

Neural Network Guided Robot Collectivity – An Experimental Setup

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Abstract: The paper presents an experimental for a mobile robot collectivity operating in a common 2-dimensional environment with unknown, stationary, obstacles. The main feature of the proposed solution is that the most important tasks in the robot collectivity (cooperation between robots, sensorial data processing and data fusion, global and local path planning, etc.), are implemented using artificial neural network (ANN) and, in particularly, cellular neural networks (CNN). The structure of the mobile robots has been reduced to a minimum, in order to increase the number of members of the collectivity and, in this way, to gain the complexity of the possible experiments.

Key-Words: mobile robot collectivity, autonomous navigation with obstacles avoidance, cooperation, ANN and CNN data processing.

1 Introduction

The robot collectivities have been intensively studied during the years [1] [2], because of their huge potential in different fields of application (industry, services, etc.) [3]. The most researches have focused on mobile robot collectivities, having in mind the larger capabilities of the mobile robots compared to the industrial, fixed, robots and, probably, in order to copy the biological model – social insects.

The authors of this paper took in to consideration the problem of mobile robots and mobile robot collectivities many years ago, with the idea to process the information using ANN and CNN networks in particularly. Some results obtained by authors on autonomous navigation of mobile robots with obstacles avoidance, using ultrasonic sensors and ANN for data processing, local path finding and trajectory planning, are given in [4] [5] [6] [7].

In the last years it has been proved that CNN are valuable tools for industrial robots control [8] and global path finding and trajectory planning of mobile robots [9] [10] [11] [12] [13] [14] [15]. Some already obtained results demonstrate the huge potential of CNN networks for studies in the field of mobile robot collectivities. A number of well-known scenarios with mobile robot collectivities have been

successfully implemented using CNN networks [16] [17] and the studies are in progress.

However, the main lack of our research activity in this field is the unavailability of an experimental set-up, to prove in real conditions the obtained results. The simulators, used up to day, have some advantages (simple to use, inexpensive, etc.), but in the same time they impose a number of constrains:

- Some scenarios, like experiments of mobile robots cooperation, are difficult to simulate,
- In some cases, the validity of the results of simulation should be taken into consideration,
- Often, unexpected and new problems can arise during an experiment, which are a valuable source for further research.

We started the development of the experimental set-up with the following ideas in mind:

- The proposed set-up should allow implementing quite complex experiments, with a collectivity having at least 5-6 mobile robots,
- The experimental set-up will include the necessary hardware and software resources to be able to implement local and global path finding and trajectory planning algorithms,

- Experiments with both type of neural networks (traditional ANN and CNN) will be possible,
- Full control over the each mobile robot included in the collectivity.

In the following, the structure of the hardware and software parts of the proposed experimental set-up will be described. Then, it will be discussed shortly an example of implementation of two algorithms, for local and global path finding and trajectory planning. Finally, the obtain results and further research will be also presented.

2 The proposed experimental setup

A general schematic of the proposed experimental set-up is given in Fig. 1.

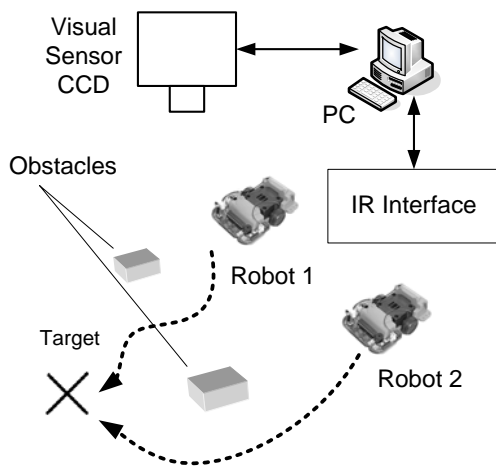


Fig. 1. The structure of the robot colony

An experiment may include one or more mobile robots which are navigating in the work place toward a target, with obstacles avoidance. The movement of mobile robots in order to reach the target is controlled step by step by a personal computer (PC), which communicates with the robots through a wireless infrared (IR) system.

The PC supervises the whole activity of the robot colony by processing the images of the work place acquired by a visual sensor (a CCD camera). As a result, possible trajectories - free of obstacles are determined for each robot and based upon these information optimal trajectories are then established (usually the shortest trajectories).

The activity presented in the above is known in robotics as global path planning. The global path planning methods approach the problem of navigation only from a geometrical point of view and in some cases fall because do not take in to consideration the kinematics and dynamics of the robot and, also, the rapidly changing in the surrounded environment. The best results are

obtained by combining the global methods with the local path planning.

The local methods compensate the uncertainty of data sets given by the global method and take into account the dynamically changing in the work place. Local planning is based on the sensorial information acquired from the surrounding of the robot and processed in real time.

The local path planning can be implemented in our experiment using ultrasonic and IR sensorial information. For this purpose, each mobile robot includes onboard ultrasonic sensors (for obstacles detection in the mid range in front of the robot) and IR proximity detectors (for obstacles detection nearby robot), as can be seen in Fig. 2. These parts,

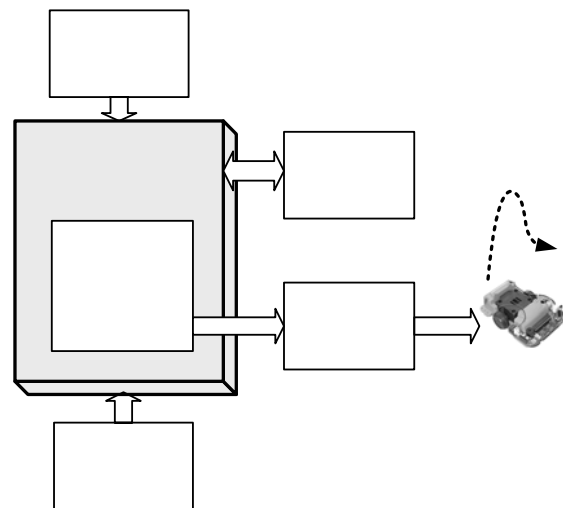


Fig. 2. The structure of a mobile robot

together with the IR interface, for data communication with the PC, and the driver circuits, that control the movement mechanism, are connected to a microcontroller system.

It should be noted that the ultrasonic sensorial system is a bio-inspired from the echo locator of the bats: the ultrasonic transducers are disposed on the same line, with the transmitting transducer placed between the other two sensors, which are used for detecting the echoes. The above mentioned solution has the advantages of simplicity and speed in operation, as we shall see later. The IR proximity detectors have been included in the MR structure as an additional aid, to detect unpredictable obstacles, which appear in a rapid changing environment and cannot be detected by the ultrasonic system.

The microconverter system is build around a high performance, low power microconverter chip from Analog Devices [18]. This microconverter includes on the same chip an optimized 8052 core, offering

up to 25 MIPS peak performance, high speed A/D and D/A converters and a large variety of peripherals (timers/counters, SPI, I2C, UART interfaces, PWM channels, etc.). The microconverter chip is full functionally with a supply voltage as low as 3 V.

The microconverter system plays multiple functions:

- Acquire information from the surrounding work place using ultrasonic sensors and IR proximity detectors;

- Based upon this information, the presence of obstacles is detected and a local path planning is realized;

- Controls the movement mechanism for MR navigation with obstacles avoidance;

- Microconverter system is also responsible for communication with the remote control unit (PC).

The movement mechanism of the MR includes two wheels, controlled by two geared dc motors. The microconverter system adjusts independently the speed of two wheels in order to change the direction of the movement. Two PWM channels of the microconverter chip connected to the DC motor drivers are used for this purpose.

The IR communication system of the robot contains a minimum of components: an IR optical transceiver and a stand-alone IrDA encoder/decoder. The last device is connected between the outputs of the UART (included on the microconverter chip) and the transceiver. The same circuits are included in the IR interface, connected to the serial port of the PC.

The transfer of data from the PC to the mobile robots takes place by sending 9 bits/ byte of information. The 9th bit is used to discriminate the address byte from the data bytes. The all mobile robots process the address byte, while only the mobile robot having assigned the same address as that included in the message receives the data.

The software application is, perhaps, the most important part of our experimental set-up. The easy in use and a full control over the whole system strongly depends of the software capabilities. The software application implemented in the proposed experimental set-up is very similar to that presented in [19] and includes:

- A small footprint and limited capabilities real time operating system (RTOS) TinyOS, specially design by authors for microcontroller systems and running on the microconverter system;

- A software library, containing subroutines for all peripherals existing on the microconverter chip and for mobile robot applications;

- A Graphical User Interface (GUI), running on

the PC, capable to transmit messages, in order to control the microconverter program flow. GUI is also used to visualize analog and digital data received from the mobile robot.

TinyOS, presented in more detail in [19], have two main responsibilities:

- Supervises the information exchange between the microconverter system and the PC. Data exchange take place in the form of messages: command messages and process messages from PC to MR and data messages from mobile robot to PC;

- Executes immediately and unconditionally the command messages while process messages, which are stored as a sequence of messages in the internal data memory of the microconverter chip and data messages are executed only in the processing mode (after the execution of a START command).

Command messages are used mainly for the following two purposes: to interact with TinyOS and to manually control the behaviour of the MR (to move forward and backward, to turn to the right/left, etc.).

Process messages, already stored in the internal data memory of the microconverter chip, are interpreted by TinyOS and the corresponding subroutines are executed. These subroutines, included in the software library, are resident in the program memory of the microconverter chip. Each subroutine, invoked by a process message, is responsible for a specific operation executed by the microconverter system (A/D and D/A conversions, digital I/O, data processing, etc.), called process. More processes can be executed in the same time, by time-sharing. The only limitation for the subroutines which are executed at a time, is to invoke processes of different type.

Data messages are used to transmit data from the mobile robots to the PC. These data are mainly sensorial information acquired by the onboard sensors or some internal parameters of the robot that characterize its behavior. The received data are then visualized in the proper form (analog or digital), using the GUI running on the PC.

Initially, the possibility to acquire and visualize data has been introduced for debug and software maintenance purposes only. But this feature can extend the capabilities of the mobile robots if appropriate sensorial systems are provided on board.

An important feature of the proposed experimental set-up is the TinyOS's capability to add, in a simple manner, new software applications to the software library. Only few rules are to be respected regarding the new developed subroutine for this purpose. This problem is extensively presented in [19] and will not be discussed here.

3 Implementation of an experiment

In the following, it will be presented, as an example, the procedure of implementation on the proposed tool of a simple experiment: the movement of a mobile robot collectively to the same target, with obstacles avoidance. We will suppose, as in a real case, that the global and local path finding and trajectory planning algorithm are already developed. The scope of the experiment is to validate in real conditions these algorithms.

3.1 The local path planning

For the local path planning it will be used the algorithms developed and proved by simulation in [4][5][6][7]. These algorithms detect obstacles by processing ultrasonic sensorial signals and can be easily implemented on the proposed experimental set-up whose mobile robots are equipped with ultrasonic transducers.

We will summarize, in the following, the main ideas behind these algorithms.

As we already mentioned, ultrasonic system includes three transducers, placed in the same line, as in Fig. 3 (the transmitter transducer in the middle of

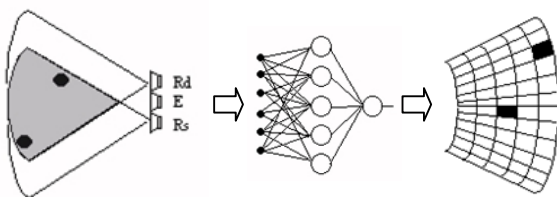


Fig. 3. The structure of the ultrasonic system

the reception sensors). The presence of an obstacle can be detected in the area represented in grey, which is the common place of the individual fields investigated by each reception sensor.

The amplitude of the received echo pulses is a measure of the distance from the robot to the obstacles, while the difference in time of the moment of occurrences of these pulses give the azimuth of obstacles relative to the median axis of the sensorial system. A single transmitted pulse and the resulting echoes are needed in order to locate all the obstacles in front of the robot. In this way, the presented method for obstacles detection is in the same time simple (only three transducers are necessary for implementation) and fast.

As results from Fig. 3, samples of echoes pulses, received by ultrasonic sensors are processed by an artificial neural network ANN1 (a simple perceptron). ANN1 extract the relevant information

for the mobile robot movement: the distance and the azimuth of each obstacle in front of the robot and is capable to indicate the presence of obstacles in the investigated area.

Please also observe that ANN1 has a limited resolution. It means that ANN1 is capable to indicate the presence of obstacles in a limited number of small discrete areas in front of the robot, equal with the number of the neural networks outputs. These discrete areas result by dividing the supervised area using an appropriate grid [4], as is illustrated in Fig. 3.

Actually, the output levels of ANN1 network reflects the probability of existing obstacles in each of the discrete area mentioned above. This information has to be processed again, in order to obtain the value of the azimuth of the mobile robot trajectory which avoidances obstacles.

The processing unit for this task includes two neural networks ANN2 and ANN3, connected as can be seen in Fig. 4. ANN2 network acts as a classification engine, and is capable to recognize

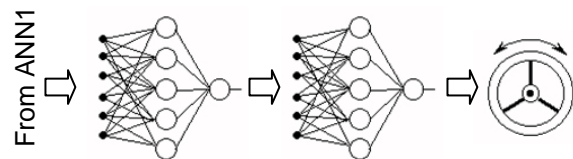


Fig. 4. ANN used for the determination of the azimuth

different scenarios, with different positions of obstacles relative to the position of mobile robot. Based upon this information, the third neural network, ANN3, issues to its output the signed value of the azimuth, that allow the movement of MR with obstacles avoidance.

All the above mentioned ANN have been developed using simple perceptron type networks, and can easily implemented on the microconverter system.

3.2 The global path planning

The global path planning has the following two main purposes:

- To find possible paths to target, free of obstacles, and

- Based upon this information to generate a valid trajectory of the mobile robot, which satisfies some constrains (usually, the shortest way to the target).

The above mentioned processes are repeated periodically for each discrete movement (step) of the robot and the information that results in this way is used to reach the target avoiding the collisions with obstacles. In fact, the guidance information represents the direction to be followed by the robot in the next step.

The availability in the experimental tool of a visual sensor, capable to acquire the image of the whole work space (robots and obstacles) suggest the idea of implementation the global path planning based on image processing. Moreover, having in mind the author's experience in the field of mobile robots and robot collectivities controlled by CNN, we will use in our experiment these valuable tools.

Of course, the CNN will be software simulated on the personal computers, which drastically reduces the speed of processing. However, the other valuable properties of CNN still remain and the decrease of processing speed is a compromise which will be accepted for the moment.

The difficult task in the image processing using CNN is to find an appropriate sequence of templates which allow to obtain the desired result to the output of the network. In the previous author's research it has been developed templates for different scenarios with mobile robots and robot collectivities. In the next figure is presented, as an example, the final result obtained by simulation of the behavior of two mobile robots in their moving toward the same target [17] (Fig. 5).

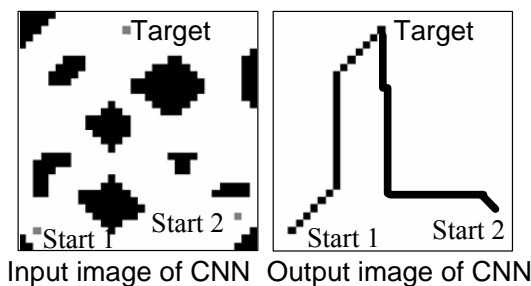


Fig. 6. The movement of a small collectivity of robots to the same target

It follows from the above results that all we have to do to implement the global path planning algorithm is to extract from the planned trajectory, for each discrete position of the robot, the direction of the moment in the next step. This information has to be transmitted periodically to each robot of the collectivity.

3.3 Planning the trajectory

In the previous sections we have seen how can be

implement in the experimental setup the local and global path planning algorithms. The problem which arises now is how to define the robot's trajectory based upon these data. The following algorithm is proposed for this purpose:

- If no obstacles are in front of the mobile robot, the trajectory of the movement will be controlled by the global path planning algorithm;
- In the presence of obstacles, the local path planning will control the robot movement. However, the actual direction of the movement will be chosen as close as possible to the direction given by the global path planning algorithm (which is the direction to the target).

4 Conclusion and further research

The proposed experimental set-up is a complex project and requires much effort to be completed. Up to date, the hardware part has been developed and the prototype of a mobile robot is already done. A collectivity of six robots will be available soon.

The PCB, carrying out the electronic circuits and sensors, is placed on a small dimension, commercial chassis (Robo Jr series chassis [19]). This has all the features needed to build a fully autonomous robot vehicle including battery compartments, geared dc motors and provision for circuit board mounting.

Compared to other similar experiments, known in the literature [20][21][22], the proposed solution features by concentration in the same place (the PC in this case) the information of the whole collectivity (the images of the working space). As a result, some important advantages occur:

- The information to be processed on each mobile robot and, as a consequence, the complexity of these devices are drastically reduced; in this way, the potential number of members of the collectivity is increased.
- A higher speed of signal processing, accomplished by a powerful PC instead of a suite of small microcontroller systems installed on each robot of the collectivity.

Future improvements of the proposed solution are already planned. The most important of them is the hardware implementation of CNN networks, in a FPGA development board. This fact will significantly increase the processing speed, which may be an important factor in some experiments.

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