論文の内容の要旨

Abstract of dissertation

論文題目　Mobile Robot Control Scheme Based on Distributed and Onboard Sensors
(分散されたセンサとオンボードセンサに基づく移動ロボットの制御スキームに関する研究)

氏　　名　ブルシュチッチ　ドラジェン
Dražen Brščić

Mobile robots are becoming more and more sophisticated and the research on them is turning towards new applications. One of the desired advancement of mobile robots nowadays is their deployment in spaces that are populated by humans, like homes, offices, public spaces, etc. This will make possible new applications, such as robot servants or other service robots. However up to this date, there are almost no working implementations of robots in such environments. The reason for that lies in the fact that the robotic intelligence has still not matured to a level that would allow easy coexistence with humans. Computers are not yet able to grasp and deal with the complex organization of our lives, and the resulting complexity of our actions and the environments we live in.

The standard approach to the application of mobile robots is to provide the robot with sensors and computing power, and implement the necessary intelligence to do the required tasks, much in the same way like humans do. However, seeing that using this approach we are still not able to achieve the needed smartness and abilities of the mobile robot, in this thesis we propose a different approach to the problem. This is to distribute the intelligence between the robot and the space it acts in, under the assumption that this kind of synergic combination of outside and inside intelligence will lead to a considerable advantage when compared to the standard all-onboard approach.

Therefore, in the thesis we work on the control of the mobile robot in environments that have distributed sensing and computing power. These types of spaces are given the name Intelligent Spaces. Although the research on such spaces is steadily growing, its application for better control of mobile robot has not yet been discussed. This is the objective of this thesis. The thesis is divided into several chapters, which present parts of the work done during the doctoral course.

Chapter 2 gives an overview of what Intelligent Spaces are, what are their characteristics and what can be done with them. As a fairly new research ground there it has not progressed very much, however the benefits of having distributed intelligence in the space are steadily catching the interests of many researches. The number of applications on the human understanding or human machine interaction is steadily rising, and it is expected that this kind of concept will become standard in that

area. An overview of similar researches is also given, describing the basic trends and similar research areas, such as ubiquitous computing or sensor networks. After that the connection between mobile robots and Intelligent Spaces is described. Here we discuss what is that mobile robots offer when implemented in Intelligent Spaces – this can be broadly be divided into two applications: media for physical services and mobile sensing device. Following that, we discuss the main merits the introduction of Intelligent Space has for mobile robots, however a detailed discussion on that topic is reserved for later chapters.

The following chapter 3 is concerned with the motion control of the mobile robot. Considering the type of application we are aiming at in this work, here we consider several methods for robot control and compare their characteristics. The control is divided into two parts: global path planning and local path following and obstacle avoidance. Each of these parts is explained and the methods explained and compared in experiments. Then path planning and obstacle avoidance – i.e. the methods which gave the best result: Field D* method and the Dynamic Window approach – are combined together in order to get a control method that has good navigation characteristics and can achieve movement at high speeds with consideration of obstacles or humans around the robot and without bumping into them. The basic two-step method is also expanded in order to achieve better behavior in the vicinity of dynamic objects. Since in the environments we are trying to make are robots move there will be many dynamic objects, mostly humans, this type of improvement is needed. We describe a rather simple but effective moving object avoidance algorithm based on the prediction of the future position.

The methods described in chapter 3 rely heavily on the measurement and estimation of the relevant variables, which in this case are the position and speeds of both the mobile robot and the humans in the space, and the position of walls and static objects – in other words the map of the space. These tracking and mapping tasks are dealt with in chapter 4, where sensing inside Intelligent Spaces is described. Here the accent is on the deployment of sensors that are distributed and fixed at different locations in the space. A description of mainly used sensors for this type of applications is given, and afterwards the details of the implementation of tracking using the ultrasound positioning system and multiple laser range finders are described.

The ultrasound system can only be used as is, and due to its relatively complex installation and other factors it is probably not a good solution for real spaces, except perhaps for specific situations. However it gives a testbed for other sensing system due to its good accuracy. Laser range finders on the other hand are easy to be applied in everyday environments, due to their small size, accuracy and easy installation. But, a laser range finder as it is does not provide tracking or mapping abilities. We describe the developed method for tracking and mapping, which allows the sensors to be quickly installed and connected together to give a complete sensing system. This way any space can be easily turned into an Intelligent Space. Apart from the basic method for tracking we also discuss mapping, calibration and placement of the sensors. Another important part of the tracking system is the ability to distinguish between types of objects (i.e. humans or robots), and the implementation of that function is also described in this chapter.

In chapter 5 sensing using the mobile robot's onboard sensors in addition to the distributed sensors of the Intelligent Space is discussed. The inclusion of a mobile sensor into the network of static sensors from chapter 4 is not straightforward, as the two types of sensors have different characteristics. This is analyzed here, and the main factor is pointed out: the motion of the mobile robot introduces correlations in the estimate (similar to the SLAM problem), which in turn can result in an increase of the computational and communicational burden of the tracking system. In order to avoid this, we introduce the use of the Covariance Intersection method, in which case it is possible to combine the two types of sensors directly, however at the cost of a higher uncertainty in the estimate, than in the case when not using this method. Also here we analyze several different types of information fusion architectures that can be used for such a combined sensor tracking system. Analyzed are centralized, decentralized and distributed architectures, and the modalities of their application are considered. The main reason for choosing one or the other lies in the fact that mobile robots are present in the system.

Finaly, a different method for tracking with both distributed and onboard sensors that uses a geometric model of both the robot and the environment is presented. The tracking method is based on particle filters, and implementations of both simple tracking and tracking and model building (or mapping) are presented. A comparison with the first method is given.

In chapter 6 the results from the previous chapters are combined in order to obtain a complete mobile robot control system based on the cooperative sensing using both onboard sensors and sensors distributed in the space. Here we discuss the proposed control scheme and analyze what are the advantages that can be realized when external sensors from Intelligent Space are added in order to enhance the overall sensing abilities needed by the mobile robot. The parts of the control system that are improved the most are the ability to understand the humans' movement and predict their future plans through constant observation, the ability to "see" and measure what would usually be impossible only with onboard sensors and also a large improvement in the robot localization and object tracking characteristics. We also argue that this type of implementation greatly improves the robot's characteristics, to the point that its introduction into populated and dynamic spaces of our everyday life becomes feasible and even easy.

The discussion is followed by experimental results, where the merits of the proposed scheme are demonstrated in several different situations. The experiments show that the novel scheme indeed has a great influence on the robot's performance.

The thesis concludes with a list of contributions, plans for future work and a comment on the perspective of mobile robots that move and work in our vicinity.