	.000	.021	.001

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Figure 5.38 The result of the Wilcoxon test for usability.

tools (62%), while the *Icicle F+C* is scored as the third favourite tool (57%), illustrated in Figure 5.41.

Some comments provided by the participants about their favourite layouts are listed below:

P1: *"I like the Sunburst Pop-Up technique as it is straightforward, easy to use and understandable."*

P2: *"When I used the Sunburst Pop-Up, I felt comfortable to answer the questions as it is easy to spot the structure of the arguments. In StackedBoxes the clicking on any nodes on the sunburst and see how the arguments flow on another view is good, but this technique took some time for me to get used of it. For me, the Icicle F+C is not tidily presented and I feel it is a messy picture."*

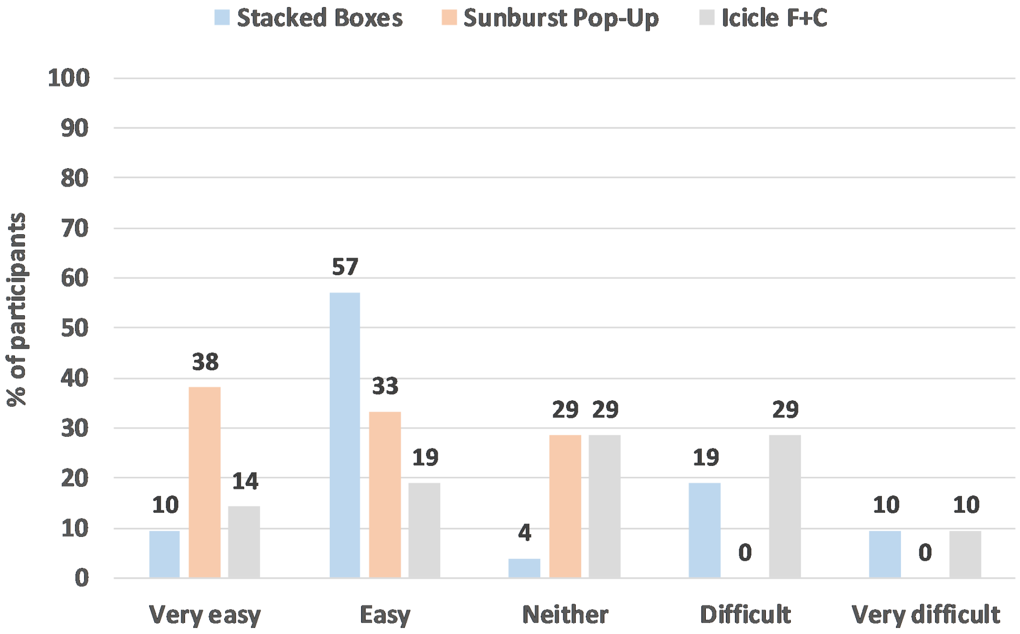
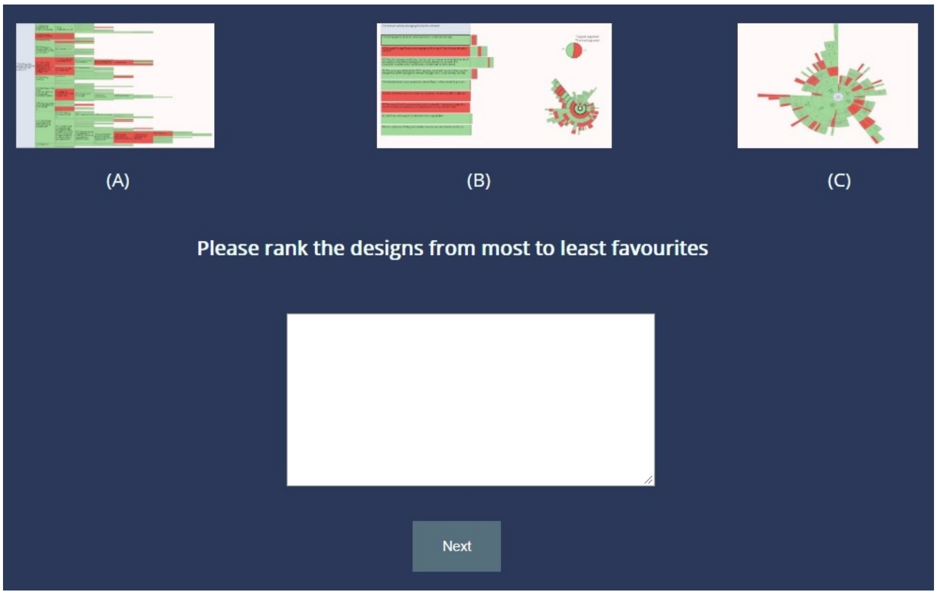


Figure 5.39 The percentage of usability results by tools.



Please rank the designs from most to least favourites

Figure 5.40 The study question about the preferred tools.

P3: *"Regarding the Icicle F+C, I did not like the presentation and feels that it is awful. Finding the results of the search is difficult. I liked the StackedBoxes; the navigation using the keyboard is a nice feature, especially using Alt+S to navigate through the search results. I did not use the sunburst in the coordinated view at all until I came*

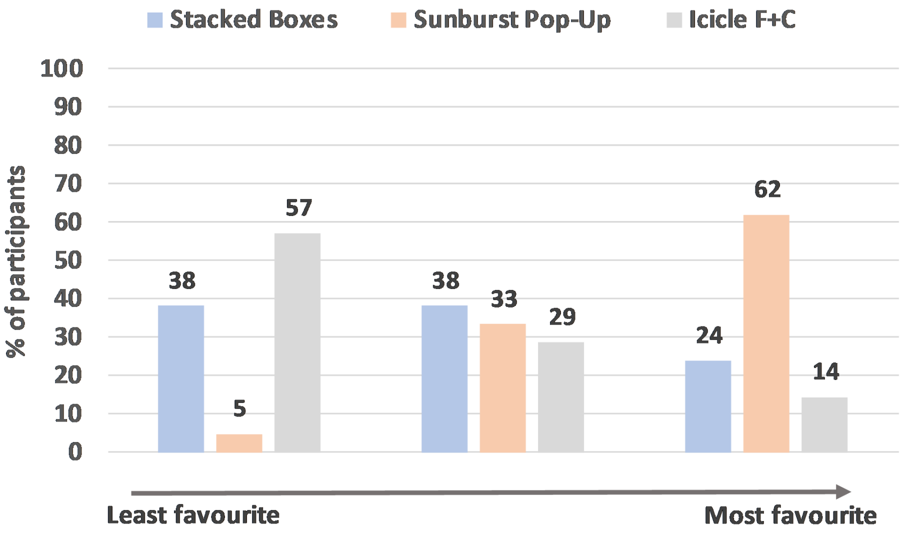


Figure 5.41 The order of preferred for each tool, ranked by the participants.

through the question that related to the structure. I loved Sunburst Pop-Up as it is very easy to navigate and read the text and it is my favourite."

P4: *"I liked the Icicle F+C as I can easily read the text. It is difficult to find the search result in this layout because the nodes are tiny when we go far away from the centre. StackedBoxes I liked the navigation through the keyboard and jumping immediately through the search results. However, I found this layout very difficult to read and navigate. Sunburst Pop-Up the structure is very clear. I struggled with the position of the list and the navigation in this one. I wish that the Alt+S is applied for all the techniques."*

P5: *"I hate the Icicle F+C. It is not familiar to the eyes. The size of the nodes is very different, and some nodes are tiny. The Sunburst Pop-Up is very easy; the structure is clear. Nothing complicated in it."*

These comments show that the participants found the sunburst layout to display the structure more easily than the icicle plot. In the following section, the evaluation results and the hypotheses are discussed in details.

5.2 Discussion

Our goal with this study was to identify the tool that performed better across our three tasks concerning time and error. Results suggested that there was no significant difference in time between the tools. However, the time that the participants spent to answer the questions in *Sunburst Pop-Up* was less than other tools. Also, *Sunburst Pop-Up* demonstrated better performance than *Icicle F+C* in the CS and C tasks. There is no difference between the three tools in the S task. However, the average error in the *Sunburst Pop-Up* (19%) is less than the other tools (*StackedBoxes* 24% and *Icicle F+C* 38%). A possible reason is that sunburst in *Sunburst Pop-Up* and *StackedBoxes* has an explicit structure. Also, the *stacked-labels* makes it easy to read the text.

Regarding the subjective rating, our results show that *Sunburst Pop-Up* is the easiest tool to navigate. Also, the participants found the *stacked-labels* straightforward for reading text with some comments about the position of the list. This is evident in Table 5.4 which reflects that the accuracy of the *Sunburst Pop-Up* is highest in all the tasks compared with the other two tools. Additionally, the accuracy of the *StackedBoxes* is higher than the *Icicle F+C*. The *StackedBoxes* includes many features, which requires more time for the participants to get used.

Therefore, referring to our hypotheses in section 5.1.1, H1 concerning the accuracy can be accepted that *Sunburst Pop-Up* performed better, and that the participants preferred it to *Icicle F+C*. The evaluation results showed the *stacked-labels* approach to be better than the F+C in *Icicle F+C*, so H2 was rejected. H3 can not be accepted or rejected as our results do not show evidence that *StackedBoxes* are more or less accurate than the other tools in the statistical test. However, the *StackedBoxes* is preferred over the *Icicle F+C* as shown in Table 5.4.

Table 5.4 The accuracy of the three tools in all the tasks.

	Stacked Boxes	Sunburst Pop-Up	Icicle F+C
CSN	86%	95%	57%
CSF	81%	85%	48%
C	48%	81%	29%
S	76%	81%	62%

To conclude, *Sunburst Pop-Up* performed better than other tools and was preferred by the participants. Some suggestions were made to improve the position of the *stacked-labels*. In 4.2.1.3, another three options for the position of the *stacked-labels* were proposed, implemented, and discussed with the experts during the interviews.

5.3 Expert Feedback

Expert's (analysts) reviews are a valuable and quick way to evaluate visualisation tools. However, the experts are not always available, and their precious time makes it difficult to get a large number of them involved in the evaluation.

Four experts were interviewed to evaluate the three tools from the argumentation perspective. The experts work on different argument domains including argument visualisation, argument mining, and sustainable travel behaviours. Three of the experts were involved in our user requirements collection interviews. Each one-to-one interview lasted between 60 and 90 minutes. In the evaluation session, the previous three tools were explained. The experts tried the three tools and conversed about the proposed new three positions of the *stacked-labels*. The advantages and disadvantages of each one were discussed.

The interviews with the first two experts showed that they were in favour of the *Stacked-Boxes* tool. The *stacked-boxes* offers a fixed framework to read the text and navigate through the nodes. The feedback from the experts are listed below:

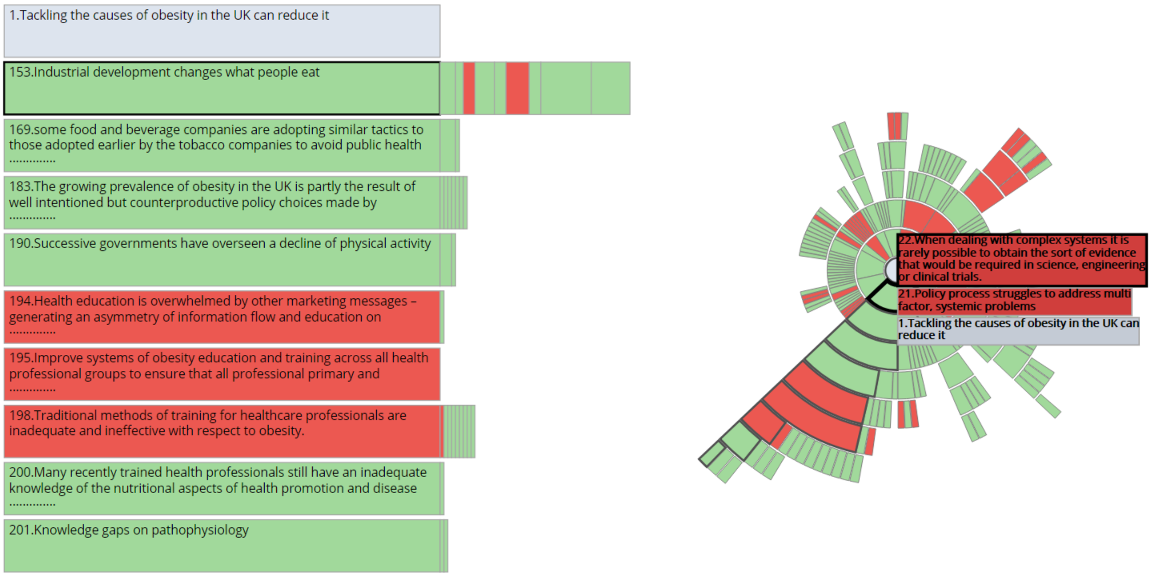
(E1): *"The StackedBoxes is my favourite. I love the radial visualisation (sunburst) which show me the arguments' structure, the relationships between them. The way of presenting the text is incredibly readable. Something I like in Sunburst Pop-Up and miss in the StackedBoxes is the navigation through the nodes in radial which help me read the text fast without losing the structure. I am now working on the project to create datasets using one tool to present the argument. This tool uses a node-link layout. I cannot create an argument visualisation more than 30 or a maximum of 50 nodes. If we have visualisation like the one you presented to me now, it will be scalable and acceptable more for the end users."*

(E2): *"I do not like the Icicle F+C; it has some good features like showing the thread of the arguments. However, at the same time, the nodes become very small when you go* *far away from the centre. It does not give the sense of overview which does not help me to engage in answering the questions. I really like the radial one (sunburst), and it is easy to see the structure of arguments. I like that the feature give the number of nodes, and it is useful to know how many nodes in total. I like the way you present the search nodes, and you did not change the colour only make the nodes darker which I still know that the node is supporting or opposing. The Sunburst Pop-Up is very attractive, but to read the text I should go over the nodes, it is a useful feature for quick navigation, but I prefer the boxes one."*

Due to the strong agreement, following these interviews, the combination between the *StackedBoxes* and *Sunburst Pop-Up* tools were proposed before proceeding (Figure 5.42). The combination aims to display one argument chain in the *stacked-boxes* and allow users to navigate through the sunburst layout to explore and read more arguments using the *stacked-labels*. This combination is especially helpful if the user wants to compare two arguments. In this case, the text of one argument can be displayed in the *stacked-boxes*, and users can go through the sunburst layout and read the text of the other argument using the *stacked-labels*. The combination satisfies user requirement R8. After implementing the combined prototype, our interviews were continued with the other two experts. During these interviews, the four tools were presented. The experts agreed with the previous two that the *StackedBoxes* tool is helpful to read and navigate through the text. They have also acknowledged the benefits of the combined prototype especially in terms of the offered navigation features and suggested highlighting the *stacked-labels* chain in the sunburst to improve the navigation. Some feedback from the experts is transcribed below:

(E3): *"I like the radial presentation in general. It gives the overall of a graph. It is more compact than the node-link representation. I think the node-link addressed the big problem, as it became complex and hard to get the overview when the nodes over 50. I do not like that the list of labels covers the structure of the radial. I also like Icicle F+C, the text in it is more readable. The disadvantage of this presentation from my opinion is that I feel that the first level of nodes is more important than the one in the bottom. This presentation may be misleading to the user. I prefer the combination between StackedBoxes and Sunburst Pop-Up which give more option for reading the text and navigation."*

(E4): *"Form my respect for the one who spent a lot of time trying to present the structure of the arguments, the combination between the Sunburst Pop-Up and StackedBoxes is useful for me than the other individually. The combination makes a lot of sense for the people who are working in argumentation. It gives us the benefit of seeing the overview structure merged with the benefit of reading and navigate the text, faster through the stacked-labels or by a fixed view. The icicle view works nicely, but the radial is easier and intuitive to understand the structure than an icicle. Also, the radial is easy to engage and easy to see the depth and density of the arguments. Although, some advantage of the icicle is the size of the node that can hold the text."*



1.Tackling the causes of obesity in the UK can reduce it

153.Industrial development changes what people eat

169.some food and beverage companies are adopting similar tactics to those adopted earlier by the tobacco companies to avoid public health ....

183.The growing prevalence of obesity in the UK is partly the result of well intentioned but counterproductive policy choices made by ....

190.Successive governments have overseen a decline of physical activity

194.Health education is overwhelmed by other marketing messages – generating an asymmetry of information flow and education on ....

195.Improve systems of obesity education and training across all health professional groups to ensure that all professional primary and ....

198.Traditional methods of training for healthcare professionals are inadequate and ineffective with respect to obesity.

200.Many recently trained health professionals still have an inadequate knowledge of the nutritional aspects of health promotion and disease ....

201.Knowledge gaps on pathophysiology

22.When dealing with complex systems it is rarely possible to obtain the sort of evidence that would be required in science, engineering or clinical trials.

21.Policy process struggles to address multi factor, systemic problems

1.Tackling the causes of obesity in the UK can reduce it

Figure 5.42 The combination prototype between sunburst with pop-up labels and stacked boxes with radial layout.

The positions of the *stacked-labels* was discussed with the experts. The result showed that the **Stacked-Label-2** is preferred as it is near the focused node and shows the same order of the arguments in the graph.

5.4 Summary

In this Chapter, the three tools were evaluated in two stages. The first one was a user study with twenty-one participants and the second was with four argumentation experts. Both expert and non-expert users agreed that the sunburst layout presents the overview of the arguments data and the argument structure better than the icicle plot. Also, three participants mentioned that they could not understand the structure at all in the icicle. However, the text in the first tiers of the icicle layout can be easily read due to the large size of the nodes in these tiers.

With respect to reading the text, non-expert users found the *stacked-labels* fast and easy to use. Also, they feel that they needed more time to get used to the *StackedBoxes*. On the other hand, using the keyboard in navigating the *stacked-boxes* was complimented as a useful feature. The same positive comments were received for having a keyboard shortcut to jump between the search results. From the experts' perspective, they need to read the text carefully and understand it to analyse the structure of the argument, which they can do using the *StackedBoxes*. Meanwhile, the separate radial layout is good to show the overall structure of the arguments.

In the next Chapter, the contributions of this research are summarised. Then, limitations and future work are discussed.

Chapter 6

Conclusion and Future Work

This research aims to provide argument experts with techniques and tools to help understand arguments by providing the balance between an overview of data and the details of the argument when the argument dataset exceeds a hundred nodes. The main challenge facing the development of argument tools is that argument data is textual and thus, needs considerable space to present and explore. Also, having an overview of the structure and the ability to examine the details are essential to understand arguments. To achieve this, the research questions that motivated this research were laid out in Chapter 1:

- "[Q1] Which visualisation techniques should be deployed to provide an overview of argument structure?"
- "[Q2] How can visualisation techniques help to provide legible text for reading argument contents while still providing an overview of structure?"

To answer these questions, the literature and research surrounding argumentation and ArgVis tools were reviewed. Also, interviews with seven argument experts were conducted to investigate and collect the requirements of ArgVis tools and techniques. The collected requirements can be summarised as follows:

(R1) Present arguments all at once to discover how they connect with each other. Also, explore the relations between argument elements

(R2) Be able to read the argument content

(R3) Allow argument experts to keep track of where they are relative to the overall argument structure

(R4) The ability to zoom in and out to navigate the graph

(R5) Collapse unneeded arguments

(R6) Provide a summary of the argument relations types

(R7) Enable users to compare arguments

The following summarises the contributions to knowledge this work has made in relation to the research questions. After that, the limitations and future work are discussed.

6.1 Contributions:

To answer the research questions and achieve the balance between overview and read argument contents, a hybrid tool called *AVT* that combines *StackedBoxes* and *Sunburst Pop-Up* was developed. This hybrid tool displays one argument chain in the *stacked-boxes* and allow users to navigate through the sunburst layout to explore and read more arguments using the *stacked-labels*. In pursuit of developing this tool that satisfies the user requirements, the following techniques and tools were developed.

- **The first technique** is *stacked-boxes*. This novel technique passed five design development cycles until the final version was achieved. This technique presents the focused node, parents (upper levels), the first child in each level under the focused node and the siblings for all the levels as a navigable strip of siblings. It helps users to read textual datasets, e.g. list of emails and conversation. The navigation through this technique is fast and easy by using the keyboard or mouse-clicking; users can read and move quickly between levels, or through sibling nodes.

- **The second technique** is *stacked-labels* integrated with a sunburst layout. This novel technique is a list of labels, i.e. boxes, stacked on top of each other from the root to the hovered node. The width and height of each box has the dimensions of the wrapped text.

Four options for the location of the *stacked-labels* were proposed (**Stacked-Label-1**, **Stacked-Label-2**, **Stacked-Label-3**, **Stacked-Label-4**). After implementing these four options, it was found that **Stacked-Label-2** and **Stacked-Label-3** could go outside the window border. Also, in **Stacked-Label-1**, the location of the *stacked-labels* is presented far from the hovered node, especially when the node is far from the centre of the sunburst. Therefore, **Stacked-Label-4** was chosen as the *stacked-labels* list is always located inside the window.

This technique is inspired by excentric labelling. The labels in *stacked-labels* are related to each other with hierarchy relationship. Users can read the text from the parent until the hovered node, which offers a fast navigation of the text/labels.

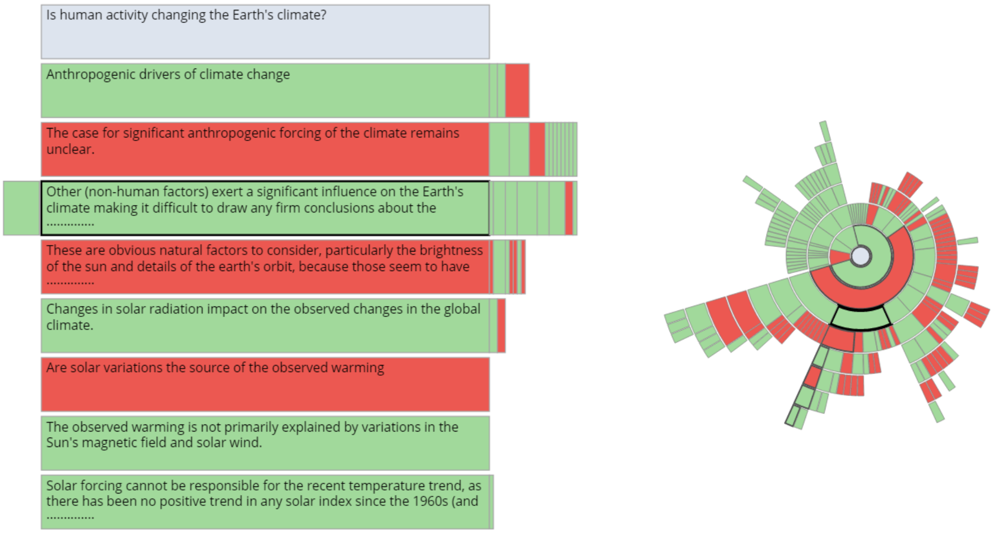
- **The third technique** is the F+C which enlarged all the parents of the focused node, as well as all the focused node's children. The whole chain of the focused node is enlarged, which help users to easily navigate through the text.

To help experts explore how the arguments connect to each other, by displaying the data overview while maintaining the ability to read the argument contents, three tools were designed as detailed below.

- **The first tool** is *StackedBoxes* which relies on the coordinated view between a sunburst to provide the structure and novel *stacked-boxes* for reading and navigation of text, as shown in Figure 6.1. The sunburst view is rotated to show the argument in the same direction as in the stacked boxes.

- **The second tool** is *Sunburst Pop-Up* which overlays text on demand on a sunburst visualisation. The sunburst was the main layout in this technique while *stacked-labels* was used for reading the text in an integrated view (Figure 6.2).

- **The third tool** is *Icicle F+C* which an adaptation of an icicle plot to visualise the structure while using F+C to enlarge the argument. F+C works when the users click on any node of the icicle plot. The root node is located at the left-hand side, while child nodes stretch towards the right. This orientation of the icicle presents the text horizontally and was chosen as it gives more space for the text (Figure 6.3).



Is human activity changing the Earth's climate?

Anthropogenic drivers of climate change

The case for significant anthropogenic forcing of the climate remains unclear.

Other (non-human factors) exert a significant influence on the Earth's climate making it difficult to draw any firm conclusions about the ....

These are obvious natural factors to consider, particularly the brightness of the sun and details of the earth's orbit, because those seem to have ....

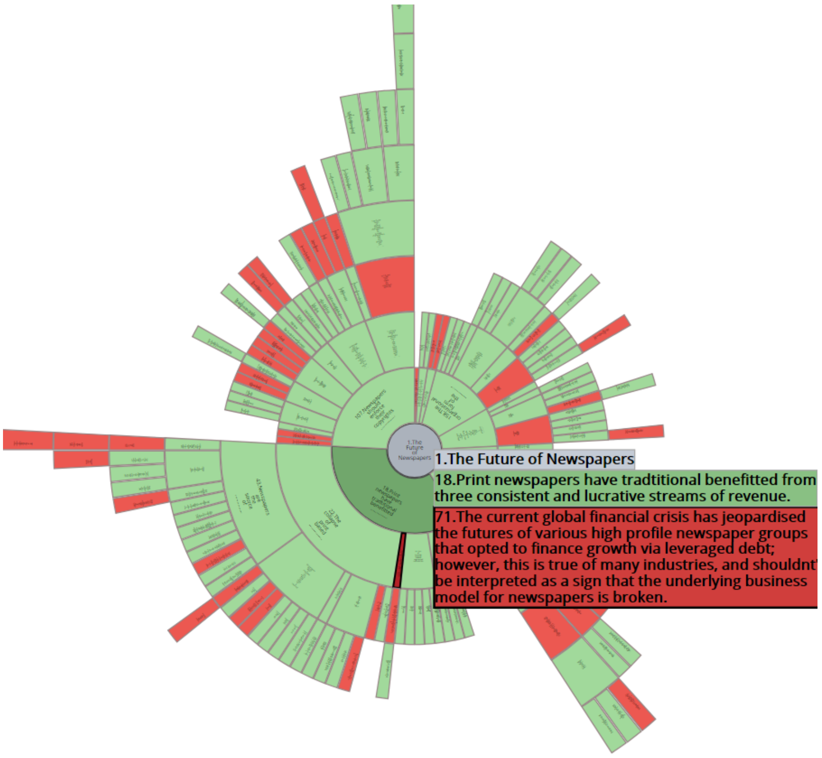
Changes in solar radiation impact on the observed changes in the global climate.

Are solar variations the source of the observed warming

The observed warming is not primarily explained by variations in the Sun's magnetic field and solar wind.

Solar forcing cannot be responsible for the recent temperature trend, as there has been no positive trend in any solar index since the 1960s (and ....

Figure 6.1 The *StackedBoxes*, a coordinated view between the *stacked-boxes* on the left for reading the text and sunburst on the right for showing the argument structure.



1.The Future of Newspapers

18.Print newspapers have tradtitional benefitted from three consistent and lucrative streams of revenue.

71.The current global financial crisis has jeopardised the futures of various high profile newspaper groups that opted to finance growth via leveraged debt; however, this is true of many industries, and shouldnt' be interpreted as a sign that the underlying business model for newspapers is broken.

Figure 6.2 The *Sunburst Pop-Up*, the sunburst is the main layout that shows the structure and *stacked-labels* help reading the text.

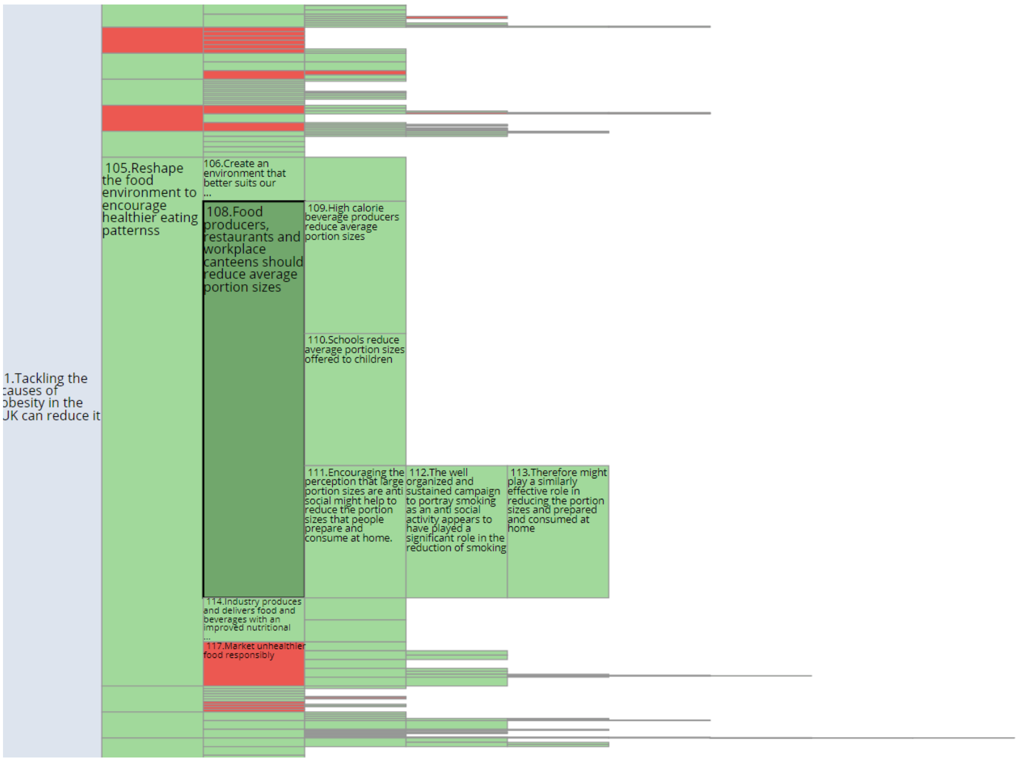

1.Tackling the causes of obesity in the UK can reduce it
105.Reshape the food environment to encourage healthier eating patternss
106.Create an environment that better suits our ...
108.Food producers, restaurants and workplace canteens should reduce average portion sizes
109.High calorie beverage producers reduce average portion sizes
110.Schools reduce average portion sizes offered to children
111.Encouraging the perception that large portion sizes are anti social might help to reduce the portion sizes that people prepare and consume at home.
112.The well organized and sustained campaign to portray smoking as an anti social activity appears to have played a significant role in the reduction of smoking
113.Therefore might play a similarly effective role in reducing the portion sizes and prepared and consumed at home
114.Industry produces and delivers food and beverages with an improved nutritional ...
117.Market unhealthier food responsibly

Figure 6.3 The *Icicle F+C*, the icicle plot visualises the argument overview and F+C helps reading the text.

After applying the three tools (*StackedBoxes*, *Sunburst Pop-Up*, *Icicle F+C*), they were evaluated in two stages. The first stage was a control user study to compare and evaluate the tools. The second stage was an expert review.

Control user study: the controlled experiment aimed to explore how efficiently the participants use the three tools and compare between them. There were three tasks to test: exploring the overview, reading the text, and checking the logic flow of the argument. The hypotheses for this study were:

H1: A sunburst layout performs better (time and error) than an icicle plot, as the sunburst is one of the top performing visualisation layouts.

H2: F+C technique is better than *stacked-labels* list as the positing of the list of the *stacked-labels* is not fixed and only display when the user hover.

H3: The *StackedBoxes* performs better than the other tools (*Sunburst Pop-Up*, *Icicle F+C*) as users can read the text carefully and navigate through the sibling nodes, whereas, they can still show the overall structure of the arguments.

Results showed that there was no significant difference in time between the tools. However, the time that the participants spent answering the questions in *Sunburst Pop-Up* was less than the other tools. Also, *Sunburst Pop-Up* has better performance than *Icicle F+C* in two tasks. There was no difference between the three tools in the third task.

Regarding the subjective rating, results showed that *Sunburst Pop-Up* list was the most straightforward tool to navigate and that the participants found the *stacked-labels* list was simple for reading text, with some comments about the position of the list. The accuracy of the *Sunburst Pop-Up* tool was the highest in all the tasks compared with the other two tools. Also, the accuracy of the *StackedBoxes* tool was higher than the *Icicle F+C*. To conclude, *Sunburst Pop-Up* performed better than the other tools and was preferred by the participants.

Regarding our hypotheses, H1 is accepted as the evaluation results showed that the sunburst performed better than icicle plot. Also, H2 was rejected as *stacked-labels* were shown to be better than the F+C technique. Our evaluation results did not show any evidence that *StackedBoxes* was better than the other tools, so H3 can not be accepted or rejected.

Expert feedback: four experts were interviewed to evaluate the three tools from the argumentation perspective. Interviews with the first two experts showed that they were in favour of the *StackedBoxes* tool as it helped to read the text and navigate through the arguments. After these two interviews, a hybrid tool (main contribution) was developed, in agreement with the experts, to harness the benefit of having *StackedBoxes* and *Sunburst Pop-Up* in one tool. Then, the other two interviews were conducted with all four tools being presented. The experts found *StackedBoxes* useful for reading and navigating through the text. Also, they acknowledged the benefits of the hybrid tool.

The participants of the control user study found that the *Sunburst Pop-Up* was fast and easy for reading the text. Additionally, they claimed more time was needed to get used to the *StackedBoxes*. From the experts' perspective, *StackedBoxes* and *AVT* were better than the other tools for reading the text carefully and understanding it.

6.2 Limitations

In this thesis, four tools were proposed to help experts to visualise, explore, and understand arguments. The outcomes are promising but there is still room for improvement that can be the target of future work.

First, three real datasets from DebateGraph were used to compare and evaluate the proposed tools. The size of the datasets was around 200 nodes. In future, the tools will be deployed on larger datasets to check if the size of the data can affect the obtained results. Second, it will be potentially more effective if the experts test the tools using their own datasets and tasks to provide feedback about their experience. Third, the evaluation with experts was crucial for this study. However, the sample size of the experts/analysts was relatively small due to the difficulty in finding a good number with the limited time available for this research. Increasing the number of participants can potentially increase the reliability of the study outcomes.

6.3 Future Work

This research has made considerable progress in answering questions about helping argumentation experts to understand and explore arguments. However, there are still many new challenges, ideas, and problems to cover as future work. In the following, some future research directions are outlined.

More text analysis techniques can be applied to help experts when reading and understanding the text. For example, further develop the tool to produce a summary of displayed arguments and highlight the main topics in given datasets. Furthermore, allowing users to add or delete arguments or restructure the arguments datasets from their perspective will help them in analysing arguments (one of the argument experts requirement, R11). Involving information about the participants (R8, R9), who engage in discussion/debate and the relations between them can shed the light on the nature of the deliberation [170].

The proposed techniques in this thesis have mainly focused on tree argument datasets. To be inclusive of all argument dataset types, the research can be extended to solve the same highlighted space problem but for complex network arguments datasets.

The designed tools can be applied in various domains where the space is problematic to present the text, e.g. reading maps. The *stacked-labels* list is a fast technique; it can be used in navigating and reading labels in compacted graphs without causing an overlap. By using this technique,

The *stacked-boxes* can be applied in mobile devices, tablets, or any devices with a limited screen size as this layout compacts space for text display and provides features for quick navigation through the text, i.e. navigating news and emails. In addition, incorporating the touch screen feature in our tools will provide faster and easier navigation between sibling nodes compared to using a keyboard. Moreover, *Icicle F+C* tool can also be used in mobile devices to provide the data overview and allow users to explore and read the text.

Furthermore, the red and green colours, which were used to reflect the oppose and support relations, are problematic for people who suffer from CVD. The colour has been changed for a colour blind palette on the final version of our tools. However, the effectiveness of this approach with arguments are yet to be tested. Therefore, a colour study needs to be conducted to explore alternative colour schemes that can better reflect the support and oppose relationships between the arguments while considering colour blindness.

Bibliography

[1] T. Govier, *A Practical Study of Argument*. Cengage Learning, 2013.

[2] T. Van Gelder, “Argument mapping with reason! able,” *The American Philosophical Association Newsletter on Philosophy and Computers*, vol. 2, no. 1, pp. 85–90, 2002.

[3] V. Bullen, D. Price, and V. Bullen, “Debategraph: A new way to address the complexity of obesity,” *British Journal of Obesity*, vol. 1, pp. 54–59, 2015.

[4] P. Baldwin and D. Price, “Debategraph,” 2008. https://debategraph.org/.

[5] G. Betz and S. Cacean, *Ethical aspects of climate engineering*. KIT Scientific Publishing, 2012.

[6] N. Benn and A. Macintosh, “Policy commons–visualizing arguments in policy consultation,” in *Int. Conf. on Electronic Participation*, pp. 61–72, Springer, 2012.

[7] C. S. Carr, “Using computer supported argument visualization to teach legal argumentation,” in *Visualizing Argumentation*, pp. 75–96, Springer, 2003.

[8] C. Reed, “Is it a monologue, a dialogue or a turn in a dialogue,” in *Proceedings of the 4th International Conference on Argumentation (ISSA98)*, Citeseer, 1998.

[9] A. Rocci, “Connective predicates in monologic and dialogic argumentation,” *Studies in Communication Sciences, Special Issue Argumentation in Dialogic Interaction*, pp. 97–118, 2005.

[10] D. J. O’Keefe, “Two concepts of argument,” *The Journal of the American Forensic Association*, vol. 13, no. 3, pp. 121–128, 1977.

[11] C. Reed and D. Long, “Persuasive monologue,” in *Proceedings of the OSSA Conference on Argument and Rhetoric*, Citeseer, 1997.

[12] J. Andriessen, “Arguing to Learn.,” in *The Cambridge handbook of: The learning sciences.*, pp. 443–459, Cambridge University Press, 2006.

[13] J. C. Roberts, C. J. Headleand, and P. D. Ritsos, *Five Design-Sheets: Creative Design and Sketching for Computing and Visualisation*. Springer, 2017.

[14] F. Bex, S. Van den Braak, H. Van Oostendorp, H. Prakken, B. Verheij, and G. Vreeswijk, “Sense-making software for crime investigation: how to combine stories and arguments?,” *Law, Probability & Risk*, vol. 6, no. 1-4, pp. 145–168, 2007.

[15] J. Schneider, T. Groza, and A. Passant, "A review of argumentation for the social semantic web," *Semant. web*, vol. 4, pp. 159–218, Apr. 2013.

[16] S. Buckingham Shum, A. MacLean, V. M. Bellotti, and N. V. Hammond, "Graphical argumentation and design cognition," *Human–Computer Interaction*, vol. 12, no. 3, pp. 267–300, 1997.

[17] I. Rahwan, "Mass argumentation and the semantic web," *Web Semantics: Science, Services and Agents on the World Wide Web*, vol. 6, no. 1, pp. 29–37, 2008.

[18] C. Reed and G. Rowe, "A pluralist approach to argument diagramming," *Law, Probability & Risk*, vol. 6, no. 1-4, pp. 59–85, 2007.

[19] J. Goodwin, "Wigmore's chart method," *Informal Logic*, vol. 20, no. 3, 2000.

[20] M. Chalamish, D. Gabbay, and U. Schild, "Intelligent evaluation of evidence using wigmore diagrams," in *Proceedings of the 13th International Conference on Artificial Intelligence and Law*, ICAIL '11, (New York, NY, USA), pp. 61–65, ACM, 2011.

[21] G. Rowe and C. Reed, "Translating wigmore diagrams," *Frontiers in Artificial Intelligence and Applications*, vol. 144, pp. 171–183, 2006.

[22] V. Leucari, "Analysis of complex patterns of evidence in legal cases: Wigmore charts vs. bayesian networks," *Artificial Intelligence and Law*, vol. 4, pp. 173–182, 2012.

[23] S. E. Toulmin, *The Uses of Argument.* Cambridge University Press, 2 ed., 2003.

[24] F. H. Van Eemeren, R. Grootendorst, and T. Kruiger, "Handbook of argumentation theory: A critical survey of classical backgrounds and modern studies," vol. 7, 2019.

[25] W. Kunz and H. W. Rittel, "Issues as elements of information systems," tech. rep., Institute of Urban and Regional Development, Univ. of California, 1970.

[26] J. Conklin and M. L. Begeman, "gibis: A tool for all reasons," *Journal of the American Society for Information Science*, vol. 40, no. 3, pp. 200–213, 1989.

[27] K. Awati, "Mapping project dialogues using ibis: a case study and some reflections," *International Journal of Managing Projects in Business*, vol. 4, no. 3, pp. 498–511, 2011.

[28] S. Willmott, G. Vreeswijk, C. Chesnevar, M. South, J. McGinnis, S. Modgil, I. Rahwan, C. Reed, and G. Simari, "Towards an argument interchange format for multiagent systems," in *3rd international workshop on argumentation in multi-agent systems, ArgMAS-06*, pp. 17–34, 2006.

[29] C. Chesñevar, J. McGinnis, S. Modgil, I. Rahwan, C. Reed, G. Simari, M. South, G. Vreeswijk, and S. Willmott, "Towards an argument interchange format," *Knowl. Eng. Rev.*, vol. 21, pp. 293–316, Dec. 2006.

[30] C. Reed, S. Wells, J. Devereux, and G. Rowe, "Aif+: Dialogue in the argument interchange format.," *Frontiers in Artificial Intelligence and Applications*, vol. 172, pp. 311–323, 2008.

[31] C. Reed and G. Rowe, “Toulmin diagrams in theory & practice: Theory neutrality in argument representation,” *Argumentation*, vol. 19, pp. 267–286, 2005.

[32] N. Oren, M. Luck, and C. Reed, “Moving between argumentation frameworks,” in *Proceedings of the 2010 International Conference on Computational Models of Argument*, IOS Press, 2010.

[33] F. Bex, T. F. Gordon, J. Lawrence, and C. Reed, “Interchanging arguments between carneades and aif.,” in *COMMA*, pp. 390–397, 2012.

[34] G. Rowe, F. Macagno, C. Reed, and D. Walton, “Araucaria as a tool for diagramming arguments in teaching and studying philosophy,” *Teaching Philosophy*, vol. 29, no. 2, pp. 111–124, 2006.

[35] T. Van Gelder, “The rationale for rationale™,” *Law, probability and risk*, vol. 6, no. 1-4, pp. 23–42, 2007.

[36] J. Lawrence, M. Snaith, B. Konat, K. Budzynska, and C. Reed, “Debating technology for dialogical argument: Sensemaking, engagement, and analytics,” *ACM Transactions on Internet Technology (TOIT)*, vol. 17, no. 3, pp. 1–23, 2017.

[37] M. Davies, A. Barnett, and T. van Gelder, “Using computer-aided argument mapping to teach reasoning,” *Windsor Studies in Argumentation*, 2019.

[38] T. van Gelder, “Enhancing deliberation through computer supported argument visualization,” in *Visualizing Argumentation* (P. A. Kirschner, S. J. B. Shum, and C. S. Carr, eds.), pp. 97–115, Berlin, Heidelberg: Springer-Verlag, 2003.

[39] C. P. Dwyer, M. J. Hogan, and I. Stewart, “The evaluation of argument mapping as a learning tool: Comparing the effects of map reading versus text reading on comprehension and recall of arguments,” *Thinking Skills and Creativity*, vol. 5, no. 1, pp. 16–22, 2010.

[40] C. P. Dwyer, M. J. Hogan, and I. Stewart, “An evaluation of argument mapping as a method of enhancing critical thinking performance in e-learning environments,” *Metacognition and Learning*, vol. 7, no. 3, pp. 219–244, 2012.

[41] C. M. A. Ortiz, *Does philosophy improve critical thinking skills?* University of Melbourne, Department of Philosophy, 2007.

[42] G. Brun and G. Betz, “Analysing practical argumentation,” in *The argumentative turn in policy analysis*, pp. 39–77, Springer, 2016.

[43] P. Saint-Dizier, “Argument mining: the bottleneck of knowledge and language resources,” European Language Resources Association (ELRA), May 2016.

[44] G. Rowe and C. Reed, “Diagramming the argument interchange,” *Computational Models of Argument: Proceedings of COMMA 2008*, vol. 172, pp. 348–359, 2008.

[45] J. J. L. Mathilde and C. Reed, “Ova+: An argument analysis interface,” in *Computational Models of Argument: Proceedings of COMMA*, vol. 266, pp. 463–464, 2014.

[46] J. Douglas and S. Wells, “Monkeypuzzle - towards next generation, free open-source, argument analysis tools,” in *17th International Workshop on Computational Models of Natural Argument(CMNA17)*, 2017.

[47] A. Peldszus and M. Stede, “From argument diagrams to argumentation mining in texts: A survey,” *International Journal of Cognitive Informatics and Natural Intelligence (IJCINI)*, vol. 7, no. 1, pp. 1–31, 2013.

[48] R. Swanson, B. Ecker, and M. Walker, “Argument mining: Extracting arguments from online dialogue,” in *Proceedings of the 16th annual meeting of the special interest group on discourse and dialogue*, pp. 217–226, 2015.

[49] N. Benn and A. Macintosh, “Argument visualization for eparticipation: towards a research agenda and prototype tool,” in *International Conference on Electronic Participation*, pp. 60–73, Springer, 2011.

[50] O. Scheuer, F. Loll, N. Pinkwart, and B. M. McLaren, “Computer-supported argumentation: A review of the state of the art,” *Int. Journal of Computer-Supported Collaborative Learning*, vol. 5, no. 1, pp. 43–102, 2010.

[51] P. A. Kirschner, S. J. Buckingham-Shum, and C. S. Carr, *Visualizing argumentation: Software tools for collaborative and educational sense-making*. Springer Science & Business Media, 2012.

[52] S. K. Card, J. D. Mackinlay, and B. Shneiderman, *Using Vision to Think*, p. 579–581. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., 1999.

[53] M. Khan and S. S. Khan, “Data and information visualization methods, and interactive mechanisms: A survey,” *International Journal of Computer Applications*, vol. 34, no. 1, pp. 1–14, 2011.

[54] K. Kucher and A. Kerren, “Text visualization browser: A visual survey of text visualization techniques,” *Poster Abstracts of IEEE VIS*, vol. 2014, 2014.

[55] T. Munzner, *Visualization Analysis and Design*. AK Peters Visualization Series, CRC Press, 2015.

[56] H.-J. Schulz, “Treevis. net: A tree visualization reference,” *IEEE Computer Graphics and Applications*, no. 6, pp. 11–15, 2011.

[57] T. Von Landesberger, A. Kuijper, T. Schreck, J. Kohlhammer, J. J. van Wijk, J.-D. Fekete, and D. W. Fellner, “Visual analysis of large graphs: state-of-the-art and future research challenges,” in *Computer graphics forum*, vol. 30, pp. 1719–1749, Wiley Online Library, 2011.

[58] J. Heer, M. Bostock, V. Ogievetsky, *et al.*, “A tour through the visualization zoo.,” *Commun. Acm*, vol. 53, no. 6, pp. 59–67, 2010.

[59] M. Okoe, R. Jianu, and S. Kobourov, “Node-link or adjacency matrices: Old question, new insights,” *IEEE Transactions on Visualization and Computer Graphics*, vol. 25, pp. 2940–2952, Oct 2019.

[60] I. Herman, G. Melancon, and M. S. Marshall, "Graph visualization and navigation in information visualization: A survey," *IEEE Transactions on Visualization and Computer Graphics*, vol. 6, pp. 24–43, Jan 2000.

[61] S. Zhao, M. J. McGuffin, and M. H. Chignell, "Elastic hierarchies: combining treemaps and node-link diagrams," in *IEEE Symposium on Information Visualization, INFOVIS 2005*, pp. 57–64, Oct 2005.

[62] S. Liu, W. Cui, Y. Wu, and M. Liu, "A survey on information visualization: recent advances and challenges," *The Visual Computer*, vol. 30, no. 12, pp. 1373–1393, 2014.

[63] M. Ghoniem, J.-D. Fekete, and P. Castagliola, "On the readability of graphs using node-link and matrix-based representations: a controlled experiment and statistical analysis," *Information Visualization*, vol. 4, no. 2, pp. 114–135, 2005.

[64] N. Henry, J. Fekete, and M. J. McGuffin, "Nodetrix: a hybrid visualization of social networks," *IEEE Transactions on Visualization and Computer Graphics*, vol. 13, pp. 1302–1309, Nov 2007.

[65] B. Shneiderman, "Tree visualization with tree-maps: 2-d space-filling approach," *ACM Trans. on Graphics (TOG)*, vol. 11, no. 1, pp. 92–99, 1992.

[66] J. Stasko, R. Catrambone, M. Guzdial, and K. McDonald, "An evaluation of space-filling information visualizations for depicting hierarchical structures," *International journal of human-computer studies*, vol. 53, no. 5, pp. 663–694, 2000.

[67] C. Collins, S. Carpendale, and G. Penn, "Docuburst: Visualizing document content using language structure," in *Computer graphics forum*, vol. 28, pp. 1039–1046, Wiley Online Library, 2009.

[68] J. B. Kruskal and J. M. Landwehr, "Icicle plots: Better displays for hierarchical clustering," *The American Statistician*, vol. 37, no. 2, pp. 162–168, 1983.

[69] M. Graham and J. Kennedy, "A survey of multiple tree visualisation," *Information Visualization*, vol. 9, no. 4, pp. 235–252, 2010.

[70] E. Hoque and G. Carenini, "Convis: A visual text analytic system for exploring blog conversations," in *Computer Graphics Forum*, vol. 33, pp. 221–230, Wiley Online Library, 2014.

[71] Y. Gil and V. Ratnakar, "Trusting information sources one citizen at a time," in *International Semantic Web Conference*, pp. 162–176, Springer, 2002.

[72] A. Katifori, C. Halatsis, G. Lepouras, C. Vassilakis, and E. Giannopoulou, "Ontology visualization methods–a survey," *ACM Computing Surveys (CSUR)*, vol. 39, no. 4, p. 10, 2007.

[73] V. Pascual-Cid and A. Kaltenbrunner, "Exploring asynchronous online discussions through hierarchical visualisation," in *2009 13th International Conference Information Visualisation*, pp. 191–196, July 2009.

[74] I. Bacher, B. M. Namee, and J. D. Kelleher, “Using icicle trees to encode the hierarchical structure of source code,” in *Eurographics Conference on Visualization, EuroVis 2016, Short Papers, Groningen, The Netherlands, 6-10 June 2016* (E. Bertini, N. Elmqvist, and T. Wischgoll, eds.), pp. 97–101, Eurographics Association, 2016.

[75] N. Cawthon and A. V. Moere, “The effect of aesthetic on the usability of data visualization,” in *Int. Conf. Information Visualization, IV’07, 2007*, pp. 637–648, IEEE, 2007.

[76] L. Woodburn, Y. Yang, and K. Marriott, “Interactive visualisation of hierarchical quantitative data: An evaluation,” in *2019 IEEE Visualization Conference (VIS)*, pp. 96–100, IEEE, 2019.

[77] C. Ware, *Information Visualization: Perception for Design*. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., 3 ed., 2012.

[78] C. North and B. Shneiderman, “Snap-together visualization: can users construct and operate coordinated visualizations?,” *International Journal of Human-Computer Studies*, vol. 53, no. 5, pp. 715–739, 2000.

[79] G. Convertino, J. Chen, B. Yost, Y.-S. Ryu, and C. North, “Exploring context switching and cognition in dual-view coordinated visualizations,” in *Proceedings International Conference on Coordinated and Multiple Views in Exploratory Visualization-CMV 2003-*, pp. 55–62, IEEE, 2003.

[80] J. C. Roberts, “State of the art: Coordinated & multiple views in exploratory visualization,” in *Fifth International Conference on Coordinated and Multiple Views in Exploratory Visualization (CMV 2007)*, pp. 61–71, IEEE, 2007.

[81] G. M. Namata, B. Staats, L. Getoor, and B. Shneiderman, “A dual-view approach to interactive network visualization,” in *Proceedings of the sixteenth ACM conference on Conference on information and knowledge management*, pp. 939–942, ACM, 2007.

[82] C. Chang, B. Bach, T. Dwyer, and K. Marriott, “Evaluating perceptually complementary views for network exploration tasks,” in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pp. 1397–1407, ACM, 2017.

[83] S. Jänicke, G. Franzini, M. F. Cheema, and G. Scheuermann, “Visual text analysis in digital humanities,” in *Computer Graphics Forum*, vol. 36, pp. 226–250, Wiley Online Library, 2017.

[84] K. Kim, S. Ko, N. Elmqvist, and D. S. Ebert, “Wordbridge: Using composite tag clouds in node-link diagrams for visualizing content and relations in text corpora,” in *2011 44th Hawaii International Conference on System Sciences*, pp. 1–8, IEEE, 2011.

[85] K.-P. Yee and M. Hearst, “Content-centered discussion mapping,” *Online Deliberation*, 2005.

[86] G. D. Venolia and C. Neustaedter, “Understanding sequence and reply relationships within email conversations: a mixed-model visualization,” in *Proceedings of the SIGCHI conference on Human factors in computing systems*, pp. 361–368, 2003.

[87] S. Latif, K. Su, and F. Beck, "Authoring Combined Textual and Visual Descriptions of Graph Data," in *EuroVis 2019 - Short Papers* (J. Johansson, F. Sadlo, and G. E. Marai, eds.), The Eurographics Association, 2019.

[88] B. Kerr, "Thread arcs: an email thread visualization," in *IEEE Symposium on Information Visualization 2003 (IEEE Cat. No.03TH8714)*, pp. 211–218, Oct 2003.

[89] E. Pitsos, "Kialo," 2007. https://www.kialo.com/.

[90] M. A. Smith and A. T. Fiore, "Visualization components for persistent conversations," in *Proceedings of the SIGCHI conference on Human factors in computing systems*, pp. 136–143, ACM, 2001.

[91] M. Wattenberg and D. Millen, "Conversation thumbnails for large-scale discussions," in *CHI'03 extended abstracts on Human factors in computing systems*, pp. 742–743, ACM, 2003.

[92] H. Lam, "A framework of interaction costs in information visualization," *IEEE Transactions on Visualization and Computer Graphics*, vol. 14, pp. 1149–1156, Nov 2008.

[93] B. Shneiderman, "The eyes have it: A task by data type taxonomy for information visualizations," in *The craft of information visualization*, pp. 364–371, Elsevier, 2003.

[94] B. Craft and P. Cairns, "Beyond guidelines: what can we learn from the visual information seeking mantra?," in *Ninth International Conference on Information Visualisation (IV'05)*, pp. 110–118, IEEE, 2005.

[95] C. Plaisant, D. Carr, and B. Shneiderman, "Image-browser taxonomy and guidelines for designers," *IEEE Software*, vol. 12, pp. 21–32, March 1995.

[96] M. A. Hearst *et al.*, "User interfaces and visualization," *Modern information retrieval*, pp. 257–323, 1999.

[97] M. Sarkar and M. H. Brown, "Graphical fisheye views," *Commun. ACM*, vol. 37, pp. 73–83, Dec. 1994.

[98] A. Cockburn, A. Karlson, and B. B. Bederson, "A review of overview+ detail, zooming, and focus+ context interfaces," *ACM Computing Surveys (CSUR)*, vol. 41, no. 1, pp. 1–31, 2009.

[99] G. G. Robertson, J. D. Mackinlay, and S. Card, "The perspective wall: Detail and context smoothly integrated," in *Proceedings of ACM CHI*, vol. 91, pp. 173–179, 1991.

[100] G. G. Robertson and J. D. Mackinlay, "The document lens," in *ACM Symposium on User Interface Software and Technology*, pp. 101–108, 1993.

[101] P. Craig and J. Kennedy, "Concept relationship editor: A visual interface to support the assertion of synonymy relationships between taxonomic classifications," in *Visualization and Data Analysis 2008*, Int. Society for Optics and Photonics, 2008.

[102] B. Alper, H. Yang, E. Haber, and E. Kandogan, "Opinionblocks: Visualizing consumer reviews," in *IEEE VisWeek 2011 Workshop on Interactive Visual Text Analytics for Decision Making*, 2011.

[103] H. Mumtaz, M. van Garderen, F. Beck, and D. Weiskopf, “Label placement for outliers in scatterplots,” in *EuroVis 2019 - Short Papers*, The Eurographics Association, apr 2019.

[104] K. Hartmann, T. Götzelmann, K. Ali, and T. Strothotte, “Metrics for functional and aesthetic label layouts,” in *International Symposium on Smart Graphics*, pp. 115–126, Springer, 2005.

[105] M. A. Bekos, B. Niedermann, and M. Nöllenburg, “External labeling techniques: A taxonomy and survey,” in *Computer Graphics Forum*, vol. 38, pp. 833–860, Wiley Online Library, 2019.

[106] M. Fink, J.-H. Haunert, A. Schulz, J. Spoerhase, and A. Wolff, “Algorithms for labeling focus regions,” *IEEE Trans. on Visualization and Computer Graphics*, vol. 18, no. 12, pp. 2583–2592, 2012.

[107] M. A. Bekos, M. Kaufmann, A. Symvonis, and A. Wolff, “Boundary labeling: Models and efficient algorithms for rectangular maps,” *Computational Geometry*, vol. 36, no. 3, pp. 215–236, 2007.

[108] J.-D. Fekete and C. Plaisant, “Excentric labeling: dynamic neighborhood labeling for data visualization,” in *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, pp. 512–519, 1999.

[109] E. Bertini, M. Rigamonti, and D. Lalanne, “Extended excentric labeling,” in *Computer Graphics Forum*, vol. 28, pp. 927–934, Wiley Online Library, 2009.

[110] S. Oeltze-Jafra and B. Preim, “Survey of labeling techniques in medical visualizations,” in *Proceedings of the 4th Eurographics Workshop on Visual Computing for Biology and Medicine*, pp. 199–208, Eurographics Association, 2014.

[111] T. Van Gelder, “Enhancing deliberation through computer supported argument visualization,” in *Visualizing Argumentation*, pp. 97–115, Springer, 2003.

[112] D. Walton, *Fundamentals of Critical Argumentation*. Cambridge University Press, 2005.

[113] F. Loll, O. Scheuer, B. M. McLaren, and N. Pinkwart, “Computer-supported argumentation learning: a survey of teachers, researchers, and system developers,” in *European Conference on Technology Enhanced Learning*, pp. 530–535, Springer, 2010.

[114] N. Benn and A. Macintosh, “Investigating visual languages for argument mapping,” in *Narrative and Hypertext 2011 Proceedings a Workshop at ACM Hypertext*, p. 55, 2011.

[115] C. Reed, K. Budzynska, R. Duthie, M. Janier, B. Konat, J. Lawrence, A. Pease, and M. Snaith, “The argument web: An online ecosystem of tools, systems and services for argumentation,” *Philosophy & Technology*, vol. 30, no. 2, pp. 137–160, 2017.

[116] S. W. Van den Braak, *Sensemaking software for crime analysis*. PhD thesis, Utrecht University, 2010.

[117] D. Khartabil, S. Wells, and J. Kennedy, "Large-scale argument visualization (lsav).," in *EuroVis (Posters)*, pp. 65–67, 2016.

[118] M. Klein, "Enabling large-scale deliberation using attention-mediation metrics," *Computer Supported Cooperative Work (CSCW)*, vol. 21, no. 4-5, pp. 449–473, 2012.

[119] N. Karacapilidis and D. Papadias, "Computer supported argumentation and collaborative decision making: the hermes system," *Information Systems*, vol. 26, no. 4, pp. 259 – 277, 2001.

[120] B. Verheij, "Artificial argument assistants for defeasible argumentation," *Artificial Intelligence*, vol. 150, no. 1, pp. 291 – 324, 2003. AI and Law.

[121] S. Mcalister, A. Ravenscroft, and E. Scanlon, "Combining interaction and context design to support collaborative argumentation using a tool for synchronous cmc," *Journal of Computer Assisted Learning*, vol. 20, no. 3, pp. 194–204, 2004.

[122] D. C. Hair, "Legalese: A legal argumentation tool," *ACM SIGCHI Bulletin*, vol. 23, no. 1, pp. 71–74, 1991.

[123] A. D. Liddo and S. B. Shum, "The evidence hub: harnessing the collective intelligence of communities to build evidence-based knowledge," in *Large Scale Ideation and Deliberation Workshop*, 2013.

[124] B. Fu, N. F. Noy, and M.-A. Storey, "Indented tree or graph? a usability study of ontology visualization techniques in the context of class mapping evaluation," in *Int. Semantic Web Conference*, pp. 117–134, Springer, 2013.

[125] T. van Gelder, "The rationale for rationale x2122;," *Law, Probability and Risk*, vol. 6, pp. 23–42, March 2007.

[126] J. D. Lowrance, I. W. Harrison, and A. C. Rodriguez, "Structured argumentation for analysis," in *Proceedings of the 12th International Conference on Systems Research, Informatics, and Cybernetics: Focus Symposia on Advances in Computer-Based and Web-Based Collaborative Systems*, pp. 47–57, 2000.

[127] A. Karamanou, N. Loutas, and K. Tarabanis, "Argvis: structuring political deliberations using innovative visualisation technologies," in *International Conference on Electronic Participation*, pp. 87–98, Springer, 2011.

[128] T. van Gelder, "Enhancing deliberation through computer supported argument visualization," in *Visualizing Argumentation*, pp. 97–115, Berlin, Heidelberg: Springer-Verlag, 2003.

[129] T. Dragon, M. Mavrikis, B. M. McLaren, A. Harrer, C. Kynigos, R. Wegerif, and Y. Yang, "Metafora: A web-based platform for learning to learn together in science and mathematics," *IEEE Transactions on Learning Technologies*, vol. 6, pp. 197–207, July 2013.

[130] S. B. Shum, "Cohere: Towards web 2.0 argumentation," in *Proc. COMMA'08: 2nd International Conference on Computational Models of Argument*, pp. 97–108, IOS Press, May 2008.

[131] F. Loll and N. Pinkwart, "Lasad: Flexible representations for computer-based collaborative argumentation," *International Journal of Human-Computer Studies*, vol. 71, no. 1, pp. 91–109, 2013.

[132] N. Pinkwart, V. Aleven, K. Ashley, and C. Lynch, "Evaluating legal argument instruction with graphical representations using largo," in *Proceedings of the 2007 Conference on Artificial Intelligence in Education: Building Technology Rich Learning Contexts That Work*, (Amsterdam, The Netherlands, The Netherlands), pp. 101–108, IOS Press, 2007.

[133] T. F. Gordon, H. Prakken, and D. Walton, "The carneades model of argument and burden of proof," *Artificial Intelligence*, vol. 171, no. 10-15, pp. 875–896, 2007.

[134] P. Bell, "Using argument representations to make thinking visible for individuals and groups," in *Computer Support for Collaborative Learning*, pp. 10–19, Int. Society of the Learning Sciences, 1997.

[135] B. Johnson and B. Shneiderman, "Tree-maps: a space-filling approach to the visualization of hierarchical information structures," pp. 284–291, Oct 1991.

[136] D. Suthers, A. Weiner, J. Connelly, and M. Paolucci, "Belvedere: Engaging students in critical discussion of science and public policy issues," in *Proceedings of the 7th World Conference on Artificial Intelligence in Education*, pp. 266–273, Washington, DC, 1995.

[137] R. J. Heuer, *Psychology of intelligence analysis*. Center for the Study of Intelligence, 1999.

[138] R. E. Horn, "Infrastructure for navigating interdisciplinary debates: Critical decisions for representing argumentation," in *Visualizing argumentation*, pp. 165–184, Springer, 2003.

[139] D. C. Schneider, C. Voigt, and G. Betz, "Argunet-a software tool for collaborative argumentation analysis and research," in *7th Workshop on Computational Models of Natural Argument (CMNA VII)*, 2007.

[140] P. Sbarski, T. van Gelder, K. Marriott, D. Prager, and A. Bulka, "Visualizing argument structure," in *International Symposium on Visual Computing*, pp. 129–138, Springer, 2008.

[141] and D. Fisher, R. Dhamija, and M. Hearst, "Animated exploration of dynamic graphs with radial layout," in *IEEE Symposium on Information Visualization, 2001. INFOVIS 2001.*, pp. 43–50, Oct 2001.

[142] B. Konat, J. Lawrence, J. Park, K. Budzynska, and C. Reed, "A corpus of argument networks: Using graph properties to analyse divisive issues," in *Proceedings of the Tenth International Conference on Language Resources and Evaluation (LREC'16)*, pp. 3899–3906, 2016.

[143] D. A. Kolb, "The revenge of the page," in *Proceedings of the nineteenth ACM conference on Hypertext and hypermedia*, pp. 89–96, ACM, 2008.

[144] A. Kremling, “Denkwelt descartes,” in *GAP.9*, p. 162, 2015.

[145] J. Heer and M. Agrawala, “Software design patterns for information visualization,” *IEEE transactions on visualization and computer graphics*, vol. 12, no. 5, pp. 853–860, 2006.

[146] B. Shneiderman and C. Plaisant, “Strategies for evaluating information visualization tools: multi-dimensional in-depth long-term case studies,” in *Proceedings of the 2006 AVI workshop on BEyond time and errors: novel evaluation methods for information visualization*, pp. 1–7, ACM, 2006.

[147] E. Zudilova-Seinstra, T. Adriaansen, and R. Van Liere, “Overview of interactive visualisation,” in *Trends in Interactive Visualization*, pp. 3–15, Springer, 2009.

[148] C. Plaisant, “The challenge of information visualization evaluation,” in *Proceedings of the working conference on Advanced visual interfaces*, pp. 109–116, ACM, 2004.

[149] M. Tory and T. Moller, “Human factors in visualization research,” *IEEE transactions on visualization and computer graphics*, vol. 10, no. 1, pp. 72–84, 2004.

[150] T. Munzner, “A nested process model for visualization design and validation,” *IEEE Transactions on Visualization & Computer Graphics*, no. 6, pp. 921–928, 2009.

[151] C. Abras, D. Maloney-Krichmar, J. Preece, *et al.*, “User-centered design,” *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications*, vol. 37, no. 4, pp. 445–456, 2004.

[152] N. Elmqvist and J. S. Yi, “Patterns for visualization evaluation,” *Information Visualization*, vol. 14, no. 3, pp. 250–269, 2015.

[153] S. Carpendale, “Evaluating information visualizations,” in *Information visualization*, pp. 19–45, Springer, 2008.

[154] H. Lam, E. Bertini, P. Isenberg, C. Plaisant, and S. Carpendale, “Empirical studies in information visualization: Seven scenarios,” *IEEE transactions on visualization and computer graphics*, vol. 18, no. 9, pp. 1520–1536, 2012.

[155] C. Lewis and J. Rieman, *Task-centered User Interface Design: A Practical Introduction*. University of Colorado, Boulder, Department of Computer Science, 1993.

[156] J. L. Gabbard, D. Hix, and J. E. Swan, “User-centered design and evaluation of virtual environments,” *IEEE computer Graphics and Applications*, vol. 19, no. 6, pp. 51–59, 1999.

[157] J. Corbin and A. Strauss, *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage publications, 2014.

[158] A. H. Hilal and S. S. Alabri, “Using NVivo for data analysis in qualitative research,” *International Interdisciplinary Journal of Education*, vol. 2, no. 2, pp. 181–186, 2013.

[159] B. Shneiderman, “The eyes have it: a task by data type taxonomy for information visualizations,” in *Proceedings 1996 IEEE Symposium on Visual Languages*, pp. 336–343, Sep. 1996.

[160] M. Bostock, V. Ogievetsky, and J. Heer, “D^3 data-driven documents,” *IEEE Transactions on Visualization & Computer Graphics*, no. 12, pp. 2301–2309, 2011.

[161] S. Murray, *Interactive Data Visualization for the Web: An Introduction to Designing with.* " O’Reilly Media, Inc.", 2017.

[162] S. Guldamlasioglu, “Web-based information visualization using javascript,” Master’s thesis, 2015.

[163] D. Khartabil and S. Wells, “Mapping Increasingly Large Networks of Argumentative Inferences,” *2nd European Conference on Argumentation: Argumentation and Inference*, 2017.

[164] M. Harrower and C. A. Brewer, “Colorbrewer. org: an online tool for selecting colour schemes for maps,” *The Cartographic Journal*, vol. 40, no. 1, pp. 27–37, 2003.

[165] A. Chaparro and M. Chaparro, “Applications of color in design for color-deficient users,” *Ergonomics in Design*, vol. 25, no. 1, pp. 23–30, 2017.

[166] T. Isenberg, P. Isenberg, J. Chen, M. Sedlmair, and T. Möller, “A systematic review on the practice of evaluating visualization,” *IEEE Transactions on Visualization and Computer Graphics*, vol. 19, no. 12, pp. 2818–2827, 2013.

[167] H. Abdi, “Holm’s sequential bonferroni procedure,” *Encyclopedia of research design*, vol. 1, no. 8, pp. 1–8, 2010.

[168] M. Marusteri and V. Bacarea, “Comparing groups for statistical differences: how to choose the right statistical test?,” *Biochemia medica: Biochemia medica*, vol. 20, no. 1, pp. 15–32, 2010.

[169] A. Field, *Discovering Statistics Using IBM SPSS Statistics*. Sage Publications Ltd., 4th ed., 2013.

[170] B. Plüss, F. Sperrle, V. Gold, M. El-Assady, A. Hautli-Janisz, K. Budzynska, and C. Reed, “Augmenting public deliberations through stream argument analytics and visualisations,” in *LEVIA’18: Leipzig Symposium On Visualization In Applications 2018*, 2018.

Appendix A

Ethical Form for Experts Interviews

We are investigating the visualisation of large-scale arguments. Our aim is to ensure that people can easily comprehend, understand, and work with arguments within a problem domain even as the number of participants increases and the amount of data grows bigger.

Please tick all relevant boxes as appropriate:

1.	I have read and understand the aim of the research	□
2.	I voluntarily agree to participate in the research	□
3.	I understand I can withdraw at any time without giving reasons and that I will not be penalised for withdrawing nor will I be questioned on why I have withdrawn	□
4.	I understand that the information provided by me will be held totally anonymously	□
5.	I agree that the interview being recorded in audio/ video format or other forms of data collection	□
6.	I agree that the anonymised data is used in research, publications, sharing and archiving	□
7.	I understand that other researchers on Edinburgh Napier university will have access to this anonymised data only if they agree to preserve the confidentiality of the data and if they agree to the terms, I have specified in this form	□
8.	I am free to answer or avoid any particular question	□

Participant:

______________________ ______________________ ______________

Name of Participant Signature Date

Researcher:

______________________ ______________________ ______________

Name of Researcher Signature Date

Appendix B

Ethical Form for User Study Interviews

Usability study

1- What is your gender?

○ Male

○ Female

○ Other

2- What is your age?

○ Under 20 years

○ 20-25 years

○ 26-30 years

○ 31-35 years

● 36-40 years

○ Over 40 years

○ I prefer not to say

3- Are you blind colour?

○ No

○ Yes

○ I don't know

4- Are you familiar with the use of a computer?

○ No

○ Yes

Edinburgh Napier University requires that all persons who participate in research studies give their written consent to do so. Please read the following and sign it if you agree with what it says.

1. I freely and voluntarily consent to be a participant in this research to be conducted by Dana Khartabil, who is postgraduate student in the Edinburgh Napier School of Computing.

2. I have been informed of the broad goal of this research study. I have been told what is expected of me and that the study should take no longer than one hour to complete.

3. I have been told that my responses will be anonymised. My name will not be linked with the research materials, and I will not be identified or identifiable in any report subsequently produced by the researcher.

4. I also understand that if at any time during the interview. If I feel unable or unwilling to continue, I am free to leave. That is, my participation in this study is completely voluntary, and I may withdraw from it at any time without negative consequences.

5. In addition, should I not wish to answer any particular question or questions, I am free to decline.

6. I have been given the opportunity to ask questions regarding the interview and my questions have been answered to my satisfaction.

7. I have read and understand the above and consent to participate in this study. My signature is not a waiver of any legal rights. Furthermore, I understand that I will be able to keep a copy of this consent form for my records.

Participant's Name   Participant's Signature

-----------------------------------   -----------------------------------

Date

I have explained and defined in detail the research procedure in which the respondent has consented to participate. Furthermore, I will retain one copy of the informed consent form for my records.

Researcher’s Name Researcher’s Signature

----------------------------------- -----------------------------------

Date

Appendix C

Interview Instruction

Instructions

Thank you for agreeing to participate in this study!

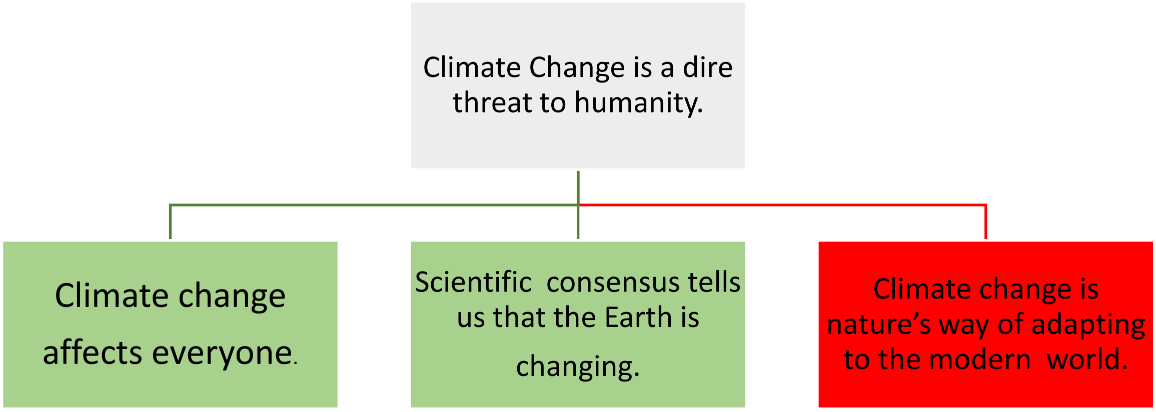
Arguments are the structure of many statements called premises which are offering the reasons for a conclusion or a claim. The relations between the premises and conclusion can be supporting and opposing. Red denotes a contrast relation while green denotes a support one.

Comparison between three visualisation techniques for argument navigation

This study is to compare three techniques that help users to navigate and understand large set of argumentation text. The first technique is the space-efficient Icicle layout. This layout shows an overview of the data and allows the user to read and navigate the text using the fish-eye technique.

The second technique is the Stacked boxes with radial layout. The stacked layout presents the nodes as boxes stacked above each other with the sibling of each level is displayed on the side of each node.

The third one is the space-efficient radial layout with a list of labelling which pop-up when the user hovers over the layout. The pop-up list reflects the text from the parent node to the hovering one.


Climate Change is a dire threat to humanity.
Climate change affects everyone.
Scientific consensus tells us that the Earth is changing.
Climate change is nature's way of adapting to the modern world.

1- The Icicle with focus and context technique:

Figure. 1 shows the Icicle layout with fisheye technique.

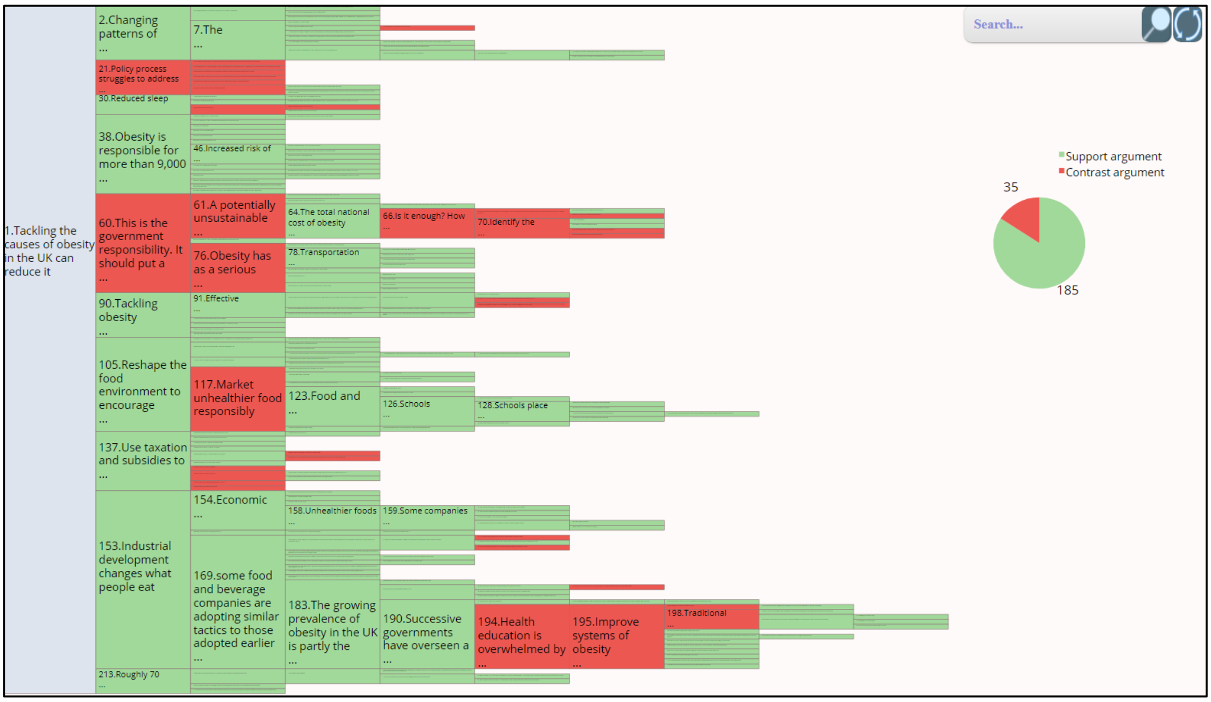
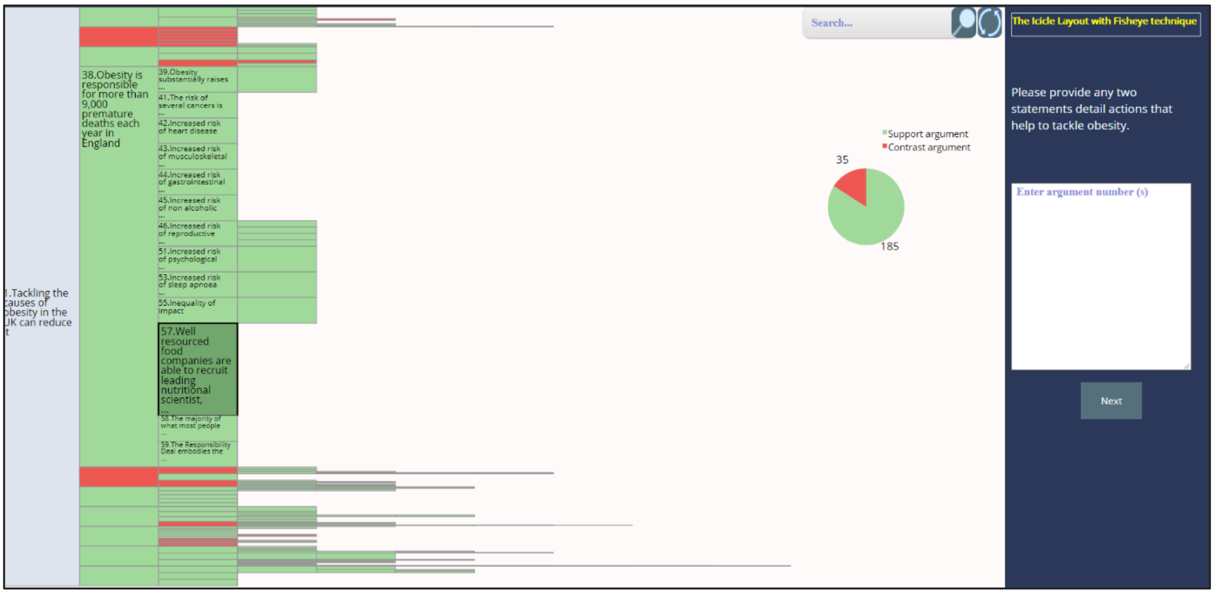

Search...
1.Tackling the causes of obesity in the UK can reduce it
2.Changing patterns of ...
7.The ...
21.Policy process struggles to address
30.Reduced sleep
38.Obesity is responsible for more than 9,000 ...
46.Increased risk of ...
60.This is the government responsibility. It should put a ...
61.A potentially unsustainable ...
64.The total national cost of obesity
66.Is it enough? How
70.Identify the
76.Obesity has as a serious ...
78.Transportation
90.Tackling obesity ...
91.Effective
105.Reshape the food environment to encourage ...
117.Market unhealthier food responsibly
123.Food and ...
126.Schools
128.Schools place
137.Use taxation and subsidies to ...
153.Industrial development changes what people eat
154.Economic ...
158.Unhealthier foods
159.Some companies
169.some food and beverage companies are adopting similar tactics to those adopted earlier ...
183.The growing prevalence of obesity in the UK is partly the ...
190.Successive governments have overseen a ...
194.Health education is overwhelmed by ...
195.Improve systems of obesity ...
198.Traditional
213.Roughly 70 ...
Support argument
Contrast argument
35
185

Figure. 1.1 Icicle layout

When you click on any node, the node's branch from the parent node to the children expands to show the text of the branch. The clicked node will occupy more space than the sibling nodes as illustrated in Figure 1.2.


Search...
1.Tackling the causes of obesity in the UK can reduce it
38.Obesity is responsible for more than 9,000 premature deaths each year in England
39.Obesity substantially raises
41.The risk of several cancers is
42.Increased risk of heart disease
43.Increased risk of musculoskeletal
44.Increased risk of gastrointestinal
45.Increased risk of non alcoholic
46.Increased risk of reproductive
51.Increased risk of psychological
53.Increased risk of sleep apnoea
55.Inequality of impact
57.Well resourced food companies are able to recruit leading nutritional scientist, ...
58.The majority of what most people
59.The Responsibility Deal embodies the
Support argument
Contrast argument
35
185
The Icicle Layout with Fisheye technique
Enter argument number (s)
Next

Please provide any two statements detail actions that help to tackle obesity.

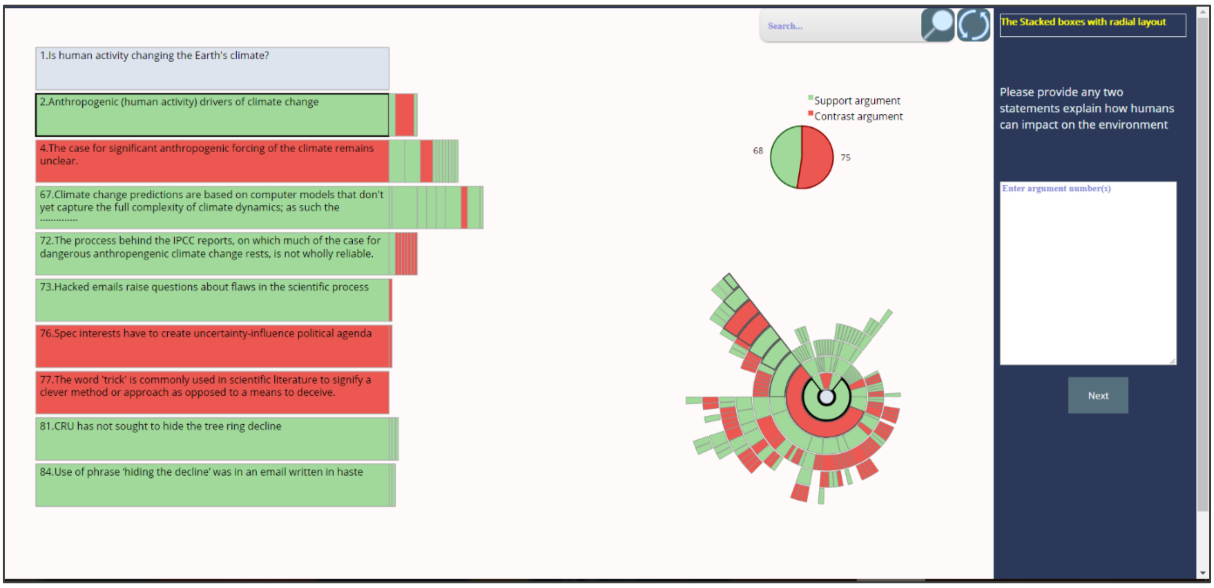
Figure. 1.2 Icicle layout with focus and context technique.

You can search for any word. The search results, i.e., nodes that contain the searched word(s), will be recognised by a darker shade of red and green depending on the node type. Please be infomed that when you look for a specific word like “eat”, all the words that contain this keyword like cr**eat**e or tr**eat** will appear in the search results.

There are 7 questions for this layout. To help you answer the questions, you can right-click on the node of interest and the number of the node will be transferred immediately to the text box.

2- The stacked boxes with sunburst layout:

In the second layout, the stacked boxes layout is located on the left side of the interface and the sunburst one is on the right as shown in Figure 2.1. The stacked boxes reflect a branch of the argument with a large number of children nodes. The data is sorted depending on the largest number of children in the branch. The radial shows the overview of the whole dataset.



1.Is human activity changing the Earth's climate?

2.Anthropogenic (human activity) drivers of climate change

4.The case for significant anthropogenic forcing of the climate remains unclear.

67.Climate change predictions are based on computer models that don't yet capture the full complexity of climate dynamics; as such the ....

72.The proccess behind the IPCC reports, on which much of the case for dangerous anthropengenic climate change rests, is not wholly reliable.

73.Hacked emails raise questions about flaws in the scientific process

76.Spec interests have to create uncertainty-influence political agenda

77.The word 'trick' is commonly used in scientific literature to signify a clever method or approach as opposed to a means to deceive.

81.CRU has not sought to hide the tree ring decline

84.Use of phrase 'hiding the decline' was in an email written in haste

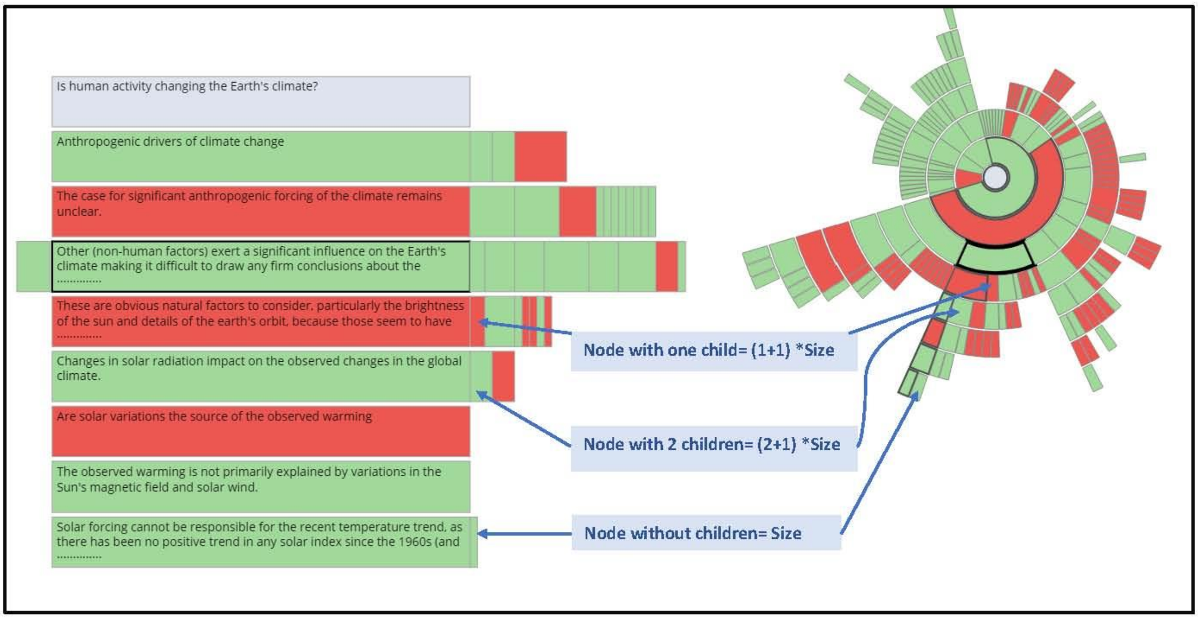
The Stacked boxes with radial layout

Please provide any two statements explain how humans can impact on the environment

Enter argument number(s)

Figure. 2.1 Stacked boxes layout with the sunburst layout.

The boxes reflect the branch from the parent to the last child in that branch. In each level, the sibling of each node is placed next to the branch nodes. The size of each sibling reflects the size of the first level of the children.



Is human activity changing the Earth's climate?

Anthropogenic drivers of climate change

The case for significant anthropogenic forcing of the climate remains unclear.

Other (non-human factors) exert a significant influence on the Earth's climate making it difficult to draw any firm conclusions about the ....

These are obvious natural factors to consider, particularly the brightness of the sun and details of the earth's orbit, because those seem to have ....

Changes in solar radiation impact on the observed changes in the global climate.

Are solar variations the source of the observed warming

The observed warming is not primarily explained by variations in the Sun's magnetic field and solar wind.

Solar forcing cannot be responsible for the recent temperature trend, as there has been no positive trend in any solar index since the 1960s (and ....

Node with one child= (1+1) *Size

Node with 2 children= (2+1) *Size

Node without children= Size

Figure. 2.2 Stacked boxes with the sibling.

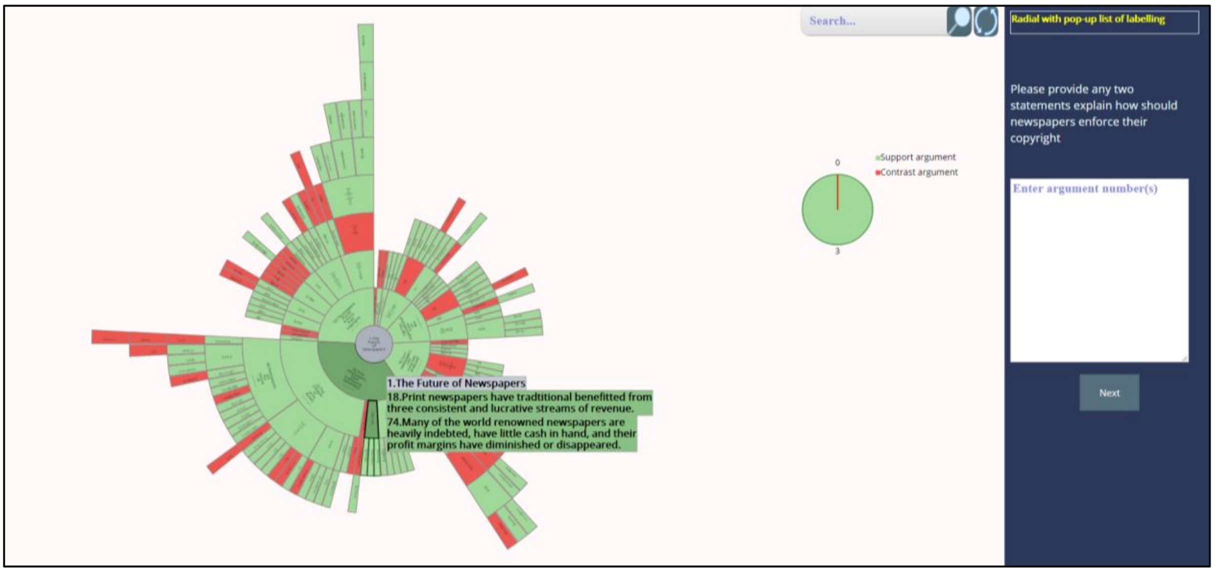
You can search for any word. The search results, i.e., nodes that contain the searched word(s), will be recognised by a darker shade of red and green depending on the node type. Please be infomed that when you look for a specific word like “eat”, all the words that contain this keyword like cr**eat**e or tr**eat** will appear in the search results.

To navigate through the search results, you can use **Alt+S**.

There are 7 questions for this layout. To help you answer the questions, you can right-click on the node of interest and the number of the node will be transferred immediately to the text box.

3- The sunburst layout with the pop-up labels:

The sunburst layout with the list of pop-up labels is shown in Figure 3.1.



1.The Future of Newspapers

18.Print newspapers have tradtitional benefitted from three consistent and lucrative streams of revenue.

74.Many of the world renowned newspapers are heavily indebted, have little cash in hand, and their profit margins have diminished or disappeared.

Please provide any two statements explain how should newspapers enforce their copyright

Figure. 3.1 The sunburst layout with the list of labelling.

When the user hovers over the layout, the list of labelling from the parent to the hovering nodes pop-up to allow the user to read the text from the parent to the hovering node.

You can search for any word. The search results, i.e., nodes that contain the searched word(s), will be recognised by a darker shade of red and green depending on the node type. Please be infomed that when you look for a specific word like “eat”, all the words that contain this keyword like cr**eat**e or tr**eat** will appear in the search results.

There are 7 questions for this layout. To help you answer the questions, you can right-click on the node of interest and the number of the node will be transferred immediately to the text box.

Thank you again for your participation in this study!