Machine Learning Tools applied to the Qualitative Analysis of Decision-Making Strategies

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Abstract

When conducting qualitative analysis a good deal of time is taken for the purpose of establishing user requirements. Task analysis may yield inconsistent results when dealing with a number of incidents occurring in a dynamic environment. Particularly when issues related to making decisions in a timely manner are involved, it is common for those making the decisions to enact particular decision-making strategies. How do we establish what these strategies are, then design a UI that supports all of the identified strategies? By using machine learning techniques it is possible to significantly reduce the time required to analyse qualitative datasets. In this work a Self Organising Map (SOM) reduced the time taken to analyse qualitative data compared to using an Emergent Themes Analysis (ETA), on the same initial data. The results obtained from using the SOM were encouraging as it reduced the analysis time and provided more in-depth data compared to the ETA.

Keywords:

Emergent Themes Analysis, Cognitive Domain Analysis, Self organising Map, Qualitative Analysis

INTRODUCTION

A downside of conducting qualitative analysis is that it takes time to interpret the data that is gathered. This is especially true when assessing interview data. Interviews that run for (say) 30 minutes may take 15 to 20 pages in transcript form. The time taken to read, comprehend, and then extract common themes from this data can be quite significant.

So how can we save time, but still come out with useful results? Using an existing case study, two methods of divining information from a series of interviews are compared. The initial interviews were conducted with dispatchers working in the London Ambulance Service (LAS). The aim of these interviews was to determine the decision strategies used by ambulance dispatchers. The interviews were based on the Critical Decision Method (CDM) research technique (Klein et al, 1989). The CDM is a retrospective interview technique that required the dispatchers to recall a memorable incident that they dispatched ambulances to. Whilst the dispatchers were recalling each incident, decision points were identified and placed along a timeline. The dispatchers helped organise the timeline to ensure that the key points were in the correct order. The dispatchers were then questioned further to determine why they made each decision, what information they based their decisions on, what information they considered and what difficulties they encountered. The data gathered from the CDM was then analysed using an Emergent Themes Analysis (ETA) (Wong and Blandford, 2002). This involved the initial identification of broad themes that occurred across all of the interviews. These themes were subsequently dissected into smaller sub themes. Each of the sub themes were then identified further to identify each decision activity; the cues that the dispatchers used, their considerations when performing these activities, knowledge requirements of the dispatchers and the source of their information. Finally this information was summarised into decision strategies.

An alternative to the ETA analysis was formulated taking advantage of machine learning techniques. A 'map' was created by cross-referencing decisions against the decision-making techniques. This 'map' was then encoded in a manner suitable for input to a spatio-temporal Self Organising Map (SOM). It was hoped that the use of a SOM would allow the determination of knowledge or patterns.

How do we interpret the data?

Given tasks and possible decision strategies have been identified, what then? What we really need to know is this: do the users have a set path that is followed in the completion of their duties, or is the work environment more decision based, requiring a more complex user interface? If the former, what is the work flow? If the latter, what decisions need to be supported, and what data needs to be presented and when?

Before beginning, it is important to note that some analysis had already been attempted. The interviews themselves had been formulated and undertaken using the Critical Decision Method interview technique (Wong and Blandford, in press). The interviews were then transcribed, and these transcriptions were used as the basis for analysis. Each interview ended by creating a timeline of events and the decisions made when completing the tasks.

The transcriptions also underwent an Emergent Themes Analysis to identify the main tasks and sub-tasks. The Emergent Themes Analysis also identified some decision-making strategies used by the controllers

The very first attempt to find correlations between controllers involved creating a map for each event described by the controller. Each map showed which decision-making strategies were used when completing each task.

When identifying decision-making strategies during Emergent Themes Analysis (based upon the interview transcripts), strategies were grouped with the tasks that appeared to be related. However, when the timelines were analysed and the results compared to the results of the Emergent Themes Analysis, it was discovered that often the relationships did not hold. Instead, several decision-making techniques are used in the completion of each task. So, instead of grouping decision-making strategies together, an attempt was made to correlate all tasks against all decision methods identified.

This analysis led to the addition of 5 tasks that had not been identified previously, each task identified by at least 2 controllers.

Each interview was mapped using a revised version of Figure 1. This forms a direct spatio-temporal relationship; what, where and when something happened. It was expected that, when maps from different controllers were overlaid, consistent patterns would emerge.

Task	Assess Situation					
Sub Task	Read the ticket	Determine nature of incident	Determine if single or multiple ambulance incident	Ascertain location of incident	Identify access routes to incident location	Consider time of day issues, eg traffic
Decision Strategy						
Control Ears' - listening in to what is going on around the allocator - check for corroboration.						
Compare 'tickets' for similar / same / related events						
Integrate data from dispatate sources						
Task	Assess Resources					
Sub Task	Identify and locate nearest available ambulances to incident location	Identify and locate nearest hospitals and type of facilities at the hospitals	Assess impact of choice of vehicle on coverage in immediate locality and beyond	Identify, locate and assess availability of additional resources that		
Decision Strategy						
anticipate events and only allocate what is necessary - maintain a 'backup'						
Confirm availability of nearest available resource.						
Task	Plan and select a course of action					
Sub Task	Assign ambulance to a job / call / incident	Group duplicate calls that may arrive at different times with	Identifying and marking ambulances that could be assigned to the next	Refer to a map of an incident area for major incidents, or		

Figure 1. Sample portion of apparent tasks, sub-tasks and decision strategies

Initially, an attempt was made to correlate decision strategies to task groups (Blandford and Wong, 2004). When mapped against actual examples of work done (tasks and decision strategies used in completing these tasks) it was discovered that there was no clear correlation. Each dispatcher used whatever decision strategy they felt appropriate for the task at hand. A different visualisation method was employed that used all sub-task and decision strategies, and maps created for each example. In the process of this mapping, it was discovered that a number of common tasks were not actually identified, even though they were undertaken by a number of dispatchers.

The resultant maps demonstrated that, although there appears to be some grouping, there is no clear pattern to view. A sample is shown as Figure 2.

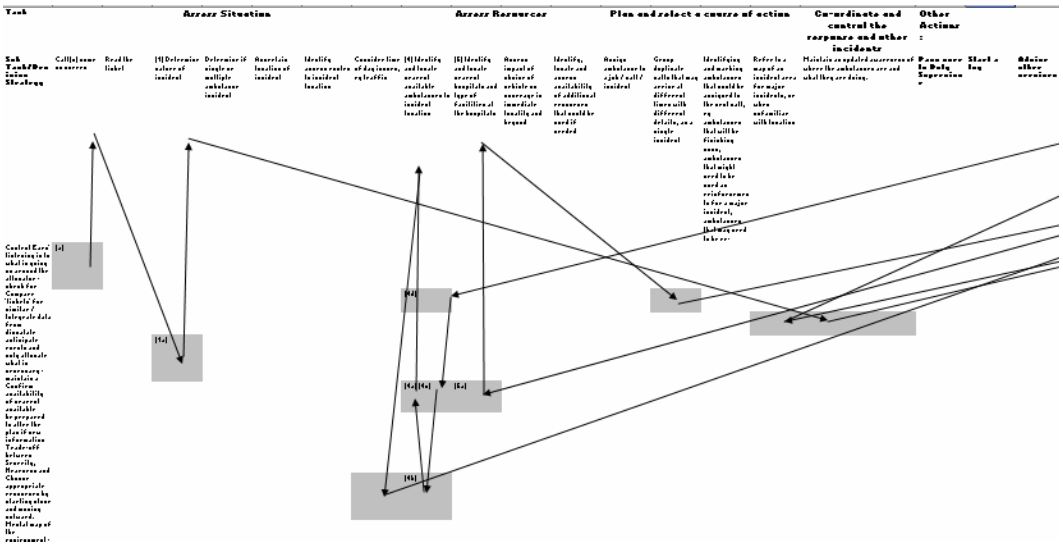

Figure 2. Sample portion of Tasks and sub-tasks (top) and decision strategies (side). The arrows show the trajectory or path taken by the controller during the particular event.

SELF ORGANISING MAPS

At this stage it was determined that some other means of describing spatio-temporal relationships was required. Research into pattern recognition techniques suggested that it might be appropriate to use a Self Organising Map (SOM) for this situation. SOMs are useful where patterns are thought to exist, but we are not sure how or why. The SOM is also an unsupervised learning technique. That is, we cannot know in advance what the ‘correct’ result for any example will be, therefore cannot train the tool in the same way that we would were we to use an artificial neural network or rule based system.

It was decided to try the use of a Kohonen SOM, in particular a variant that uses spatio-temporal references (Kohonen, 2004).

In general terms, a SOM can work with data in multiple dimensions. The output represents the Euclidean distance between clusters described in 2 dimensions in the form of a web or map. SOMs are particularly useful when patterns may be guessed at, but not clearly identified by traditional statistical methods.

Expected benefits:

The SOM has the ability to group items in terms of multiple dimensions, and display these in 2 dimensions. In this case, we want to determine the relationship between decision strategies (row position), the task under way (the column position) and their relationship in time. The added benefit is that like items will be grouped, which allows the system developer to see what data needs to be provided to support these like elements within the task structure.

Challenges in data selection:

When conducting interviews with the emergency dispatch operators, it must be remembered that they face a dynamic environment, and make decisions in differing orders to suit the situation. Each operator has a unique way of expressing their solutions to problems and will usually work independently of others.

One confounding factor when attempting a direct comparison between incident timelines is that, because each operator is describing a unique incident, unique patterns will result. That is, each 'map' for task/decision comparison is quite different simply because the task requirements are different. So the challenge with data is to find some means of describing the different number of tasks and decisions possible, and which of these have been used for the incident described. When conducting qualitative analysis this is common, but most automated tools require data sets to be similar in size and specification.

Data Preparation:

The SOM requires that data be presented as normalised numerical values. Each decision/task point (spreadsheet cell reference) was given a value between 0 and 1.

Temporal data may be run in 'single file', use a fixed size method, or use a moving window technique. The single file method has a single value on each data line, beginning with the first and running through in order of time. Multiple values may be passed through end-to-end. This is useful where there are many, similar, examples available.

The fixed size method assumes that all examples have the same number of waypoints in their trajectory. Each complete trajectory becomes a single example. In this instance each example has a different number of waypoints, so this encoding method is not viable.

In this case a moving window technique was used. Each row must also be of the same dimension; that is, number of elements in each input row. 3 waypoints per data line are included, the centre waypoint becoming the label value. Packing values (0 and 1) are used for the first and last lines of each example, providing a fixed begin and exit point. This encoding method is used where there are few examples of varying temporal length, as was the case in this instance.

As the maps were created in MS Excel, the cell address was used as a data label for the SOM row. The rows of a file prepared for use may look something like:

0	0.040909091	0.039393939	B3
0.040909091	0.039393939	0.124242424	B2
…			
0.354545455	0.515151515	0.866666667	N4
0.515151515	0.866666667	1	W2

TOOLS USED

The SOMToolbox, as developed by researchers at the Helsinki University of Technology was used for this work. The SOMToolbox is an implementation of the SOM as first propose by Tuevo Kohonen (1995). This updates and improves on the MatLab SOM toolbox. Data to be input is formatted in a text file that is then read by the MatLab code. To generate the visualisations, the existing GUI was used, although modified to allow labelling of the resultant maps (as shown in Figure 3).

Visualisation of output

There are two distinct visualisations that may be used in order to understand the results. Both are mapping techniques. These are presented, along with the methods of understanding and an interpretation of the results.

The first is a traditional SOM with a hexagonal lattice. This represents like/related items in a spatially related manner. If this visualisation was generated with the raw values, before training, then they would appear to be randomly distributed across the map area. After training, the visualisation is run, and the result will be similar to Figure 3. The colour segments represent the different groupings identified by the SOM. From this it can be assumed that there is no tight relationship between similar data points because what appear to be similar groups (blue shaded in the upper signet, red shaded in the lower segment) have become disjoint.

When we look at a different mapping, where the relationships are represented 3 dimensionally, a different pattern emerges – one that suggests a reason for the apparent lack of relationship when viewing the hex SOM representation. In Figure 4, we see that there are two groups of tasks (the vertical axis) using the same decision strategies (the horizontal axis). This multi-dimensional representation suggests that, depending upon the person and problem, either of two techniques may be employed.

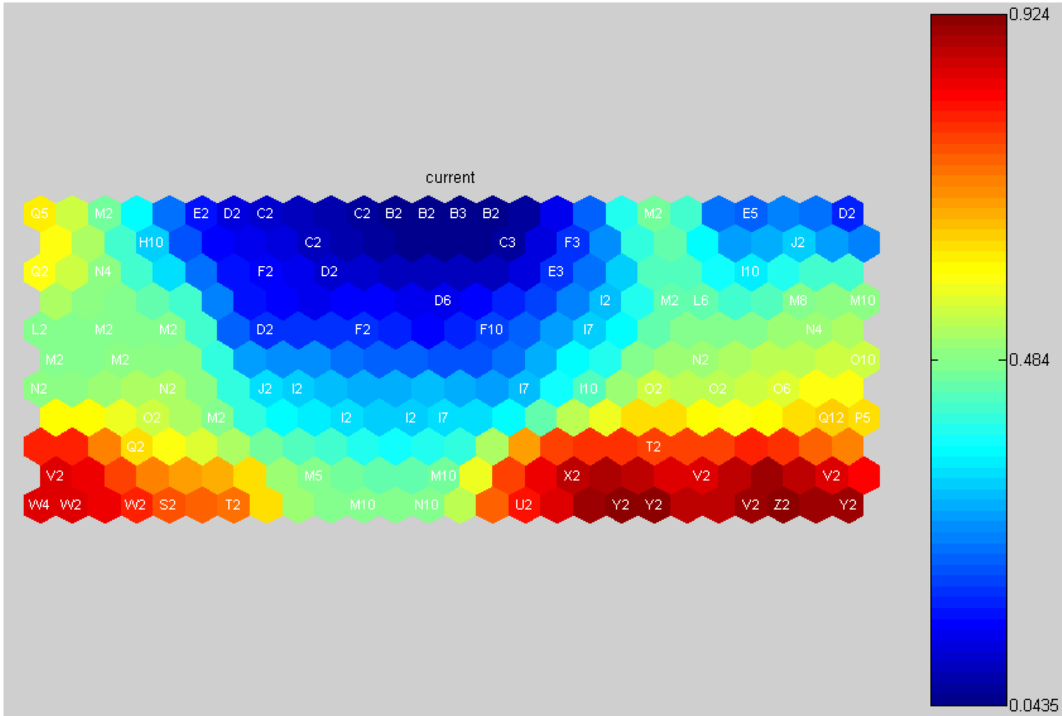

Figure 3. A matrix visualisation, with cell references displayed. Each shading represents 'similar' items.

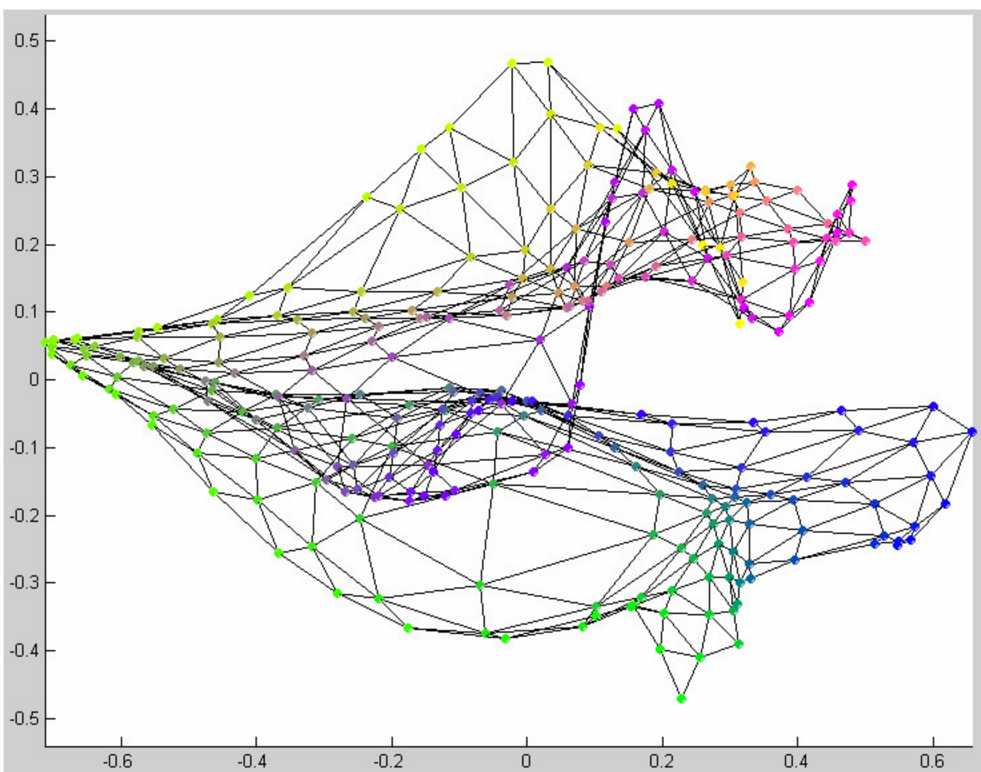

Figure 4. A 3D map, showing clearly two patterns with a single overlapping area

The network mapping also demonstrates a clear overlap that represents common tasks. The common task here is to ‘dispatch an ambulance’.

By interpolating the data points over the mapping (in this case, cell reference points from the timeline maps) we attempt to identify common pathways. There appears to be a correlation between sections of the original rather than discrete pathways. Looking at the data labels in the hex lattice representation it appears that one pattern represents ‘allocating resources according to what resources are available’ and the other ‘allocate resources according to the problem faced’. The lighter areas in Figure 3 represent the allocation task — 'send resource'. In this instance, the inter-relationships are not as clear as displayed in the network mapping.

Interpreting the SOM outputs in this manner suggests that operators may choose to employ two kinds of decision strategy. One strategy involves finding what resources are available then allocating resources. The other strategy requires that the dispatcher assesses requirement and formulates a plan prior to allocating resources. It is possible for both strategies to be employed within a single incident. For example, an operator may receive a call, be unsure of the extent of the incident, and respond by immediately sending an ambulance according to what is available. After receiving feedback from the first ambulance on scene, the operator may then plan for more resources to be sent, and allocate resources accordingly. Operators may use a number of different decision strategies depending upon the nature of the incident, the task being undertaken and concurrent events. There is overlap when the resource allocation task occurs.

RESULT SUMMARY

It is recognised that developers following a task-based development method may create a number of disparate UI forms that may not fully support the way that people work. Instead, when taking the way in which people make decisions (tasks *and* decision strategies) it is seen that all elements related to a particular event, need to be displayed together to allow the operators opportunity to make suitable decisions. In practice, this may be a display that allows the event data (or at least a subset), the available resources, and the linkages between them to be displayed. There also needs to be some means of grouping multiple calls for a single event (or multiple related events) together on-screen, as this is a task common to all operators, and one that takes some time to complete.

FUTURE WORK

Although useful, this descriptive technique does not answer two questions. The first is how do the results relate to UI design? The second relates to earlier stages – can the process of establishing decision strategies and tasks be simplified?

UI Design? In this instance, the lack of clear spatio-temporal workflows suggests that any UI design will need to support all parts of the task process equally. Why? With no clear path it could be argued that many strategies exist, and an appropriate strategy may be employed according to the situation. The second is that the groupings identified, while distinct, also have regions of overlap. Overlap is principally in the region of assigning resources (this occurs no matter the problem at hand). However, a dispatcher may use multiple decision strategy/task groupings within a single event, so the UI designer cannot concentrate on a single methodology of work. Rather, the UI must support all possible combinations. However, this tool cannot say how these may be displayed or put together – something left to the developer.

Can we use this form of tool to extract the task/sub-tasks/decision strategies, without going through the qualitative data extraction process? Again, this implementation relies on knowing some factors already. However, the means of extracting these factors may be simplified. When interviewed, dispatchers had opportunity to create in a visual manner a list of the steps they took in reacting to the situation, in a visual or graphical manner. This turned out to be useful when creating maps where tasks and sub-tasks could be identified directly, along with the decision strategies identified (which data was being looked at and why – determining purpose). In conjunction with interview transcripts, the mapping process took around 3 to 4 hours per interview – a significant time saving compared to traditional qualitative methods. The initial mapping and analysis of 6 interviews of data (comparing tasks and decision strategies) took around 24 hours. The process of formatting data, applying the SOM, then confirm patterns within the task and decision strategies employed added around 18 hours. This latter process, utilising ETA analysis took around 40 hours — a significant time saving.

CONCLUSION

The purpose of this analysis was to determine whether machine-learning techniques could be used to aid in the analysis of qualitative data. In this instance the data is a series of interviews with ambulance dispatchers. The aim of the interviews was to identify the way in which decisions are made under particularly difficult circumstances.

Traditional methods (for instance ETA) take a significant amount of time, and results are dependant upon the experience and ability of the researcher. An alternative method was desired that would enable time to be saved. The use of a SOM was investigated, and the opportunity to use a Spatio-Temporal SOM was suggested.

Such a tool was obtained, and data formatted to suit. Results are interpreted by adding data labels to the trained network then assessing patterns or groups identified.

Using traditional methods, with the same number of interviews, analysis took in excess of 40 hours. The results obtained were indicative; the researcher identified no clear pattern but suggested that a pattern may exist. Using the SOM took almost 18 hours. It is assumed that less time will be taken in the future as the analysis protocol has now been worked through. Results with regard to pattern identification are particularly encouraging as excellent (and unexpected) results were attained.

Further work is to be carried out to validate this approach. Interviews with ambulance dispatchers in New Zealand have been completed during 2003 and will be subject to the same analysis process.

An additional data set, being interviews with Process Controllers, is also to be used to validate the technique. These interviews have a similar goal, but feature a different work domain. The controllers are under similar pressures to perform complex tasks in a very tight time frame.

REFERENCES

1. Klein, G., Calderwood, R., and Macgregor, D., (1989). *Critical decision Method for Elicting Knowledge.* IEEE Transactions on Systems, Man and Cybernectics. **19**(3): p. 462-472.

2. Wong, B.L.W. and Blandford, A., (2002). *Analysing Ambulance Dispatcher Decision Making: Trialing Emergent Themes Analysis*. in *HF2002, Human Factors Conference "Design for the whole person - integrating physical, cognitive and social aspects"*. Melbourne, Australia: A joint conference of the Ergonomics Society of Australia (ESA) and the Computer Human Interaction Special Interest Group (CHISIG).

3. Wong, B.L.W. and Blandford, A. "Decision Strategies for Emergency Medical Dispatch: A Case Study", in press

4. Kohonen, T. SOMToolbox available for download from http://www.cis.hut.fi/projects/somtoolbox . This link is correct at January 2004.

5. Kohonen, T. (1995). *Self-Organizing Maps*. Series in Information Sciences, Vol. 30. Springer, Heidelberg. Second ed. 1997. http://www.cis.hut.fi/projects/somtoolbox/theory/somalgorithm.shtml.

6. Blandford, Ann, & Wong, B.L. William. (2004). Situation Awareness in Emergency Medical Dispatch. *International Journal of Human-Computer Studies, 61*(4), 421-452.

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