Electronics/Computers

Integrated Spacesuit Audio System Enhances Speech Quality and Reduces Noise

This technology can also be adapted for teleconferencing, telemedicine, wireless voice communication, and other hands-free communications.

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A new approach has been proposed for increasing astronaut comfort and speech capture. Currently, the special design of a spacesuit forms an extreme acoustic environment making it difficult to capture clear speech without compromising comfort. The current system, called Communication-Cap-based Audio (CCA), relies on a single microphone placed close to the subject's mouth. While this results in clear audio, it also has problems: wire fatigue, blind mating, interference with food/drink, need for custom communication caps, and not being able to adjust the microphone during extravehicular activities.

The proposed Integrated Spacesuit Audio (ISA) system is to incorporate the microphones into the helmet and use software to extract voice signals from background noise. The system would rely on an array of microphones to en-hance speech quality. It will feature performance similar to the CCA system while providing comfort, ease of use, and logistical convenience. In this study, the feasibility of using microphone array beam forming or multichannel noise reduction plus a single-channel post-filter to combat a variety of in-helmet noise was validated.

The developed multichannel plus single-channel noise reduction approach can effectively enhance the intelligibility or quality of the speech from the subject. Using the acoustic data recorded inside spacesuits, it was shown that the developed multichannel noise reduction algorithm can help improve the signal-to-noise ratio (SNR) by approximately 20 dB in ideal cases, and 8–12 dB in worst cases. With four microphones, the multichannel noise reduction algorithm can yield a 4–5 dB gain in SNR with no distortion, and 12–15 dB SNR with a moderate amount of speech distortion. This new approach is more practical and more advantageous than the traditional microphone array beam-forming solutions.

This system would be applicable not only for spaceflight, but also for telecollaboration, human-machine interface, hands-free in-car phone interface, acoustic surveillance, and any kind of system where wide-area sound sensing is important.

Hardware Implementation of a Bilateral Subtraction Filter

Modules like this one are necessary for real-time stereoscopic machine vision.

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A bilateral subtraction filter has been implemented as a hardware module in the form of a field-programmable gate array (FPGA). In general, a bilateral subtraction filter is a key subsystem of a high-quality stereoscopic machine vision system that utilizes images that are large and/or dense. Bilateral subtraction filters have been implemented in software on general-purpose computers, but the processing speeds attainable in this way — even on computers containing the fastest processors — are insufficient for real-time applications. The present FPGA bilateral subtraction filter is intended to accelerate processing to real-time speed and to be a prototype of a link in a stereoscopic-machine-vision processing chain, now under development, that would process large and/or dense images in real time and would be implemented in an FPGA.

In terms that are necessarily oversimplified for the sake of brevity, a bilateral subtraction filter is a smoothing, edge-preserving filter for suppressing low-frequency noise. The filter operation amounts to replacing the value for each pixel with a weighted average of the values of that pixel and the neighboring pixels in a predefined neighborhood or window (e.g., a 9×9 window). The filter weights depend partly on pixel values and partly on the window size.

The present FPGA implementation of a bilateral subtraction filter utilizes a 9×9 window. This implementation was designed to take advantage of the ability to do many of the component computa-tions in parallel pipelines to enable processing of image data at the rate at which they are generated. The filter can be considered to be divided into the following parts (see figure):

- An image pixel pipeline with a 9×9-pixel window generator,
- An array of processing elements;
- An adder tree;
- A smoothing-and-delaying unit; and
- A subtraction unit.

After each 9×9 window is created, the affected pixel data are fed to the processing elements. Each processing element is fed the pixel value for its position in the window as well as the pixel value for the central pixel of the window. The absolute difference between these two pixel values is calculated and