Echo-Based distance measurement on Mobile device

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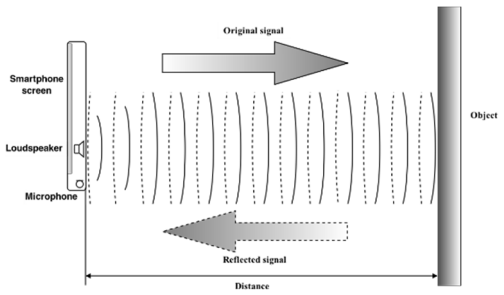
Introduction

The aim of this work is to create application for mobile device to measure distance using echo. The pricip is based sonar - transmit the sound with devices loudspeaker and receive reflection from distant object using devices microphone. Finally, the time between transmitting and receiveing is converted into distance. Before the application was created, the mobile devices components were analyzed and the sound for measuring is designed based on results. Next, the implementation of aforementioned algorithm in application for Android operation system with solution for communication and synchronization between individual components of application. Finally, application has been tested.



USING SMARTPHONE TO MEASURE DISTANCE 1

Algorithm of distance measuring application

The algorithm of distance measurement performs several steps:

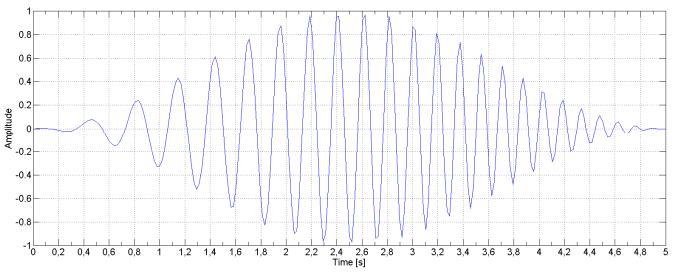
1. Start recording on device, wait 100 milliseconds to give the device time to .
2. Play the original sound wave on device with speaker pointed to distant object. Once the playing is finished, wait 100 milliseconds.
3. Stop the recording on device.
4. Locate first value bigger than treshold and mark it *startOfSeparation*. Separate recorded signal to 25 ms long individual measurement, starting from *startOfSeparation* minus three milliseconds.
5. Perform cross-correlation of each individual measurement with corresponding original signal.
6. Calculate mean cross-correlation from all cross-correlations.
7. Locate the first maximum in mean cross-correlation, this corresponds to signal recorded directly through device, with negligible delay.
8. Locate second maximum in the rest of cross-correlation, starting with index of the first maximum + 135 samples. This corresponds to reflected signal from object.
9. Calculate number of samples betweem the first and the second maximum, calculate distance from samples using formula: $d = \frac{rsN}{2Fs}$, where d is distance, rs is speed of sound, N is number of samples and Fs is sampling frequency.

Sounds for measuring

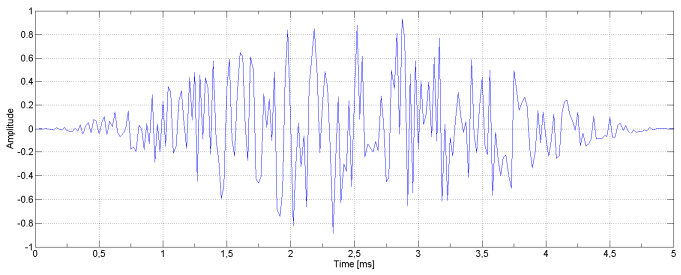
Three candidates were tested for measuring: chrip, white noise and filtered white noise. First two mentionen have parameters set to respect the limitations of loudspeaker and microphone of device – frequency is in range 2 000 Hz – 7 500 Hz. To not loss refleted sound from object in transmitted sound, the length of all transmitted sounds is five milliseconds. This length allows to measure distances from approximately 0.5 metres. The upper limit is determined by strength of signal, for average mobile device, it is approximately 3.5 metres.

Chirp

Chirp is cosine wave shaped signal with growing frequency over time, frequency range:
2 000 Hz – 7 500 Hz.



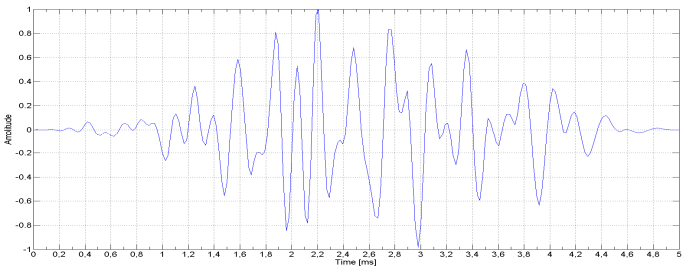
White noise



White noise is random independent signal, it is obtained generating random data.

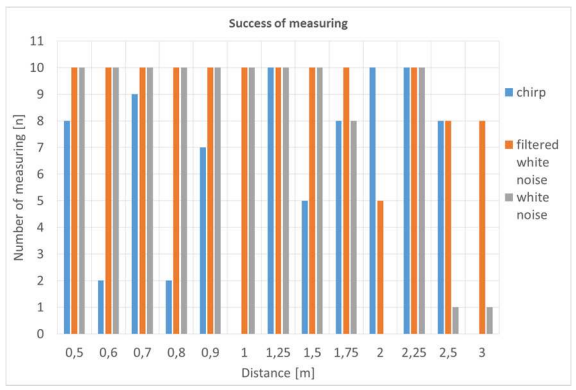
Filtered white noise

Filtered white noise is white noise filtered through band-pass filter to contain only frequencies:
2 000 Hz – 7 500 Hz.

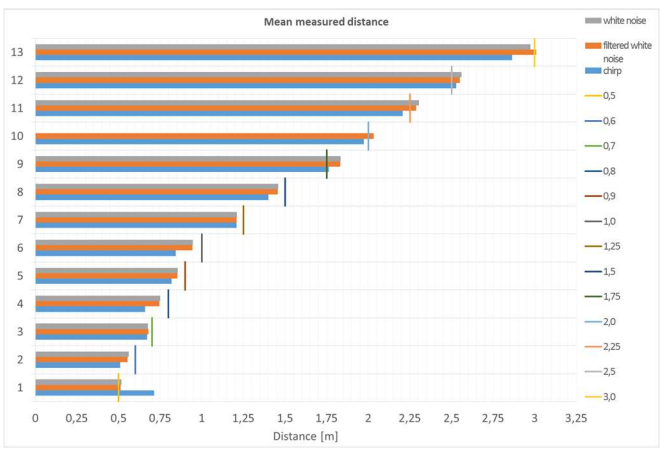


Testing

Thirteen different distances were measured, each of them has been measured ten times.



The first graph shows the number of succesful measurements. The measurement is consider succesful, if the difference between measured distance and the real distance is less then one tenth of meter.



On the second graph, the accuracy of measurement is seen. The vertical line indicates the real distance. The horizontal lines are average values measured using signals.

Conclusion

The application with designed algorithm achieves the best results using filtered white noise with frequency range 2 000 Hz to 7 500 Hz, the range of distances it is able to measure is from half a meter to approximately three meters taking into account the noise environment. Using filtered white noise, the accuracy of measurement is one tenth of meter and the average success rate is 93 %.

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2015