Dynamic Interscalar Methods for Adaptive Design Futures

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Abstract. This paper addresses our current environmental and political climate directly, disseminating work from a research-based, upper-level architecture studio located at the border of Mexico and the United States. Dynamic digital tools and methods were developed to connect multiple scales of spatialized data. Additional field tools, including electromagnetic field (EMF) meters, environmental sensors, and micro-photography, enabled real-time dynamics to be combined with photogrammetry, satellite and GIS data. The selected outcomes utilize the methodological framework in different ways. Three presiding significant outcomes demonstrated from this work include: 1) micro-macro scale inquiry through spatio-temporal data collection and fieldwork; 2) parametric digital tools for emergent design optimization linking natural and artificial systems; and 3) human-machine-nature interactions for cultural awareness, participation, and activism. Collectively, these three functions of the methodology shift practice towards an alter-disciplinary logic to enable adaptive design outcomes that are responsive to a range of issues presented through site-specific climate change dynamics.

Keywords: Generative Design, Dynamic Modeling, Bio-inspired Design, Digital Pedagogy, Sustainability

1 Introduction

Contemporary conditions of environmental devastation and social inequity, combined with disruptive technologies, require that we drastically rethink our future academic directions and design pedagogies for the built environment. These challenging issues, both universal and contextually diverse, form a territory that necessitates creative and critical responses moving forwards. The Fourth Industrial Revolution and Anthropocene Age frame more inclusive design scenarios, which work with our natural systems rather than in opposition, letting these complex realities be ecological design drivers.

Considering this broad frame of reference within which contemporary architecture might take place, our work focuses on a regionally specific context to inform place-based outcomes of multi-scalar methods for developing adaptive design techniques. The regional context for testing the development of the dynamic interscalar methods is the Sonoran Desert, which spans from northern Sonora, Mexico into southern Arizona in the United States. The Sonoran Desert is rich in its ecological diversity, natural biomes, urban conditions, and sociocultural and political histories. While the expanded ambition situates itself amidst climate change complexities, the work remains adept to the narrow focus of honed discovery through context-specific phenomena to inform relevant design responses. The process of discovery is enabled through the integrated multi-scalar methods and combination of theory foundations, interactive digital tools, field measurement devices, and critical thinking for potential futures that exist outside of current assumptions and constraints of the embedded logics in existing systems and technologies.

To have a rich, inclusive design process it is important to incorporate both quantitative and qualitative methods.

"*There is incredible creativity and innovation necessary to balance the objective and the subjective, the quantitative and the qualitative, especially when each is backed by thorough study and observation of the natural world*" (Andraos, 2017, 8).

Trends for evidence-based design, utilizing data-driven tools and quantitative assessment measures, are becoming more prevalent in practices of architecture. Past trends emphasized the phenomenological and qualitative conditions of human experience, materials, and environments to bring meaning to architecture. Other, somewhat marginalized and less conventional practices might engage political agendas and emphasize social cause, but regular methods for translating these domains into built works are not entirely solidified. However, in each of these approaches, a tendency for reductionism and loss of opportunity to address necessary complexities can result. With a mixed methods approach to the design process, combining spatial and temporal analysis with real-time empirical data and simulation modeling, the outcomes are likely to be more robust for resilience to climate change and for adaptation to diverse socio-cultural conditions.

2 Methodology

The mixed methods design approach was executed in an upper-level design studio, titled Climate Change and Design, which was composed of a mix of 20 undergraduate and graduate students from various backgrounds in the fall semester of 2020. The main pedagogical premise was that to respond to the seemingly invisible and complex issue of climate change, we as designers need to incorporate more dynamic forms of modeling and awareness of multiple scales and systems into our design process.

Dynamic modeling and agent-based design has a long lineage, from the early works of John Holland on *Adaptation in Natural and Artificial Systems*, Greg Lynn's incorporation of animation software in the design process and John Frazer's pedagogical work on *Evolutionary Architecture* at the Architectural Association to name a few. Today, these methods are often incorporated into parametric and generative design as well as being used in analysis and simulation methodologies as design drivers or as post-rationalizations. Many progressive designers' goal is to incorporate more and more parameters into their digital models, ideally in a live way, to attempt to replicate the complexity of the real. These aspirations are typically tied to the computation limitations of hardware and software and the designer's knowledge of these parameters.

In addition to working with dynamic digital tools, the notion of boundary conditions at multiple scales and the incorporation of complexity theory and its implications were introduced in the methods. Readings from Melanie Mitchell (Mitchell, 2011) and Geoffrey West (West, 2017) of the Santa Fe Institute introduced students to complexity theory and its conceptual connections across disciplines and scales. Our studio's digital pedagogy attempted to advance these methodologies by also incorporating interscalar fieldwork into the parametric and agent-based virtual workflows and design process. This moves towards *trans-scalar design* (Moe, 2019). In addition, students were encouraged to research seemingly more invisible and ephemeral physical phenomena in their fieldwork, to build a more complex understanding of the real. "*The spatial disciplines hold a powerful tool: the ability to make visible the invisible around us*" (Murphy, 2020). Here we provide details of the dynamic modeling and interscalar fieldwork methods.

2.1 Dynamic modeling

Architecture has its origins in shelter from climate, historically, this trajectory has led to a general philosophical and physical separation from the world around us. The goal of the studio was to connect students more closely with the realities of nature and climate and their dynamic forces, with the premise that knowledge and awareness of adaptability and change are key to future sustainable, architectural designs.

"*Time is implicated in any notion of change in architecture; as a design dimension, time is often neglected and is insufficiently explored either in design studio projects in schools or in real-world projects*" (Kolarevic and Parlac, 2015).

This concept of change and time can be manifest in several ways but incorporating dynamic forms of modeling into the design process is probably the most straightforward.

Various workshops were held by the authors and outside specialists to introduce students to new platforms and expand skill sets to include coding in Processing (Fry and Reas, 2020), Arduino (Arduino, 2020), and proficiency with the geographic information system (GIS) ArcGIS Online (ESRI, 2020). Predominant tools were based around the Rhino (McNeel, 2020) and Grasshopper (Rutten, 2014) programs, with inputs from Arduino and ArcGIS to facilitate data at differing scales. Figure 1 shows an example of the studio's preferred connection between Rhino and GIS software using the Grasshopper plug-in Meerkat GIS (Lowe, 2014) and its connection with various Google application programming interfaces (APIs). This enables a live connection to ArcGIS, although at some points requires computationally intensive processing depending on the amounts of data being used (Mark and Ultmann, 2016).

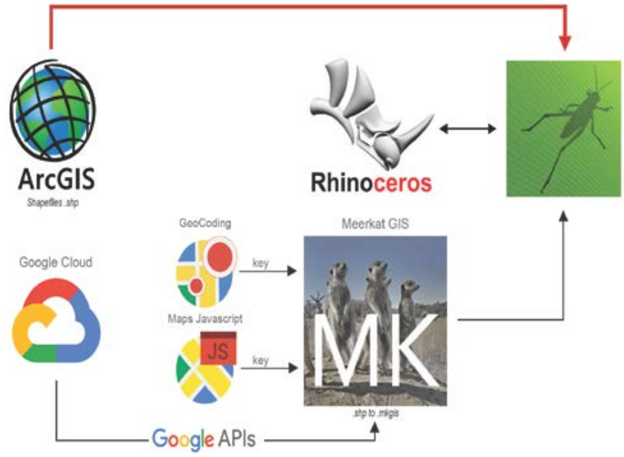

Figure 1. Diagram showing how to link ArcGIS with Grasshopper plug-in Meerkat GIS. Source: Authors, 2021.

This scaffolding of primary digital tools was enriched by additional tools and techniques, often at the leadership of students. Figure 2 is an example of a student incorporating TouchDesigner (Derivative, 2020), an interactive visual programming language, into her process.

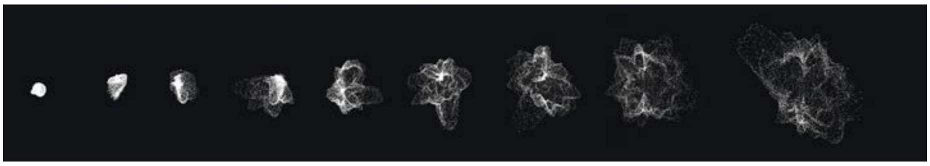

Figure 2. Agent-based behavioral algorithm simulation with TouchDesigner. Source: Ashwaq Jundus, 2020.

2.2 Interscalar fieldwork

In order to hone the applicability of abstract dynamic modeling techniques described in the previous section, field measurement devices are introduced for self-directed exploration in the Sonoran Desert context (Fig. 3). In this effort, students are deployed for independent inquiry with tools of their choosing to discover the non-obvious and often unnoticed aspects of a given place. The measurement and sensing devices allow for a closer study of micro-scale conditions, including thermal, radiant, optical, acoustic, energetic, fluid, and chemical phenomena. In comparison to traditional site analysis methods, which primarily depend on urban-scale mapping techniques, basic photography, and solar path studies to inform the relationships between a site and its surroundings, the experience and discovery of site conditions through digital sensing devices that expose seemingly intangible phenomena provides new insights about site dynamics and adaptive elements in the environment.

By introducing new tools to the architecture design process that could eventually become common practice, the discipline itself begins to shift in a necessary direction with methods that integrate climate change dynamics into the assessment of micro-scale phenomena and towards adaptive responses in design conception. This effort is lending to an *alter-disciplinary* approach to the practice of architecture, one that engages tools and techniques previously not integrated and otherwise utilized primarily by scientific and environmental disciplines. The use of real-time sensing devices in the field, such as microclimate weather stations, also engages the architect with the temporal dynamics and pulse of life that can be linked with the dynamic digital modeling

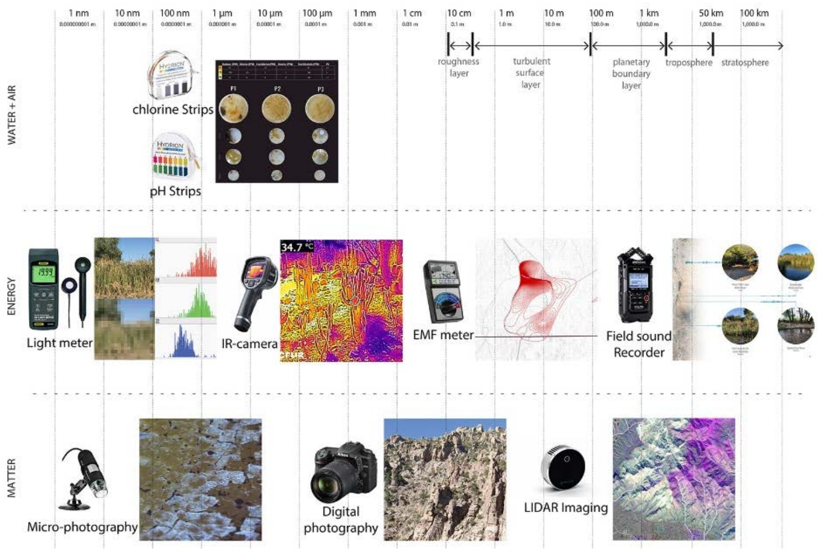

Figure 3. Interscalar field tools and digital measurement devices, with student outcomes. Source: Authors, 2021.

tools to inform visualizations of patterns and narratives for interpretation in the process of design. When micro-scale data collection feeds into the scaled-up digital landscape, whether through GIS or interactive plug-ins for Rhino-Grasshopper, the relevancy of site-specific phenomena is actualized. Interscalar relationships are potentially discovered through these connections and by way of co-linking empirical data with simulated investigations.

Some examples of how the field measurements are conducted and the range of phenomena studied are presented here. A few students had great interest in the issue of water in our region because of prevalent drought in contrast with flashfloods in addition to migrant deaths from dehydration and other water access challenges. These phenomena exemplify the relationship between broad climate change issues and context specific study. Students collected water samples from various points along the regional Nogales Wash and Santa Cruz River and used field devices and digital analysis tools in a lab to assess water quality and chemistry (Fig. 4). They then made correlations from the micro-scale qualitative data with the regional-scale geography of the water-flow directions and mapped the meandering paths back-and-forth from the Arizona and Mexico terrain.

Their discovery in this process revealed the influence of Arizona copper mining activities on originating water in the wash before it flows into Mexico where it carries with it trace metals and constituents that affect water and soil quality. At another point of water sampling, where the wash flows back into Arizona and reaches a treatment plant, the water is cleansed and free of the previous trace elements, as well as *e-coli* reduction, as it proceeds north towards populated areas of Arizona. This field exercise is just one example that exposes the geo-political dilemma of environmental inequities, which caused the students to begin to critique these existing conditions through their design formulations.

Other students were extremely curious about the electromagnetic and low-frequency waves transmitted in the region and set out to document the phenomena with field devices that translate wavelengths not readily audible or

Figure 4. Santa Cruz River (left) and Nogales Wash (right) water sampling field work informing scaled-up regional mapping. Source: Ellie Franzen and Athena Myers, 2020.

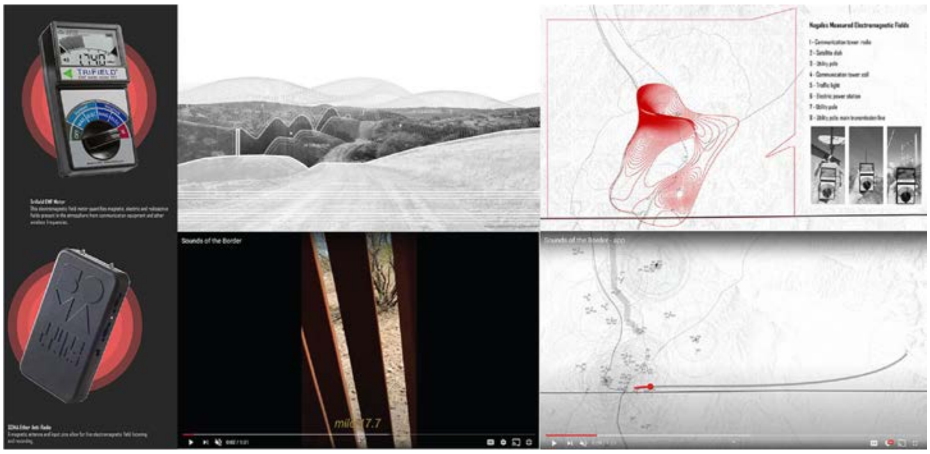

Figure 5. EMF (top) and anti-radio (bottom) devices and related fieldwork measures and translations into regional scale mapping and interactive apps (right). Source: Pawel Sapiecha and Rachel Schultz, 2020.

visible to the human ear or eye. The field research investigates regional electromagnetic fields (EMF) using a digital EMF reader as well as the low-frequency radio waves at the border wall with an analog anti-radio device (Fig. 5).

Documentation of these recordings and translation of the geo-spatial coordinates with digital mapping tools begin to reveal patterns and gaps of both communication and energy fields. The sounds recorded through the anti-radio device when attached to the existing border wall metal fins bring to light the regionally specific Latino stations that are prevalent and also ascribe a new role to the physical infrastructure. These sounds varied from white noise and chatter to audible music and dialogues. Their mapping process began with connecting these sounds, via a Processing script, to their geo-locations on maps with their EM fields.

Such discoveries as these with regional water and sound by the students provided inspiration for their subsequent studio design proposals. The integration of the digital and dynamic modeling with the interscalar fieldwork enabled a co-linked methodology to inform an emergent design process and one which allows for outcomes that are responsive and adaptive to context.

3 Results

To address the question of how we might design for adaptation amidst the current climate change and border challenges in the Sonoran Desert and the less known future impacts - tools and methods were introduced to advance the understanding and knowledge about existing conditions in the environment (both built and natural). The integration between site-specific and micro-scale digital measurement techniques with regional scale GIS mapping and concurrent spatio-temporal modeling methods is informing alternative design outcomes - ones which highlight the invisible and instill processes as much or more than products and artifacts.

In the selected examples for this paper, which focus on water and sound phenomenon, the project outcomes emphasize interaction between human experiences with the infrastructural, natural and energetic forces (electromagnetics and fluids). In part, this demonstrates how adaptive design futures will rely on an active engagement between the built environment and human experience so that the social awareness of climate change can become embedded in everyday actions and behaviors can shift and evolve accordingly. One expanded project outcome is provided here.

3.1 Adaptive design proposal: borderwall as antenna

Several students focused on aspects of sound, verses prioritizing the typical visually biased phenomena. The Spatial Sound Institute in Budapest, founded in 2015, believes that "*the way we evolve our listening will be the way we evolve our environment*." Students' previously mentioned fieldwork with EMF readers and anti-radios inspired further research into the question: what can we learn about regional communication from the invisible world of data and energy transfer? The focus was on attempting to understand the reality of these infrastructural systems in terms of the amount of energy that is produced and how this works at a geo-political border, seeking to reveal the causes and effects. These inquiries led to research on websites like EdgeUno Global Infrastructure (Infrapedia, 2020) and the Homeland Infrastructure Foundation Level Data (U.S. Dept. Homeland Security, 2017), where it became apparent that the network of data lines that crossed the border were few and far between. This network was confirmed by the traceroute software tools, which enabled the students to map a regional Internet Protocol Network (IPN) route (Fig. 6). Rather than utilizing an existing direct IPN for a transborder communication between Tucson, AZ and Hermosillo, Mexico, the circuitous routing highlights the extreme inefficiency of the network and its resulting unnecessary energy usage.

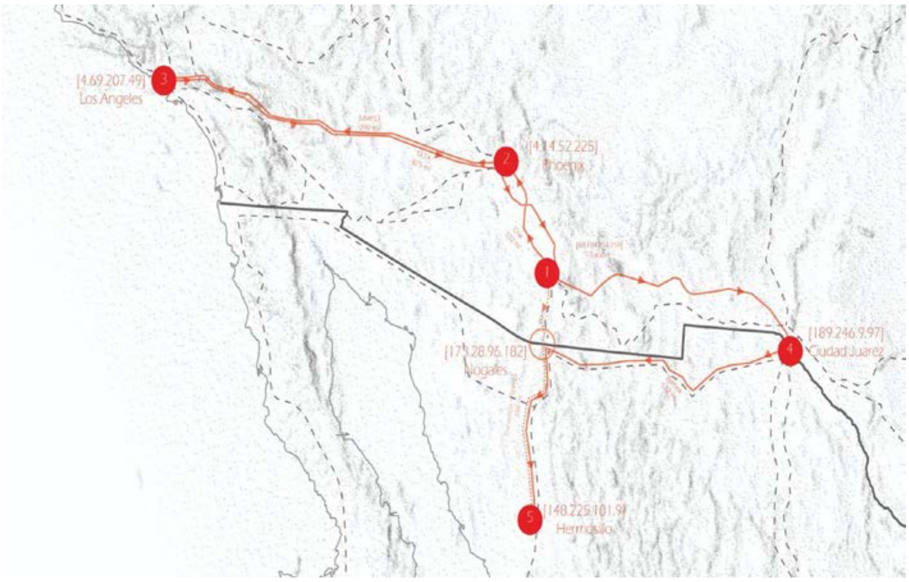

Figure 6. Mapping of regional IPN for cross border communication, using traceroute software. Source: Pawel Sapiecha and Rachel Schultz, 2020.

Ultimately, the students arrived at a parametric design for manipulating the existing border wall metal fins by warping the elements to curve in specific directions that both focus and project the radio waves (Fig. 7). Creating a landscape plaza to encourage people to gather around the installation locations, humans can then interact with the installation through microphones and speakers (sending their own messages across the border) and also listening to EMF sounds that are broadcast cross-border when received through the focal fins.

The warping of the fins is very specific to the regional radio tower sites and radial projection ranges of the EMF waves, optimizing reception and transmission and serving as a bidirectional communication system. During the studio reviews, one of the critics made reference to the *Border Tuner* project by artist Rafael Lozano-Hemmer (Lozano-Hemmer, 2019), which engages transborder participants at the border at night with intersecting searchlights to enable direct communication when the lights cross paths. The *Border as Antenna* student team also inferred that their installation could be used for climate emergency broadcasting in scenarios when the internet might be down. Through this proposal the border wall takes on a new intelligence, one that was already inherent to the material construction, made apparent through the research discovery and attenuated through the design.

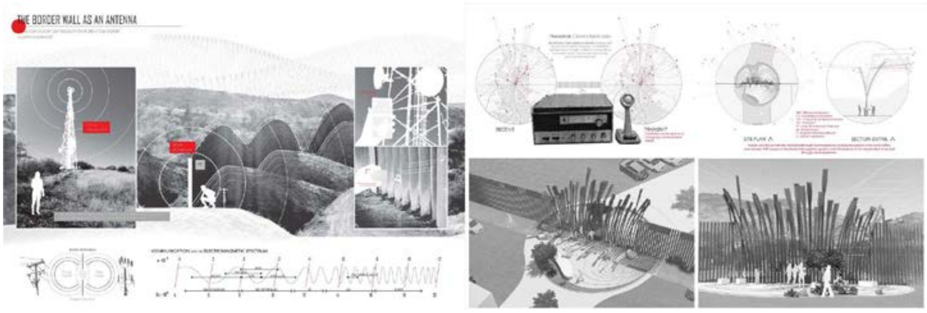

Figure 7. *Borderwall as Antenna* final design images showing plaza and antennas. Source: Pawel Sapiecha and Rachel Schultz, 2020.

3.2 Expanding beyond the visual and anthropocentric

The results from the research-based design efforts clearly begin to articulate the potential of linking interscalar methods of digital sensing and dynamic modeling alongside GIS mapping to better inform adaptive and responsive futures. It is the design process that is shifting from this methodology and requires skill development with co-linking sensing techniques and dynamic modeling tools in architecture practices, re-framing design practices through an *alter-disciplinary* approach.

The purpose of the interscalar fieldwork is in part to incorporate more senses into the equation to start comprehending the complexity and richness of reality. It begins to blur the boundaries and exchanges of the human-built and natural environments and increases students' understanding of the inter-connectivity of the world. The focus of revelation of the environment varied from student to student and ranged from the previously mentioned water issues to pollution in the air and the awareness of the infrastructure and energy that is used to create our digital culture. This methodology attempts to broaden an understanding that our built actions in the environment are not neutral and that there are spatial effects and consequences beyond the concept of shelter.

Three presiding significant outcomes demonstrated from this work include: 1) micro-macro scale inquiry through spatio-temporal data collection and field work; 2) parametric digital tools for emergent design optimization linking natural and artificial systems; and 3) human-machine-nature interactions for cultural awareness, participation, and activism. Collectively, these three functions of the methodology shift practice towards an *alter-disciplinary* logic to enable adaptive design outcomes that are responsive to a range of issues presented through climate change dynamics.

4 Discussion

The studio outcomes were a mix of expected and unexpected results, but the projects that created layers of complexity and not complications, particularly relating to dynamic natural and artificial systems, definitely were the most rich and successful. These project authors were also generally the most digitally adept students in the group, which ties into many successful global design practices. Other, less digitally able students often had great conceptual ideas, but lacked the confidence to move forward with some of their earlier research processes, and tended to resort back to old ways of design thinking and digital methodologies. The digital methodology introduced in this studio was generally a new approach for most students, where their prior architectural education consisted of traditional 2D representational emphasis, with 3D digital models often coming out of this 2D world rather than the opposite way around. Some students who were used to designing in 3D generally did not incorporate the notion of time into their designs, particularly into the early aspects of design generation beyond typical site analysis. Student research and work was always disseminated as a group at regular intervals in order to facilitate the development of the weaker students with the group's collective intelligence.

The pedagogical design challenge is incorporating research and dynamic digital methods and field work into an emergent design process, i.e. as a design generator, embracing and trusting the messiness of this nonlinear process, especially when they have generally been previously trained to work in a more hierarchical, straight forward way. These processes, like emergence, relating to complexity theory and climate change, give agency to students and are now excitingly being embraced beyond the scientific community to connect us to the humanities and arts, relating the environment with issues of social justice in new profound ways (Brown, 2015). Collective intelligence gives us the ability to cooperate and share, without destroying the individuality of students.

In future iterations it will be useful to create a stronger scaffold for the weaker students so they could succeed, without constraining the more advanced ones. This could be achieved by bringing more focus and direction on climate phenomena, with particular tools, methods and exercises for the less digitally adept students, yet still allowing them to be creative and breathe.

Throughout the semester it was clear that learning these dynamic, virtual and real-world methodologies and the focus on multiscalar natural and human built systems set students up well to address our changing world; a necessary part of the process of starting to address climate change and sustainability. Beyond the class, ideally, we would have more impact on the broader curriculum starting on day one of foundation rather than typically addressing these issues and methodologies at more advanced level courses where additional technical and conceptual training is required.

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