Serious Games for Disaster Risk Reduction Spatial Thinking

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1. Introduction

Spatial thinking is a learnable skill for structuring and solving spatial problems and decision making support, such as using a map to support navigation or structuring time using spatial metaphors (i.e. "the event is *far off* in the future"). The National Research Council (2006) defined *spatial thinking* as an amalgam of three items—concepts of space, tools of representation, and processes of reasoning (National Research Council 2006). *Serious games* target non-entertainment purposes using gaming concepts, such as a score based on actions taken for measuring game player learning and progress (Michael and Chen 2005).

In this paper, we present a theoretical framework and preliminary disaster risk reduction (DRR) serious spatial thinking game implementation. Our motivation for developing the framework and subsequent serious game is to:

1. Develop a new spatial thinking ability quantification method that can inform GIScience research, and
2. Implement scenarios and simulations that use commercial Geographic Information Systems (GIS) tools for novices to learn spatial thinking in a variety of application domains, such as DRR.

We are designing and developing our theoretical framework and current serious DRR spatial thinking game in close coordination and partnership with United Nations educational capacity development and DRR leaders. We believe that this connection demonstrates the societal relevance and broader impacts of our research (see United Nations University Institute for Environment and Human Security (n.d.)).

1.1 Theoretical Framework

Virtual geography-based games have seen growing research attention for teaching concepts, such as resource management and human-environment relations (Ahlqvist et al. 2012; Cheng et al. 2010). However, this prior work has not made an explicit focus using serious game concepts to measure and teach spatial thinking ability in novices (e.g., students) through industry-standard, commercial-grade GIS tools. A serious game would create a closer connection between the serious gaming experience and real-life (Ohmori et al. 2003). Figure 1 graphically summarizes our theoretical framework.

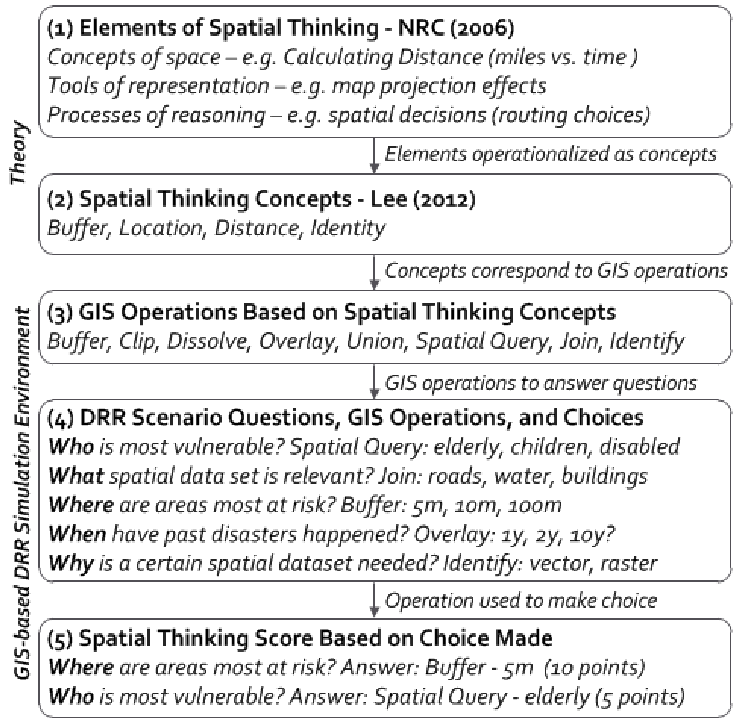


Figure 1: Serious Spatial Thinking Game Theoretical Framework. Parenthetical numbers in the text below refer to Figure 1 parenthetical numbers.

The framework starts with (1) the elements of spatial thinking defined in National Research Council (2006). Spatial thinking elements are then operationalized as (2) spatial thinking concepts based on Lee and Bednarz (2012) research to develop a spatial thinking ability test (STAT). For example, the spatial concept of a buffer can be considered a combination of the concepts of space and a tool of representation. Lee and Bednarz (2012) outlined tangible spatial thinking concepts specifically to measure spatial thinking ability via the STAT—concepts that we incorporate into our theoretical framework to justify quantifying spatial thinking ability. Many spatial thinking concepts, like buffer, correspond directly to (3) GIS operations found in industry-standard GIS tools such as ArcGIS[1]. Game players then match GIS operations, grounded in relevant spatial thinking concepts as defined in the literature, to develop (4) DRR serious game scenario questions and GIS operations to answer a given question. Finally, a score (5) based on spatial thinking choices made to allow the game player understand decisions made and the spatial thinking processes behind those decisions (Ohmori et al. 2003; Berse, Bendimerad, and Asami 2011).

2. Prototype Serious Spatial Thinking Game—Costal City Hurricane

Our prototype serious game was built inside ArcGIS using python GUI tools. Specific game scenario questions, GIS operations, and choices are encoded using JSON—see Blochel et al. (2013) for further game technical implementation details. Figure 2 shows the python-based game interface (bottom right) incorporated into ArcGIS for a coastal city hurricane scenario.

[1] www.arcgis.com

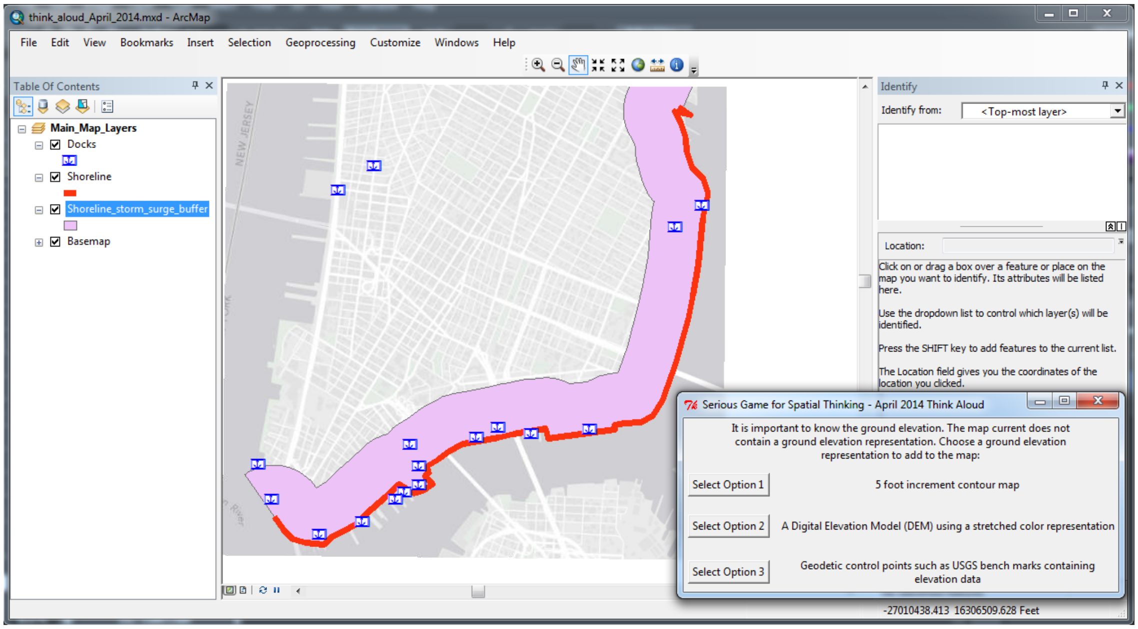
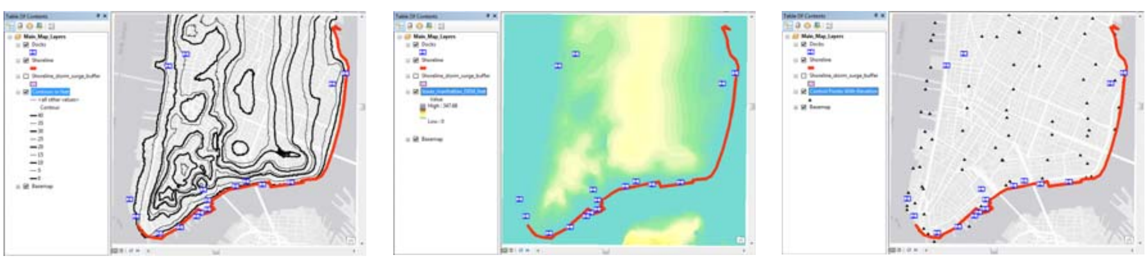


Figure 2: The serious spatial thinking game inside ArcGIS. In this example, the game player has just made a storm surge extent choice based on previous question choices (as seen by the purple buffer) and is now being prompted to select a ground elevation representation.

We are currently using a coastal city hurricane scenario in the game based on actual events from 2012 Hurricane Sandy and established hurricane disaster planning scenarios from the literature (US Department of Homeland Security 2006). In our game scenario, a Category 5 hurricane is approaching a coastal city and the game player must utilize spatial thinking supported by GIS to make choices (Figure 3a-c).


3a – Contour Map 3b – DEM 3c – Survey controls

Figures 3a-c: The three choices for the question shown in the bottom-right of Figure 2.

Figures 3a-c show three choices for determining the best elevation representation for thinking spatially about storm surge impact—a 5′ contour map (3a), a stretched color Digital Elevation Model (DEM) representation (3b), or geodetic control points containing elevation (3c). As per our theoretical framework, the line (contours), raster (DEM), and point (survey controls) aspects of the choices closely relate to spatial thinking component VIII on the STAT—"comprehending geographic features represented as point, line, or polygon" outlined in Lee and Bednarz (2012, 20). Furthermore, the choices are a good example of prompting novice spatial reasoning. An expert would know that a contour map would likely be the best choice of elevation representation to allow for ease of comparison with other layers via overlay. A DEM would be a second-best choice, and survey control points are the worst choice— as by themselves, they cannot easily convey elevation as a continuous surface.

2.2 Preliminary Results

We are currently using our serious spatial thinking game environment to gather evidence on novice spatial thinking supported with GIS tools via think-aloud sessions. Specifically, novices use the environment to answer a series of questions similar to those in Figures 2 and 3. They verbally express what they are thinking spatially about when using the environment, akin to prior spatial thinking/think-aloud research (Taylor and Tenbrink 2013). To date, we have tested seven college students (six graduate, one undergraduate) with an average two prior GIS classes (but no DRR experience) before participating in the think-aloud session, four of the seven are native English speakers and one is a deaf and hard of hearing. Select preliminary results indicate students with some GIS experience but unfamiliar with the DRR application domain are fairly capable at utilizing spatial thinking for different representation types such as points, lines, or polygons—"*with these choices* (about elevation), *you're really going to want to know how the water's going to flow in and where the water will go, so this last one* (the survey control points, Figure 3c) *doesn't have as much information as the first two*" (contour lines—Figure 3a and DEM—Figure 3b). However, more complex spatial thinking questions, such as choosing between clip, intersect, and union for determining priority evacuation areas revealed spatial thinking ability gaps — even after two GIS classes ("*I'm not that familiar with intersect*") and challenges with applying more advanced spatial thinking to the DRR domain — "*I think that where the storm surge buffer and the HAZMAT* (hazardous material) *buffer overlap is where you will want medical treatment…but I am blanking as to which* (GIS) *tool is the one best to use.*.(for determining the medical treatment areas)."

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