A Method for the Visual Representation of Historic Multivariate Point Data

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Abstract

The visual representation of multivariate spatial and temporal data is important for interpreting and analysing historical geographic patterns that change over time. The introduction of geospatial technologies in historical scholarship has challenged the suitability of current visual representations due to the need for greater temporal emphasis and the tracking of historical events over time. This research presents a holistic multivariate approach to historical visual representation for point based historical data. The method has been developed through extending the spatial presence in information graphics and through meaningful spatial classification. This paper demonstrates the benefits gained from integrating historical, geographic, temporal, and attribute data through the development of a case study on the history of Melbourne's cinema venues between 1946 and 1986.

1- Introduction

The ability to visually convey historical information is a current issue in historical research. When this historical information is given a geographical context, the complexity of the analysis, interpretation, and subsequent visualisation increases dramatically. Through use of a Historical Geographic Information System (Historical GIS) it has been possible to integrate the disciplines of geography and history. Historical GIS incorporates methods of analysis, data mining, and visual representation of historical spatial data for the aid of historical enquiry, the support of historical

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scholarship, and the analysis of the geographical significance of historical events.

The use of temporal point data within Historical GIS has received increasing interest in many research projects focused on historical events. This interest is evident in the variety of projects that Historical GIS has attracted such as documenting the distribution of witch trials in England in the late 1600s (Ray 2002); challenging the causes of the Great Plains Dust Bowl of the 1930s (Cunfer 2008); and the creation of a European Atlas of Literature (Piatti et al. 2008).

The uniqueness of spatial historical data, through its often unconventional spatial data sources and temporal significance, requires an approach to visual representation that is equally unique in its treatment of the data characteristics. This study recognises that there is a need to develop an approach that considers in more depth the treatment of time and space, multivariate analysis and interpretation, and the importance of visual communication. A review of the visualisation techniques adopted for Historical GIS projects highlights the lack of multivariate representation for point feature data. Whilst there are a number of Historical GIS projects that include multiple variables in analysis (Cunfer 2008; Gong and Tiller 2009), there is little attempt to create a multivariate holistic representation for historic investigation. This research aims to do this through extending the spatial dimension of time-series graphs to enhance the explanatory power of graphic displays (Tufte 2001), and through developing a multivariate temporal visualisation through a cartographic technique rather than technology.

This paper aims to demonstrate the value of visual representations for historical research in the context of exploring the history of cinema venues in Melbourne, Australia between 1946 and 1986.

2- Background

Combining data that is historical, geographic, and thematically changing requires an approach to visual representation that can show the relationships and patterns of all elements concurrently. The relatively new field of Historical GIS has tentatively begun to address the challenges that have arisen from current attempts to visualise the type of data found in historical scholarship. A review of approaches to visual representation in Historical GIS and the challenges that they pose are discussed below.

2.1 Historical GIS

The ability to ask geographical questions, to gain new insights from historical investigation, and to present these insights and findings in a way that stresses the geographical context of the research are the aspects that drives the field of Historical GIS. Applying GIS to different historical projects has been the focus of most research in this area, where historical researchers using GIS often refer to it as *following a GIS approach* (Gregory and Ell 2007). However, the emergence of Historical GIS has given GIS a historical context not only in its application but in its scholarly practice, and supports the claim that it is more than just a collection of methods; it is now being recognised as a subfield within historical studies (Knowles 2008). Historical GIS challenges the traditional mode of communication for historians – narrative communication. As a result, the visual methods used in Historical GIS need to be effective and persuasive in presenting results, supporting evidence, and geographical context so much more so than if applied to disciplines that are familiar with visual communication.

A review of the visualisation techniques used in Historical GIS reveals a number of approaches, the main types being: differentiating and ordered visual variables (Cunfer 2008; Donahue 2008); isarithmic (DeBats and Lethbridge 2005), and choropleth statistical surfaces (Healey and Delve 2007); charts and graphs (Gregory 2000); and three-dimensional representations (Shimizu and Fuse 2006). The treatment of time utilised by almost all of the projects reviewed fell into either a snapshot approach, or timeline/time-series approach. Whilst both are very effective in the spatial sciences, the challenges associated with interpreting change through multiple frames (the snapshot approach), and the lack of geographical context for spatial understanding (a timeline/time-series approach) has hampered their suitability for the representation and analysis of historical events.

3- Approach

The nature of historical events is challenging to describe, especially in the form of a data structure. Based on a review of the important aspects of historical events at point specific locations, a set of criteria was established for the development of the visualisation, being:

1. temporal accuracies were to be maintained
2. aggregation of location and attributes were to be avoided
3. the ability to display multiple attributes concurrently and,
4. to represent the temporal dimension in one image

This criteria is hard to satisfy through conventional techniques found in Historical GIS. As a result, visualising historical events requires an approach beyond the univariate and bivariate representations currently provided. Despite advances in multivariate representations, it remains difficult to present a holistic view of multivariate spatial patterns (Guo et al. 2005). This research proposes a new method of visualising multivariate historical data that addresses the challenges and criteria identified above by creating a visualisation that centres on two main concepts; (1) extending the spatial presence in information graphics; and (2) creating a holistic treatment of time. Both of which will be discussed in the subsections below.

3.1 Extending the Spatial Presence in Data Graphics

Data Graphics make use of a combination of visual variables such as points, lines, symbols, shading, and colour to visually display measured quantities (Tufte 2001). The works of William Playfair (1759-1823) led the way in the principles for fundamental graphical designs, developing time-series, scatterplots, and multivariate displays. Tufte (2001) argues that the use of time-series displays coupled with the spatial dimension, so that the data are moving over space as well as over time, is especially effective for enhancing the explanatory power of time-series data. Time-series graphs have been used extensively in Historical GIS to display information, yet most do not convey the data in its geographical context. Instead, their treatment of location or of the spatial dimension is more abstract.

By taking an abstracted view of space, this research has extended the time-series graphic technique to create a more position oriented representation. A simple graph of a chosen variable against a regular division of time was chosen as the platform of the visualisation. The geographical space was then divided into eight cardinal direction grids, of 45 degree segments, originating from a central location of influence (in this case the CBD). Therefore, the classification of direction from the centre was given to a venue based on where their coordinates fell within the direction grid. This produced a framework of eight time-series graphs (Figure 1).

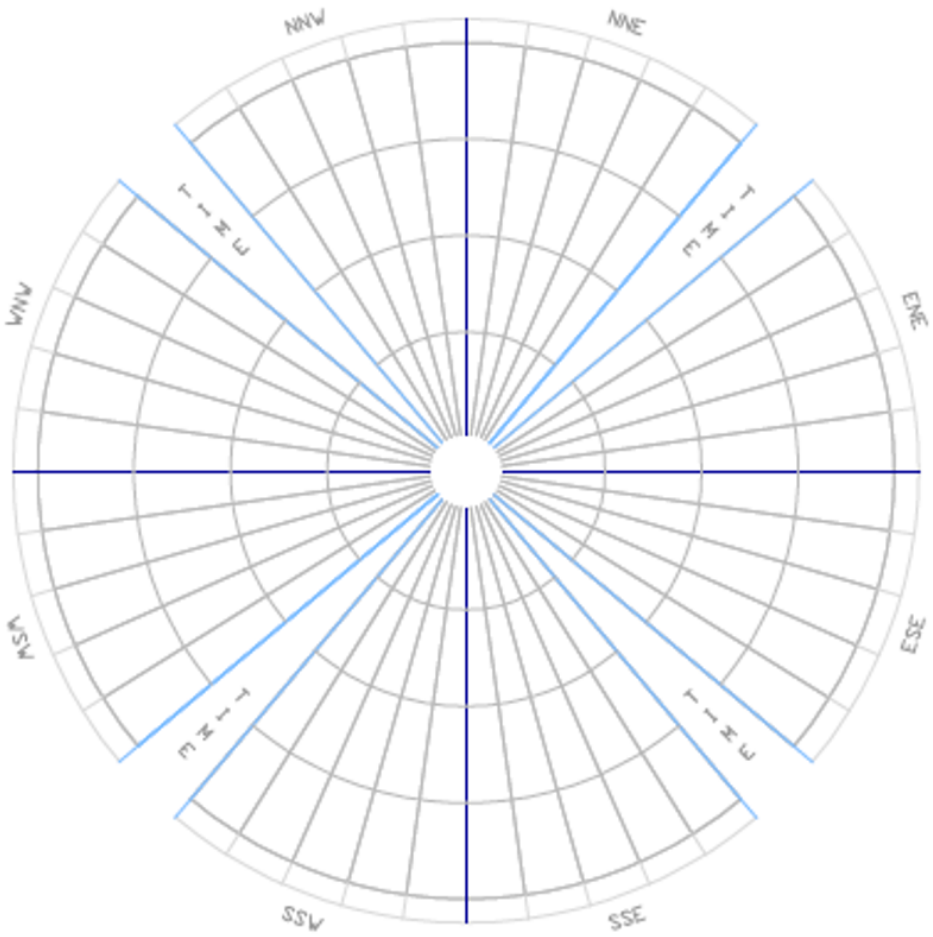

Figure 1: The graphic framework of the combined time-series graphs

3.2 Creating a Holistic Treatment of Time

The time-series approach has created a view of time that encompasses the entire temporal dimension. The ability to recognise change over time was one of the main issues for the data, so for the ease of visual interpretation the temporal dimension was dealt with within the one holistic display. Due to the need of maintaining the exact temporal records collected, it was impossible to present the data using the most common method of time treatment in Historical GIS; snapshots, without resorting to hundreds of sequential images to cover the temporal granularity needed. Time-series enabled the integrity of the temporal records to be maintained.

4- Development of the Visualisation

The history of cinema venues provides an excellent case study for developing a method of visualising change over time for point feature geographic entities. This is because venues, whilst geographically static, have associated variables that change over time such as seating capacity, change in ownership, and change in screen numbers. In the context of this research, the term cinema venue has been adopted from the work of cinema historian Robert Allen, defining venue as the coming together of physical location, agency, and event (Allen 2008). The use of humanities data within Historical GIS is an area of increasing interest largely due to the recent *spatial turn* in humanities studies (Jessop 2008). Several authors have attempted to explain this *spatial turn* in cinema through the term *Cinematic Cartography* which is characterised loosely by the ways in which cinema and cartography have converged (Roberts 2010), forming a hybrid form of cartography (Caquard and Fraser Taylor 2009). Roberts (2010) provides a typology of the varying thematic areas within cinematic cartography, one of which is *Mapping Film Consumption and Production* . Historical GIS is particularly prevalent in this field and has been used both as a way of mapping the geographies of film production and consumption (Caquard 2009b), and in the analysis of geographical patterns of cinema operation and influence (Klenotic 2007; Verhoeven et al. 2010).

The visual techniques used to communicate the information found in these projects include highlighting cinema venues on historical maps (The University Library 2008), tree graphs of Markov Chain analysis (Verhoeven et al. 2010), differentiating and ordering visual variables (Hallam 2009), choropleth mapping (Verhoeven et al. 2009), and graphs (Caquard 2009a). These methods present a number of challenges for visualising historical data such as: the lack of multivariate representations, the static treatment of time, and the lack of visual representations for interpretation and analysis. The following subsections will attempt to address these challenges in relation to the development of a new visualisation method.

4.1 Case Study: Melbourne's Cinema Venues

The approach discussed above was applied to historic cinema venue data from the Cinema and Audiences in Australia Research Project (CAARP) database for the city of Melbourne, Australia. CAARP holds information

on every known venue screening films (whether it be a public hall or technical college) incorporating opening and closing dates, name, capacity, screen numbers, primary purpose, ownership, management, and spatial location (latitude and longitude). Each of these records is time stamped so changes are easily distinguished. The data was extracted from the online database and organised simply into a time stamped relational database for use in ArcGIS. In this case study, the developed approach was used to visually represent chosen variables concerning cinema venue operation in order to explore, investigate, and interpret multivariate spatial patterns over time.

The temporal scale chosen was between 1946 and 1986 and a total of 289 cinema venues operated during this period in Melbourne. There has been very little Australian research into distribution and exhibition practises, especially during the post-war period (Verhoeven 2006), despite it being a time of much cultural change, especially because of the introduction of television in 1956. This research attempts to assist in addressing this deficit.

4.2 Treatment of Space and Time

The spatial organisation of each individual venue is based on the variables of distance and direction. This classification method reduces visual complexity in a meaningful way by taking the spatial coordinate values, street addresses and suburbs and transforming them into classes of direction and distance from Melbourne CBD. Therefore, classification is given to a venue based on where their coordinates fall within the distance/direction grid. Distance has been used in classifying historical spatial data in the area of relational graphics (Fyfe and Holdsworth 2009; Gregory 2008). The method has been adopted for forming part of the classification for Melbourne's cinema venues due to the central location of the city and the influence of distance from the CBD on cinema distribution and exhibition practises. The classes adopted for the visualisation divide the geography of Melbourne into six radial intervals from the CBD and are shown in Table 1, and graphically in Figure 2a.

Just as distance is an influential geographical variable for cinema distribution, so to is the directional location of cinemas from the CBD. The classification of eight cardinal directions have been outlined above, and have been combined with the distance classification to create two venue variables

based around the spatial dimension (see Fig. 2). By not strictly mapping individual venue coordinates, the treatment of space is more flexible and can be utilised in much the same way as any other variable, such as seating capacity or ownership. The spatial classification has the advantages of reflecting the geographical nature of cinema operation whilst still maintaining a position oriented view.

The time-series approach to time treatment was chosen to produce a holistic representation of time and to accurately track the development of a venue over time. Through this method, it is possible to track every individual cinema venue separately throughout the expanse of the timeline and identify the time of change and the type of change that took place.

Distance Class Number	1	2	3	4	5	6
Distance Interval From CBD (Kms)	0 – 1	1 – 5	5 – 10	10 – 20	20 – 50	50+

Table 1: Distances adopted for distance classification

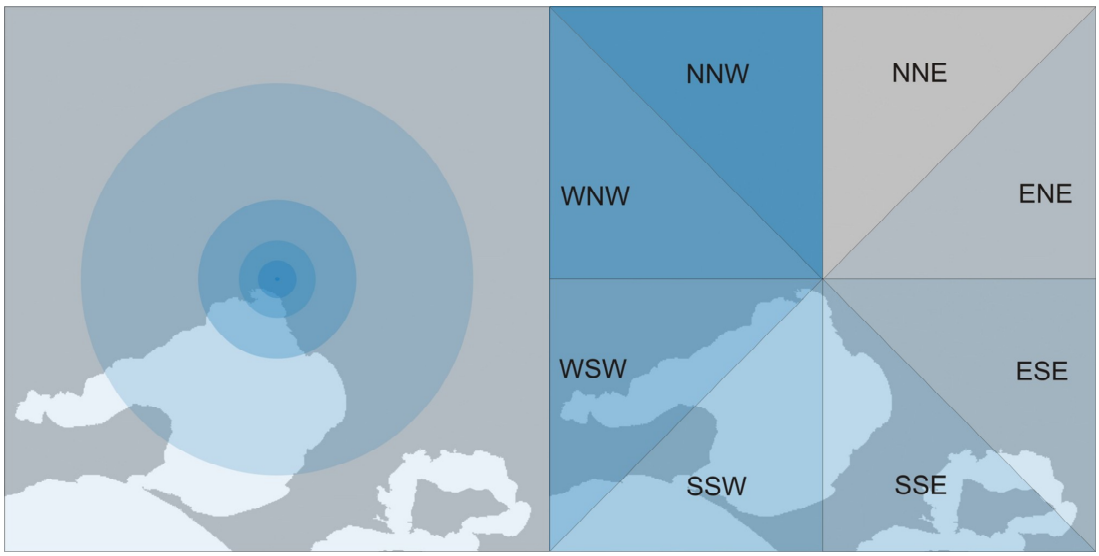

Figure 2a : Distance classification ***Figure 2b :*** Direction classification

4.3 From Point to Line

After the coordinates are used for the spatial classification of each individual cinema venue, the exact location is no longer required. Instead of representing the venues as points in space, these positions are transformed into lines that rest within the spatial framework. Because of its continual nature, a line can be tracked through a time-series far more effectively than

a point. Another advantage of using lines instead of points for representing the venues is the capacity for greater variability. Just as a point can vary the primary visual variables of size, shape, and colour, so too can a line utilising line width, line style, and colour. But when these graphic elements are transferred onto the graphic space, a linear feature can vary in its shape (through changes in direction and curves) and length where a point cannot. This means greater flexibility in use and also greater capacity for representing multivariate data.

By combining these visual variables, it is possible to represent multiple variables in the one display and depict the time in which each of these variables changed. For example, Fig. 3 depicts the history of a cinema venue between 1946 and 1970. The length of the line indicates the lifetime of the cinema, and we can see that it closes in 1967. The central axis shows capacity, and therefore any change in the direction of the curve indicates a change in capacity (a change occurred in 1952, showing a small increase in capacity and then again in 1964, showing a decrease to approximately 750). The colour, line style and line width indicate additional variables; distance, primary purpose, and number of screens respectively. By considering a cinema venue not as a location but as a historical lifetime, it is possible to embrace a more abstracted view of space and achieve a more holistic and multivariate representation for comparison.

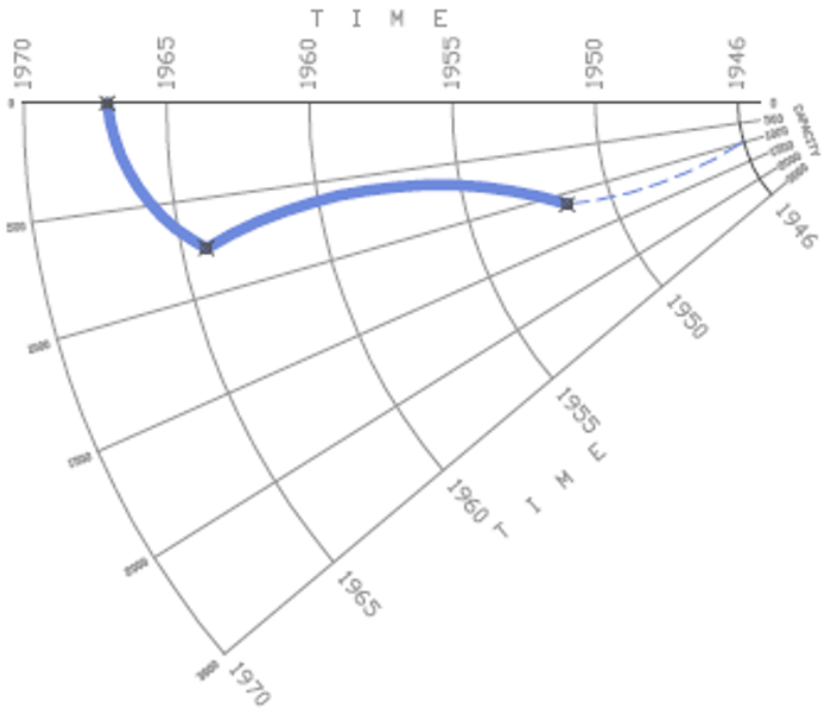

Figure 3: The history of a single cinema venue

4.4 Geographic and Temporal Analysis

The main functions of analysis and comparison can be achieved in a single display due to combining multiple variables, the spatial dimension, and the entire temporal span. It is possible to analyse the changes and characteristics of individual venues and to compare individual venues to other venues in the same area. Visual comparisons and pattern detection can be made for geographic, attribute, and temporal characteristics. Additional analyses can be achieved by manipulation of the main display through selecting those venues based on attribute and spatial classification. This allows certain aspects to be investigated more thoroughly and relationships between variables to be viewed clearly and simply. Fig. 4 shows a set of data for both the main display (Fig. 4a) and then once a selection has taken place (Fig. 4b). In this case, the user has specified to view only those cinemas with a capacity of less than 1000 in order to simplify the results and make the interpretation of patterns clearer.

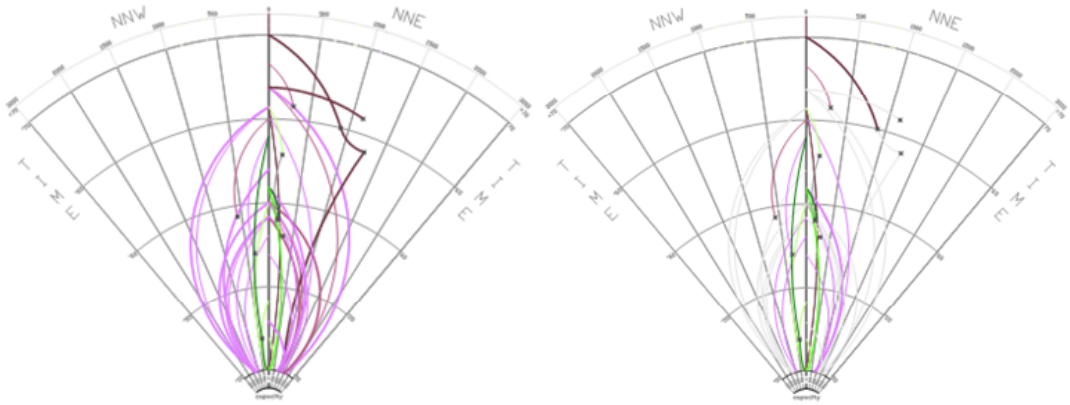

Figure 4a: All capacity records for Northern venues ***Figure 4b***: Northern venues with a capacity less than 1000

5- Case Study Results

This research project involved developing a visual representation in order to answer a number of geographical questions for the data, exploring the geographical distribution, patterns, and differences for all questions. Such questions included: *what is the longevity of cinemas operating in 1946, and how does change affect the longevity of large cinema companies?* An initial exploratory analysis was performed to identify those variables that

were important to display for each question and the relevant data was extracted for visualisation. To show the effectiveness of the derived visualisation only one geographical question will be explored in the subsections below; *how does change affect the longevity of large cinema companies?*

5.1 Development

Large cinema companies in Melbourne operated throughout 1946-86. Exploring the effect change has on the longevity of large cinema companies required assigning visual variables to the chosen attributes, these were:

1. Distance from the CBD – the central axis against the timeline
2. Name of the cinema company – line colour
3. Number of changes between 1946-86 – line width
4. Role of the cinema company – line style

The spatial classification of direction and the temporal dimension is fixed for all questions; time is divided by radial intervals from the centre, and direction is depicted by the cardinal position on the grid. Fig. 5 shows the resulting visual representation of the geographical question. Each line refers to an individual cinema venue and its operation can be traced through time. Many of the venues existed before the study period of 1946 and therefore show their opening date as 1946. Each of the curved lines begins on a grid line to indicate the distance from the CBD (the closer to the central line the closer to the city), and ends on its closing date at the central line. This emphasises the end of the operation of the cinema and also allows for greater visual interpretation when exploring closing dates. The integration of all visual variables presents a single display of all elements concurrently, encouraging multivariate and temporal visual spatial analysis.

5.2 Case Study Findings and Results

The resulting visual representation of the changing nature of large cinema companies demonstrates the capacity for thorough visual analysis of multivariate data over space and time. The total number of lines indicates the number of large cinema venues operating during the time period, yet it is easy to see that this number is not uniform over space or time. The more densely populated North and East of the city have a strong presence of

large companies, the majority of which are found within 20km of the city centre. The large number of converging lines between 1956 and 1966 refers to a large number of closures during this period and is found throughout the extent of Melbourne. The sheer number of closures is also evident if we look at the longevity of those cinemas that were operating in 1946; for only a handful of these cinemas lasted past 1986. We can see a cluster of new cinemas opening between 1965 and 1975, occurring after a short break from the peak of closures, distributed mainly in the East and North of the city. The lack of new cinemas opening in the West outside of the CBD is clearly shown. Indeed, there are no large cinema companies operating in this area past 1975.

Further associations and findings can be found when we interpret the data in relation to the other variables of change, name, and company role. The dominance of the blue curves is indicative of the dominance of Hoyts cinema venues. The large numbers of Hoyts cinemas are found throughout Melbourne and at varying distances from the CBD. However, the majority of these cinemas do not survive past 1970, and of those that do they experience some form of change indicated by the width of the line. This suggests that a Hoyts cinema operating in 1946 would most likely not last past 1970 unless they made adjustments to their cinema such as adding another screen or decreasing seating capacity. Another interesting association is the comparison between Hoyts and the Greater Union Theatres. Greater Union, represented in red, shows that all venues that existed in 1946 adjusted to the times and had a longer lifespan than the average Hoyts; making a possible association between change and longevity.

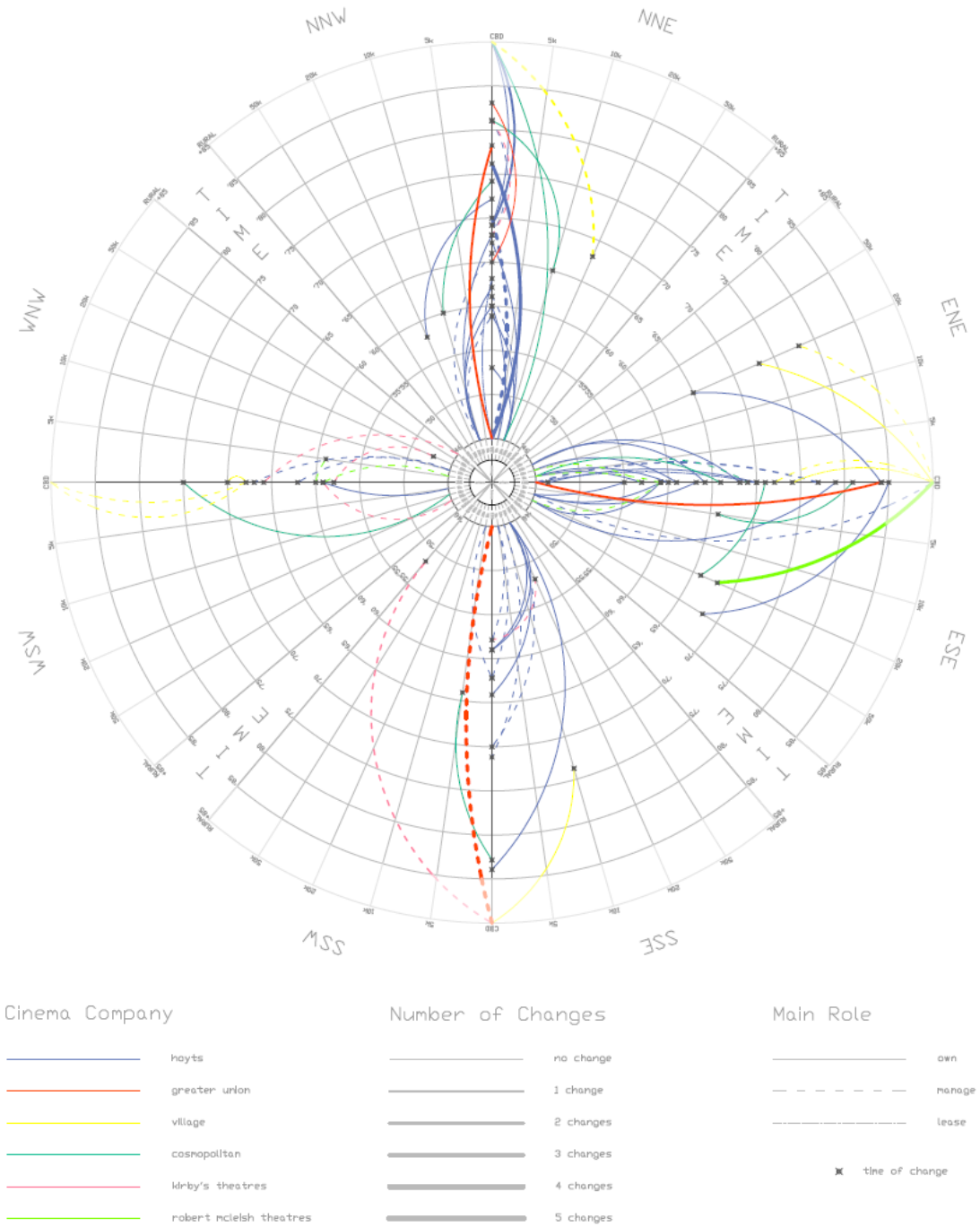

Figure 5: The resultant visual representation of the geographical question, *how does change affect the longevity of large cinema companies?*

If this venue layer is combined with information about the cinema industry or societal events, some direction of explanation may be provided. For example, the introduction of television in Melbourne did not occur until around 1956 and this may go to some lengths to explain the large amount of closures shortly after this, although further data on the uptake of TV consumption would be required to definitively secure this observation. By

creating visual access to the data, historians can think of the information in a geographical context, and analyse the data in a way that is not possible without the introduction of time and space.

6- Summary and Conclusions

This research has developed a method for the treatment of historical point data in visual representations. It has sought to extend the use of multivariate representations in Historical GIS through an approach that incorporates a holistic treatment of time and a spatial extension of simple data graphics. The method consists of several components that are combined to produce a final visual representation which includes a spatial extension of time-series graphics and the abstraction of point feature data. These components have been developed to successfully communicate multivariate and temporal spatial information and produce insights into patterns of historical point data. By creating a holistic representation, visual interpretations of spatial patterns for multiple attributes and the entire temporal dimension can be analysed without resorting to comparisons of multiple displays of temporal and attribute snapshots.

The history of cinema venues has provided the developed method with a case study to validate the success of the final visual representation. It has created visual access to historical cinema records, allowed relationships between attributes to be explored, and provided a visual representation for the analysis of multivariate and temporal dimensions. It is possible that the success of this application can be applied to almost any historical events for which location and time are recorded, provided they have a central point of influence and a temporal lifespan.

Future developments will focus on the automation of the visualisation process for screen display to provide a method that is interactive and question specific. This will allow the analytical capabilities of the method to be fully realised. However, one of the main benefits of creating a holistic visual representation is the ability to work with hardcopy paper representations. Hard copies allow the entirety of the data to be viewed whilst particular areas can be examined. It gives the option of highlighting interesting patterns and differences for later inspection. Usability testing will be required to further the development of the method, focusing particularly on the use for historical investigation. Future research will also

assess the method of its ability to be used in other historical applications, and will attempt to provide a geographical and graphic context to a variety of historical events.

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