Autonomous Vehicle Navigation with Ultrasound Beams

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Motivation

Ultrasound based autonomous vehicle navigation systems are more suitable than LIDARs for military uses

- Ultrasonic beams attenuate faster than laser beams allowing autonomous vehicles to navigate without exposing their locations
- Ultrasonic is less affected by harsh weather conditions
- Ultrasound based navigation systems can be made small and energy efficient

Fundamental Research Questions

What biosonar mechanisms can we use to build an energy efficient ultrasound sensing system? (e.g. bats)

What mechanism can efficiently steer beams to scan surroundings?

What types of ultrasound beams can provide long detection range?

How can we generate 3D images of surroundings with reflected ultrasonic beams returning from different directions?

Objectives

Build a prototype for ultrasound-based vehicle navigation system

- Develop a lens that can steer beams from a fixed sound source
- Generate ultrasonic beams that can reach the far-field (∼100m)
- Create 3D maps of surroundings in various environments

Approach

i. Design a lens that transmits acoustic beams in desired directions

Refractive indices for beam forming lenses

We control the gradient of the acoustic refractive index inside a metamaterial-based device to obtain lenses that transform cylindrical waves into beams propagating in controlled directions

ii. Develop a mechanism to reconfigure the acoustic lens

Beam steering with a reconfigurable lens

By changing the shape of the lens bottom we can control the direction of transmitted beams

Results

- Lens was optimized to allow controlling phase at the lens exit with minimum surface deformation and maximum energy transmission

Surface height vs Refractive Index

Lens surface elevation up to 1.6mm was sufficient to achieve phase variation required for 20° steering

- Lens design was validated with 3D simulations that include losses from thermal and viscous effects.

Lens simulation in thermo-viscous module

Simulation result showed that the lens would successfully form and steer ultrasonic beams

- Built a prototype of the lens to demonstrate beam steering

Lens fabrication with a 3D printer

Inclusions are 0.25mm thick and 1.2mm tall. Also, the gap between each inclusion is 0.25mm.

Conclusions

- An acoustic lens can simultaneously form beams and control their directions without moving the sound source or rotating the system
- The lens is designed to minimize insertion loss and thus couple most of the source energy into the scanning beam. Consequently, it is able to image obstacles far from the sensor

Future Work

- Develop an actuation mechanism to automatize the lens
- Evaluate the sensing system in various environments
- Use biosonar-inspired methods to create maps of the environment from received echoes