Visual Analysis of History of World Cup: A Dynamic Network with Dynamic Hierarchy and Geographic Clustering

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Abstract. In this paper, we present new visual analysis methods for history of the FIFA World Cup competition data, a social network from Graph Drawing 2006 Competition. Our methods are based on the use of network analysis method, and new visualization methods for dynamic graphs with dynamic hierarchy and geographic clustering.

More specifically, we derive a dynamic network with geographic clustering from the history of the FIFA World Cup competition data, based on who-beats-whom relationship. Combined with the *centrality* analysis (which defines dynamic hierarchy) and the use of the *union of graphs* (which determines the overall layout topology), we present three new visualization methods for dynamic graphs with dynamic hierarchy and geographic clustering: wheel layout, radial layout and hierarchical layout.

Our experimental results show that our visual analysis methods can clearly reveal the overall winner of the World Cup competition history as well as the strong and weak countries. Further, one can analyze and compare the performance of each country for each year along the context with their overall performance. This enables to confirm the expected and discover the unexpected.

1 Introduction

Recent technological advances have led to the production of a lot of data, and consequently have led to many large and complex network models in many domains. Examples include:

- Webgraphs, where the nodes are web pages and relationships are hyperlinks, are somewhat similar to social networks and software graphs. They are huge: the whole web consists of billions of nodes.

- Social networks: These include telephone call graphs (used to trace terrorists), money movement networks (used to detect money laundering), and citation networks or collaboration networks. These networks can be very large.
- Biological networks: Protein-protein interaction (PPI) networks, metabolic pathways, gene regulatory networks and phylogenetic networks are used by biologists to analyze and engineer biochemical materials. In general, they have only a few thousand nodes; however, the relationships are very complex.
- Software engineering: Large-scale software engineering deals with very large sets of software modules and relationships between them. Analysis of such networks is essential for design, performance tuning, and refactoring legacy code.

Visualization can be an effective analysis tool for such networks. Good visualization reveals the hidden structure of the networks and amplifies human understanding, thus leading to new insights, findings and predictions. However, constructing good visualizations of such networks can be very challenging.

Recently, many methods for visualization of large graphs have been suggested. For example, see the recent proceedings of Graph Drawing and Information Visualization conferences [16]. Methods include fast multi-level force directed methods [12, 11], spectral graph drawing [15], geometric or combinatorial clustering methods [21, 23], and multidimensional methods [13]. However, current visualization methods tend to exhibit one or more of the following problems: *scalability*, *visual complexity*, *domain complexity* and *interaction*.

Note that some of the network structures exhibit more complex relationships, i.e, multiple relationships, dynamic relationships or temporal relationships. Methods are available for visualization of such temporal or dynamic networks including using an animation or a 2.5D visualization [1, 8, 9, 3, 10, 18].

However, they only considered the dynamics of network topologies, i.e. addition or deletion of nodes and edges based on different time frames. On the other hand, recently a method for visualizing affiliation dynamics of the IMDB (Internet Movie Data Base) was introduced [4].

In this paper, we consider a more complex network model of both *dynamic topology* and *dynamic properties* (or attributes). More specifically, we consider a dynamic temporal network with two attributes: dynamic hierarchy and geographic clustering structure. We present three visualization methods for dynamic network with dynamic hierarchy and geographic clustering: *wheel* layout, *radial* layout, and *hierarchical* layout.

Our methods are evaluated with a social network, history of the FIFA World Cup Competition data set. More specifically, we derive a dynamic network with geographic clustering from the history of the FIFA World Cup Competition data, based on *who-beats-whom relationship*.

Combined with the *centrality* analysis from the social network analysis [2, 24] which defines dynamic hierarchy, and the use of the *union of graphs* which determines the overall layout topology, our visualization methods can clearly reveal the overall winner of the World Cup competition history as well as the strong and weak countries.

Further, one can analyze and compare the performance of each country for each year along the context with their overall performance. This enables us to confirm the expected and discover the unexpected [22].

This paper is organized as follows. In Section 2, we explain our network model with example data set, the FIFA World Cup competition data. We describe our analysis method in Section 3. Our visualization techniques and results are presented in Section 4. Section 5 concludes.

2 The FIFA World Cup Competition History Data Set

Our research was originally motivated from the Graph Drawing Competition 2006 to visualize the evolution of the FIFA World Cup competition history. We first briefly explain the details of the data set in order to explain the network model that we derived from the given data set, which eventually motivated the design of our new techniques.

The FIFA (Federation Internationale de Football Association) World Cup is one of the most popular and long-lasting sports event in the world. As a record of the World Cup history, the results of each tournament are widely available and frequently used by the sports teams as well as the general public. For example, every four years, during the the tournament's final phase, many media outlets analyze such historical record to predict the performance of the teams.

The FIFA World Cup competition history data set has complex relationships between the teams from each country changing over time, thus leading to a set of directed graphs which consist of nodes representing each country and edges representing their matches. Recently, the data set became a popular challenging data set for both social network community (i.e. Sunbelt 2004 Viszard Session) and graph drawing community (i.e. Graph Drawing Competition 2006) for analysis and visualization purpose.

More specifically, the data set contains the results of all the matches played in the final rounds since the Cup's founding in 1930. The FIFA has organized the World Cup every four years, but due to the World War II, only 18 tournaments have been held so far.

There are in total 79 countries that have ever joined the Cup's final rounds. Further, they can be clustered based on their geographic locations and the Football Federations. There are six different federations: AFC (Asia), CAF (Africa), CONCACAF (North America), CONMEBOL (South America), OFC (Oceania) and UEFA (Europe).

Therefore, from the data set, we can derive a series of 18 directed graphs with the following properties:

- Dynamic network: Each year, the graph has been dynamically changing. That is, some nodes are disappeared and some new nodes are added. In addition, the edge sets are dynamically changing based on their matches. There is some overlap of nodes between each year, as most of the strong countries joined the final games many times.
- Temporal network: Each network has a time stamp. Thus the ordering of each graph is fixed by the time series.
- Geographic clustering structure: Each network can be clustered according to the 6 continental confederations.

3 Analysis for Dynamic Hierarchy

In this section, we now describe how to define a dynamic hierarchy for the dynamic network of the FIFA World Cup.

The overall result of each match can inherently define a hierarchy between countries. Some countries won many matches, whereas the other countries lost many matches. Furthermore, some countries joined the final game many times, whereas the other countries joined only a few times. Obviously, the most interesting question to ask is to analyze the overall winner of the World Cup history, and to identify the top countries of strong performance in order to predict the next winner.

Based on the previous *centrality* analysis from the Sunbelt 2004 Viszard Session, we also used the centrality analysis from the social network analysis to define a hierarchical attribute for each node in the network. Centrality index is an important concept in network analysis for analyzing the importance of actors embedded in the social network [2, 24]. Recently, centrality analysis has been widely used by visualization researchers, see [2, 6, 7, 19, 20]. Note that in our case, the centrality analysis define a dynamic hierarchy, based on the performance of each country in each year.

In particular, we compute both the overall performance and the performance of each year, to confirm the expected events and detect the unexpected events. For this purpose, we designed a new approach based on the *union* of a dynamic graph as follows.

For each year, we construct a directed graph $G_i, i = 1, \ldots, 18$, based on the results of matches in each year. Then, we construct the union of graphs $G = G_1 \cup G_2 \cup \ldots \cup G_{18}$ in order to analyze the global performance.

There are many centrality measures available based on the different definition of the importance in the specific applications, such as degree, betweenness, stress, and the eigenvalue centralities. For details of each definition, see [2, 24].

We performed several centrality analysis on each G_i as well as the union graph G, as used in the Sunbelt 2004 Viszard Session. Based on the results, we finally chose the *degree* centrality to roughly approximate the overall winner.

Degree centrality $c_D(v)$ of a node v is the number of edges incident to v in undirected graphs. The use of degree centrality makes sense, as in general, strong teams participated and played many times than weak teams. For example, Brazil played in every world cup so far, and won against many teams.

4 Visualization of Dynamic Networks with Dynamic Hierarchy

In this section, we now describe our new layout methods for visual analysis of dynamic networks with dynamic hierarchy: wheel layout, radial layout and hierarchical layout.

4.1 Wheel Layout

In the *wheel* layout, we place each country in the outermost circle of the wheel, and then represent the performance (i.e. the centrality value) of each country for each year using the size of nodes along each wheel as an inner circle.

More specifically, we first divide a wheel into 6 wedges based on the federations clustering, and then place each country inside each wedge alphabetically in counter-clockwise order. Alternatively, one may use the centrality values instead.

The centrality values of each country are represented by the size of the nodes along each wheel. The centrality values for the same year form an inner concentric circle with the same node color. The inner circle corresponding to year 1930 is the inner most circle near the center, and the circle corresponding to year 2006 is placed next to the outermost circle. Figure 1 shows a wheel layout based on the degree centrality.

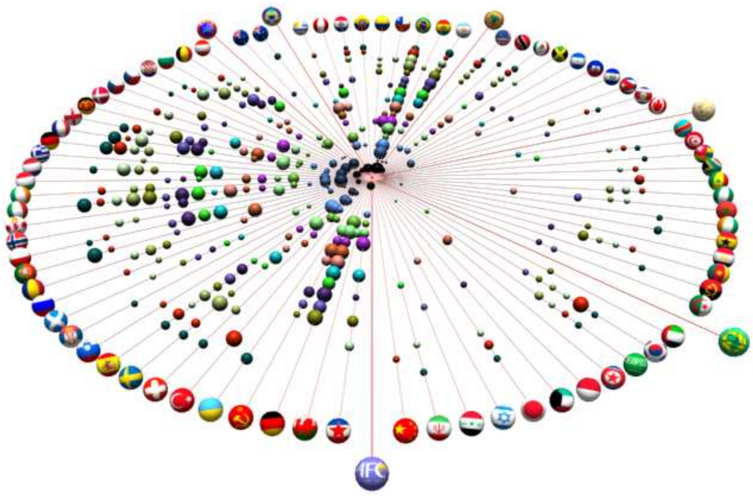

Fig. 1. Wheel layout with degree centrality analysis.

Note that in the wheel layout, the *overview* of the evolution of the performance of each country over the years can be easily seen on its corresponding line. For example, it is clear that Brazil, Germany and Italy are the strongest group in the history of FIFA World Cup, as they have many large circles along the wheel.

Moreover, one can compare the performance between countries of a specific year, by inspecting the sizes along the concentric circle represented by the same color.

Furthermore, one can easily compare the performance between the continents and inside each continent. For example, in general the European countries are much more stronger than the other continents. Among the Asian countries, South Korea performed relatively well.

In order to reveal the evolution of the performance in the history of FIFA World Cup, we created an animation, which is available at: http://www.cs.usyd.edu.au/ visual/valacon/awards.htm

However, one of the disadvantage in the Wheel layout is that it does not show the network topology structure of each graph. To support this property, we designed a radial layout and hierarchical layout, which clearly display the network structure of each year to find out more *details*.

4.2 Radial Layout

In order to simultaneously display the network topology and the performance, we used a radial drawing convention from the social network analysis for displaying centrality. That is, we place the node with the highest centrality value in the union graph G at the center of the drawing, and then place the nodes with the next high centrality values using the concentric circles. However, we made the following important modifications.

First, instead of using the exact centrality value for each node to define each concentric circle, which may end up with too many circles, we used some abstraction. We divide all the countries into a winner plus 3 groups (i.e. strong, medium and weak), based on the range of their centrality values. Then we place the strong group in the innermost circle, and place the weak category in the outermost circle.

Second, in order to enable simultaneous *global* analysis (i.e. overall performance) and *local* analysis (i.e. performance of the specific year), we fix the location of each country in each circle of the radial layout, based on the centrality value of the union of graphs G. More specifically, we first divide each circle into federation regions, and then evenly distribute each node in each region, sorted by the centrality values of the nodes in G.

Finally, we use the size of each node based on the centrality values of the graph G_i of a specific year, in order to enable the local analysis.

Note that our approach can achieve preserving the *mental map* [17] of the dynamic networks (i.e. no change of the location of a node in each layout).

More importantly, we can support important visual analysis: confirm the expected (i.e. a node with large size in the innermost circle, or a node with small size in the outermost circle), and detect the unexpected (i.e. a node with large size in the outermost circle, or a node with small size in the innermost circle).

We now describe more specific details of each step.

Circle assignment We divide all the countries into a winner and 3 groups (i.e. strong, medium and weak), based on the range of their centrality values in the union of graphs G. Then we place the strong group in the innermost circle, and place the weak category in the outermost circle.

More specifically, the circle L of each node v is determined by the *normalized* degree centrality value $c_D(v)$ of the union graph G as follows:

$$L(v) = \begin{cases} 0 \text{ if } c_D(v) = 1 \\ 1 \text{ if } 0.45 \leq c_D(v) < 1 \\ 2 \text{ if } 0.15 \leq c_D(v) < 0.45 \\ 3 \text{ if } c_D(v) < 0.15 \end{cases}$$

As a result, Brazil is the overall winner by the degree centrality, and there are 8 countries in the innermost circle: Italy, West Germany, England, France, Spain, Sweden from Europe, plus Argentina and Mexico. There are 21 countries in the middle circle, and 49 countries in the outermost circle.

Node placement and geographic clustering To enable simultaneous visual analysis for both overall performance and performance of a specific year, and to preserve the mental map [17] of the dynamic networks, we fix the location of each country in the radial layout of the union graph G and $G_i, i = 1, \ldots, 18$.

We first divide each circle into 6 federation regions to preserve a geographic clustering and to enable analysis between the continents. Then we evenly distribute each node in each region, sorted by the centrality values of the nodes in G.

To distribute the nodes in each circle evenly, the position of a node v is computed as follows:

$$x(v) = L(v)R(v)\cos(2\pi \frac{i(v)}{N(v)}) \tag{1}$$

$$y(v) = L(v)R(v)\sin(2\pi \frac{i(v)}{N(v)}) \tag{2}$$

where $L(v)$ represents the circle assignment, $R(v)$ represents the radius of the innermost circle, $N(v)$ represents the number of nodes in that circle, and $i(v)$ represents an ordering of the node in the circle.

We also color each cluster in order to support analysis and comparison of the performance of each federation using the area with a specific color. The color codes are: red - UEFA (Europe), pink - CONCACAF (North America), green - CONMEBOL (South America), yellow - AFC (Asia), black - CAF (Africa), blue - OFC (Australia and New Zealand).

Figure 2 shows the result of the radial layout, and Figure 3 shows the union of graph G.

Centrality mapping for local analysis and results To produce a radial layout for each graph $G_i, i = 1, \ldots, 18$, we use the same layout as the union of graph G, with the size of each node represented by the centrality values of the nodes in G_i, in order to enable both the global and local analysis. In addition, as the direction of the edges, which represents "who beats whom" relationship, can be meaningful for detailed analysis, we represent each edge with directions.

Note that our method can support important visual analysis: confirm the expected (i.e. a node with large size in the innermost circle, or a node with small size in the

Fig. 2. Result of circle assignment, node ordering and geographic clustering.

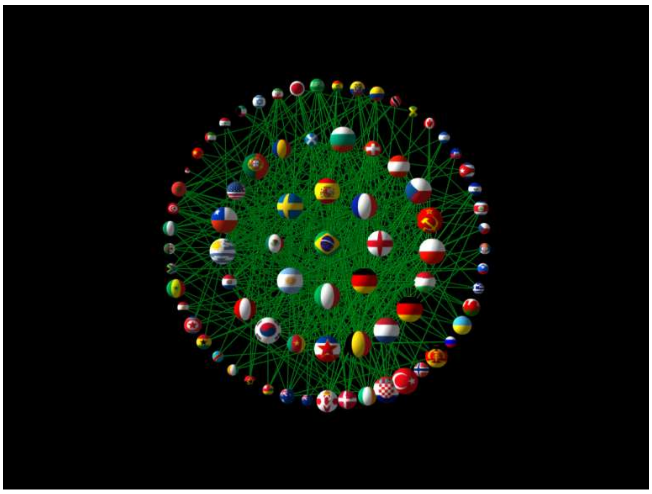

Fig. 3. The union of graphs.

outermost circle), and the detection of the unexpected (i.e. a node with large size in the outermost circle, or a node with small size in the innermost circle).

In summary, in the radial layout, we can analyze each team's performance of a specific year along the context of its overall performance, by looking at the embedded position and the size of a node simultaneously. For example, Figure 4 shows a radial layout of year 2002. It is obvious that Turkey (respectively, South Korea) performed extraordinarily well in that year: the size of the node is one of the top four, although it is placed in the third (respectively, second) circle.

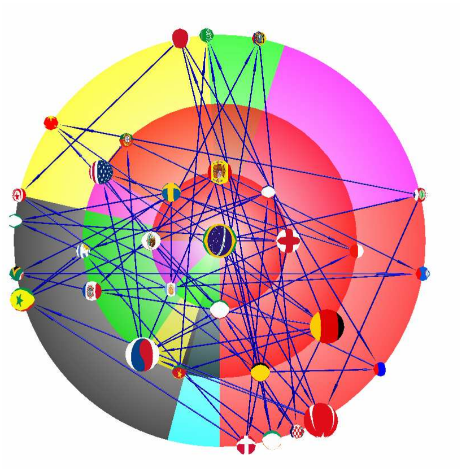

Fig. 4. Radial layout of year 2002.

To show the evolution of the performance of each year (see Figure 5), we produced an animation, which can be download from: http://www.cs.usyd.edu.au/ visual/valacon/awards.htm

A few interesting events can be found out from the animation. The most straightforward finding is the change of rules. In 1982, the number of participated teams increased from 16 to 24, then in 1994, it was expanded to 32. These changes led to more nodes, and more complex relationships between them. Compare Figures 6, 7, and 8.

For geographic comparison, in the early years, the competitions were mainly between the European and the South American counties, thus the nodes were appeared only in some specific region of the layout (see Figures 6). While in recent years, especially after the expansion in 1994, the nodes in the layout are much better distributed, which may indicates a "fairer" game (see Figures 4).

For a specific country, we can see that, Brazil actually did not perform very well in the early years of World Cup history, although now it is undoubtedly the best performer overall. Also, note that from the given data set, one can find West Germany in the innermost circle, and (the united) Germany in the middle circle, and East Germany in the outermost circle.

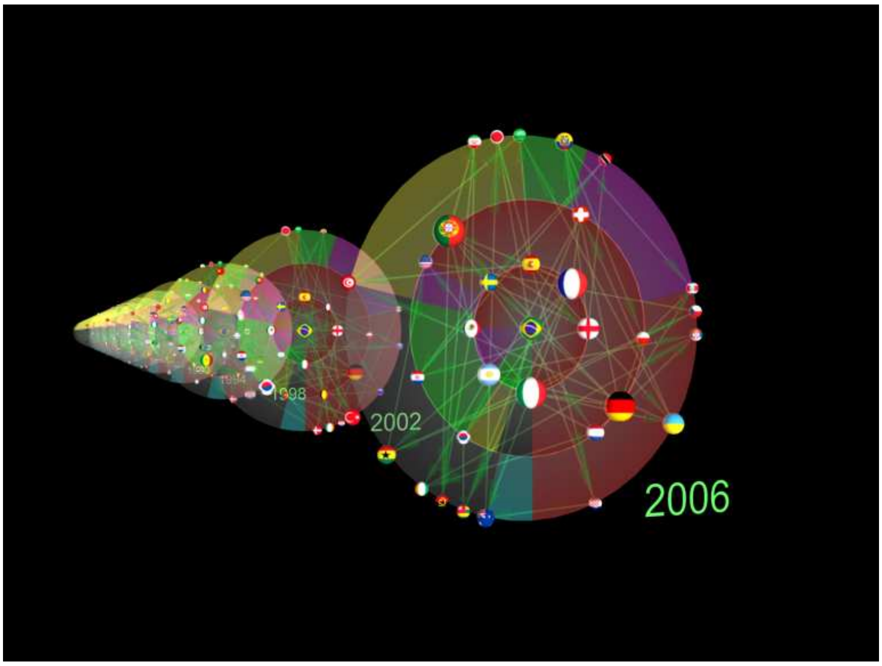

Fig. 5. Evolution of team performance.

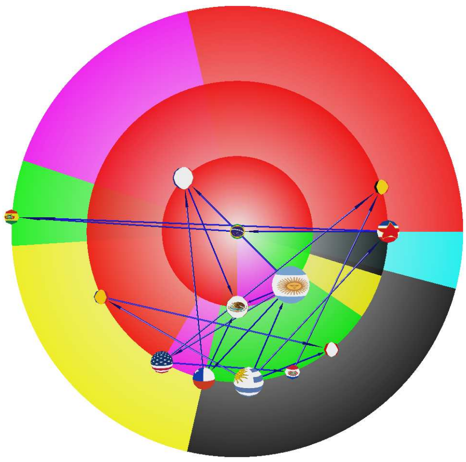

Fig. 6. Radial layout of year 1930 with 16 teams.

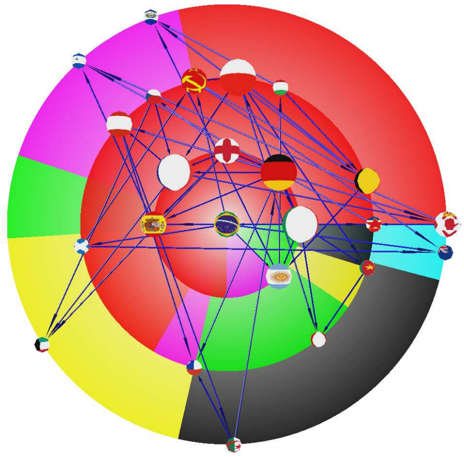

Fig. 7. Radial layout of year 1982 with 24 teams.

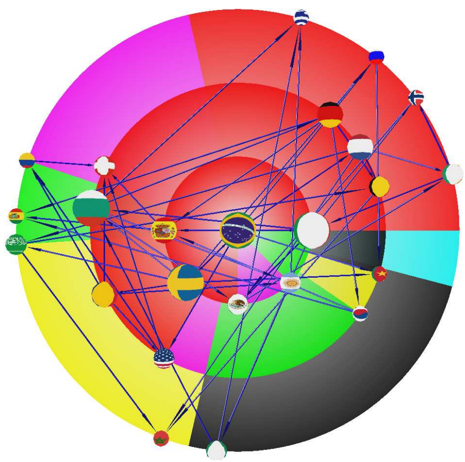

Fig. 8. Radial layout of year 1994 with 32 teams.

In summary, compared with the wheel layout, the radial layout can display the topology of the network, i.e. who-beats-whom relationships. It clearly shows the overall winner, Brazil in the center. Further, visual comparison between regional performance is clearly visible based on the use of coloring.

However, it shows many edge crossings, as the ordering of nodes inside each geographic clustering is not based on the crossing minimization method. This can be improved by using one of the crossing minimization method for radial graph layout, or using a curve representation instead of straight-line edge representation [14].

4.3 Hierarchical layout

As an alternative view of the radial layout for displaying centrality, we also designed a hierarchical layout for displaying centrality. The main idea of using the centrality analysis and the union of graphs are similar to the radial layout. However, there are two main differences:

- For each year, the teams are placed on layers (i.e. parallel lines) instead of concentric circles. The level indicates a team's overall performance: the higher the level, the better the performance.
- In each layer, the football federation clustering is preserved: each federation is shown as a coloured region. Within each region, countries are sorted by their centrality value in decreasing order from left to right.

More specifically, the layout of the union graph G is computed according to the centrality values, as in the radial layout (i.e. into 4 layers with Brazil on the top layer). Once the layering is done, the nodes within each layer are clustered first according to football federation, and then sorted by the centrality value within each cluster.

The resulting visualization of the union graph G is shown in Figure 9. Note that the dominance of the European teams (shown in red region) is very clear.

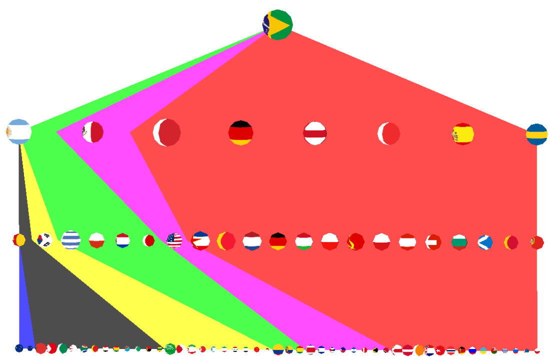

Fig. 9. Hierarchical layout of the union graph.

As with the radial layout, the union graph layout (i.e., the same layering and the same ordering inside each layer) is used for the layout of each individual World Cup graph to preserve the mental map [17] and to support simultaneous visual analysis (i.e. global performance and the local performance).

We also used the size of node to represent the performance of the particular year. In this way, we can confirm the expected (i.e. we expect the countries in the upper layer perform better than the lower ones; similarly, we expect the countries in the left side perform better than the right ones in the same level), and detect the unexpected (i.e. the country in the lowest layer with large node size, or the country in the top upper layer with small size; similarly, the country in the right side with larger node size, or the country in the left side with smaller size in the same level).

The results of the visualization of the entire World Cup history using the hierarchical layout are shown in Figure10.

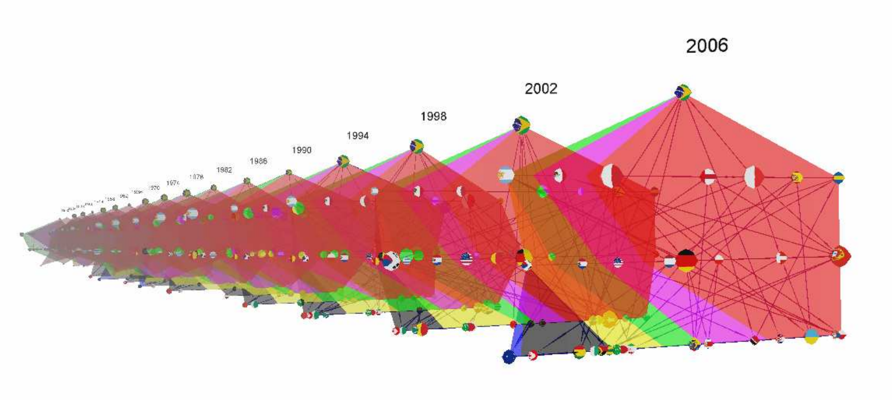

Fig. 10. Hierarchical layouts of the entire World Cup history.

From the layering method, we expect that teams on the upper layer (good overall performance) with large node size (good performance of that particular year). However, this is not always true, as observed in most of the World Cup games. For instance, the performance of Brazil in the top layer was not so good in 1930 (Figure 11), whereas Turkey from the lowest layer performed very well in 2002 (Figure 13).

From the series of hierarchical layout, it is also possible to see the change of World Cup team structure visually. Here "structure" refers to the number of teams in each layer, the ratio of teams from different football federation, and team performance.

For example, the structure of the 1930 World Cup graph (Figure 11) is significantly different from that of the union World Cup graph (Figure 9); whereas recent World Cups, such as 1986 (Figure 12) and 2002 (Figure 13), have a similar structure to that of the union graph.

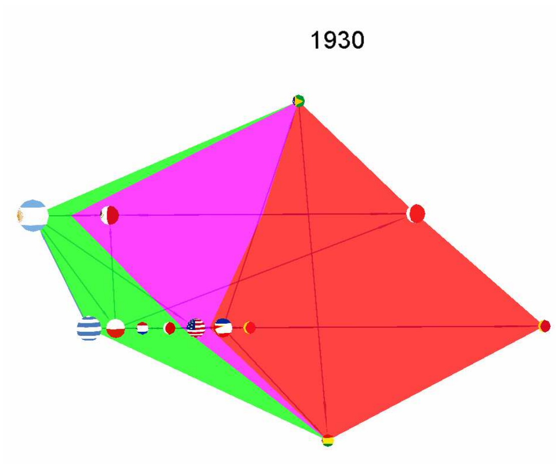

Fig. 11. Hierarchical layout of World Cup 1930.

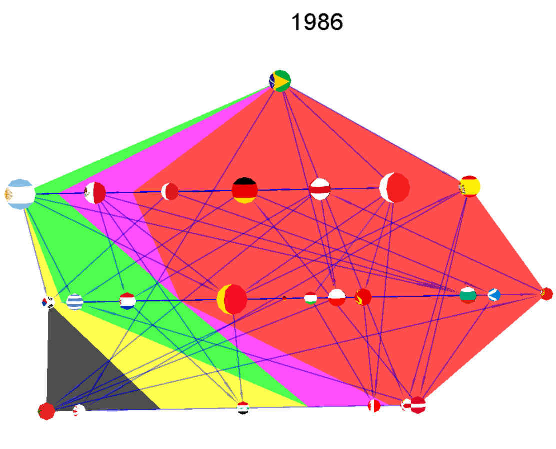

Fig. 12. Hierarchical layout of World Cup 1986.

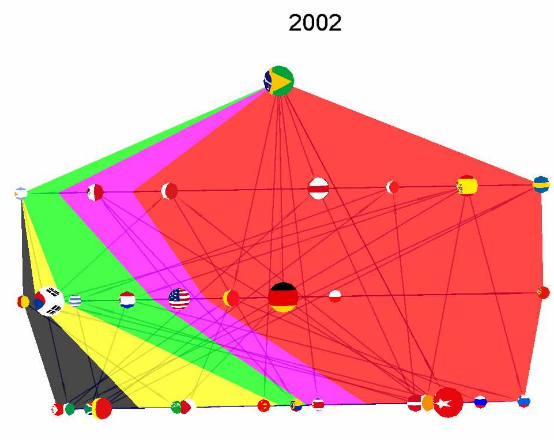

Fig. 13. Hierarchical layout of World Cup 2002.

In summary, compared with the radial layout, the hierarchical layout tends to create less crossings. It also preserves geographic clustering between the layers continuously, which makes the overall visual comparison between regional performance more visible.

However, the use of straight-line edge representation makes some of intra-layer edges not clearly visible. This can be improved by using a curve representation for such case, where any overlap between intra-layer edges occur [5].

5 Conclusion

Three new methods for visual analysis of dynamic networks with dynamic hierarchy and geographic clustering were presented: *wheel* layout, *radial* layout and *hierarchical* layout. Combined with the *centrality* analysis and use of the *union of graphs*, our visualization methods can clearly reveal the overall winner of the World Cup competition history, and identify the strong groups and weak countries.

More importantly, one can analyze and compare the performance of each country for each year along the context of their overall performance. This enables to *confirm the expected* events and *discover the unexpected* events [22].

Further analysis such as evolution of performance of each country, comparison of performance between the continents and inside each continent, comparison between different years are also supported.

For large networks, one can combine our methods with other well-established network analysis methods [2, 24] such as *island*, *blockmodelling*, or *k-core* in order to reduce the size of the network.

Our future work include combination with different analysis methods and more dynamic version of the union of graphs, and integration with interaction methods for each layout to support more detailed findings. A formal evaluation of our methods with different data sets is planned in order to formally support our findings.

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