DYNAMIC SIMULATION OF EXTERNAL VISUAL PRIVACY IN ARAB MUSLIM NEIGHBORHOODS

A case study of Emirati neighborhoods in Abu Dhabi, UAE

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Abstract. The countries of the Gulf Cooperation Council have, in the recent years, undertaken several initiatives to make sustainability central to their urban agendas. This research aims to operationalize the concept of sustainable development – environmental, economic, and socio-cultural – in the region, and develop parameters that define it. Using native neighborhoods in Abu Dhabi as a case study, it focuses on the development process of a computational toolkit which has two major components – a quantitative toolkit which contains modules for simulation of aspects of environmental and economic sustainability, and a spatial toolkit which contains modules for simulation of socio-spatial practices associated with the specific social and cultural context. One of the primary needs of these communities, identified through an extensive review of literature and through conversations with Emiratis, is that of visual and acoustical privacy. Privacy from neighbors and passers-by, externally, and between genders, internally within the house. Using this as a starting point, this paper describes the development process of a module that aims to measure levels of external visual privacy of surfaces at a housing plot level, from neighbors and passers-by. The first section of the paper establishes the context of the research. The second section focuses on describing the process of modeling built form and testing it for visibility and thus, privacy.

1. Introduction

This paper is a part of a research effort aiming to define the parameters of sustainable development in the Gulf Cooperation Council (GCC) region. Using Abu Dhabi as a case study, it focuses on operationalizing these parameters into a digital toolset that will allow urban professionals to dynamically model urban form and design for increased levels of sustainability – environmental, economic and socio-cultural. This paper focuses on the aspect of social sustainability, and discusses an external visual privacy module aimed at the simulation of privacy through a series of visibility analyses.

In recent years there has been a lot of dialogue around the issue of social sustainability in cities. Broadly defined as "the continuing ability of a city to function as a long-term viable setting for human interaction, communication and cultural development."(Yiftachel and Hedgcock, 1993), social sustainability is more difficult to measure than the other aspects of sustainability. Additionally, "all-purpose indicators of social sustainability are too general to be useful", and thus, indicators specific to local contexts and issues need to be developed. (McKenzie, 2004). In order to aid the development of socially sustainable neighborhoods for native communities in the region, this ongoing research aims to establish local parameters and metrics for social sustainability, and develop a digital toolkit that allows for simulation and testing of designs for these parameters.

Cities of GCC states have had a brief history of urban development, spurred by the establishment and growth of the hydro-carbon industry in the region, and sustained by it. The sudden inflow of wealth from and labor for the oil industry triggered a need for urgent urban development. Since local communities were small, foreign labor was invited to drive this growth.(Hamouche, 2004) This resulted in the importation of Western urban planning and design ideas – gridded street layouts, super blocks, and villa typologies.(Eben Saleh, 1997) Villa housing projects developed by the oil companies for their employees, came to be seen by governments and the local population as 'modern' and soon became the primary model for residential development, one that local communities aspired to.(Bahammam, 1998) The villa typology, criticized by many as being environmentally and socially unsustainable, has now become embedded in the urban diction of the region through building regulations and standards.(Bahammam, 1998) This has accelerated the transformation of local communities, resulting in the distinctive national identity being threatened by an emerging global and international identity. (Mahgoub, 2004)

The lifestyles of local communities, primarily Muslim, are guided by the rules and principles laid down by Shari'a law. This set of Islamic regulations establishes several principles and cultural needs guiding socio-spatial practices, which shape neighborhood and urban form. (Al-Hathloul, 1996; Alshuwaikhat, 1999; Bianca, 2000; Eben Saleh, 1997) One of these needs is that of visual privacy in residential neighborhoods, addressing the risk of strangers looking into the domestic domain which is regarded as a female space.(Bianca, 2000; Othman et al., 2015) Traditionally, this was controlled through various built elements, such as the placement of doors and windows, the heights of adjacent buildings, and the incorporation of internal courtyards and gendered spaces within the houses (Abu-Lughod, 1987; Othman et al., 2015). Additionally, traditional neighborhoods "revealed a hierarchy of domains beginning with private spaces contiguous to the dwelling unit, semi-private spaces under the control of immediate neighbors, and public spaces and circulation routes." (Eben Saleh, 1997). However, contemporary neighborhoods have often been criticized for not attributing the same amount of importance to this need. (Al□Kodmany, 1999; Bahammam, 1998)

This paper addresses this need by illustrating the development, and outlining the potential application, of a module aimed at measuring and designing for external visual privacy. This module is a part of a larger toolset that spatializes and digitally simulates for the various social and cultural needs of native communities in the region.

2. Case Study

Abu Dhabi is the capital and largest of the seven emirates that form the UAE, having an area of 67,340 sq. km, and population of 2.65 million, nineteen percent of whom are native Emiratis. (Abu Dhabi e-Government, 2016) Despite forming such a small proportion of the total population, Emirati neighborhoods dominate the urban landscape (approximately 55% as per initial GIS spatial data calculations), as shown in Figure 1. Neighborhoods are constructed and villas allocated to Emirati families at no or minimal cost through a welfare program facilitated by the Abu Dhabi Housing Authority (ADHA). The widespread default to the villa typology, as well as the top-down planning and construction process pose a significant opportunity to rethink housing in the GCC region and drive new residential development towards social sustainability. This research focuses on Emirati neighborhoods in Abu Dhabi as a basis for testing and designing for local parameters of social sustainability.

Figure 1. Low-rise neighborhoods in Abu Dhabi city.

3. Digital toolset for social sustainability design

Academic and professional discourse outlines social sustainability as one of the three pillars of sustainable development. (Murphy, 2012) In recent years, several local and global agencies have developed a series of social sustainability indicators attempting to measure equity, access to services, and social connectivity, among others. (Axelsson et al., 2013) However, the general quality of these indicators, and the disconnect between these indicators and their physical implications, restrict the use of these to predominantly theoretical conversations.

This ongoing research aims to analyze the spatial dimensions of socio-cultural needs of the local population, and convert them into parameters that can be digitally modeled and simulated. Through an extensive review of literature and conversations with stakeholders, the research team identified such needs that Emiratis prioritize for their neighborhoods. This includes needs such as privacy, flexibility, hospitality, neighborly cooperation and personalization. (Al-Kodmany, 1999; Bianca, 2000; Saleh, 2004; Tomah et al., 2016).

4. Spatializing privacy

One of the primary socio-cultural needs of the Emiratis is that of privacy – both internally within the home, and externally from passers-by and neighbors. This need relates to the segregation of genders within households and neighborhoods stemming from religious beliefs. (Abu-Lughod, 1987) It also emphasizes the need for the separation of private, semi-private, semi-public and public spaces within the Emirati neighborhood. (Al-Kodmany, 1999; Othman et al., 2015; Saleh, 2004; Tomah et al., 2016)

Being an aspect that is typically measured qualitatively, this research proposes a method of spatializing privacy and simulating it digitally, thus allowing designers and planners to experiment with urban form and develop solutions that address this need. Since this research focuses on sustainability at a neighborhood scale, this module focuses on the simulation of external visual privacy only. However, the same concepts of visibility analysis can be used to simulate privacy within houses to guide internal space configuration.

4.1 EXTERNAL PRIVACY: ALGORITHM

The tool yields privacy levels for grid cells measured for horizontal and vertical surfaces at a house/plot level within neighborhood settings, thus evaluating privacy from passers-by on adjacent streets and open spaces, and neighbors. Simply, it measures the level of visibility of any point on a target plot from vantage points on adjacent plots and external spaces. The methodology for the analysis and measurement is described below and illustrated in Fig. 2.

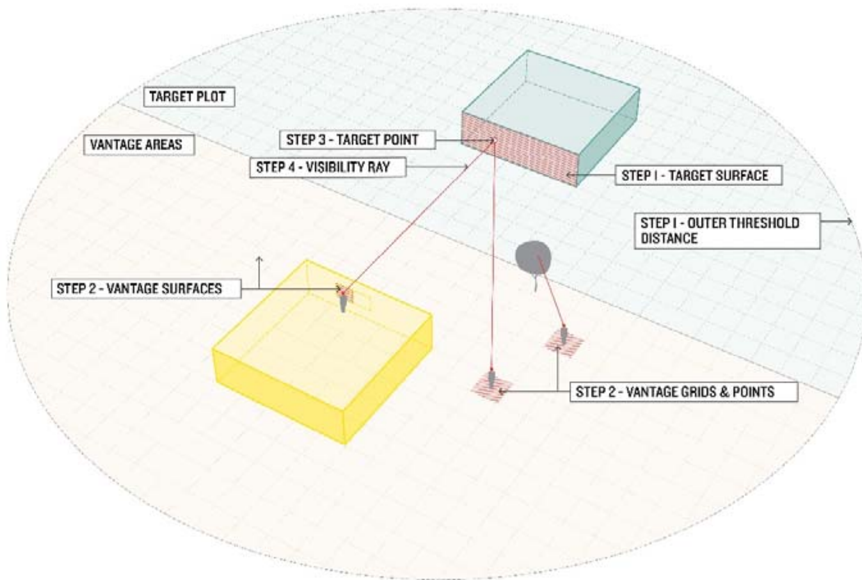

Figure 2. A simple case illustrating the external privacy algorithm.

Step 1 – Set up base parameters

The first step in the process includes setting up the base for the analysis including the target plot for which privacy needs to be measured, and the outer threshold distance beyond which visibility is assumed to be null. Once a complete neighborhood model is built, allowing this distance to be parametric permits flexibility of increasing or decreasing the maximum visible area within the neighborhood.

Step 2 – Select vantage surfaces

Identifying all vertical and horizontal surfaces (typically windows, ground planes, roof tops etc.) which allow for vantage points to the target plot.

Step 3 – Generate vantage and target points

In order to establish vantage and target points from and to which visibility is to be measured, surfaces need to be divided into grids. The number of grid units should be parametric to allow for increasing accuracy as per available computation capacity. For horizontal surfaces, the grid centroids are calculated, and points projected vertically to viewing or target levels. For vertical surfaces, points are to be established within the grid cells at viewing or target levels. For viewing levels, standing and seating eye levels of 165 cm and 75 cm respectively are set as defaults, but can be changed parametrically as needed. Likewise, for target cells, default point heights are set at eye level of 160 cm and torso level of 95 cm, to account for the visibility of faces and bodies within the house. Once this is done, points that are within window boundaries become active while those outside windows remain dormant. This allows for consideration only of points that allow for visibility in and out of the building, while still calculating points on blank walls to allow rapid, parametric re-configuration and sizing of windows.

Step 4 – Measure visibility/privacy

Once the vantage and target points have been established, visibility rays are drawn from all vantage points to all target points to measure for levels of visibility to any specific target point. Lines that form an angle with the surface that is above either the threshold for reflectance, in the case of windows, or the maximum viewing angle of 90 degrees, as well as those that intersect with solid obstacles in their paths, are deleted. These variables are made parametric to allow for manipulation of window surface treatments. After this process, an index of visibility per grid unit is calculated based on the number of visibility rays incident on it as shown in Figure 3.

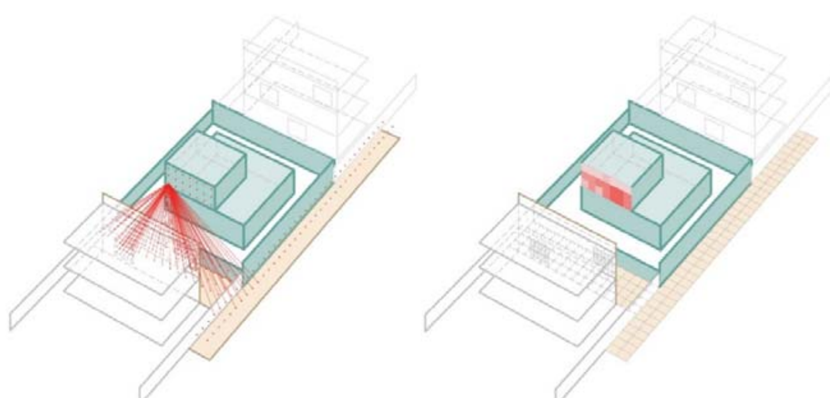

Figure 3. Generation of visibility rays to measure index of visibility for target surface grid.

4.2 EXISTING THEORY AND METHODS

This tool borrows from established concepts of isovists and isovist fields (Benedikt, 1979) to perform a series of visibility analyses to determine the levels of privacy for surfaces within plots in a neighborhood. Several algorithms have been developed in the past based on the isovist concept to perform visibility analyses, especially within the architecture realm. These include the work of (Desyllas and Duxbury, 2001; Schroder et al., 2007; Turner, 2001) within the field of space syntax, which uses Visibility Graph Analysis (VGA) to create maps based on the visibility between points, primarily in two-dimensional plan view. It also includes the work of (Morello and Ratti, 2009) who extend the isovist concept into the third dimension at an urban scale to measure visual perception.

The research presented in this paper uses ideas and concepts outlined in the literature above and extends and focuses them to measure privacy levels for both horizontal and vertical surfaces at a neighborhood scale. It differs from existing methods in the following ways: 1) it outlines a new, more sophisticated application of the isovist concept, catered specifically to designers working in the Arab, Muslim context, and thus providing focused analysis of specific, selected surfaces to allow for rapid feedback; 2) it is a novel module for the Rhinoceros and Grasshopper platforms which allow designers to work with physical models as they measure and design for privacy; 3) it allows for nuanced design feedback by accounting for the effects of visibility into internal spaces from external spaces through various wall and window treatments; and finally 4) it allows for flexibility through the parametric design of variables, making it widely applicable even in other cultural and social contexts.

4.3 EXTERNAL PRIVACY: APPLICATION

The index of visibility helps designers to measure visibility, and thus privacy, of existing houses, and guide design for privacy of new houses. The parametric variables allow for dynamic modeling by providing feedback about levels of privacy. The toolset allows designers to plan and design neighborhoods by enabling the location of private, semi-private, semi-public and public areas within plots as they relate to their surrounding plots, and designing for fenestrations within the building envelope. Once combined with other sustainability modules, the toolset allows for analysis of trade-offs between various strategies for addressing the need for privacy and other social sustainability parameters.

4.4 LIMITATIONS AND NEXT STEPS

The tool is in its initial stage of development and will address several of the following limitations through its progress. Including them here outlines not only the limitations of the tool as it currently stands, but also establishes next steps for its development.

For windows, there is a vision zone where visibility changes as per the location of an individual relative to the location of the window within the house. Accounting for this specificity will increase the accuracy of the visibility measurement.

Clarity of vision reduces with distance, in most cases. Thus, weighting visibility rays based on their lengths (distances between vantage and target points) would enable a more accurate measurement of privacy.

5. Conclusion

In order to achieve holistic sustainability, local social and cultural needs of communities need to be an integral part of the sustainability dialogue. However, the vague and qualitative nature of social and cultural parameters makes it difficult for urban professionals to effectively measure and design for these. This research hopes to set an example for these professionals by exhibiting the practical translation of these qualitative needs, defined within the socio-cultural context of local and regional stakeholder groups, into spatial and measurable features that can be digitally modeled and simulated.

Even though this toolkit is being designed specifically for native neighborhoods in Abu Dhabi, the authors see it as being widely applicable for the region due to the inherent parametric nature of the modules, and the expandability of the toolkit by addition of topical and regionally appropriate modules as needed.

This paper presents a module that is a piece of a larger toolset that aims to spatialize and simulate several other social and cultural parameters prioritized by native communities in the GCC region. These modules can be used individually by designers when focusing on specific aspects of house designs, as well as in pairs or groups to prioritize certain aspects over others. Trade-offs between various parameters can be measured and strategies for addressing those trade-offs be tested dynamically. The social sustainability toolset is also seen as a part of a larger holistic sustainability toolkit that includes modules for environmental and economic sustainability. Through this, this research aims to address the existing practice of approaching specific parameters of sustainability independently, thus looking at sustainable development as a holistic concept.

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