

QUANTIFYING THE HUMAN THERMAL-HEAT-STRESS IN CENTRAL EUROPEAN CITIES WITH BOTWORLD AND ON SITE-INTERVIEWS AS ANALYSING TOOL TO ESTIMATE THE THERMAL SENSATION OF PEDESTRIANS

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ABSTRACT

The here presented Multi-Agent-System BOTworld is able to estimate the thermal sensation of pedestrians in cities. It is based on the microclimatic model ENVI-met. BOTworld was used in the cooperation project KLIMES to enable to give information about the heat stress of pedestrians in central European cities within the context of climate change and its adaptation. The aim of the presented study was to evaluate the model BOTworld via on site-interviews according to their suitability, considering existing urban structures, to develop planning strategies to ensure outdoor human thermal comfort during extreme heat waves in the summer

KEYWORDS: BOTworld, on site-Interviews, thermal sensation, dPET, thermal comfort, heat stress, Multi-Agent-System

1. INTRODUCTION

The aim of this study was to test the results of BOTWorld and the interviews according to their suitability in terms of thermal heat stress on hot summer days in central European cities. The presented poster shows results of the approach to analyse thermal heat stress during a hot summer day in Kassel (Germany), via subjective data derived from interviews and the Multi-Agent-Model BOTWorld. To validate the simulation process, data was used, which was conducted by on-site interviews taken at the 07/31/2008. The Multi-Agent-Model BOTWorld can be used for simulating the dynamic component of heat stress, meaning it takes into account the development of heat stress of pedestrians while moving through the urban open space. This is seen as a realistic way of approaching heat stress and can therefore be an instrument for planners to identify heat stress in the open space and develop strategies to mitigate those.

The aim of this study was to test the results of BOTworld and the interviews according to their suitability in terms of assessing the threshold of thermal heat stress on hot summer days in European cities.

2. BOTworld

The agents in BOTworld are virtual pedestrians (BOTs) with multiple properties. In the presented study, the agents represent an urban population e.g. persons being 5 to 80 years, with various BMI (Body Mass Index) and the possibility to react individually on different environmental conditions like solar radiation, shade and humidity. Reactions can be an increase in the sweat production, an adjustment in clothing or an alternative route with more for thermal comfort suitable climate conditions.

BOTworld offers to calculate various output parameters like energy balance, dynamic PET (Physiological Equivalent Temperature), PMV (Predicted Mean Vote) etc. BOTworld also offers different settings for the agents when they pass or move within the model. Walking speed, talking time to other Bots and the choice of alternative routes if environmental conditions are uncomfortable, can be set in the model (see Fig. 1).

In addition to that the BOTs are able to assess the covered distance with a fuzzy logic approach. This means they can assess their walking route considering heat due to an assessment of their skin temperature versus wind speed, or, in a more general way, the inner human conditions versus the outdoor conditions.

BOTWorld allows visualising each Bot after a model run. So, there is the possibility to visualise each BOTs walking route as well as their thermal history. If you take Bot "Gregory", e.g., who started at Point A with his route to target B, he experiences several changes in his personal thermal conditions during his walk, which are indicated by different colours (see fig. 2).

2.1 EVALUATING THE THERMAL HEAT STRESS DYNAMICALLY

The human thermal comfort analysis with BOTworld is based on a dynamic two-node model. As each agent carries its own thermal system through the environment, therefore supports BOTworld a consideration of the thermal history from each agent when assessing the thermal comfort and the environmental perception. During the project KLIMES the simulation results are compared with meteorological measurements and on site-interviews with pedestrians during hot summer days in Kassel. The aim of the study is to identify uncomfortable

hot areas in city quarters or street canyons in relation to pedestrian activity and movement patterns. The examples shown are derived from one public square in Kassel.

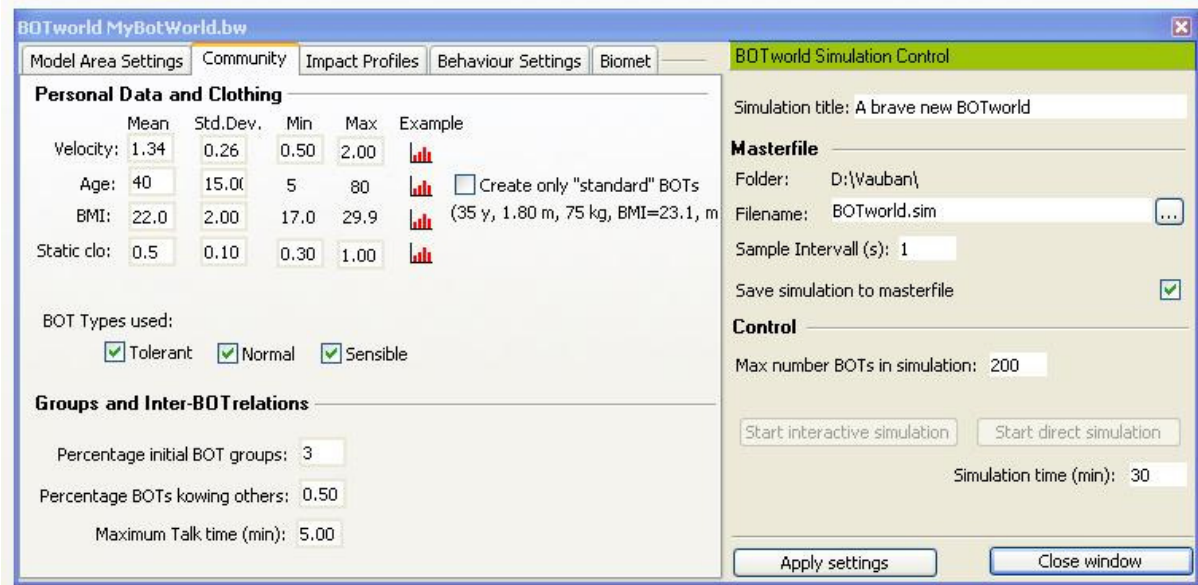


Fig. 1: One possible setting for the Bots before they are released into the model area. For various scenrios different settings can be chosen. The settings can create BOTs at different ages and BMI or simply standard BOTs.

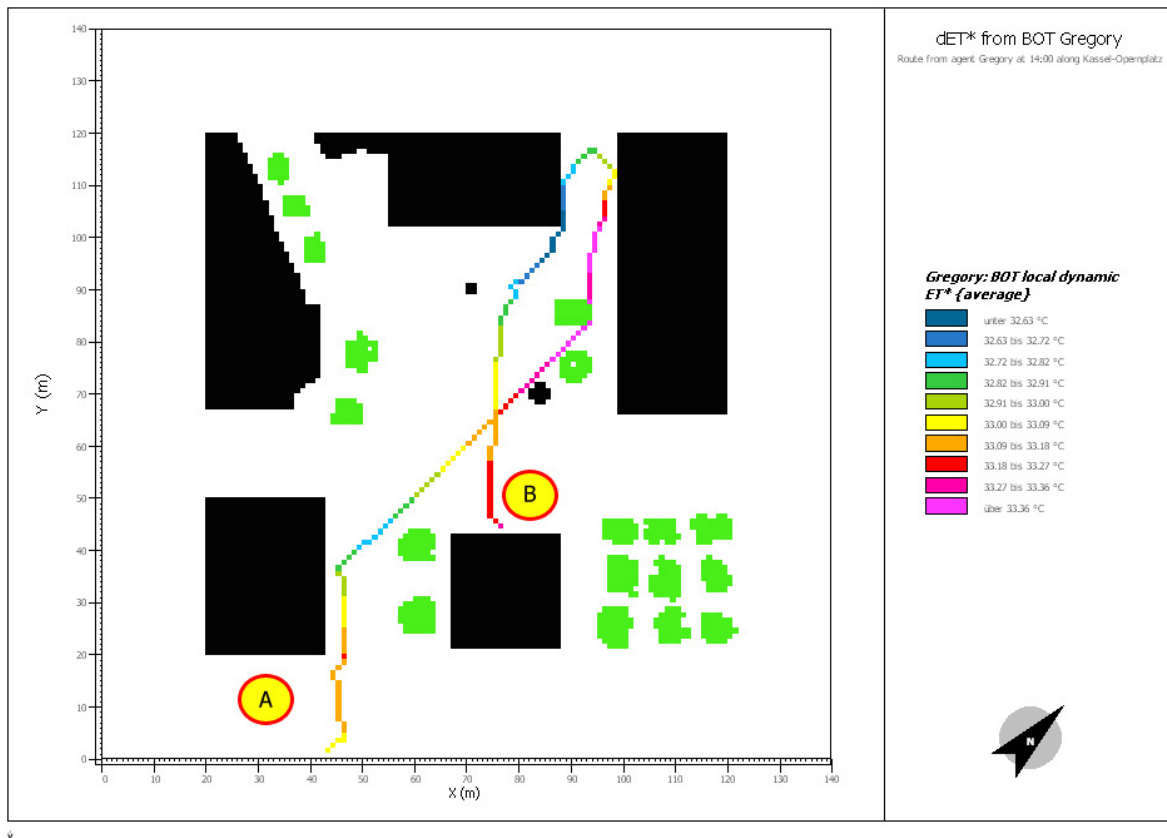


Fig. 2: BOTworld allows visualising each Bot after a model run. During his walk he experiences several changes in his personal thermal conditions which are indicated by the different colours.

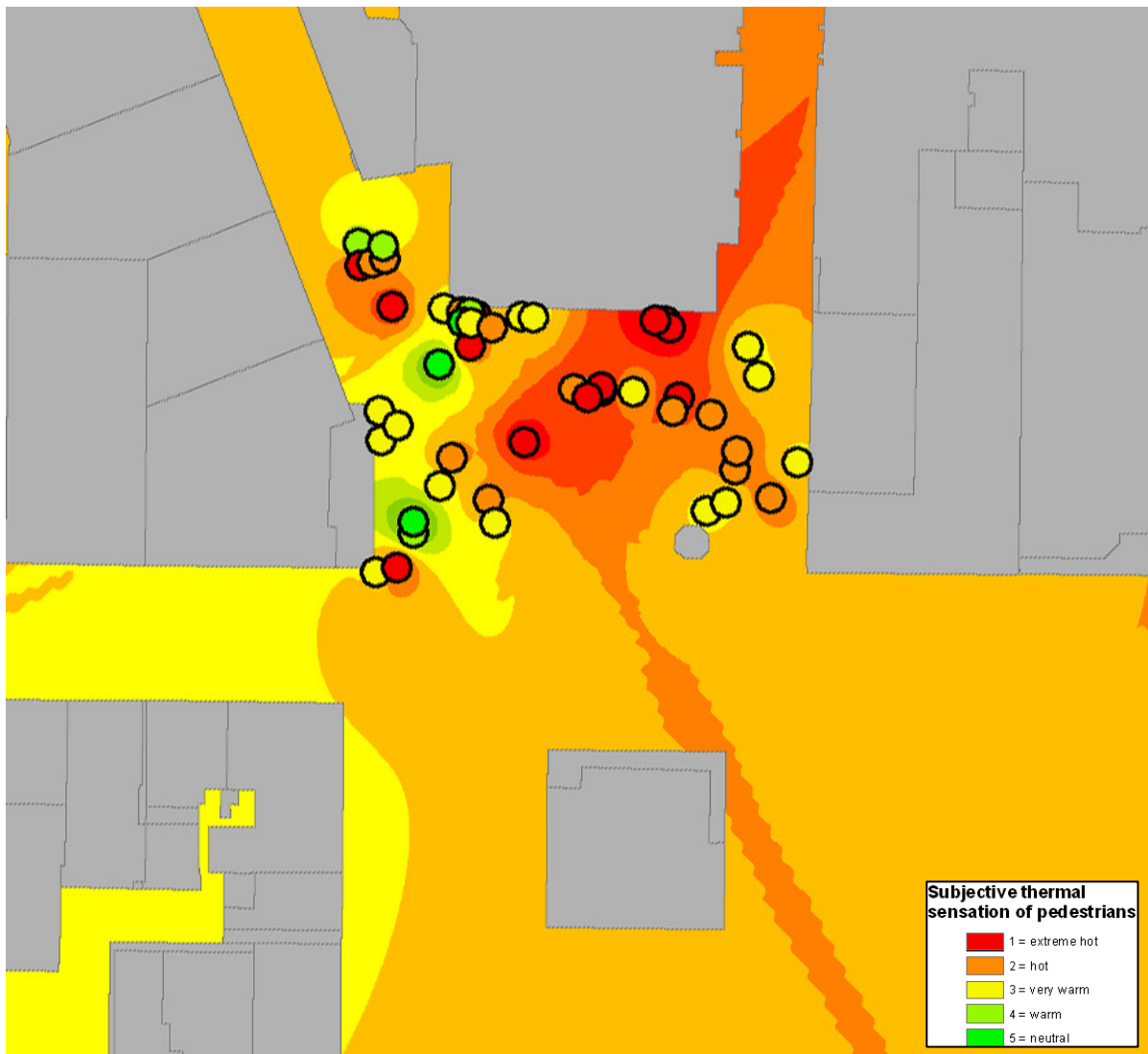


Fig. 3: Map generated from on-site-interviews representing the subjective thermal sensation of pedestrians at the Opernplatz in Kassel, Germany, taken between 14:00 and 16:00. Each point represents an on-site-interview coloured due to the thermal sensation of each pedestrian. The results were interpolated with Inverse Distance Weighting.

In addition to that the BOTs are able to assess their covered distance with a fuzzy logic approach. This means they can assess their walking route considering heat due to an assessment of their skin temperature versus wind speed, or, in a more general way, the inner human conditions versus the outdoor conditions.

2.2 METEOROLOGICAL REFERENCE DATA

The maximum air temperature during that day was 30 °C. In addition to the interviews, meteorological measurements were conducted with a mobile meteorological station. The interviews were conducted from 2 pm to 9 pm and divided into three intervals from 2 to 4:30 pm, 5 to 6:30 pm and 7 to 9 pm (CET). Additional results were derived from the Multi-Agent-System BOTWorld©. The BOTWorld simulations were conducted on the basis of the meteorological measurements taken during the interviews. The simulations were made for every hour from 2 pm to 9 pm (CET). The aim was to adapt BOTWorld and its results to the interviews concerning thermal sensation. Focus was the interval between 2 and 4 pm (CET), which was the interval with the highest solar radiation and highest air temperatures.

2.3 ON SITE-INTERVIEWS

The approach to evaluate influences of certain urban structures or elements on human thermal comfort was to carry out different microclimatic measurements and on-site-interviews. This was realized through measurements with one temporary reference station and two mobile recording systems. The meteorological parameters conducted were air temperature, wind speed and humidity, but also radiation coming from all six sides. Furthermore, another mobile system was used, measuring the same parameters but only where interviews were carried out. Using this methodology every person and its subjective perception can be related to objective data of

the mobile station. The mobile station measures three minute means of meteorological data being the base to calculate PET. Finally there is one PET value for each participant of the interviews.

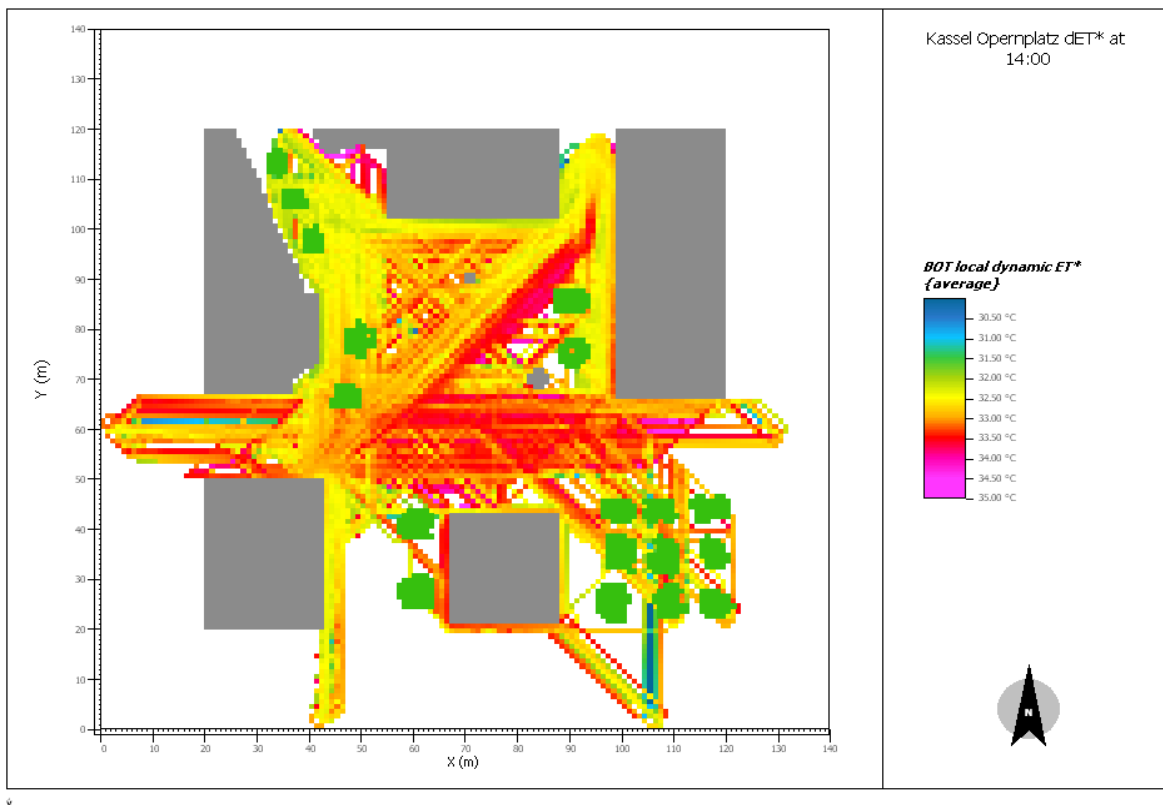


Fig. 4: Map of the square Opernplatz in Kassel at 2 pm (CET) derived from BOTworld to calculate the dynamic PET. The red and pink areas indicate the warmest areas along the square.

The subjective perception was measured with the question “How do you perceive the heat today?” and could be assessed on an eight point scale, ranging from very hot, hot, very warm and warm over neutral to cool and cold. As the aim was to quantify heat stress and the interviews were conducted on a hot day, only assessments from very hot to neutral were observed.

3. RESULTS

The results show that the interviews and meteorological measurements mainly match, especially in the very hot areas. Still the uncertainty of psychological factors has to be taken into account. The perception of places concerning its thermal comfort is closely linked to psychological matters. A square’s outer appearance influences thermal comfort as well as, for example, the people’s attachment to a place (Knez, 2005; Knez, Thorsson 2006). So thermal perception does not only rely on the microclimate. For example people in temperate regions, as in central Europe, seek warm areas although thermally uncomfortable during a summer day, whereas people in hot regions avoid places like the Opernplatz (Tzu-Ping Lin, 2009). This explains differences concerning the evaluation of the subjective thermal sensation and the results from BOTWorld.

A second advantage of BOTWorld is that it takes the thermal history of each BOT into account. If a BOT for example crosses a hot square, he will not feel immediately uncomfortable or sense heat stress. This dynamic approach is also a reason why the model matches with the interviews especially in the heat sensitive areas. Therefore it can be a helpful instrument for urban planners considering where to place, e.g., vegetation, if they are about to increase the vegetation in urban quarters. The results show that subjective thermal perception has a dynamic component (thermal history). This variety in assessing heat stress makes it difficult to define static benchmarks as well as it shows the influence of urban structures and the individual adaptation of pedestrians. The subjective perception map (Fig. 4) in connection with the dynamic modelling (Fig. 3) gives a realistic picture.

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