Paper Number: 27697

Air flow visualization with infrared thermography

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ABSTRACT

Air is transparent for long wave infrared radiation. Therefore, initially it is impossible with thermography to visualize any type of airflow, on the other hand, an important issue for many building, industrial and research applications.

The authors have developed a simple and affordable technique to visualize dynamics of airflows with the use of any type of infrared camera.

Several examples of the application of the method are shown at this paper, and future and promising new developments are presented.

Keywords: *Infrared; thermography; airflow visualization*

1. Introduction

Air is almost fully transparent for long wave radiation, the usual electromagnetic radiation range used by commercial maintenance thermal cameras, 8-14 microns wavelength. At the majority of common applications, infrared transparency of air at this range is an absolute advantage! If not, infrared thermography had not been developed until the actual state!

In very usual applications for buildings, the thermal camera is used to "visualize" air leakages and infiltrations. However, at this case, really air is not visualized. In fact, we actually see the thermal effect of air flowing over and parallel to an opaque surface.

Figure 1. Example of air leakages at the internal side of a rehabilitated roof in an alqueria: cold and hot air leakages.

A study of the "estate of the art" has been carried out, observing that the available techniques nowadays seem too complex for an industrial or not laboratory application:

- Visualization of airflow using infrared thermography, from V. Narayanan, R.H. Page and J. Seyed-Yagoobi (2003).
- Infrared thermography for convective heat transfer measurements, from Giovanni Maria Carlomagno and Gennaro Cardone (2010).
- Experimental visualization of the flow characteristics of the outflow of a split air conditioner indoor unit by meshed infrared thermography and stereo particle image velocimetry from Ziya Haktan Karadeniz ⇑, Dilek Kumlutas_, Özgün Özer, from the Department of Mechanical Engineering, Dokuz Eylul University, Bornova, Izmir, Turkey (2012).

At the first of these papers from Narayanan, a trace quantity of sulfur hexafluoride (SF6) gas is injected into the flow field to detect intensity patterns. Equations that relate the intensity patterns to volume-averaged temperature and SF6 mass concentration are presented.

The third one presents a novel application of infrared thermography called *Meshed Infrared Thermography* (MIT), used to determine and visualize the temperature profile in an air flow field, was introduced for the first time and used to investigate the temperature distribution at the outflow section of the SAC indoor unit. The *MIT* method is based on the measurement screen technique; however, the measurement screen is replaced with a measurement mesh, which is formed by the periodic placement of dull black-painted metal spheres on pieces of rope that are tightly fixed to a metal frame.

At Inframation 2010, Raphael Danjoux presented the paper "Visualization of air flows with an infrared camera. Presentation of a simple technique and example of data analysis". The method in this case is based in the visualization of the effect of air on an opaque surface, in these cases, low mass, low thermal inertia: a piece of cardboard paper, where a mesh or grid is printed to accurately determine positions and temperatures.

2. Procedure description

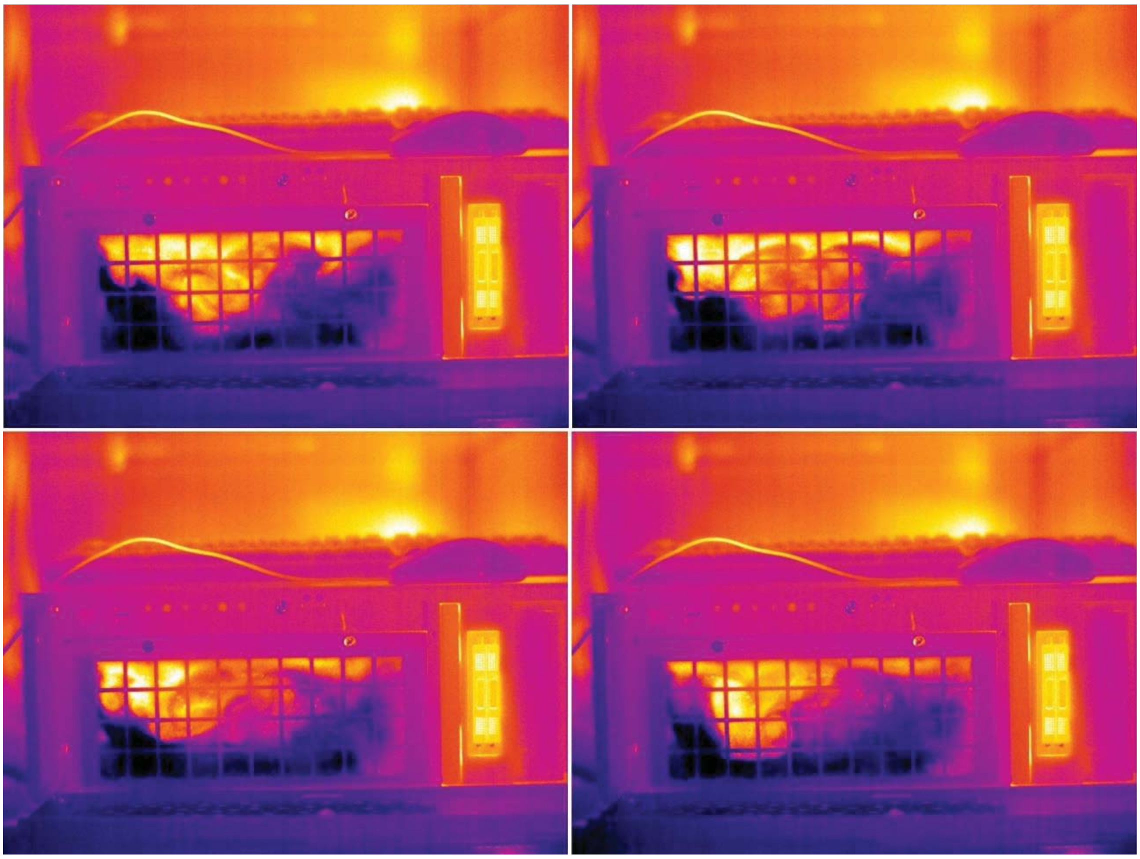

Figure 1. First detected results.

As it often happened in other branches of science, and there are famous examples like Alexander Fleming with the discovery of penicillin, the origin of the technique was also by chance, while a thermography training course was been developed in a room where a computer acting as a server was working. The author of this article, and the own trainees too observed a strange thermal pattern in motion, as it from figure 1. The four images at the figure are time spaced 0,25 seconds, as they were taken at the maximum frame velocity of the thermal equipment, a Flir SC620 Thermacam with a resolution of 640 x 480 and NETD lower than 40 mK at 30 C.

Figure 2. Server computer where the first airflow visualization was detected.

The visual image corresponding with the thermographies shown at figure 1 are also visualized at figure 2. The almost blocked air filter of the air inlet for the cooling of the server is shown.

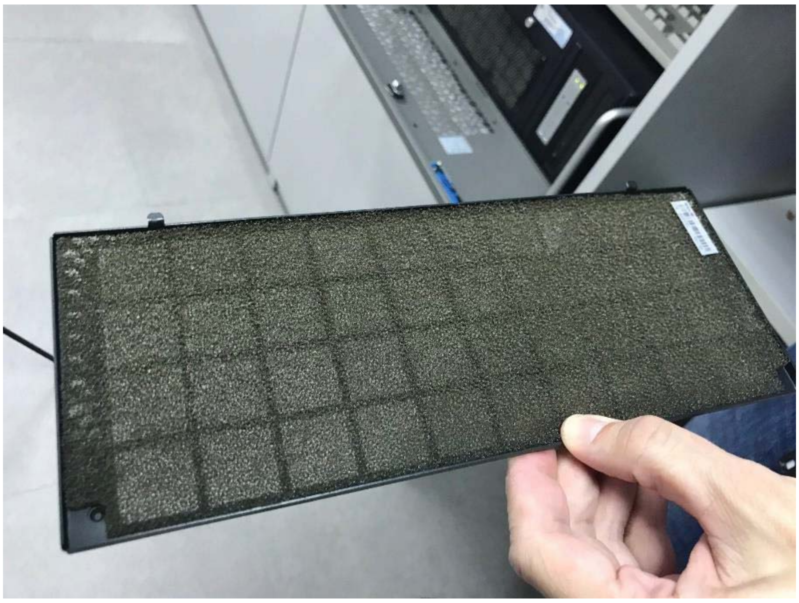

Figure 3. Blocked air filter.

If the described filter shown at figure 3 is removed, the shown thermal pattern is changed to the image shown at figure 4, almost still with the fans used to cool the computer. No image from the air:

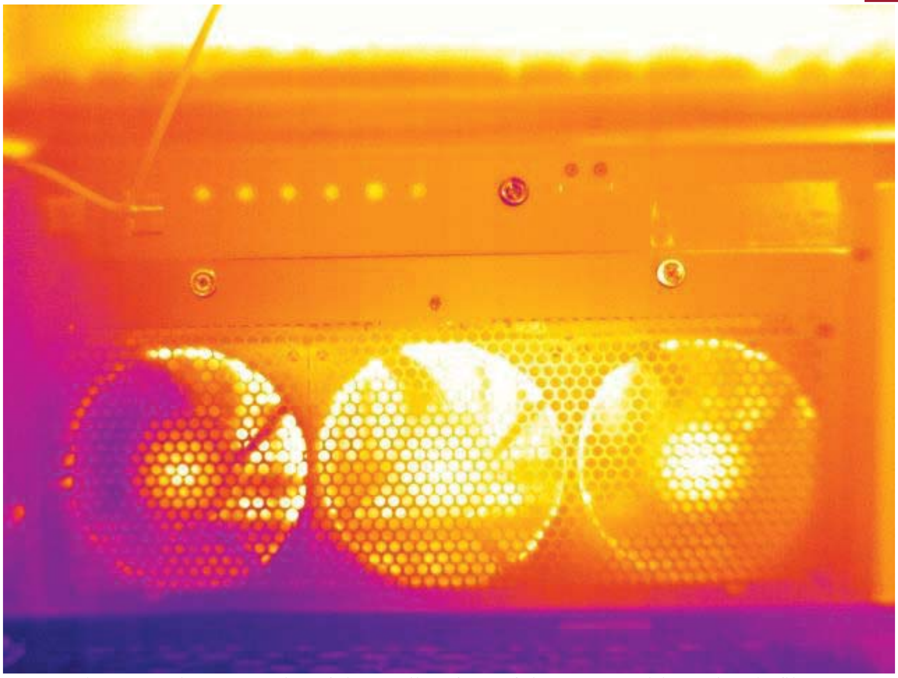

Figure 4. Thermography of the cooling fans of the server, without the air filter.

Therefore, although it seemed completely strange, the reason to visualize the thermal pattern in motion for air flowing inside the fans was the own blockage effect of the dust at the air filter!

The next step, once the phenomena were registered and documented, was trying to achieve a physical explanation of the actual observation.

The own dust particles at the surface of the filter allows to track the airflow and its thermal pattern. They are opaque to infrared radiation, and their low size and mass implies a very fast thermal response to the changes in temperature from the air, which is in contact with them.

Therefore, the observed phenomena is completely logical and reasonable. Once it is explained and valued, some questions arise:

- Is it possible to reproduce the results systematically?
- What are the best conditions to obtain the optimum results?
- What systems and installations are adequate to apply the technique?

In this paper, some of these questions are answered; other fundamental ones will be studied in future proposed works.

3. Experimental set up to reproduce the airflow visualization

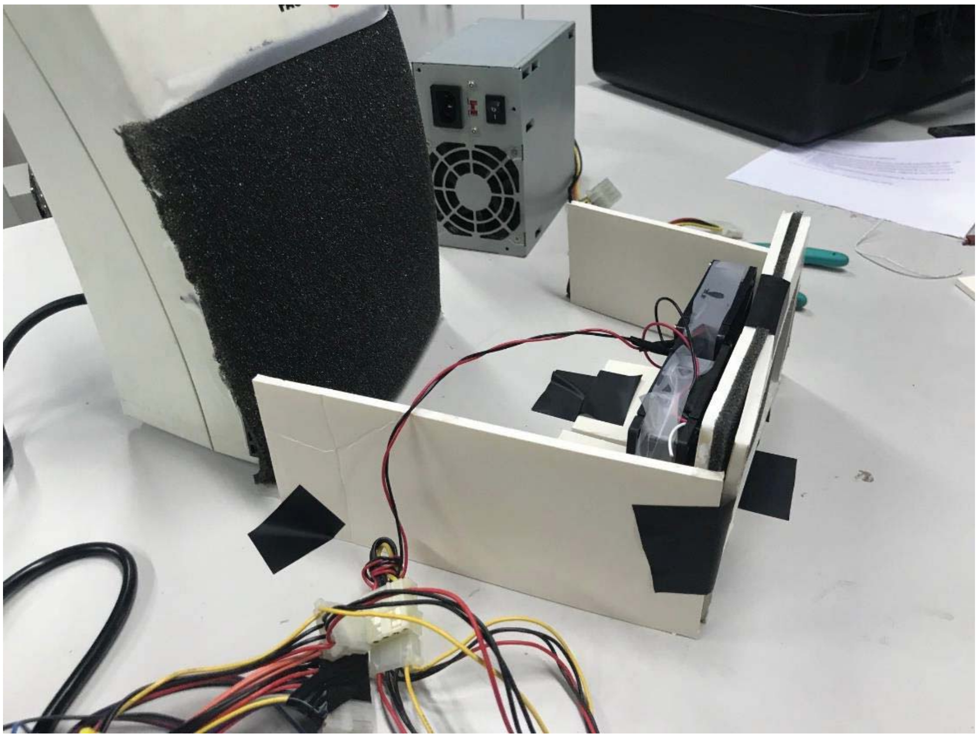

Figure 5. Thermography of the setup used to reproduce the experiment: cooling fans of the server, without air filter.

At the Infrared Thermography Laboratory from Departamento de Termodinámica Aplicada de la Universidad Politécnica de Valencia, an experimental set up was designed to try to visualize the inlet flow in two computer fans, a similar case to the original one, detected initially.

With the objective to obtain the necessary thermal contrast, a domestic air heater was used, placed at the back of the fans, a distance about 15 cm.

At the front part of the two computer fans, the air filters were placed. These filters was blocked with real “home” dust, taken from a domestic vacuum cleaner!

Two different types of commercial air filter were tested:

Figure 6 First type of air filter tested.

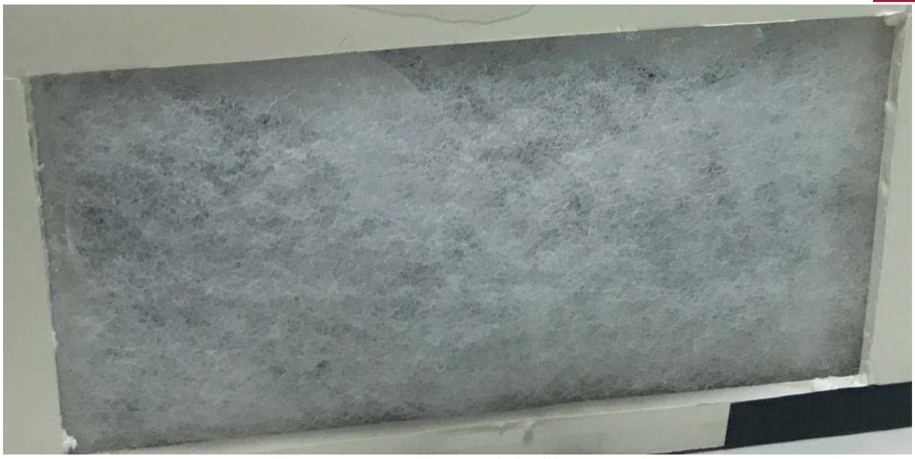

Figure 7. Second type of air filter tested.

The initial results were quite successful: the thermal pattern shows clearly the air vortex at the inlet of the two computer fans:

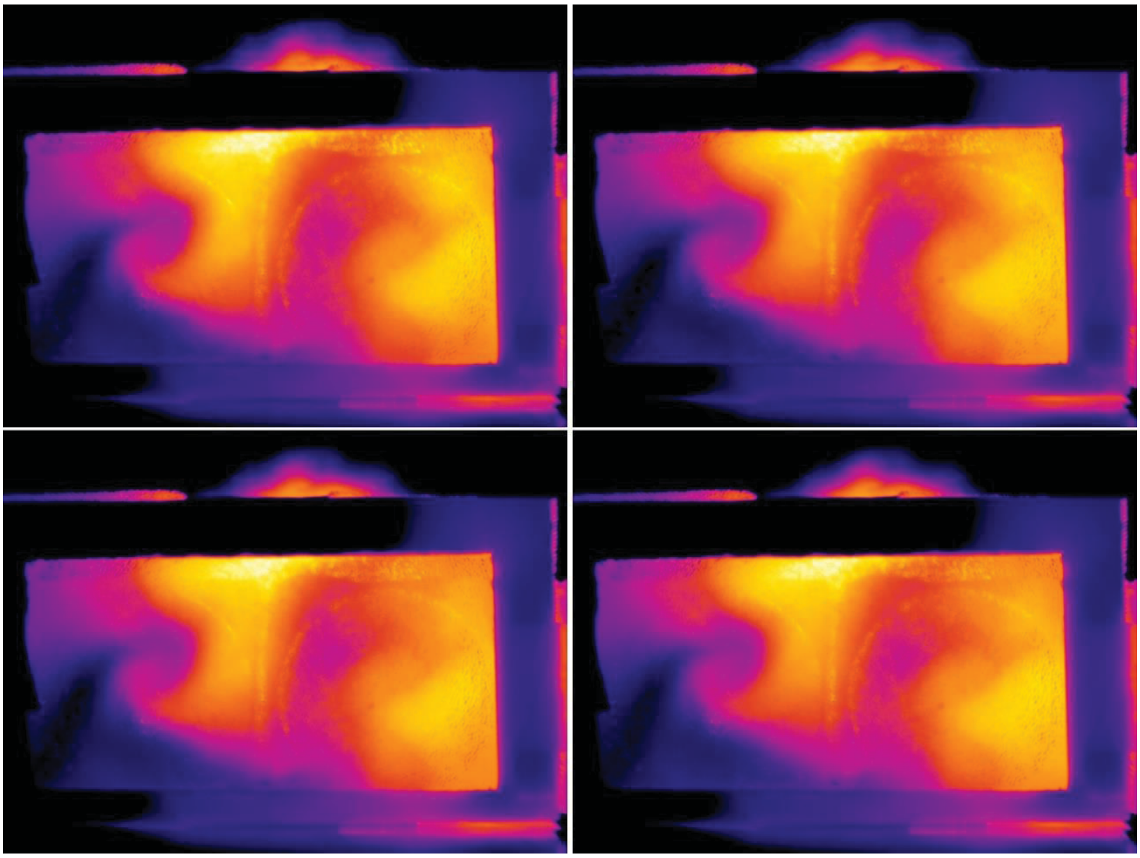

Figure 8. Air flow visualization of the inlet for two computer fans.

The four shown images taken at different time intervals are very similar, showing that this geometric and thermal configuration is quite stable, completely different to the previously one registered at the server room.

Changes in the relative position between the fans and the air heater was made, to test if there was any change in the thermal pattern:

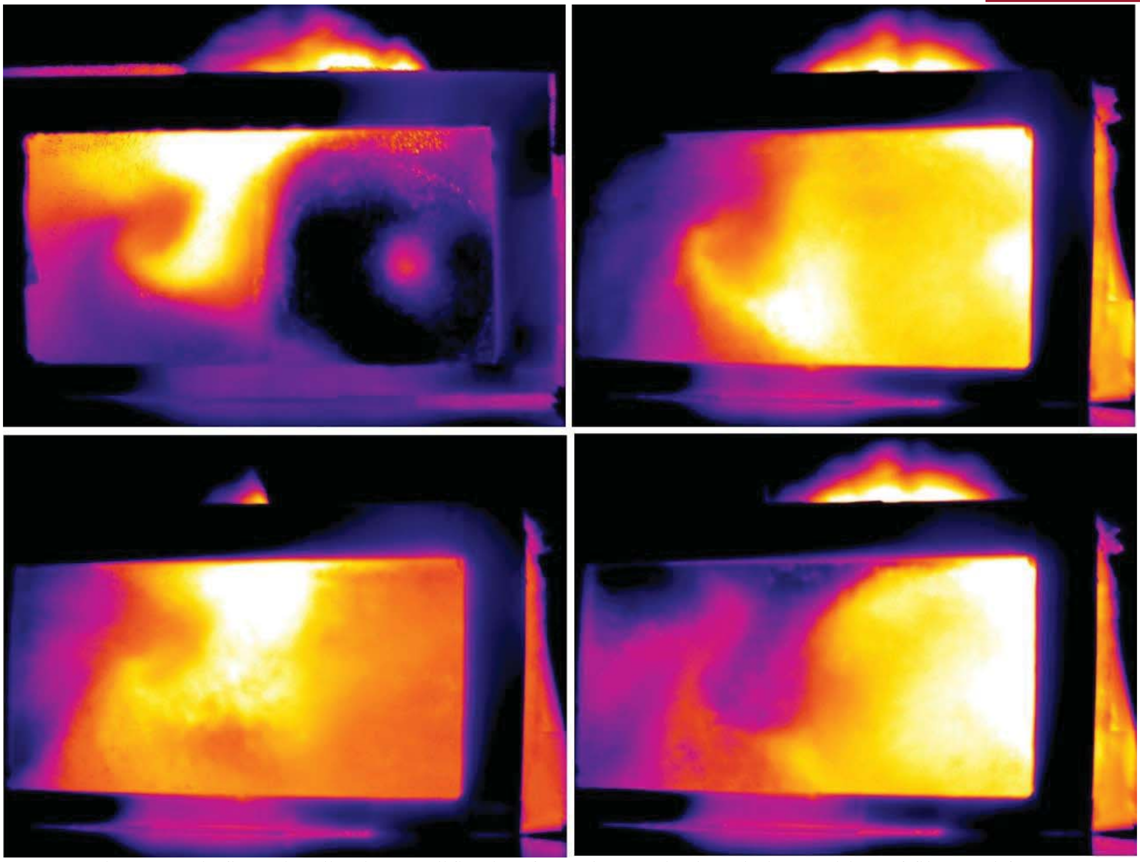

Figure 9. Air flow visualization modification from changes in the relative position of filter and fans.

These first results are quite hopeful and show the successful application of the technique.

4. Future necessary developments

The next step is a complete and exhaustive study of the best options for the airflow visualization:

- Type, structure, dimensions and geometry for the best air filter

It is possible that the best air filter configuration could depend of the visualized phenomenon. Too thick filter could not be the best option: it even might modify the initial thermal patterns, from the own obstruction generated, visualizating at the end a different thermal situation.

- Particle characteristics

Size, density, specific heat… seems to be the most important parameters to take into account for airflow visualization, but also another ones as, for example, possible toxicity or interaction with the air flow must also be considered.

- Other geometries: installations, equipments, gases…

It is also necessary try to apply the technique to quite different configurations, and real installations, industrial equipment, buildings… Obviously, the described technique could be applied to any transparent gas for infrared radiation, not exclusively air.

5. Conclusions

- A simple technique for airflow visualization is presented and described
- It has been successfully checked at real study cases
- Any type of commercial thermal camera could be used
- Laboratory conditions are not necessary
- It is fundamental the future analysis of the best options to obtain good results: mainly filter geometry and particle characteristics.

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