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Soft Computing in Advanced Robotics

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Preface

Intelligent system and robotics are inevitably bound up; intelligent robots makes embodiment of system integration by using the intelligent systems. We can figure out that intelligent systems are to cell units, while intelligent robots are to body components. The two technologies have been synchronized in progress. Making leverage of the robotics and intelligent systems, applications cover boundlessly the range from our daily life to space station; manufacturing, healthcare, environment, energy, education, personal assistance, logistics. This book aims at presenting the research results in relevance with intelligent robotics technology. We propose to researchers and practitioners some methods to advance the intelligent systems and apply them to advanced robotics technology. This book consists of 10 contributions that feature mobile robots, robot emotion, electric power steering, mulit-agent, fuzzy visual navigation, adaptive network-based fuzzy inference system, swarm EKF localization and inspection robot. This edition is published in original, peer reviewed contributions covering from initial design to final prototypes and authorization.

To help readers understand articles, we describe the short introduction of each article as follows;

1. "Network-Based Subsumption Architecture for Broadcast Control of Multiple Mobile Robots Based on a Poor Hardware/Software Platform": The article says, although each robot has an only poor hardware platform with a limitation of software development, the proposed wireless network-based subsumption architecture enables them to be broadcastly controlled and to be hierarchically implemented a high-level software architecture such as a schooling behavior.

2. "Expressions of Emotions of Koala Robot Based on Laban Movement Analysis": This paper describes the mechanism and the control system of a koala robot which is able to express various kinds of emotions based on the Laban Movement Analysis. In order to react to an action, the robot should have a lot of sensors such as a force sensor, a distance sensor, and an infrared sensor.

3. "Development of Steering Controller for Electric Vehicle": This development is that the exited On/Off signals calculated by the steering controller for the rotation speed and direction of the motor are transmitted to the stepping motor. A coupler is installed

between the central axes of the motor and the position sensor in order to protect the sensor.

4. "Design of Cruise Control System for Electric Vehicle Using Piece-Wised Control": This article proposes a design scheme of a speed controller for an unmanned ground vehicle's speed compensator using a piece-wised control. The performance of nonlinearity can be improved through the closed-loop control to compensate it.

5. "Vibration Minimization of Tower Typed 2-Wheeled Mobile Robot Using Acceleration and Deceleration Velocity Profile Method": This paper proposes the velocity profile method with acceleration and deceleration to minimize the vibration of the 2-wheeled mobile robot. They have experimented three axis gyro sensors and three axis acceleration sensors mounted on the top of robot to measure the vibration and to analyze the effects of velocity profile.

6. "A Multi-Agent Context-Based Personalized User Preference Profile Construction Approach": This paper proposes a context-based personalized user preference profile construction approach to comprehensively track the user's local behaviors and user's web behavior of new inputted query, so that user can avoid the limitation of different vector.

7. "Fuzzy Visual Navigation Method for Autonomous Freight Transportation Robot": This paper proposes a fuzzy visual navigation method for the freight transportation robot. While the robot is driving to carry out transportation function in the various environments, it uses sensor information from ultrasonic sensors, RFID sensors and camera. A virtual map based on RFID nodes is designed and a path is generated for navigation.

8. "Design of Adaptive Network-based Fuzzy Inference System for Obstacle Avoidance of Mobile Robot": This paper utilizes the ANFIS method to record the path to the destination and to provide more rules to evaluate the situation. It is then possible to change the output and rules of the fuzzy inference system to obtain a better result. It shows the feasibility of obstacle-avoidance performance using the ANFIS method.

9. "Swarm EKF Localization for a Multiple Robot System with Range-Only Measurements": This paper proposes swarm EKF localization, a hybrid of two inference algorithms, extended Kalman filter (EKF) and belief propagation (BP), with a capability of choosing how many dependencies of random variables are exploited in inference using the concept of neighborhood. Also, this paper presents a numerical experiment result of swarm EKF localizations.

10. "Inspection Robot for Parallel Entry Boiler Header Pipe": This article presents the development of inspection robot for parallel entry boiler header pipes with drastic change in diameter. The robot is able to retract when entering the parallel entry and expand in bigger pipe. Camera gimbal mechanism enables the robot to acquire 360° inner pipe surface image with its position.

We would appreciate it if readers could get useful information from the articles and contribute to creating innovative and novel technology or theory on the advanced robotics. Thank you.

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Contents

Network-Based Subsumption Architecture for Broadcast Control of Multiple Mobile Robots Based on a Poor Hardware/Software Platform

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Abstract. In this paper, a wireless network-based subsumption architecture is proposed for a broadcast control of multiple mobile robots and for reduction of the total design cost required for constructing the system. When designing an actual experimental system using multiple mobile robots, there exits a serious requirement to suppress the total design cost with the increase of the number of robots. Even though each robot has an only poor hardware platform with a limitation of software development, the proposed wireless network-based subsumption architecture enables them to be broadcastly controlled and to be hierarchically implemented a high-level software architecture such as a schooling behavior. Also, this system enables the multiple mobile robots to be omitted the complicated download process of hex code program in debugging work because the debugging is conducted only on a supervisory server, so that the high maintainability can be performed. The multi-robots monitor running on the supervisory server and the agent dispatcher determining to which agent the highest priority of execution should be given, are further described.

Keywords: multiple mobile robots, network-based subsumption architecture, broadcast control, server supervisory control, Multi-robots monitor, Agent dispatcher, PSD sensor, flex sensor.

1 Introduction

Many network-based robotic systems and multiple mobile robots systems have been proposed according to various objectives. First of all, let us survey some valid papers mainly with some actual experimental results in chronological order. Parsons and Canny proposed an algorithm for planning the motions of several mobile robots which share the same workspace containing polygonal obstacles [1]. Each robot has an ability of independent translational motion in two dimensions. The algorithm computes a path for each robot which avoids all obstacles in the workspace as well as the other robots. Barman et al. developed an extensible facility for multiple mobile robots [2]. The system consists of nine radio-controlled mobile robots, two CCD color video cameras, a video

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transmitter and tuner, radio controllers, an image processing hardware and so on. Software for tracking control is described. Kube and Zhang examined the problem of controlling multiple behavior-based autonomous robots [3,4]. Based on observations made from the study of social insects, they proposed five simple mechanisms used to invoke group behavior in simple sensor-based mobile robots. They also constructed a system of five homogeneous sensor-based mobile robots with capability of achieving simple collective task. Noreils described an architecture for cooperative and autonomous mobile robots [5]. The cooperation is composed of two phases. One is the collaboration where a task is decomposed into subtasks. The other is the coordination where robots actually coordinate their activities to fulfill the initial task using the notion of coordinated protocols. This architecture showed benefits of modularity, robustness and programmability.

Also, Azarm and Schmidt presented a novel approach to do conflict-resolution for multiple mobile robots [6]. A framework for negotiation is developed by using the online motion planning, which permits quick decentralized and parallel decision-making. The key objective of the negotiation procedure is dynamic assignment of robot motion priorities. The basic performance is evaluated from experiments using only two mobile robots. Bennewitz and Burgard considered the problem of path planning for teams of mobile robots [7]. It presented a decoupled and prioritized approach to coordinate the movements of the mobile robots in their environment. The proposed algorithm computes the paths for the individual robots in the configuration-time space. To estimate the risk of colliding with other robots, it uses a probabilistic model of the robots motions. Guo and Parker proposed a distributed and optimal motion planning algorithm for multiple robots, in which the computationally expensive problem was decomposed into two modules, i.e., path planning and velocity planning [8]. The D* search method was applied in both modules, based on either geometric formulation or schedule formulation. The algorithm was implemented in a group of Nomad 200 indoor robots, so that successful results were obtained. Parker outlined the project that demonstrated a team of 100+ heterogeneous robots solving an indoor reconnaissance and surveillance task [9]. The specific problem to be solved was shown with the robot team. The focus was on the impact of heterogeneity on the collaborative solution approach that the robot team must take. Pimentel and Campos addressed the problem of multi-mobile robot cooperation with strict communication constraints which are considered indispensable for successful task execution [10]. The problem is instantiated as a cooperative search and rescue task, and is modeled as a minimization of an energy functional which accounts for network connectivity, other relevant robot and task requirements in order to select locally optimal actions for each robot.

Antonelli et al. presented two experimental case studies performed using a multi-robots system made of six Khepera II mobile robots [11]. The experiments are aimed at testing the performances and the robustness of a behavior-based technique, called the null-space-based behavioral control (NSB). The NSB approach was developed to control a generic team of autonomous vehicles and it was implemented on a centralized architecture to control a platoon of autonomous mobile robots at a kinematic level [12]. Also, Mondada et al. developed a particular designed mobile robot called e-puck which targets engineering education at university level [13].

As for network-based system, for example, Zhan et al. presented the autonomous mobile robot interactive behavior in ubiquitous computing environment, in which multimodal network-based interfaces for human-robot interactions (HRI) was constructed. The mobile robot consisted of seven systems including vision, speech, remote supervisory and sensory systems, locomotion, robotic arms and power management systems [14]. Han and Payandeh developed a novel low-cost micro mobile robotic system which could be used as a part of the research and development in sensor and networked-based dynamical system for indoor applications. The developed system could be integrated as a part of the sensor fusion for localization of mobile agents in complement with information from the camera network [15].

The subsumption architecture proposed by Brooks is one of typical behavior-based artificial intelligences [16]. The subsumption architecture has been successfully implemented in the controllers of various types of robots, where layers of control system are built to let the robot operate at increasing levels of competence. In this paper, a wireless network-based subsumption architecture is proposed for broadcast control of multiple mobile robots and for reduction of the total design cost required for constructing the system. When designing an actual experimental system, i.e., not simulation, by using multiple mobile robots, there exits a serious demand to suppress the total design cost that is proportional with the increase of the number of robots. Even though each robot has only simple hardware platform with limitations of software development environment, the proposed architecture enables to construct a high-level software architecture such as a schooling behavior. The schooling behavior means that the robots behave like carps and other fishes in a Japanese artificial circular pond. Multi-robots monitor running on the supervisory server and agent dispatcher determining to which agent the highest priority of execution should be given, are described. In addition, this system enables the multiple mobile robots to be removed the complicated download process of hex code program in debugging work because the debugging is conducted only on a supervisory server, so that the high maintainability can be achieved. The basic processing capability of the wireless network-based subsumption architecture is experimentally evaluated in association with the easy measurement of the communication time, which can be regarded as a metrics similar to round-trip time or latency in networking. A simple and reliable measurement method using a Windows multimedia timer and packet data is introduced.

2 Multiple Mobile Robots System

2.1 Basic Structure of Multiple Mobile Robots

Figure 1 shows the developed multiple mobile robots system, in which each of them equips with six distance sensors [17]. The main body of the robot is an omni-directional mobile robot with three wheels provided by TOSADENSHI LTD [18]. A MicroConverter ADuC814ARU provided by ANALOG DEVIVES is mounted on the control board of the mobile robot. A simple DC motor without an encoder is built in each wheel, so that the robot has a high cost performance. In order to measure the distances