**LETTER OF RESUBMISSION**  // previous No. 945/22 | PI - Jonathan Natanian **02/11/2022**

**Solar urban districts: A generative method for multi-criteria solar design of dense urban fabrics.**

**SUMMARY**

First and foremost, we would like to thank the selection committee for their time and consideration, as well as for gathering the invaluable comments that assisted me substantially to improve the proposal.

Based on the reviewers’ comments, this revision focuses on the following aspects:

**a. Integrating Machine Learning (ML) methods**

**>** This revision includes the exploration of Machine Learning (ML) methods, namely prediction metamodels to be trained to emulate the performance of the several environmental performance indicators, and in turn, serve as performance objectives for the Multi-Objective Optimization (MOO). The application of ML methods will reinforce our computational prediction methodology and unlock new possibilities to upscale the solar block generator we have already developed to the district scale. That addition also brings significant innovation to the proposal, as the integration of ML methods into environmental urban analysis is in its very first steps.

**b. Unlocking public access to the data and tools**

**>** The datasets which will be generated in the project to train the prediction metamodels will be submitted to an appropriate data responsory open to the public. The generated datasets, as well as the computational workflows, will be prepared and adapted if needed, in terms of both access and format, properly stored and publicly shared in the relevant subject-related platforms and/or repositories. That will serve as an important contribution to the scientific community as well as a vehicle for the future development of the project.

**c. Addressing several methodological and technological hurdles**

**>** Several important points which were raised by the reviewers were addressed in this resubmission: (1) The available computational power for our project is now boosted by cutting-edge computational capabilities we recently acquired – both through new hardware, including a 64 cores workstation, as well as through cloud computing infrastructure; (2) The lab is currently collaborating with Dr. Thomas Wortmann (University of Stuttgart) on a project focusing on clustering and weighing environmental performance metrics for optimization frameworks. Some of those methods will be used here to compare the effectiveness of different solar performance metrics for the optimization sequence; (3) the ‘cross-climatic’ approach of the proposal was revised to be *climatically robust* – meaning that by exploring different sub-climatic zones in Israel as well as future climate we will strive to develop a climatically robust approach which we see as an important feature of our approach; (4) The impact of mixed-use programs on the form-finding process and in turn, the building performance explorations, will be conducted using the new methodologies we are currently developing in the lab for a new project we lead for the Israeli Ministry of Energy on Energy performance in heterogeneous urban districts; (5) We added a short description on the workflow we will use to explore the energy and daylight performance of the voxelated urban blocks.

**d. Elaborating on the innovative aspects of the project**

**>** We believe thatour proposal is novel in many aspects; 1) it offers a new voxelated method for performance-based design, and 2) it reconnects different tools performance indicators which are currently fragmented, under a harmonized optimization based-approach which will allow for a more reliable and inclusive environmental analysis. Our proposal focuses on hot climatic regions, which are currently misrepresented, and offers a climatically robust exploration of different periods and local climatic zones within them. In addition to the optimization algorithms we will use, this resubmission includes ML methods which are rarely used in the context of environmentally driven form finding.

**e. The potential impact of the proposed project on planning policy and design practice.**

**>** We see great potential for an interface between our methodology and local policies. Our simulation parameters, performance metrics, and urban and climatic contexts are carefully defined according to local standards and policies, and as such, our methodology can be part of the long-awaited change toward informed planning and design. However, in this proposal, we focus solely on the development and exploration of our workflow and lay the foundations for further work in higher TRLs to establish several applications which can effectively bridge the gap between scientific research on environmental performance and local policies/ design practices.

**RESPONSE TO THE REVIEWERS’ COMMENTS**

The following pages describe the response to the reviewers’ comments in detail

**REVIEWER #1**

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| PI's Response | Reviewer’s comment |
|  | **>** **Technical hurdles to address:** |
| We acquired new hardware and cloud computing capabilities which together with AI and ML methods will help us achieve our goals.  | 1. The computational power and time required to run simulations and calculate metrics.  |
| We are currently involved in two ongoing projects, which are dedicated to developing metrics, to test their effectiveness and weigh their impact in multi-criteria optimization. Insights from those projects will inform the development of our workflow here.  | 2. How human experience and quantified metrics can be brought under a unified optimization framework? |
| 3. The development of a method to compare the effectiveness of different solar performance metrics. |
|  | **> Points for additional consideration:** |
| We changed the scope of the climatic exploration from “cross-climatic” to “climatically robust”. Our project will focus on different sub-climatic zones in a hot Mediterranean climate (arid, coastal, etc.) rather than explore different climatic regions.  | 4. Is the proposed methodological framework truly “cross-climatic”? … you will need to consider significantly different climate zones or narrow your research scope. |
| We will test our workflow for both residential and office building programs and design properties using the methodologies we are currently developing for the Israeli Ministry of Energy for a project on mixed-use districts.  | 5. While the emphasis is on form finding, the building performance is directly dependenton building program/use and its characteristics  |
| We now integrate the use of ML methods across the revised proposal. | 6. The proposal mentions ML in the expected results section but does not elaborate on how ML is used in the methodology. |
| We now include a short description for that part of the analysis which will be conducted using the same Honeybee workflow.  | 7. It is unclear how the voxelized urban blocks can be converted into multi-zonal building models that can be used by Honeybee for Energy and Daylighting. |
|  | **> Weaknesses** |
| We hope that the revised proposal answers this issue. We added an explanation about the transferability of our method which we see as very relevant to many other contexts. The open-access approach we have reinforced in this revision strongly supports that.  | 8. The scope of the project is a bit wide and not sufficiently explained in depth. Some questions regarding the transferability of the method to other contexts (climates, construction practices, local architectural/urban design patterns, and planning laws) remain relatively open. |
| Thank you for your comment, in addition to the resources our lab recently acquired (see comment #1), our collaborators have vast and diverse computational abilities which will assist us in dealing with any computational challenges. | 9. The proposed methodological framework can quickly become very resource-intensive in terms of computational power; however, the research team has the experience to deal with this issue effectively. |
| Following the proposal guidelines, a schedule and work plan description, including an explanatory note, appear immediately after the collaborators’ support letters.  | 10. Dissemination activities and deliverables are not presented in adequate detail. |
| 11. A Gantt chart could help visualize how the individual tasks are broken into work packages  |

**REVIEWER #2**

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| PI’s response | Reviewer’s comment |
| Thank you, we have added an important clarification on this point. The data and workflows generated in this project will be organized in terms of access and format, properly stored, and publicly shared in the relevant subject-related repositories. | 1. The project may evolve into an open-access data lake for cross-checking multiple climates and cities in a potentially large community. However, this is not clearly explained, and the availability of results is not clearly stated. |

**REVIEWER #3**

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| PI’s response | Reviewer’s comment |
| As solar design is becoming increasingly important to achieve the objective of positive energy and zero carbon district design, this project offers a pioneering perspective into the widely used ‘solar envelope’ method in the pursuit of those goals. The scientific significance of the project stems from the several innovative aspects it brings (see the response to comment #6 below). Thus, we believe that this project's results will appeal to the scientific community, urban designers, and policymakers, while establishing new links between them. | 1. The proposed methodology lacks innovation and originality. It is unclear the real and innovative contribution of the proposed methodology and the scientific outcomes and impacts carried out from it and how the research can contribute to the advancements of the research field and a broader societal impact. |
| 2. the proposed methodology is grounded on an existing and well know suite of modeling and environmental analysis tools widely used by the scientific community in the field of research. |
| This resubmission includes ML methods which are rarely used in the context of environmentally driven form finding. We will be using validated simulation engines which are regarded as industry standards and thus monitoring campaigns will be out of the proposal scope.  | 3. The innovation of the approach should be grounded through the application of more advanced computers (e.g., co-simulation approach, deep learning techniques) and visualization techniques (i.e. digital twins) and supported by a monitoring campaign for experimental data to be used to validate the proposed methodology. |
| The creation of a multi-player interface is indeed one of the applications we see for the methodology we will explore here. However, we see this proposal as focusing on establishing the foundations for solar-driven urban design from which several other applications may branch out.  | 4. The potential societal impact should be posed towards the creation of a multi-player arena around the solar energy planning process to assess the effects, impacts, and consequences of the optimization process for building form-finding and/or district morphology. |
| As a new faculty member that is true. However, I am happy to report that I recently recruited a Ph.D. candidate and a Postdoctoral fellow. | 5. The PI lacks experience in Ph.D. supervision and co-supervision. |
|  | **> Weaknesses** |
| We believe that the solar-driven approach we offer here is innovative in several aspects beyond the state-of-the-art: (1) the holistic environmental approach for solar design, in which several environmental criteria which are currently fragmented come together, (2) the integration of advanced MOO algorithms and the exploration of multi-criteria decision making in urban design, (3) the integration of ML methods and prediction metamodels for rapid large scale environmental evaluations, (4) our focus on hot climates which are currently misrepresented, and, (5) the diverse and future climatic conditions we will explore here towards climatically robust analyses.  | 6. Lack of innovative methodology and advanced computer and visualization technologiesbeyond the state-of-the-art. |
| 7. The proposed project has a low potential to develop approaches and methods beyond those that are state-of-the-art in the discipline.  |
| See response to comment #3  | 8. Lack of support for a monitoring campaign for experimental data to validate the methodology. |
| Our recruitment process will emphasize gender balance which we regard highly.  | 9. The project consortium is lacking gender balance. |

**REVIEWER #4**

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| PI' response | Reviewer’s comment |
| We see great potential for an interface between our methodology and local policies. Our simulation parameters, performance metrics, urban and climatic contexts are carefully defined according to local standards and policies. However, in this proposal, we focus solely on the development and exploration of our workflow and lay the foundations for further work in higher TRLs which will build applications to bridge the gap you rightfully highlighted.  | 1. One of the strong points of the proposal is the development of a holistic evaluation of the urban-scale environmental performance. This point however needs to be informed by local policies and environmental parameters. |
| 2. One important part of the background research and review of existing methods would be consultation with policymakers, review of policies, and identification of the implementable components of a solar envelope in the context of urban development.  |
| Thank you, we added an important clarification on that. The data and workflows generated in this project will be organized in terms of access and format, properly stored, and publicly shared in the relevant subject-related repositories. We agree that this will serve as an important contribution to the scientific community as well as a vehicle for the future development of the project.  | 3. It is not clear how the project aims to store and disseminate this data both for the development of the project as well as for future use by other projects. The use of a proper database solution – instead of Excel files – would be strongly encouraged to ensure future applications have access to this data. |
| 4. A good repository development and dissemination plan before the start of the project would be strongly advised. |
| As part of the optimization part, we will test several MOO algorithms (also including model-based algorithms). We do agree that ML and specifically meta-modelling methods can boost the potential of our proposal, especially in a multi-criteria evaluation at the urban scale, which is why we integrated ML into our revised methodology.  | 5. A final point relates to the use of MOO algorithms. Genetic algorithms are most favorable for the optimization of vast solution spaces but since the interest is to evaluate and further develop standards, other AI/ML techniques could also be explored (such as clustering and classification). |