UNIVERSITÀ DI BOLOGNA

School of Engineering

Master Degree in Automation Engineering

Distributed Control Systems

COVERAGE CONTROL FOR COOPERATIVE MULTI-ROBOT NETWORKS

Professor: **Giuseppe Notarstefano**

Students:
Donato Brusamento
Mattia Micozzi
Guido Carnevale
Lorenzo Draghetti

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Abstract

The aim of the project hereby presented was to transpose the algorithms described in the research paper [1] into a proper Matlab environment suitable for simulation and results analysis.

The aforementioned algorithms has been simplified in order to adapt to both an offline, sequential approach (from now on called **offline**,or **centralized**) and to a parallel (single machine), asynchronous one (from now on called **online**,or **distributed**).
In both approaches, the simulation implements a simple proportional closed loop control, but while in the former it is all done inside a centralized *for loop*, in which informations about each agent is readily available to all others, in the latter we tried to be more faithful to the original formulation, in which every agents has to exchange with other agents informations about each other's positions in a timely manner, while being "deaf" (to a certain extent) in-between successive communications.

To achieve all of this we've made use of Matlab's *Parallel Computing Toolbox* to simulate the independent agents as communicating threads.
In the distributed version of the simulation we also implemented a visual comparison between the two approaches so to show how they bring slightly different results.

Contents

List of Figures

Introduction

A mobile wireless sensor network (MWSN) can be defined as a wireless sensor network (WSN) in which the sensor nodes are mobile. For example the nodes can be wheeled robots scattered in a given area.
MWSNs are a an emerging field of research in contrast to their well-established predecessor. They are much more flexible than static sensor networks as they can be deployed in any scenario and deal with rapid topology changes due to node failures or new added sensors. In general each node consists of a radio transceiver, a microcontroller powered by a battery and one or more sensors to detect certain properties of the environment. [2]
Typical applications of this kind of network are environment monitoring, surveillance, search and recovery operation, exploration.
A problem that can arise in this context is the optimization of the coverage of a given area knowing the distribution density function, defined on that area, of a given property we would like to measure. The objective of this project was to implement a distributed and asynchronous algorithm to solve this problem, following the method proposed in the research paper [1].

The framework (scenario?) we considered, as suggested on the abovementioned paper, is the following: n mobile sensor-robots modelled as simple integrators strewn on a convex polytope(area) defined in $\mathbb{R}^2$; on this area a random normal density function $\phi : Q \to \mathbb{R}_+$ is defined to represent the distribution of the feature that sensors have to measure. Each node has sensing(can locate the other nodes positions) and communication capabilities. The proposed algorithm is the Lloyd one, a gradient descent method that guarantees the convergence to an optimal solution from the point of view of nodes coverage and degradation of sensing capabilities exploiting the notion of Voronoi partition. Considering a convex polytope Q in $\mathbb{R}^N$ and n sensors, for the sensor positions $P = \{p_1, ..., p_n\}$ the optimal partition of Q is the Voronoi partition $V(P) = \{V_1, ..., V_n\}$, where V_i is the Voronoi cell of the i-th sensor:

$$V_i = \{q \in Q | \, \|q - p_i\| \leq \|q - p_j\|, \forall j \neq i\}$$

Basically each V_i represents the space region in which sensor i is performing

his task.
Conceptually this algorithm runs iteratively other 2 algorithm: one, called "Adjust-sensing radius algorithm", to compute the voronoi cell of each sensor and the other "Monitoring algorithm" to check if the computation of the Voronoi cell has to be updated because of some changes in the network(variation of nodes positions, node failures,...).
We implemented this procedure on Matlab in 2 ways:

1. in a centralized sequential way
2. in a distributed parallel fashion, exploiting files reading-writing to realize communication among nodes

These two implementations and the differences between them are well-explained and analysed in this report
In particular, in the first chapter the problem set-up and the implemented solutions are described; the second chapter contains the analysis of the obtained results; final conclusions end the report.

INTRODUCTION MUST BE MAX 2 PAG

Motivations

Contributions

Describe what is the contribution of this project.

Chapter 1

Chapter 1
Problem set-up and solutions

First-chapter for problem set-up and description of the implemented solution.

1.1 Section title

1.1.1 Subsection title

Citation [**?**]

Chapter 2

Chapter 2

Results analysis

Second chapter for description of the results (simulations and experiments where applicable).

2.1 Section title

2.1.1 Subsection title

Citation [**?**]

Conclusions

Bibliography

[1] J. Cortés, S. Martìnez, T. Karatas, F. Bullo. "Coverage Control for Mobile Sensing Networks" IEEE Transactions on Robotics and Automation, Vol. 20, No. 2, April 2004

[2] T. Hayes and F.H. Ali. "Mobile Wireless Sensor Networks: Applications and Routing Protocols" Handbook of Research on Next Generation Mobile Communications Systems. 2016.