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Wall temperatures dependency determination using correlation analysis

Introduction

Intelligent house being able to control temperature in a room or whole house was among the first things that intelligent houses were able to do. Intelligent house can turn off or lower the heating temperature while you are not at home and resume the heating when you come home. The analysis presented in this paper can serve for further processing or helping choose significant parameters (temperatures) which should be taken into account when working with a system (building) with similar structural condition.

Building construction

The intelligent building where the measuring was done provided us with data set containing temperature values throughout the year 2013 from January to December. The building is located on the land of Faculty of Civil Engineering at VŠB – Technical University of Ostrava as it is their property.

The first Figure depicts types of installed temperature sensors and their locations. The red dot shows temperature sensors located inside the building and installed on the ceiling. Five consecutive red dots show temperature sensors located inside the wall. The building consists of five rooms, but during the statistical processing we have only processed temperatures from room 203; specifically it was *inside sensor S3_2* and *wall sensor S2_1*. This wall is located on the northern side of the building. Outer temperature measuring sensor is not shown on this figure.

On the next figure the detailed information about the wall temperature sensors is shown. As you can see, there are five sensors, each located in the different layer of the peripheral wall. The first two sensors located closest to the inside part are named 1 Interier and 2 Interier. The middle sensor is called 3 Middle. The two remaining sensors located closest to the outside of the house are called 4 Exterier and 5 Exterier.

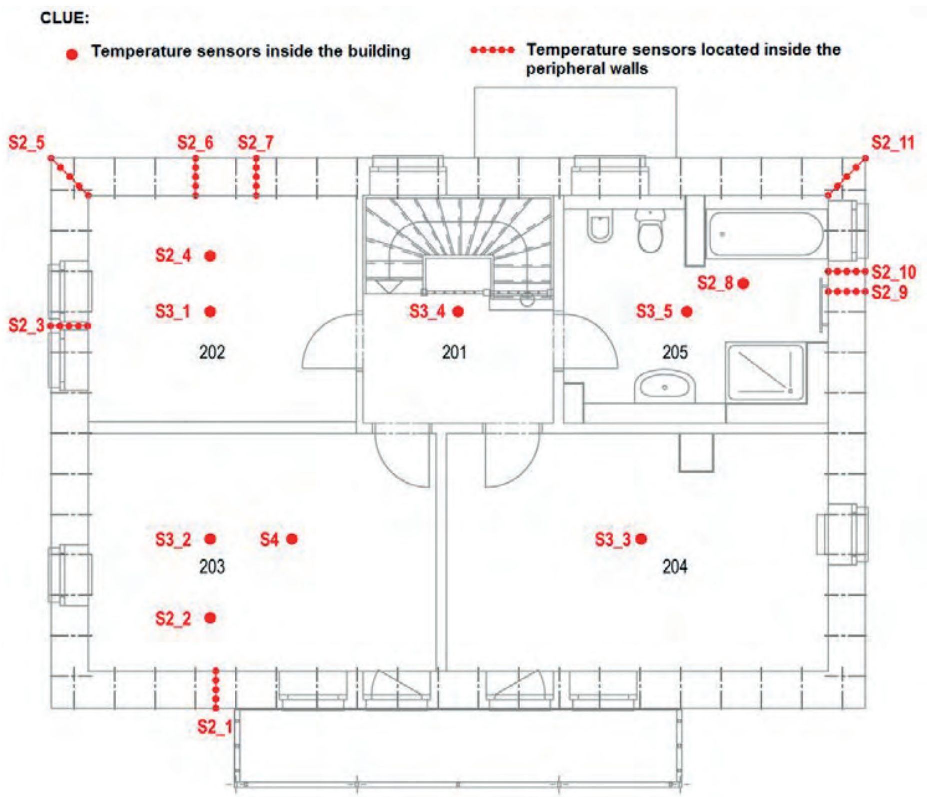

Fig. 1. Temperature sensors located in the building

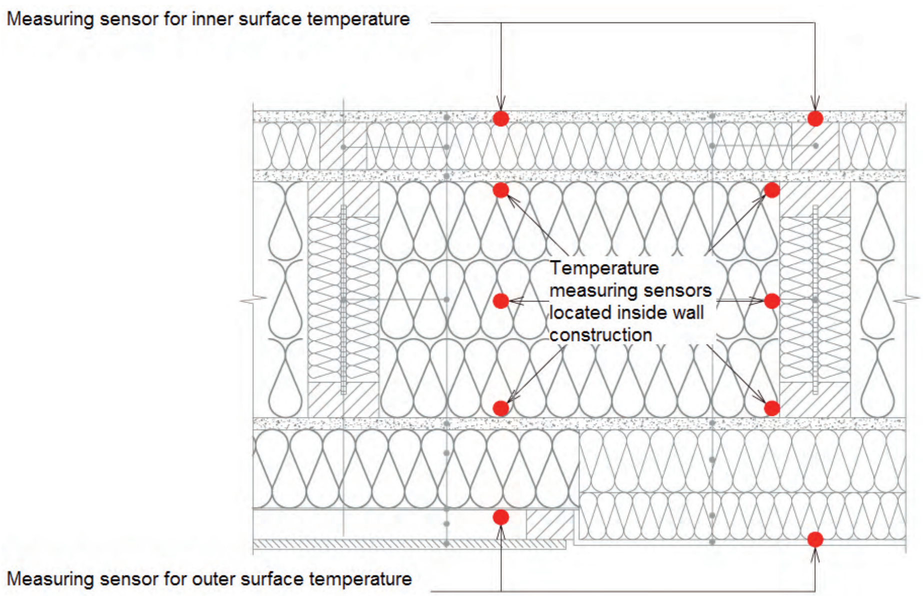

Fig. 2. Inside wall temperature Sensors

Processing results

To determine the relations between each temperature sensor we have used correlation coefficients. The correlation coefficient contained in the matrices can be read in the following way: the closer the number is to 1, the closer the relations of the two quantities are. We say these quantities are correlated. The ideal case is number 1 (or number very close to 1), which means that there is linear dependence between two quantities and that they are directly dependent. If the number is getting closer to 0, it means that the quantities cease to be linearly dependent. If the number is exactly 0, it means that there is absolutely no linear dependence. If the coefficient gets below 0, we call it anticorrelation. It is described as one quantity increasing and second quantity linearly decreasing with the final value of -1. Detailed determination is mentioned in the following Table 1.

Tab. 1. Correlation statements [2]

Coefficient	Correlation
0.01–0.09	None
0.10–0.29	Low
0.30–0.49	Medium
0.50–0.69	Substantial
0.70–0.89	Very strong
0.90–0.99	Almost perfect

Let us have a look on the correlation matrix for December.

On Figure 3 you can see that the inside temperature (T inside) is correlated the most with the temperature inside the wall located closest to the outside (1 interier with the value of *0.9980*). With every next comparison of the inside temperature (T inside) with temperatures in the wall outwards (the black arrow), it is clear that quantities cease to be dependent. Specifically in December, the inside temperature has high correlation coefficient with two more quantities (2 interier – *0.9697* and 3 middle – *0.8081*). But when comparing with the next wall sensor we find quite a low number (4 exterier – *0.3146*) followed by almost zero coefficient at 5 exterier sensor.

On the other hand, the outside temperature (8 outside) is correlated most with the temperature measured by the sensor located closest to the outside (5 exterior – *0.8603*). With every next comparison of the outside temperature (8 outside) with temperatures in the wall inwards (blue arrow) there occurs a gradual loss of linear dependency.

Correlation (table1.sta)
Correlations are significant at level p < ,05000
N=744

Variable	1 Interier	2 Interier	3 Middle	4 Exterier	5 Exterier	T air	T inside	8 Outside
1 Interier	1,000000	0,979910	0,824901	0,331347	-0,104140	0,997486	0,998063	-0,140105
2 Interier	0,979910	1,000000	0,905074	0,446986	-0,078946	0,966472	0,969725	-0,095536
3 Middle	0,824901	0,905074	1,000000	0,773476	0,127251	0,802270	0,808170	0,176687
4 Exterier	0,331347	0,446986	0,773476	1,000000	0,439978	0,308649	0,314611	0,603318
5 Exterier	-0,104140	-0,078946	0,127251	0,439978	1,000000	-0,089253	-0,082770	0,860309
T air	0,997486	0,966472	0,802270	0,308649	-0,089253	1,000000	0,999820	-0,138888
T inside	0,998063	0,969725	0,808170	0,314611	-0,082770	0,999820	1,000000	-0,134970
8 Outside	-0,140105	-0,095536	0,176687	0,603318	0,860309	-0,138888	-0,134970	1,000000

Fig. 3. Correlation matrix – December

Dependency on the inner temperature

We can say the temperature inside the walls on positions 1, 2 and 3 have significant dependency on the inside temperature. On positions 4 and 5 the dependency on inside temperature is very low, in case of sensor 5 it is almost zero. A logical view is confirmed here saying that the temperate measured in the sensor located closest to the outside will not be affected by inside temperature. Whether significant heating occurs inside of the house or not will have no effect on the mentioned temperature on position 5.

Dependency on the outside temperature

Temperatures measured on positions 4 and 5 have got significant dependency on the outside temperature. Change occurs at sensor 3, when correlation decreases to *0.1767* showing very low dependency. We can say that temperatures measured at sensors 1, 2 and 3 change independently from outside temperature in December.

Dependency of inside temperature on outside temperature

The correlation coefficient of the inside and outside temperature is very low *(-0.1350)* as well as sensor 1 (1 interier) temperature and sensor 5 (5 exterier) temperature, which is also low *(-0.1041)*.

On the next figure there is almost zero correlation between the first two quantities *(-0.1350)*, let us not assume any linear dependency. This phenomenon is caused by a daily temperature span during winter months. Inside the house the heating is maintaining the same temperature so the daily difference is in units of degrees although outside temperature can jump from above zero to below zero in hours. Then the outside difference can be in dozens of degrees.

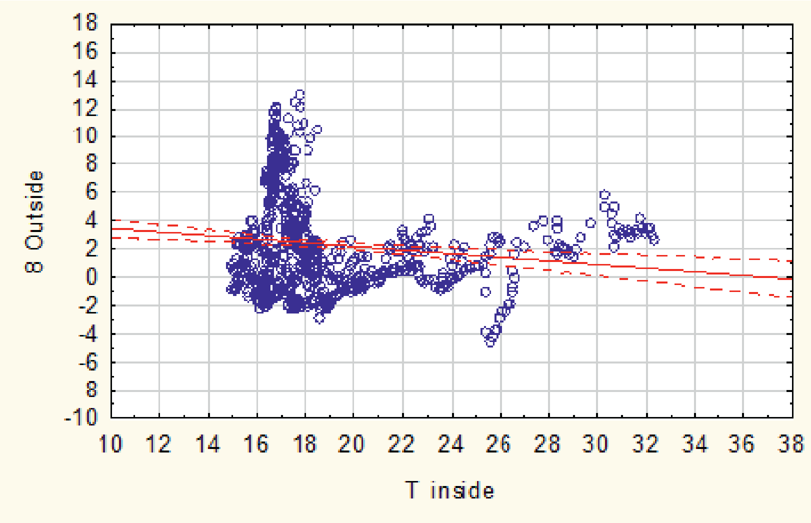

Fig. 4. Outside vs. Inside

December vs. July

There is a slight difference when comparing temperatures in winter and summer. While in winter the inside temperature was correlated with first three inner temperatures (1, 2 and 3), in summer the correlation extends to the fourth sensor which has significant correlation to the inside temperature *(0.7876)*. Even the last, fifth sensor has medium-low correlation to the inside temperature *(0.349),* which means that lesser linear dependency exists.

Conclusion

This analysis could serve for further processing or when developing new systems, for example a system able to predict upcoming temperatures based on the historical measured stored data. As it was mentioned, the provided dataset was from January to December of 2013. Having another set of temperature data, for example from the year 2014, and having a chance to find repeating patterns in these two years would make it possible to predict temperatures in the year 2015 using f-transform calculus. After the prediction we could easily compare them to actual ones once they would get measured and calculate how precise the prediction was.

Acknowledgements

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Abstract

This paper is focused on the statistical processing of temperature data measured in intelligent building with a goal to obtain their dependencies between each temperature sensor located inside the building and also inside the peripheral walls. Intelligent house we have received data from is constructed for academic purposes and is equipped with temperature sensors in every room and in every four walls. We have focused on the northern side of the house and compared data from walls and inside (outside) of the building.

Key words: temperature sensor, intelligent building, correlation coefficient

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