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# Indoor thermal condition in urban heat island: Comparison of the artificial neural network and regression methods prediction

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ABSTRACT

A side effect of urbanization, urban heat island (UHI), is well known in increases of ambient air temperature. This increase further leads to a rise in indoor environment temperature, reduction of thermal comfort, increase of cooling demand, and heat related morbidity and mortality especially among vulnerable people such as the elderlies and those living in poorly ventilated buildings. Thus, it is imperative for cities to be empowered with predictive tools during extreme heat waves in order to be able to provide emergency plans. For this purpose, it is utmost importance to develop specialized tools to predict the indoor conditions based on the outdoor conditions recorded at the weather stations. In order to develop a reliable warning system artificial neural network (ANN) and regression method were proposed and tested for an indoor air temperature forecasting application with respect to neighborhood parameters. To find the most practical approach, a cross comparison of the models was conducted by two different levels of simulation in order to present the capturing and prediction performance of the developed models. In general, the ANN model showed better accuracy in predicting the indoor dry-bulb temperature while it was more complicated in implementation.



## 1. Introduction

Industrial revolution between 1760 and 1840 demanded a massive population as labors to be settled within urban areas. The rush behind this mass settlement resulted in an unplanned urbanization lasted until the recent era. The urban to rural population gradually increased from less than 10% in 1800 to less than 30% at the end of Second World War, 1945. Due to various socio-economic reasons urbanization had even a higher growth slope from less than 30% to about 50% between the Second World War and the recent time. During these years cities experienced significantly higher temperatures than their nearby rural areas [1]. This phenomenon, known as urban heat island (UHI), has been broadly investigated and documented in many cities, i.e. London [2], Montreal Island [3], Toulouse [4], Mediterranean cities [5], Mexico [6], Atlanta [7], and Hong Kong [8].

The undesired side effects of UHI on decreasing outdoor air quality, increasing air conditioning energy consumption, heat related illness and mortality are among the motives to study its influential parameters, mitigation strategies and prediction methods. UHI is mainly intensified during heat waves which are reported to be more frequent in the recent years. Hajat et al. [9] defined heat wave as a three day rolling average above the 97th percentile value of 21.5 °C. Heat waves are ranked first as the cause of human mortality compared to other meteorological hazards, i.e. floods, hurricanes, and tornadoes while they poses threats to property and human health [10]. The National Weather Service Office of Climate, Water, and Weather Services estimated that a total of 2248 people throughout the United States lost their lives due to extreme heat waves between 1986 and 2000. Moreover, a loss of 2200 million dollars was estimated due to the extreme heat weather during the same period [10]. The death of around 50,000 people in heat wave of August 2003, in Europe is the recent example of an intensified heat island [1].

The frequency and severity of extreme weather events and heat waves are projected to increase as a result of climate change. Meanwhile, the global warming trends are projected to double the likelihood of such events [11]. Further projections suggest a heat wave of similar magnitude of summer 2003 may occur as frequently as every three years by the 2050s [12–14]. Considering the growing numbers of vulnerable people (e.g. elderly and children) and increasing social isolation, significant number of people will be susceptible to heat wave-intensified heat islands. Thus, establishment of heat watch-warning systems and mitigation plans is necessary in order to protect the public and especially vulnerable habitants.

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In many cities, the primary heat alert systems were based on the computation of the outdoor temperature and heat index [15,16]. However, the dynamic interaction between building and external climate is extremely complex, including a large number of complicated variables and phenomena. The fact that the human body responds to the total effect of all-weather variables interacting simultaneously on it, rather than to individual meteorological elements, encourages researchers to design more effective heat watch-warning systems; obviously, a better emergency plan leads to an improvement in human health survival by reducing the number of morbidity and mortality. One should add that the vulnerable groups of people mainly spend more time in their places than outside during a heat wave day [17]. Thus, the predicting indoor thermal conditions rather than that of the outdoor thermal condition helps city planners to provide better emergency plans for vulnerable people. This means that the development of a heat alert system based on the indoor thermal conditions is highly preferred.

To date, there are limited studies that have been carried out to explore the use of different statistical and numerical methods in predicting indoor air condition during intensified UHI with the heat wave. As one of the major drawback, the complex interaction between outdoor and indoor is barely resolved while various building simulation programs are mainly decoupled from non-isothermal airflow passing over the buildings' surfaces [18]. On the other hand, outdoor models barely consider the indoor interactions inside a building (i.e. generated and stored heat) where it is assumed as an isolated objects in such models. Hence, to link the complex interaction between indoor and outdoor environments, the statistical methods have the advantages of being simpler and faster in the prediction applications. The traditional models are mainly driven based on the regression approach [19]. With emerging more advanced techniques such as the artificial neural network (ANN), however, more accurate prediction is expected.

Regression models have been widely used for the predicting and forecasting purposes [20]. In regression analysis, a linear or non-linear correlation between a dependent variable and one or more independent variables is assumed. The distant observations from the rest of data can have huge effects on the linear regression by decreasing the accuracy of the prediction since extreme values cannot be always captured in the predictions.

Artificial neural networks (ANNs) are known as effective method for approximating non-linear model function. Considering the

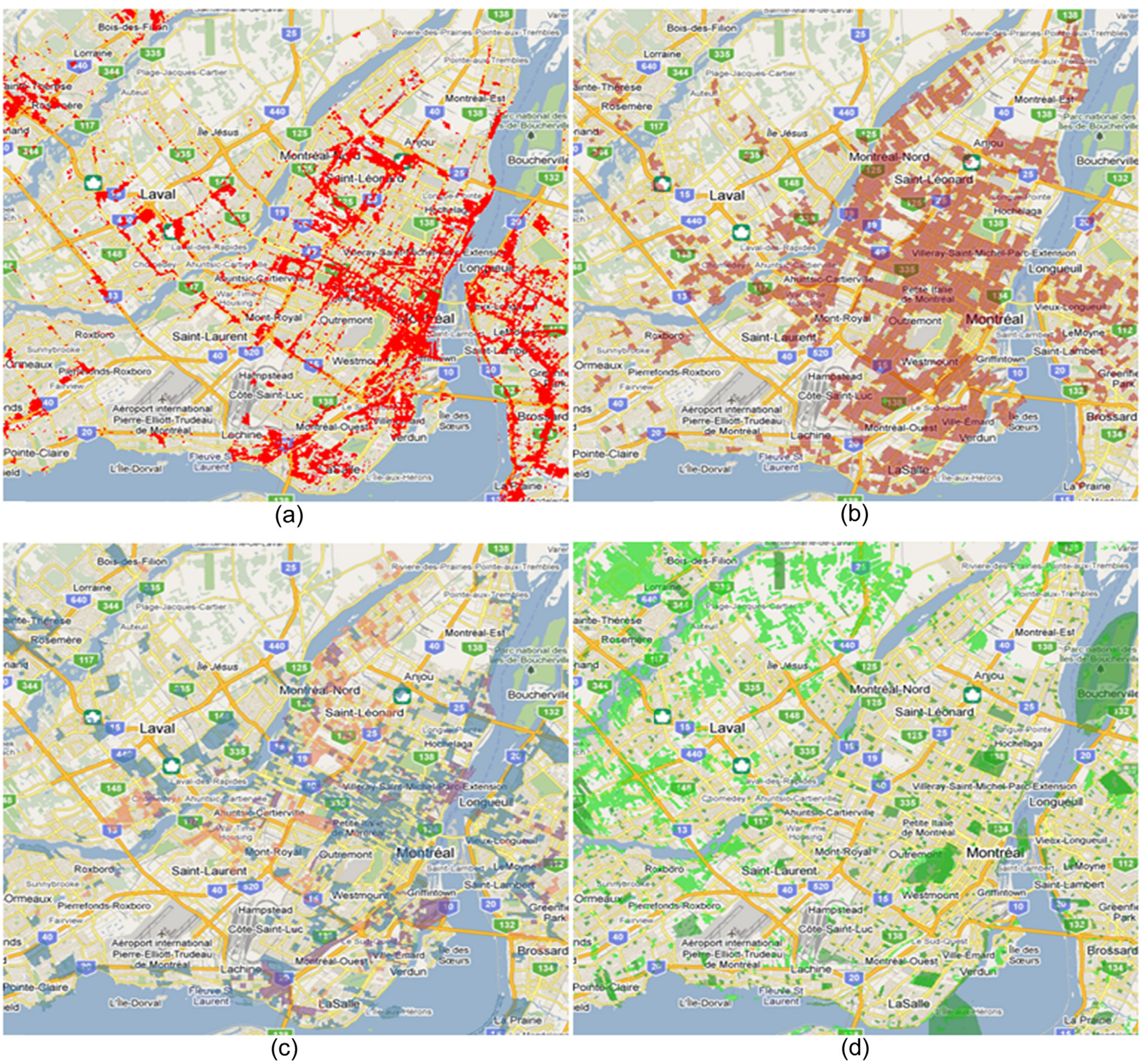


**Fig. 1.** (a) High surface temperatures, (b) high population density, (c) socio-economically deprived areas, and (d) minimal vegetation.