From question to query: GIS for Impact Assessment

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Abstract

The abstract presents a research that stems from a lack of integration between the Impact Assessment (IA) and Geographical Information Science (GIS) domains. While already since a couple of decades GIS has proven to benefit IA, in practice it is used roughly in one out of two assessments. In GIS, the dominance of system commands over information contents only widens the gap between the two domains. To bridge the significant gap this research takes a set of typical questions in IA and suggests that they can be translated into GIS commands by matching spatial and impact ontologies.

Keywords: impact assessment; ontology matching; question based computing.

1 Introduction

In light of present-day challenges of resource scarcity, climate change and changing demographics (Retief et al. 2016) impact assessment and appraisal of projects, programmes, plans and policies has become a basic requirement before their implementation. In this context, Impact Assessment (IA) is the process of identifying the future consequences of a current or proposed action (Partidario et al., 2012), in contrast to IA as a term often used for monitoring and auditing changes in the environment after the implementation.

Although the usefulness of GIS in all stages of IA has been recognised already a couple of decades ago (Eedy, 1995; Joao et al., 1996), the latest reviews on different IA types show that use of GIS is still not a given (see Patouillard et al. (2018) for Life Cycle Assessment; Zelenakova et al. (2017) for Environmental Impact Assessment, Perminova et al. (2016) for Land Use Impact Assessment, Roudgarmi (2018) for Cumulative Effects Assessment).

Rather than blaming IA practice for the lack of practical skills in GIS, the reasons can be found on the other side. Kuhn & Ballatore (2015) and Vahedi et al. (2016) have criticised GIS for being a closed field where professionals take pride in complexity. Even if GIS is relatively easy to customise, system commands still dominate over information contents, which makes them difficult to use by a non-GIS expert. To remediate this shortfall, Kuhn & Ballatore (2015) took the initiative to devise a simple language for spatial computing that could be used by other field specialists without having to learn the specifics of GIS. As a follow-up, more attempts have been emerging in recent years to create a general translation layer between standard GIS operations and human language (Hofer et al., 2017, Scheider et al., 2018) or to match GIS with MCDA for decision making (Jelokhani-Niaraki et al., 2018).

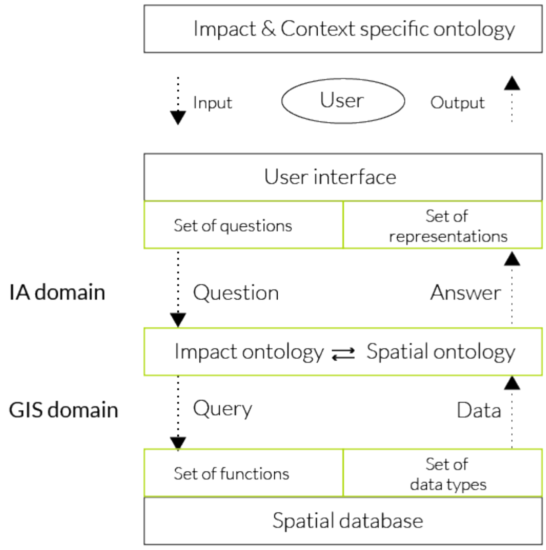
This research builds upon these earlier attempts to further specify how the question-based computing can be applied in IA in particular.

2 Ambition

Both spatial (e.g. locations of sensitive habitats, residential areas, infrastructures, environmental quality and land use) and IA-specific data sources are more and more accessible as open web resources, which theoretically allows their integration into a single system. However, the terminology in the field of IA is often confusing for the GIS specialists, while GIS language and querying capabilities are foreign to the people carrying out an IA (Mwenda et al., 2015). The existing tools aiming to facilitate GIS and IA integration are topic specific and therefore rarely reused, especially when multiple impacts need to be assessed of which each one would require a separate specialised tool.

The proposed integration aims to be platform agnostic and to be used between any chosen user application (e.g. web application as well as GIS software) and spatial database (e.g. web resource as well as local) as shown in Figure 1. An IA expert needs to be able to ask a question using the IA terminology which should then be translated into a spatial query. The spatial query result should then be translated back into a form of representation that is meaningful for an IA but not exclusively a GIS expert.

Figure 1: Conceptual scheme that shows the missing translation component (in green) in between the two domains: GIS and IA.



3 Proposal

The conceptualizations of the real-world objects differ in the IA and GIS communities even if both communities are concerned with the same objects. Consolidation between both conceptualisations can be done by integrating the most abstract and fundamental ontologies of the two domains (Schwering et al., 2004).

To enable the semantic translation, the two representative ontologies must be sufficiently abstract and of reduced complexity (Schwering et al., 2004). As a representative ontology of the GIS domain, the conceptualisation by Kuhn and Ballatore (2015) fits the requirements of sufficient abstraction and generalisation. While GIS is a rather ontology-rich domain, the formal conceptualisation descriptions are very rare in the IA domain. Therefore, a suitable abstract ontology has been derived based on the selection of most common questions with spatial dimension. The ontology is available at: https://github.com/rusne/ImpactOntology/blob/master/ontologies/Impact.owl

The translation is meant to provide an IA expert with a complete and comprehensive set of tools to ask the relevant questions which can be later automatically translated into GIS queries. The tools are not named after what they do but what kind of question they are able to answer, since an IA expert only needs to understand which types of problems can be solved with particular methods, what is required as input, and how to interpret outputs, rather than how the actual method or algorithm internally works. As assessment of each specific impact has its own specific conceptualisation, the link between an impact specific ontology and the general impact ontology is performed by a system user (i.e. IA expert) while formulating the question and providing input to data.

Table 1 presents the first set of tools, their correspondence with both ontologies and a set of answer representations in the interface. The questions/tools have been formulated by performing a literature study on the IAs that have used GIS in the assessment process.

4 Next Steps

The presented set of questions currently translates only into abstract GIS concepts and does not connect to any of the specific query languages and GIS operations. In order to validate the effectiveness of the translation and to demonstrate its usefulness, the next steps include: confirming that the proposed set can sufficiently accommodate IA questions by involving IA expert; verifying that a sufficiently wide variety of impacts can be assessed by connecting the abstract ontologies with the impact specific ones; and testing the overall framework with concrete datasets.

Finally, long term goals include accommodating the needs of Impact Significance Assessment which means that the translation framework needs to allow stakeholders and experts not only asking questions but also providing spatially differentiated answers to the questions about context importance (Sileryte et al., 2018).

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Table 1: Basic set of questions as tools to be used by an IA expert. Each question requires certain class instances from an Impact Ontology as an input. These instances then can be automatically translated into corresponding classes within a Spatial Ontology through ontology matching. Once the question is formulated using the Spatial Ontology, it gets translated into a GIS query. Later, the answers (query results) are translated back into relevant representations for a user interface.

Set of questions	**Input**		**Output**	**Set of representations**
	Impact Ontology	**Spatial Ontology**		
Where_is (what, *when)	what: ContextElement, EffectSource, ImpactReceiver *when: temporalProperty	Entity	Location	Shape(s)
How_much_at (where, what, *when)	where: Locality what: impactProperty, *when: temporalProperty	Entity, Location (Point)	Number	Number
How_much_in (where, what, *when)	where: Locality, EffectZone, ImpactZone what: impactProperty, ContextElement, *when: temporalProperty	Entity, Location (Area)	numericalValue	Number
How_much_where (what, *when)	what: ContextElement, Impact, Effect *when: temporalProperty	Entity	Field	Shapes & Numbers
What (where, *when)	where: EffectZone, ImpactZone *when: temporalProperty	Location	Object	Shape(s)
How (what, what, *when)	what: ContextElement *when: temporalProperty	Entity, Entity	Relation	Shape & Number/ Text
From_where_to_where (what, *when)	what: Impact, Effect *when: temporalProperty	Relation	Network	Shape & Number/ Text
When (what)	what: Impact, Effect	Event	temporalValue	Text
How_long (what)	what: Impact, Effect	Event	temporalValue	Number
Where_when (what)	what: Impact, Effect	Event	Location, interval	Shape(s) & Text