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The Interpolation of Data as a Tool to Reduce the Timing of Detection of Microclimatic Parameters: Application of the Method in the Field

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Abstract: Measurements on physical quantities related with microclimate assessments take a great amount of time due to the long adaptation time of the probes. Interpolation techniques can be useful to reduce the total evaluation time, thanks to the ability to predict the final measured values, starting from the values read during the first 10-12 minutes of the adaptation process.

Key words: microclimate surveys, thermal comfort, thermal stress, interpolation techniques

1. Introduction

The measurement times of technical assessments on thermal stress or comfort are heavily influenced by the response time of the instrumentation normally adopted in this context [1]. Conforming to international technical standards results in a very low frequency of measurements, of the order of 2/h, which in some cases may need to be reduced to one survey per hour [2]. To date, most of the time taken to carry out a microclimatic survey can be considered unproductive because it is spent in time of adaptation of the probes, up to almost 75% of the total time. The growing need for technical checks in this sector, however, requires greater production efficiency, without the reliability of the physical quantities under measurement being affected. With this objective, a method was presented that currently allows to reduce measurement times by about a half [3]. This method was tested in the measurement of the globe-thermometer temperature, because of the long response time of the sensor.

The present study has the dual purpose of extending the fitting method to the determination of other physical quantities, such as air temperature and relative humidity, which sensors can have not negligible time constants, and to return the results extrapolated from 47 surveys performed over four days of investigations.

2. Material and Methods

The fitting method permits the prediction of the values of the physical quantities measured by the sensors after their relaxation time, using interpolation of the data collected in the first minutes of each survey. The algorithm uses the Eq. (1) which governs acclimatization in stationary systems [4]:

$$\boldsymbol{X(t) = X_1 + (X_2 - X_1) \cdot \left(1 - e^{-\frac{t}{\tau}}\right)} \qquad (1)$$

To estimate the three free parameters of the system, in particular the parameter X_2 which represents the value of the physical quantity X at equilibrium with the environment. The algorithm works by interpolating the data returned by the probe in the first minutes of the adaptation time. This procedure has been tested for each of the 47 surveys, to predict temperature of globe-thermometer (T_g), air temperature (T_a) and

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relative humidity (RH), changing the starting and the ending point of the fitting interval, using a minimum duration of 300 seconds and limiting the final instant to 720 seconds (12 minutes). Fig. 1 shows the graphic comparison between samples collected in a single survey (represented by points) and the trend lines drawn starting from the parameters calculated in one of the fits performed on the collected data.

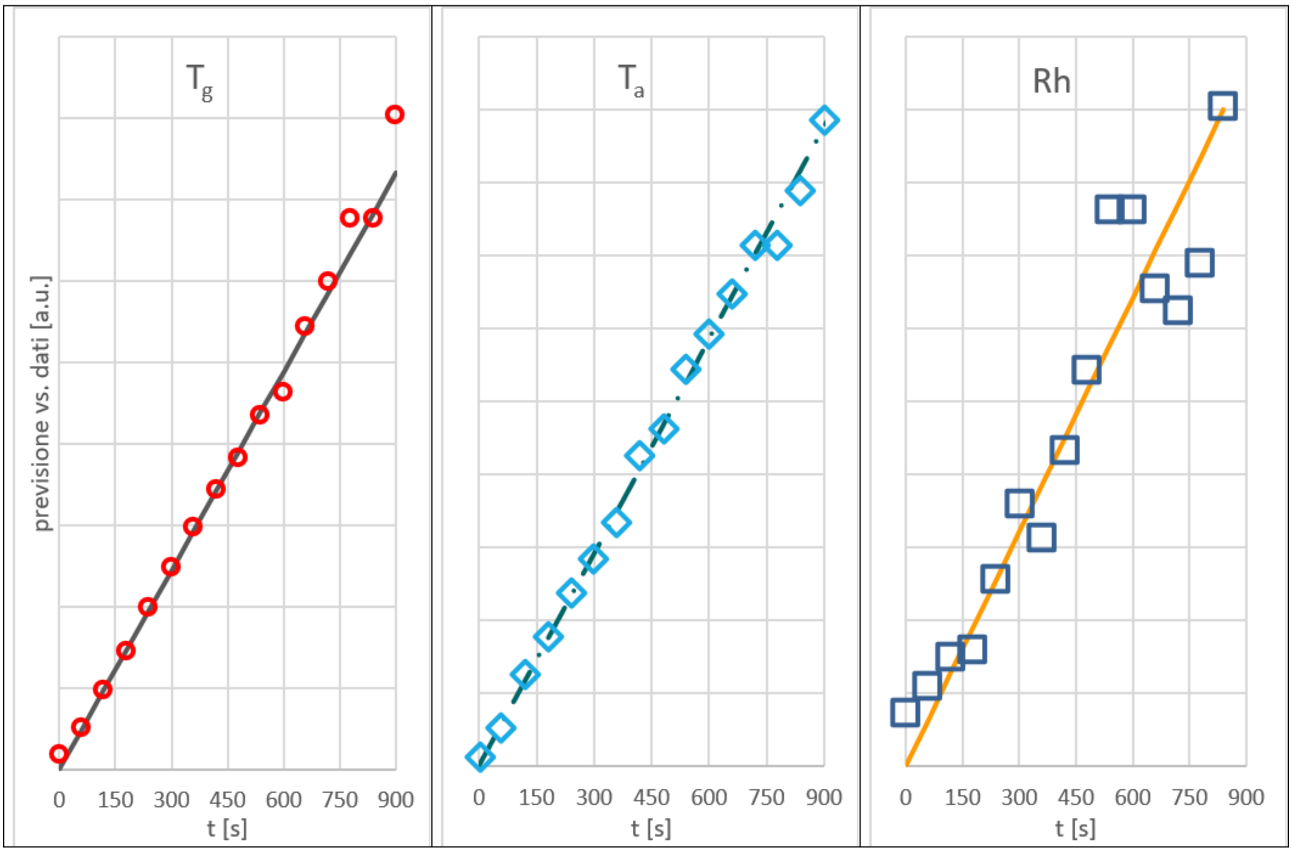

Fig. 1 Graphic restitution of the linearization of the temporal response of sensors for the measurement of different physical quantities during a microclimatic survey: globe-temperature (graph on the left), air temperature (in the center), relative humidity (on the right).

3. Results and Discussion

The results of the application of the fitting algorithm were compared with the arithmetic mean calculated on the last minutes of each survey, i.e., after the achievement of thermal equilibrium by the probes: the outcome of the interpolation is considered positive if the difference between the mean and the expected value is less than 0.2°C for T_a and T_g, 2% for Rh.

The procedure prepared allowed us to perform a total of 2990 interpolations for each of the 3 physical quantities, with an average of about 64 fits completed for each survey. Table 1 summarizes the outcome of the comparison of the results with the arithmetic averages: for the magnitudes T_a and T_g, it was possible to find at least one result obtained with the fitting method that could be considered positive in 44 surveys out of 47. The *a posteriori* verification of the surveys' trend with negative results showed non-stationary behaviors by the physical magnitude under observation, underlying that those surveys had to be rejected. In the case of relative humidity, in all the surveys at least one interpolation led to results acceptable to the limits imposed. It should also be noted that for some surveys (9 in the case of globe-temperature and 8 for relative humidity) almost all the fits returned results compatible with those obtained with the standard procedure.

Table 1 Quantitative analysis of the percentage of interpolations successful, for each physical quantity, on the total of the 47 surveys examined.

% of positive outcomes per single survey	number of findings		
	T_g	T_a	RH
p = 0	3	3	0
0 < p ≤ 10	7	10	2
10 < p ≤ 20	2	6	2
20 < p ≤ 30	3	4	3
30 < p ≤ 40	3	5	3
40 < p ≤ 50	3	8	5
50 < p ≤ 60	4	4	6
60 < p ≤ 70	4	4	6
70 < p ≤ 80	4	2	4
80 < p ≤ 90	5	1	8
90 < p ≤ 100	9	0	8
TOT	47	47	47

4. Conclusion

The application of the proposed interpolation method for the reduction of the timing of measurements of the globe-thermometer temperature is also applicable for the prediction of other physical quantities such as temperature and relative humidity of the air. According to the study carried out on 47 real cases, only in some circumscribed situations is the fitting procedure inapplicable, i.e., those in which the stationary conditions required by the method are not respected; the latter are, however, a fundamental requirement for the evaluation of the stress or thermal comfort indices starting by measuring the physical parameters of an environment.

The results of this study indicate that with a measurement lasting 12 minutes, the interpolation method can provide an accurate prediction of microclimatic parameters. The results also indicate that the procedure at the moment cannot be used uncritically: the fit must be carried out on different sets of samples, recorded in the first 12 minutes of adaptation of the probe, to determine the most correct forecast value.

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