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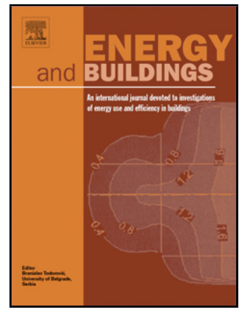

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Author: Henning Metzmacher Daniel Wölki Carolin Schmidt Jérôme Frisch Christoph van Treeck

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Real-time human skin temperature analysis using thermal image recognition for thermal comfort assessment

Henning Metzmacher[a,*], Daniel Wölki[a], Carolin Schmidt[a], Jérôme Frisch[a], Christoph van Treeck[a]

[a] *Institute of Energy Efficiency and Sustainable Building, E3D, RWTH Aachen University, Germany*

Abstract

This paper presents a system for the real-time analysis of human skin temperatures using sensor fusion and thermal image recognition. The aim of this work is to introduce an open and extensible framework that supports multi-modal sensor input with a focus on merging optical data and conventional sensor input for advanced thermal comfort analysis. The goal is to obtain a more complete representation of a person in various indoor climatic conditions. Methods proposed in this paper are important for research and industrial applications with respect to the real-time analysis of thermal comfort and human physiology in indoor climates. Although this paper mainly focuses on the analysis of skin temperatures, the proposed architecture is conceived for being extendable for statistical evaluation and numerical models. Arbitrary software components can be integrated as data sources and sinks by means of a conventional TCP/IP networking interface. Main contributions of this paper are a general architecture for the fusion of multi-modal sensor input using a centralized data server structure, a method for combining depth-map based face and pose tracking with a thermal imaging device and preliminary studies demonstrating the behavior and validity of the system.

Keywords: Thermal comfort, skin temperature, image recognition, infrared thermography, sensor fusion, multimodal sensing, face tracking, pose tracking

1. Introduction

Providing a contact-less, real-time method for the localized evaluation of human skin temperature has direct applications in the evaluation of human thermal comfort as well as related automation and individualization of indoor air conditioning. Heating and cooling of buildings and closed spaces using air conditioning or HVAC (short for heating, ventilation and air conditioning) systems makes up a large portion of energy consumption in the world. Currently, HVAC systems account for the largest energy end use both in the residential and non-residential sector [1]. Energy consumption for space conditioning by end uses in the residential sector are estimated at 53% in the USA and 62% and in the UK [1]. Air conditioning systems commonly focus on the climatization of large portions of the building or single rooms. Automation here is based on general sensory input but does not attempt to analyze individual requirements of residents.

Air conditioning also plays an important role in the automotive sector. Most modern vehicles rely on HVAC systems to keep the cabin climate at a healthy and comfortable temperature. Reduction in energy consumption here is especially important for future electric vehicles that solely rely on battery power where air conditioning systems greatly impact driving range. The use of a conventional HVAC system in an electric vehicle can cut the driving range by as much as 50% [2]. Local climatization that focus on the individual rather than the entire cabin enclosure offer great potential for energy reduction and for increase of driving range. Similar to the building domain this requires a system that provides detailed and accurate information about the individual's state of thermal comfort.

The use of thermographic imaging technology in this context is straightforward. Infrared thermography is a non-invasive, non-destructive tool for measuring surface temperatures that can be adopted for the evaluation of human thermal comfort. Advances in the field of image processing, analysis and classification allow for the extraction of detailed information from thermographic imagery. With low-cost depth sensing

*Corresponding author

Email address: metzmacher@e3d.rwth-aachen.de (Henning Metzmacher)

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