Network for Comfort and Energy Use in Buildings
Work Group: Simulation

Ideas and suggestions for linking dynamic thermal simulation models of buildings and human occupants

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The aim of the NCEUB-network is to define and promote the research effort needed to understand and enhance the thermal comfort of building occupants whilst minimising the energy use of buildings.

Current National and International Standards for thermal comfort are based on steady-state models developed from laboratory experiments. Whilst acceptable for AC buildings, various difficulties arise especially when assessing occupant comfort levels in naturally ventilated (NV) building.

Today, dynamic thermal simulation is an established technique for analysing the behaviour of whole buildings including heating demands, cooling loads, and solar gains. Current state-of-the-art building simulation programs (BSP's) such as ESP-r provide comprehensive predictions of indoor air temperature, humidity, and interior surface temperatures for specified weather and site data, built design and operations. However, various problems arise mainly because of the behaviour of building occupants. Because no clear model of occupant behaviour exists, building simulators tend to assume best practice or some simplified model of behaviour. New up-to-date approaches to modelling people and buildings are needed.

There are now sophisticated dynamic models of human physiology and thermal comfort (DMPC) which are beginning to address the problem of providing psychophysical simulation of occupant responses in NV buildings. These models enable predictions of human responses to non steady-state conditions that can deviate from thermoneutral conditions towards both warm and cold. Coupling state-of-the-art DMPC models with sophisticated BSP's would open doors for realistic simulation of the building/building-occupant systems and allow detailed thermal comfort analysis under conditions to which building occupants are exposed in daily life.

One objective of the NCEUB Work Group 'Simulation' is therefore to explore ways how to link/couple DMPC's and BSP's simulation tools in order:

– to enable detailed thermal comfort analysis of the time-varying and spatially inhomogeneous conditions in building,
– to explain the differences between current-standard steady-state comfort models and field survey findings,
– to investigate perceptual trigger levels for occupants' behavioural action.

The first step in developing a computerised procedure for linking DMPC and BSP is to identify the predicted parameters and variables that need to be exchanged between the two simulation tools. Figure 1 is a schematic diagram of a procedure that has been outlined to link the multi-segmental IESD-Fiala model of human heat transfer and thermal comfort with esp-r. The procedure consists of three stages: (1) generation and preparation of the required input data for the IESD-Fiala model, (2) dynamic physiological comfort simulation of building occupants, and (3) data post-processing.

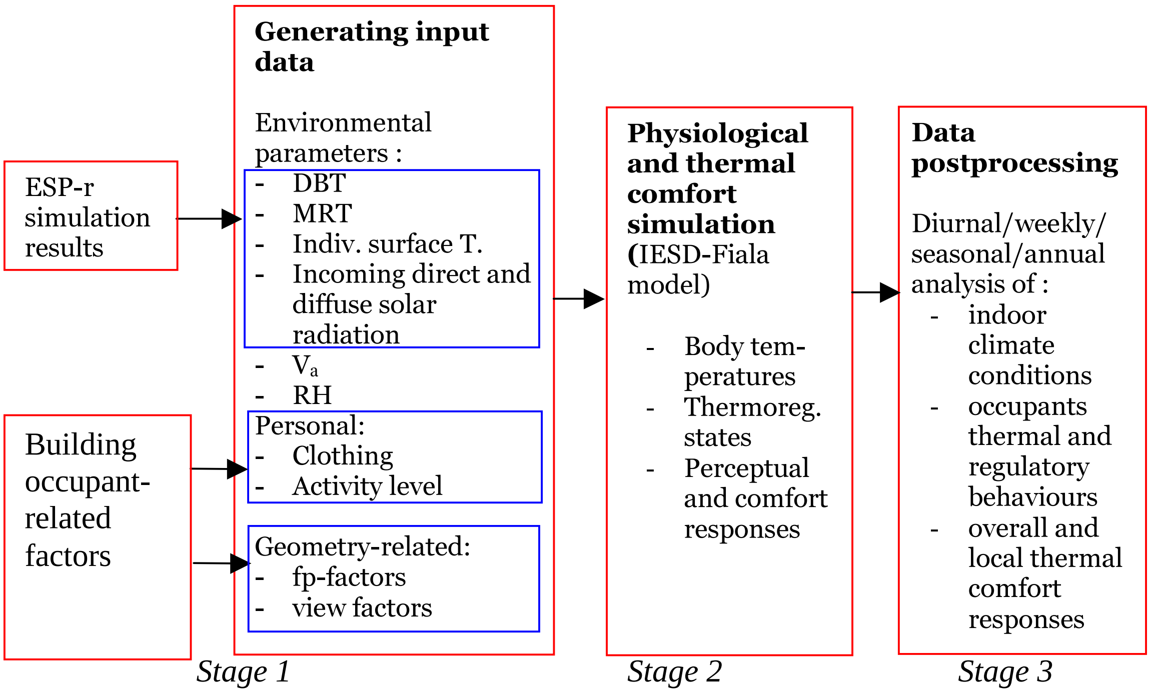

Figure 1 Schematic diagram of a computerised procedure linking the IESD-Fiala model with esp-r.

In stage 1, six environmental parameters and four 'personal' parameters are needed to create the necessary input data to be used with the IESD-Fiala model. The environmental variables predicted by esp-r required include: zone DBT, zone MRT, temperature of surface(s) that might considerably deviate from MRT (e.g. windows), and the (direct and diffuse) solar radiation entering the occupied zone. Two further parameters are required as input data into the physiological comfort model: air velocity (V_a) and the zone relative humidity (RH). These two parameters can either be user-defined or estimated as time-dependently variables predicted by the esp-r model of the building extended for moisture mass transfer and airflow network models. Esp-r offers both as an integral part of the simulation software.

The four ‘personal’ (subjective) parameters are: (i) projected area factors (fp) of individual body parts with respect to both direct and diffuse solar radiation, (ii) view factors between individual body parts of the occupant and surrounding surfaces of the zone, (iii) clothing and (iv) the occupants’ activity levels. The two human geometry-related factors (fp and φ) can be predicted as pre-processor calculations using simulation tools developed at IESD. The other two personal parameters, i.e. clothing and activity level, are user-defined as time-dependent variables considering the season, any prescribed dress code (and possible variations), type of work, etc.

Stage 2 and 3: based on the input data from stage 1 the IESD-Fiala model can be run to predict the occupants’ dynamic physiological and thermal comfort responses for the period of time of interest. These can include diurnal, weekly, monthly, seasonal etc simulations. The simulation results provided as time-series are then subjected to statistical analysis to evaluate the physiological and perceptual responses and to draw conclusions re occupants’ thermal and perceptual behaviours, occupant adaptive action, any feedback loops to building operation and indoor climate control, etc.