Engineering Effective Visual Metaphors for ATM Management Applications

O Saal, E Blake and AE Krzesinski

Collaborative Visual Computing Laboratory
Department of Computer Science
University of Cape Town
South Africa

{oliver,edwin}@cs.uct.ac.za aek1@cs.sun.ac.za
Tel: +27-21-6502670 Fax : +27-21-6899465

ABSTRACT

We have visualised ATM network connectivity with respect to traffic service classes and the logical and the physical structure of the network. We developed a visual representation to display information specific to how an ATM network can alter its *virtual path connection network (VPCN)* as well as a visual metaphor to convey this information in a compact view. Our intention is to provide administrators and researchers with a concise display of the changes in the virtual structure of an ATM network.

1 MANAGEMENT OF COMPLEX ATM NETWORKS

Dynamic reconfiguration has been proposed as a simple and robust resource management control to manage ATM networks. It causes the network to respond optimally to slow variations in traffic call patterns. The network is logically configured as a *virtual path connection network*, or VPCN[4].

An example of a hierarchical control resource management model, *DROP* or *Dynamic Reconfiguration and Optimisation Program*, has been developed by the University of Stellenbosch[2, 3].

This model employs an algorithm which changes the virtual network structure to accommodate and optimise the utilisation of *origin-destination-* or *OD* pair capacity. The reconfiguration occurs when there are changes in traffic demands causing the network to restructure and adapt to the new load.

Because dynamic reconfiguration is constantly changing the logical network routes, it is difficult to understand the interactions between changing traffic demands and the logical connections on which they are carried.

To this end, we require tools to help administrators manage this network. The data generated by these high speed networks is *complex* and requires training before one can understand its content. A large portion of this data is also *abstract*. This coupled with the large amount of data amplifies the problem of understanding.

To efficiently configure and operate networks, as well as manage performance and reliability for the user, these vast data sets must be understandable. Increasingly, *visualisation* proves key to achieving this goal[5].

This paper examines a new visual representation or *metaphor* to show the connectivity of an ATM network. It highlights problems of past visual tools and shows how our metaphor addresses traditional network tool problems. We outline the design of our ATM network metaphor and provide subjective testing results to support our design objectives.

2 PAST NETWORK VISUALISATION TOOLS

Processing complex information is best achieved through visual representations and images. In most visual applications, we make use of *metaphors* to allow easy understanding of complex data. A *metaphor* is a graphical object used to represent physical or abstract data. Metaphors relay information through factors such as colour, geometrical shape, location and orientation.

Visualisation can be used to show the performance of ATM network reconfiguration in handling traffic demands and variations, highlighting times when additional capacity might be required, or illustrating the impact of network anomalies.

Conventional network analysis tools tend to concentrate more on the structure of the physical network and less on the VPCN[1, 6]. ATM networks cater for various traffic services and can guarantee a QoS[1] for individual traffic services. Traditional analysis tools often overlook this feature and as a result concentrate mainly on cell level analysis with little regard for the higher level call services.

Past visual network metaphors have also largely employed geographic context as a node placement algorithm. This does not accommodate the abstract data generated by our ATM model. In turn, the geographic layout of nodes causes display clutter when viewing large networks. The clutter is caused when many routes overlap or obscure each other. Since the abstract data places greater emphasis on logical connections, we need to consider metaphors which minimise the geographic importance of the network model.

Many past metaphors do not address the following ATM features adequately:

1. **dynamic reconfiguration**,
2. **abstract data**,
3. **network scalability**.

Other important design goals for a good network metaphor include:

1. **easy learnability of the metaphor**
2. **correct and concise understanding of the network**.

[1] Quality of Service

NetView is a network visualisation tool developed at University of Cape Town. *NetView* provides metaphors which interpret the current condition and performance of the VPCN network in a visual three-dimensional representation.

The following section outlines the design of our main 3D metaphor to monitor ATM network connectivity. We list its main advantages and the network data it represents.

3 PLATTER METAPHOR AND CURRENT SYSTEM IMPLEMENTATION

The *platter metaphor* has been developed over several months between the University of Cape Town's and Stellenbosch University's Computer Science departments[8, 9]. It is the result of several prototypes designed to show detailed information about our ATM reconfiguration application. Its has numerous features which make it particular useful for ATM applications such as dynamic reconfiguration:

- Easy to learn (short learning curve)
- Ability to represent abstract network data
- Configurable for various network applications
- Suitable for sparse and large networks

Our current application focuses on the **capacity of individual logical routes** as well as the the **combined capacity for the OD pair**.

Capacity

The *platter metaphor* consists of concentric rings forming a platter shape. Each ring represents a predefined capacity. As platter rings progress inwards, towards the centre, the capacity increases. Figure 2(d) shows the rings of the platter.

Logical routes

The platter metaphor uses *logical routes* as its data. Each route is represented as a *three-dimensional pillar* on the platter while its capacity is encoded by its closeness or proximity to the platter centre. Routes closest to the centre have the highest capacity for that ATM configuration. Figures 1 and 2 demonstrate the layout and properties of the routes.

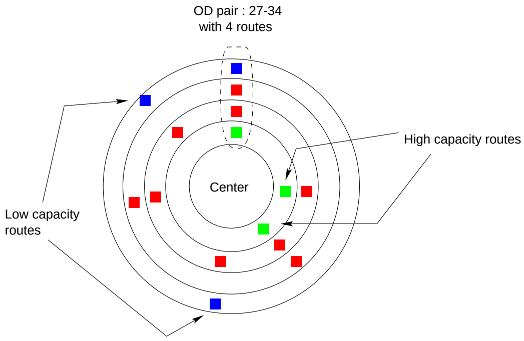

Figure 1: Top down (2D) view of the *platter metaphor*: each square represents a *route with capacity*. Routes belonging the same *OD pairs* are aligned to form a spoke from the centre to the edge of the platter. The capacity of each route is indicated by its proximity to the centre. Higher capacity routes are represented as squares closest to the centre while lower capacities are closer to the platter edge.

Origin-Destination pairs

An *OD pair* is represented by the collection of routes in a straight line projecting from the centre towards the edge of the *platter* (see figure 1). The image formed by multiple OD pairs resembles the spokes of a wheel. Figures 1 and 2 show arrangement of routes to form an OD pair.

There exists numerous advantages to this design:

1. *Clutter* can be minimised by aggregating a number of routes into a single pillar.

2. Route information can be represented using the height, radius and material properties of each *pillar*.

3. The *symmetrical design* allows user to spot interesting trends and patterns at a *quick glance*.

4. Overall network context is maintained, allowing users to investigate individual OD pairs without losing focus on other interesting network features.

To confirm the effectiveness of the platter metaphor, we applied the metaphor to our dynamic reconfiguration ATM application. We used this application in a subjective experiment.

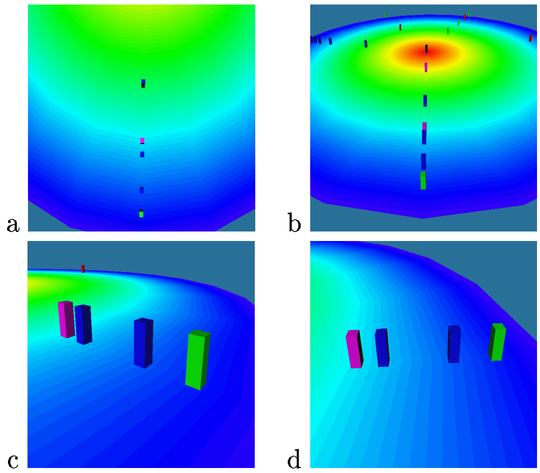

Figure 2: Various screen shots depicting individual routes and OD pairs : (a) Shows the straight arrangement of routes forming an OD pair. (b) An oblique view of each OD pair with the centre of the platter visible. (c) Close up of individual routes. Each route has a colour which represents their logical length in this application. (d) This figure shows the distinct rings which represent a capacity range.

4 SUBJECTIVE EXPERIMENTS USING THE PLATTER METAPHOR

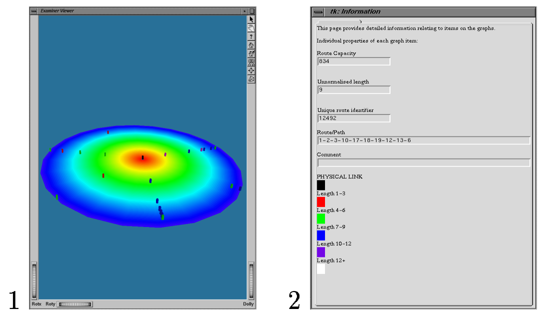

Figure 3: The following figure shows the visualisation setup used in the subjective testing experiment. (a) Oblique view of the platter metaphor (2) Information window showing detailed information about individual routes.

To evaluate the effectiveness of this metaphor, we analyse the metaphor and how well it conveys ATM network reconfiguration information. Two important hypotheses were investigated:

1. H0: Time taken to learn and interpret the

metaphor.

2. H1: Correct interpretation and understanding of current network conditions

Our experiment is suited to subjective testing because it engages users and their understanding of the data. We recruited network administrators and researchers to perform this experiment. These subjects are representative of the actual users who will make use of this tool in their work. Their responses to a network questionnaire based on the metaphor will be recorded and analysed to evaluate the advantages or drawbacks of the metaphor.

It is difficult to quantify knowledge gained through visualisation. This is well recognised as a problem of measuring subjective understanding. To this end, we approached testing our hypotheses by segmenting the questionnaire into distinct sections. Each section requires varying network skills to answer its constituent questions successfully.

We analysed the scores for each section against the expected score of an experienced ATM network administrator. We obtained the *expected ATM administrator scores* by observing the minimum, mean and maximum scores of ATM administrators in the experiment. Our hypotheses can be analysed by comparing the recorded mean scores against the expected ATM administrator scores.

4.1 SUBJECTIVE TESTING

The subjective experiment required subjects who have experience in network management or system administration. The format of the experiment is designed in the following manner:

1. Tutorial (group or individual)

2. Questionnaire (individual)

The tutorial phase is a 10 to 15 minute learning session for subjects. It is conducted either using a single or pair of subjects. This phase introduces the *platter metaphor*, the *problems* it addresses and an *example of its implementation.* Subjects have the opportunity to ask questions at the end of the tutorial to verify that their understanding is correct.

The questionnaire phase follows the tutorial phase. Its main purpose is to extract information from each subject on their understanding of the current network properties. Each subject is isolated in a room with a multiple-choice questionnaire and a computer containing the metaphor program.

This questionnaire has five sections:

1. Physical appearance of the metaphor

2. Extraction of quantitative network information

3. Direct interaction and extraction of detailed route information

4. Problem solving using information contained in the metaphor

5. Making administrative decisions based on the information provided by the metaphor

We base the understanding of subjects on the scores they achieved in the experiment. The scores are separated into *Sections 1 to 4* and *Section 5*. *Section 1 to 4* are based on the properties of the metaphor, the network units and conditions they represent. *Section 5* is an administrative questions asking the subjects to verify properties of the network as represented by the metaphor.

The experiment was conducted by an assistant and myself with at most two subjects at a time. Careful experiment design and a controlled environment are employed to ensure valid, reliable and repeatable results.

4.2 EXPERIMENT RESULTS

We approached the experiment in two phases: a *pilot experiment* to minimise flaws in the questionnaire followed by the *final experiment* to generate our final results. It is accepted as standard practice to conduct pilot tests for first-time subjective experiments[7]. The *pilot experiment* was conducted using Computer Science Honours students. The *final experiment* recruited subjects from the Computer Science and Electrical Engineering departments at UCT. Subjects required some experience in network management or system administration to participate in the final experiment. We recruited 10 subjects (9 males,1 female) from the Computer Science department and 4 subjects from Electrical Engineering.

We compiled and analysed the questionnaire results using *STATISTICA* and *Excel97*.

To reiterate, our main hypotheses are stated as follows:

- H0: Time taken to learn the metaphor is short

- H1: Subjects have a correct and concise understanding of the network conditions.

We present the main findings in tables 1, 2 and 3.

H0 : Timing results

Table 1 show an increasing section time for Section 1 to Section 5. The questionnaire was designed to become more difficult as subjects progressed through each section. As expected, the section times increased. This validates our funnelling questionnaire design which required varied network skills for each section.

Section time(min)	Min	Mean	Max
T1	1	2.64	10
T2	2	4.00	11
T3	2	4.14	10
T4	4	7.64	22
T5	2	5.00	16
Total time	14	23.43	59

Table 1: This table highlights the section and total times for the experiment. The unit of time is minutes. The times are increasing as subjects progress through the experiment. The questionnaire was designed to become more difficult the further subjects progressed. The total mean time highlights a short average time of 23.43 minutes to complete the questionnaire.

The final mean time for the questionnaire phase of the experiment is 23.43 minutes. This is considered acceptable by today's standards. It is not uncommon to have network tools which require hours or days of training before subjects have adequate grasp of its functionality.

H1: Cognitive results

Table 2 confirms the hypothesis, *H1*, which states that subjects have a correct understanding of the current network configuration. The mean scores for all subjects for each section fell into the range expected of an ATM network administrator. The mean scores for *Sections 3 to 5* are close to the upper bound of the expected ATM administrator score. This implies that the platter metaphor is making the more difficult network tasks easier.

In the following sections, we draw our main conclusions and state the significance of the experiment results.

	Mean Score	Expected Score
Section 1	83.93% (3.357)	80%-100%
Section 2	85.57% (3.429)	80%-100%
Section 3	78.58% (3.143)	50%-100%
Section 4	88.10% (2.643)	50%-90%
Section 5	66.08% (2.643)	50%-75%
Total Score	80.08% (15.21)	70%-100%

Table 2: This table shows the mean score for each section and the *total score*. The *expected score* range is provided in the right column. Notice that the *mean scores* for each section falls in the *expected score* range. Sections 3 to 5 show that the mean score is closer to the upper bound of the expected score range. This provides evidence that the platter is well suited for difficult network tasks.

Metric(Final)	Min	Mean	Max	Total
Section 1 to 4	3	12.57	15	15
Section 5	1	2.64	4	4
Total Score	4	15.21	19	19
Total Score(%)	21.05	80.08	100.00	100.00

Table 3: This table shows the means score achieved for partitioned sections in the questionnaire. The questionnaire shows that the mean score is 80.08% with some subjects achieving 100%.

4.3 HYPOTHESES CONFIRMATION

H1 : Time taken to achieve this understanding is small

From the data collected, we have compiled the following results to support our timing hypothesis. We proved that most users are able to learn and comprehend the platter metaphor within 30 minutes. The mean time is 23.43 minutes in the final experiment.

We can also conclude that the difference between novice subjects' (pilot users) and expert subjects' (final users) times is *insignificant*. This implies that neither group is favoured to comprehend the metaphor faster. It has however been shown that their scores are different for Section 5 (Administrative network section), which is expected.

H0 : Subjects have a correct understanding of the network conditions

The primary goal stated that the understanding of the current network configuration was correct. We attempted to show the mean score for each section fell into a score range expected of an ATM administrator. Table 2 provides the mean scores and the expected range.

The final mean experiment score is 80.08%. The results support our primary hypothesis of a mean score lying in the range of 70% to 100%. We were able to show that there exists an good understanding of the *platter metaphor* by all subjects.

5 CONCLUSION

We have refined our visual representation, or metaphor, to visualise the dynamic structure of an ATM network. This metaphor known as the *platter metaphor* was designed to show the connectivity of an ATM network after dynamic reconfiguration. To test the effectiveness of the platter metaphor, we conducted a subjective experiment using network administrators and researchers.

The following hypotheses were investigated and confirmed:

1. Time taken to learn and understand the metaphor is short.
2. Subjects have a correct and concise understanding of the current network conditions.

The experiment was conducted in a controlled environment using experienced researchers. A multiple choice questionnaire was used to elicit responses from the network users.

We compared the results achieved in the experiment against the results expected of an ATM network administrator. The mean score for subjects in this is 80.08%. The mean time taken to interpret a network configuration is 23.43 minutes.

These experiment results support our visualisation design objectives that the *platter metaphor* is beneficial when administrating abstract communication network. It requires a short time to comprehend many of its properties. It also emphasises that the platter metaphor does not require expert administrative knowledge to monitor a network. It should be noted that prior administrative experience does aid in making network decisions. This experience will increase as users become more accustom to the tool.

REFERENCES

[1] Richard A. Becker, Stephen G. Eick, and Allan R. Wilks. Visualizing Network Data. *IEEE Transactions on Visualization and Computer Graphics*, March 1995.

[2] S.A. Berezner and A.E. Krzesinski. Call admision and routing in ATM networks based on Virtual Path Separation. In *4th Int Conf on Broadband Communications*, Stuttgart Germany, April 1998. 4th Int Conf on Broadband Communications.

[3] S.A. Berezner and A.E. Krzesinski. Optimal Reconfiguration of Large Manhattan grids. Technical report, University of Natal and University of Stellenbosch, 1998.

[4] JM De Kock and AE Krzesinski. Computing an Optimal Virtual Path Connection network by Simulated Annealing. In *SATNAC98 Proceedings 1st Annual South African Telecommunications, Network and Applications Conference*, pages 611–617. Department of Computer Science, University of Stellenbosch, 1998.

[5] Eleftherios E. Koutsofios, Stephen C. North, and Daniel A. Keim. Visualizing large telecommunication data sets. *Computer Graphics and Applications*, pages 16–19, May/June 1999.

[6] Stephen E. Lamm, Will H. Scullin, and Daniel A. Reed. Real Time Geographic Visualisation of WWW traffic. Technical report, University of Illinois, Unknown.

[7] A.N Oppenhiem. Questionnaire design, interviewing and attitude measurement. Printers Publishers Ltd., 1992.

[8] Oliver Saal, E. Blake, and A. Krzesinski. Visualisation of ATM network connectivity and topology. In *SATNAC99 Proceedings 2nd Annual South African Telecommunications, Network and Applications Conference*, pages 71–78. University of Cape Town, Unviersity of Cape Town Press, September 1999.

[9] Oliver Saal, Jinsong Feng, E. Blake, and A. Krzesinski. Visualisation of ATM network connectivity and topology. In *SATNAC98 Proceedings 1st Annual South African Telecommunications, Network and Applications Conference*, pages 71–78. University of Cape Town, University of Cape Town Press, August 1998.