Editorial

Interaction of Robots with the Environment

The intrinsic property of robots is their ability to interact with the environment. The type of the environment in which robots operate can be employed as one of many classification criteria distinguishing them into broad classes, i.e. industrial, service or field robots. This distinction is implied by the degree of structuring that the environment exhibits. Industrial robots operate in very structured environment, like in the factories, service robots populate offices and homes, where the location of furniture or people changes, while field robots operate in forests or fields where the structure is hard to define whatsoever. The structure of the environment in which the robot operates implies how it interacts with its surroundings. This issue of *Journal of Automation, Mobile Robotics and Intelligent Systems* (JAMRIS) is devoted to the subject of how robots interact with the environment depending on its structure. A closer inspection of this topic should lead to the deduction of commonalities influencing the design of future robot control and perception systems.

The idea of publishing an issue of JAMRIS devoted to interaction of robots with the environment emerged in the discussions during the 12th *National Conference on Robotics* organized by the Department of Fundamental Cybernetics and Robotics, Institute of Computer Engineering, Control and Robotics, Wrocław University of Technology in Świeradów-Zdrój, from the 12th to the16th of September 2012. This conference showed that the Polish robotics community has produced significant results in this field, and thus the Program Committee decided that it would be beneficial, if those achievements would be put together within one publication, so that they could complement each other. Hence, a selected group of authors working on diverse aspects of robot-environment interaction was invited to submit papers describing their research results. Based on the conference presentations, the papers contained in this issue of JAMRIS are their extended and more comprehensive English versions, subjected to the regular JAMRIS review procedure.

Gratitude should be expressed to all of the reviewers who provided in depth comments enabling many clarifications and overall improvement of the contents of the papers presented in this topical issue of JAMRIS.

This volume of JAMRIS is composed of 8 papers that provide insight into four aspects of robot-environment interaction:

- interaction of redundant robots executing repeatable tasks within the factory environment,
- physical interaction of manipulators with rigid objects in diverse environments, including home and office settings,
- interaction of mobile robots or walking machines with semi-structured and unstructured environments,
- interaction of robot companions with people.

The first paper of this volume is devoted to the interaction of redundant robots with a well structured environment, in which usually repeatable tasks are executed. Ignacy Dulęba and Michał Opałka authored the paper *On Application of Elastic Band Method to Repeatable Inverse Kinematics in Robot Manipulators,* in which they tackle the problem of generating closed loop trajectories for an end-effector motion of a redundant manipulator, in such a way that the initial and the terminal manipulator configurations will be the same. This problem arises when a redundant manipulator has to execute repeatable motions in the operational and the respective configuration space. For that purpose the elastic band method is used to design a repeatable inverse kinematics algorithm for robot manipulators. The final solution is obtained through optimization techniques. By simulating two robots the authors compare their solution with a standard pseudo-inverse Jacobian algorithm, which does not preserve repeatability of inverse kinematics.

Next two papers are devoted to manipulators physically interacting with rigid objects. This requires force and torque control, which can be obtained through changing the mechanical impedance properties of the robot. The papers present both how such controllers should be designed and the utilization of such controllers in task execution.

Edward Jezierski and Artur Gmerek in the paper entitled *Impedance Controllers for Electric-Driven Robots* provide an insight into the design of robot actuation control exhibiting compliance. Based on the information about approaching an obstacle, obtained from a proximity sensor, the mechanical impedance of the manipulator is adjusted, thus inducing into the device the required compliance, hence reducing the collision impact. Experimental results obtained by controlling a brushless DC motor and simulation of a 2 dof manipulator illustrate and validate the proposed control algorithms.

The article entitled *Safe Strategy of Door Opening with Impedance Controlled Manipulator*, by Tomasz Winiarski, Konrad Banachowicz and Maciej Stefańczyk, concentrates on a single activity of service robots, namely their ability to open doors of rooms or cupboards. To that end impedance control law taking into account force and velocity constraints imposed by the manipulated object was employed. Those constraints are due the safety of the performed operation and directly influence the control law. The structure and operation of the designed controller is described formally. The conducted experiments validate the proposed control strategy.

The third group of papers focuses on the interaction of diverse mobile robots with their environments. As their autonomous navigation requires both adequate perception of the environment and motion planning, those are the subjects investigated by those papers.

The results of research conducted by Maciej Stefańczyk, Konrad Banachowicz, Michał Walęcki and Tomasz Winiarski are presented in the paper *3D Camera and Lidar Utilization for Mobile Robot Navigation*. The authors deal with a navigation system based on the Kinect sensor and a laser scanner capable of detecting obstacles in indoor environments. The control system behaviour is specified in terms of transition functions. The localization of the robot relative to the map is performed by an Extended Kalman filter taking as its arguments three sources of data: wheel encoders, gyroscope, and the laser scanner. Global robot position relative to the provided approximate map is calculated, using a particle filter. The functioning of the system is verified in a cluttered office environment in which the mobile robot operates.

The paper *Optimization-Based Approach for Motion Planning of a Robot Walking on Rough Terrain* authored by Dominik Belter, describes an algorithm generating leg-end and body trajectories for a hexapod robot walking on an uneven terrain. For that purpose it uses Rapidly Exploring Random Tree Connect and Particle Swarm Optimization algorithms. Static stability of the machine and motion constraints imposed by obstacles are taken into account. The quality of the elaborated algorithms was tested by simulation.

The work of Michał Nowicki and Piotr Skrzypczyński entitled *Experimental Verification of a Walking Robot Self-Localization System with the Kinect Sensor* concerns the identification of egomotion of a RGB-D sensor mounted on a hexapod robot. The presented algorithm relies purely on the depth information, i.e. a point cloud. The considerations fall into a broad category related to the design of Simultaneous Localization and Mapping algorithms. A two-stage point cloud matching procedure exploiting salient features in the range data is employed. It first uses feature-based matching procedure utilising Normal Aligned Radial Feature detectors/descriptors followed by Iterative Closest Points algorithm.

The fourth group of papers deals with natural interaction of robots with people who inhabit the environment, thus from the point of view of an autonomous robot are simply a part of it. Acceptable interaction of robots and humans will be possible, only if they can socialize, thus the study of emotions is a prerequisite to this. Hence, the identification of emotions from facial expressions as well as speech tone and prosody is the topic of the next two papers.

Mateusz Żarkowski in the paper entitled *Extensive Feature Set Approach in Facial Expression Recognition in Static Images* concentrates on facial emotion recognition of a person interacting with a robot. The system recognizes seven human emotions. The system relies on feature extraction and selection, which facilitates the definition of new features and adding them to the feature set. Face tracking and parametrization is performed by FaceTracker software, while feature selection is done by data mining software.

The paper *Speech Emotion Recognition System for Social Robots, authored by* Łukasz Juszkiewicz, focuses on social robots, e.g. robot companions. Emotions of the person interacting with the robot are recognised using global acoustic features of speech. Four phases of Polish or German speech processing are described, namely: calculation of speech parameters, acoustic feature extraction, feature selection and classification. The paper makes an interesting observation that purely acoustic recognition system has problems with distinguishing anger and joy, thus could result in a grave misjudgement of response by a social robot.

All of the mentioned particular aspects of robot-environment interaction are at the forefront of the currently ongoing research into this subject. Each of the papers gives a valuable insight into a particular problem, providing its formulation and deriving a solution. This selection of papers reveals the wide scope and diversity of contemporary robotics.

Cezary Zieliński
Krzysztof Tchoń