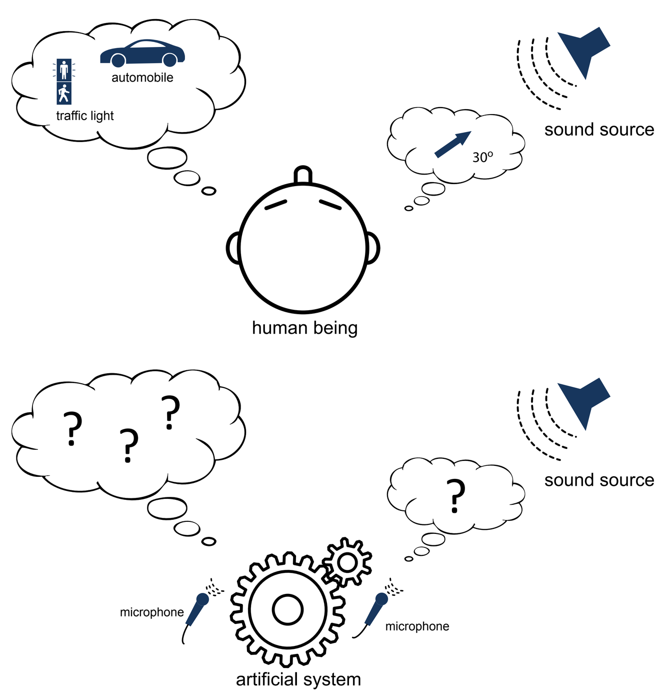
Wearable Sound Localization Assistive Device for the Hearing Impaired

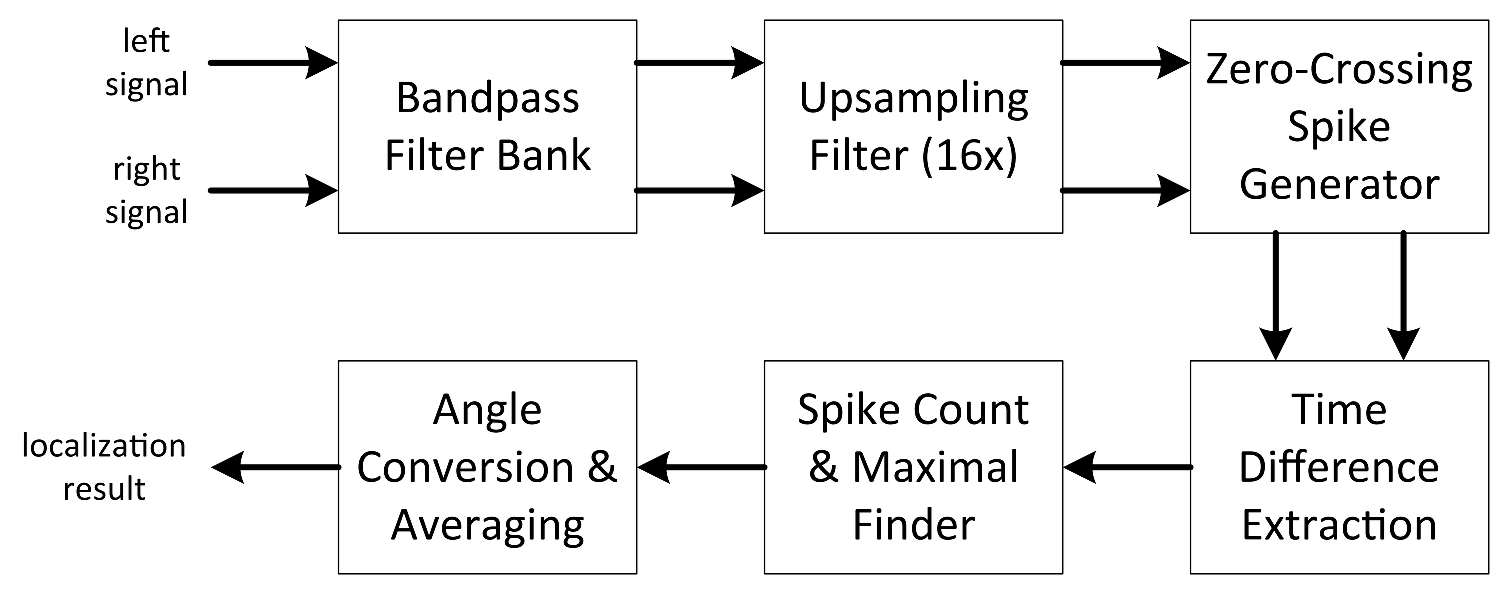
Mauricio Kugler, Hiroyuki Sakamoto & Masatoki Suto
Department of Computer Science & Engineering, Nagoya Institute of Technology, JAPAN

Abstract: The sense of hearing can provide immediate information about remote events, even when outside of the field of vision and beyond obstacles, facilitating functioning in uncontrolled environments. Hearing impairment can thus have a huge disabling effect on an individual. This paper proposes a wearable self-contained dedicated device capable of full-plane sound localization. The system, shaped as a glass frame, uses only four microphones spaced by 10 mm, and is initially targeted at a resolution of 45°. The individual binaural angles are calculated by a process loosely based on the human hearing system. These angles are then combined in order to determine the final direction. A prototype of the proposed system was implemented using 3D printing and MEMS microphones. Experiments with the prototype in a reverberant environment show an error of 6.73° when it is tested standalone and 21.16° when tested in a dummy head.

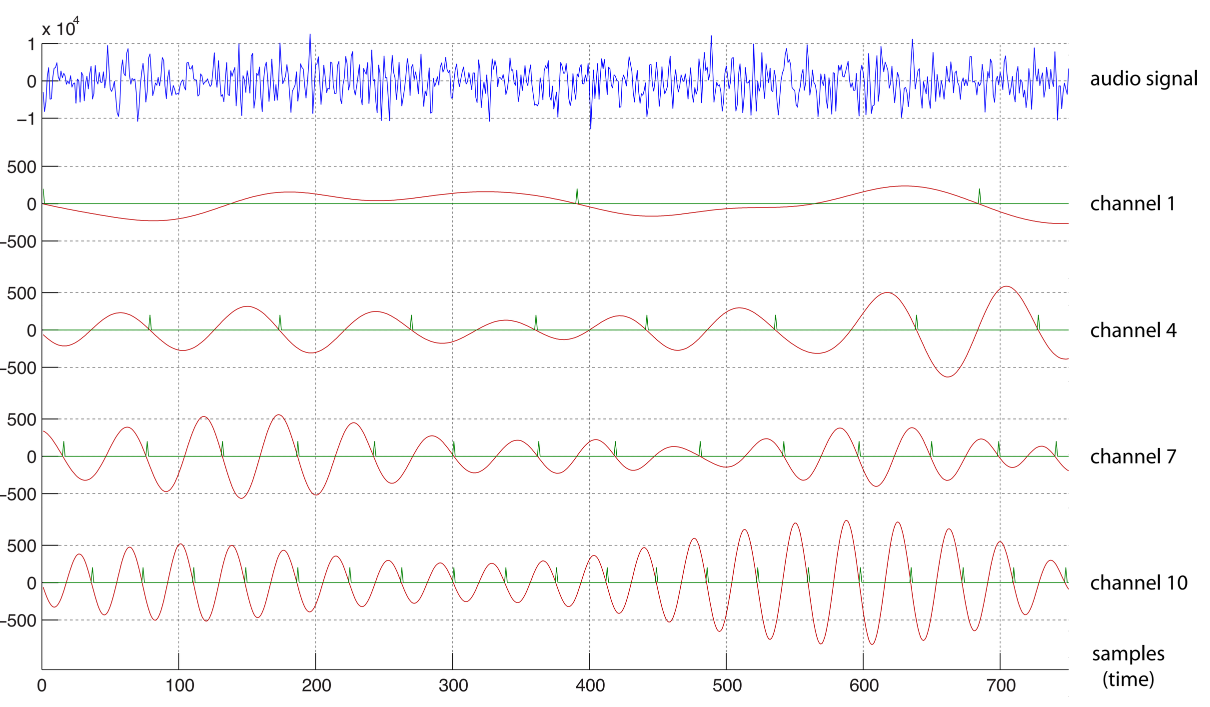
Motivation



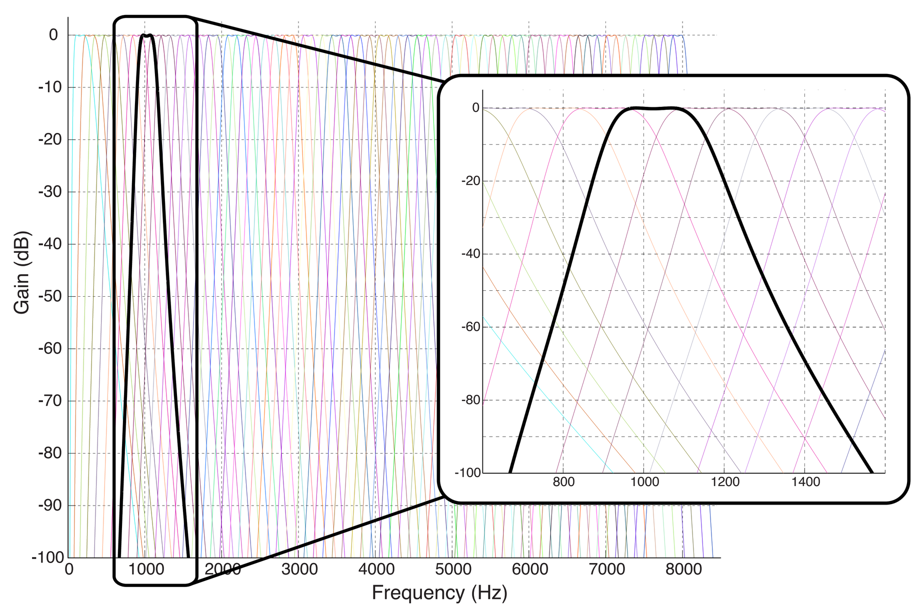
Localization System Overview



Pre-Processing Summary

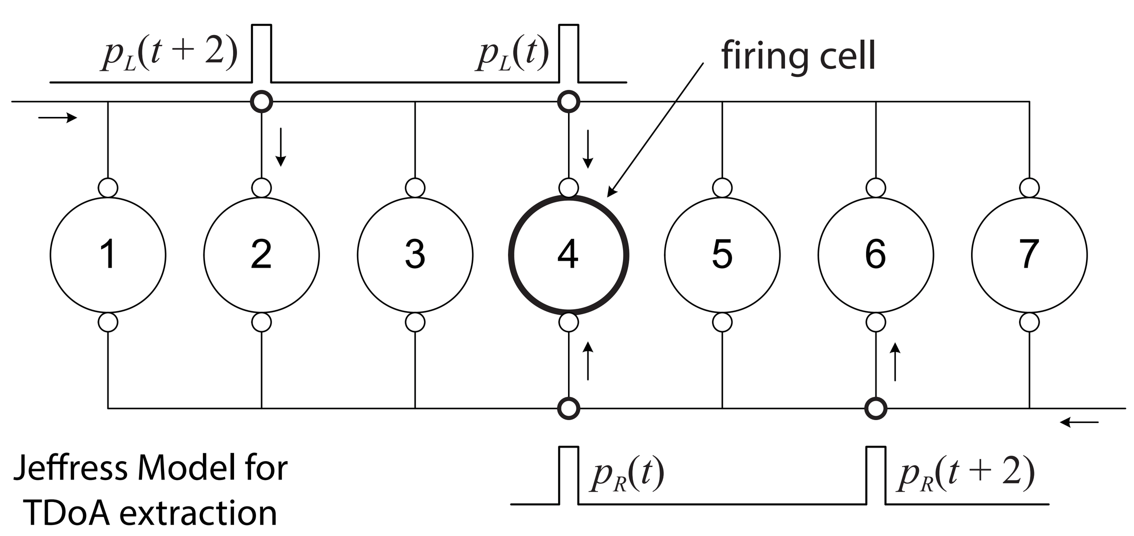


Band-pass filtering



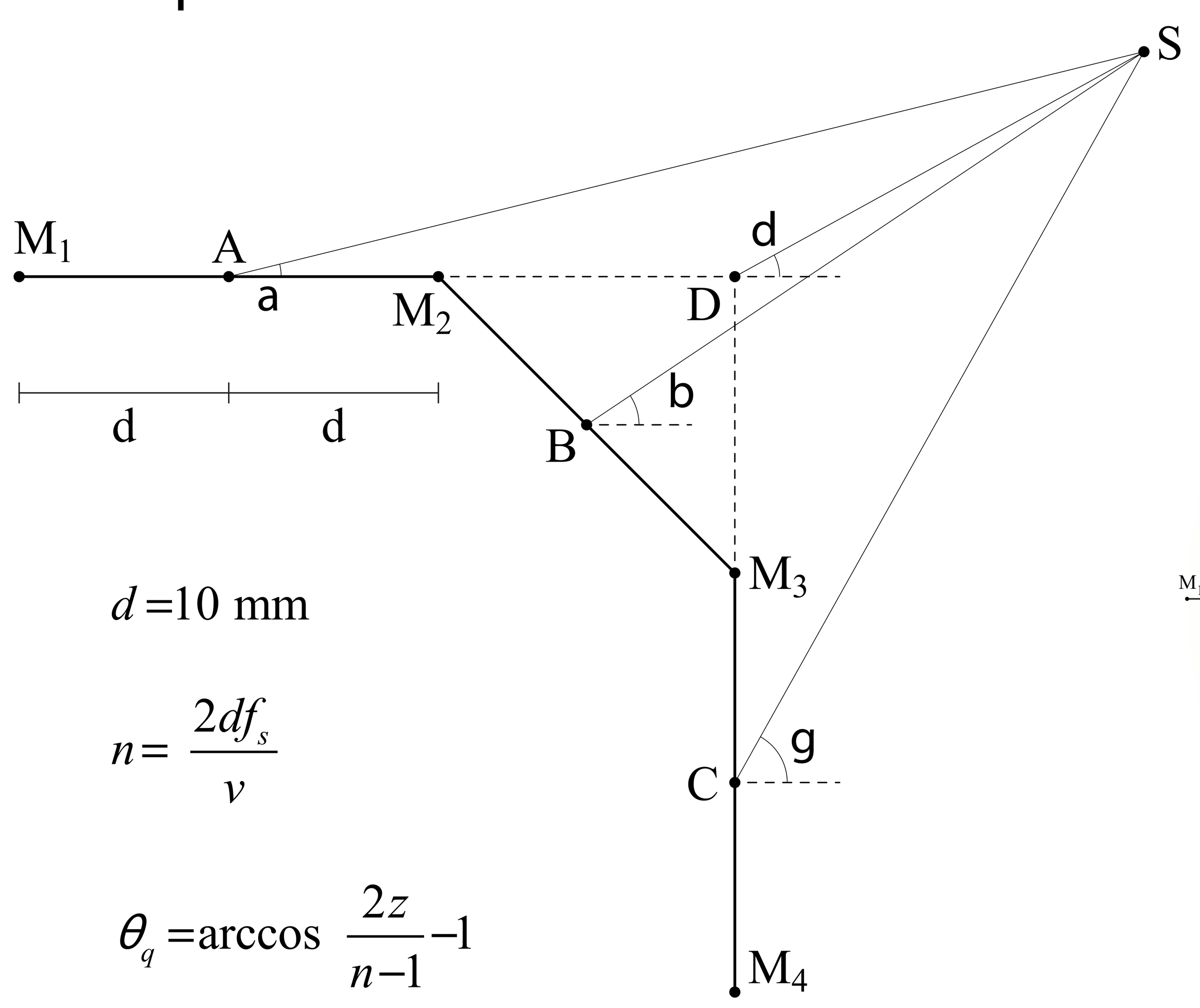
IIR 4th order, 4 stages elliptical filters @ 48kHz, 100Hz ~ 8kHz, 64 channels, s.p. floating point

Time-Difference Extraction



Jeffress Model for TDoA extraction

Proposed Model



$$d = 10\text{ mm}$$

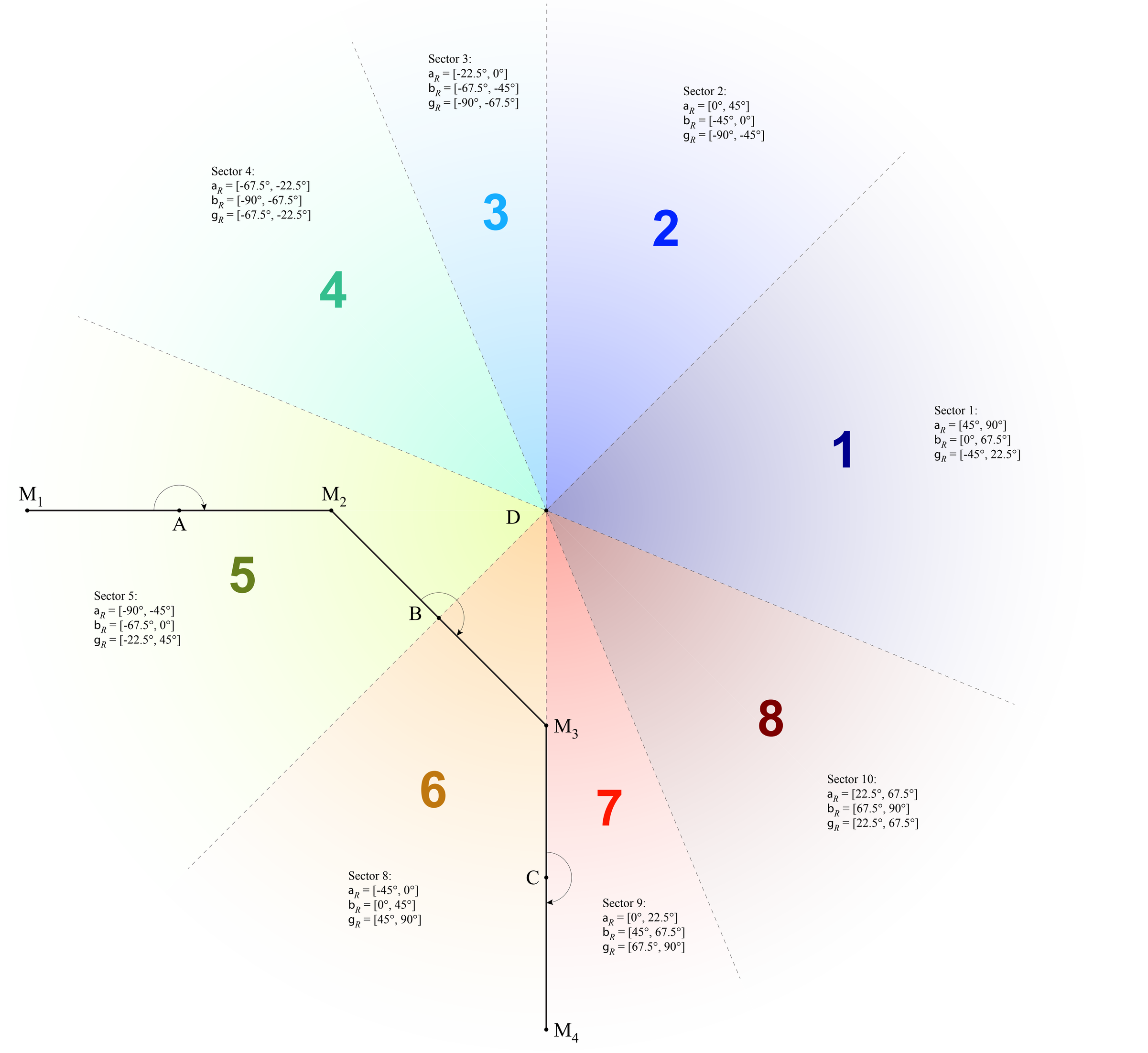
$$n = \frac{2 d f_s}{v}$$

$$\theta_q = \arccos\left(\frac{2z}{n-1} - 1\right)$$

$$v = \lambda f_{max} \qquad f_{max} = \frac{v}{2d}$$

$$\delta = \arctan\frac{A_y \tan\beta - B_y \tan\alpha + (B_x - A_x)\tan\alpha\tan\beta}{A_y - B_y - A_x\tan\alpha + B_x\tan\beta}$$

Angular Sectors

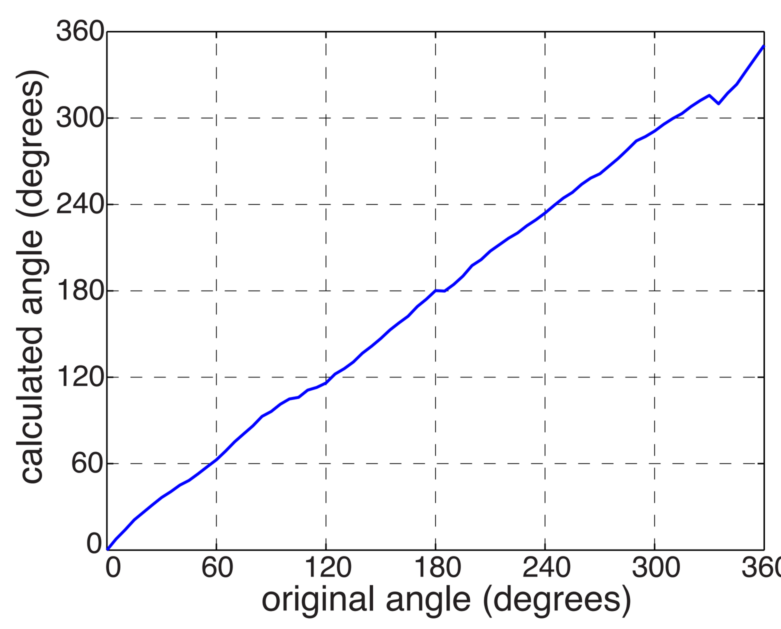


Only two of the binaural angles are required to determine the angle δ. As the Jeffress model presents low resolution for angles close to -90° or +90°, the two angles further from these regions are chosen, reducing the overall error of the system.

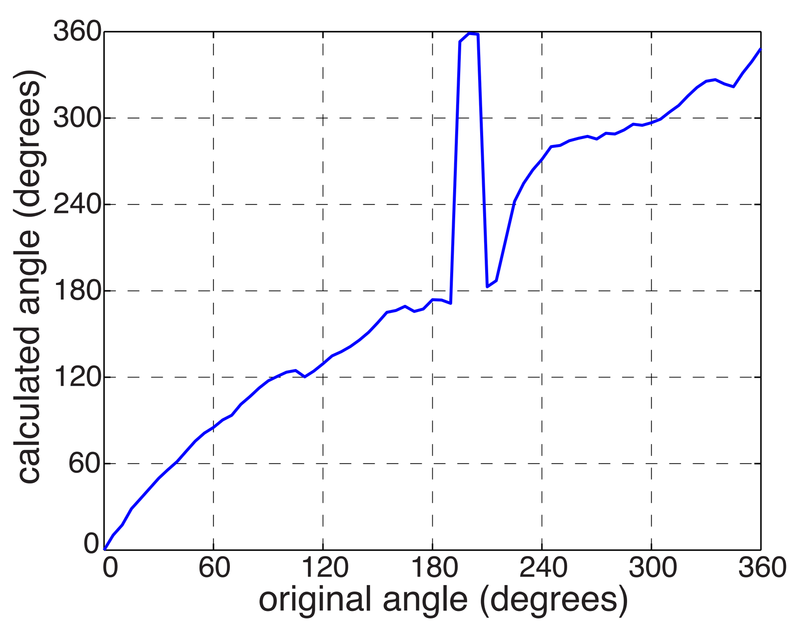
Hardware Prototype

3D-printed wearable sound localization prototype, placed on the dummy head. It contains four INMP401 MEMS microphones separated by 10 mm, powered by a CR2032 battery. The processing unit is not included in this early version.

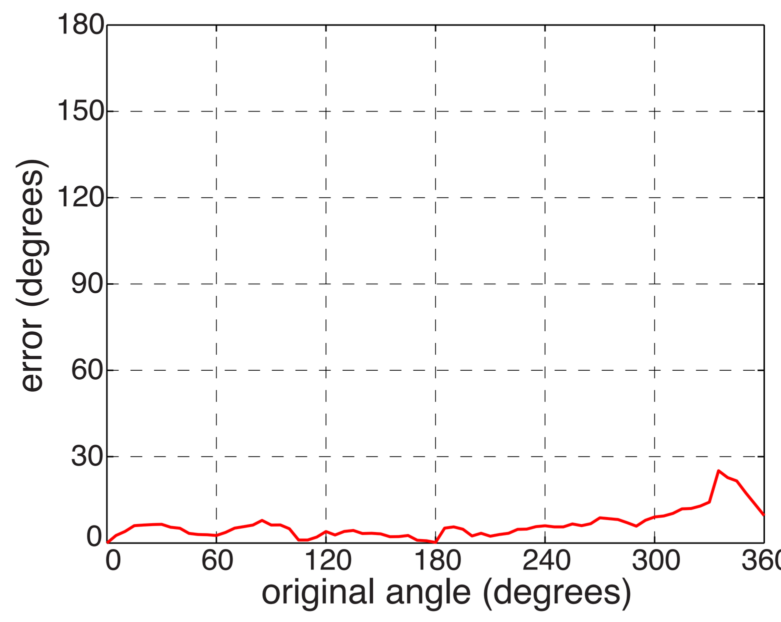
Experiments: Localization Accuracy

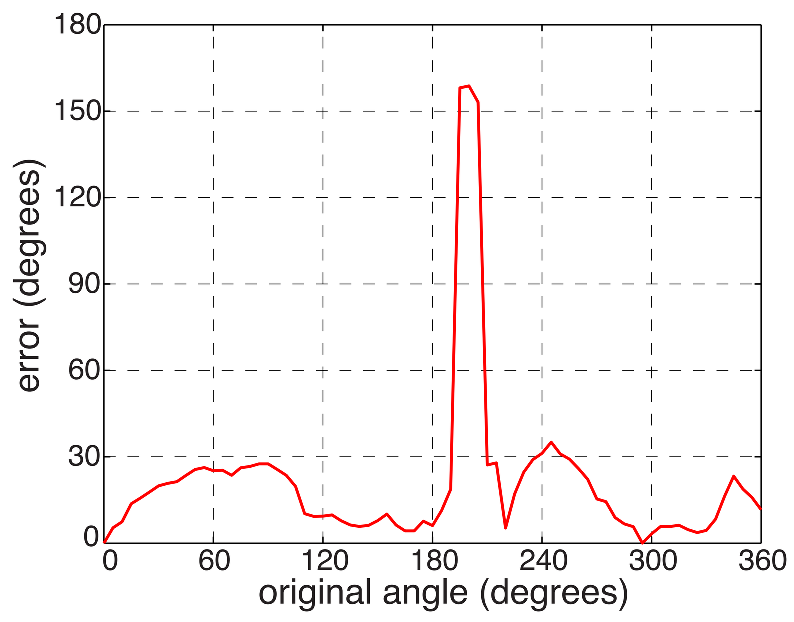


Localization results (above) and angular error (below) of the stand-alone prototype average error = 6.73°, maximal error = 20.41°

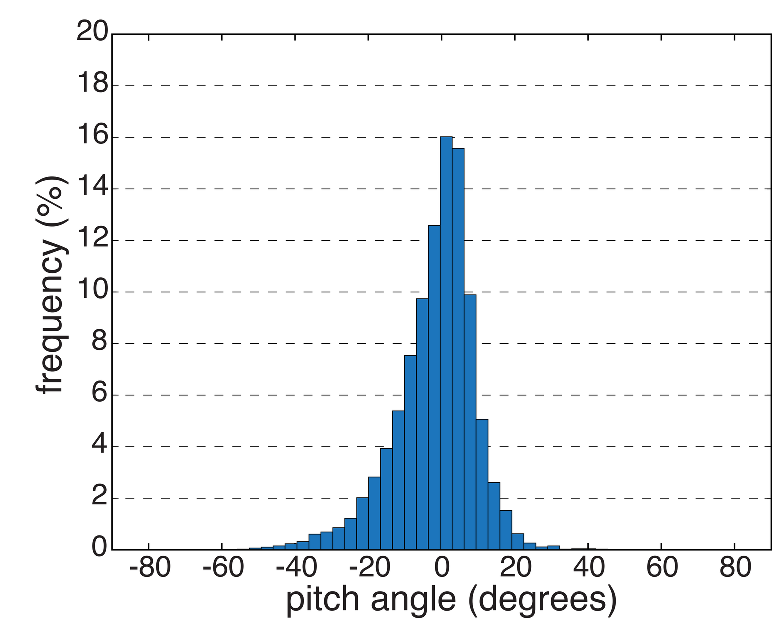


Localization results (above) and angular error (below) of the prototype on the dummy head: average error = 21.16°, maximal error = 158.77°

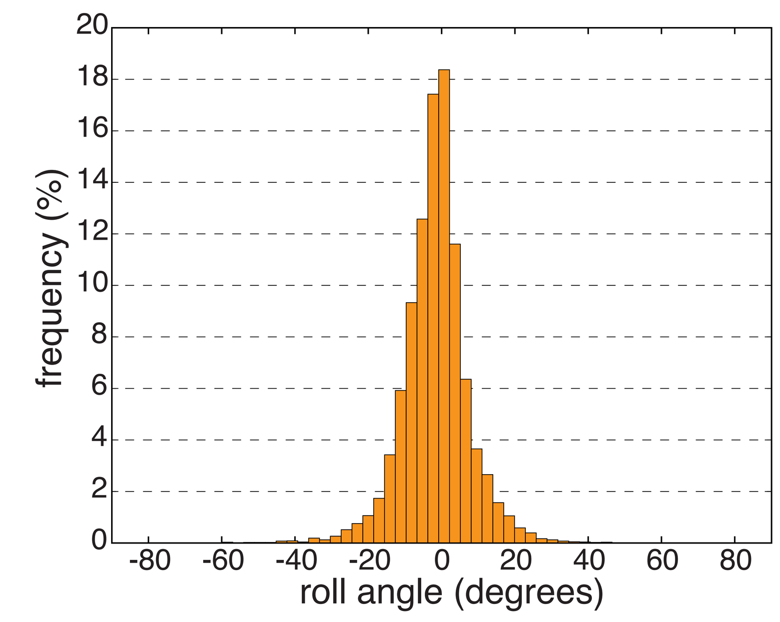




Attitude Estimation



MMA8451Q accelerometer, fs = 12.5Hz, fc = 0.5Hz
Pitch: average = -1.72°, standard deviation = 10.79°
Roll angle: average = -1.57°, standard deviation = 8.74°



Mauricio Kugler (mauricio@kugler.com), Nagoya Institute of Technology, Showa-ku, Gokiso-cho, 466-8555, Nagoya, JAPAN, Tel: +81-52-735-5461