Cooperative Robot Movements for Guiding and Regrouping People using Cost Function Evaluation

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Abstract—The objective of this research is to optimize robots’ cooperative work and obtain the minimum displacement of humans in a guiding people mission, where some individuals can escape from the formation and must be regrouped by robots. The guiding mission is done in an urban environment, with obstacles and building constraints, where people can move freely and using multiple mobile robots which work cooperatively. In this paper, the forces that actuate toward robots will be studied, which are the forces between robots and humans and the forces between humans. Our goal is to find out the minimum work required for robots to lead and regroup people. We have developed a cost function that minimizes the work required in order to do this cooperative task.

I. INTRODUCTION

The interaction between social robotics and cooperative robotics areas is a new field of study. Therefore, the number of publications that exist nowadays is quiet short, specifically, if we refer to the study of guiding a group of people in urban areas with several robots. We can find some works using a single robot leading people in exhibitions and museums [2], or in hospitals [3]. In previous work [4], a model for guiding people in a dynamic environment using several robots working in a cooperative way was presented. This model is called “Discrete Time Motion” (DTM), which is used to represent people and robot motions.

In this research we present a method to optimize locally the tasks assignment to robots for doing their missions. Robots’ assignation are done by analyzing the minimum work required to do such task, where the function to minimize is based on one hand, by robot’s motion, and, on the other hand, by the impact of such motions on people’s displacement.

II. OPTIMAL ROBOT TASK ASSIGNMENT FOR COOPERATIVE MISSION

The cost function, described below, speaks in Work terms, and it can be divided as: (i) Robot work motion, and (ii) Human work motion.

In order to know what robots’ tasks are, we have considered the following situations: (i) The leader robot has to guide people, (ii) one robot has to look for the person (or people) that can potentially escape from the crowd formation and push him (or them) to regroup him (or them) into group, and, (iii) one robot has to go behind the people in order to push them in case that the crowd formation is broken down.

The Robot tasks that we are considering are, Leader task which computes a path planning and moves to the next point, where exists a drag force that will attract people behind the robot. Looking for a person that goes away task: The robot moves to the estimated position of the individual who goes away from the crowd formation, the estimation is computed using a Particle Filter [1]. Pushing task: The robot pushes a person that has gone away in order to reach the crowd formation. Crowd traversing task: The robot has to move through the formation to achieve the estimated position of the person that goes away from the crowd formation. In this work we are not taken into account this situation, due to safety reasons. We use the equations defined in previous works on human behavior with other individuals [6]. Working with autonomous mobile robots, the robot $i$ work motion is expressed by:

\[ f^m_i = m_ia_i \]

\[ W^m_i = f^m_i\Delta x_i \]

where $m_i$ is the mass of the $i$-th robot, $a_i$ its acceleration and $\Delta x_i$ the space traversed by the robot to achieve its goal.

The effect of robots on people as forces is: leader robot; attractive (dragging) force, it is inversely proportional to the distance, until a certain distance, and, shepherdling robot: Repulsive (pushing, traversing) force, has a repulsive effect inside people’s living space.

The dragging force is necessary when the leader robot guides the group of people from one place to another. It acts as an attractive force, the force applied by robot leader $i$ to each person $j$ and the dragging work are defined by:

\[ f^m_i = m_ia_i \]

\[ W^m_i = f^m_i\Delta x_i \]
where \( d_{ij}(t) \) is the normalized vector pointing from person \( j \) to robot \( i \) at instant \( t \). See [5] for more information about the parameter \( C_{ij} \), which reflects the attraction coefficient over the individual \( j \), and it depends on the distance between the robot leader and person \( j \). Where \( \Delta s_{ij} \) is the distance traveled by the person \( j \).

The Pushing force is given by the repulsive effect developed by shepherding robot on the group of people, for regrouping a person (or the broken crowd) in the main crowd formation. The territorial effect may be described as a repulsive social force, and the work can be computed as:

\[
f_{ij}^p(t) = \frac{-C_{ij} x_i(t) - x_j(t)}{d_{ij}(t)}
\]

\[
d_{ij}(t) = \left\| x_i(t) - x_j(t) \right\|
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\[
W_i = \sum f_{ij}^p \Delta s_{ij}, \forall \text{ person } j
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