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Indoor Localization Using Controlled Ambient Sound

Ish Rishabh
University of California, Irvine
irishabh@uci.edu

Don Kimber
FX Palo Alto Laboratory, Inc.
kimber@fxpal.com

John Adcock
FX Palo Alto Laboratory, Inc.
adcock@fxpal.com

ABSTRACT

Indoor locations such as malls, stores, museums, or office spaces are often equipped with loudspeakers to play music, or sound conditioning speakers to play noise or ambient sounds to soften environmental noise. We present a system which can leverage this infrastructure with little modification, to support indoor localization of devices like smartphones, tablets and laptops, without the need of any specialized hardware in these devices.

The system employs an acoustic localization scheme requiring no explicit prior synchronization between playing and recording systems. Controlled sounds played from multiple speakers at known locations are recorded by the device to be located. The signals used are low energy periodic pseudo random white noise with short period of about 0.5sec. A running average of the windowed generalized cross correlation is computed between the known reference signals and recorded signal, and peaks are used to determine which signals are present, and to estimate arrival delays for those signals. We use the cross correlation over an extended time to improve the signal-to-noise ratio and to estimate clock drift rates, necessary to compensate for mismatched speeds between the playback and recording sample clocks.

In our experiments we set up several zones of our lab, each playing distinct signals from 6 speakers, using inexpensive USB surround sound devices. The system is able to determine the zone whenever any of the signals are detected. Within a zone, when 4 or more signals are detected, it is possible to estimate the position of the microphone as well as the time difference between playing and recording clocks by, numerical optimization. Once synchronization is thus established, the position can be updated any time 3 signals are detected, and assuming a known height, position can be updated using just 2 detected signals. In a 11x7.3m meeting room the system achieved half meter accuracy 94% of the time. We have implemented an Android App, which uploads recorded audio to a server for analysis, which then returns position estimates that are shown on a floorplan in the App. We found that the system works well even when the reference signals are mixed with normally played sounds, such as music.

KEYWORDS: Location based on TOA, Location based on TDOA, Systems based on sounds.