AN AUGMENTED-REALITY APPROACH TO CO-LOCATED VISUAL EXPLORATION OF INDOOR CLIMATE DATA IN REAL ROOMS

Forsberg A-K[3]*,Pettersson L W*[1,]*, Linden E*[2]*, Sandberg M*[2]*, Seipel S*[1,3,*]

[1]*Uppsala University , Department of Information Technology, 751 05 Uppsala, Sweden*
[2]*University of Gävle , Department of Technology and Built Environment, 801 76 Gävle, Sweden*
[3] *University of Gävle , Department of Mathematics, Natural and Computer Sciences, 801 76 Gävle, Sweden*

ABSTRACT

We live in two spaces, the visible space and the non-visible but otherwise sensed space. Both spaces must satisfy our needs and there is a relation between them. If parts of the room are too cold this will lead to a restriction of the use of the room. We cannot endure draft for any longer time. Draft caused by a ventilation supply frequently leads to blockage of the supply device, which in turn gives rise to a reduction of the ventilation rate. The final result may be a deterioration of the air quality. Therefore, to be able to guarantee the air quality it is necessary to make the invisible thermal climate visible.

In this paper a novel method based on Augmented Reality for presenting the thermal climate is presented and discussed. The data, e.g. temperatures and velocities, are shown on a lightweight display. Several people can walk around in a real room and see on a screen where the hot and/or cold spots may appear. Different ventilation solutions could in that way be compared in a dialogue between different actors in the building process.

Keywords: Indoor Climate, Temperature, Senses, Vision, Augmented Reality

INTRODUCTION

Indoor climate

The physical indoor climate consists of the following physical quantities; temperature, velocity, electromagnetic radiation from equipment, contaminants, sound and light. We can sense short wave electromagnetic radiation by our vision. The other quantities are invisible, yet they may affect us. We either realize them directly by the other senses or they may, in special cases, give rise to symptoms of illness after a sufficient exposure time.

Our response to an unbalance in our heat balance is almost immediate. The reaction is that we feel too cold or too hot. In particular we can't endure draft (unwanted local cooling of a body part), caused by e.g. a ventilation supply device, for any longer period of time. Therefore we take action and one example situation is seen in Fig. 1.

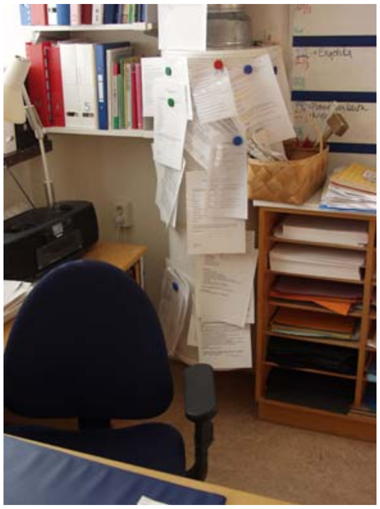

Figure 1 An office situation, the supply device has been converted to a notice board.

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[*] Corresponding author email: stefan.seipel@it.uu.se

Here, the supply device has been blocked and as a consequence the ventilation flow rate is reduced. Hence, the ventilations dilution capacity of contaminants is reduced and the air quality may be severely deteriorated. The example above demonstrates that there may be a relation between dissatisfaction with the thermal climate and the risk for a deterioration of the air quality.

We live in two spaces, the visible space and the non-visible but otherwise sensed space. Both spaces must satisfy our needs and there is a relation between the two spaces. For example, if people experience that some parts of the room are too cold this restricts the use of the room. This is what has happened in the example above. The ventilation air is supplied with an efficient ventilation system with its supply device located at floor level. The supply device is a visible object in contrast to cold air draught which is perceived in the non-visible space. Therefore, with respect to the use of the floor area, the supply device must be considered larger than its physical dimensions. An architect making the furniture plan for the best utilisation of the floor area does not have this information. Regarding utilisation of the room the supply device with its cold air supply is furniture whose overall size is not seen. This can result in what we can call a furnishing conflict.

The importance of visualisation

The above example clarifies the need to make the thermal climate visible, to guarantee a given thermal climate and air quality. The European Construction Industry has identified visualisation as a method of promoting knowledge and understanding and as a method contributing to create a collective sense of responsibility for site construction teams. By finding tools to make the indoor climate visible it would be possible to promote a constructive dialog between everyone involved in the building process. These tools could be used both in the planning of a new building and when altering an existing building or room.

Augmented Reality

Vision, the most developed human sense, is not always by itself enough to provide all information necessary to be perceived in a situation. A way to enhance our visual senses with non-visual stimuli is Augmented Reality (AR). In general, AR can supplement the physical environment with information perceptible by any human sense, but the most common applied augmentation is visual.

AR produces an environment in which Virtual objects, for example 3D-models, instructions, annotations and images are superimposed on a user's field of view of the real environment. It provides us with augmenting knowledge about the surrounding world. The advantage is that a user can explore the physical environment together with additional data generated in real-time in the context of the real world. The superimposed information can for example provide the user with information that is non- detectible through our senses. The goal is an improved performance on the task at hand. The method most used for achieving visual augmentation is a head mounted stereoscopic display, HMD. This method projects an image floating some 1-5 meters in front of the user (Annon 2001).

There are two common ways of accomplish visual Augmentation: with optical or with video technologies. A see-through head mounted display; HMD is one device that combines real and virtual. The optical see-through HMD enable the user to observe the real world and the data projected into the view using a semi-transparent mirror. For an example look at Trivisio webpage (Anon) The problem is the compromise between see-through quality and contrast of the simulated data. Optical see-through systems also have to be calibrated before each use, and there are few available on the market so far (Azuma et al 2001).

Video see-through HMD work by combining a closed-view HMD with one or two head mounted video cameras. The cameras provide the users view of the real world. Video from these cameras is combined with the data to be visualized. The result is sent to the monitors in front of the users eyes in the closed-view HMD (Azuma et al 2001). These standard closed-view HMDs do not allow any direct view of the real world. The problem here is that the users only see the world through the cameras optical system, which is no comparable to the human visions way of percept 3D information. But these systems only have to be calibrated once and the optical impression is better compared to optical see-through. These systems also are available on the market today; one example is Teak Gear, look at their web site (AnonA).

PREVIOUS WORK

This paper builds upon results from a project aiming at making the indoor climate visible. In this project whole field measurement techniques for measuring the physical quantities of the indoor climate have been developed. The velocities can be detected with a method called particle streak velocimetry (Linden et al. 1998) and (Elvsén and Sandberg 2004). By using infrared thermography (Cehlin et al. 2002) temperatures could be measured. Also the concentrations of pollutants could be detected. In that case absorption tomography (Cehlin and Sandberg 2002) is used. By using these whole field measurement techniques instead of single point measurement techniques it is possible to collect much more information in a larger volume and at the same time decrease the time of measuring. In the work described here, temperatures collected with infrared thermography have been used but the method could also be used for presenting other quantities.

Today the tools used in the ventilation industry for presenting their products are mostly two-dimensional images, graphs and tables. In product selection programs it is also possible for the developer of the ventilation system to choose the supply device, ducts and so forth and to visualize the result in three dimensions. These tools are a great help for the developer but they don’t really show what happens in the ventilated room.

This problem can be overcome by using AR techniques, which have been successfully used in other applications. Classical examples are computer assisted instruction for maintaining and repair, CAI (Feiner et al. 1993), industrial training (Caudell and Mizell 1992), annotation and advertising, see PVI web site (AnonB). AR is also widely used in entertainment (Ohshima et al 1999), military training, navigation and targeting (Livingstone et al. 2005), (Livingstone et al. 2002), (Azuma 2001), and medical visualization (Bajura et al. 1992), (Duborset et. Al. 1999), see also Medlibre website (AnonC).

RESEARCH METHODS

Our choice of method differs from the usual Augmented Reality approach. Instead of using a HMD we use a moveable display, to interactively slice through the data that is spatially correlated. In an earlier paper (Pettersson et al. 2004) we have described the concept of a handheld device prototype implementation, In situ tomographic data display, for visualizing data that is co-located with the user’s physical environment.

The present work brings together and combines knowledge from Indoor Environmental Engineering, Computer, and Cognitive Science. The used method is based on registering a three-dimensional array of pre-measured ventilation data and the data is displayed in the physical working environment of the user. The metaphor is that the user cuts through the data in the physical space with the spatially tracked and calibrated display. With help of the IR-camera tracking the user can walk around in physically space and the display constantly present the updated ventilation data in real-time in the users physical environment.

TECHNICAL APPARATUS

To collect the three-dimensional array of temperatures a digital infrared camera, in conjunction with a low thermal mass screen was used. The screen was located parallel with the airflow direction during the experiment. By moving the screen the whole field around the diffuser was mapped.

As illustrated in figure 2, the data to be visualized can be considered as a field over a three-dimensional domain, which is located in the physical environment.

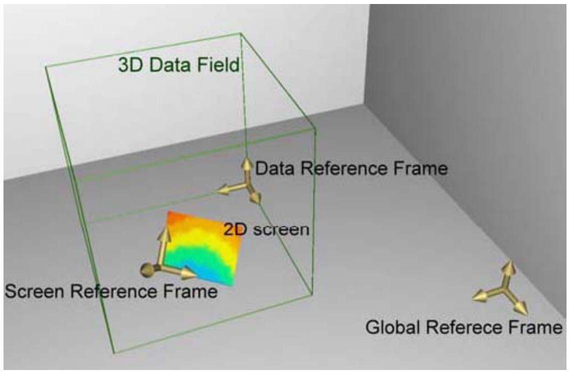

Figure 2. The spatial relation between screen and data field in the physical environment

Initially, a calibration of the three-dimensional data field must be performed in order to describe the extent, position, and orientation of the field in its physical environment. This calibration procedure involves registering corresponding reference points in the physical environment. At least three such markers are required to derive the spatial calibration.
The new with our approach is, that 2D cross-sections is not performed in an on-screen display of a virtual 3D model of the environment. Instead, we transform the data sampling and rendering process into the physical working environment of the user. Hereby, both the data to be visualized and the physical display are metrically correlated and coincide at the same locus. We developed software to perform the data registration, display tracking and tomographic resampling and display. The software utilizes volumetric texture mapping functionality that is provided by the hardware according to the OpenGL 1.2 standards specification.

The prototype consists of a laptop computer, illustrated in figure 3, with a powerful 3D graphics engine that is capable of storing large data fields in texture memory and which renders large volumetric textures at real-time frame rates. On the rear side of the display, an array of three infrared light emitting diodes (LED) is attached. It is part of the Dynasight*TM* tracking equipment that allows registering the positions of the LED´s at a 30Hz sample rate.

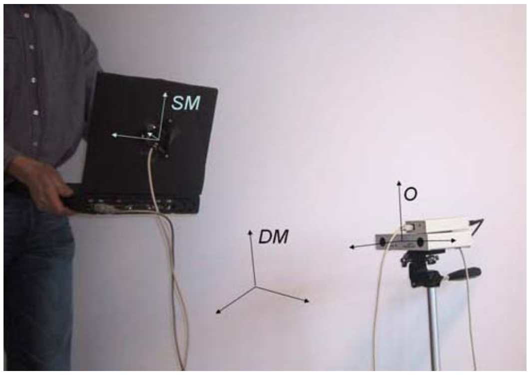

Figure 3. The prototype implementation uses optical tracking with active markers attached to the rear side of the laptop screen. The picture illustrates the relation between the three reference frames in physical space.

RESULT AND DISCUSSION

In this paper a tool for visualizing the thermal climate in a room that is going to be altered is explained. If the room will be provided with a new heating/cooling and ventilation it is very valuable to be able to walk around in the real room and see the thermal climate generated by the new systems beforehand. This could be done by Augmented Reality.

The goal of the application is to visualize the effect of future changes in the ventilation environment. The method allows the user to see ventilation data sets in their actual environmental context. With help of the augmented reality approach the user can look at several possible solutions based on the pre-measured data, actually illustrated ventilation plans changes. Finally the user can compare the different plans according to actual positions in the room and find the best solution for the actual task at hand. This proposed approach is intended to enhance the understanding and communication within the different professions working with ventilation environment. Our goal is to introduce a tool, based on our cognitive ability to interpret visualized data. We have chosen an AR-approach because it renders possible understanding of the actual ventilation data in combination with the real room environment. The user can walk around in the room and see where the hot and/or cold spots, not so suitable for furniture, may appear with different ventilation solutions.

CONCLUSION AND IMPLICATIONS

By using Augmented Reality it is possible to present the thermal climate in real buildings. Summarized advantages of the early evaluation:

- The display does not require head tracking of the observer to work correctly.
- Since the data rendered on the display are spatially calibrated 2D cross-sections of the data, there is, in contrast to Augmented Reality based presentations, no need for viewer dependent projections of the data.
- The method improves collaborative work and it enables several users to explore the data at the same time.
- The mobility increases the potential of the Augmented Reality technology; it can provide the user with information of the current position and orientation of the display in physical space with help of the 3D position-measuring device based on IR-camera tracking.

ONGOING WORK

The weight of the laptop display used as a moveable display here is far too heavy for real situations. In our ongoing work the application is transformed to work on a small lightweight display instead. Current focus also includes a usability study, concerning accuracy in spatial perception compared to stationary display visualization technique. In our future work we are going to look at different types of colour scales for thermographic visualizations. The purpose of this study is to find an easy interpreted scale that is suitable for adding rich information to our perception of visualized data.

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