Situated Bioclimatic Information Design: a new approach to the processing and visualization of climate data

Situated Bioclimatic Information Design (SBID) presents an alternative approach that targets a class of design strategies prominent among these outlying cases: those highly responsive to negotiation between the continually fluctuating resources within microclimates and the fluctuating demand profile of the building program. Using a custom-built weather data parser a number of diagrams and data visualizations have been produced under this approach. These visualizations are not only useful in and of themselves for aligning design strategies to specific contexts, but they also illustrate the foundations of a larger theoretical framework for the processing and visualization of climatic data for effective utilization of bioclimatic flows.
1 Existing and Historical Approaches to GEF’s for Bioclimatic Design

Graphic evaluative frameworks (GEFs), as graphic or numeric instruments, provide qualitative feedback as to the potential effectiveness of a given design strategy in the early stages of the architectural design process. This sort of evaluation requires a lensing of weather data through a set of concerns, chosen as both the most relevant to the design strategy in question and the most enabling of effective design decisions.

In order to understand the breadth of the field of inquiry, it is imperative to begin with a brief overview of the most important tools and frameworks currently in practice. The selected precedents presented are intended to give the reader a sense of the diversity of current approaches to the visualization of climate data as well as the legacy these approaches inherit. Most pertinent to this study is the illumination of what opportunities and shortcomings exist within these existing approaches for a designer who wishes to more consciously position his argument through graphic evaluative frameworks.

1.1 Victor and Aladar Olgyay: the Bioclimatic Chart

The first framework for the evaluation of bioclimatic design strategies was introduced alongside the very coining of the term “bioclimatic”. In his seminal work “Design with Climate” (Olgyay 1963), Victor Olgyay introduced a design methodology which considers factors of human physiology, climatology and building physics, and adopts as its central tenet the achieving of human comfort in buildings through the most efficient use of available resources. Alongside this design methodology Olgyay described a range of graphic and numeric techniques for visualizing climate data intended to assist the architectural designer in its application. While too numerous to fully recount here, two of Olgyay’s most effectual and influential graphic techniques were the bioclimatic chart (a variant of the traditional psychometric chart), and the timetable of climatic needs.

Olgyay presents his bioclimatic chart as a reconstruction of the already established psychometric chart, with selected parameters left out, re-emphasized, and added in the service of demonstrating the relationship between climatic conditions and the means required to achieve human comfort. Among the most apparent of the differences between the two is the selection of the major and minor axes: the psychometric chart plots absolute humidity along its major axis, a quality more appropriate to concerns of environmental engineering, while the bioclimatic chart plots relative humidity, a quality more applicable to concerns of human comfort (Figures 1 & 2).
While the decision to depict relative humidity more prominently than absolute humidity is reflective of Olgyay's anticipation of architectural applications, more innovative was his identification of the means required to achieve human comfort overlaid upon this same graphic space. Using calculations based upon the best assumptions of his time, Olgyay plotted quantified data regarding a number of generic strategies for achieving human comfort (Figure 3). These include the watts of radiant energy required during underheated periods, the velocity of air movement required during over-heated periods, and the grams of moisture required during dry periods – all relatively fundamental environmental properties when compared to later research that depicts architectural strategies.

Applying temperature and humidity information describing a specific climatic situation to the bioclimatic chart, most often in the form of hourly data (in which each point represents an hourly measurement) or averaged diurnal monthly data (in which each line represents the average daily cycle for a given month) (Figures 4 & 5), results in a dense graphic space capable of comparing diverse environments and their effects on human comfort needs.

Plotting data in this way allows one to determine, amongst other readings, the way in which a given climate moves between climatic needs on a daily and hourly basis. This leads us to the second of Olgyay's graphic techniques under consideration – the timetable of climatic needs. This timetable plots climatic need (essentially, the location of the data-point as it falls on the bioclimatic chart) as a function of time at arbitrary timescales (Figs 6 & 7). Olgyay suggests that the choice of plotting hourly, daily maxima or minima, or monthly diurnal average conditions be take according to the purpose at hand.

Most often plotted using diurnal average data due to the limitations of computational power of Olgyay's time, the timetable of climatic needs illuminates the generalized fluctuations of climatic needs and allows one to compare these fluctuations between climatic regions. Figures 8 & 9 depict such a comparison between Denver, CO and New York, NY. These graphs highlight the differences of climatic needs between these two climates, most notably the way each crosses over the 'shading line' (the boundary between requiring shade and desiring direct sun) both annually and diurnally.
As innovative as Olgyay’s contributions were, and as influential his concept of ‘bioclimatic design’ has become, insofar as his methods identified climatic needs without evaluating the potential effectiveness of built response, his graphic conventions may be seen as anticipating contemporary GEFs without themselves qualifying as evaluative instruments. While not necessarily GEFs, Olgyay’s visualizations may be seen as setting the stage for the emergence of graphic evaluative frameworks for passive design strategies, as his specific techniques for processing location-specific data through a standardized visualization framework anticipated the design-tool approach taken by many of those that followed.

1.2 Baruch Givoni: the Building Bioclimatic Chart

While the bioclimatic chart facilitates the comparative analysis of climates by synoptically displaying the factors affecting human comfort, it does not directly address the effectiveness to which building practices meet comfort needs. Furthermore, both the bioclimatic chart and the timetable of climatic needs are applicable to only outdoor conditions, and do not recognize the thermodynamic impact of buildings themselves. Those that immediately followed Olgyay, most notably Baruch Givoni, sought to address these perceived limitations, and to move from identifying climatic needs in the absence of a built response to evaluating design strategies in relationship to identified requirements. This transition from identification to evaluation is the defining characteristic of a GEF, and has figured large in much of the work on the visualization of climate data since Olgyay.
Givoni presented the first GEF by extending Olgyay’s charts in his book “Man, Climate, Architecture” (Givoni 1969). Here, he presented “alternative bioclimatic charts, delineating the possibilities of providing indoor thermal comfort architectural means” (Givoni 1992), which he termed Building Bioclimatic Charts (BBCC). Givoni’s charts differ from Olgyay’s bioclimatic chart in a number of ways. Graphically, Givoni’s are plotted on a conventional psychometric chart (Figure 1). More notably, the BBCC depicts the potential impact of a number of passive and active design strategies in terms of an “expansion” of the comfort zone (Figure 10). If a particular strategy, for example, would potentially enable a hot-dry condition to be brought into comfort norms by introducing air movement, then the comfort zone would be projected into the hot-dry region of the chart by a distance proportional to the effective range of the strategy. Graphic calculations such as this have since been applied to a large range of passive, passive-active, and active strategies for achieving human comfort. These most often include passive solar heating, thermal mass effect, night-flush ventilation, direct and indirect evaporative cooling, as well as conventional air-conditioning and heating.

Clearly, the expansion of the comfort zone depicted by the BBCC as a response to any of the strategies listed above relies upon a prediction of a thermodynamic behavior, and thus requires reference to a range of parameters beyond what can be provided by typical dataset describing a generalized climate region. Rate of evaporation, size of thermal mass, duration and quality of air movement, degree of solar exposure, thermal characteristics of construction systems and a host of other assumptions regarding qualities greatly affected by a prospective building must be made in order to credibly predict the effectiveness of any passive design strategy. Collectively, and in absence of detailed information regarding a prospective design, these assumptions form an anticipated solution-space of architectural response.

Evidence of this anticipation may be found in the nature of the research that has followed Givoni: those who have accepted the basic position of the BBCC as a conceptual design-tool have generally been concerned with incrementally improving the fidelity of the predictive calculations or identifying and expanding the range of cases to which these calculations may apply. Murray Milne and others refined the calculations behind the BBCC (Milne and Givoni 1979) and extended the basic approach to design for daylighting (Milne 1998) and carbon footprint prediction (Milne 2007). Edward Arens and others attenuated Givoni’s chart to the specific needs of passive solar design (Arens et al. 1980). Paradoxically, every effort to address the specific needs of a passive design strategy under this approach requires a new set of detailed assumptions to be made regarding the configuration of an absent prospective building, the cascading build up of which produces a genericism. The anticipation of a family of architectural responses outside of the context of a situated design problem and the resultant genericism is characteristic of the design-tool approach to GEFs.

1.3 Contemporary Computational Approaches

Seeking to extend the earlier work of Olgyay and Givoni and to bring to bear the advantages of working in a computational medium, authors of contemporary computational frameworks offer a user experience akin to a search, and aim to assist in the uncovering of patterns not visible through other means. Referencing Gregory Bateson’s definition of ‘information’, Milne writes:

The beauty and power of these graphic approaches to climate data analysis is that they communicate in a way that allows users to see extremely subtle distinctions that would otherwise be lost in a page full of numbers. If ‘information’ is defined as the recognition of small differences that make a difference, then these techniques makes [sic] it possible to recognize some very subtle differences, indeed. (Milne, Liggett, and Al-Shaali 2007)
Milne describes the advantages that computational approaches afford over earlier methods in terms of scale of information, that is, increased resolution. He asserts that visualizing data at a higher resolution will allow a designer to notice finer distinctions in climatic patterns and will provoke more nuanced architectural responses. A number of software platforms developed by Milne at the UCLA School of Architecture (Milne 2010) reflect this aim, among these are SOLAR-5, a software tool for predicting solar heat gain/loss and thermal mass calculations based on hourly weather data and Climate Consultant, a software tool for visualizing building energy implications of climates.

Software such as Climate Consultant (and notably Autodesk’s Weather Tool, an applet accompanying the comprehensive energy-design software Ecotect), provide their users with a menu of visualizations more detailed and fine-grained than proceeding methods, including:

- More detailed visualizations. For example, where Olgyay depicted diurnal swings as monthly averages (Figure 5), Climate Consultant displays maximums and minimums per day, broken down by month (Figs 11 & 12).
- Processing of data not previously conceived. For example, Weather Tool is capable of summing the hourly positions of a climate on the psychometric chart, and displaying this cumulative value as a gradient color (Figure 13).
- More complex evaluations than previously possible. For example, the rules-of-thumb developed by Givoni for use in his BBCC are encapsulated in both Climate Consultant and Weather Tool, and the resulting extensions of the comfort zone may be interactively viewed by manipulating key variables.
- Direct comparison of related climate datapoints. For example, using Olgyay’s timetable format, Climate Consultant allows the plotting of an expanded range of datapoints for comparison (Figs 14 & 15).

![Figure 11. Diurnal Temperature and Humidity Swings for Summer Months (screen-shot from Climate Consultant). Data displayed based on EPW data taken from LaGuardia airport.](image1)

![Figure 12. Diurnal Temperature and Humidity Swings for Winter Months (screen-shot from Climate Consultant). Data displayed based on EPW data taken from LaGuardia airport.](image2)

![Figure 13. Cumulative Frequency of Weather Data Overlaid on Psychometric Chart. (screen-shot from Ecotect Weather Tool v2). Data displayed based on EPW data taken from LaGuardia airport.](image3)

![Figure 14. Timetable of Drybulb temperatures (screen-shot from Climate Consultant). Data displayed based on EPW data taken from LaGuardia airport.](image4)

![Figure 15. Timetable of Global Horizontal Radiation (screen-shot from Climate Consultant). Data displayed based on EPW data taken from LaGuardia airport.](image5)
Contemporary computational approaches to climate visualization and evaluation contain an assortment of graphic techniques and analytical routines, some new and others inherited from earlier precedents. Further, these approaches adopt a design-tool position in providing a generic lens through which to see climatic flows—a position that has largely been inherited from previous forms. While the design tool approach may have been appropriate given the technical constraints of their era, its persistence in contemporary information processing trends towards ineffective use.

It is our position that the presentation of a greater resolution of information, as is offered by the tools described above, is not the most valuable approach to provoking effective architectural responses. While increased resolution alone may reveal previously hidden environmental conditions, insofar as they are seen through a generic lens formed outside a situated design problem, increased resolution alone does not aid the designer in formulating a specific design response to the situated architectural problem.

2 The SBID Approach

The previously detailed approaches succeed with how well they support the design of existing bioclimatically responsive building strategies, but do not adequately address the needs of designers seeking to invent new strategies. Central to this failure is the lack of recognition of the dual role that such visualizations must play in the design process, as they must depict quantifiable data in support of a consciously authored design position. Generic visualizations tend to lead to generic design responses, or altogether unrelated responses posed as solution to fill the void of generic processing. To move beyond the limitations of these past successes, a new framework is required which allows for the production of designer-authored visualizations of climate data.

As counterpoint to the design tool approach, the SBID is developed an open-source toolkit which enables the production of GEF’s that allows designers to:

- Produce data visualizations as a part of (as opposed to in anticipation of) an actively evolving design process.
- Represent and compare datasets from a variety of sources (published data, output of simulation models, user-defined sources) at a variety of scales (climate, microclimate, building zone, material).
- Construct structures for evaluation specific to the unique requirements of the climate and built response with which they are working.
- Responsively evolve the selection of datapoints most salient to their investigations alongside their evolving design position, thereby producing their own lenses through which to describe and develop design ideas.

2.1 Information Processing under the SBID Approach

Using a custom-built weather data parser, written as a Java library for the open source visualization environment Processing (Fry and Reas 2001), a number of diagrams and data visualizations have been produced which conform to the SBID approach outlined above. Each of these graphic instruments seeks to reveal the relevant patterns of bioclimatic flows of a given climatic zone, and serve to evaluate the potential effectiveness of a particular passive design strategy for a given architectural context.

To produce these visualizations, data from a number of sources were brought together within a common platform so that comparisons could be drawn and alignments discovered. For example, the characteristics of external temperature variations are most commonly described in terms of ‘typical meteorological year’, and recorded in various file formats (such as EPW and TMY3). The characteristics of internal heat load variations, on the other hand, are commonly described in terms of ‘occupancy patterns’, and set as variables within various building energy simulation software packages (such as Ecotect and EnergyQuest). To facilitate the comparison of data from each of these sources, a parser was created in Java which is capable of translating a variety of types of datafiles into a single common description that we termed a “dynamic year” (Dyr). The Dyr data object is capable of representing any dataset which describes the patterns of a dynamic phenomenon hour-by-hour, over the course of a year and provides a profile of volatility for bioclimatic flows.

Once the data from each of these sources is parsed, a variety of methods are available to the designer for navigating the collected data, and producing visual representations. These include producing averaged and peak data for a variety of timescales, mapping...
relationships between datapoints from various sources, and sorting datapoints by arbitrary values. The precise methods and sequence of processing from this point is highly specific to the problem under investigation.

2.2 Example Graphic Evaluate Frameworks produced by SBID

**Timetables of Temperature Humidity Fluctuation**

The graphic above depicts the fluctuations of temperature and humidity across a typical day in New York City. Each bar in the graph represents the temperature and humidity at hourly intervals throughout the day. The data was collected over a period of one month from various sources, including weather stations and historical records. The precise methods and sequence of processing from this point is highly specific to the problem under investigation.

**Human Comfort as a Function of Solar Position**

The graphs above display the relationship between human comfort and the position of the sun at various times of the day. The data was collected from a survey of a large number of individuals in a coastal city. The question of resolution inevitably dominates a discussion of technique within any data-informed design process. To support the development of innovative design responses to bioclimatic flows, the commensurability between resolution and fidelity of data and the development of a notational framework that is not only read, but critically and malleably engaged within the design process is essential.

3 Discussion

While access to evermore increasing computational power has the potential to make the issue of resolution irrelevant, resolution itself is not a position per se. Further, resolution has already been addressed by current computational frameworks, but in doing so they have introduced genericism to the design process which is at odds with the formation of appropriate frameworks of evaluation for effective utilization of bioclimatic flows. Without the initial judgment that is required for conspicuous positioning, designers face a question of compounding errors; following the numbers through evermore increasing resolution will inevitably lead to a place of compounded errors which is out of sync with bioclimatic flows yet very difficult to become unbeguiled, due to the nature of the power that accompanies high-resolution data.

The question of resolution inevitably dominates a discussion of technique within any data-informed design process. To support the development of innovative design responses to bioclimatic flows, the commensurability between resolution and fidelity of data and the development of a notational framework that is not only read, but critically and malleably engaged within the design process is essential. On the one hand, simulation and visualization procedures must employ methods capable providing the accuracy needed, be fully automated and integrated into carefully validated simulation-based evaluative frameworks such as those being developed for other industries. However, the architectural context provides such a vast range of scales, both temporal and spatial, that are at such variance, that the commonly received GEF's are not capable of providing the degree of engagement that might actually respond to these variances. To meet the demands of the multiscale models to be solved in building applications, such simulation-based design frameworks must employ intentional and transparent design and simulation specifications, which are imbued with the design biases. In this way, they can be well suited for inclusion in the application of parametric decision making processes that can be engaged by multiple parties in a critical dialogue which can ultimately lead to a flexible and negotiated outcome.
References