Energy-efficient High-Performance Acoustic Processing Unit

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***Abstract*—An embedded 24-channel acoustic processing system consisting of an FPGA based front-end and a multi-core micro-controller subsystem is presented here. It is specifically designed for a smart building solution estimating the occupancy level of rooms and areas solely based on acoustic features and source localization. The overall goal is to use this occupancy estimate to lower the energy consumption of large buildings. An overview of the hardware and software concept as well as a brief description of the acoustic occupancy level estimation is given. The APU was developed as part of the EU FP7 project - Sounds for Energy Control of Buildings (S4ECoB)[1].**

I. Motivation

The building sector is responsible for about 40% of the energy consumption in industrial countries and one third of CO_2 emissions. More than 60% of building energy consumption is used for heating, ventilation, air conditioning (HVAC) and lighting [1]. Energy-efficient operation of buildings depends on the number of occupants. Therefore, sensing the occupancy leads to better utilization of the HVAC equipment. Up to now, no single sensing technology is available to provide required accuracy in estimating the occupancy. Given the fact that human activities add sound to living and working environments, acoustically based technologies can be particularly useful in providing valuable information, such as the building occupancy.

II. Approach

Audio monitoring is performed by a network of microphones grouped into separate microphone arrays with up to eight microphones each and an Audio Satellite Unit (ASU) for A/D conversion (see fig. 1). The audio stream (ADAT protocol encoded) is transmitted in real-time to an Audio Processing Unit (APU), up to three ASU's can be connected to a single APU. The APU consists of an FPGA based audio interface / preprocessing board and an embedded CPU board connected via external memory interface (GPMC). The selection of an ARM Cortex A9 dual core processor and an overall very low APU power consumption (in contrast to conventional PC's) are results of an extensive performance and power consumption analysis.

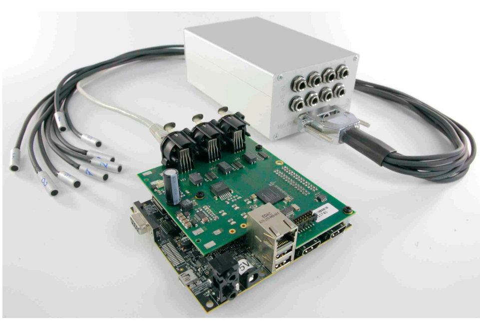

Fig. 1. Acoustic processing unit with satellite unit and 8 microphones.

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The acoustic preprocessing and occupancy estimation is realized by a plugin-like approach on the APU, allowing exchange of audio processing algorithms even at run-time. APU's are time synchronized using the PTP protocol (IEEE-1588-2008) with a clock deviation of less then $300\mu s$.

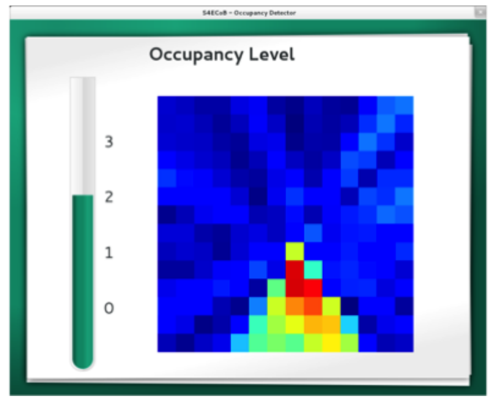

Fig. 2. GUI for occupancy level estimation and source localization.

For building energy management purposes the mapping of the number of people on a relative metric with a small number of intervals is seen to be sufficient. Two different approaches are investigated to calculate the occupancy level. The first approach is based on acoustic localization algorithms, e.g. global coherence field (GCF). Scanning the monitored area with the localization algorithm in a predefined grid-size results in a so called acoustic map (see fig. 2). For each grid-element of the monitored area the acoustic map indicates a pseudo probability for an active audio source. The second approach is based on machine learning algorithms, using Gaussian mixtures and hidden Markovs to distinguish between occupancy levels using audio samples recorded before. This approach offers the possibility to include potential noise sources (fans, tv, radio) and initially unknown events into the set of events to be detected.

III. Conclusion

We have introduced a novel network embedded acoustic processing system for estimating the occupancy level in rooms and buildings. In the S4ECoB project the proposed system will be deployed and validated in three large commercial and public buildings such as shopping malls and airport gateway areas.

The demonstrator consists of a sphere serving as housing for an ASU and its 8 microphones connected to an APU executing the occupancy estimation algorithms outlined above. The estimated occupancy level as well as the positions of sound sources are shown with the help of a special GUI.

References

[1] P. Bertoldi and B. Atanasiu, *Electricity Consumption and Efficiency Trends in the Enlarged European Union*, European Commission, Institute for Environment and Sustainability, 2007.