Theme

- Design something that reduce our field work for acoustic monitoring.
- At present, making audio recording requires an investment of time and energy. Microphones must be setup, connected to amplifiers and filters, and then passed into a computer’s sound card. If the microphone is not positioned properly.
- If multiple measurements are needed from around a room, a significant portion of time will be spent just moving the microphone and cables.
- Drone can be a effective solution in this.

Impulse response: gives complete acoustic information

- In order to properly simulate and improve the acoustics of any space, engineers often rely on measuring the room's impulse response.

- An impulse response is capable of completely describing the audio characteristics of any space and location. This includes measuring the **delay time of the direct sound waves** proceeding from the audio source to the listener position as well as any **indirect waves that may reverberate off** the walls and result in the listener hearing an echo.

- Since the impulse response contains all of the acoustic data about what a listener will hear for a large range of frequencies, Impulse responses can be very useful in identifying problems with the acoustics of such halls and providing solutions to improve the audio performance of the room.

Why it is needed?

- Unfortunately, one impulse response is only valid for one specific set of audio source and listener positions. If one wants to simulate the acoustics in a separate part of the auditorium, another impulse response is needed.

- While each recording only takes a few seconds, it takes significantly longer to move the microphone and/or loudspeaker for each recording, as it means physically picking up the stand, dragging the audio cables to the next position, and then returning to the computer to start the recording once again. Thus it requires lots of time and energy.

Challenges:

Quadcopter imposed challenges	Maximum payload of 100 grams	Reducing payload will make the quadcopter more stable and increase flight time.
	Low power design	Any embedded design on the quadcopter should utilize a low power design in order to extend battery life.
	Low noise recordings	Remove any noise generated from quadcopter.
	Increased microphone stability	Prevent microphone from moving during recordings as much as possible.
Audio measurements and embedded systems	Synchronization within recording sample rate	For recordings to really be useful, the exact time that both playback and recording started must be known.
	Meet ADC and DAC hard real-time deadlines	Missed ADC or DAC deadlines will result in corrupted audio, so data must be recorded from/fed to the peripherals in time.
	Quality audio performance	Hardware must be able to produce good quality sound output and make good quality sound recordings.

Overview of Embedded system capable of acoustic monitoring on hovering quadcopters

	iPod Touch [24]	Raspberry Pi [25]	nRF51822-EK [26]	SAM4L Xplained Pro [27]
Processor	Apple A4 (ARM Cortex A8)	Broadcom BCM2835 (ARM11)	nRF51822 SoC (ARM Cortex M0)	SAM4LC4 (ARM Cortex M4)
Memory	512 MB	512 MB	256kb Flash ROM & 16kb RAM	256kb Flash ROM & 32kb RAM
Operating System	Full OS pre-installed, non-deterministic timing	Linux OS recommended, mostly deterministic timing	No default OS, fully deterministic timing	No default OS, fully deterministic timing
ADC / Audio Recording	Integrated microphone	No ADC included	10 bit ADC included	12 bit ADC included
DAC / Audio Playback	Integrated speaker and headphone jack	Integrated headphone jack	No DAC included	Audio bitstream DAC
Audio Storage	Integrated hard-drive	External SD card required	No default storage medium	USB host
Wireless Connectivity	Wi-Fi and Bluetooth included	External Wi-Fi or Bluetooth module required	Low power Bluetooth included	Atmel Zigbit modules required
Power Managment	10 hour battery included and low power processor	USB power and no low power mode	Button battery and very low power processor	USB power or external battery and very low power processor
Software Development	Proprietary Apple software and hardware required	Very easy implementation on Linux OS	Build software from scratch and pre-built libraries	Build software from scratch and pre-built libraries

Analysis based on above table

- For audio signal generation and recording, a hard-real time operating system is normally required for certain tasks.
- For example, audio must be generated and sent to the DAC at a very specific frequency. The same is true for recording data from the ADC. Not sending data to the DAC at the proper speed or reading the ADC at the wrong time will result in corrupted audio. Other tasks are not as critical and can be completed when the operating system has some idle time.
- The **Apple iPod Touch's iOS** is a real-time operating system at a very low level, but there are no real-time guarantees. However, peripheral interfaces, such as the ADC and DAC should complete in real-time such that there is no degradation in quality. So long as other tasks in the user app do not have any real-time needs, iOS is a good choice for an operating system.
- Multiple real-time operating systems are available for the **Raspberry Pi**, though most can only provide soft real-time guarantees because the GPU is a closed system and there are no guarantees on how often it will interrupt the processor. Any sort of system that uses the GPU will lose any hard real-time guarantees.
- The **Nordic and Atmel processors** are both capable of using hard real-time operating systems.

Approach

- Each embedded system will likely need to generate a high quality audio signal or record the audio signal in a high quality. Thus, the systems will need to include an ADC or DAC, respectively.

- Recorded signals will also need to be saved to some external media and playback audio will either be read from external media or algorithmically generated, all in real-time, meaning the system also must operate in a deterministic way.

- The iPod Touch located approximately 20 cm away from the loudspeaker that will play a sine sweep signal. After the loudspeakers finished playing, the iPod Touch would continue to record for slightly longer to capture any indirect reverberations that may still be approaching the device.

- Finally, since the audio recording will be on-board a quadcopter, there must be some form of wireless communication between the remote recording system and the ground system.

How it will work?

- The system needs to wirelessly synchronize two nodes, one on the ground connected to the PC and loudspeaker, and the other in the air attached to the quadcopter.

- On command from the PC, the ground node would alert the remote node to begin recording at the same time as the iPod Touch located approximately 20 cm away from the loudspeaker began playing a sine swept signal in real time.

- The remote node will record this audio to a USB flash drive and after the recording will be finished, would finalize the recording by trimming excess sound from the beginning and end of the recording.

- After the loudspeakers finished playing, the iPod Touch would continue to record for slightly longer to capture any indirect reverberations that may still be approaching the device.

Why audio recording?

Under normal circumstances, impulse responses are recorded using the same sound card. This allows the recording and playback audio to begin at the exact same sample. Each additional recording and playback sample is continually synchronized as there is only one clock on the sound card that controls the timing of the samples.

When using a quadcopter, utilizing the same sound card for both playback and recording is not an option. Instead, the sampling on the two nodes needs to be synchronized. Audio is typically recorded at sampling frequencies from 8 kHz for low quality wireless microphones to 48 kHz for professional audio equipment. To have sample accurate clocks, the accuracy must therefore be 125 s for 8 kHz and 20.83 s for a 48 kHz sample frequency.

A goal for this project therefore should be to maintain a clock accuracy of at least 21 s in the worst case scenario. If this occurs, it should be possible for the ground node to know exactly when the quadcopter node begins recording, and for the quadcopter node to know exactly when the ground node begins playback.

Effect of Quadcopter Stability and Movement

Two possible errors are hypothesized to occur due to the quadcopter's instability.

- The first is interference with high frequency noise. A 10 kHz frequency sound has a wavelength of approximately 3.4 cm at 20° C through air. If a quadcopter is constantly moving by even a few centimeters, it is believed that this could potentially cause interference.

- The second possible error resulting from quadcopter movement could come from indirect sounds. Indirect noises must travel a greater distance and therefore take longer to reach the quadcopter. If the quadcopter drifts during this time, the indirect sound will arrive at the quadcopter at a different time than if the quadcopter had remained motionless.

Effect of Microphone position on noise reduction

The original recordings is that the positions below the quadcopter receive a lot of wind noise, much more than the positions above and beside the quadcopter received. This wind noise would need to be removed in some way if future iterations included the microphone position below the quadcopter.

Figure shows lower levels of noise overall and multiple peaks. This was especially true in the lower frequencies up to about 1000 Hz. After 1000 Hz, there was a significant amount of noise over the base noise level of the microphone in the quiet room, but even in this region there occurred a few peaks.

These results support the idea that it may be possible to cancel tonal noises with active cancellation. That is, it may be possible to reduce the noise of the peaks in the frequency response graphs for the positions above and beside the quadcopter. However, there is still a significant amount of wideband noise outside of the peaks which may prove more difficult to remove.

Conclusion

Quadcopter noise cancellation: Two types of noise cancellation exist: passive and active. For passive noise cancellation, several methods of cancelling sound from the noisy components including wrapping insulating materials around the loud components and putting up a protective housing around the propellers. For active noise cancellation, the noise from the quadcopter is cancelled by electronics. The modification in propeller positioning system can be the basis for an active noise cancellation filter.

Above study shows that acoustic monitoring is possible but no doubt, it has wide complexity and challenges but it is possible and will be of great use in various applications.

Thanking you