Outdoor Comfort: the ENVI-BUG tool to evaluate PMV values point by point

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Abstract

Studies on Outdoor Comfort in urban open spaces adopt several tools and software to simulate a microclimate model, energy performance and the fluid-dynamics of winds. The output data, therefore, of these software solutions, e.g. temperature, wind velocity, relative humidity, should be the input data to evaluate the comfort indexes. In the present paper, we describe ENVI-BUG, an ENVI-met algorithmic app developed by Grasshopper, that uses the LadyBug method to rapidly calculate the distribution of local PMV.

1. Introduction

The Building Simulation Application research fields include three points of view:

a) a study from an energetic point of view e.g. the energy needed by building envelopes, or only envelope systems, HVAC components, building control, etc.;

b) the study of the effect of human behaviour and user behaviour on building energy consumption; also included in this field are the laws and regulations for the effectiveness on energy policies for the building and real estate sectors;

c) the study of the effect of buildings on human comfort, thermal comfort, Indoor Air Quality, Indoor Environmental Quality, Lighting, Acoustic, etc.

Therefore, in Building Simulation another kind of comfort and building effect on human comfort could be considered: outdoor comfort simulation.

Outdoor Comfort is a specific field of study and is combined with the Urban Heat Island (UHI) phenomenon; in other words, if the outdoor temperature increases, the UHI increases. Therefore, energy consumption by HVAC in cooling mode increases, because people prefer to stay inside buildings rather than in outdoor open spaces. Following this point of view, a greater understanding of outdoor comfort could increase the use of outdoor open spaces.

Outdoor comfort depends on the Built Environment, on the relationship between materials and energy use, on Global Climate change and local micro-climate: Temperature, Solar Radiation, Wind distribution, Wind Speed, Absolute and Relative Humidity.

The relationship between energy and climate in the urban building environment and the factors that influence the Urban Heat Island are described in several studies, some of these summarised by M. Santamouris (Santamouris, 2011), G.M. Stavrakakis et al. (Stavrakakis, 2012) and in RUROS by CRES (CRES 2014).

The main common software solutions to model outdoor comfort, also described in Dessì V. (Dessì, 2008) and UHI-CE Project, are:

- ENVI-met, is a three-dimensional microclimate model designed to simulate the surface-plant-air interactions in an urban environment with a typical resolution of 0.5 to 10 m in space and 10 sec in time. Typical areas of application are Urban Climatology, Architecture, Building Design or Environmental Planning, etc. ENVI-met is a prognostic

model based on the fundamental laws of fluid dynamics and thermo- dynamics;

- RayMan is a freely available radiation and human bioclimate model. The model simulates the short and long-wave radiation flux densities from the three-dimensional surroundings in simple and complex environments, described in Matzarakis et.al. (Matzarakis, 2007);

- SkyHelios (Tzu-Ping Lin, 2012) is a tool for applied climatology, calculating the continuous sky view factor and sunshine duration in high spatial and temporal resolution for each point in a complex area.

All the software above requires expert users - it is not simple to use – therefore not useful during the design-process.

2. Goal of paper

In this paper, we describe a tool to support designers in order to evaluate Outdoor Thermal Comfort, by PMV index, in 3-D. The new tool, called ENVI-BUG, is used to model outdoor comfort and combines ENVI-met and LadyBug input data.

3. Methodology and software solutions

The methodology developed concerns a contemporary use of three kinds of software:

- ENVI-met, to obtain microclimate data distribution in outdoor spaces;
- LadyBug. Rhinoceros and Grasshopper to develop ENVI-met data in 3-D and to input data by human body to evaluate a PMV index;
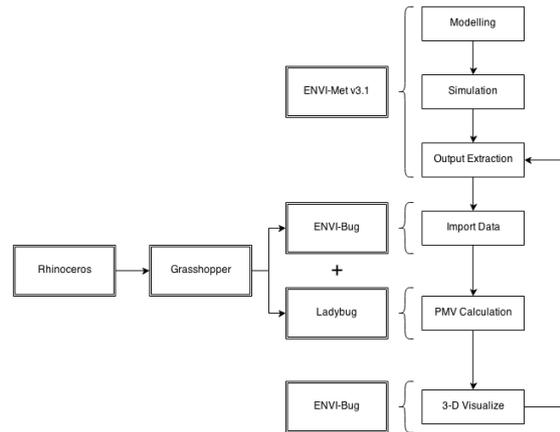- ENVI-BUG to see 3-D results.

Fig. 1 – ENVI-BUG flow chart

3.1 ENVI-Met and LadyBug

ENVI-met software is a freeware to analyse the outdoor microclimate around a single building, an open space or a neighbourhood. It is possible to visualize ENVI-met results with the Leonardo application. The result is a 2D coloured planimetry or section, in which each colour corresponds to a range value.

LadyBug software is an open source environmental plugin for Grasshopper3D that helps architects and engineers create an environmentally conscious architectural design. LadyBug imports standard EnergyPlus Weather files (.EPW) into Grasshopper and provides a variety of 3D interactive graphics to support the decision-making process during the initial stages of design. LadyBug was developed by Mostapha Sadeghipour Roudsari. (Sadeghipour Roudsari, 2013),

3.2 ENVI-BUG

ENVI-BUG Software is a generative algorithm (or plugin) that combines ENVI-met, Rhinoceros, Grasshopper and LadyBug.

The aim of ENVI-BUG is to obtain 3-D output results of ENVI-met and to simulate a punctual distribution of PMV, in 3D space, with several human body and clothes data.

In order to use ENVI-met and ENV-bug, we need to arrange (Figure 4):

- the "file folder" (called OUT_ENVIMET_CSV) where we will save all input data file. In order to allow the plugin to make a complete file directory, the file must be a test (*.csv) file;
- the Rhinoceros file (*.3dm), of the case study, because Grasshopper can only run after Rhinoceros has started. The ENVI-BUG files are in *.3dm in order to:
  - o save any 3-D geometry, tree or graphics changed;
  - o insert a "model-man" to represent punctual PMV;
- the Grasshopper file (*.gh) with ENVI-BUG plugin.

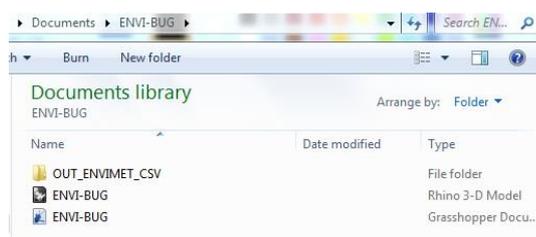To start ENVI-BUG, we must to drag "ENVI-BUG.gh" into the Grasshopper Canvas.

Fig. 2 – File folder for ENVI-BUG

4. Modelling results

ENVI-Met v3.1 includes 4 output modules: Configuration Editor, ENVIEddi, LEONARDO 3.75 and "Xtract tool". The "Xtract tool" is to export output data.

The ENVI-BUG permits two kinds of simulation for the PMV index:

  a) Plan-space distribution - in this case we need to set ENVI-met "Xtract tool" with the human body at a height of 1.6 m. Then we need to export file data into the *.csv file.
  b) Urban Canyon (section) simulation - in this case we need to set an ENVI-met section, then use "Xtract tool" to export file data into the *.csv file.

The above extraction will be done for each variable: air-temperature, wind speed, mean radiant temperature, Relative Humidity. The Open space (building, place, train, people etc.) must be simulated in 3-D with Rhinoceros.

When we start ENVI-BUG, it instantly reads the *.csv data in the OUT_ENVIMET_CSV folder and subsequently converts data into point grid values. Then the above grid is visualized in Rhino Viewport and each grid node has a PMV number (Figure 3).

Fig. 3 – The 3-Dimension visualization of PMV vectors (z)

5. Case-study and results

An example of ENVI-BUG application is discussed in the following paragraphs.

The case study is a Social Housing District called "Pilastro" located in Bologna (44.511°N, 11.397°E).

The scenarios are:

a) the Actual Condition of things of Urban Canyon, the Height/Width ratio is 1, the track road and car parks are in asphalt; the vertical building surface has several textures and colours (red, grey and white);

b) the Designed/Simulated Condition, concerns the horizontal surface of Urban Canyon, especially if we simulate:

  - a new road (one way) instead of a car-park;
  - a substitution of the current road with grass.

Fig. 4 – Case Study portion of "Pilastro District"

5.1 Results of PMV indexes in Horizontal Distribution

The Analysis of Actual Condition (a) reports a homogeneous zone of maximum discomfort in the central area. The main discomfort is when human body activity is just 1 met (sitting).

Figures 5.a, 5.b show the results of PMV distribution in Actual Condition within the space of urban canyon, for human body activities: Sitting (a), Standing (b)
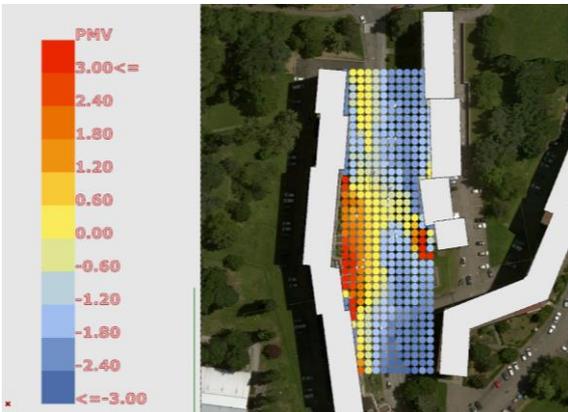

Fig. 5.a – Actual Condition of PMV Distribution – Metabolic Activity: Sitting (1 met)
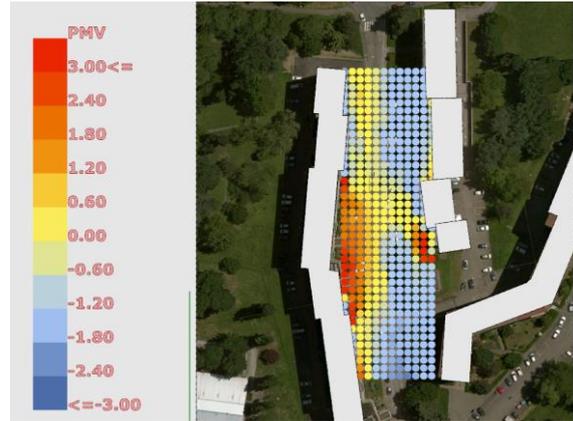

Fig. 5.b – Actual Condition of PMV Distribution – Metabolic Activity: Standing (1.2 met)

The results of (b) Designed/Simulated Condition show a decrease of the discomfort area.

Figures 6.a, 6.b show results of PMV distribution for human body activities: Sitting (a), Standing (b), Walking 2mph (c)

As shown in the case of Walking, the discomfort area is larger than the Sitting or Standing activities, depending only on metabolism (met). In spite of this, Figure 14.c of the Simulated Condition shows a lower discomfort compared with the Actual Condition.

In the case of Sitting, the comfort condition, before and after simulation, shows a decrease in the discomfort-area.
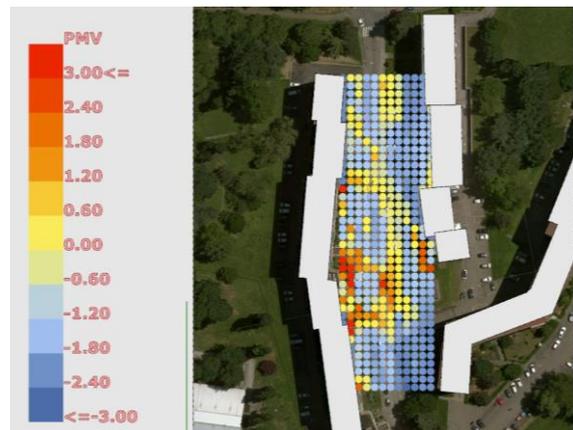

Fig. 6.b – Design Condition of PMV Distribution – Metabolic Activity: Standing (1.2 met)
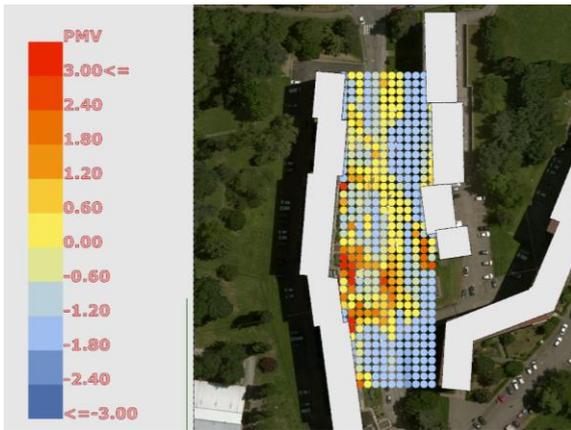
Fig. 6.b – Design Condition of PMV Distribution – Metabolic Activity: Standing (1.2 met)

6. Conclusions

The present outdoor comfort simulation tools – like ENVI-met – show some lack of usefulness and interface with the users.

This study describes a new tool to improve ENVI-met use, in order to simulate several input data and to show the spatial distribution of PMV.

In order to make and to assess design choices, it is better to have a good graphic visualization of the results.

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UHI Project aims at developing mitigation and risk prevention and management strategies concerning the urban heat island (UHI) phenomenon. http://eu-uhi.eu/