# Enhancing Interpretation of Uncertain Information in Navigational Commands for Service Robots Using Neuro-Fuzzy Approach

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Degree of Doctor of Philosophy

Department of Electrical Engineering

University of Moratuwa

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# DECLARATION

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I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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M. A. Viraj J. Muthugala Date

The above candidate has carried out research for the PhD thesis under my supervision.

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Dr. A. G. Buddhika P. Jayasekara Date

## Abstract

An intelligent service robot is a machine that is able to gather information from the environment and use its knowledge to operate safely in a meaningful and purposive manner. Intelligent service robots are currently being developed to cater to demands in emerging areas of robotic applications such as caretaking and assistance, healthcare and edutainment. These service robots are intended to be operated by nonexpert users. Hence, they should have the ability to interact with humans in a human-friendly manner. Humans prefer to use voice instructions, responses, and suggestions in their daily interactions. Such voice instructions and responses often include uncertain information such as "little" and "far" rather than precise quantitative values. The uncertain information such as "little" and "far" have no definitive meanings and depend heavily on factors such as environment, context, user and experience. Therefore, the ability of robots to understand uncertain information is a crucial factor in the implementation of human-friendly interactive features in robots.

This research has been conducted with the intention of developing effective methodologies for interpreting uncertain notions such as "little", "near" and "far" in navigational user commands in order to enhance human-robot interaction. The natural tendencies of humans have been considered for the development of the methodologies since ability of the robot in replicating the natural behavior of humans vastly enhances the rapport between the robot and the user. The methodologies have been developed using fuzzy logic and fuzzy neural networks that are capable of adapting the perception of uncertain information according to the environment, experience and user. User studies have been conducted in artificially created domestic environments to experimentally validate the performance of the proposed methods. An intelligent service robot named as Moratuwa Intelligent Robot (MIRob), which has been developed as a part of the research, has been used for the experiments.

The robot's perception of distance and direction related uncertain information in navigation commands is adapted according to the environment. According to the experimental results, a service robot can effectively cope with distance-related uncertain information when the robot's perception of distance-related uncertain information is adapted to the environment. The effectiveness can be further improved by perceiving the environment in a human-like manner. The adaptation of the directional perception in accordance to the environment remarkably improves the overall interpretation ability of uncertain notions. User feedback is used to adapt the perception toward the user while adapting to the environment and this adaptation vastly improves user satisfaction. Methods have also been proposed to interpret the uncertain information in relation to relative references and the methods are capable of replicating human-like behavior. Furthermore, the information conveyed though pointing gestures that accompany voice instructions is fused to further enhance the understanding of the user instructions. This fusion significantly reduces the errors in interpreting the uncertain information. Furthermore, it reduces the number of steps required to navigate a robot toward a goal. A vast research gap is still remaining in this particular research niche for future developments and hence possible future improvements are also synthesized.

***Keywords*-Understanding Uncertain Information; Human-Friendly Robotics; Human-Robot Interaction; Social Robotics, Service Robotics**

# DEDICATION

*To my beloved parents*

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# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES