بسم الله الرحمن الرحيم

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شبكة المعلومات الجامعية

التوثيق الإلكتروني والميكروفيلم

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AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
DEPARTMENT OF MECHATRONICS

Audio-Visual Trajectory Planning in Dynamic Environment and Navigation Assist System for Autonomous System

A Thesis submitted in the Partial Fulfillment for the Requirement of the Degree of PhD in Mechanical Engineering

By

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MSc in Mechanical Engineering 2009

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Statement

This dissertation is submitted to Ain Shams University in partial fulfillment of the degree of Doctor of Philosophy in Mechanical Engineering.

The work included in this thesis was carried out by the author at the department of Mechatronics, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis was submitted for a degree or qualifications at any other university or institution.

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List of Publications

1. M. A. Awad-Allah, M. A. Abdelaziz, M. A. Shahin and F. A. Tolbah "A modified Sampling Method for Localization Accuracy Improvement of Monte Carlo Localization". *18th International Conference on Applied Mechanics and Mechanical Engineering*, Military Technical College, 3-5 April, 2018.

2. M. A. Awad-Allah, A. Hamdy, M. A. Abdelaziz, M. A. Shahin and F. A. Tolbah “A two-stage approach for passive sound source localization based on the SRP-PHAT algorithm,” *APSIPA Transactions on Signal and Information Processing*, Cambridge University Press, 9, p. e8, 2020.

Abstract

Autonomous systems pose several opportunities and challenges at the same time in many civilian and military applications. Auditory system is an essential ingredient in robotics and Sound Source Localization (SSL) is an important part of such system. Such system may become essential when other sensing systems (vision for example), are impaired due to bad lighting conditions or any other reason. The auditory system is even expected to be economical and small enough to fit on the robot which adds more difficulties to the constraints of accuracy and robustness.

In this work, a two-stage approach to the acoustic localization problem is suggested. The aim is to minimize the search area for the SRP-PHAT algorithm and increase the reliability and accuracy of the localization system especially when using low cost compact microphone array. The search area is minimized by estimating the Direction of Arrival (DoA) of the acoustic location and then forming a boundary around this estimated DoA according to the confidence level of this estimation along with the range of the microphone array.

The Root Mean Square Error (RMSE) obtained with the proposed approach is lower than SRP-PHAT algorithm in more than 90% of the cases. The results obtained also proved that the proposed approach is successful even when only 1000 search points are used instead of 125000 points in case of the conventional algorithm, which greatly reduces the time of calculations to be less than 1% of time taken with conventional algorithm.

This means that the proposed approach develops a robust, accurate, computationally non-intensive SSL system that can be used on a mobile robot to find the coordinates of a sound source in an indoor environment using a small microphone array. Navigation to that source is thus made through optimal trajectory planning and avoiding static as well dynamic obstacles after the robot is equipped with all needed of hardware and software. The complete set presents a safe and reliable autonomous system.

Key words: Sound localization, Autonomous system, Robot navigation, Face detection.

Table of Contents

List of Symbols

c	Sound speed
M	Microphone array
m	Microphone location
N	Number of sample point
n	Wheel rpm of robot
r	Acoustic range of the microphone array
$S_i(\omega)$	Acoustic signal in the frequency domain of microphone i
$S_i(\tau)$	Acoustic signal in the time domain of microphone i
$\vec{u}$	Unit direction vector
v	Longitudinal velocity of robot
W	Wheel base of robot
x	x-axis
y	y-axis
z	z-axis
ε_1	Gaussian noise of DoA in azimuth
ε_2	Gaussian noise of DoA in elevation
σ_1	Standard deviation of DoA in azimuth
σ_2	Standard deviation of DoA in elevation
$\hat{\theta}$	True DoA azimuth angle
$\hat{\phi}$	True DoA elevation angle
θ	Estimated DoA azimuth angle
ϕ	Estimated DoA elevation angle
τ_{ij}	Time difference of sound between microphone i and microphone j

$\mathcal{F}$	Fourier Transform
$\mathcal{F}^{-1}$	Inverse Fourier Transform
ψ_{PHAT}	PHAT weighting function
γ	Wheel angle of robot
f	Sound frequency
λ	Wave length
ρ	Wheel diameter of robot
ω	Yaw rate of robot