Automated Production Systems, robotics, research, University of Zilina

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RESEARCH IN AREA OF ROBOTICS AT THE DEPARTMENT OF AUTOMATION AND PRODUCTION SYSTEMS AT THE UNIVERSITY OF ZILINA

Abstract

The article deals with the review of current state and particular results of research in field of robotics ongoing at the Department of Automation and Production Systems at the University of Zilina. There are described more detailed the projects solved in area of industrial robots with serial and parallel kinematic structure, human-robot collaboration, mobile robots, vision guided robots, simulation software tools, etc. The results - methods, developed software and equipment can be applied in practice as well as in academia.

1. INTRODUCTION

Industrial robots have a distinct set of capabilities that allow them to perform a wide range of tasks: spot and arc welding, picking up components, machine tending, spraying, assembling, carrying of different technological effectors and general manipulation with parts. As European economies start to recover from the recession, manufacturing companies are seeking ways to ramp up production in a flexible way [1].

In field of robotics are visible several trends both in practice and academia, for example:

- application of unconventional kinematic structures,
- application of machine vision systems for grasping of randomly placed objects,
- integration of safety systems and monitoring devices,
- so-called collaborative robotics (cooperation between robot and human operator),
- software for simulation of robots behaviour,
- mobile robotics,
- cooperation of multi-arm systems,
- application of different kind of sensors (eg. force/torque sensors),

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2. RESEARCH IN AREA OF ROBOTICS AT THE DAPS

The team oriented on robotics and automated production and assembly systems at the Department of Automation and Production Systems (DAPS), Faculty of Mechanical Engineering, University of Zilina (UNIZA) try to follow these upper mentioned trends in both teaching as well as research [2]. In next 6 sections will be shortly described the most important projects solved at the authors workplace within last few years.

2.1. Mechanisms with unconventional kinematics for robot and machine tool design

General parallel kinematic structure (PKS) is mechanism with closed kinematic chain, which consists of the base, platform and at least two reciprocally independent leading legs. Parallel links (struts, legs) are joining between the base and the movable platform. Motion of the platform is controlled by a change of linear or angular parameters of legs acting in parallel system.

The initial impulse to aim with this area at our department was established in 2002 during the study stay of our students at TU Chemnitz in Germany [3]. There they attended also a conference about parallel kinematic structures organized by Fraunhofer Institute - IWU Chemnitz. This conference influenced the future orientation of our research, which resulted in the development of several mechanism prototypes – among other the first real functional model of hexapod mechanism in our region (figure 1, right hand side). This prototype was developed and built in years from 2005 till 2008 to verify the functionality of its components, including our own control system and simulation software.

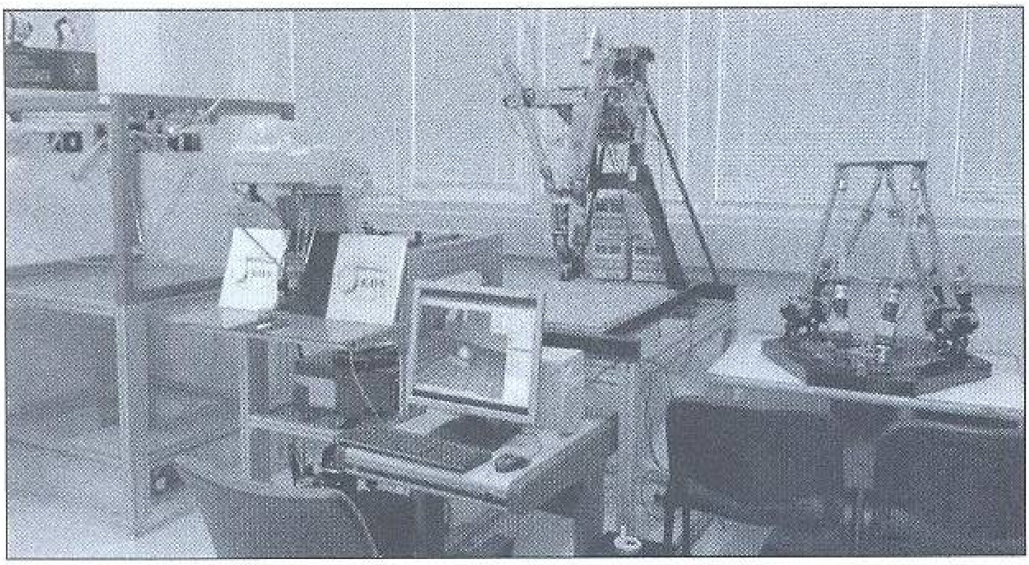
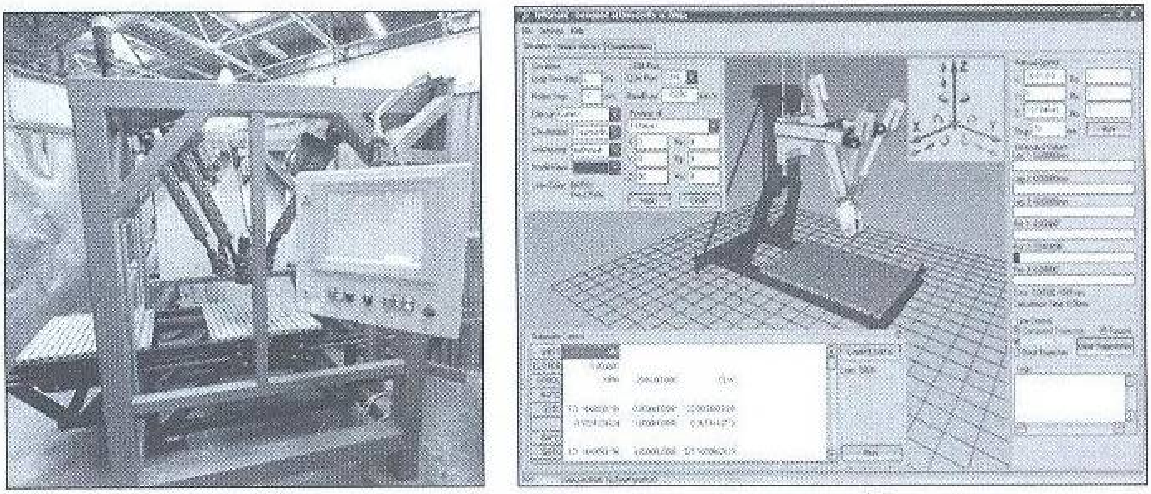


Fig. 1. Laboratory of parallel kinematic structures at DAPS at UNIZA (from left to right: prototype of delta robot, delta robot FANUC M-1iA, prototype of Trivariant and Hexapod)

Another logical step was the decision to develop and subsequently build a prototype of machine tool with parameters allowing its real deployment in practice. In order to achieve this goal, it was necessary to obtain adequate funding. This was done in 2009, when we succeeded with a project from the Structural Funds. During this period (2009 – 2013) there were designed some construction concepts of PKS and different kind of simulation software for these types of mechanism (figure 2). As the main results we can consider the prototypes of CNC machine tools with hexapodic kinematic structure and trivariant hybrid kinematic structure.

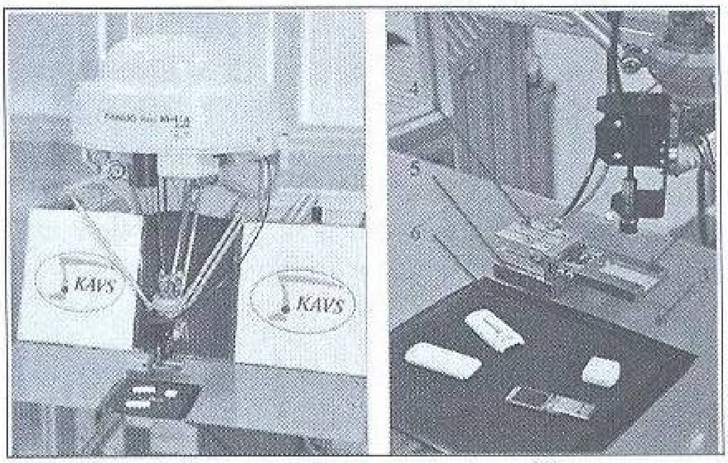


a) b)

Fig. 2. Prototype of CNC machine tool with PKS for 5D milling operations called Hexapod ZU (a) and special software for simulation and control of mechanism with hybrid kinematic structure (b), both designed at DAPS at UNIZA

2.2. Integration of camera system in control of serial and parallel robots

The capabilities of industrial robots can be increased by different peripheral devices like feeders, belt conveyors, camera systems, systems for automatic tool changing, etc. So we decided to prepare a special robot workcell for testing, research as well as training of students in area of Vision Guided Robots. In upper mentioned Laboratory of parallel kinematic structures the camera system was installed on our *FANUC M-1iA* robot, which will serve the robot guidance and creation of programs supported by *iR Vision* system. This configuration enables the implementation of handling tasks with variable components location on designed workplace. Hardware part of *iR Vision* system is made up of camera *Sony XC-56* (in Fig. 3, a - the black cylinder mounted in the middle of robot frame), the lens and connecting cable. The software tool is based on *WEB server*.



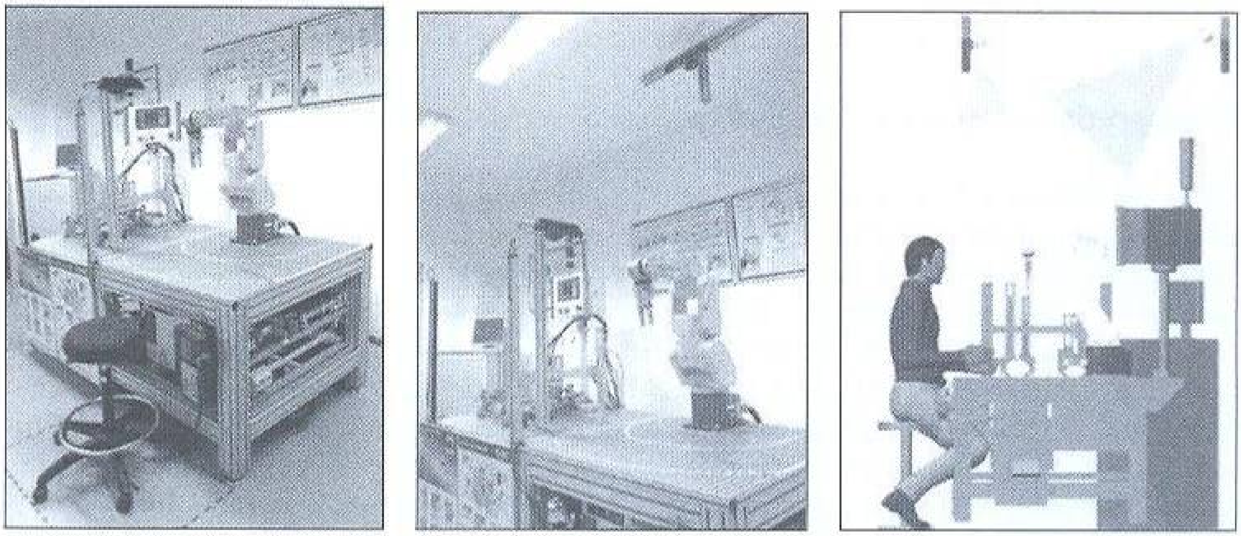
a) b)

Fig. 3. Workplace with delta robot FANUC M-1iA (a) and decomposed USB stick – the object of automated assembly process (b): 1- holder with suction gripper, 2- fingers of assembly jig, 3- table, 4- two-fingers gripper, 5- support pad, 6- contrast material inside the range of camera.

We decided for the smallest delta robot made by company FANUC called M-1iA/0.5A with 6 DOFs for our application. This robot has a cylindrical workspace with maximum diameter 280 mm and height 100 mm. The maximum payload is limited to 0.5 kg. The testing workcell as well as the example of assembly process is shown in Fig. 3.

2.3 Safety of robotized workcells and collaborative robotics

This research area deals with the solution of the safe human-robot collaboration in a shared – collaborative workplace. The attention was focused on the proposal of functional structure of the safety system that is able to detect and recognize a moving object within the monitored workspace, with the goal to avoid undesirable collisions between robot and human [4]. The open-source platform ROS was used for the safety system creation. There, the three-level safety system using three devices Microsoft Kinect of the 1st generation, the criterion for the safe control of the robot movement evaluation and the strategies of the robot behaviour within the specified collaborative space were proposed. The proposed system was tested at our *LWAS* (Laboratory workplace for automated assembly) robotic cell equipped with serial robot *FANUC LR Mate 200iC* (fig. 4).



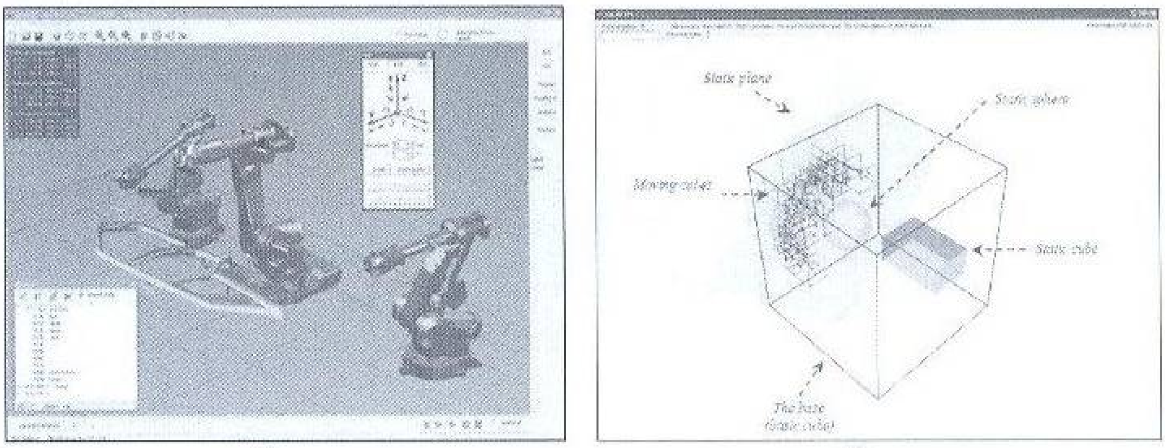
a) b) c)

Fig. 4. Testing workplace with serial robot FANUC LR Mate 200iC equipped with optical barrier and safety zones (a), sensors for safe human-robot collaboration (b) and simulation (c).

Besides the human-robot collaboration there are tested the real application capabilities of *ROS* (*Robot Operating System*) system for 3D data processing and calculations of information required for obstacles detection and presence of the operator within the collaborative subspace.

2.4 Simulation of robotics systems

Mainly for teaching and training of students, but also for research activities it was necessary to have suitable software tool/s for offline programming and behaviour simulation of any general robot (and all our robots as well). In 2008 we started to develop the first version of our own 3D simulation software in programming language Delphi. The latest version called *RoboSim* (from 2013, [5]), where can be simulate the cooperation of several robots, is shown in figure 5-a. Later there was added also special module for collision detection (fig. 5-b) which can identify any collision between the robot arm and any object within the workspace. In the future we would like to continue on its enlargement to form of "anti-collision control system".



a) b)

Fig. 5. Special software for simulation of industrial robots behaviour within 3D space (a) and the principle of integrated collision detection (b) designed at DAPS at UNIZA.

For offline programming and simulation we are also using software *Roboguide* distributed by company *FANUC*. This software allows us to prepare and simulate the control programs for any *FANUC* industrial robots [6]. It is use mainly for practical training of students, but some experiments were done also during the solution of certain dissertation thesis.

2.5 Mobile robotics

In area of mobile robotics there were developed several design concepts of mobile robot locomotion system, undercarriage and control systems as well as two simulation software tools – one for localization, mapping, path planning, collision avoidance and navigation within metric maps; and the second one for transformation of metric map into the topological structure.

By robot navigation within a space with obstacles, the goal is to find a collision-free path of robot from the starting to the target (goal) position. Navigation strategies can be classified into several groups from the viewpoint of method of sensors' data processing, representation and type of environment and level of path planning. There are many approaches depending on types of obstacles, dimensionality of the space and restrictions for robot movements.

At the beginning there were proposed two concepts of mobile robot undercarriage. One of them, the three-wheeled robot with differential control, was also realized regarding to do the first tests of navigation algorithms [3].

The second step was the development of simulation software *MobilnyRobot* for simulation of path planning within 2D metric maps of indoor spaces (see figure 6).

During the cooperation with industrial partner was solved the project of wheeled mobile robot intended for the components` in-process transport between the warehouse and assembly or testing area. The design process included the development of the mechanical, drive, sensor and control subsystems as well as a navigation system.

Although there can be found several available mobile robots in the market (e.g. CEITruck Aurora), we decided to develop our own system of automatic guided vehicles (fig. 7) which will be open for next labor and testing as a joint project between our department and business sector.

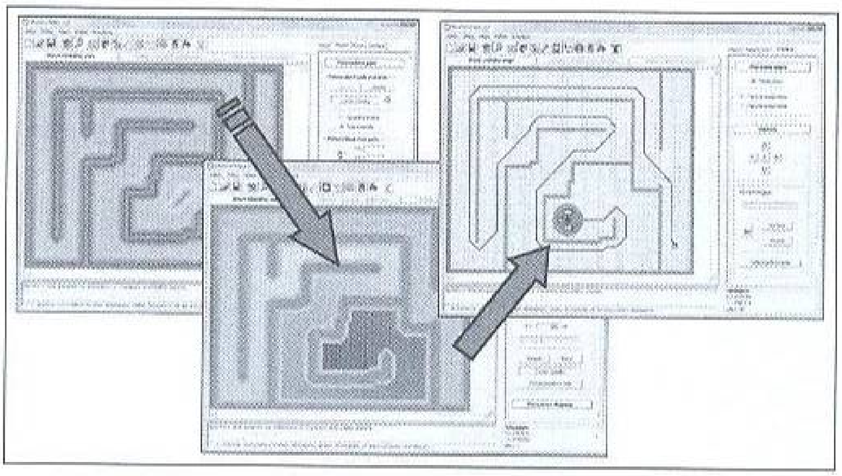


Fig. 6. Special software for simulation of mobile robots behaviour within 2D indoor environment within metric maps designed at DAPS at UNIZA [3].

The proposed robot had to be designed for in-process transport within a closed production hall with a flat industrial floor. It was chosen a mobile robot with on-top storage area with dimensions 600x800mm, chassis payload up to 200 kg and maximum speed up to $1 m.s^{-1}$. By designing of the robot undercarriage arrangement, it was necessary to take into account the required agility, maneuverability and stability. We have chosen four-wheeled undercarriage with a differential control (modification of the three-wheeled undercarriage) and without suspension due to the application for indoor environments, relatively smooth floor surface, the required stability and due to the type of transported components. The chassis was equipped with a pair of fixed driven wheels in rear and a pair of freely rotatable support non-driven wheels in front side (figure 6).

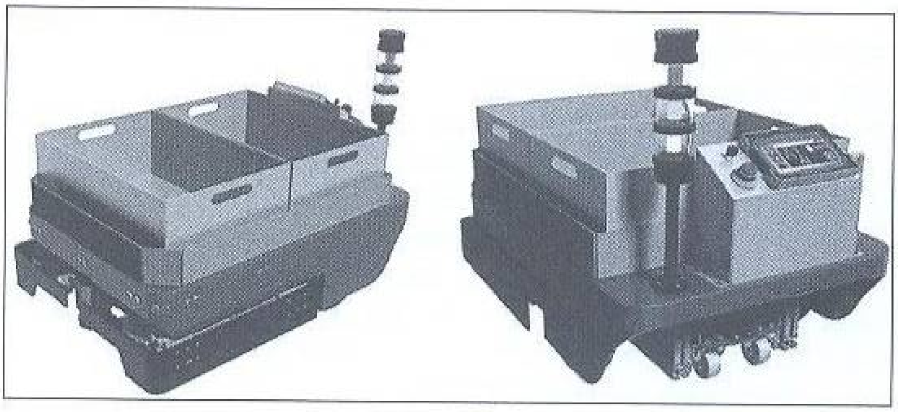


Fig. 7. The visualization of mobile robot first prototype designed at DAPS at UNIZA.

This article presents the particular results from the design process of the mobile robot for in-process transport for application in production plant. Designed control system is suitable for any wheeled mobile robot for indoor application with differential control. Every part was developed according to the requirements defined at the beginning. The functionality of final control system was verified on the testing platform based on modified undercarriage of vacuum-cleaner iRobot Roomba. When the designed undercarriage will be finished and prepared for testing we will done the real tests of whole system also in industrial environment.

2.6 Manipulator for battery swapping system for electric vehicles

Our department cooperated with the industrial partner – co. *Koval Systems, Ltd.* on the development of automatic battery swapping station during last three years. This station is intended for commercial vehicles of company Greenway. Nowadays the process of batteries' changing is carried out by a forklift and a human operator. The main drawback of this solution is handling with heavy accumulator blocks and then is required stiffness and robustness of whole system. Our innovation is based on replacement of the forklift by special automatic manipulator [7]. This mechanism will work with battery blocks up to the weight 1 tonne. Required total time for whole operation is less than 3 minutes. Battery charging is more time consuming compared to filling a gas tank. One solution is a battery swapping system.

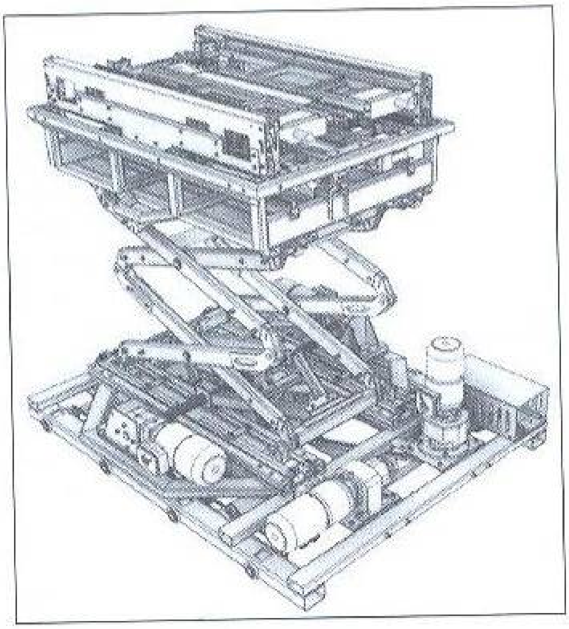


Fig. 8. The visualization of special manipulator for battery swapping system for electric vehicles` recharging stations designed in cooperation between DAPS at UNIZA and industrial partner – company *Koval Systems, Ltd.* [7]

A scissor lift relies upon the elongation of a collapsible mechanism to provide vertical elevation in ratio to a rotational or linear input. The structural components of the pantograph serve as opposing line segments within adjacent parallelograms. Geometric changes are therefore uniform across the mechanism. Whole manipulator (fig. 8) is carrying on the moving chassis or undercarriage. During the design process it was necessary to take into account the dimensions and weight of the load (battery units), the parameters of the lifting mechanism as well as the space limitations for the motion along the car. The lifting scissor mechanism is connected directly to the upper platform of the undercarriage and provides the vertical motion of the battery. This makes it possible to adjust the height position of a loading mechanism to the height of cargo loading area of each vehicle as well as for placing the batteries into the storage rack. The special static platform is connected directly to the frame of vehicle. The battery area is situated inside the cargo space closely behind cabin. Static platform ensures stiff and safe anchoring the battery inside the vehicle and prevent unwanted movement and possible injuring of the driver or other humans. Whole device is powered by 3 electric motors in total.

3. CONCLUSIONS

The article depict a short review of current state of the research and more detailed view on selected individual projects in field of robotics at the DAPS at the University of Žilina. The projects were oriented mainly in area of industrial robots with serial and parallel kinematic structure, human-robot collaboration, mobile robotics, vision guided robots, simulation software tools and others. Although some projects have already been completed, we are still trying to continue to improve the proposed solutions, as well as continue to find out new potential areas for further research.

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BADANIA W OBSZARZE ROBOTYKI REALIZOWANE W KATEDRZE AUTOMATYZACJI I SYSTEMÓW PRODUKCYJNYCH NA UNIWERSYTECIE ŻYLIŃSKIM

Streszczenie

Artykuł dotyczy przeglądu aktualnego stanu i konkretnych wyników badań w dziedzinie robotyki prowadzonych w Katedrze Automatyki i Systemów Produkcyjnych Uniwersytetu w Żylinie. Opisano tu szczegółowo projekty badawcze związane z robotami przemysłowymi o szeregowej i równoległej strukturze kinematycznej, z współdziałaniem człowieka z robotem, z wykorzystaniem robotów mobilnych, robotów sterowanych za pomocą systemu rozpoznawania obrazów, z oprogramowaniem do symulacji itp. Wyniki badań, w tym opracowane metody, oprogramowanie oraz sprzęt mogą być stosowane w praktyce, jak również na uczelniach.