SURROGATE CITY FINDER - WEATHER DATA TOOL

Vishal Garg, T.V.S Nikhil, Hema Rallapalli,
Aviruch Bhatia, Jegibabu Subhash, Chetan Kasireddy
International Institute of Information Technology, Hyderabad, India.

ABSTRACT

Weather data is the one of the important inputs for the building energy simulation and is available for almost all major cities of the world. However, there are still some cities, for which weather data is not readily available in the format suitable for energy simulation. To address this problem, we have developed a web-based tool called Surrogate City Finder (SCF). For a given location, for which there is no weather file available, the tool shortlists the best-matched weather files based on parameters such as the latitude, altitude, and temperature range of the given location. The SCF tool has been tested by analysing the annual energy consumption of 16-reference building models simulated for eight locations from different international climate zones and their surrogate cities. In most cases, the deviation in annual energy consumption was within two percent.

INTRODUCTION

Meteorological data is a key component for doing energy simulations to predict energy needs in a building and system sizing. Energy simulation tools are becoming increasingly sophisticated, that makes it possible to define building systems in detail, resulting in simulations close to building's realistic performance. Weather data is an important aspect when simulating the thermal behaviour of the building because the accuracy of the results are based on it.

Over the years (Hensen, J.L.M., 1999) has stressed the importance and availability of accurate weather data for building simulations. However, for many locations around the world there is no weather data readily available for use in building simulation. While local knowledge can sometimes aid in the selection of appropriate weather data for a specific site, this is not always sufficient or known. When the location in question does not have readily available weather data, it is common to choose the available weather file that is nearest to the required location. In many cases, the climates of both the locations could be very different. For example, Lonavala (a hill station near Pune, India) has the nearest available weather data file of Pune, but both the climates are quite different. Using such a weather file would give inaccurate results. The difference may be overlooked based on the geographical location or proximity to Pune. However, this may lead to erroneous conclusions on the performance, sizing, and feasibility assessment of building energy systems.

According to (Briggs et al. 2003), a method was devised to include elevation, heating degree-days (HDD), cooling degree-days (CDD), and distance for selecting weather files for a location without weather data. This method links populated places to National Oceanic and Atmospheric Administration (NOAA) weather data, and selecting appropriate weather files based on the 'equivalent latitude miles.' The equivalent latitude miles (ELM) metric is derived from an equation that uses heating degree days (HDD), cooling degree days (CDD) and elevation differences between a base location and possible nearby weather file locations. However, the data about HDD and CDD is not readily available for all locations making this method difficult to apply.

Therefore, there is a need for a tool that can shortlist the best matched weather data file from all the available weather files based on factors such as latitude, altitude, temperature range, and distance. This paper described a tool named "Surrogate City Finder", which is capable of shortlisting the best-matched weather file based on parameters such as the latitude, altitude, temperature range, and distance. The tool was tested by running several simulations and the results are presented in the following sections.

DESCRIPTION OF SCF TOOL

The Surrogate City Finder Tool is an easy to use web-based tool that can be used by building energy simulation professionals, researchers, HVAC designers and so on. The tool can be accessed from

http://cityfinder.cbs.iiit.ac.in

Input

The main input for the tool is location that needs weather data. The tool automatically populates its latitude, longitude, and altitude. The user interface is shown in Figure 1. The tool allows users to filter the locations based on:

- Latitude
- Altitude
- Temperature
- Distance

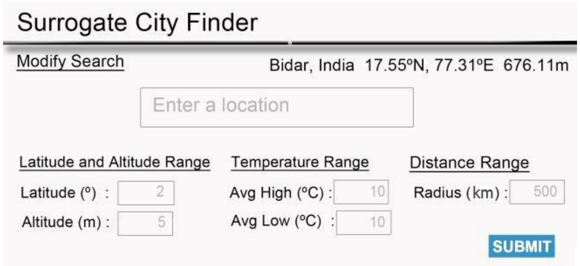

Figure 1 User Interface

Process

Based on the name of the location, its latitude, longitude, altitude, temperature values are extracted from Wikipedia (the Free Encyclopaedia). This extraction is done by parsing the page source. These values are then compared to all the weather data files available in available in EnergyPlus weather format on US-DOE website (Weather data, 2014). There are various filters that facilitate the user to narrow down the data files by specific latitude range, altitude range, temperature difference, and distance from the required location. The tool identifies various locations that match the weather of the location, performs a check on the degree with which it matches various weather data files available within a specified range.

Root Mean Square (RMS) error is calculated for the input city and all the available cities, for average monthly minimum, average monthly maximum, and average monthly temperature. Then the weather files for the cities are listed with the minimum RMS error for the average temperature.

The user has the advantage to choose from these weather files. The tool also allows the user to see the temperature variation profile of the average maximum and average minimum temperatures for all the months in a year for the entered location and selected location as shown in Figure 3.

Output

An interactive google map interface displays the input location along with the surrogate cities that follows input criteria shown in Figure 1. The tool also displays a graph showing the temperature variation between the required location and selected surrogate city. By comparing the graphs, the user can gain a quick understanding of the differences between the two locations as shown in Figure 3.

System Interface

SCF was developed on Ubuntu platform using Python language (2014). Python uses ‘Mechanize’ for navigation, ‘Beautiful Soup’ (2014) to get weather files data from EnergyPlus weather data link and web services are used to call the API for capturing values such as humidity and temperature. The web application is hosted on a Linux server connecting to a database server. An Apache web server accepts all requests from the client and forwards SCF Tool specific requests to Tomcat 5.5 (2014) Servlet container with scripting languages like Python and Jscript. A development database is hosted locally using MySQL (2014). On the client side, an OS that is capable of running a modern web browser such as Mozilla Firefox 31.0, Google Chrome & Internet Explorer 9 with enabled Cookies, which supports HTML version 4.0 or higher is required. The HTTP protocol is used to facilitate communications between the client and server. Data flow diagram is shown in Figure 2.

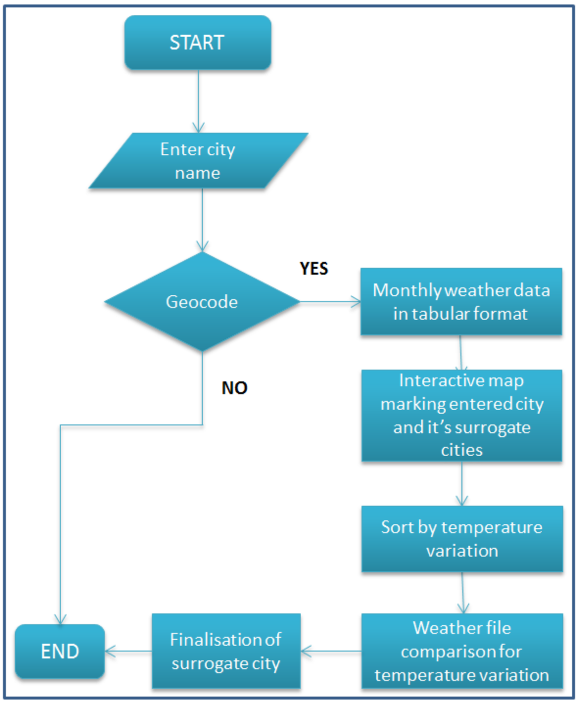

Figure 2 Data Flow Diagram

Dependencies of the tool

The correct functioning of SCF tool will partly be dependent on the availability and correctness of the data retrieved from Wikipedia and the accuracy of the available EnergyPlus weather data (Weather data, 2014).

TESTING OF THE TOOL

Simulations were done for 16 building prototypes with weather data of cities from eight climate zones and compared with simulations with weather data for their surrogate cities. The results are presented in this section.

Description of the Simulation models

The U.S. Department of Energy (DOE), as a part of the Building Technologies Program (BTP) in conjunction with three of its national laboratories: Pacific Northwest National Laboratory, Lawrence Berkeley National Laboratory, and National Renewable Energy Laboratory, has developed commercial reference buildings models. There are 16 building types representing approximately 70% of the commercial buildings in the U.S. according to the report published by the National Renewable Energy Laboratory titled U.S. Department of Energy Commercial Reference Building Models of the National Building Stock (Deru M. et al. 2010). These reference models represent new construction that is compliant with ASHRAE 90.1-2004 and US New Construction, 2011 code. They provide a consistent baseline of comparison and improve the value of computer energy simulations using software such as EnergyPlus. List of reference building types with their description (Building Technology Program, 2012) is in Table 1.

The reference models used in this paper were converted to version 8.2 of EnergyPlus with IDF version updater utility. To analyse the performance of the SCF tool over different models and climates, the reference buildings were used for the simulations.

Table 1 List of reference building types with their description

Building Number	Building Type	Area (ft^2)	No. of floors
1	Full service restaurant	5500	1
2	Hospital	241,351	5
3	Large hotel	122,120	6
4	Large office	498,588	12
5	Medium office	53,628	3
6	Midrise apartment	33,740	4
7	Outpatient health care	40,946	3
8	Primary School	73,960	1
9	Quick service Restaurant	2,500	1
10	Secondary school	210,887	2
11	Small hotel	43,200	4
12	Small office	5,500	1
13	Stand-alone retail	24,962	1
14	Strip mall	22,500	1
15	Super market	45,000	1
16	Warehouse	52,045	1

These 16 models were simulated for various locations (Table 2) in different climate zones along with their surrogate cities to find the closeness in results. The surrogate cities were finalized based on the minimum total RMS error among the locations that are within a range of 2º latitude, 100 m altitude and average temperature high and low within a range of 5ºC.

The hourly energy consumption of the location and its surrogate city are compared using Root Mean Square Error (RMSE) value. The variability is obtained by squaring the difference between paired data points, summing the squared differences over each interval through the period, and then dividing by the number of points, which yields the mean squared error. The square root of this quantity yields the root mean squared error. The C_v(RMSE) is obtained by dividing the RMSE by the mean of the data.

Table 2 List of locations from various international climate zones and their surrogate cities

S.No.	Locations	International Climate Zone (as provided in ASHRAE 90.1, 2010).	Surrogate City best match based on RMS total
1	Hyderabad, India	1	Sholapur, India
2	Cairo, Egypt	2	Ismailia, Egypt
3	Sydney, Australia	3	Williamtown, Australia
4	Barcelona, Spain	4	Olbia, Italy
5	Dublin, Ireland	5	Aughton, Great Britain
6	Stockholm, Sweden	6	Oslo.Fornebu, Norway
7	Helsinki, Finland	7	Saint-Petersburg, Russia
8	Yellow knife, Canada	8	McGrath, AK, USA

RESULTS

The annual energy consumption of 16 building types in 8 locations from different international climate zones and their surrogate cities were run and the results were analysed for the degree of deviation as shown in Figure 4. The variability of the hourly energy consumption of the selected location and its surrogate city using the RMSE value are presented in Table 3.

It is observed that most of the weather files match closely with their surrogate cities, falling within the range of 2 percent for total energy consumption. Further deviation is observed in the case of cold climate for which the data availability is very low. A little variation is also seen in the case of warehouse building type, which could be because it is majorly a storage space.

Table 3 Calculation of Cv(RMSE) for hourly energy consumption

S. No.	Building Type	Hyderabad-Sholapur	Cairo-Ismailia	Sydney-Williamtown	Barcelona-Olbia	Dublin-Aughton	Stockholm-Oslo.Fornebu	Helsinki-Saint-Petersburg	Yellowknife-McGrath
1	Full service restaurant	7.0%	8.9%	9.6%	7.5%	2.4%	4.3%	4.5%	4.2%
2	Hospital	4.1%	3.2%	4.7%	4.2%	2.9%	4.0%	4.0%	4.1%
3	Large hotel	8.6%	7.3%	8.2%	7.8%	5.3%	5.9%	5.7%	5.5%
3	Large office	6.7%	6.4%	7.6%	6.4%	3.1%	4.3%	4.4%	4.1%
5	Medium office	8.4%	9.8%	10.7%	10.2%	13.5%	16.4%	16.7%	26.0%
6	Midrise apartment	10.4%	13.5%	16.7%	11.4%	5.8%	9.7%	9.8%	12.1%
7	Outpatient health care	5.6%	6.6%	7.9%	6.4%	5.9%	8.2%	8.8%	10.7%
8	Primary school	11.5%	15.2%	17.0%	12.1%	6.5%	8.9%	8.9%	7.8%
9	Quick service Restaurant	5.8%	6.9%	7.1%	5.5%	1.6%	3.0%	3.3%	3.2%
10	Secondary School	14.6%	20.2%	24.5%	18.6%	7.1%	10.6%	11.1%	8.9%
11	Small hotel	5.4%	7.0%	8.5%	6.4%	5.7%	11.8%	14.1%	29.6%
12	Small office	8.4%	10.0%	10.4%	8.0%	5.8%	8.3%	8.8%	9.6%
13	Stand-alone retail	8.9%	12.1%	14.9%	10.3%	6.0%	7.6%	8.2%	8.3%
14	Strip mall	9.3%	12.4%	15.3%	10.9%	5.4%	8.5%	9.4%	9.3%
15	Super market	5.7%	6.0%	8.2%	6.6%	5.9%	6.1%	6.2%	5.5%
16	Warehouse	20.3%	19.9%	28.0%	17.7%	11.3%	12.0%	11.4%	12.6%

CONCLUSION

As discussed in the previous sections, SCF was developed to identify the best matching weather file for a location anywhere in the world based on the latitude, altitude, and temperature inputs by the user. The tool has been tested by analysing the annual energy consumption of 16 reference-building models simulated for eight locations from different international climate zones and their surrogate cities to understand the degree of deviation. It was found that the deviation in annual energy consumption was mostly within the range of 2 percent. SCF is a useful tool that can help energy modellers, system designers, and practitioners find readily available weather files to run building simulations that benefit building owners and occupants. As of now, SCF has been tested on conditioned buildings only. SCF has not been used to run simulations on unconditioned buildings. In future, SCF will be tested on unconditioned buildings with different sensitivities such as external wall insulation, roof insulation, shading, and different types of glass. Further, it should be noted that if the results of the energy simulations are within a close range it does not necessarily imply that the weather data of the two locations are also closely matching. More testing is needed, especially comparison of weather files of each surrogate pair to find effectiveness of this tool.

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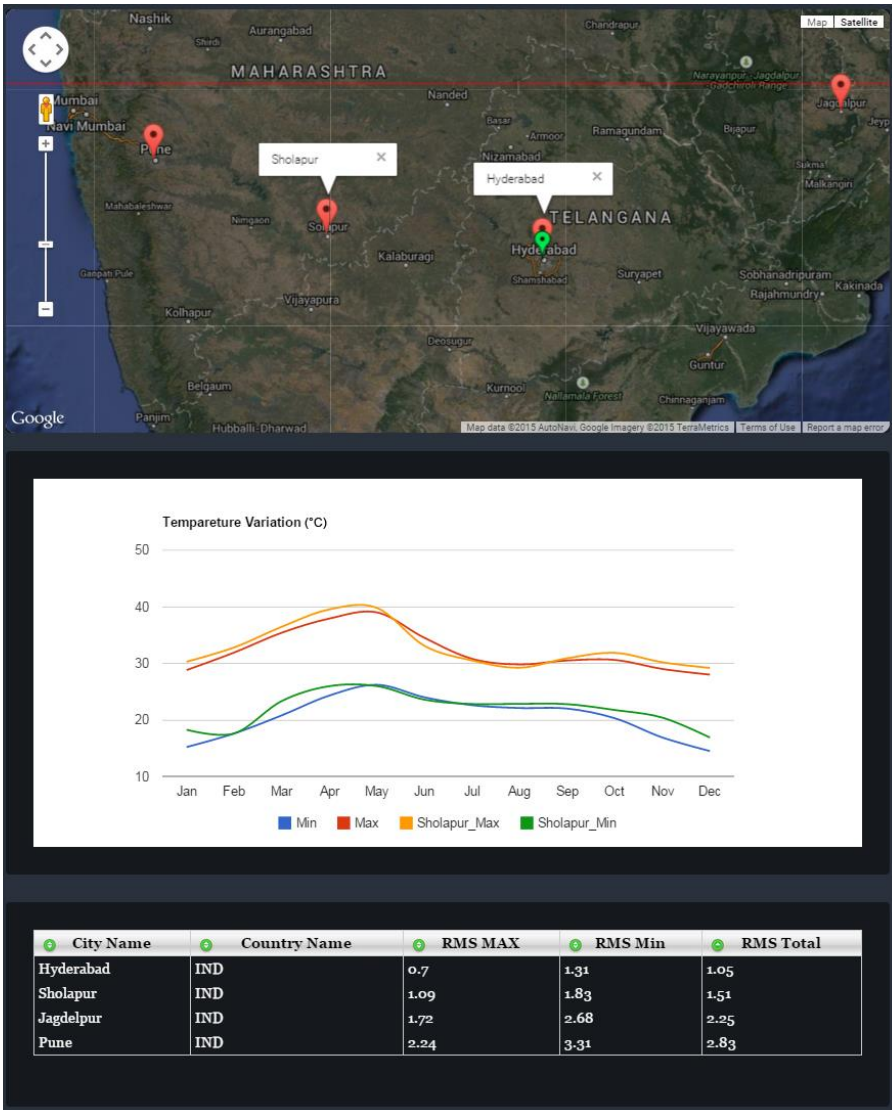

Figure 3 Output Screen

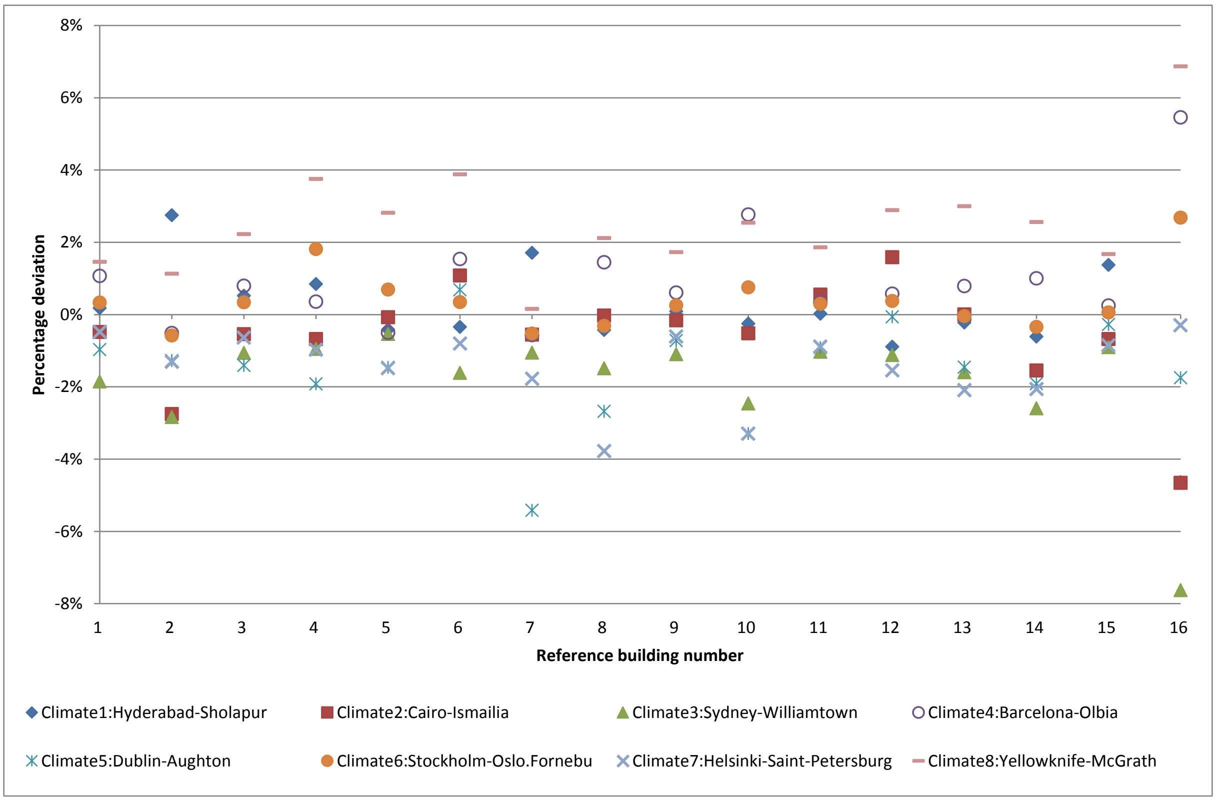

Figure 4 Graph representing the percentage deviation in annual energy consumption between various locations and their surrogate cities for different building types.