Renewable and Sustainable Energy Reviews 64 (2016) 466–476

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Management and estimation of thermal comfort, carbon dioxide emission and economic growth by support vector machine

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ARTICLE INFO

Article history:
Received 1 June 2015
Received in revised form
24 April 2016
Accepted 19 June 2016

Keywords:
Thermal comfort
Economic growth
Carbon dioxide emission
Support vector machine

ABSTRACT

Urbanization and climate change are two defining environmental phenomena and these two processes are increasingly interconnected, as rapid urbanization is often accompanied by a change in lifestyle, increasing consumptions and energy uses, which contribute heavily towards climate change and thermal comfort. Success of public urban areas in attraction of residents depends on thermal comfort of the visitors. Thermal comfort of urban open spaces is variable, because it depends on climatic parameters and other influences, which are changeable throughout the year, as well as during the day. Therefore, the prediction of thermal comfort is significant in order to enable planning the time of usage of urban open spaces. This paper presents Support Vector Machine (SVM) to predict thermal comfort of visitors at an open urban area. Results from SVM-FFA were compared with two other soft computing method namely artificial neural network (ANN) and genetic programming (GP). The purpose of this research is also to predict carbon dioxide (CO2) emission based on the urban and rural population growth. Estimating carbon dioxide (CO2) emissions at an urban scale is the first step for adaptation and mitigation of climate change by local governments. The environment that governs the relationships between carbon dioxide (CO2) emissions and gross domestic product (GDP) changes over time due to variations in economic growth, regulatory policy and technology. The relationship between economic growth and carbon dioxide emissions is considered as one of the most important empirical relationships. GDP is also predicted based on CO2 emissions. The reliability of the computational models were accessed based on simulation results and using several statistical indicators.

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http://dx.doi.org/10.1016/j.rser.2016.06.034
1364-0321/

1. Introduction

1.1. Thermal comfort

In recent years there is rising interest for linking urban planning, environmental health and the quality of life [1]. Public open spaces are recognized as the opportunity for achieving healthy environment for inhabitants in cities. Pleasant thermal comfort allows adequate conditions for longer duration of stay of users at the urban open space, which can contribute to health, relaxation, socialization and entertainment of children and adults. Staying outdoors can save energy for heating or cooling devices for work. Hence the importance of the thermal comfort of urban open spaces is reflected in the sociological and even ecological and economic sense. The frequency of usage of urban open spaces is strongly affected by the relation between microclimatic conditions of urban open spaces and human comfort, therefore this relation must be taken into consideration during urban design and planning [2]. In order to describe and assess human thermal comfort the concept of thermal index was developed at the beginning of the 20th century by Gagge, Hill and Barnard [3]. The possibility to assess the human thermal condition by one single number which integrates all relevant parameters was first recognized by Fanger in 1972 [4]. Since then more than 40 indices were developed and among most used ones are Predicted Mean Vote (PMV), Physiologically Equivalent Temperature (PET), Standard Effective Temperature (SET) and Perceived Temperature (PT) [5]. PET was introduced by Hoppe and Mayer and represents equivalent to the air temperature at which the heat balance of the human body is maintained with core and skin temperatures equal to those under the conditions being assessed. Numerous research in outdoor thermal comfort assessment which included PET were conducted for different climatic regions and areas like Italy [6], Iran [5], Greece [4], Spain [7] and other.

Thermal comfort of pedestrians is an important factor affecting outdoor activities of visitors at public places such as commercial plazas, parks, streets, etc. Ameliorating outdoors thermal stress encourage inhabitants to use these places more, which in turn benefits the city socially and economically. For instance, the availability of shaded areas outdoor in a hot summer or presence of water features under dry climatic conditions may attract more people and enhance the outdoor activities. In order to modify the outdoor microclimatic conditions with appropriate design strategies [8], designers require a tool that could predict visitor's comfort level with respect to the changes in various climatic parameters.

Thermal comfort models are numerous; however, they are mostly developed based upon the same principles which might be either the body energy balance model or the adaptive model. This is proven that the energy balance model cannot fully describe the human thermal sensation, confirming the decisive role of thermal adaptation [9]. Indeed, assessment outdoor thermal comfort deals with various environmental, behavioral and psychological parameters [9–11]. By using these models, a growing number of studies addressed the correlation between the urban canyons geometry and their energy budget. Indeed, the concept of managing the climate dimensions through urban design is distinguished by far [12]. Nevertheless, it is not practically and holistically well-done due to the complexity of the processes.

Previous research works dealing with the visitor's thermal comfort have mostly considered indoor spaces [13]. Studies conducted for indoor spaces follow simple procedures and have limited variables. For example, at the indoor space the subject wears same cloth in all seasons regardless of the outdoor climatic conditions. However, a similar study in outdoor setting involves numerous complex factors and this makes such studies more complicated compared to the indoor studies.

In fact, pedestrians expect variability in the conditions to which they are exposed such as changes of sun and shade, variation in air velocities, and etc. Moreover, people wear diverse cloths for outdoor spaces based on type of climatic, social and cultural zones. Hence, study focusing on the outdoors cannot make simplified assumption by fixing type of cloth worn by subjects. In addition, the influence of a specific microclimatic parameter may differ in different situations e.g. solar radiation in hot summer and cold winter conditions. Air velocity outdoors is normally higher than indoors and may give comfort to visitors to certain extend during summer. Role of water features are considerable particularly in arid regions. On the other hand, due to physiological and psychological impacts, individual differences play an important role in thermal perception. Meanwhile, these effects, particularly gender, are well known on indoor thermal comfort [14–19]. Nevertheless, these effects have not been thoroughly investigated for some other demographic factors on outdoor thermal comfort. Therefore, these factors need to be considered for evaluating response of subjects at outdoor spaces.

1.2. Carbon dioxide (CO2) emission

Urban form is increasingly being recognized by scientists for the potential role it might play in the coordination of sustainable urban development and the reduction of carbon dioxide (CO2) emissions. However, despite increasing interest in the morphology of cities in climate change science, few quantitative estimates have been made of the effects of urban form on CO2 emissions. Over half the world's population lives in cities and the number of people that live in urban areas is constantly increasing [20]. Currently, it is unanimously recognized that urban form can strongly impact on a fast-growing city's contribution to global climate change through the production of CO2 emissions, and as such, it is clearly necessary to undertake appropriate strategic spatial planning and urban design measures in order to reduce CO2 emissions and thereby address the anticipated impact of global warming [21]. Despite this urgent imperative, existing literature engaging in the task of quantifying the impacts of urban forms on CO2 emissions is limited [22]. Also carbon emissions due to rural energy consumption in have not yet been sufficiently addressed or quantified.

In study [23] was examined the carbon dioxide emissions and its influential factors through the proposed algorithm and the statistical method, providing a theoretical support for further measures to reduce emissions. The results in study [24] was indicated that the total direct CO2 emissions resulting from rural energy consumption have nearly tripled and quantitatively illustrated the importance of rural energy consumption as a contributor to overall carbon emission. The aim of the study [25] was