# VISUALISATION OF CFD RESULTS IN A VIRTUAL REALITY ENVIRONMENT

Kjeld Svidt[1], Bjarne Bjerg[2]

[1]Aalborg University, Sohngaardsholmsvej 57, DK-9000, Aalborg, Denmark
Tel: +45 9635 8546, Email: ks@civil.auc.dk, Web: it.civil.auc.dk/ks

[2]Royal Veterinary and Agricultural University, Grønnegårdsvej 8, 1870 Frederiksberg C, Denmark
Tel: +45 3528 3586, Email: bb@kvl.dk, Web: www.kvl.dk

## Summary

This paper describes our experiences with Virtual Reality visualisation of CFD results in an immersive environment. The data for visualisation were simulation results of airflow and temperature distribution in livestock buildings. Four different configurations of ventilation system were studied. Low momentum air supply was studied with air supply near the floor and through the ceiling respectively. High momentum air supply was studied in configurations with a slot inlet as well as a number of individual inlets. The three-dimensional airflow has been visualised in panorama and a six-sided CAVE. The flow was visualised by interactively controlled planes of velocity vectors and air temperature as well as streamlines and moving particles.

## Introduction

The Danish research programme "*Control of airflow in livestock buildings"* was a five-year project focusing on computer simulation of airflow and indoor environment in livestock buildings. During the project, the researchers have used different kinds of traditional post processing software to analyse and visualise simulation results. More details of the results can be found in a number of publications from the research group. See e.g. Bjerg et al 1999, 2000, 2002, Zhang et al 1999, 2000 and Svidt et al 1998, 2001.

At the end of the project results have been presented at seminars for researchers, professionals in the ventilation industry and consultants from the agricultural extension service.

For these seminars, a few cases reflecting research results as well as problem-cases from the industry were selected to be presented in the Virtual Reality facilities at Aalborg University.

## Methodology

### *What is virtual reality?*

The term Virtual Reality (VR) was introduced in the late 1980es and there exist many different views of its meaning depending on which context it is used in.

Generally we will define Virtual Reality as *an environment trying to convince your senses that something virtual is real*. It will normally include some of the following elements:

- Real-time interaction with the model
    - mouse or keyboard
    - tracking of persons
    - tracking of interaction devices
    - haptic devices

- Stereo viewing
    - active
    - passive

- A certain degree of immersion
    - wide screens, power walls
    - large curved screens
    - CAVE
    - Head mounted displays

In the present case, a high degree of immersion, stereo viewing and tracking of persons and interaction devices are the VR elements that differentiate the visualisation from a more "traditional" 3D-visualisation.

For more information on Virtual Reality visualisation, see. e.g. Stuart 2001, Giallorenzo et al 1999, Christiansson et al 2001.

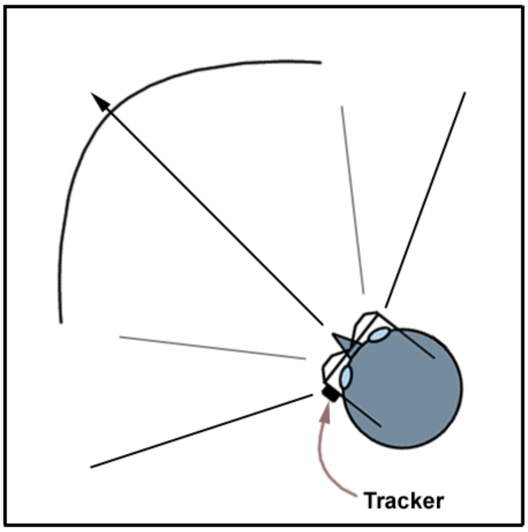


Figure 1. The 6-sided CAVE has backprojection on all sides and position tracking of the main viewer.

*Virtual Reality facilities at Aalborg University*
The VR Media Lab was established in 1999 with three different display systems powered by one 16 CPU Onyx2 graphics computer. The display systems are:

1) The 6-sided CAVE, i.e. a cube (2.5 m x 2.5 m x 2.5 m) with real-time image projection on all six sides. By means of an electromagnetic tracking system the viewer can move in (or around) the visualized object. This installation is preferably for one viewer (fig. 1).
2) The Panorama, which accommodates up to 28 persons placed in front of a large cylindrical screen with a diameter of 7.1 meters, 160 degrees and a height of 3.5 meters, thus the major part of the viewers field of vision is covered (fig. 2).
3) The 3D Auditorium accommodates up to 80 persons placed traditionally in front of a large screen measuring 8 x 2.85 meters.

All three arenas have electromagnetic tracking of interaction devices, so the presenter can interact directly with the model in front of the audience.

*Simulation and visualisation methods*
The visualised airflow has been calculated with the commercial CFD-code Fluent version 5.5. For further details about the simulations see the publications mentioned above. The stored results were converted and then displayed with the visualisation code VU (www.cerca.umontreal.ca/vu).

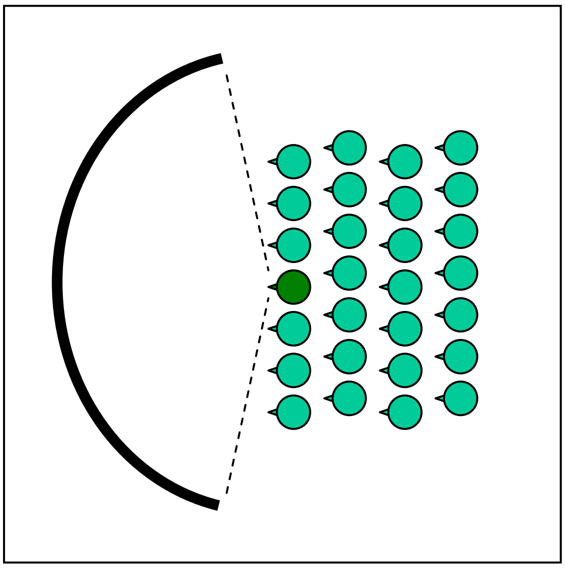


Figure 2. The panorama with a large cylindrical screen accommodates up to 28 persons.

With this software, the presenter could interactively move and scale the model and in real-time navigate in the three-dimensional data set by means of “handheld” streamlines, vector planes etc.

There was no real-time coupling between the visualisation and the CFD-simulation; i.e. geometry and boundary conditions could not be changed on the fly.

**Cases selected for visualisation**
The following cases were selected for Virtual Reality presentation:

1. 3D airflow in a laboratory set-up with an isothermal slot inlet
2. Airflow and CO2-concentrations in a laboratory set-up with 4 wall inlets and “pig simulators”
3. Simulation of displacement ventilation in a room with closed pen partitions
4. Airflow in a similar room with a low momentum ceiling inlet
5. Airflow in a room with a radial inlet device

Cases 1, 2 and 3 are examples from the research project, which have been investigated in details by means of CFD and full scale laboratory measurements. Case 4 and 5 are simulations of problem cases from real life buildings. They were selected in close collaboration with consultants from the industry to demonstrate some of the simulation and visualisation possibilities to people from the industry.

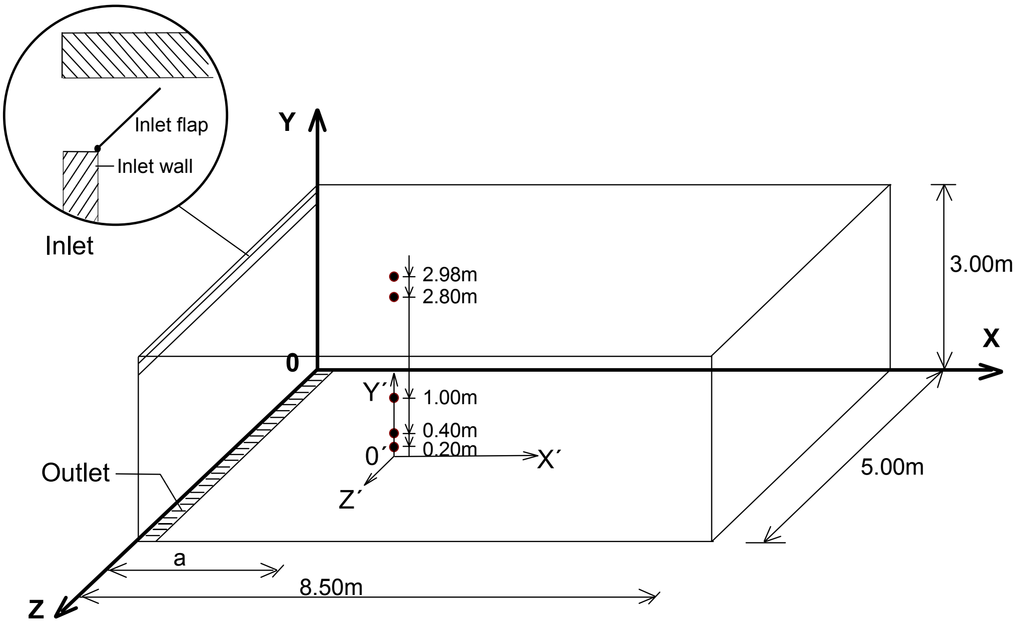
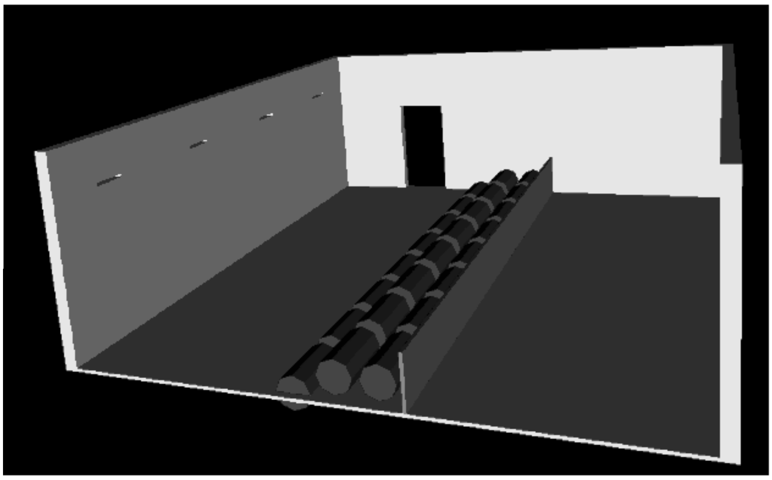


Figure 3. Case 1. 3D airflow in a laboratory set-up with an isothermal slot inlet.

Figure 4. Case 2. Airflow and CO2 concentration in a laboratory set-up with 4 wall inlets and “pig simulators”



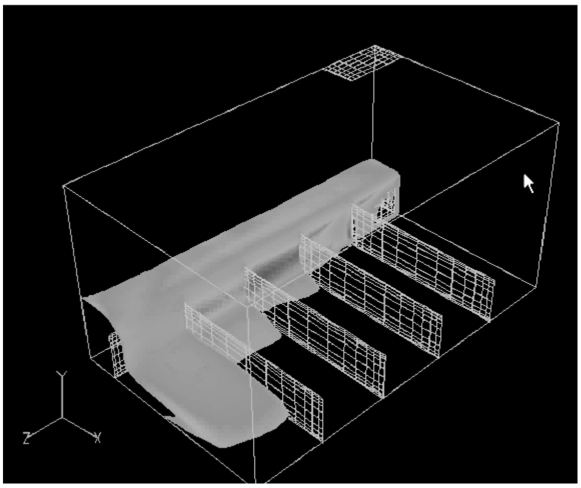


Figure 5. Case 3 - 4. Airflow in a room with closed pen partitions.

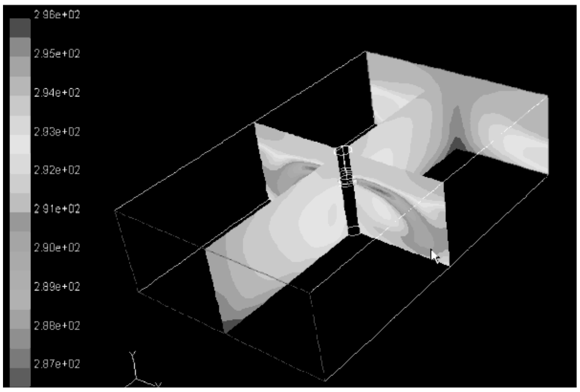


Figure 6. Case 5. Airflow in a room with a radial inlet device.

## Results and Conclusions

The VR facilities proved to be very efficient to visualise the three-dimensional airflow for people with no special background in 3D modelling and fluid motion.

The results were visualised with filled contour planes or vector planes which the presenting person could move arbitrarily in the model.

In addition the presenter could place or interactively move around seed points for streamlines or moving particles in an intuitive way by moving physically around in the model.

Especially the CAVE gave a very persuasive experience of being inside a virtual room with a virtual airflow. However this is mainly a one-person experience. Only a couple of additional persons staying close to the tracked person can have the correct view in the CAVE.

It is our experience that it requires some training to navigate in the models and to scale and position them in a suitable way in relation to the physical surroundings (the audience, the panorama screen, the walls of the CAVE etc.)

## Acknowledgements

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