A MATLAB-BASED SIMULATION TOOL FOR BUILDING THERMAL PERFORMANCE ANALYSIS

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ABSTRACT

This paper presents the development of a simulation tool based on the Matlab computational environment for building temperature performance analysis with automatic control. The simulation tool contains mathematical models for buildings, HVAC (Heating, Ventilation and Air Conditioning) systems, sensors, weather data and control algorithms. The building mathematical model is described in terms of state-space variables, with a lumped approach for the room air governing equations – energy and mass balances. In this context, the simulation tool structure and components are explained. Five control strategies applied to HVAC systems, integrated to building zones, are discussed as well. A simulation example illustrates the use of the software presented.

INTRODUCTION

The mathematical description of thermal behavior of building systems is complex since it involves the modeling of several interconnect subsystems, each one containing long-time constants, non-linearities and uncertainties such as convection coefficients, material properties etc. Moreover, external unpredicted perturbations, i.e., external weather (temperature, humidity), soil temperature, radiation effects and other sources of energy, such as people, illuminations and equipments, should also be taken into account.

Some points related with building modeling include the analysis of thermal comfort and energy consumption. Several software environments for building simulation are available all over the world, for instance, DOE-2, BLAST, EnergyPlus, Genopt, SPARK, Energy-10. However, computer processing power has been considerably improved in the last decade so that the use of mathematical packages such as Matlab/Simulink can be considered also as a good option for performing simulation-based building thermal analysis. In addition, the use of Simulink features has provided a user-friendly environment for fast configuration of inputs and outputs of the different subsystems included in the building and equipments, such as HVAC (Heating, Ventilation and Air Conditioning).

In this way, a mathematical model for building simulation by using Matlab/Simulink environment is presented in Hudson and Underwood (1999). In this approach, the building is represented by an RC electric circuit and the model is considered adequate for high mass buildings since they are predominantly capacitive. In Mendes et. al. (2001), a lumped approach is used to model the room air temperature and a multi-layer model for the building envelope. The building model allows studying the transient analysis of room air temperature when it is submitted to sinusoidal variation of external air temperature. In Mendes et al. (2002), the model is extended in order to incorporate hygrothermal dynamics of the building and external humidity data. Both works use Matlab/Simulink environment. Another quite interesting example of Matlab/Simulink used in thermal system modeling is the SIMBAD Building and HVAC Toolbox (Riederer et al., 2001). This toolbox provides a large number of ready-to-use HVAC models and related utilities to perform dynamic simulation of HVAC plants. For simulation involving control, this toolbox must be connected to other existing toolboxes.

Another important aspect is the analysis of thermal comfort and energy consumption and its relation with HVAC system control. By using an adequate mathematical model of the building, it is possible to use techniques of automatic control in the regulation of thermal zone temperature and humidity. Some examples of this approach are Dion et al. (1991), Huang and Lam (1997), Ghoumari et al. (2001), Oliveira et. al. (2003).

The present work describes the development of a toolbox based on the Matlab/Simulink software for hygrothermal building simulation and performance analysis of HVAC automatic control systems. The proposed software version is modularity written, allowing easy expansion and interchangeability of building, HVAC and control systems. The simulation tool contains models for buildings, HVAC systems, sensors and controllers, and actual or typical weather

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Building Ventilation Mat Santamouris,Peter Wouters,2006-06-01 Ensuring optimum ventilation performance is a vital part of building design Prepared by recognized experts from Europe and the US and published in association with the International Energy Agency s Air Infiltration and Ventilation Centre AIVC this authoritative work provides organized classified and evaluated information on advances in the key areas of building ventilation relevant to all building types Complexities in airflow behaviour climatic influences occupancy patterns and pollutant emission characteristics make selecting the most appropriate ventilation strategy especially difficult Recognizing such complexities the editors bring together expertise on each key issue From components to computer tools this book offers detailed coverage on design analysis and performance and is an important and comprehensive publication in this field Building Ventilation will be an invaluable reference for professionals in the building services industry architects researchers including postgraduate students studying building service engineering and HVAC and anyone with a role in energy efficient building design

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in the social housing sector in the Eastern Mediterranean basin This book presents a novel methodological framework for the optimisation of post war social housing developments in the Eastern Mediterranean climate The authors draw on semi structured interviews to present evidence on in situ thermal sensation and provide the results of walk through and walk in thermographic surveys to highlight building fabric performance and highlight anomalies in the building envelopes The authors go on to show how this data informed retrofit design solution can be applied to reduce household energy consumption increase awareness of domestic energy use and inform effective policymaking decisions in energy use in the Eastern Mediterranean basin including the development of Energy Performance Certificate schemes This book will be of great interest to students and scholars of energy policy energy efficiency and planning It will also assist architects building engineers and other practitioners in closing the gap between the current understanding and the actual performance of existing residential building stocks in the Eastern Mediterranean basin **eWork and eBusiness in Architecture, Engineering and Construction** Jan Karlshoj,Raimar Scherer,2018-09-03 eWork and eBusiness in Architecture Engineering and Construction 2018 collects the papers presented at the 12th European Conference on Product and Process Modelling ECPPM 2018 Copenhagen 12 14 September 2018 The contributions cover complementary thematic areas that hold great promise towards the advancement of research and technological development in the modelling of complex engineering systems encompassing a substantial number of high quality contributions on a large spectrum of topics pertaining to ICT deployment instances in AEC FM including Information and Knowledge Management Construction Management Description Logics and Ontology Application in AEC Risk Management 5D nD Modelling Simulation and Augmented Reality Infrastructure Condition Assessment Standardization of Data Structures Regulatory and Legal Aspects Multi Model and distributed Data Management System Identification Industrilized Production Smart Products and Services Interoperability Smart Cities Sustainable Buildings and Urban Environments Collaboration and Teamwork BIM Implementation and Deployment Building Performance Simulation Intelligent Catalogues and Services eWork and eBusiness in Architecture Engineering and Construction 2018 represents a rich and comprehensive resource for academics and researchers working in the interdisciplinary areas of information technology applications in architecture engineering and construction In the last two decades the biennial ECPPM European Conference on Product and Process Modelling conference series as the oldest BIM conference has provided a unique platform for the presentation and discussion of the most recent advances with regard to the ICT Information and Communication Technology applications in the AEC FM Architecture Engineering Construction and Facilities Management domains **Livestock Environment VI** Richard R. Stowell,Ray Bucklin,Robert William Bottcher,2001 *Journal of the Indian Institute of Science* Indian Institute of Science, Bangalore,2006 Solar-Assisted Air-Conditioning in Buildings H.-M. Henning,2007-08 This second edition of a hugely important work on this subject still plugs a gap in the literature It is a source of crucial support to the planner in the design of solar assisted air conditioning

systems which use solar collectors as a heat source Air conditioning contributes significantly to the energy consumption of buildings in many countries and a promising possibility for energy reduction is the use of solar thermal energy in solar assisted air conditioning systems However until today only a few systems have been installed world wide and design and operation experiences are fairly poor   **CASES ...** ,2006   **Oil & Gas Science and Technology** ,2007   *Paper* ,1995   **Bulletin de L'Institut International Du Froid** ,2009   Winter Annual Meeting American Society of Mechanical Engineers,1995   **Thermal Quadrupoles** Denis Maillet,2000-11-17 This superb text describes a novel and powerful method for allowing design engineers to firstly model a linear problem in heat conduction then build a solution in an explicit form and finally obtain a numerical solution It constitutes a modelling and calculation tool based on a very efficient and systemic methodological approach Solving the heat equations through integral transforms does not constitute a new subject However finding a solution generally constitutes only one part of the problem In design problems an initial thermal design has to be tested through the calculation of the temperature or flux field followed by an analysis of this field in terms of constraints A modified design is then proposed followed by a new thermal field calculation and so on until the right design is found The thermal quadrupole method allows this often painful iterative procedure to be removed by allowing only one calculation The chapters in this book increase in complexity from a rapid presentation of the method for one dimensional transient problems in chapter one to non uniform boundary conditions or inhomogeneous media in chapter six In addition a wide range of corrected problems of contemporary interest are presented mainly in chapters three and six with their numerical implementation in MATLAB r language This book covers the whole scope of linear problems and presents a wide range of concrete issues of contemporary interest such as harmonic excitations of buildings transfer in composite media thermal contact resistance and moving material heat transfer Extensions of this method to coupled transfers in a semi transparent medium and to mass transfer in porous media are considered respectively in chapters seven and eight Chapter nine is devoted to practical numerical methods that can be used to inverse the Laplace transform Written from an engineering perspective with applications to real engineering problems this book will be of significant interest not only to researchers lecturers and graduate students in mechanical engineering thermodynamics and process engineers needing to model a heat transfer problem to obtain optimized operating conditions but also to researchers interested in the simulation or design of experiments where heat transfer play a significant role   *IEEE Transactions on Circuits and Systems* ,2005   **Government Reports Announcements & Index** ,1996   Annual Index/abstracts of SAE Technical Papers ,2006   *Forthcoming Books* Rose Arny,2001-08   CEP Software Directory ,1992

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