

ASSESSING URBAN MICROCLIMATE FROM THE USER'S PERSPECTIVE- MULTI-AGENT SYSTEMS AS A NEW TOOL IN URBAN BIOMETEOROLOGY

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1 INTRODUCTION

Attractive public open spaces can serve as key design elements for enhancing life quality in urban areas and to diminish the negative effects of urbanization. In order to fulfil this task and to serve as small oasis inside an artificial environment, open spaces must meet the expectation of the potential users and offer the right mix of environmental, economic and social conditions. It is well known that the local microclimate offered by an area is one of the main factors that drive the individual perception and assessment of an outdoor environment. The right mix of sun and shade or the shelter from wind - Pleasant conditions will attract people who, in return, will make these areas more attractive for shops, restaurants or other facilities depending on pedestrian frequentation.

Traditionally, static thermal indices like PMV are used to express the impact of local climate onto the thermal comfort of humans exposed to these conditions. These indices relate the average thermal comfort more or less directly to the local meteorological conditions. However, under the complex and varying microclimate conditions found in urban areas, the response of the human thermoregulatory system is normally far from reaching such static conditions, hence the assessment found by static indexes often overrate the local conditions, especially in the case of hot discomfort. Dynamic Multi-Node models of the human thermoregulatory system are a better approach to simulate the reaction of the human body on varying climate exposures. As these models are individual based, they are also able to simulate different human characters such as age, weight or climate adaptation which is not possible with community indexes like PMV. In order to be practically applicable, Multi-Node models require a computational framework which simulates typical movement patterns of the users though the urban environment and provides the biometeorological models with the required microclimate data as input. One elegant way to construct such a system is to link the individual based thermal comfort model to a Multi-Agent Simulation system. In such a system, software agents take the role of the virtual humans moving through the model environment and different microclimate conditions while their thermal comfort is monitored constantly.

2 METHODS

The method of Multi-Agent (MA) simulations allows the simulation of complex systems by focussing on the single actor, the so-called agent. Each agent represents a virtual pedestrian with given physiological properties such as gender or body mass and certain routing targets generating the movement through the model environment. While following their plans, these agents are virtually exposed to different climate conditions, just like real pedestrians would be. The impact of these climate environments on the individual thermal comfort, are continuously monitored using a simple transient 2-node model of the human thermoregulatory system (Individual Thermal Comfort Model ITCM, see other paper in this proceedings). The MA system BOTworld was developed to simulate and analyse pedestrian movement and thermal comfort in complex urban environments (see www.botworld.info). The simulation system integrates –amongst other modules– the biometeorological thermal comfort model ITCM, the pedestrian traffic simulation model *PedWalk* and the required microscale meteorological data. During the simulation, the latter are provided as boundary conditions for the ITC model. Figure 1 shows the basic concept of the Multi-Agent simulation system BOTworld focussing on the thermal comfort simulation.

After simulating a sufficient number of virtual pedestrian walks (1400 agents in the example shown in Figure 2), the data generated by the comfort model are gathered and aggregated with respect to the objective of the analysis. Typical aggregation methods are for example spatial aggregation,

summarizing the state of all agents visiting selected locations of the area, or individual aggregation which reports about the state of all agents at a given time.

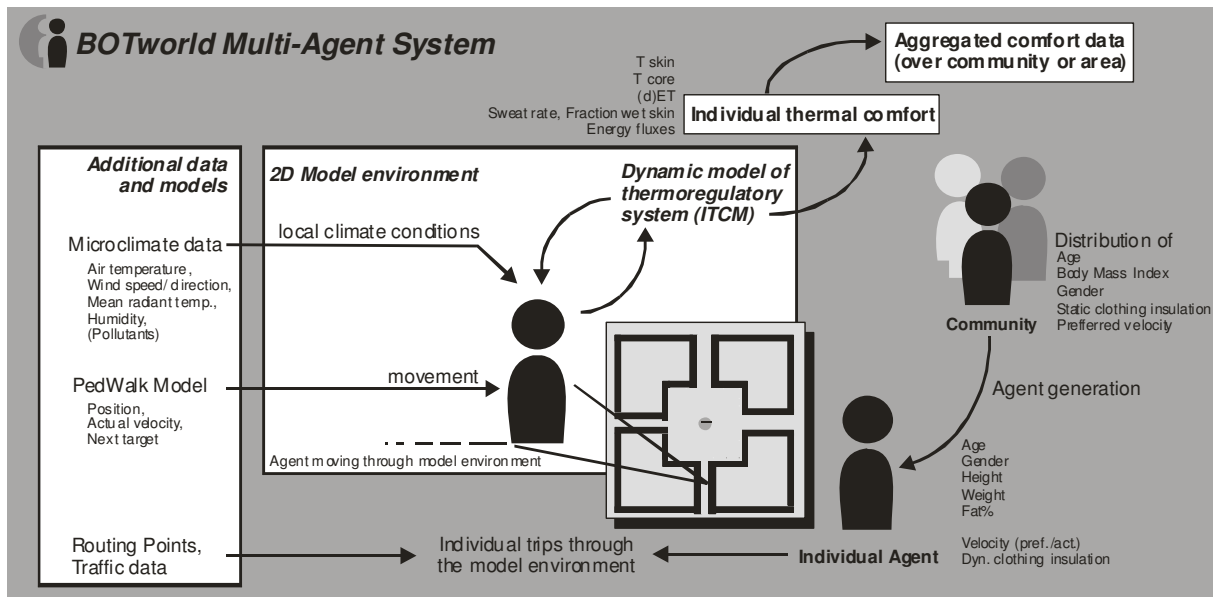


Figure 1: Schematic overview over the BOTworld simulation system

As the agents constantly monitor their internal state, they are able to adopt their routes through the urban environment with respect to their thermal state. So, if an agent feels hot, he will favour the shady side of the street rather than the sunlit one. This aspect is not discussed in this paper due to space limitations.

3 RESULTS

In order to demonstrate some typical model results, a simple open space with the size 200 m x 200 m including four 150 m long connecting streets has been analysed. The area is numerically resolved into 2 m x 2m grid cells. In order to calculate thermal comfort the driving meteorological parameters (Air temperature, wind speed and direction, mean radiant temperature and air humidity.) are required for each of these grid cell. In general it is irrelevant from which source these data come as long as they are complete over the entire model area and fit with the structure of the urban morphology. For this study, the microclimate model ENVI-met (Bruse, 1998) has been used to simulate the required input data for the BOTworld system. The situation used in this paper relates to the 14:00 CET situation with a clear sky and moderate northern winds. The air temperature is around 25 °C with small variations inside the model domain. For demonstration purposes the mean radiant temperature was set quite high and reaches up to 75 °C.

The BOTworld simulation results shown in Figure 2 compare the dynamic Effective Temperature (d)ET with the static counterparts (s)ET and PMV. The (d)ET value is a thermal comfort indicator analogous to the "normal" Effective Temperature (Gagge, 1986) or PET (Höppe, 1999) but uses the actual dynamic skin and core temperature of the agent instead of the skin and core temperature under steady-state conditions. Contrary, the static Effective Temperature corresponds to the situation under stationary conditions and is therefore more or less equal to ET/PET except that it is calculated using the ITC model.

The simulated dynamical Effective Temperature values are within the range of 35.5 to 38.0 °C thus indicating "hot", but not "very hot" conditions. The distribution of sun and shade in the area can be traced well in the (d)ET values with a difference of around 1 K between the sunny and the shady street sides. For a comparison between the dynamical thermal comfort index (d)ET and the results obtained from static indices, the frequency distribution of the static Effective Temperature (s)ET is shown as additional curve in histogram (a) and the spatial difference between both values is plotted in Figure 2 (c).

From the frequency distribution it can be seen, that thermal comfort described by the dynamic indicator shows a significant different behavior compared to the static index: While the high (s)ET values are well distributed between 36.0 and 43.0 °C with a mean around 38.5 °C, the (d)ET values appear quite concentrated between 35.5 and 38.0 °C. Inside the shaded areas the (s)ET values range around 25.0 °C, indicating slightly warm conditions. This secondary peak cannot be observed in the (d)ET values. As the virtual pedestrians are only exposed to these cooler conditions for a limited time and sunny and hot conditions overweigh in the area, the cooling effect of the shaded section will probably lead to a small bias of the (d)ET peak towards the cooler conditions, but does not resolve in a single secondary peak.

Like (s)ET, PMV shown in Figure 2 (b) shows a basically two-peaked data distribution with the major peak representing the sunny areas and the smaller peak with values from the shaded areas. The data from the sunny areas show PMV values between 3 and 4.5 with a clear emphasis of the values in the "very hot" range around 4.0. Hence, the PMV values for the sunny locations indicate slightly hotter conditions than the (s)ET counterpart.

4 DISCUSSION

The main problem when applying static thermal indices to complex outdoor thermal environments is the non-balanced energy budget that can be relevant at many locations, especially at those locations where people enter a different climate environment. From Figure 2 it can be seen that at locations where the energy budget is almost balanced (core zone of the open space), the differences between (d)ET and (s)ET begin to vanish and the static index gives an appropriate representation of the thermal conditions even under dynamic conditions. Contrary, locations with non-balanced energy budgets, here especially in the shaded areas, show great differences up to 10 K between the dynamic and static version of ET. Here, the static index overrates the impact of the local meteorological conditions on the individual thermal comfort.

In this example the sunny conditions outweigh the shaded areas; hence the impact of the shaded areas on thermal comfort is overrated when using static indices. If the situation is inversed and the shaded areas dominate, the effect would be the opposite and the impact of the sunny sections would be overrated. In a more complex real environment, a mix between both extremes is the most frequent case. In these cases it is very difficult to take into account the impact of different microclimate patches on the local thermal comfort without using a numerical simulation model based on individual movement like BOTworld.

5 CONCLUSION

In this paper the very simple example of an open urban space was used to illustrate the spatial differences between dynamic and static thermal indices. Using the method of Multi-Agent simulation, the thermoregulatory system of each single virtual pedestrian has been simulated using the simple 2-node ITCM model. When summarising the single thermal experiences it is possible to transform them back into the spatial context and produce maps of thermal comfort. In these maps not only the local meteorological situation is the governing parameter for thermal comfort, but also the pedestrian movement patterns and the dynamic aspects that arise from the exposure to different climate conditions are taken into account.

References

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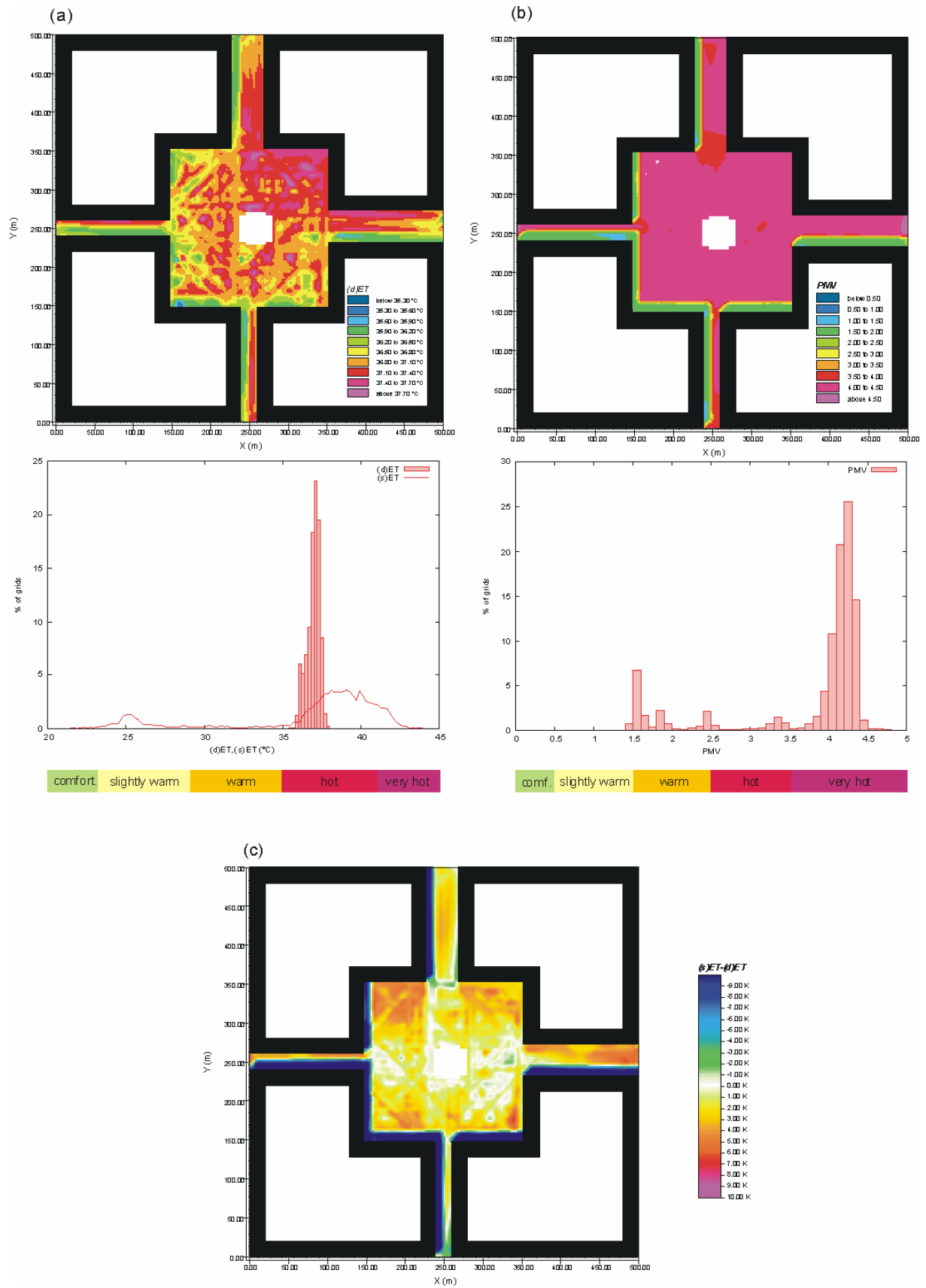


Figure 2: Example results from the BOTworld system for a simple open space. Spatial distribution and frequency distribution of dynamic Effective Temperature (a), PMV (b) and difference between static and dynamic effective temperature (c, only spatial distribution) in the model area for the 14:00 CET situation.