# Programmable ecosystems: creating an architectural design tool through urban environmental analysis

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**Abstract**

How does the increased complexity in the design process affect architectural thinking? Can we shift the nature of design towards the integration of sustainable design strategies? Nowadays, the combined effects of urbanization, global climate warming and the continuous increase of human flow give rise on a decrease of the air quality as well as an increase in temperature, aesthetic and noise pollution. While human presence has a significant impact on the urban environment, the urban conditions radically affect the qualities of the design at micro and macro scale. The current study demonstrates that architectural and urban design can be largely influenced by environmental variables that radically alter the urban conditions. Influenced by combined inputs, activity and deliverables, design can be seen as a decision – focused process that offers the opportunity to connect conceptual complexity with scientific data.

*Keywords: Climate data; design process; environmental simulation; complexity*

## INTRODUCTION

How does the visualization of urban climate factors transform the flow of decisions in the architectural design process? Is it possible to create architecture that respires, by maintaining a constant energy exchange with the outside world [1]? Urban climatology generates sensed data, which can contribute to descriptive climatic studies and determine parameters for model and experimental techniques [2]. Urban open sourcing provides a huge pool of climate factors and triggers the creation of a new model for engaging designers with complex scientific data. Notwithstanding the abundance of climate data and tools for urban data modeling, designers with no specific knowledge on environmental analysis do not enter in the process of translating data into design parameter as 'it takes many hours just to know where to start' [3]. Moreover, there is not enough research depicting the percentage of designers using the available data sets to reshape their proposals.

Here, we demonstrate that less data wins over big data. In that sense, the filtering and right visualization of climate factors constitutes a significant part of the architectural design process. Open sourcing the city provides a valuable set of data available directly to city users, designers and environmental experts. However, the abundance of data is not enough to promote data-driven design methods, as it confuses architects and planners and renders the design process even more complex and difficult. Intelligent cities miss the opportunity to mobilize technologies, making them invisible and putting them in command rather than in dialogue with the users [4]. However, open source city provides users with an excessive amount of data that has to be filtered in many ways before being adapted to the design process. The scope of this experimental study is to examine the degree to which designers can incorporate simple climate data into their design proposals as well as to estimate the contribution of each parameter to the design process. The conducted experiment forms a case study in the context of designing an interactive online platform for architects, citizens and decision-makers, by offering design prototypes and suggesting new ways to use urban climate factors. During the development of this tool, environmental simulation is used to bridge the gap between urban, architectural design and scientific data by stimulating the environmental concern of the public and through user interaction. The paper is divided into five sections: **Section 2** is devoted to the methodological framework of this study, **Section 3** refers to the data capturing and processing, **Section 4** describes the expected results and **Section 5** discusses the potential of this study towards the empowering of both social and architectural innovation and contains concluding remarks.

## METHODOLOGY

In the framework of the Architectural Design Studio IV at the Technical University of Crete, we explored the concept of mapping the urban environment as a lens through which to reshape the design process. Mapping is by default directional, in the sense that it is created for specific use. Ironically, while GIS-based mechanisms such as OpenStreet Map and Geofabrik tools have increased mapping prevalence in the design process, maps are no longer conceived as a product of understanding data sets, but as a result of pure data visualization. This dramatically alters the integration of data into the design process, as the designer becomes unable to consider the challenges for climate to positively contribute to the design. How can we engage architects with urban physics? The best design work comes out of a strong research base, which may rely on demographics, on use patterns, on flows of capital [5]. In that sense, we invited students to participate to a series of short exercises and lectures to render climate data understandable and actionable. The Architectural Design Studio involved the selection of a city block in the centre of Chania (**Fig.** 1), where students were required to propose housing typologies for 1 to 4 persons, offices, shops and a business incubator in a total of 4.200 sq.m. built space.


**Fig. 1**: Case study area, Architectural Design IV, Spring 2015.

The concept of the experiment included the creation of a set of parameters to estimate the different ways in which they are incorporated and involved in the design as well as what aspects of the mapping are regarded as the most significant in the design decisions. Capturing, validating, interpreting and presenting climate data also formed part of these exercises, aiming to present in a quick, clean and concise way complex scientific data to the designers. Data mining and visualization took place after the submission of preliminary proposals, as we intend to estimate the number of proposals that will be reshaped in relation with the extracted data as well as the relative amount of radical interventions suggested after synthesizing multiple narratives of architecture, structure and environment. We also aspire to gain valuable insight in defining the optimal moment to incorporate sustainability strategies in the design process. On the one hand, providing the designer with climate data too early could potentially be a threat. On the other hand, sustainability is a complex parameter that may alter radically the design concept and should be taken into consideration at an early design stage through simplified data.

## DATA MINING, VALIDATION AND PROCESSING

The parameters selected were temperature, humidity, air pollution levels and surface temperature imagery. The capture of data was done through the use of sensors and a thermal camera. Data gathering consists of three layers of information: data captured through sensors located at fixed points of the city block, data obtained through portable sensors at critical points of the city around the city block and thermal imaging of the four elevations of the block. Given the practical difficulty to continuously monitor the microenvironment, it was important to select the monitoring periods during which sampling measurements would be conducted [6]. In our case, data gathering took place during one relatively warm day of May, given that the scope of the exercise was not to create a big spectrum of data throughout a large period of time, but to create a relatively valid 'datascape' that would replace the empirical data in the architectural design process. In our case, the use of sensors for creating an urban environmental map of the case study area is primarily needed to engage students with data-driven design approaches. In that sense, the radius of validity is not as important as the filtering of the information to be visualized.


**Fig. 2**: Fixed temperature, humidity logger


**Fig. 3**: Fixed CO2 data logger

Field monitoring was conducted from 9.00 am to 9.00 pm. Fixed temperature, humidity sensors were located at the four corners of the city block (**Table** 1), while one CO2 sensor was installed at the joint corner of the two roads with the heaviest traffic. Portable meters, measuring temperature, humidity and CO2 emissions were used to map 15 different points around and inside the block, capturing data once every hour for each point. Specifically, four LOGIT loggers were programmed to capture data related to temperature and humidity at the corners of the city block every 10 minutes (**Fig**.2). The HOBO logger saved every 10 minutes data referring to CO2 levels of the point with the heaviest traffic. (**Fig**.3).

**Fig. 4**: Thermal camera

**Fig. 5** Thermal imagery process

Thermal imaging was conducted every two hours throughout the day. In order to capture maximum thermal imaging detail, every elevation of the block was divided into four parts (**Fig**.4,5). As a result, each elevation was captured five times in total. Thermal imaging, apart from allowing to gain control over the materiality of the tested surfaces, it offers the chance to directly measure the surface temperature, which is crucial for the urban energy balance and modulates the air temperature of the lowest atmospheric level [2]. This led to basic assumptions regarding the air temperature of the street canyons around the city block.

**Table 1**: Data extracted from Logit [Temperature Humidity Logger #1]

LTH: Logger Memory; Temperature Humidity Logger #1. Sample Interval Is 10 Mins. Logging Started At: 4:47 ĪĪ 5/5/2015

| Samp # | Temp (F) | Humidity (%RH) | Dew Point (F) | Date | Time |
|---|---|---|---|---|---|
| 0 | 77.41 | 57.39 | 61.18 | 05/05/15 | 16:47:12.0 |
| 1 | 80.63 | 53.01 | 61.92 | 05/05/15 | 16:57:12.0 |
| 2 | 80.34 | 52.68 | 61.47 | 05/05/15 | 17:07:12.0 |
| 3 | 81.41 | 52.16 | 62.19 | 05/05/15 | 17:17:12.0 |
| 4 | 83.17 | 50.19 | 62.71 | 05/05/15 | 17:27:12.0 |
| 5 | 84.54 | 48.93 | 63.23 | 05/05/15 | 17:37:12.0 |
| 6 | 85.32 | 48.05 | 63.43 | 05/05/15 | 17:47:12.0 |
| 7 | 85.71 | 47.48 | 63.44 | 05/05/15 | 17:57:12.0 |
| 8 | 85.81 | 47.00 | 63.24 | 05/05/15 | 18:07:12.0 |
| 9 | 85.81 | 46.68 | 63.05 | 05/05/15 | 18:17:12.0 |
| 10 | 85.71 | 46.43 | 62.81 | 05/05/15 | 18:27:12.0 |
| 11 | 85.42 | 45.77 | 62.13 | 05/05/15 | 18:37:12.0 |
| 12 | 84.93 | 45.70 | 61.65 | 05/05/15 | 18:47:12.0 |
| 13 | 84.25 | 46.03 | 61.23 | 05/05/15 | 18:57:12.0 |
| 14 | 83.66 | 47.00 | 61.29 | 05/05/15 | 19:07:12.0 |
| 15 | 82.88 | 47.79 | 61.05 | 05/05/15 | 19:17:12.0 |
| 16 | 82.29 | 48.36 | 60.85 | 05/05/15 | 19:27:12.0 |
| 17 | 81.71 | 48.84 | 60.59 | 05/05/15 | 19:37:12.0 |
| 18 | 81.22 | 49.24 | 60.38 | 05/05/15 | 19:47:12.0 |
| 19 | 81.02 | 49.59 | 60.40 | 05/05/15 | 19:57:12.0 |
| 20 | 80.63 | 49.84 | 60.18 | 05/05/15 | 20:07:12.0 |
| 21 | 80.24 | 50.09 | 59.97 | 05/05/15 | 20:17:12.0 |
| 22 | 79.95 | 50.31 | 59.82 | 05/05/15 | 20:27:12.0 |
| 23 | 79.66 | 50.49 | 59.65 | 05/05/15 | 20:37:12.0 |
| 24 | 79.46 | 50.75 | 59.62 | 05/05/15 | 20:47:12.0 |
| 25 | 79.26 | 50.90 | 59.52 | 05/05/15 | 20:57:12.0 |
| 26 | 79.17 | 51.09 | 59.53 | 05/05/15 | 21:07:12.0 |
| 27 | 79.07 | 51.28 | 59.55 | 05/05/15 | 21:17:12.0 |
| 28 | 78.78 | 51.41 | 59.35 | 05/05/15 | 21:27:12.0 |
| 29 | 78.78 | 51.61 | 59.46 | 05/05/15 | 21:37:12.0 |

Validation of temperature, humidity and air pollution was achieved by comparing data captured through fixed and portable sensors at the four fixed points of the city block.
The captured data is interactively visualized and processed through the Processing GUI, giving the possibility to the designers to 'extract' visual data of different points of the case study area and save it easily in picture format. Through thermal imagery, elevation captures are translated into .gif format files that depict the transformation of surface temperature over time. Data processing allows designers to create a climate 'snapshot' of the case study area to superimpose on their preliminary design proposal and calibrate the design concept with the streamlined scientific input.

## EXPECTED RESULTS

By creating an interactive map of the urban tissue, we intend to break through the barrier of complexity, providing the students with the results directly linked to the architectural design process. This enables to overpass the step of determining which sets of data can be useful to the design proposal. Instead, they have the chance to adjust the design proposal, or even create evaluation criteria related to the energy efficiency to the preliminary design, based on the data acquired.
However, non-experts are not able to decipher data linked to environmental parameters. Given the fact that a small fraction of the Architectural Studio students volunteered to participate to the field exercise, it is expected that the team of students involved in the mapping process will achieve the maximum calibration between architectural design and scientific data. Understanding the issues of climate requires a minimum exposure to the mapping process at a preliminary stage of the design.
We also expect to witness a big percentage of slight transformations to the core design and small 'green' interventions at a small scale. Even if designers have the essential data at the right time, they experience difficulties in fully integrating the climate data into the design process, since the proposal, even at its preliminary stage, has solved a big number of complex parameters. Designers often convert a sustainable strategy into the main axis of the design proposal early in the design process. As a result, when integrated at a more advanced level, the environmental parameters tend to alter the materiality of the suggested volumes, the greening of roofs, or the integration of solar panels. Although these strategies contribute to a more energy-efficient solution, they are effective only if integrated early and intelligently into the design process.

## CONCLUSION AND FURTHER APPLICATION

This experiment shows how innovation in design process facilitates a link between multidisciplinary approaches of design, with a growing control over design optimization techniques and over a substantial improvement in building quality. The process of capturing the essential data in combination with the valid representation of the acquired data could shape a powerful key tool for architects. The tool could also provide experts and non-experts with links to more detailed information, offering a deeper understanding of the urban climate conditions. In order to leverage the full potential of this strategy, more experiments have to be conducted across students, young and experienced designers, as the ability to incorporate scientific data is directly linked to design experience. Sustainability is a concern that should be addressed on every architectural project, so it is important to refine the complex process of interpreting the environmental effects on a site.

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