Fundamentals of Geodesign

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1 Introduction

These are exciting times in the world of design and planning technology: available tools and technologies can provide 3D walkthroughs of design proposals which are verging on cinematographic. The elements considered now include not only individual structures, but also increasingly complex landscapes, some with terrain, plants, running water, crowds of people and even cityscapes (PAAR & MALTE, 2007; PARISH & MÜLLER, 2001). However, while there is ever-increasing capability for visually elegant representations, in many cases, their beauty is almost literally only skin-deep. Frequently missing is any understanding of the objects beyond that required to generate the representations themselves (ERVIN & HASBROUCK, 2001).

Sophisticated as they may be, such visual simulation systems often lack the capacity to simulate even simple socioeconomic or environmental processes, leaving designers, stakeholders and the public blind to the full consequences of proposed actions. The more sophisticated "building information modeling" (BIM) approaches now appearing are an improvement in that we are beginning to have representations which can support building performance evaluation. However, the focus of these tools remains on individual new building construction within representations containing almost no information about their geographic context. Conversely, the representation of built forms within geographic information systems (GIS) remains overlay simplistic, usually consisting of 2d footprints. This makes it difficult to conduct neighborhood, city or regional scale assessments that take into account important characteristics of design proposals.

Fortunately, a variety of alternative formulations are possible, and these are supported by substantial parallel progress in the world of distributed geospatial data creation and management. The lessons learned in developing desktop spatial decision support systems for specific purposes can be brought to bear in designing a new generation of tools. At the same time, important advances have been made in internet-based communication technologies, including not only support for new flows of spatial information, but also new means for distributed conversations between interested parties.

These changes in circumstance and technologies call for a reconsideration of the way in which geographic information systems and design tools work, both individually and jointly. Approximately 5 years ago, this realization began to take the form of a new vision for geographic design, or geodesign. A small team at the GIS software company ESRI, was tasked with assessing and removing barriers to designers' use of GIS. The initial goals were to support a sketching interface within GIS which removed the setup overhead involved in conventional GIS editing, and to connect this directly to geoprocessing models so as to support design-time feedback. The first half of this mission was accomplished in ArcSketch, an add-on to ArcGIS which supported a novel mechanism for rapidly generating spatial features with attributes (ESRI, 2005). The second goal, that of tightly coupling design and evaluation has not yet been added to mainstream GIS. However, he concept is alive and well in numerous special-purpose decision support tools, notably Placeway's CommunityViz and Criterion Planner's INDEX.

In the last several years, “geodesign” has begun to be discussed more broadly, and in a fashion which transcends any particular software vendor or tool implementation. Thus this paper seeks to define the term, to examine some of the strengths and difficulties, and to consider future prospects for research in this area.

2 What is GeoDesign?

Geodesign is a design and planning method which tightly couples the creation of a design proposal with impact simulations informed by geographic context (FLAXMAN, 2010). In an ideal case, a planner or designer receives real-time guidance on performance at every phase of design from early site visit or conceptual sketch to final detail. The use of contextual geographic information means that design performance can be evaluated relative to local conditions, and that evaluation can and should consider off-site impacts. The focus is on supporting “human in the loop” design, providing continuous feedback on multiple aspects of performance and improving designs-in-progress rather than on post-hoc evaluation.

2.1 Motivation

We live in a rapidly-urbanizing world where environmental degradation is threatening not only local ecosystems, but the biodiversity and climate of the entire planet (VIÉ ET AL., 2009; IPCC, 2007). In this context, the ability to evaluate the sustainability of designs and plans is critical. These types of problems will not be addressed by small increases in individual building performance: they require the ability to design and test interactions between design interventions and a variety of ecological conditions and ecosystem services. Solutions to these problems require the ability build support for futures which are significantly different than current practices, and this in turn requires the active involvement of stakeholders as well as designers. Unfortunately, conventional design methods and physical planning tools are neither robust nor scalable: they do not support rapid and iterative impact assessment or sharing of proposals in forms which encourage the generation of improved alternatives.

In the first 40 years of the digital era, the discovery, download, extraction, reformatting and importation of spatial data were laborious manual processes, even when performed using computers. Up until the 1990s, data acquisition and reformatting often consumed 80% or more of spatial analysis project budgets. In the last few years, a new paradigm has emerged in which these processes have become both automated and seamless. With “on-demand stream processing,” data are stored online, processed incrementally where most efficient, and accessed wherever convenient.

At the same time, new business models and policy decisions have provided worldwide access to high resolution current imagery and many other information layers which traditionally required significant expertise to access. Technologies such as GPS-enabled cell phones and cameras allow designers and the general public not only to access information, but also to participate in data collection and comment on data collected by others. This combination of ideas and ubiquitous networking is leading to vastly richer representations of current conditions.

However, for environmentally-oriented designers and planners, most of this new information is simply a “better basemap”. There is no support for the analytic operations which form the basis of spatial planning, and little interoperability with conventional design tools. For those who spend their time advocating for improved future conditions, the representations supported remain shallow.

The concern of this geodesign is how to leverage these important new possibilities, while being mindful to avoid the kinds of gaps, omissions and culture-wars which characterized the first 30 years of development of GIS, CAD and visualization. Design tools and spatial information systems are being re-invented as we speak. A much broader universe of people are participating than in the early days of computing, and this is leading to many new creative solutions. However this also brings the danger that lessons learned will be ignored and that instead of more capable and interoperable tools, we emerge with a digital tower of Babel in which things that are difficult to represent are simply ignored.

An important starting point is to consider how the digital representations we choose affect how proposals are viewed and evaluated. I have three main concerns. The first is how we can make effective use of designers’ graphical skills to generate representations which are indeed beautiful – but also have the kinds of semantic structure which make them computable and shareable. The second is how we represent “function” as well as structure, especially of complex systems. The importance of depicting natural systems, human systems, and coupled human and natural systems can hardly be overstated: most every major planning and design issue from inclusionary zoning to global warming now requires consideration of functional processes and not simply static object inventories. Third, how might we structure professional representations in a way which invites deeper and more substantive public participation, so that formal and informal knowledge (art, science and culture) can be tapped?

The first question – that of representation – lies near the heart of design. Architecture and landscape architecture have always aspired to be more than decorative arts. We create graphic representations as a way of thinking and of conveying ideas, but ultimately the canvas we paint is the earth. Because of this, we inevitably have social and environmental responsibilities to meet. This has long been recognized by the design professions themselves, but more recently has emerged as an enormous source of professional opportunity – but only if designers can provide and demonstrate substantive performance as well as inspiration. Traditionally, choice of representation has been largely individualistic and idiosyncratic. In a digital world, this choice has social consequence: the use of fully ad hoc representations makes computational design evaluation impossible.

The second question – that of functional representation – turns out to hinge upon on the first. It is only when we develop relatively sophisticated shared digital representations that we can routinely perform assessment of systems-level functions. In particular, I believe that two aspects of representation are critical: georeferencing and semantics. Georeferencing ties a concept to a specific place on earth, whereas semantic coding helps to ensure that meaning is coupled to data. Georeferencing is important to functional representation because very few systems are scale free. As soon as something even rough is known about size and location, an immense body of knowledge is unleashed. This includes basic spatial proximity relationships, but also legal and cultural settings. Similarly, the representation of even a few semantic characteristics also connects to a broader world of information. For example, it is difficult to infer much from a blue line on a piece of paper. If we learn that it represents a stream centerline, we then have semantic knowledge which connects to various arts and sciences. If we also learn the position of this stream in the world, we are then able to connect it back to its watershed, its historic context, and in some places, even its current flow rate and level of pollution.

The third major issue – the public accessibility of a representation – is more traditionally a professional planner's concern than a designer's. However, I would argue that the need for public representations is not a function of profession so much as a function of social and spatial scale of action. If we as a profession are to make an impact on the world beyond that of advocating for a single client's interest in a relatively small area, then we must pay attention to the relationship between representation and participation. At a minimum, this implies finding ways of representing things which are broadly understood. With increasing frequency, it means finding ways to enable stakeholder creativity using interactive representations.

These are complex questions, for which a wide variety of answers are likely, both in terms of substantive and procedural methods. However, I propose that "geodesign" can provide a unifying, technology-enabled but platform-neutral approach. While this approach in itself is not new, the development of standards which support its widespread deployment across distributed computing environments may bring it a new degree of prominence and importance in planning and design. Furthermore, conventional planning process metrics and frameworks fail to account for critical aspects of geodesign and may need to be enhanced or rethought.

2.2 Conventional Design Pipelines

In order to understand how geodesign concepts differ from conventional CAD or GIS methods, it is important to understand how both georeferencing and semantics have typically been handled with each workflow. In the case of GIS, this is about an 11-step process, outlined in Figure 1 below.

Design Instantiation

Pick a bounded study area and create geographic reference

Create one feature class for each type of object to be represented

Digitize raw feature geometry as geometric primitives

Add attribution

Save in file or database

Evaluation

Examine input data for geographic reference, types of primitives, structure of attribution

Create geoprocessing model(s) reflecting specific input data

Test and calibrate the evaluation model(s)

Save model(s) and outputs in files or databases

Run evaluations for each design proposal

Manually repeat each evaluation if underlying data or design has changed

Fig. 1: Traditional GIS Workflow

Conceptually, design is reduced to plan digitization, and disconnected from evaluation. In other words, no useful feedback is provided to a designer by the GIS system beyond the simple ability to underlay pre-existing layers. Relative to other manual and professional design tools, there are also significant practical impediments. Before sketching, a user must establish geographic references, develop abstract data structures and determine their disk storage location structure. In most GIS systems, compound geometries or curves are not supported, and elements must be drawn as either point, line or polygon primitives.

Within traditional GIS work flows, evaluations are organized as an end-stage output product, often produced by a separate team. This process takes as input; the design data created and must be manually run on every version of every plan. For real-world applications in which both designs and evaluation models change over time, this places a large file management burden on system users because hundreds to thousands of files must be organized, distributed and tracked. Since the underlying software systems do not natively understand the higher-level concepts of a "scenario" or an "evaluation" this is typically done through complex file naming conventions relying on social conventions for enforcement.

2.3 Computer-aided Design

Traditional CAD workflows are similar in that they move from design to evaluation (see Fig. 2). The major differences are in the structure and content of the data created.

Design
Pick a page scale
Digitize geometries using primitives or advanced tools in abstract space
Use colors or layers to represent attributes of data
Save in file or database
Evaluation
Use plug-in tool to evaluate particular aspect of design (for example, cost schedule)
Use separate plug-ins for other evaluations
Repeat as needed for other versions or scenarios

Fig. 2: Traditional CAD Workflow

Traditional CAD workflows are predominant in many design and engineering markets. The major advantage to this environment is its immediacy and the availability of specialized drawing tools – experienced users can jump straight from concept to design. However, the savings in initial setup time often come at the expense of significant complexity later in the process, particularly when evaluation is attempted. Geographic references are not typically established, which means that any tie to external real-world information must be later re-established by manual georeferencing (a painful and mundane process at best). Attributes are stored either as text label points, colors or layers. These can be ambiguous references, difficult for a human being to interpret by eye, and impossible for a computer to guess reliably. Because data are structured ad-hoc, significant effort must often be expended later to re-encode information differently to meet the requirements of various evaluation models. Finally, it is relatively difficult to share CAD files, even to users with the same software, unless layer naming and graphics standards are made clear with external documentation. CAD workflows frequently rely on graphical conventions to encode semantic meaning, and this is very fragile and error-prone.

2.4 GeoDesign Workflows

In contrast to the prior two workflows, consider how a hypothetical geodesign process might work (Fig. 3). A user begins by picking a study area geographically. This sets up a context within which design is conducted and evaluated, and for connecting proposals to a real place. Technically, this also establishes scales and geocoordinate systems implicitly, without requiring user understanding of the details of projections and datums.

Design Instantiation

Pick a site or area of study

Pick suitable feature representations, based on standard or custom data models

Adjust visual portrayal (symbology) as desired

Select suitable evaluation models based on availability, project needs

Integrated Design/Sketch Evaluation

Sketch features (symantically rich and georeferenced by default)

Sketch evaluation tools give feedback without blocking drawing

Running selected models on design iterations is default and automatic

Full Impact Evaluation

Same technical structure as sketch models (simply take longer to run)

Models run as background tasks (typically as web geoprocessing services)

Model results streamed back to design client incrementally as computed

Evaluation models recognize design context in addition to input design data

Appropriate analysis context can vary by model

Fig. 3: GeoDesign Process-Flow

After selecting a study area, a variety of information is available to the designer. Significantly, this includes a number of depictions of existing conditions, including key environmental, social and economic aspects. For example, in most parts of the U.S., over 250 geographic data layers are available. Embedded within these representations are a set of standard classifications and data models. For example, not only is vegetation described, but it is described using a particular classification system. An important concept in geodesign is to leverage these syntactic structures by allowing a designer to discover and appropriate classes directly from existing maps (of the area or elsewhere). If an appropriate feature class type is available, the designer can pick it up and use it immediately. From the choice of a type (or prototype), a series of graphical and semantic defaults is established. When the user starts to draw, a geocoordinate system, database schemas and symbology have already been established. All of those elements are user-adjustable, but they are given sensible defaults and semantic information is separated from symbology. In those cases where a designer is proposing something semantically novel, mechanisms are needed to develop custom typologies. However, even in these circumstances, much of the supporting infrastructure required can usually be well described by supporting the subtyping of existing classification schemes.

This aspect of geodesign is conceptually similar to Building Information Modeling (BIM), in that design tools manage both semantic and representational data. Because the domain of geodesign is significantly broader than BIM, ERVIN (2007) has proposed the need for LIM, or “Landscape Information Models.” Examples of this kind of thinking in particular domains include ESRI’s GIS “data models” and the CityGML OpenGIS standard (STADLER & KOLBE, 2007).

Once, one or more representations are selected the designer can be offered a set of sketch evaluation models compatible with these representations. This "model discovery" phase could take advantage of the expressed intentions of the designer in picking a particular area and set of features to draw. For example, if a designer decides to lay out a road in Alaska, a variety of specialized road models can come into play. These can be based on common issues related to a category (for example, accounting for impervious cover), or can be adjusted to include local concerns (permafrost, or intersection standards or ordinances). Mechanisms must be provided to allow designers to construct or adjust models as appropriate. But it is also the case that a variety of geodesign models could be produced by subject specialists, either as commercial products, or for advocacy reasons (encouraging consideration of particular performance factors in design).

As soon as a feature begins to be drawn or is completed, the difference between a geodesign workflow and conventional GIS or CAD design methods becomes clear: evaluation starts to take place immediately. The exact form of this evaluation and the feedback provided is model-specific, but the general idea is to provide a live "dashboard" to the designer. For example, this might include a geographically-sensitive cost estimator, an impervious surface index, and a count of units built. Similar feedback mechanisms already exist in both CAD and GIS, usually in the form of add-ons or extensions. However, there is substantial benefit to embedding such capabilities into a general purpose architecture. First, because geodesign features contain a database structure (or schema), it is possible for evaluation models to be relatively robust. Unlike traditional CAD and GIS systems, the inputs are guaranteed to match model requirements. Second, evaluation can either take place locally, or be distributed to remote servers. As each portion of the evaluation is completed, the results can be streamed into the current design editing environment. This lowers the time between proposal and evaluation to the minimum technically possible.

Each evaluation, like each design, is timestamped and change tracked. This is important in maintaining correspondence across multiple iterations of design, and between various scenarios and their evaluations. The management of such dependencies is typically very difficult in existing design or analysis systems because they don't track this type of metadata.

2.5 GeoDesign in Action

While the full process outlined remains hypothetical, aspects are already available in current software tools. Moreover, both in terms of concerns and methods, this formulation has very old intellectual roots. Geodesign concepts have been embedded in a variety of planning support systems (for review, see BRAIL ET AL., 2007). To varying degrees, many existing GIS-based planning tools have adopted some form of this approach. For example Orton's CommunitzVis and NatureServ's Vista support the ability to generate a planning scenario and evaluate its consequences according to a set of metrics. Criterion Planner's INDEX software goes one step beyond this in providing scenario generation tools as well as indicators. While there have been some limited case-study based studies examining deployments of these methods, there have as of yet been relatively few comparative studies.

Strategic choices in GeoDesign Implementation

Only when we separate the general principles from the specific implementations can we talk about some of the trade-off involved, without considering specific indicators. The first issue is that of design tools, and the digital representations which they create. If we consider design to be entirely separate from evaluation, it can become difficult to impossible to evaluate a proposal because the information required may be incomplete or missing. In general, many of the interoperability problems between CAD and GIS fall in this area. For example, it is impossible to create a building energy analysis without a representation of building components which contains information about their energy performance.

This is more than a simple issue of missing data. The problem is in some fashion how to support deferring a decision. It is often premature to generate a detailed description of something when fleshing out an initial concept. Seen in this light, the reluctance of a designer to initially specify materials is a rational choice and work method. The metaphysical problem is that computers have great difficulty dealing with ambiguity. One option is simply to disable all evaluations which require knowledge of materials until later in the design process. A second might be to provide materials of purposely varying levels of specificity to be refined later. For example, hydrologic run-off is a key issue in site design. To a first order approximation, it is not necessary to know detailed material characteristics to compute run-off, simply pervious and impervious cover. So a system could provide a default for roads which is impervious, and for unmodified terrain which is impervious. If more sophistication was warranted, it could even perform a sensitivity test and report a range of outcomes based on “typical materials” then allow a designer to drill down and specify details later.

An important issue here then becomes that of material libraries and design system defaults. If appropriate libraries can be provided, then it becomes considerably easier for a designer to generate even concept drawings with defaults allowing sensible preliminary evaluations. A materials palette can allow a designer to specify an attribute such as imperviousness indirectly, since this can be an attribute of the material.

This general concept of material attributes can be used even on conceptual designs. For example, ESRI’s ArcSketch prototype (Fig. 4) allows the assignment of arbitrary GIS attributes to a symbol. Once a symbol palette is created in this way, it becomes vastly simpler to perform analyses on geometry as it is created, since symbols can carry semantic information instead of merely graphical information. The process of creating features with appropriate attributes is reduced from a multistep computational process to the act of selecting an appropriate symbol and beginning to draw.

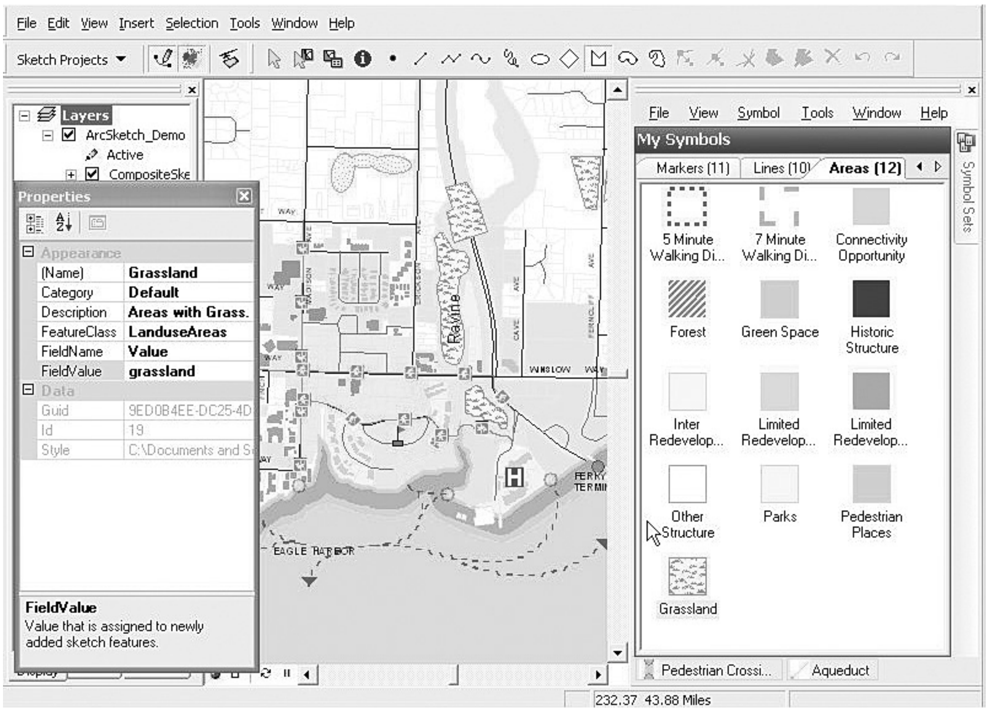

Fig. 4: ESRI ArcSketch (ESRI, 2005)

The second major challenge in geodesign systems is to avoid the design evaluation process from blocking the design process. A large class of evaluation computations can be done with modern computers in very near realtime. Typically this includes anything directly linked to geometry being created through a multiplier, such as the cost of pavement, or the length of driveway. However, there are many non-trivial computations which still require substantially more than real-time to compute. For example, a hydrologic runoff analysis might take 15 seconds for a small site. This is just slow enough that a different architectural model is needed to avoid "blocking" the drawing task. It is now technically possible to "stream" design evaluations, so that results are visualized incrementally as computed, while allowing data generation to proceed interactively. Unfortunately, the addition of this kind of capability requires some rather deep changes to existing software, and is thus not available in all applications.

One way of making streaming evaluation processes more widely available is to leverage existing web-based standards and protocols. The basic idea is to have one local "design machine" and one or more additional "evaluation machines" operating as servers. In this way, the computational burden of evaluation can be off-loaded from the computer hardware focused on design generation. This scheme also scales well, especially for evaluations which can be conducted in parallel. For example, the computation of which parts of a design are built on steep slopes could be broken into arbitrary geographic tiles, and answered on a tile-by-tile basis, with results streaming back to a single design client.

Also, an unrelated evaluation, for example of biodiversity impacts, could be run on an entirely different server.

Process	Location
Design	Machine 1
Evaluate	Machine 1
Visualize Impacts	Machine 1
Re-design	Machine 1

Fig. 5a: Single-Machine Design Evaluation

Process	Location 1	Location 2	Location 3
Design	Run Design Interface	Evaluation Process 1	Evaluation Process 2
Visualize Impacts	Present Visualization	Compute Visualization 1	Compute Visualization 2
Redesign	Run Design Interface	Redesign Evaluation Process 1	Redesign Evaluation Process 2

Fig. 5b: Conceptual Scheme for Distributed Design Evaluation

However distributed evaluation carries the cost of requiring network connectivity. It also means that processing power must be available for conducting the evaluation on some server somewhere. While increasingly common, this is not uniformly available. The current limitation of distributed design evaluation systems is not technical but social and financial – it is not yet clear how to charge for access to the appropriate computing resources.

3 Planning Process Issues

In simplest form, the geodesign concept does not speak to the important social and professional issues of who is designing or planning for whom. An individual might deploy a geodesign tool to design their backyard garden, with geographic input used only to determine which plants might be appropriate to general latitude, and impact measures being a plant list and estimated cost – impacts on neighbors or others being trivial.

However, the geodesign concept is particularly valuable when applied to large and complex planning problems where neighborhood and regional affects are significant. It is at this scale when impacts are no longer simple accounting models roughly linear relative to input assumptions. It is also at such scales that the types of impacts exceed a single disciplinary perspective. For example, a proposal for a new inclusionary-zoning district is a matter of public policy which has significant and complex impacts on neighborhoods, private developers and community development patterns over time.

In more complex implementation situations, several general new concerns emerge. The first is that process design, including the organization and sequencing of public and professional activities, become critical. This is true not only in practical and logistical terms, but also as relates to the legitimacy and transparency of semi-public and public processes. In such situations, "design" is a multiparty process occurring over an extended period of time. The accessibility of design proposals and their evaluations becomes important to control. On the one hand, there are professional contexts in which secrecy and competition play important roles, and on the other hand, there are also those in which complete openness and a full "record of decision" are required.

The general planning method supported by geodesign is that of repeated design evaluation in geographic context relative to multiple explicit criteria. The planning obligation is that of substantive participation of affected parties both in the generation of alternatives and in the selection of appropriate evaluative measures. A simple example at one scale might be the design of a new public school commissioned by a school board. Even if undertaken for a particular client, an obligatory aspect of stakeholder-based planning would be the development of a consultative process, perhaps in this case involving students, teachers and neighbors of a prospective site, as well as the board itself. The methodological aspect would require that a set of performance measures be defined by the stakeholder group. These might include quantitative aspects such as legal requirements or cost estimates, but also formal inclusion of qualitative measures, such as citizen feedback. The overall geodesign framework posits no single decision process, since this may vary based on context: it only supports a social process in which multiple design alternatives are generated and considered.

These are important issues, since systems designed with different implicit or explicit answers to those questions would have rather different characteristics. It is possible to imagine "participatory geodesign" along the lines of participatory GIS, supporting deliberative democracy by expanding opportunities for substantive public involvement. In theory, this could involve public engagement in generating either alternative plans, or alternative evaluation criteria, or both. The work of VARGAS-MORENO (2009) provides an early example of the use of sketch-planning technologies to enable broader participation in planning. The basic idea was that of a spatial Delphi process in which individual opinion was brought together in anonomized form, with feedback loops where individuals were asked to reconsider their original ideas based on the combination of their ideas with other proposals. This kind of process builds design and public process on top of the basic design-evaluation idea.

4 Conclusions and Future Work

GeoDesign is a refinement and restatement of a set of ideas which have already been independently invented multiple times. Indeed, the concept is evolving as this is being written, with two expert group meetings having taken place, one in Santa Barbara, California (2009) and the other in Redlands, California (2010). The definition provided above is just one of several under discussion. It asserts the need for a design proposal – different from simple spatial analysis of history or current conditions – and for context-sensitive impact evaluation. It does not specify by which means a proposal is imagined, or how a computer might assist in generation of abstract alternatives or diagrams. As ERVIN

(2009) rightly points out, there is much room for improvement in this regard, asking: "what is Design, that we might aid it, with a mindlessly literal, very fast assistant with a relentless memory and no imagination (i.e. a computer)?" The formulation above depends on the notion of evaluation, which in turn implies that goals and objectives must somehow be defined and at least qualified if not quantified. This is an admittedly limited view of design and design tools, but it does reflect what is technically feasible in the short to medium term.

A major axiom of geodesign is that iteration leads to improved design. The intellectual underpinnings of this approach come from the theory constructionist learning (Papert), which take a view of learning as a reconstruction rather than as a transmission of knowledge. According to Papert, "learning is most effective when part of an activity the learner experiences [is] constructing a meaningful product." Several aspects of this may be testable in particular circumstances, and the results of such empirical study would be very useful in determining tradeoffs in real-world systems design.

Rapid iteration and multicriteria analyses have a long history in professional practice, but there are known trade-offs between breadth, depth and execution speed. Meeting the performance standards of "real time" interactivity requires model computation in about 1/30 of a second, which is likely feasible only for simple screening/buffering and overlay models. As of this writing, only some current GIS systems use graphics card acceleration at all. Similarly, supporting public discussions or sketch design likely requires maximum model response times on the order of 3-4 seconds. Routine support of this level of performance will require innovations in the decomposition of models so that they become scale and extent-sensitive. Is such an effort warranted? Human-computer interface research in applied planning and design contexts will be needed to determine this. But how to measure success is a tricky issue. There is evidence of stakeholder plans being incrementally improved by the use of explicit multi-criteria planning systems. For example, plans developed by citizen stakeholders using Criterion Planner's INDEX software have been shown to improve across multiple dimensions in successive rounds (ALLEN, 2007). However, the overall extent or limitations to stakeholder learning remain poorly characterized.

A geodesign formulation does not remove the need for scoping, nor does it magically create appropriate models. What it might do, is to create an ecosystem within which a variety of models and indicators might be rapidly deployed and shared. It is likely that large libraries of simple models could be developed based on standard national and international data sets. By encouraging the development of plans in formats which support evaluation, it will broaden the potential market for evaluation models and lowers the cost of producing them. It might also lower the cost of deploying a model in a new location, even where expert intervention is required, because the web services formulation radically reduces software installation and configuration time and allows modeling to be distributed geographically as well as technically. In order for this to take place, it is necessary that geodesign evaluation services be created in open and interoperable formats, and that work on appropriate semantic representations of design domains is significantly expanded. For example, the CityGML standard is currently the most well developed single broad-scale data model, but it lacks some of the semantic elements which would be needed to evaluate the compliance of a plan with the leading green development standard in North America

("LEED-ND"). These problems are not insolvable, but neither are they trivial. For example, consider innovations such as "green roofs" and on-site septic treatment.

Despite the inevitable complications, the geodesign concept remains worth pursuing because it has enormous potential to improve design and planning processes. At the 2010 Geodesign conference, Bran Ferren (FERREN, 2010) made the observation that many of the most important technologies in human history were important because they built on our capacity for "storytelling". In this sense, geodesign can itself be thought of as a narrative device. If our societal goals in achieving sustainability are to be anything beyond rhetoric, we will need to develop design processes which couple advanced geospatial technologies with all of the human creativity that we can muster.

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