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Visualization of the Allocation of Corporate Funding: A Design Study

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CCS Concepts

•**Human-centered computing** → **Visualization;** *HCI design and evaluation methods; Visual analytics; Visualization design and evaluation methods;* • **Information systems** → Enterprise resource planning;

Keywords

Visualization, User-centred Design, Dynamic Graph, User Interaction

ABSTRACT

This paper explores the use of a visualisation as a tool to support the practice of fund matching or intra-company loaning at Old Mutual. Additionally it explores the effectiveness of user centred design methods for creating such a visualisation. We present a dynamic graph visualisation of the fund matching data allowing users to see how funds are allocated between sub-companies at Old Mutual at any point in time in a 3 year window. We use end user experts and Honours HCI students to evaluate our designs over three iterations of design and evaluation. We find that the visualisation design is successful and that user centred design process provides valuable feedback for visualisation design.

1. INTRODUCTION

Parent companies are composed of a number of sub-companies which function independently for day to day business purposes. These sub-companies can be categorized by their available funding. Either as sources which are companies with excess funding or requirements, companies requiring additional funding.

Ordinarily companies that require additional funding would need to request loans from external entities such as banks. However, within parent companies, loans between these funding sources and requirements can be made. This creates a complex problem where as many as 100 sources and requirements must be matched in an optimal manner.

In addition to the number of entities involved each source or requirement is complex in itself. Each source has its own interest rate, tax class and a number of other variables and is only available for a specific time window. Each requirement has a similar number of data dimensions and also requires funding for a certain window.

Of greatest concern to the parent company is avoiding excess interest expense from a sub-optimal set of allocations. However, there is a large amount of contextual information that is also necessary for creating an optimal solution to this problem. Currently this process is carried out manually using purely textual tools such as Microsoft Excel. This results in a slow process that is prone to human error.

We aim to simplify the problem of optimally matching sources and requirements. To do this we create a visualisation to allow for more efficient data exploration and analysis. This project is designed to work simultaneously with a tool to automatically generate solutions which can then be analysed using the visualisation.

The visualisation must be simple to understand while also retaining all essential information. Challenges in visualising this data include: selecting appropriate visual channels to differentiate sources and requirements , fitting the visualisation within a compact space and showing data changes over time.

We follow a User-Centered design (UCD) process to ensure that the visualisation meets the goals and expectations of the intended users: employees at Old Mutal[11]. We gather a number of visual queries chosen by users. Visual queries are the questions users wish to answer using the visualisation. These are based on common ways in which users interrogate the data.

We conduct three iterations of design and evaluation based on these visual queries. Each evaluation consists of a think out loud session, where users attempt to answer the visual queries using the visualisation, and an interview where users answer specific questions related to the design of the visualisation.

2. BACKGROUND

Our visualisation design includes a variety of features found in other visualisation research. These include a number of interactive visual elements. We also looked at existing visualisations in the financial field that dealt with similar data. These informed us on suitable structures such as the node-graph form. We use a number of User-based design techniques in our evaluation process. We selected the participants for these evaluations based on successful practices in similar studies.

2.1 Interactive Visualization

Visualizations are tools that allow users to answer a set of queries based on a single image or set of images which are able to represent large amounts of data. By observing the information in a visual form users are able to answer these visual queries much faster than if using only raw data[6]. To do this we use a number of visual pathways such as colour, shape, size etc. to represent different data dimensions[16]. Interactive visualisations are specifically visualisations that are designed for user interaction. This allows users to manipulate the data representation to a some extent.

Of particular interest in this paper are methods for visualising information from the financial sector as fund matching falls into this category. Dynamic graph visualisations, which are structured data representations that display time orientated data visually, are also of interest as there is a definite structure to the fund-match data and time is an essential dimension of the data.

2.1.1 *Financial Visualizations*

Within the financial sector there have been a number of efforts to visualise certain data sets. Fund manager investment is a subject of existing research in this area. It involves visualising the investments companies make in one another and how these change over time while also tracking the value of the companies involved. Although this is not exactly the same as fund matching, where all loans are made within the parent company and for specified amounts of time, they exhibit many of the same attributes. Namely they are made up of a time dependent network of objects that can be represented as a node-graph. Dwyer et al. created two variations of 3D graphs to visualise the behaviours of Fund managers.[7] Although these visualisations are relatively simple they showcase the use of node-link graphs to model data similar in nature to the data being visualised in this project.

2.1.2 *Dynamic Graph Visualizations*

Dynamic graphs are used to represent the relationships between a number of entities and how these relationships change over time.

Beck et al. explore how different variations of dynamic graph visualisations can be broken down and how the separate approaches differ from one another[3]. They discuss animation style visualisations where a sequence of graphs correlating to different points in time are mapped to a type of interactive control resulting in an animated representation. The interaction may take various forms such as a timeline or play/pause functionality. This visualisation style is useful in scenarios where the data is high dimensional or involves a large numbers of data points. By only showing single points in time we conveniently reduce the data dimensionality by 1 and eliminate all data points not relevant at that point.

Another consideration from Beck et al. is whether the data is *online* or *offline* where *online* indicates that future data is unknown and *offline* indicates all data to be visualised is known when the visualisation is created. By this definition our visualisation can be considered offline as we are aiming to visualise a complete, pre-calculated solution. This simplifies the problem of laying out the graph as all layouts can be pre-calculated from the data[3].

Node-link graphs are a subset of graph visualisations where the data is represented as a set of nodes, independent objects representing 1 or more data points, between which a number of links representing relationships can be drawn. This is the type of graph used by Dwyer et al. It is also well suited to the fund-match data where there are a number of independent entities, sources and requirements, which are related through fund allocations.

There are a number of node-link graphs using animation style methods to show the time dimension. Typically, visualisations attempt to visualise very large numbers of simple nodes[17]. However, there are examples where more complex nodes are utilized. Zhoa et al. created a visualisation where nodes both originate from and contain complex structures[18].

In their paper on visualising time-orientated data Aigner et al. emphasize that the time dimension should be given specific attention[2]. They go on to mention that users are often interested in being able to control the time dimension within the visualisation via some form of control. An example of another visualisation using a timeline slider interface can be found in the paper *Geographic visualisation: Designing manipulable maps for exploring temporally varying georeferenced statistics*[10].

2.2 User-based design

UCD was a concept pioneered by Donald Norman in the 1980s[1]. The term refers to a design process where the input from end users is incorporated into the design. This helps ensure that the design suits the user's needs. At the core of UCD is the interaction between users and designers. It is therefore essential to select a variety of users and chose a well defined method of obtaining user feedback.

2.2.1 *Participant Selection*

Choosing suitable participants for the design process is an integral part of UCD. Tory et al. found that expert evaluation was effective for detecting a number of issues with the visualisation and that by including end-user experts they received a higher quality of feedback than in a previous experiment using purely HCI expert[15]. However, they stated that having a variety of participants including HCI experts and end users was more beneficial than any single group.

2.2.2 *Evaluation Methods*

Once participants for the UCD process have been chosen it is then important to establish a method for evaluating the design. This allows the designers to get useful feedback from the users. Carpendale et al. describe a number of methodologies for evaluating visualisations. These include the think-out-loud or formative usability testing method as well as semi-structured interviews[5][12]. The think-out-loud method is a technique where participants are asked to explain their thought process in real-time as they proceed through a series of tasks. This allows the observer to understand the frustrations users face or misunderstandings they have while interacting with the design. Semi-structured interviews are a method of collecting the opinions of experiment participants. They consist of a number of questions which participants are asked to answer. However, due to the verbal format participants are able to give a wide range of feedback that may extend beyond the initial scope of the questions. This allows for collecting additional context to participant feedback and allows participants to point out particular points of interest in the design.

Hix et al. used combined formative evaluations which were carried out by end users with heuristic evaluations by HCI experts as described in Tory et al.'s paper on their own visualisation design[9]. They found that combining the evaluation procedures was effective, substantiating Tory et al.'s result.

3. METHODOLOGY

We define a number of design goals and explore the suitability of the UCD process for creating a visualisation. To do this we rely on established visualisation design principles to create an initial design. With this as a starting point we follow a UCD process to iteratively improve the design resulting in a final prototype.

3.1 Design Goals

We aim to design a visualisation to allow users to perform efficient data exploration and analysis on a fund matching solution.

We attempt to show as much information as possible and provide tools such as information filters and zoom to allow for analysis. Due to the number of data dimensions, 10/8 dimensions for sources/requirements, a variety of contextual information may be useful to users. For example, if a loan is made at a low interest rate but the source and requirement belong to different tax classes, which is problematic, the user should be able to see this. Another design goal is to keep the visualisation as simple as possible. Given the large number of data points and the high dimensionality of these points it is essential that special attention be paid to not overloading the user with visual stimuli. If this is not done the speed and accuracy with which any and all visual queries can be answered will be negatively impacted[8]

It is important that the design goals mentioned above be balanced while ensuring that the primary goal of answering the visual queries is fulfilled. To do this we need to effectively incorporate user interaction into the design such that users are able to work with only the data they at that moment.

To do this we must show all requirements/sources, the allocations between them and the data for each source/requirement such that any visual query can be answered. We must allow users to suppress data that they do not need for their current interrogation of the data but also access any data that they may possibly need. We must show how the data changes over time and display the minimum number of sources/requirements simultaneously while ensuring that this does not prevent any visual query from being answered. We must allow the user to interact with the visualisation in a way that is meaningful but ensures that the data being visualised is consistent and no information is accidently obscured. We must also ensure that the interactive functions are simple to perform and accessible for all users.

3.2 Design Principles

There are a number of well established design principles that are relevant to the design of interactive visualisations.

Shnedierman's visualisation mantra of *overview first, zoom and filter then details on demand* has been incorporated in a number of elements in the visualisation[13]. The overview gives the user context to evaluate specific components. Zooming allows the user to focus on subsections of the data. Filtering allows the user to control what information is shown. This facilitates specific queries relating to only a subset of the data dimensions.

Another design principle adhered to is keeping related objects close to one another according to the law of proximity described by Smith-Gratto et al.[14] This allows users to perceive relationships at a glance.

When objects need to be shown as distinct they are distinct on at least two visual pathways. This allows for the user to more easily differentiate between them[16].

Colours used in larger shapes (i.e. the colours representing each source) should be less bright and have lower contrast than those used to highlight smaller areas (i.e. the outlines of requirements, links and the small blocks they link to). This results in less strain on the user.

We make use of a visual metaphor to give the user a sense of what the data means. This allows the user to more easily understand the principle concept being evaluated, the transfer of funds from sources to requirements[4].

We have tried to make use of the transfer effect which allows users to draw on their everyday experiences to interpret certain visual aspects of the design.

3.3 Data

The data used for the purpose of creating prototypes was provided by Old Mutual. The data is anonymized but the scope is not reduced. We are therefore able to work with a realistic solution that was created using their current, manual method.

The data consisted of 108 requirements, 83 sources and 78 allocations. The variables of each requirement and source node were specified and each requirement, source and allocation was uniquely identifiable by its ID.

Each prototype is designed using this data and reflected it as accurately as possible. The same data set is used for all prototypes. For the earlier prototypes the data is manually translated from excel spread sheets to a visual representation. The final prototype takes in data from a JSON format and automatically converts it to the visual representation. This supports the intent for the visualisation to be used to visualise a number of automatically created solutions.

3.4 Design process

We follow a user centred design process. We worked together with the primary users, the treasury team at Old Mutual. We carried out an initial information gathering stage together with representatives from Old Mutual to better identify the needs and the expectations of our users. We conducted a number of work interviews with members of the treasury team. This allowed us to formulate a well defined set of visual queries on which to conceptualize the design. This was followed by three design cycles; A paper-prototype, a low fidelity prototype and a high fidelity prototype.

Following our initial data gathering we experimented with a variety of designs in the form of paper-prototypes.This allowed us to maintain flexibility such that any weak aspects of the designs could be identified and corrected quickly and cheaply. It also allowed for a number of alternative designs to be created without large expenditures of resources[1]. Two promising designs were chosen for which we created more detailed paper-prototypes as slideshows. This allows users to evaluate not only the static visualisation design but the interactive elements as well. The treasury team members evaluated the paper prototypes after a pilot test was performed with HCI students.

The low fidelity prototype did not have all the interactive features of the final design(eg. used a predetermined allocation and did not allow users to load their own) it allowed users to directly interact with the visualisation. The prototype is created with an html skeleton which allows for basic interactivity together with a number of still images based on those used for the paper prototype. Once we completed the prototype with changes based on the first evaluation we then carried out a second evaluation.

The final design cycle transitioned to a high fidelity prototype which included all the functionality of the design. This prototype is intended to mirror what a final product would be. It is designed using html, css, javascript, jQuery and a tool called Fabric.js. These tools allow us to automatically generate visual elements from an input JSON file. This prototype was then evaluated to establish whether users are satisfied with the final design[1].

3.5 Visual Queries

The primary function of our visualisation is to answer a set of visual queries. The queries below were formulated during an initial data gathering session with representatives from Old Mutual. The visual queries can be grouped into two categories or meta-queries:

A) How are funds allocated?

B) Is the allocation efficient?

In the list below visual queries belonging to group A are itemized by a '•' while those belonging to group B are itemized by '–'. Additionally the queries are ranked on a system of 1-3 with queries of rank three being the most important while queries of rank one are the least. In general queries from group A are considered slightly more useful than those in group B, however this never overrules the importance rank of queries. i.e. a query of rank three is always more important to answer than a query of rank two, regardless of groups.

- Which sources, companies that can provide funding, are providing loans for a requirement, companies that require funding? (3)
- Which requirements are receiving loans from a source? (3)
- What is the value of a Source or Requirement? (2)
- Which Sources, Requirements, Loans will mature soon? (2)
- What is the value of a Loan? (1)
- Which Sources, Requirements, Loans will mature in a certain time window? (1)

– What are the interest rates of Sources? (3)

– What are the interest costs of Requirements? (3)

– Where do the tenors of linked sources and requirements not match? (2)

3.6 Evaluation methods

We use end-user experts and HCI postgrad students to evaluate the visualisation design [15]. The end-user experts are drawn from the treasury team at Old Mutual. The HCI graduate students are from the 2016 UCT Honours class.

Pilot evaluations are carried out with HCI students as participants. This evaluation serves the purpose of identifying major bugs or errors within the system as well as prioritizing features to be included before the expert end user testing. They also provide a wider range of feedback than that provided by the Old Mutual team alone.

The end-user expert evaluation combines formative usability testing and participant opinion collection through a think-out-loud method and semi-structured interview method respectively.[5, 12] For the think-out-loud users attempt to answer the visual queries using the prototype. This is then followed by a semi-structured interview where participants are asked to give their opinion on a number of the visualisation features.

There are three design cycles and therefore three sets of evaluations. Additionally three participants are involved in each set of evaluations. The end-user expert evaluations are carried out in a one-on-one interview format. The semi-structured interviews consist of a well defined set of questions, which can be found in the appendix, but conversation is allowed to flow and the exploration of topics not explicitly part of the original question set can occur. For each evaluation the prototype is present for reference throughout the interview.

The HCI student evaluations take place in a group interview environment. Since these evaluations focus on design principles and error identification in the prototype we feel allowing participants to collaborate is beneficial. This lets participants link to each other's ideas and discuss possible design improvements and explore error propagation more efficiently.

4. RESULTS

4.1 Iteration 1 - Paper Prototype

4.1.1 Design

The initial view of the data is an overview of the fund allocation over the entire time period for which it is valid. From this the user can zoom to a certain point in time and is

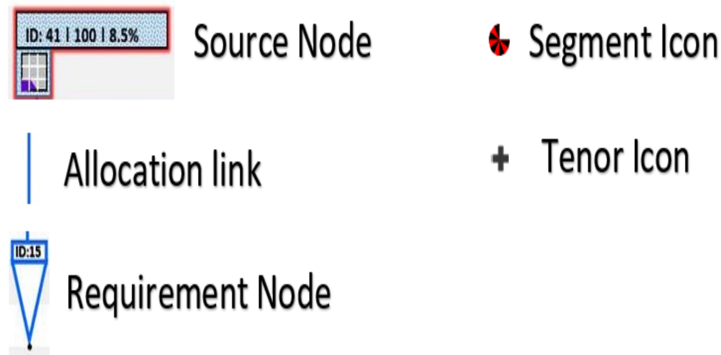

Figure 1: Key visual elements of the design

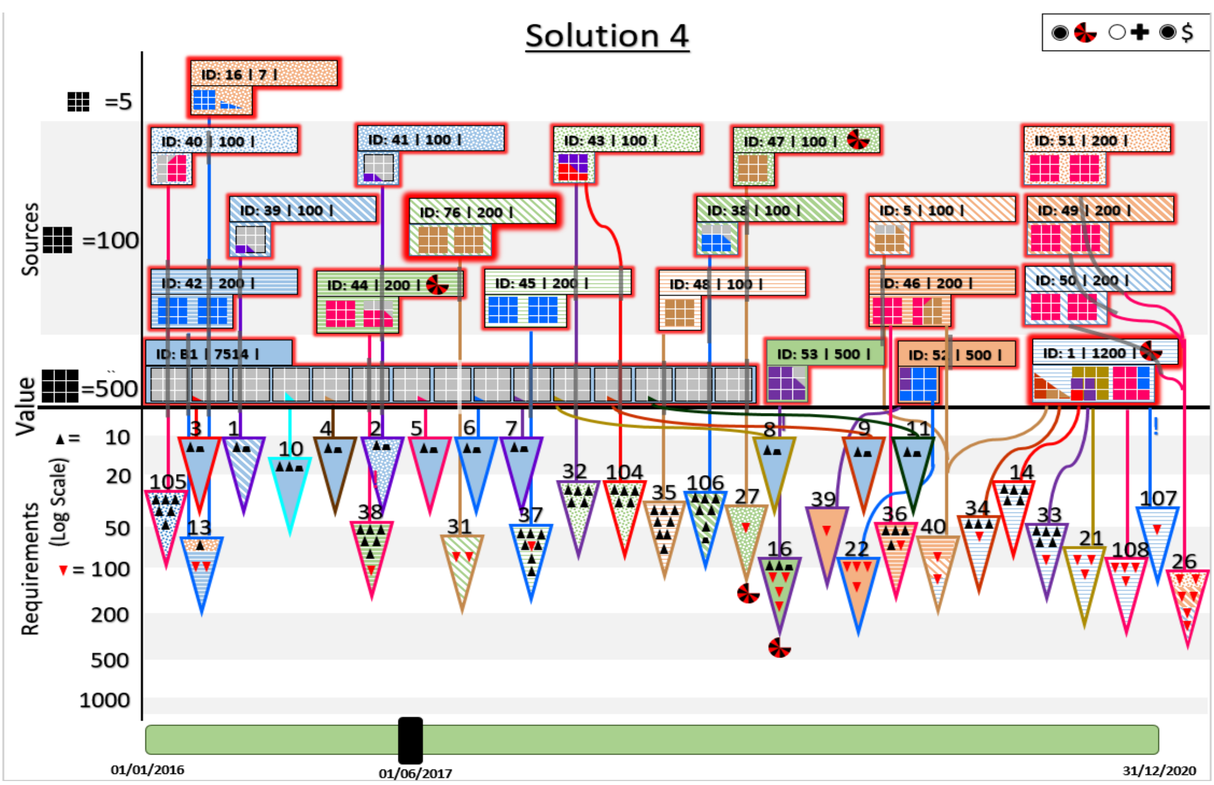

Figure 2: One of the initial designs used in the paper-prototype

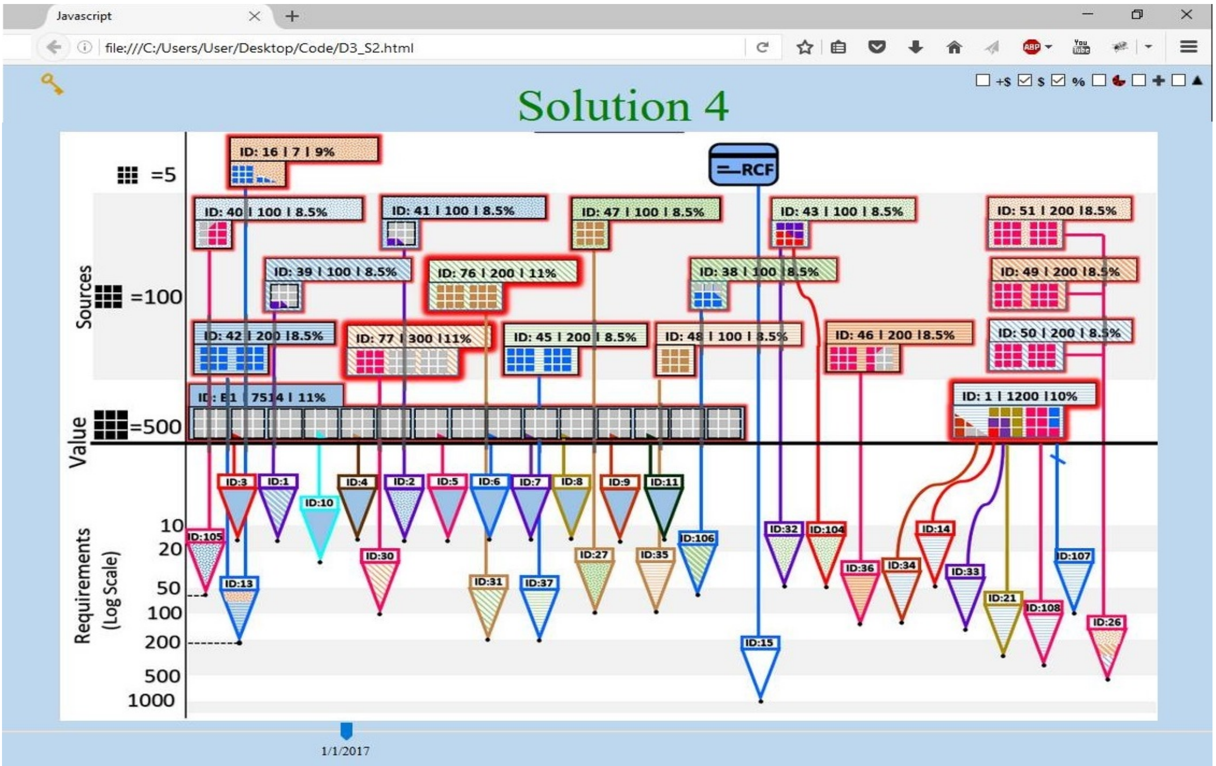

Figure 3: A screen shot of the low-fidelity prototype

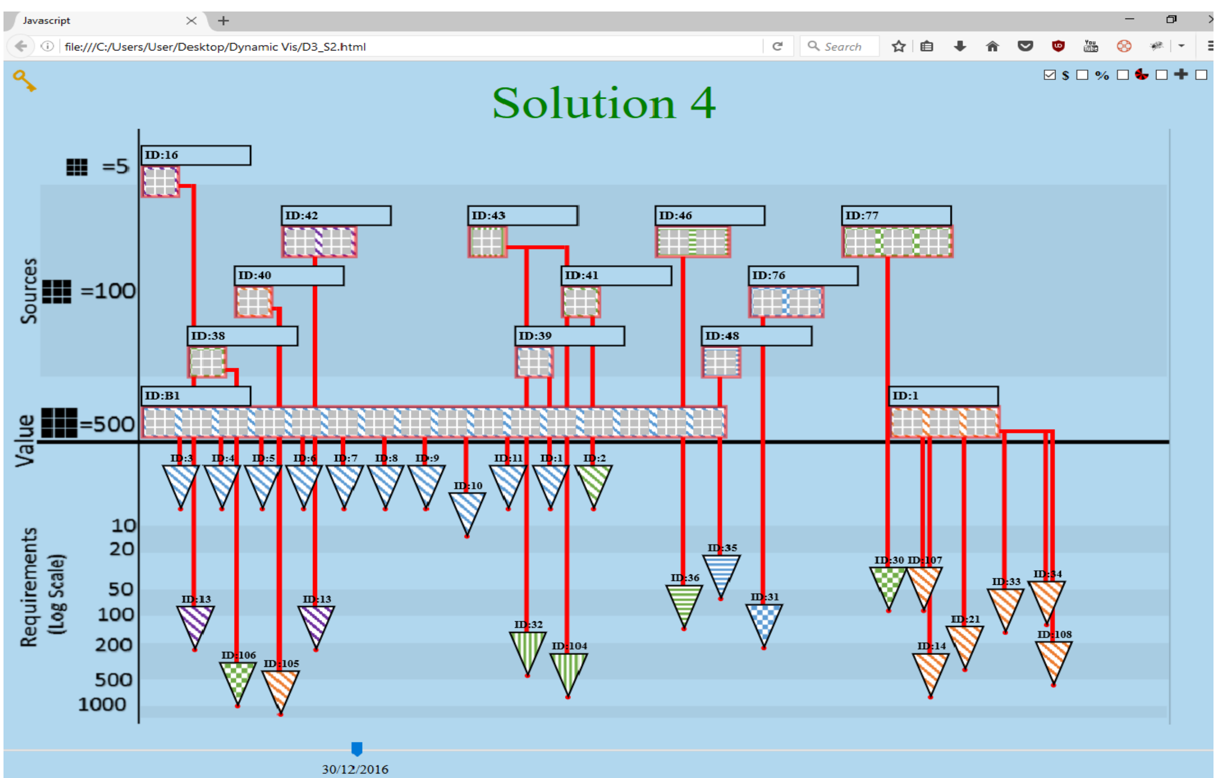

Figure 4: A screen shot of the high-fidelity prototype

presented with a much more detailed view of the data, where each source, requirement and allocation active at that point in time is visually represented. Sources are represented in the top half of the screen as rectangles while requirements are represented as triangles in the bottom half of the screen. Allocations are represented by lines linking sources to requirements. Linked source/requirement pairs or groups are typically arranged close to one another, this helps users associate them and has the additional benefit of minimizing the number of intersecting lines.

Users can filter the information displayed via a number of radio button options as well as change the date at which the data is viewed. Each radio button has a symbol next to it representing the data it is related to. A segmented 3/4 circle is associated with the tenor of sources, or requirements. A dollar sign is associated with the value nodes. A cross is associated with icons representing "segments", which correspond business sectors. By clicking on the radio buttons users may turn these visual elements on or off. The date is selected using the slider on the timeline at the bottom of the screen.

We incorporated the icon of a circle with segments to represent the tenor, which is the lifetime of a requirement/source expressed in months, remaining of sources or requirements. The twelve segments which correlate to each month of a year are reminiscent of the 12 hours on a clock. This association with time makes the representation intuitive taking advantage of the transfer effect.

Users can access the details of individual sources, requirements or allocations by hovering over them for a tooltip or clicking them to bring up an overlay of the selected node's data. This gives the 'details on demand' from Shnedierman's mantra. Users can use this to get all the precise information relating to a single source/requirement.

There is a visual metaphor included in the way the visualisation is represented. Since the sources of funding are shown in the upper half of the screen one can imagine them releasing a flow of funding down through the links to the requirement 'containers'. In this way we show how sources fill up the funding requirements.

Where possible two visual pathways have been used to differentiate each data dimension. Examples include sources/ requirements differing in both position and shape and the glow representing interest rate around sources differs both in intensity and width as interest rate changes.

The prototype consisted of a number of printed A4 images representing the results of different interactions users would be able to have with the visualisation. In Figure 2 one of these images is shown. This image represents the 'solution view' from which users should be able to answer most visual queries while also allowing them to filter and zoom on specific details of the data. The 'name' or ID of the solution being viewed is shown as a title for the user's reference.

On the left of the image there is a scale, or rather two scales. Sources are grouped into categories based on value and arranged vertically according to category such that sources with high value are near the bottom. This minimizes the number of links crossing source nodes as higher value sources are more likely to have multiple allocations. Requirements are arranged in a inverted graph format where the distance of the node representing a source below the centre line or x-axis is log-proportionate to the value of the requirement. This allows the user to quickly read the value of a requirement.

The interior blocks in source nodes indicate the value of the source as well as how it is distributed via allocations. This allows visual queries relating to the value of sources and allocations to be answered. Each requirement is outlined in a specific color, the amount which a requirement is allocated from a source is directly proportional to the value of the interior blocks in the source that are shaded with the same color as the requirement's outline. Again, this helps identify the values of allocations. It also helps users to quickly identify which requirements are receiving loans from the source. As stated above sources are grouped vertically according to value as well. Groups are differentiated by the regions of grey and white background. Within each group a single interior block represents a different amount indicated by the scale on the left. This helps users identify the approximate value of a source at a glance. The RCF (rotating credit fund) is used to represent external funding used to satisfy requirements where no suitable source is available. It is visually represented by a credit card icon.

Each requirement node has an ID above it for identification. The interior fill of the nodes links them to the source from which they are allocated funds. Each source is assigned a unique texture and all nodes with allocations from that source will have an interior filled with the same texture. This is a second visual element which can be used to tell which sources are allocated to a requirement. In the figure the nodes have interior triangles indicating their value. Small, upright black triangles represent a value of 10 while small, downright red triangles represent a value of 100. This helps users to precisely read the value of the requirement.

At the bottom of the screen is a timeline the user can manipulate. This allows the user to scroll through a range of dates and it is the allocations at the date chosen that are visualised above. This helps reduce the amount of data shown at any time to prevent information overload. It also provides time-orientated context to the allocations

Users can also click on a node to bring up a 'details' window. This showed the node the user had clicked on as well as all connected nodes. It also included the tooltip data in a panel as well as a small graph that gave additional information depending on the type of node clicked. Examples of tooltips and detail windows can be found in the appendix. Again this provides the 'details on demand' from Shnedierman's mantra.

Shown in figure 2 is Design 2. This differed from design 1 in the way that the value of requirements was visually displayed. In both designs the value of a requirement can be read off the scale to the left relative to the point of the node. However, in design 2, as is visible, the user can also read off the number of small interior triangles. In design 1 the length of the triangle itself varied based on the value of the requirement and no interior triangles were used. This meant that requirement nodes with low values were significantly smaller than those with high values. Examples of this can be seen in the appendix.

4.1.2 Evaluation

Feedback from the pilot evaluation was on the effectiveness on the visualisation and the evaluation procedure. It was found that stating the visual queries before showing the prototype was essential. Additionally, it was found that users preferred to evaluate a physical copy than a powerpoint presentation on a screen.
Feedback on the visualisation told us users found that the correspondence of glow around sources to interest rate was neither obvious nor precise. This meant that users were forced to rely on tooltip data to answer the queries relating to interest rates. Since these were identified as important visual queries this needed to be improved. This is solved in the next design by allowing users to display the interest rate textually above sources.
Users commented that the visual indicator for tenors not matching was not sufficiently obvious. They suggested that the icon should stand out more from the rest of the visualisation. A more obvious indication is added in the next design where allocations where tenors do not match have a small strike-through.
Users found the filter options useful but suggested these be extended to allow more visual cues to be filtered out.
Users were confused by the fact that both triangle depth and triangle size related to the value of requirements in Design 1. There was also some confusion as to whether the y-axis should be measured using triangle bases or tips. There is a notable lack of visual cues indicating this in the design. Two visual indicators were added in the next iteration. It was suggested that utilizing only triangle depth would be sufficient.
Another suggestion was that instead of having alternating white and grey strips indicating scale divisions between sources a white to grey colour scale was used. However, this creates an issue where if the contrast between the divisions is low it is hard to identify the division borders but if it is high then some divisions are very dark obscuring other visual details. Users found that the number of colours and patterns linking sources and requirements were sometimes overpowering. This has been alleviated in later designs by using less intense colours. Additionally they noted that visual cues would need keys related to them. A key has been added in later designs

After the pilot evaluation the visualization was then evaluated by 3 end user experts at Old Mutual.

During the think out loud portion of this evaluation users asked where they could find textual indicators of amounts such as interest rate and tenor. These are available to users by hovering over requirement or source nodes but there should perhaps be a visual indicator that such functionality exists. This suggests that users prefer textual information over visual cues. This is likely due to the necessity for precise numbers as well as experience with current, text based, tools. Users commented on the lack of a method for seeing how much of a source was unused. This was an aspect that was not previously considered in the design but there is no reason to not include it in future designs. One user interpreted the timeline as an x-axis for the graph showing requirements. This is likely due to the placement of the timeline and the unorthodox layout of the visualisation. Users also asked what the credit card (RCF) represented. This should be labelled for additional clarity. One user mentioned that the axis of the graphs shown in detail view were missing labels. This was another aspect that there is no reason not to include.

Many questions from the interview section of the evaluation were addressed in the think out loud section, additional information gained was that the values of loans were not immediately obvious as well as the interest rate indicators being obscure. From this we realise that users wanted very precise answers to these queries rather than the approximations they could quickly read off the visual elements. The timer icons indicating tenor where also too small for one user. This indicates we should take user handicaps such as poor eyesight into account.

Although users found some of the static visualisation elements lacking they suggested adding filters to textually display the information they requested during the think out loud evaluation. Once it was explained all users also found that the timeline was intuitive and useful. This enthusiasm for the interactive aspects of the design suggests that these can be used to compensate for the comprimises necessary for visualising a data set of this complexity. Users noted that there should be an indicator of which requirements and sources were new or re-financed. Two users preferred design one while the other preferred design two.

From this round of design and evaluation we found that users preferred the constant triangle size from design 2 but felt that the small triangles created to much visual noise. We also identified the need for more data to be displayed textually, leading to a number of new filter options to be added. We identified interest rates and tenors as being data dimensions that needed to be visualised more clearly.

4.2 Iteration 2 - Low fidelity Prototype

4.2.1 Design

The low fidelity prototype implements the basic interactive features of the visualisation on a single screen as well as updating the design according to feedback from the paper prototype evaluation.

A basic HTML skeleton is used to provide a simulation of the interactive experience using a number of still images based on those used in the paper prototype. Users are able to hover over any node themselves to see the tooltip or click on the node to display the detail window in a modal form. A number of filters are also usable to change that data displayed and users could use the timeline to select a date. However, filters, tooltips and detail windows are only available for a specific date and the user can only select three specific dates using the timeline. These limitations are due to the necessity of creating each view manually as well as the limited time available for the creation of the prototype.

A change in the way requirements are shown was made based on feedback from the evaluation of the paper prototype. The uniform node size from design 2 is kept and the interior triangles become a filter option that users can turn on and off. Additionally a small dot has been added to the tip of the triangle nodes to indicate that the scale should be measured to the tip of the nodes rather than the base. This helps users read off the values of requirement nodes at a glance.

A label has been added to the icon representing the RCF to make it clearer what this represents as many users were originally confused by it. Labels have also been added to the axis of the graphs in the detail views. A key that users could access by clicking an icon has been added. This explains a number of visual elements. While these changes are not directly related to specific visual queries they are intended to help the user better understand the visualisation elements. This allows users to focus on answering the visual queries.

To enhance the interactive elements of the design a number of additional filters, including a filter which showed interest rates textually above source nodes and a filter which showed the amount unused in a source instead of the total amount in the source, have been added. This allows for visual queries relating to interest rate to be answered precisely without relying on tooltips. The option to show the amount unused in a source was a direct request from the previous evaluation. Toggling filters on and off is changed to use check-boxes instead of radio buttons as this better indicates that multiple filters can be checked simultaneously.

An indicator of where tenors did not match has been added in the form of a strike through the line representing an allocation where this is the case. This allows users to answer the visual query relating to matching tenors. Previously users would need to check whether the tenor icon on linked sources and tenors matched, users found this time consuming and clumsy.

4.2.2 Evaluation

From the think out loud portion of this evaluation we find there are some issues with the way in which the filters are displayed. A common issue is that users did not know whether an icon corresponded to the check box to the left or right of it. One of the users did not initially notice the filter options and afterwards suggested that the size of them be increased. This suggests that the filter options should be given more screen space as well as more carefully arranged.

On of the users was confused as to the meaning of the scale in the detail window and supposed it was a label indicating the amount of a node. This confusion could be solved by using more screen space and better arranging visual elements.

Another user pointed out how some tenor icons are preserved in the detail view (those of linked nodes) while others are not (the icon related to the selected node). This leads to a incongruence where the selected node's tenor is expressed in absolute terms while the connected nodes' tenors are expressed relatively to the date on the timeline. This may lead to confusion when using the detail window to answer visual queries related to tenor. A suggestion by another user in the QA section to show the tooltip details of all nodes shown in the detail view provides a solution for this where all tenors are expressed in absolute terms. Another user expressed a desire to be able to see more precise numbers with regards to tenors expiring in detail view. This can also be answered by showing the tooltip info of all nodes.

From the QA session we find 2 out of 3 users felt that they could answer all visual queries, this was an improvement from 1 out of 3 during the paper prototype. However, users still found visual queries relating to tenor are not easily answerable. Users were more confident in their ability to interact with the low fidelity prototype than with the paper prototype. This is likely due to them having direct control over the interface rather than working through a third party/ demonstrator. Users were mostly happy with the existing features. However, some modifications to the detail view were suggested. Two features suggested were adding an alternative, more precise way to select dates than the timeline and a visual indicator of when sources were over allocated. A date selector similar to those found in mobile devices is a possible solution for the first suggestion. The second suggestion may be addressed by adding a large visual alert over or next to over allocated sources.

In this round of evaluation we found that we were still struggling to display tenor in a way that users felt was precise enough. We also found that we needed to pay more attention to the way in which visual elements were displayed to emphasize important features such as labels and filters.

4.3 Iteration 3 - High fidelity Prototype

4.3.1 Design

The High fidelity prototype demonstrated the full interactive potential of the design as well as the automated conversion of raw data in JSON format to a visualisation. Due to difficulties with the technology and time-constraints it did not contain all features of the design. For this reason it was presented with the low fidelity prototype for reference and users were asked to assume that certain features such as the date selector suggested in the previous evaluation would be implemented as described to them.

The prototype was created using HTML, CSS, jQuery and a tool called fabric.js. This allowed for the automated creation and positioning of nodes, allocations, tooltips, detail views and other visual elements. The prototype was only used with a single set of data however and may prove to be unreliable given certain variations in data.

The prototype took a JSON file as input and generated the visualisation based on this. This meant that the timeline and filter functions were fully operational. However, due to the automation constraints it was necessary to visualise the nodes in a less compact format than in previous designs. This resulted in the visualisation being wider than typical screen width in cases where a large number of allocations were active. This meant that users might need to scroll across the window to see all nodes and allocations. This was not optimal and additional work to ensure that nodes are packed efficiently in the available space should be carried out.

4.3.2 Evaluation

In the pilot evaluation participants suggested that visual features that were currently interfering with other visual queries should have priority for improvement before the final evaluation. An example of this was an issue where allocation lines were obscuring the text details above sources. This was fixed before the final evaluation. By prioritizing these features we ensure that all features that are implemented are clearly visible.

The expert end user evaluation for the final prototype was more detailed than previous evaluations. Participants were still asked to think out loud but the QA section addressed each visual query individually and participants were required to write down their own answers.

All visual queries identified as 'most important' in the initial data gathering phase were consistently ranked as easy to answer. However, queries related to tenors were scored poorly relative to other visual queries. Participants also reported struggling to identify the value of loans or allocations.

There were some minor recommendations for improvement of features including the ability to hover over allocations to get an 'Allocation ID' and extending the graphs shown in detailed view to show the full lifetime of the node selected. Additionally, it was suggested that the detail view was extended in such a way that users could select more than one node at a time to view in this setting.

5. DISCUSSION

Users were enthusiastic about both initial designs. It is likely that this was due to successful initial data gathering as well as good use of the design principles for creating dynamic visualisations.

Although the initial design was well received there were still a number of issues with it. Before initial data gathering with end users there were a number of ill-defined visual queries where the nature of the tasks users performed was misunderstood based on initial specification of the project. Performing the initial data gathering therefore avoided going through multiple design iterations before these issues were encountered. We therefore believe that involving the users in the design process as early as possible was extremely useful.

The pilot tests for both the paper-prototype and high-fidelity prototype were helpful, especially to identify weaknesses in the evaluation procedure. For the paper proto-type particularly the initial evaluation procedure was improved greatly by using hard copies of the images and having the visual queries present for reference at all times. Although the participants in our pilot tests were unable to comment on specific use cases their input on the general design aspects was valuable. Performing pilot tests as well as having a variety of participants in the overall evaluation process allowed us to pick up on more weaknesses than a more focused evaluation procedure would have.

Expert end user testing allowed for the visual queries to be more precisely defined and for features that were not well suited to the specific use cases encountered by end users to be improved. Progressing from the paper-prototype to the low-fidelity prototype a number of improvements were suggested and implemented. Incorporating end users in the design process allowed for us to create a visualisation that fulfilled their goals.

However, there were some issues with this testing. Firstly, the number of evaluators was 3 for the paper-prototype and low fidelity prototype. Additionally, the same expert end users were used in each round of evaluations. This meant that the results consist of a small range of subjective opinions. Additionally, there is certainly an element of learning in the testing process and users would possibly pick up on visual cues explained during earlier evaluations that new users would not. Although the UCD process resulted in a successful design it required a substantial amount of time, planning and management to arrange evaluations and process feedback. In the scope of this project it may have been more beneficial to have focussed on this aspect more and less on creating a high fidelity prototype.

Unfortunately, the creation of a high fidelity prototype was incomplete. This was due to the unexpected complexity of developing such a complex visual system. Certain features were unfortunately left out or incomplete. However, the main aspects of interactivity and automated construction of the visualisation from a JSON format were retained.

This meant that during the final evaluation users were required to imagine certain visual features and refer to the previous prototype occasionally. This certainly will have had an effect on the results although it seems unlikely that users would approve of an incomplete prototype but then disapprove of a more complete example. Users clearly felt that this was an improvement over the initial design and that it was a viable replacement or complement to existing tools. There is still room for improvement of both the design and implementation as well as an opportunity for a number of similar visualisations to fulfil the same role for different tasks in the financial sector.

6. CONCLUSIONS

In this project UCD was used to create a dynamic visualisation that users felt was effective and useful in the everyday workplace.

UCD was useful for improving the initial design and both pilot testing and expert end user testing provided valuable feedback.

In the evaluation of the final design every visual query was ranked as answerable by at least one user and all visual queries categorized as high priority were ranked as easily answerable. Additionally users expressed that they would use the visualisation either to replace or to enhance current tools. Users also said that they would use the visualisation on a regular basis.

Future work in this area would include creating a more robust high-fidelity prototype, improving the way in which tenor was visually represented and addressing the additions and modifications suggested in the evaluation of the final prototype. A case study on the use of a completely functional version of the high fidelity prototype in the workplace could also be done. This would either confirm or refute the conclusions reached based on the evaluations of the prototype.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] C. Abras, D. Maloney-Krichmar, and J. Preece. User-centered design. *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications*, 37(4):445–456, 2004.

[2] W. Aigner, S. Miksch, W. Müller, H. Schumann, and C. Tominski. Visualizing time-oriented dataâĂŤa systematic view. *Computers & Graphics*, 31(3):401–409, 2007.

[3] F. Beck, M. Burch, S. Diehl, and D. Weiskopf. The state of the art in visualizing dynamic graphs. *EuroVis STAR*, 2014.

[4] R. Borgo, A. Abdul-Rahman, F. Mohamed, P. W. Grant, I. Reppa, L. Floridi, and M. Chen. An empirical study on using visual embellishments in visualization. *Transactions on Visualization and Computer Graphics*, 18(12):2759–2768, 2012.

[5] S. Carpendale. Evaluating information visualizations. In *Information Visualization*, pages 19–45. Springer, 2008.

[6] D. A. Carr. Guidelines for designing information visualization applications. *Proceedings of ECUE*, 99:1–3, 1999.

[7] T. Dwyer and P. Eades. Visualising a fund manager flow graph with columns and worms. In *Information Visualisation*, pages 147–152. IEEE, 2002.

[8] M. J. Eppler and J. Mengis. The concept of information overload: A review of literature from organization science, accounting, marketing, mis, and related disciplines. *The information society*, 20(5):325–344, 2004.

[9] D. Hix, J. E. Swan, J. L. Gabbard, M. McGee, J. Durbin, and T. King. User-centered design and evaluation of a real-time battlefield visualization virtual environment. In *Virtual Reality*, pages 96–103. IEEE, 1999.

[10] A. M. MacEachren, F. P. Boscoe, D. Haug, and L. W. Pickle. Geographic visualization: Designing manipulable maps for exploring temporally varying georeferenced statistics. In *Information Visualization*, pages 87–94. IEEE, 1998.

[11] D. A. Norman. *The design of everyday things: Revised and expanded edition*. Basic books, 2013.

[12] P. Saraiya, C. North, and K. Duca. An insight-based methodology for evaluating bioinformatics visualizations. *IEEE transactions on visualization and computer graphics*, 11(4):443–456, 2005.

[13] B. Shneiderman. The eyes have it: A task by data type taxonomy for information visualizations. In *Visual Languages*, pages 336–343. IEEE, 1996.

[14] K. Smith-Gratto and M. M. Fisher. Gestalt theory: a foundation for instructional screen design. *Journal of Educational Technology Systems*, 27(4):361–371, 1999.

[15] M. Tory and T. Möller. Evaluating visualizations: do expert reviews work? *Computer Graphics and Applications, IEEE*, 25(5):8–11, 2005.

[16] A. Treisman. Search, similarity, and integration of features between and within dimensions. *Journal of Experimental Psychology: Human Perception and Performance*, 17(3):652, 1991.

[17] F. Van Ham and J. J. Van Wijk. Interactive visualization of small world graphs. In *Information Visualization*, pages 199–206. IEEE, 2004.

[18] S. Zhao, M. J. McGuffin, and M. H. Chignell. Elastic hierarchies: Combining treemaps and node-link diagrams. In *Symposium on Information Visualization*, pages 57–64. IEEE, 2005.

APPENDIX

A. EVALUATION 1 FEEDBACK

ABSTRACT

This is a record of the results from the first round of end user expert evaluations for the fundmatch paper prototype evaluation.

A.1 Think Out Loud Comments

A.1.1 User 1

The user asked what the numbers on top of the triangles representing requirements meant and was informed that they indicated the ID of the requirement. The user asked whether it was possible to select and view subsets of the data in anyway, eg. all loans over a certain amount. He was told that this is not currently possible. The user also asked whether there was a way to differentiate new requirements from re-financed requirements. He was told there was no way due to the designer not being informed of these classifications. The user also asked how to identify interest rates and was informed that the width and brightness of the glow around sources indicated interest rate, he then suggested that this information also be displayed textually. The user also initially believed that the circle tenor icons meant different things for requirements and sources due to their different placement relative to the nodes.

A.1.2 User 2

The user expressed his initial lack of understanding as to how to use the visualization. He initially supposed that the timeline was in fact the x-axis of the graph showing requirement amounts, asking if the leftmost requirement corresponded to having a start date at the first date shown on the timeline. Once the use of a timeline was explained to him the user was better able to discern how the visualization worked. He asked how it was possible to see the amount of funding left unused in sources and was informed that this corresponded to the section of grey blocks left. He then suggested that this was not sufficiently precise and should be displayed textually. He also felt that interest amounts should be displayed textually as he struggled to differentiate between the level of glow around sources. Additionally he felt that the tenor icons were too small to easily read and tenor information should be displayed textually. He expressed a dislike for the small triangle icons in design 2. He also commented that there should be a way to focus on one requirement or source without discarding the rest of the data.

A.1.3 User 3

The user was able to grasp the functionality of the visualization relatively quickly. She identified how to answer most visual queries without any external input. However, she tended to rely on tool tip data more than some visual cues. She stated that this was because the visual cues were not specific enough but suggested that this was sufficient as they marked points of interest for further interrogation via tooltip. Specifically she felt that she needed tooltip information to identify interest rates and precise loan amounts. She did ask what the credit card icon in sources represented and was informed that it corresponded to the RCF, she suggested that this be explicitly labeled. She felt that the detail view was useful but also mentioned that, although intuitively obvious to her, it would be a good idea to label the y-axis values of the graphs in detail view.

A.2 Answers to Interview Questions

A.2.1 Question 1

Can you answer all visual queries using the visualization?
User 1: No
User 2: No
User 3: Yes

A.2.2 Question 2

If not what visual queries can you not answer?
User 1: Cannot find loan values, Cannot find where Tenors do not match.
User 2: Cannot find loan values, Cannot find where Tenors do not match. Cannot identify how soon sources/ requirements will mature. Cannot identify precise interest rates.
User 3: N/A

A.2.3 Question 3

Are the Information Filters useful?
User 1: Yes
User 2: Yes
User 3: Yes

A.2.4 Question 4

Are the Information Filters intuitive to apply?
User 1: Could be more obvious
User 2: No
User 3: Yes

A.2.5 Question 5

Are there any Information Filters you would add/remove?
User 1: Add an indicator that shows whether requirements are new vs. re-financed
User 2: Add filters to show the unused amount in sources textually and interest rate textually.
User 3: No

A.2.6 Question 6

Is the timeline intuitive to use?
User 1: Yes
User 2: Yes, once it was explained.
User 3: Yes

A.2.7 Question 7

Are there any visual cues you struggle to identify or find non-intuitive?
User 1: The glow representing interest rates.The indicators of where Tenor did not match.
User 2: The glow representing interest rates and the timer icons representing tenor, these were too small. The indicators of where Tenor did not match.
User 3: The indicators of where Tenor did not match.

A.2.8 Question 8

Are there any visual features you would like added/ removed?
User 1: An indicator of new vs. re-financed requirements
User 2: Same size triangles (design 2) but no interior triangle icons (design 1). See all the requirements met in a time window. (Met meaning that a loan to the requirement is initiated). A way to focus on a source/requirement while retaining contextual information
User 3: Same size triangles (design 2) but no interior triangle icons (design 1).

B. EVALUTION 2 FEEDBACK

ABSTRACT

This is a record of the results from the second round of end user expert evaluations for the fundmatch low fidelity prototype evaluation.

B.1 Think Out Loud Comments

B.1.1 User 1

The first user was able to navigate the interactive visualization with little trouble. He quickly identified the how the majority of visual queries were answered. He commented that the inclusion of the key was very useful but should be more obviously clickable. One issue he had was that the label of the key in the detail view of sources seemed to indicate the value of the source. He also had difficulty in telling whether the check boxes next to the filer items were related to the icons to the left or right of themselves.

B.1.2 User 2

The second user was able to navigate through the visualization well. However he did not initially notice the filter options nor realise that he could click on sources/requirements for a detailed view. He was able to intuitively answer the visual queries relating to which sources or requirements were linked and once shown that he could turn on the interest rates using the filter he was able to easily answer the visual queries related to interest rates. The one issue he stated regarding the indication of sources/requirements expiring was that within a certain time period it would be necessary to see the number of days left before the tenor of a node ended. Currently, without calculation, it is impossible to identify the precise date a source/requirement expires.

B.1.3 User 3

The user was able to answer all visual queries in a short amount of time with minimal input from the observer. However, she was not immediately aware she could bring up a detail view by clicking on nodes. She instead relied on the key and tool tips to answer visual queries. Once she was made aware of the availability of a detailed view she d continued to make minimal use of it. She did, however, bring up the point that the tenors in detail view were inconsistent. This occurred where the selected node's tenor was stated as an absolute value and the start date was given. However, nodes connected to the selected node had their tenors represented relative to the date from which the detail view was entered by the circular icons. This problem will likely be alleviated by a suggestion that user 1 made during the QA section of the evaluation

B.2 Answers to Interview Questions

B.2.1 Question 1

Can you answer all visual queries using the visualization?
User 1: Yes
User 2: No
User 3: Yes, although some not as precisely as desired.

B.2.2 Question 2

If not what visual queries can you not answer?
User 1: N/A
User 2: Cannot find where Tenors do not match. Cannot identify how soon sources/ requirements will mature, with sufficient accuracy.
User 3: Was uncertain as to how well she could identify when sources/requirements expired in a certain window given the limited functionality of the time line.

B.2.3 Question 3

Could you interact easily with the visualization?
User 1: Yes
User 2: Mostly, filter boxes and icons were too small, key was not obviously clickable.
User 3: Yes

B.2.4 Question 4

Are there any features you would change?
User 1: In the detail view the details of the attached nodes should also be displayed textually to the right of the details of the selected node. There should be a calendar to select specific dates in addition to the time line option.
User 2: Tenors in detail view need to show precise (to the day) expiration dates of nodes
User 3: Icons related to segments need to be included in the key.

B.2.5 Question 5

Are there any features you would add?
User 1: There should be a calendar to select specific dates in addition to the time line option.
User 2: There needs to be a visual cue if sources are over allocated.
User 3: No

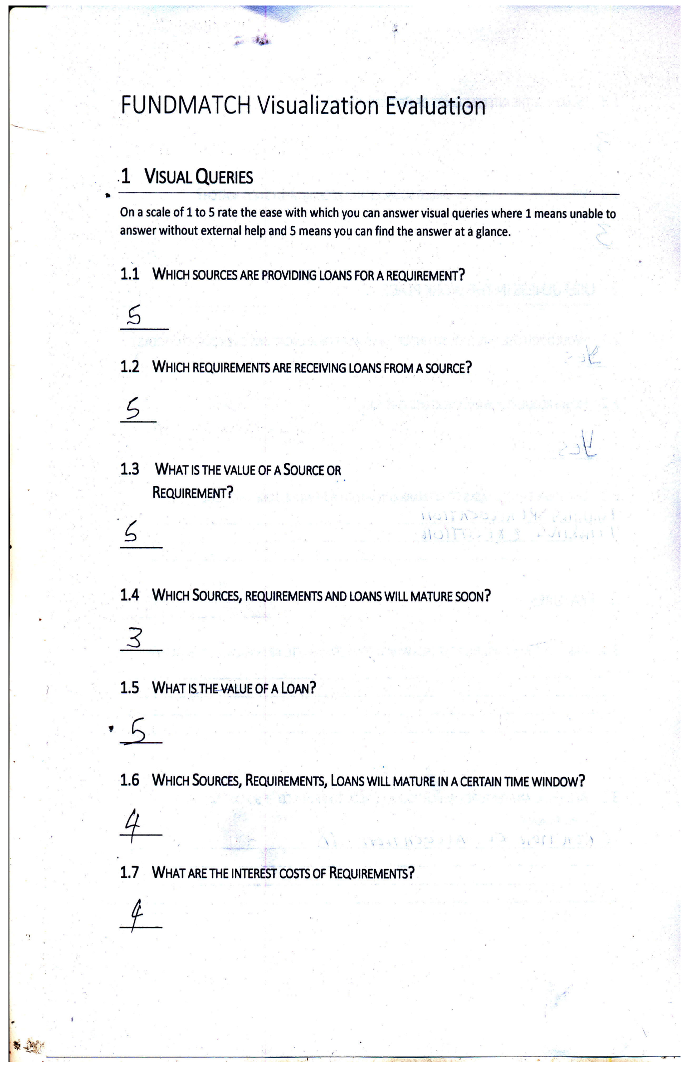
B.2.6 Question 6

Are there any other comments you would like to make?
User 1: No
User 2: It is more important to have precise tenors for sources than for requirements.
User 3: No

C. EVALUTION 3

ABSTRACT

This is a record of the results from the third and final round of end user expert evaluations for the fundmatch high fidelity prototype evaluation.


FUNDMATCH Visualization Evaluation

1 VISUAL QUERIES

On a scale of 1 to 5 rate the ease with which you can answer visual queries where 1 means unable to answer without external help and 5 means you can find the answer at a glance.

1.1 WHICH SOURCES ARE PROVIDING LOANS FOR A REQUIREMENT?

5

1.2 WHICH REQUIREMENTS ARE RECEIVING LOANS FROM A SOURCE?

5

1.3 WHAT IS THE VALUE OF A SOURCE OR REQUIREMENT?

5

1.4 WHICH SOURCES, REQUIREMENTS AND LOANS WILL MATURE SOON?

3

1.5 WHAT IS THE VALUE OF A LOAN?

5

1.6 WHICH SOURCES, REQUIREMENTS, LOANS WILL MATURE IN A CERTAIN TIME WINDOW?

4

1.7 WHAT ARE THE INTEREST COSTS OF REQUIREMENTS?

4

1.8 What are the interest costs of Requirements?

3

1.9 Where do the tenors of linked sources and requirements not match?

3

2 Usefulness in the work place

2.1 Would you use this tool to understand a set of allocations over current tools?

Yes

2.2 How frequently would you use this tool?

Yes

2.3 List some typical tasks or scenarios in which you would use this tool.

FUNDING REALLOCATION
FUNDING EXECUTION

3 Features

3.1 Are there any existing features which you feel need to be improved, if so why?

3.2 Are there any features which you feel need to be added, if so explain their functionality?

CREATION OF ALLOCATION IDS

FUNDMATCH Visualization Evaluation

1 Visual Queries

On a scale of 1 to 5 rate the ease with which you can answer visual queries where 1 means unable to answer without external help and 5 means you can find the answer at a glance.

1.1 Which sources are providing loans for a requirement?

5.

1.2 Which requirements are receiving loans from a source?

5.

1.3 What is the value of a Source or Requirement?

3.

1.4 Which Sources, requirements and loans will mature soon?

4.

1.5 What is the value of a Loan?

1.

1.6 Which Sources, Requirements, Loans will mature in a certain time window?

2

1.7 What are the interest costs of A. Requirements?

4.

A SOURCE.

1.8 WHAT ARE THE INTEREST COSTS OF REQUIREMENTS?

4

1.9 WHERE DO THE TENORS OF LINKED SOURCES AND REQUIREMENTS NOT MATCH?

3

2 USEFULNESS IN THE WORK PLACE

2.1 WOULD YOU USE THIS TOOL TO UNDERSTAND A SET OF ALLOCATIONS OVER CURRENT TOOLS?

TOGETHER

2.2 HOW FREQUENTLY WOULD YOU USE THIS TOOL?

WHENEVER A REQUIREMENT COMES UP OR ROLL OVER OR MATURITY.

2.3 LIST SOME TYPICAL TASKS OR SCENARIOS IN WHICH YOU WOULD USE THIS TOOL.

- MISMATCHING
- AVAILABILITY OF FUNDS
-

3 FEATURES

3.1 ARE THERE ANY EXISTING FEATURES WHICH YOU FEEL NEED TO BE IMPROVED, IF SO WHY?

MATURITY PROFILE OF DEPLOYED SOURCES

3.2 ARE THERE ANY FEATURES WHICH YOU FEEL NEED TO BE ADDED, IF SO EXPLAIN THEIR FUNCTIONALITY?

GRAPHIC REPRESENTATION OF INDIVIDUAL SOURCES OR COMBINATION OF SOURCES

D. DESIGN EXAMPLES WITH INTERACTION

ABSTRACT

Below are a number of images from the paper prototype. These depict the way in which users could interact with the visualisation.

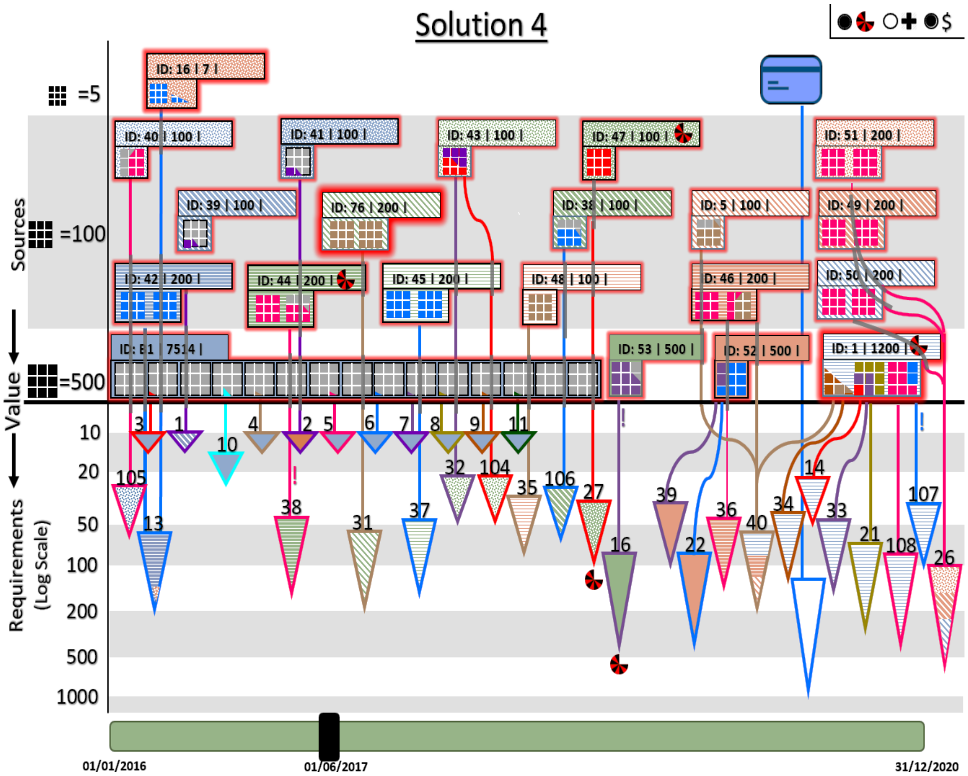


Figure 5: Paper-prototype design 1

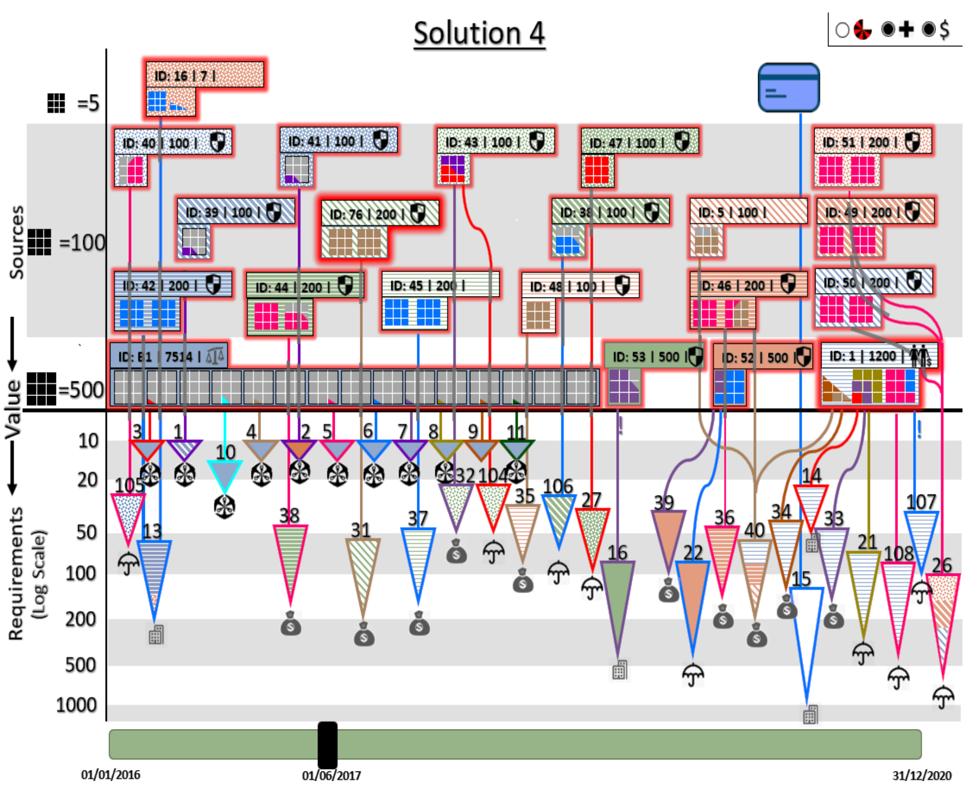


Figure 6: Paper-prototype design 1 with segment icon filter selected

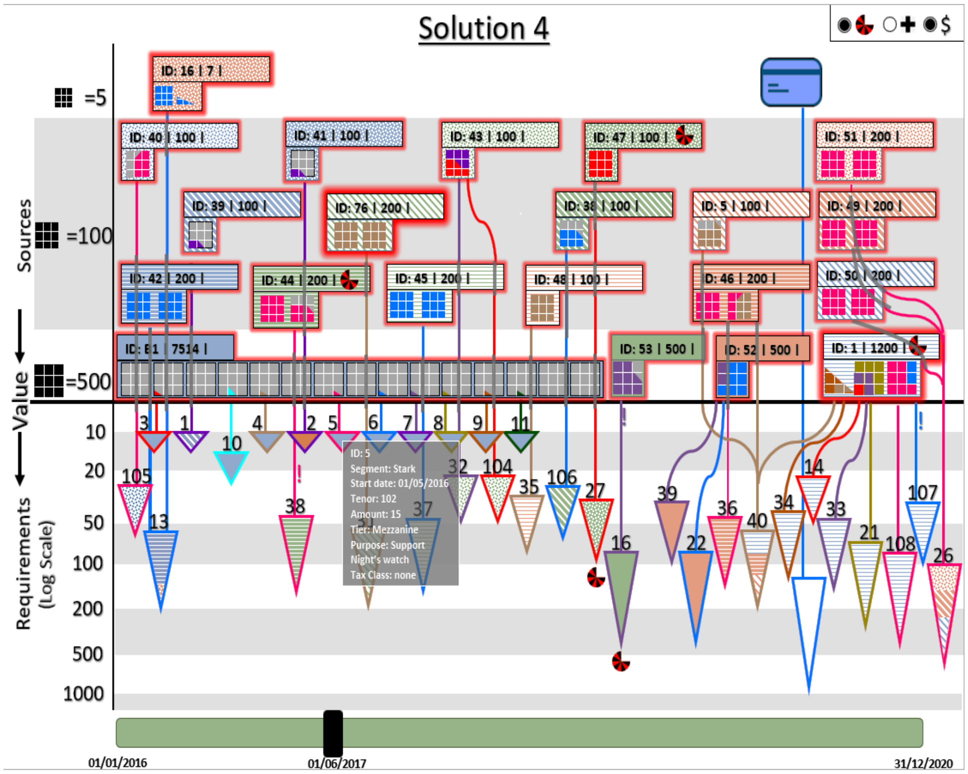


Figure 7: Paper-prototype design 1 with tooltip

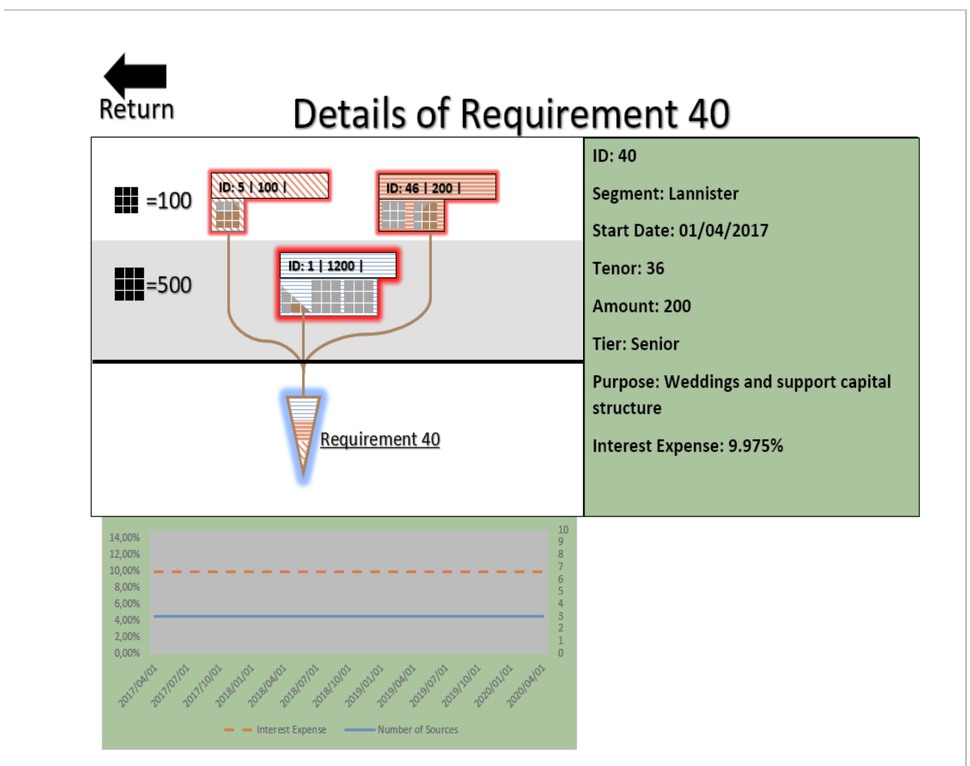


Figure 8: Paper-prototype design 1 detail view

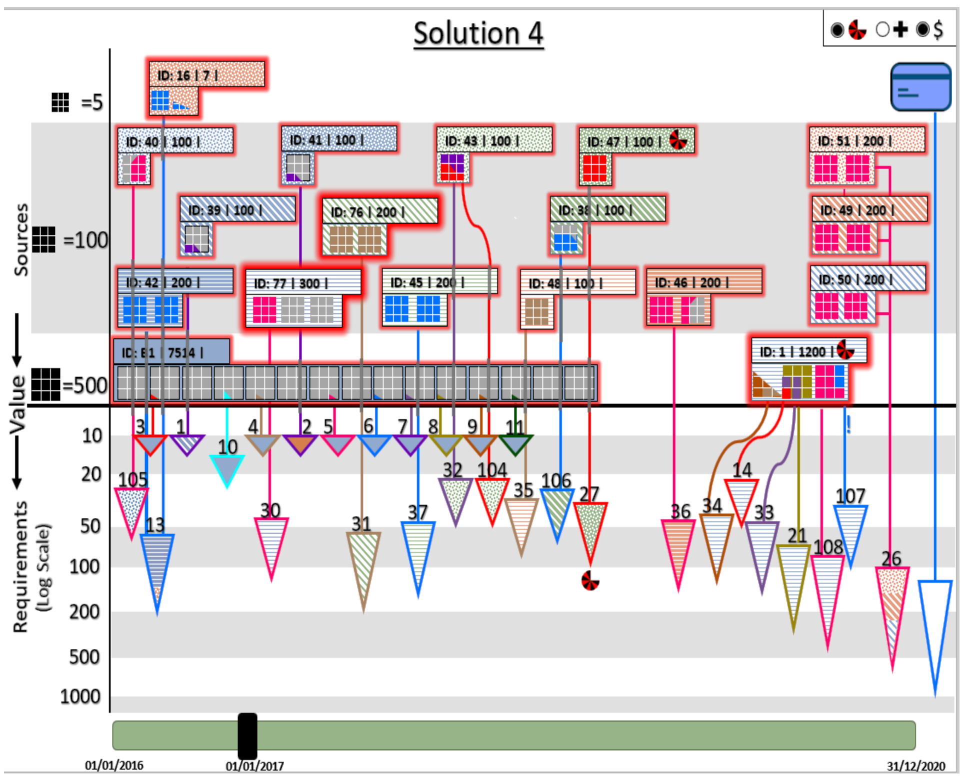


Figure 9: Paper-prototype design 1 at earlier date