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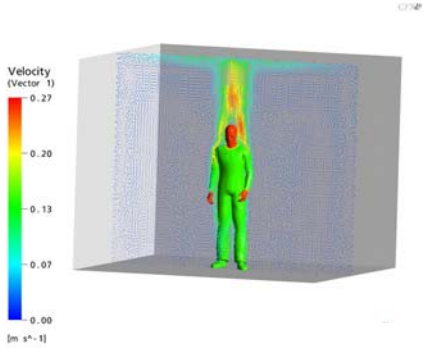
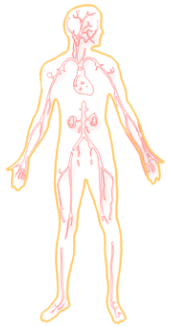
DE MONTFORT UNIVERSITY IESD

Development of coupled CFD human heat transfer for designing energy efficient and thermally comfortable indoor environments.





Presented by

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With Contributions from

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Outline of Presentation

1. Introduction
2. Mathematical Modelling of Thermal Comfort
3. Use of Computational Fluid Dynamics (CFD) in Indoor climates
4. Coupling comfort models with CFD techniques
5. Proposed Plan of Project
6. Questions & Answers

Introduction

What is meant by Coupled CFD human heat transfer?

How to model this coupled system?

- ✓ Human microclimate
- ✓ Interaction between microclimate & the surrounding
- ✓ Human thermoregulatory mechanisms

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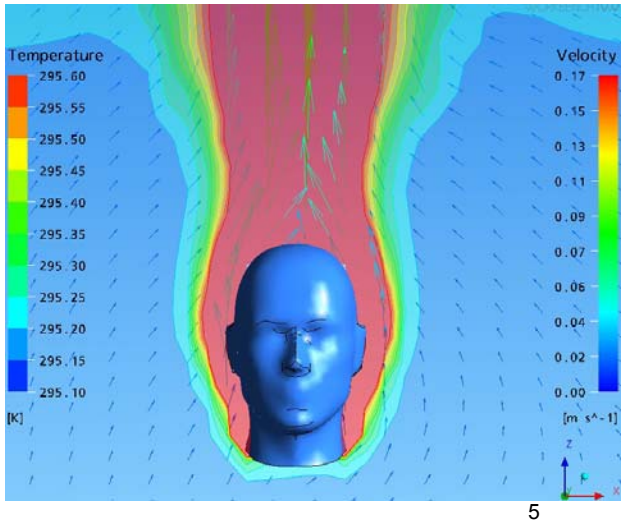
Human microclimate.

- Temperatures on the human body surface
- Moisture contents at the body surface
- Air movement close to the body
- Posture of the human body

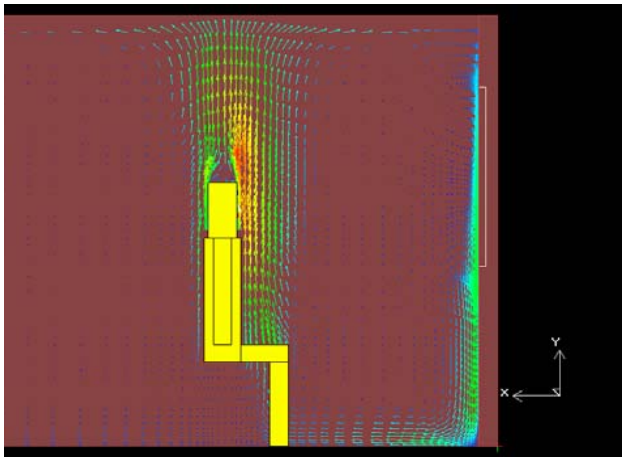
Source: Yunus A. Cengel et al, Fluid Mechanics: Fundamentals Applications.



Interaction between microclimate and the surrounding environment

- Type of surrounding
- Location of heat sources and sinks
- Strength of sources & sinks
- Movement of air and/or pollutants


Source: Yunus A. Cengel et al, Fluid Mechanics: Fundamentals
Applications.



Mathematical Modelling of Thermal Comfort

According to ASHRAE Standard 55

`` Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment´´

According to Benzinger (1979)

`` Thermal comfort is the absence of punitive impulses from both (i.e. Cutaneous and hypothalamic) receptors fields´´

Thermal Comfort Models

- ✓Adaptive Model
- ✓Fanger‘s model
- ✓Gagge‘s 2 node model
- ✓Multisegmental/multinode models

IESD Fiala Multinode Thermo-physiological Model

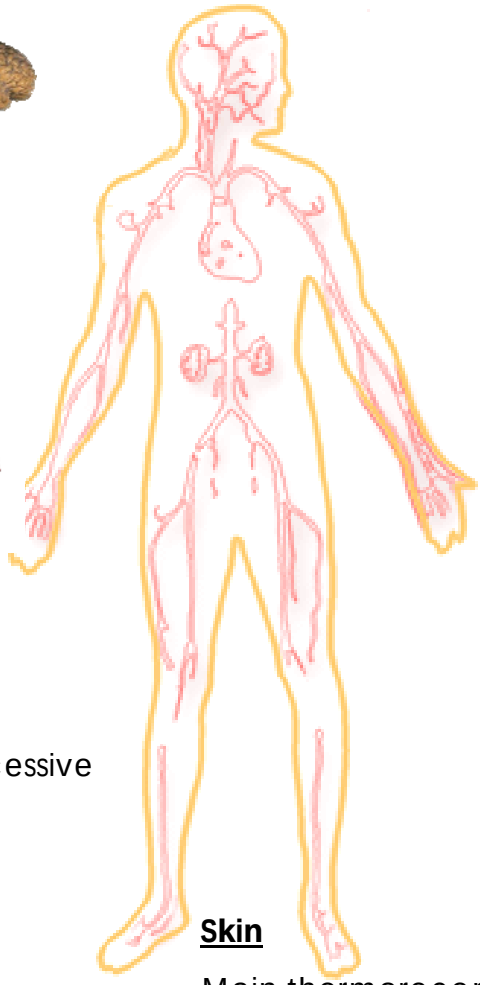
Developed by Dr. Dusan Fiala at IESD

1. 7 body tissue materials
2. 15 spherical or cylinderical body elements
3. Applicable to steady and transient environments
4. Heat transfer mechanism based on Bioheat equation by Pennes
5. Detailed human blood circulatory system
6. Handling of asymmetrical heat transfer effects
7. Prediction of a comfort indice ‘‘Dynamic thermal Sensation‘‘
8. Well validated between1 met to 10 met

IESD Fiala Multinode Thermo-physiological Model

CNS (Brain)
Posterior Hypothalamus processes information from cutaneous and other thermoreceptors

Circulatory System (Heart)
Controls the blood circulation to and from the body parts



Fats

Storing excessive energy

Skin

Main thermoreceptors

Respiratory System (Lungs)
Carry out the basic function of intake of oxygen from surroundings and excrete carbon dioxide from the bloodsteam generated as a result of energy production

Digestive System (Viscera)
Digestion of food to extract energy

Skeleton system (Bones)

Covering the vital organs, forming the inner core, supporting the muscles for bodily movement and posture

Pennes Bioheat Equation

$$k\left(\frac{\partial^2 T}{\partial r^2}+\frac{\omega}{r}\frac{\partial T}{\partial r}\right)+q_m+\rho_{bl}w_{bl}c_{bl}\left(T_{bla}-T\right)=\rho c\frac{\partial T}{\partial t}$$

Heat Conduction | metabolism | Blood perfusion rate | Heat storage in tissue mass

q_m	= Metabolic heat generation.
k	= Tissue conductance.
T	= Tissue temperature.
ω	= Geometry factor.
r	= Radius of tissue.
ρ_{bl}	= Blood density.
w_{bl}	= Blood perfusion rate.
c_{bl}	= Blood heat capacitance.
T_{bla}	= Arterial blood temperature.
c	= Tissue heat capacitance.

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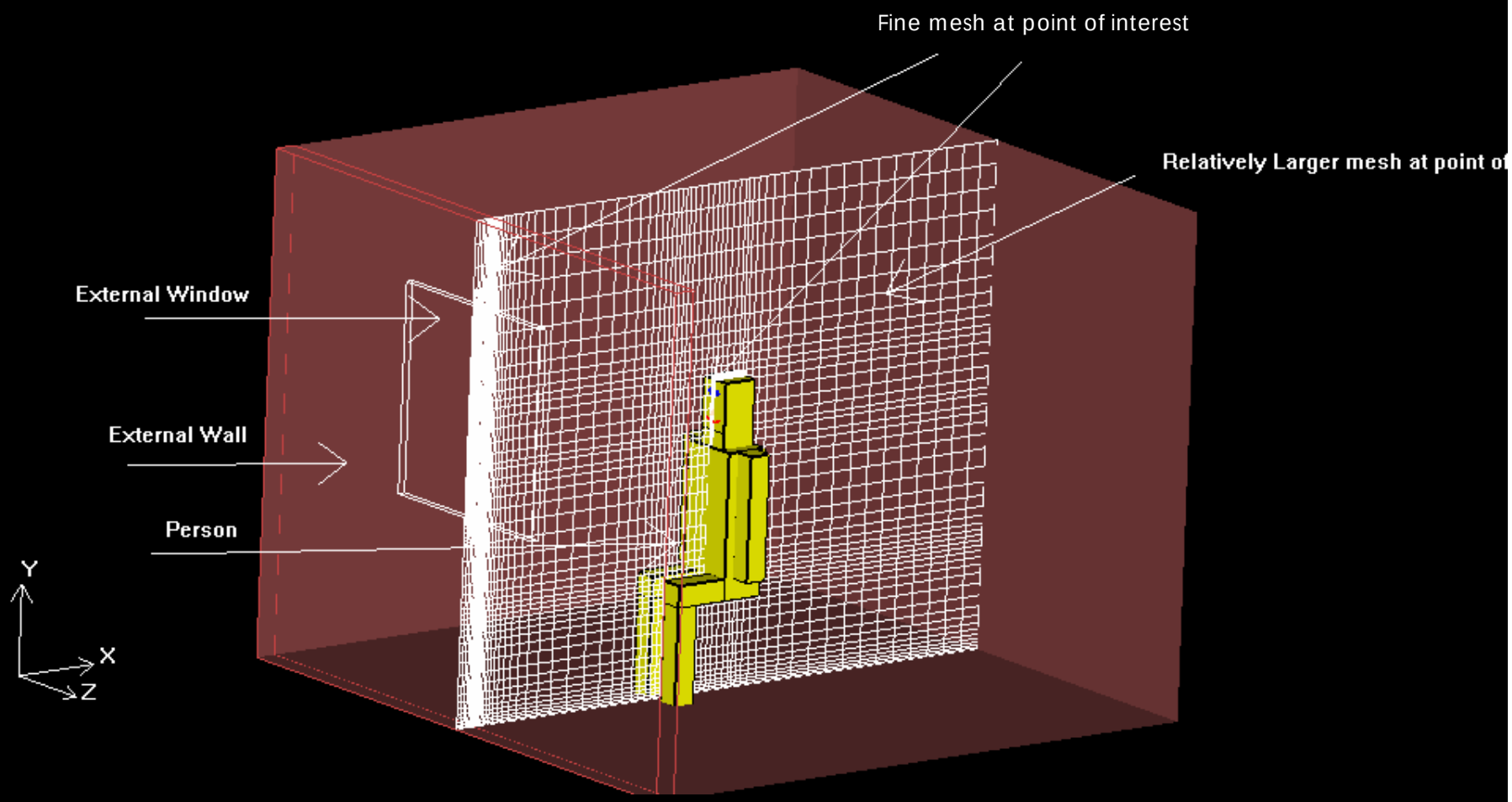
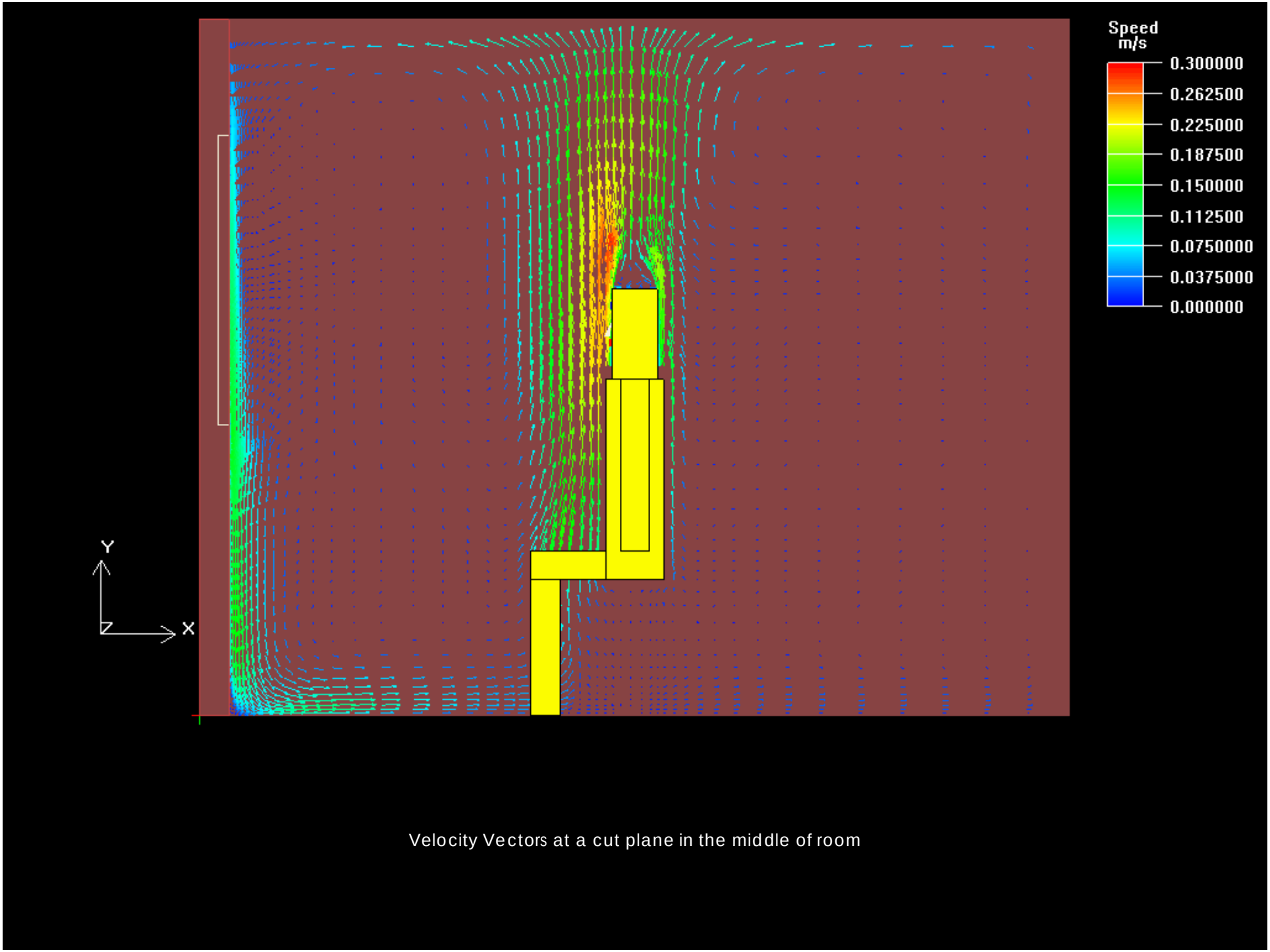
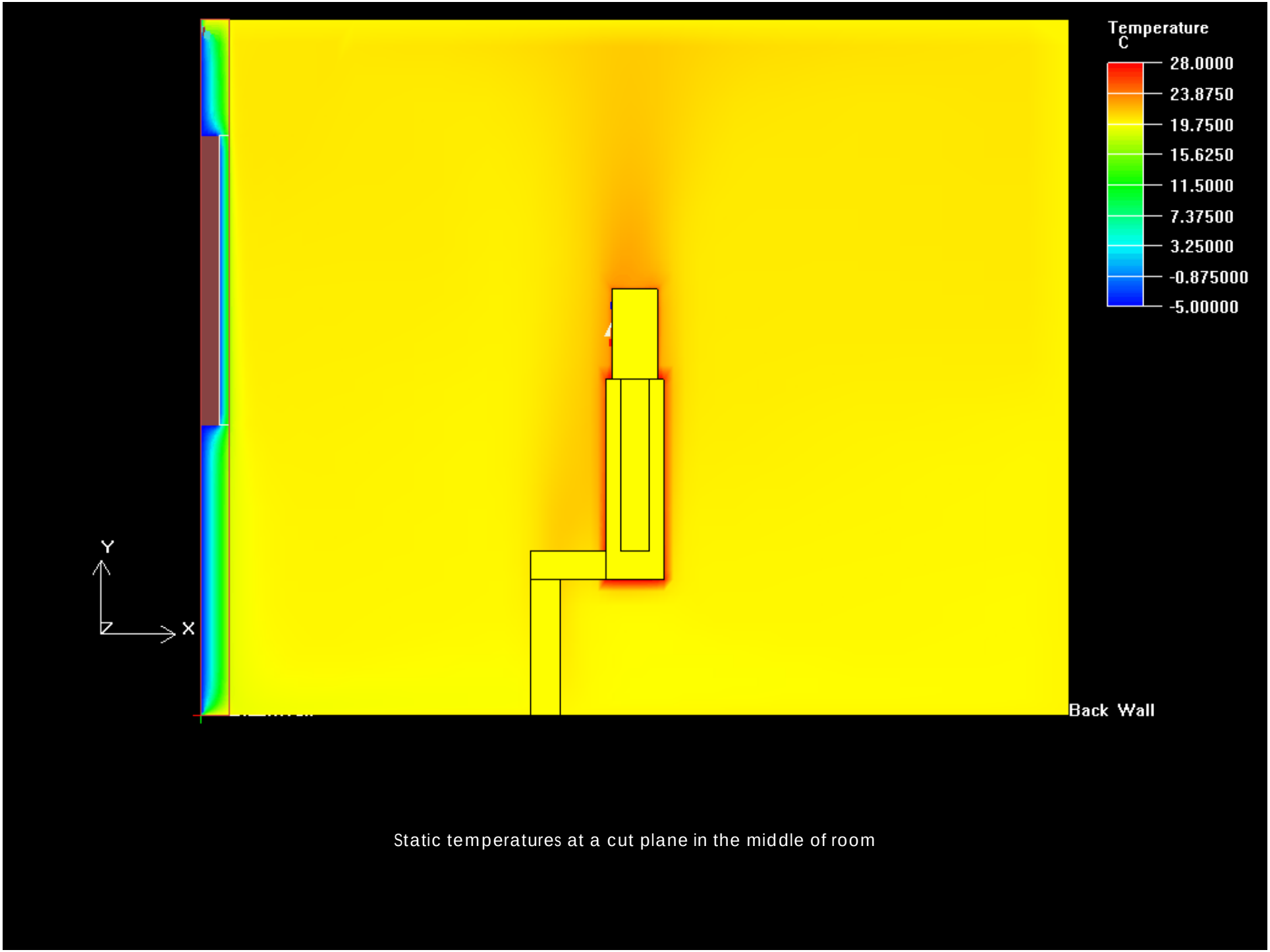
Example of a closed room with a person sitting in the room



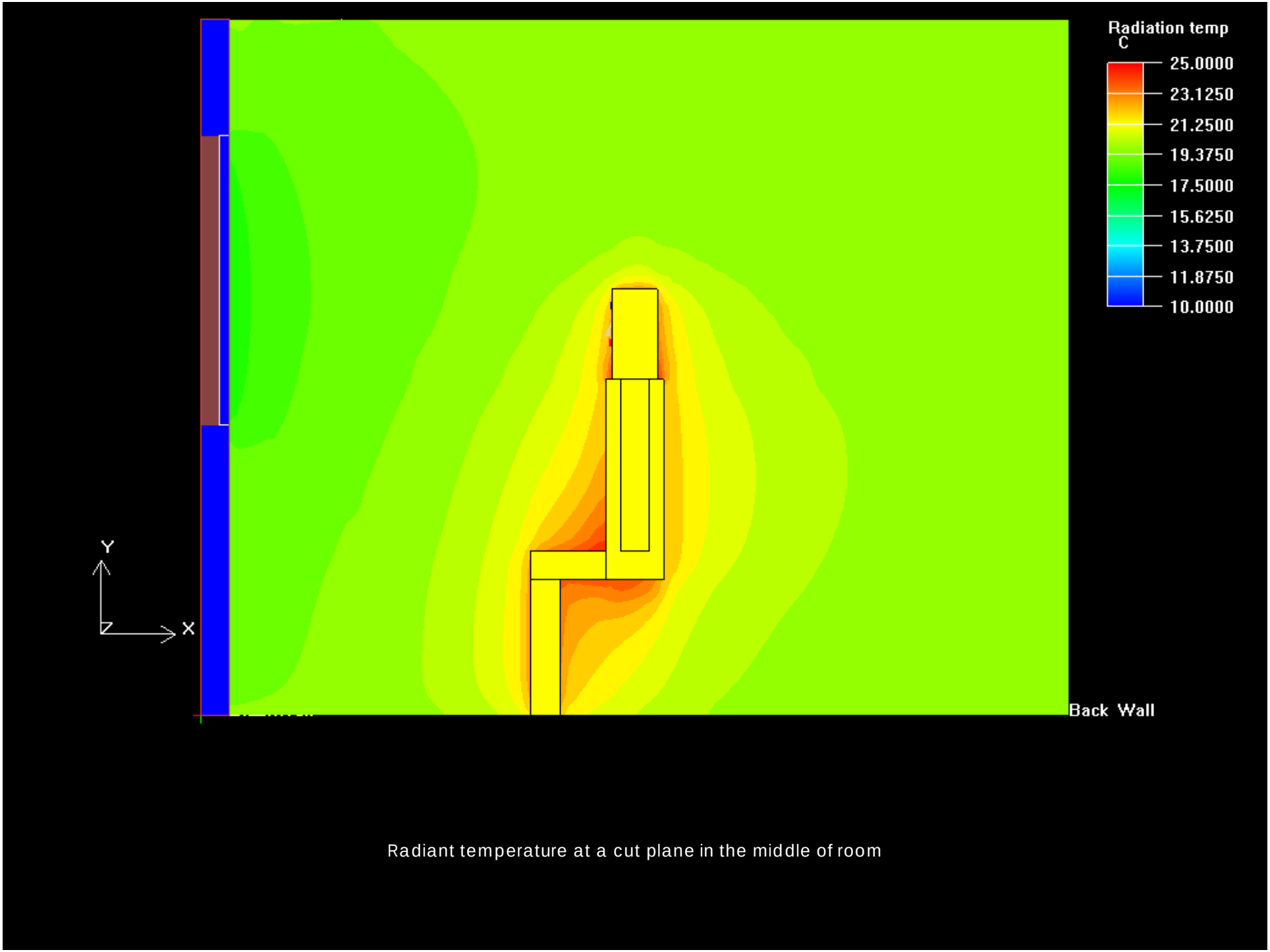
Source: Stahl & Weiss, Büro für Sonnenenergie Freiburg, Germany



Velocity Vectors at a cut plane in the middle of room



Static temperatures at a cut plane in the middle of room



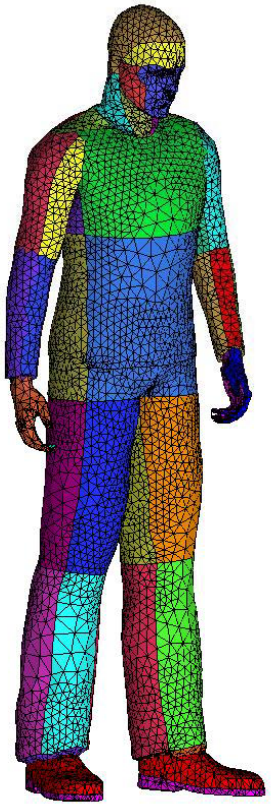
Radiant temperature at a cut plane in the middle of room

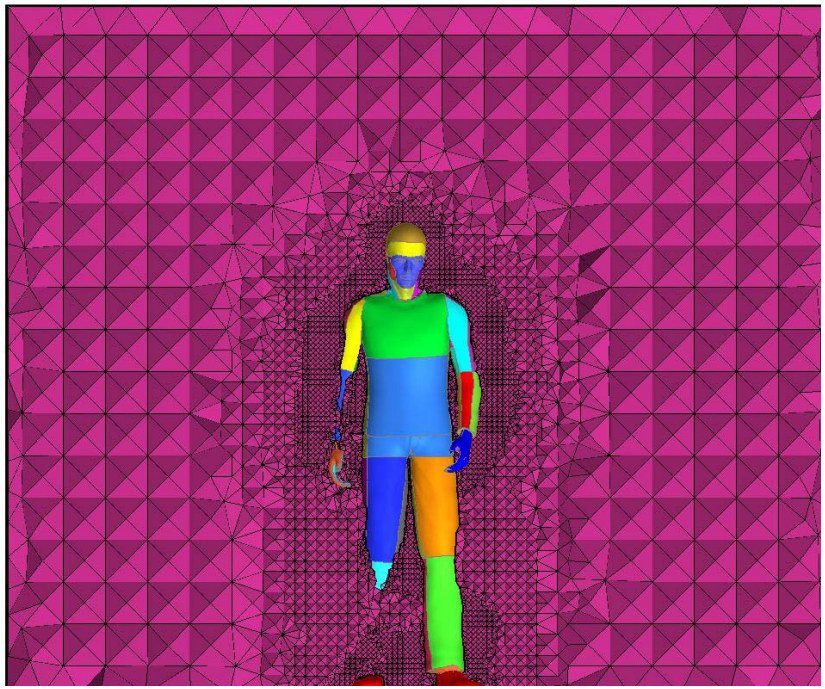
Coupling comfort models with CFD techniques.

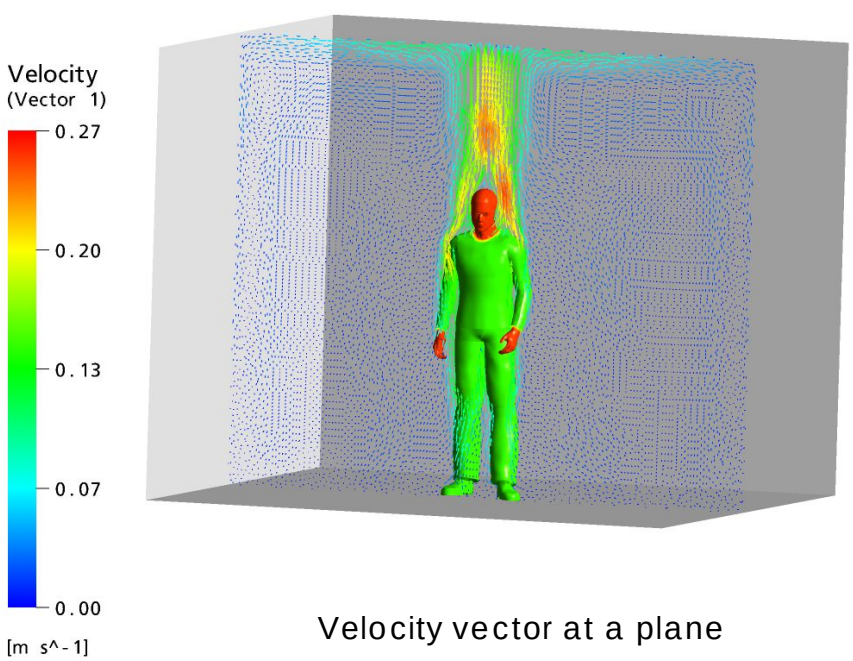
Creation of different postures for various analysis.

Subdivision of human body for CFD Simulation similar to the IESD Fiala Model subdivision.

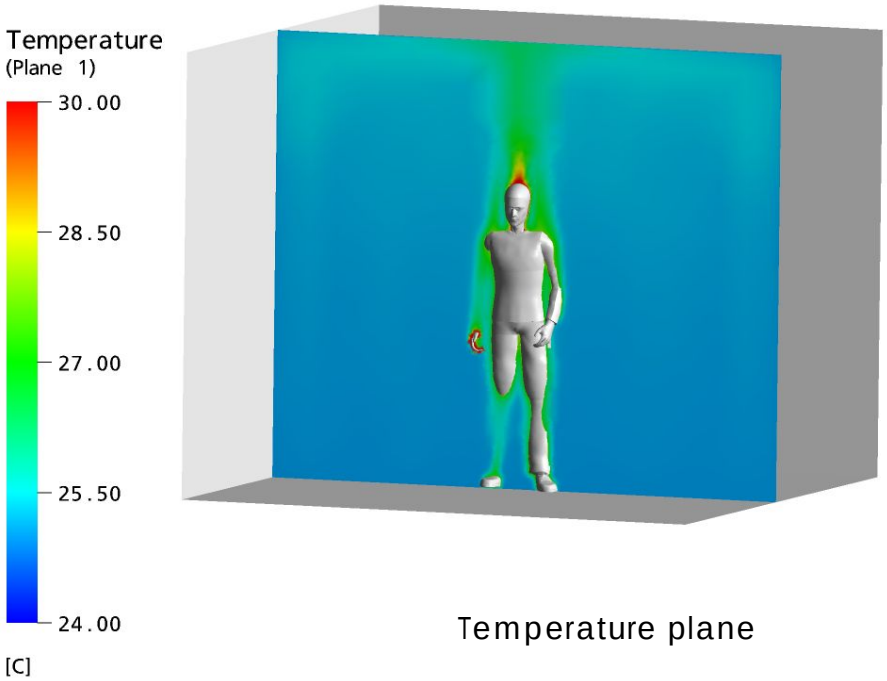
Resolving Microclimate based on boundary conditions from IESD Fiala Model, and its interaction with the surrouding







Velocity vector at a plane



Temperature plane

Results of Natural Convection Simulation

Thanks for your attention

I would be glad to answer if there are some questions