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On the (virtual) getting of wisdom: Immersive 3D interfaces for eliciting spatial information from experts

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ABSTRACT

Expert information is a valuable resource in developing robust spatial models to improve understanding and prediction of systems in health, environment, business and society. However, getting experts to reliably activate and encode what they know has proven to be an elusive goal. A root cause of this elusiveness is the fact that expert knowledge is largely tacit, i.e., experts struggle to describe what they know. The imperative to address this goal is increasing. There is a constant need for better models of expert knowledge in organizations, much observational data is sparse and inadequate for spatial modelling, and many domains have knowledgeable workers leaving in numbers. Interviews are often used for eliciting expert knowledge, due to their ease of implementation. However, there is evidence that a lack of appropriate stimuli reduces the quality of knowledge elicited. This paper explores the use of immersive 3D virtual worlds for improved knowledge elicitation, due to their priming effects on memory recall. A case study on habitat prediction for a rock wallaby species is presented, in which the new approach is trialled. This paper is one of the first that aims to combine new virtual spatial technology with expert elicitation for improved spatial statistical modelling.

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1. Introduction

The last thirty years has seen an exponential growth in interest in the development of statistical models for estimation and prediction of spatial outcomes (Cressie, 2015; Banerjee et al., 2015). However, despite the concomitant increase in availability of spatial data, there are many situations for which the data required for such models is sparse or unavailable. Canonical examples of such situations include prediction of unseen events such as potential incursions of plant pests into a country (Murray et al., 2012), estimation of abundance and location of rare species across a large or inaccessible landscape (Martin et al., 2012), or description of individual human activities at a scale or in a situation that is not readily amenable to data collection (Harman et al., 2015). In all of these cases, statistical models for estimation and prediction based only on the data may be inaccurate and imprecise.

There is, however, a rich source of other information that could potentially be used to improve the models: human experts. In the cases described above, biosecurity experts and field biologists have knowledge about important aspects of potential pest incursions (Murray et al., 2012); ecologists and conservationists know about geographic and demographic drivers associated with rare species (Caley et al., 2014a); and individuals can provide insight into how and why they perform certain activities (Harman et al., 2015).

The problems inherent in knowledge elicitation emerged when it quickly became obvious that it was not simply a process of direct "extraction". Error and bias were common and reports from subjects were often incomplete and flawed. These findings define possible errors in the knowledge elicited: (1) some aspect of the expert's knowledge may not be captured and (2) some of the expert's errors or biases may be inadvertently incorporated into the knowledge being captured. In short, it has long been established in cognitive science that an expert's ability to introspect, i.e., their ability to access what and how they know what they know, is unreliable. As a consequence, self-reported strategies, confidence ratings and the like should be treated with caution (Evans, 1988).

Accepting the premise that spatial expert information is valuable, the challenge then is how to elicit this expertise in a manner that most accurately and precisely captures the required information, and how to represent this information in a way that can be most effectively used for the target task. This task may range from an increased conceptual or qualitative understanding of a system of interest, to parameterization of a spatial statistical model based on an amalgamation of the available observational data and the elicited expert information. With this as background, it is apt to briefly reflect on how a Virtual Reality (VR) based approach to knowledge elicitation may impact the known cognitive issues bearing on knowledge elicitation.

The first issue is priming. Research in cognitive science has shown that memory is critical to expert problem solving. Part of the reason why introspection fails is that memories of relevant expertise are not sufficiently primed for retrieval. We hypothesize that the realistic nature of VR will provide a richer cross section and number of primes, which will promote more effective retrieval of expertise from memory and reduce selective processing. Once an expert becomes selectively focused or directed, expert knowledge outside of that focus is largely inaccessible. One reason why selective processing occurs is the expert cannot keep track of all the relevant features in working memory. Although the VR environment cannot extend the working memory of the expert, the environment may be able to facilitate the better tracking of them, e.g., noticing the presence or absence of expected features due to the realism of a particular VR scene.

Another pertinent cognitive issue is judgemental biases. These occur when experts seek evidence which is likely to confirm their theory (confirmation bias) or make a biased evaluation of the evidence presented (belief bias) (Burgman, 2015). Although VR could reduce these biases by presenting more 'evidence-based' information, it could alternatively be the case that the biases will be enhanced because of the realism of the evidence being presented. This could be empirically verified by comparatively broad or narrow confidence intervals placed around estimates, which may highlight respectively 'under- or overconfidence'. Knowledge elicitation methods should aim to extract expert knowledge without the biases, though this is not easy to do, and may prove even harder in a VR environment.

Finally, expert knowledge involves the ability to construct and manipulate mental models of the structure and content of the expert's domain. This includes exploration of hypothetical scenarios,