

Using the Analytic Hierarchy Process to prioritise candidate improvements to a geovisualization application

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1. Introduction

Crime and disorder reduction (CDR) research analysts ('analysts') in a UK local authority have generated suggestions for enhancing geovisualization prototypes designed using human-centred methods (Lloyd, Dykes and Radburn 2007; Lloyd, Dykes and Radburn 2008). Prioritising these candidate improvements is an important process and may require modification to established decision support techniques due to the nature of geovisualization. We explore this issue through the Analytic Hierarchy Process (AHP) (Saaty 1977).

2. Approach

Three analysts in seven experiments generate verbal transcripts totalling ~120k words that yield ~350 explicit and implicit suggestions for improving the prototypes. When coded and grouped, these give 35 possible improvements.

A clear task is to prioritise these possible improvements, initially unconstrained, and then in the context of limited development resource in order to direct development. Approaches to the first of these include multi-criteria decision analysis (MCDA) (Dodgson et al. 2000), GIS-based MCDA (Malczewski 2006), and the well established (Wasil and Golden 2003) Analytic Hierarchy Process which has been used in prioritising software development (Karlsson and Ryan 1997). AHP participants prioritise from a list by relating every possible pair of combinations. An overall score and ranking are produced for each item, along with a consistency ratio for each user.

Our 35 possible improvements would need too many pairwise comparisons for completion in a reasonable time. We group possible improvements to reduce this number (Karlsson, Olsson and Ryan 1997). Analysts consider improvement groups in turn: 'data' (aggregation, filtering and context related); 'interface' (system behaviour, complexity and speed related); 'interaction' (readability, orientation, scale, legend related) and 'new' (novel visualization tools and displays related).

Two analysts score preferences on each pairwise comparison using an integer divergent scale (Karlsson and Ryan 1997). Comments made during the test are noted, and analysts asked about the process retrospectively. The perspective of 'geovisualization expert' ('expert') was provided by one of the authors (Dykes) undertaking the same AHP pairwise comparison.

3. Findings

3.1 Quantitative findings

Marked similarities are noted in the rankings of the desirability of the 35 possible improvements prioritised by the two CDR analysts (Pearson coefficient 0.50, significant at 0.01 level; 2 tailed, n=35). This is not the case with expert's rankings, which are significantly different from both analysts'.

Figure 1 shows analysts' and expert's rankings as parallel plot small multiples, conditioned by improvement group. Analysts' priorities are skewed towards 'data related' improvements and against 'new' items. The expert's priorities are more evenly distributed, and incline towards 'interaction related' and against 'interface related' choices.

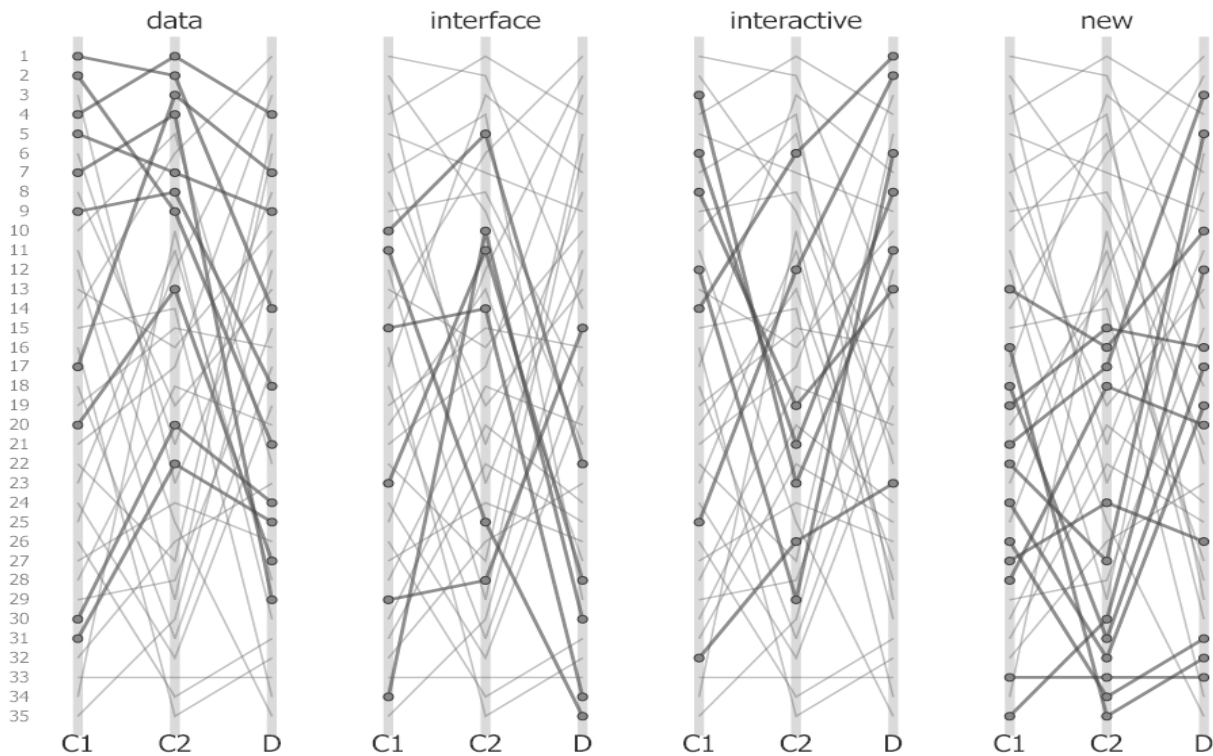


Figure 1. Parallel plots of candidate improvements ranked 1 (top) to 35 (bottom), for each metagroup: ‘data’ (10 listed improvements), ‘interface’ (6), ‘interactive’ (7) and ‘new’ (12). AHP rankings for two CDR analysts (C1 and C2) and expert (D) are shown left to right within each plot.

The AHP ‘consistency ratios’ show that for all participants the results from the ‘new’ group are noticeably less consistent than from the other groups. Analyst C1 is more consistent than the others throughout, and has the lowest dispersion as measured by the Gini coefficient, calculated from Lorenz curves (Lorenz 1905) of the same data.

Table 1. AHP consistency ratios for the four different groups of the 35 possible improvements

User \ Group	‘data’	‘interface’	‘interaction’	‘new’
CDR Analyst ‘C1’	0.03	0.09	0.04	0.49
CDR Analyst ‘C2’	0.06	0.20	0.21	0.69
Geovis expert ‘D’	0.16	0.10	0.21	0.43

3.2 Qualitative findings

CDR analysts spent considerable time before the AHP exercise clarifying details of the ‘new’ candidate improvements. This resonates with our problems mediating geovisualization possibilities to these analysts (Lloyd, Dykes and Radburn 2007) and parallels the difficulties experienced in identifying ‘undreamed of’ requirements (Robertson 2001). Comments made during the task include concerns about consistency; concerns at descriptions not differentiating sufficiently for some comparisons; and unprompted explanations being given for scores.

The CDR analysts found the AHP to be efficient and meaningful - the exercise successfully identified preferred candidate improvements. The ‘expert’ experience was less positive - a tendency to focus on the process and one’s own consistency rather than the detail of the improvements was noted, along with difficulties in interpreting improvement descriptions consistently. Achieving consistency was an important aim for all users, and two of the three participants were concerned after awarding scores of ‘1’ frequently in succession. At the very end of the AHP, one of the analysts summed up their understanding of the proposed tools as “*a guess on the back of what you are telling me*”, indicating that earlier difficulties we have reported in mediating geovisualization to analysts continue.

4. Conclusions

The two analysts have very different dispersions and different consistency ratios, but their rankings are indistinguishable, supporting the notion that the AHP is robust. The priorities of the expert are markedly different despite the high levels of engagement between analyst and expert throughout the development process. Geovisualization applications are predominantly ‘expert’ driven (Fuhrmann et al. 2005) and so the discrepancies in terms of priorities are an important finding that should be explored further with other analysts and geovisualization tool developers.

In all cases, ‘new’ candidate improvements were ranked with least consistency suggesting uncertainty about their nature and/or possible benefits. The issue may be one of communication and interpretation - unfamiliar improvements are more difficult to describe, communicate and interpret consistently with the succinct descriptions required for pairwise comparison. Including the kinds of complex novel visual features typical of geovisualization as possible improvements may thus affect the working of the AHP. This is despite our efforts to expose the CDR analysts to geovisualization techniques and prototypes over an extended period, detailed descriptions being made available during the AHP and discussion of these descriptions with individuals in advance of the process. The time spent by the analysts at the outset and the qualitative data lend weight to this conclusion, confirming our earlier findings on difficulties in mediating geovisualization to these users (Lloyd, Dykes and Radburn 2008). We also note the understandable focus of the analysts on prototype improvements that have the most bearing on their current activities rather than on innovation. This may be another limitation of the AHP, as we have previously observed these analysts more open to innovation when not asked to prioritise - indeed all 350 candidate improvements were suggested by these users working with geovisualization prototypes in our human-centred design process (Lloyd, Dykes and Radburn 2008).

Consequently, future application of AHP in geovisualization might variously:

- involve all parties in the AHP concurrently so that concepts can be discussed and interpretations clarified - AHP as a collaborative process to mediate shared understanding of priorities
- alternatively provide visual descriptions / stimuli with demos, videos or presentations available in advance of and during the process so that the candidate improvements are agreed
- use fewer, more specific candidate improvements - sampling from original suggestions rather than aggregation
- run the AHP against different *scenarios* (Lloyd, Dykes and Radburn 2007) to establish (for example) current and future priorities
- weight the results by analyst based on criteria such as consistency (from the consistency ratio) or dispersion (from the Gini coefficient)

This work has been extended using a variant of the classic knapsack problem to determine how the AHP output can help the CDR analysts prioritise possible improvements under the constraint of different value solutions and different developer costs. Results reveal that the analysts focus just as strongly on known functionality when development resources are limited, even when current tasks provide opportunity for beneficial geovisualization (Lloyd, Dykes and Radburn 2007).

Whilst showing how a decision support technique may be employed to good effect, this work also suggests that the nature of geovisualization may cause difficulties for those seeking to differentiate between different candidate geovisualization improvements, and may not provide an unambiguous development roadmap. Approaches to developing prototypes rapidly with open-source software in collaboration with prospective users in so-called patchwork prototyping (Jones, Floyd and Twidale 2007), or establishing requirements in ways that involve creativity (Maiden, Gizikis and Robertson 2004) may be beneficial in resolving the different perspectives identified here.

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Biography

David Lloyd is a PhD candidate researching the use of human-centred techniques in geovisualization at City University London in collaboration with Leicestershire County Council.

Jason Dykes is a Senior Lecturer in Geographic Information at City University London with interests in geovisualization. He is co-chair of the ICA Commission on Geovisualization, has developed a number of geovisualization software applications, and is co-editor of 'Exploring Geovisualization'.

Robert Radburn holds an ESRC UPTAP research fellowship at City University London to develop capacity for visual exploratory analysis in local government, and is a Senior Research Officer at Leicestershire County Council working with a variety of partners to support evidence-based policy.

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