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Information visualization of the minority game

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Abstract. Many dynamical systems produce large quantities of data. How can the system be understood from the output data? Often people are simply overwhelmed by the data. Traditional tools such as tables and plots are often not adequate, and new techniques are needed to help people to analyze the system. In this paper, we propose the use of two space-filling visualization tools to examine the output from a complex agent-based financial model. We measure the effectiveness and performance of these tools through usability experiments. Based on the experimental results, we develop two new visualization techniques that combine the advantages and discard the disadvantages of the information visualization tools. The model we use is an evolutionary version of the Minority Game which simulates a financial market.

1. Introduction

One important factor concerning many models is that frequently large amounts of data are produced. There is the research issue of how end-users can be presented with this data so that maximum benefits can be attained from the data production. The usual approach like a series of tables or data series plots can help people understand the simple model, but more advanced information visualization techniques [8] are needed to show more complex relationships between multiple data attributes.

For example, many financial models produce massive quantities of data, and trying to understand the interactions between the data and ‘what it all means’ is not a simple task. We ask the question of whether information visualization can aid in the understanding of data from economic models.

In this paper we consider a particular class of information visualization techniques: space-filling information visualizations; and we use data from a particular model: the Minority Game. In [5] we applied existing space-filling visualization techniques to the output of the Minority Game. In [4] we evaluated these techniques using experiments on end-users’ understanding of financial markets modeled by the Minority Game. In this paper we present new space-filling techniques designed to overcome shortcomings of the existing techniques identifier by these experiments.

2. The Model

The Minority Game [1,2] is a game consisting of several rounds where an arbitrary odd number of players choose one of two possible options each round. The two options could be zero or one, A or B,

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buy or sell, or any two things indicative of a competitive situation where there are two possible options the agents involved can choose from at any given point in time.

Each round of the game results in a majority of players choosing one of the options. The players who did not choose the majority option are in the minority and are the winners of that particular round. Each player has a score, and their score increases when they win a round.

The number of winning players each round can range from 0 to $(n-1)/2$, for a game involving n players. Each of the players can remember the winning option (the option chosen by the minority of players) for the previous m number of rounds. This m represents the memory size of each player, and is fixed for all players.

Each player is able to remember the previous m winning options, they also have a set of s strategies, each of which determines what option they should choose for the current round based on the history of previous winning options. For m rounds there are 2^m possible winning histories – thus each strategy has a size of 2^m (one bit representing the option to choose for each of the possible winning histories).

There are many variations on the Minority Game. We consider players to be agents (companies) in a financial market. Their score represents their capital stock. In our version of the game evolution occurs periodically with losers being replaced with clones of those agents with the largest capital (the winners).

3. Visualization

The usual visualization of data from the Minority Game is in a time plot at each round. It may be of the signal, number of winners, average capital stock, etc. Yet often users are concerned with other questions. For example: do the winners follow similar strategies? What is the effect of evolution on the signal?

The data from the Minority Game can be stored or represented by a tree data structure. Nodes can store data such as capital and strategy, and the edges can represent the evolutionary history of the agents. We use such a data structure to store data at each evolutionary step. At each step, the old agents become the ancestor agents of the new agents. For example, in figure 1 there are 3 agents in time $t1$. When evolution occurs, say agent A is the agent with the highest score. It duplicates itself as A^* in the next time step $t2$. Agent B, who has the lowest score, is removed out of the game. To retain the same number of agents in the model, a new agent A1 is created as a child agent of the best agent A. Agent C is neither the best nor the worst one, so it only duplicates itself in time $t2$. The root node is the time before the game starts and the leaf nodes are the final evolutionary time-step

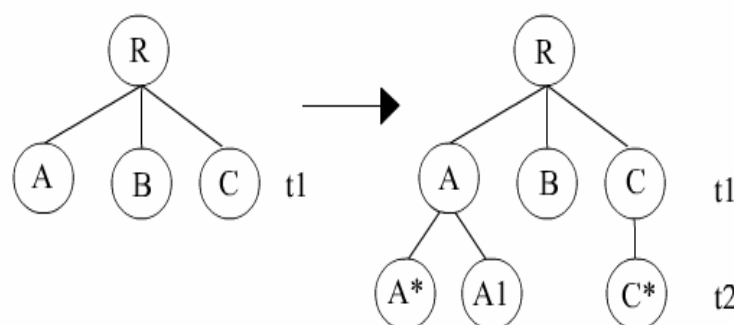


Figure 1. The evolutionary tree of a Minority Game.

Previously we have used the treemap [7,12] and sunburst [9,10] space-filling techniques to visualise the game [4,5]. A treemap uses a rectangular subdivision of space to represent a tree data structure. Figure 2 [11] gives an example of the conversion of a tree data structure into a treemap. We

used a squarified treemap in an attempt to overcome the issues of long thin rectangles appearing in the visualization. We also used a cushioning technique [11] to help the end-user to follow the evolutionary hierarchy. Finally, we used fisheye-lens techniques [3] so that the user could zoom into areas of the diagram. For the treemap we used size of rectangle to indicate the agent's score (capital stock) and used color to indicate strategy. Similar colors indicate similar strategies.

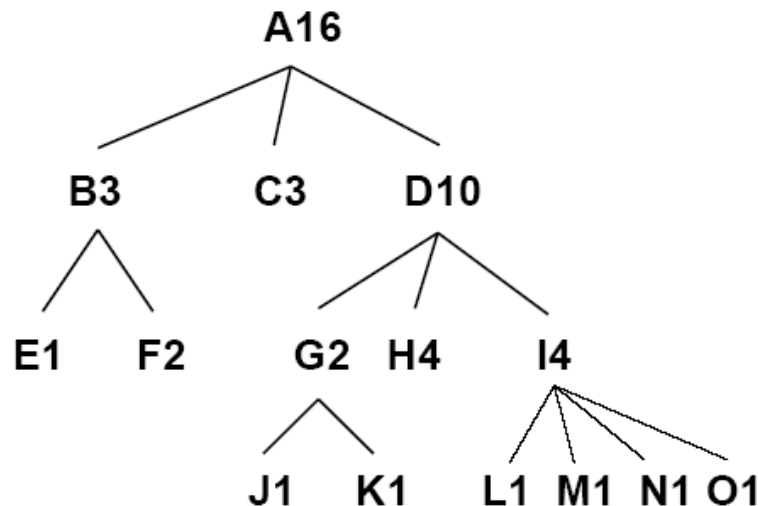


Figure 2a. A tree data structure.

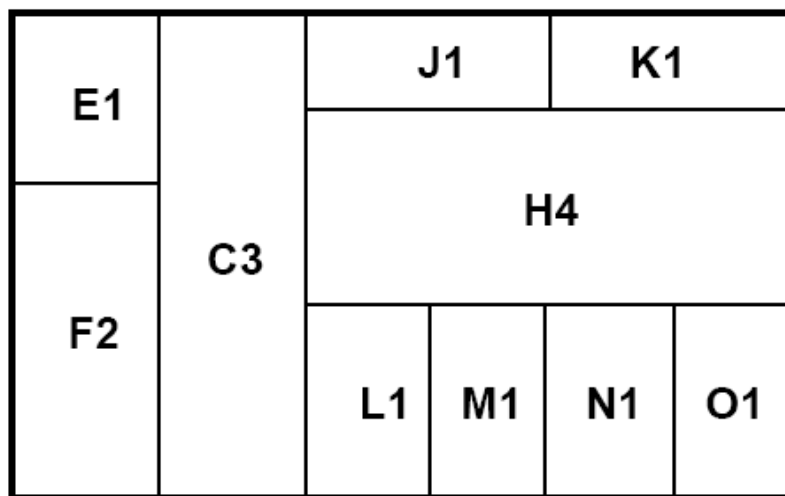


Figure 2b. Treemap visualization of figure 2a.

Sunburst is a radial space-filling visualization technique. It represents hierarchical data structures by separating space into a set of homocentric circles. The area between two adjacent circles represents one level in a tree structure. The circle in the centre represents the root node, with the hierarchy moving outward from the centre. Each circle can be separated into segments by radial lines. Each segment represents a node of the hierarchy. Child nodes are drawn within the angle occupied by their parent node. For more details see the sunburst Web site [9].

Similar to treemap, for the Minority Game visualization we used segment size to represent capital and color to represent strategy. An example of a sunburst used to visualize a Minority Game is given in figure 3.

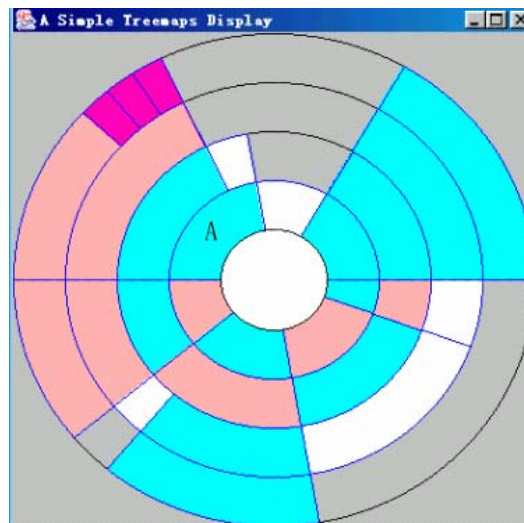


Figure 3. A sunburst visualization of a Minority Game.

In [4] we conducted usability experiments. A subjective questionnaire revealed that users prefer sunburst over treemap. From the usability experiments we drew the following conclusions:

- Sunburst is better than treemap in searching for the company with most capital.
- With a small data set it is easier than with a large data set to search the company with the most capital.
- Sunburst is better than treemap in comparing the locations of companies in the evolutionary hierarchy.
- With a small data set it is easier than with a large data set to compare the locations of companies in the evolutionary hierarchy.
- Sunburst is better than treemap in understanding the minority game model through exploring the visualization over time.
- With a small data set it is better than with a large data set to understand the minority game model through exploring the visualization over time.
- For simple tasks, fisheye-lens is not necessary, and using fisheye-lens can decrease the performance of the visualization tool.

4. New Space-Filling Techniques

The main contribution of this paper is to present two new techniques that extend sunburst, exploiting end-users' subjective preference for this technique, while incorporating the objective benefits of treemap. In particular, these new techniques attempt to overcome sunburst's shortcomings when comparing the capital of companies based on node size, and for the visualizations to make use of the available (rectangular) screen-space. The first of our new techniques we call a *filled sunburst*. A filled sunburst is a radial space-filling visualization technique, much like the traditional sunburst. However, in a filled sunburst all companies at the same level in the evolutionary hierarchy have the same angular size. To represent a property of the companies (such as their capital), a proportion of each segment is filled with color from the inner circle towards the outer, as shown in Figure 4(a) – the size of this proportion represents the value of the property. As with the traditional sunburst, the color used to fill the segment can represent another property of the companies (such as their strategies).



Figure 4a. A filled sunburst.

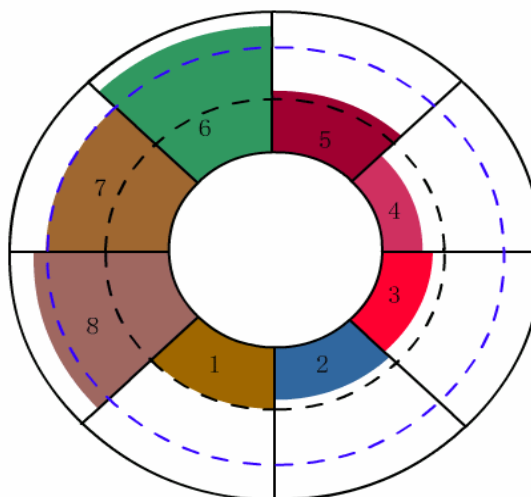


Figure 4b. A filled sunburst with “marking”.

This technique overcomes an issue of both sunburst and treemap in that the capital of companies can easily be compared across *all* companies, not just those companies which are children of the same parent in the evolutionary hierarchy. To further enhance this capability, users should be allowed to “mark” the visualisation with concentric circles that show the size of the filled region for one or more companies – all other companies can then be easily compared against these marks. This is illustrated in Figure 4(b). Alternatively, instead of increasing the proportions of the segments which are filled, users can chose to increase the size of the segments themselves by changing the radii of the concentric circles which make up the filled sunburst visualisation. This fisheye-lens technique allows users to focus their attention on one (or more) levels within the evolutionary hierarchy while retaining the context within the overall visualization.

The second new technique proposed in this paper is a *hybrid sunburst/treemap*. This technique attempts to overcome a fundamental problem of both traditional and filled sunburst visualisation, in that they are circular whereas most computer displays are rectangular! The hybrid sunburst/treemap works by placing a rectangle vertically in the centre of the visualization to represent the root of the evolutionary hierarchy. Then, the children of the root are partitioned so that roughly half are to the left

of the root and the rest are to the right. Lower levels of the evolutionary hierarchy are placed beside their parents – child companies are always drawn within the vertical range occupied by their parent companies. A tree data structure and its visualization are shown in Figure 5. The result is somewhat similar to a rectangular cartogram [6]. The same methods of proportionally filling with colour and marking as are used with the filled sunburst visualisation can be used with the hybrid sunburst/treemap visualisation technique.

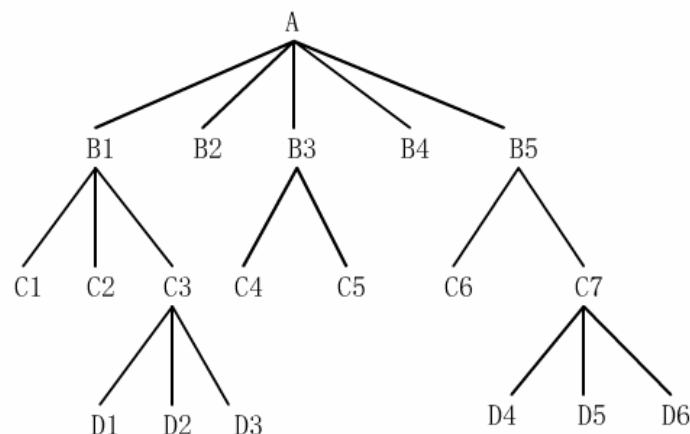


Figure 5a. A tree data structure.

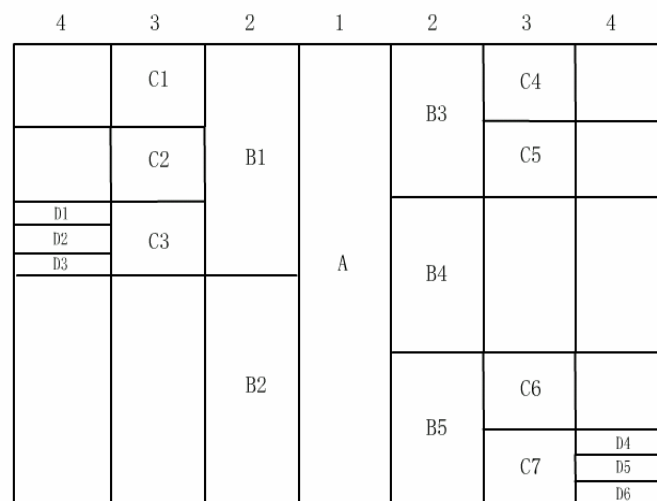


Figure 5b. Hybrid sunburst/treemap visualization of figure 5a.

One disadvantage of the hybrid sunburst/treemap technique is that it still suffers from the “long thin rectangles” experienced by normal treemaps (for example, D1 through D6 in Figure 5). A fisheye-lens technique similar to that proposed by Furnas [3] can be used. The width of each rectangle is scaled according to its “degree of interest” (DOI), which is defined as the number of companies in its level of the evolutionary hierarchy divided by the number of companies in total. The result of applying this technique to the visualization in Figure 5 can be seen in figure 6(a). Note that the left and right rectangles at each level have the same width to maintain the balance of the visualization structure.

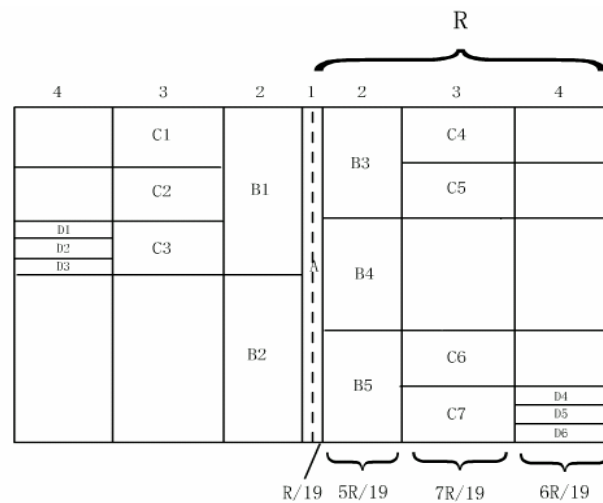


Figure 6a. DOI applied to width.

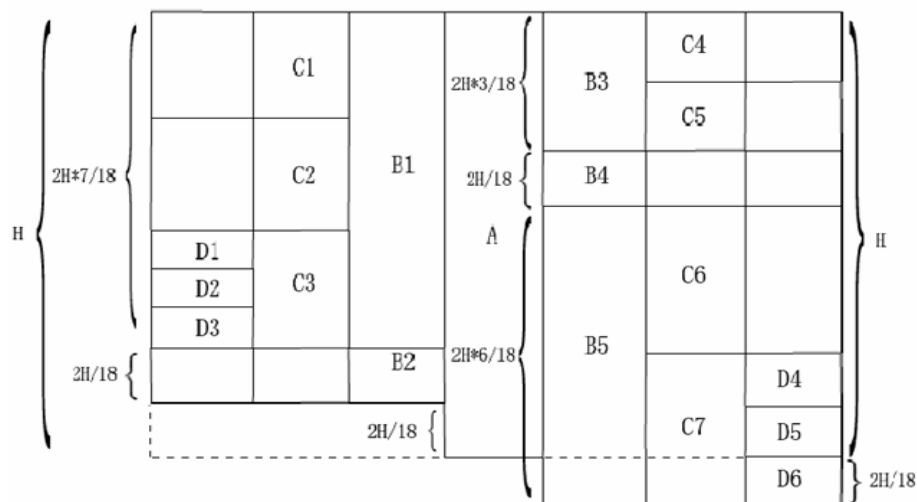


Figure 6b. DOI applied to height.

The DOI method can also be applied to the heights of subtrees in the evolutionary hierarchy by defining the DOI of each subtree to be the number of companies in the subtree divided by the number of companies in total. The height of each rectangle is then scaled by its DOI value. The result of applying this technique to the visualisation in Figure 5 can be seen in Figure 6(b). What is more, the same methods can be applied to the filled sunburst visualisation – level DOI can determine the radius of each circle while subtree DOI can determine the angle occupied by each segment.

5. Conclusion and Further Work

In this paper, we examined the issue of making sense of the large outputs from complex models. We investigated the use of space-filling information visualization tools, rather than the traditional tools of tables and plots. We compared the performance of these two tools through user experiments. Based on the conclusions of experiments, we proposed two new techniques that combine the advantages of traditional space-filling techniques and discarded the disadvantages. In the future research work, we plan to visualize the minority model with these new techniques, and to compare the performance of them with the traditional visualization techniques. We also plan to evaluate the new techniques in some actual applications.

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