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Is it already possible to optimize the urban heat balance?

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Abstract

With the rapid increase in urban population and cities sprawl worldwide – "on average, urban areas are growing twice as fast as their populations[1]" - it is mandatory to control the energy consumption and the thermal balance of large cities. The most important energy contribution, which comes from sun radiation, is strongly related to the shape of the city. Therefore, it is very important to enrich the geometrical and the physical models of the city, introducing radiosity technique and finite element modeling in order to evaluate the thermal exchanges both in the visible and in the infrared spectra.

The problem to be solved is difficult. The loads consisting into sun and sky radiations are time dependent, the system of equations is non linear, and the geometry is complex, leading to an important number of degrees of freedom[2].

In the present work, we discuss the first steps of the thermal analysis by the finite element method and of the optimization process. To illustrate this approach, a simple physical model of irradiance and an evolutionary algorithm are used to optimize the distribution of houses inside a fixed area, in order to improve the total solar radiation received.

Several objectives can be considered: during cold periods or in cold regions, a maximum of solar energy must be received by the buildings, but we could also minimize energy consumption for air-conditioning, that means to reduce the solar exposure in hot periods, or we could formulate a multicriteria problem. As a first test, we choose to maximize the irradiance function evaluated during the shortest day of the year, taking into account the influence of the surrounding buildings.

A very simple model of houses is considered: the design variables control the space distribution of hexahedral blocks. Buildings are sets of blocks which can be placed in a finite number of discrete positions defined as a mesh of the available domain; the superposition of blocks defines the height of the building. The problem is stated as a topologic optimization one: how to distribute a given volume on a fixed domain in order to optimize an objective function related to the irradiance received by all the external faces. In a second step, more precise designs are searched by varying the orientation and the dimensions of the buildings. The first step is a global optimization taking into account only discrete design variables, while the second one can be global or local optimization dealing with discrete or continuous parameters.

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[1] Karen C. **Seto**, Burak **Güneralp** & Lucy R. **Hutyra**, 2012, PNAS (Proceedings of the National Academy of Sciences) - Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools.

[2] Tom **van Eekelen**, Radiation Modeling Using the Finite Element Method, in Solar Energy at Urban Scale, chapter 11, Ed. B. Beckers, John Wiley and Sons, Inc., 2012.