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A Fuzzy System for Realtime Navigation of Mobile Robots

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Abstract. New soft-computing architectures and approaches are demanded for the control and operating systems of service robots [1]. In this paper, a fuzzy logic controlled autonomous vehicle - MORIA -, is presented. For achieving sophisticated guiding and controlling properties, local actions and global strategies are combined within the fuzzy controller. Local perceptions and global commands influence the recurrent fuzzy state variables, which on their turn activate different fuzzy rule sets. Thus, the fuzzy controller has a context dependent behaviour.

Key words: *mobile robots; recurrent fuzzy systems; goal-oriented navigation; collision avoidance; real-time control; autonomous vehicles*

1 Objectives of the Research Project

The main goal of our current research project is the development of a collision-free autonomous vehicle for unknown indoor environments. One of the main feature of such a service robot is its ability to locate itself on an existing map [2]. Therefore it has to create a map of its local surroundings based on the information recorded by its sensors.

This local map is then steadily compared to the global map previously stored in memory. Furthermore, a global path planning system generates local instructions for the navigation system, in order to reach predefined goals. Based on this approach, the planner and the navigator are robust against uncertainties und unpredictable situations, which come up during the exploration or goal-oriented navigation of the system.

Fig. 1. The autonomous vehicle MORIA

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2 Approach of the Navigator

The traditional navigators available for autonomous indoor vehicles are based on strategies that require a precise geometric map of the environment [3, 4]. Moreover, additional landmarks are often necessary to compensate uncertainties arising from control errors, sensor noise, or inaccurate models of the environment. The strategy proposed uses a reactive and goal-oriented navigation system based on fuzzy set theory [5, 6]. Through this approach, environmental uncertainties are compensated. The planner specifies the global driving direction by means of linguistic instructions, e.g., "'turn left at the next junction,"' while the navigator explores the local environment and selects the appropriate local path [7, 8]. Unlike conventional systems, the navigator reacts to environmental changes while maintaining the given global direction. Actual perceptions, linguistic instructions and the local history of the robot are combined and stored in fuzzy state variables. These state variables are the memory of the fuzzy controller and will recur in the following control loop. As different behaviours are predefined within the recurrent fuzzy system, the occurence of deadlock situations like blocked corridors are easily solved. Thus the computational rule of inference in the fuzzy algorithm allows the processing of apparently contradictory information.

3 Properties

The planner and navigator are based on fuzzy logic strategies. Therefore the system is robust against inaccurate information given by the sensors, and its behaviour is not dependent on measurement accuracy. The possibility of describing a path by means of linguistic sentences makes the system user friendly. An additional benefit of using a rule based system is that the control process becomes more comprehensible and maintainable. The fuzzy inference mechanism supports a smooth and balanced navigation. The real-time response of the autonomous vehicle is achieved through the implementation of collision avoidance strategy at the navigator level [9].

4 Implementation

The vehicle is 175cm x 90 cm x 75 cm large, and has a weight of 400kg, with a payload of 150 kg. It is equipped with ultrasonic sensors which supply the environmental information. The measured sensor values are converted independently of their accuracy into linguistic information like "'wall near"', "'wall far away"', "'junction detected at left"'. This information is passed to the navigator to control the vehicle trajectory. At the same time the linguistic information is given to the planner. This first builds a topological map of the operating environment in the exploring mode and later in the goal-oriented navigation mode updates it. Through the linguistic structured description of the map instead of a geometrical one, the needed memory space of the complete environment is relative small. A cockpit-like simulation, developed in-house, monitors the system. It enables the giving of instructions to the navigator, either automatically through the planner or manually from the user. Through this additional feature the simulation environment emphasizes the interchangeability between simulation models and reality. The simulation models implemented in our environment include sensor noise as well as the specific geometric and kinematic features of MORIA.

5 Conclusions

The main advantages of the system are the real-time response, the high reliability, and the implementation of the proposed approach on low cost hardware. Using symbolic states and commands simplifies the high-level verifications and clears the interface structures of the control process. This vehicle may be used for different transportation- and cleaning tasks or for handicapped person aid in indoor environments, e.g., administrative buildings, factories, hospitals, etc.

To insure the required high degree of flexibility and adaptability [10] of such systems, the control strategy has to include additional learning methods. Future research will concentrate on advanced automatic learning strategies like recurrent fuzzy systems theory. This will include the establishing of new fuzzy state variables, and automatic optimisation of the fuzzy rule set based on a reward and blame strategy.

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