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Foreword

The wealth of research on thermal comfort has been partially taken and crystallized into international standards, where thermal comfort is defined as: "that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation". A selection of subjective judgment scales has been described, e.g., in ISO 10551. Those scales propose a set of answers to questions as: "how do you feel at this precise moment?", or "please state how you would prefer to be now", so they allow collecting information about the thermal sensation and preference of a certain subject in a given place at a given time.

The data collected via these standardized surveys in the laboratory and in the field have been interpreted, and meaningful correlations between the answers and various physical variables have been derived, giving rise to what are generally called comfort models, for example, the Fanger whole-body steady-state heat balance model, the Pierce two-node model, the adaptive models and others. All these models have as input the *here-and-now* questions and make *here-and-now* predictions over the likely answers of a group of people in a certain environment.

But, when assessing comfort performances of an existing building or using a certain comfort target interval as one of the objectives of a building design process, one is generally interested in the overall performance. So one would attempt to consider some adequate average over time (e.g., a season, a year, etc.) and space (e.g., all occupied thermal zones of a building) of the *here-and-now* thermal comfort values, be them gathered via direct interviews in a building or calculated via one of the models. Disparate averaging algorithms have been proposed in the literature, and some are presented in the standards and available for use in applications.

All this at least in theory; in everyday practice budget constraints and other limitations have often led to using very simplified rules for assessment or design, even not making explicit which model and assumptions are taken as a basis. Averaging algorithms have been used often without an analysis of their implications on design choices, and very limited comparison between them has been performed.

But in the last years, under the renewed effort toward low- and zero-energy buildings, the issues of fine-tuning comfort and fully understanding its connection with energy use have become increasingly important and urgent to address, particularly so in warm climates and warm periods.

A number of European research projects (e.g., SCATs, Commoncense, ThermCo, KeepCool) have explored these issues and added new data to the comfort databases about occupied real buildings; conferences and networks such as NCEUB, Palenc, and IEA SHC Task 40/ECBCS Annex 52 have been a fruitful research cooperation and exchange opportunity for analyzing the implications on comfort design; some of the new findings have found their way to the recent update of the standards EN 15251, ISO 7730, and ASHRAE 55, and will influence their further ongoing revision.

The research work of Dr. Carlucci presented in this book represents an important contribution to these advancements and a fruit of his active engagement in some of the mentioned projects and networks, in the framework of his participation in the end-use Efficiency Research Group of Politecnico di Milano.

A careful review, comparison, and analysis of the large number of long-term indexes proposed in the literature were highly needed and are now hence available. Building on those, Carlucci proposes a new improved long-term general discomfort index which aims at better matching the specific objectives of real world assessment and design and to be applicable with the three main comfort models presented in the standards. It also explicitly defines the operational use of the index (e.g., how to define the length of the calculation period based on the actual climate of the site) in order to overcome the present ambiguities that often undermine the gnoseological and practical relevance of the results. Finally, he developed three computer codes in the EnergyPlus Reference Language for calculating the three versions of the new index and integrated them in the simulation environment EnergyPlus in order to calculate the new index and to report it as a direct output of the simulation.

Overall, a clear-cut methodology is here an essential tool to produce useful results for real world applications.

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Salvatore Carlucci

Contents

Symbols and Abbreviations

Symbols

α	Solar absorbance of a surface (dimensionless)
B	Digit binary code: 0–1 (dimensionless)
γ	Solar factor (%)
h	Heat transfer coefficient (W m^{-2} K^{-1}) or Hour (h)
I	Global solar irradiance on a horizontal surface (W m^{-2})
v_a	Average air velocity (m s^{-1})
PMV	Predicted mean vote (dimensionless)
PPD	Predicted percentage of dissatisfied (%)
U	Steady-state transmittance (W m^{-2} K^{-1})
θ_{op}	Operative temperature (°C)
θ_{db}	Dry-bulb temperature (°C)
θ_{mr}	Mean radiant temperature (°C)
θ_{op}	Operative temperature (°C)
θ_{os}	Sol-Air temperature (°C)
θ_{res}	Dry-resultant temperature (°C)
θ_{rm}	Running mean of outside dry-bulb temperature (°C)
wf	Weighting factor (dimensionless)

Subscripts

actual	Actual status
actual PMV	Referred to PMV calculated in actual status
c	Convective
C	Cold period
comf	Comfort
$\overline{d}$	Value averaged on a day
lower limit	Lower limit of comfort range
OC	Overcooling
OH	Overheating
out	Outdoor