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Welcome to RAAD’02

Welcome to RAAD 2002 in Balatonfüred, Hungary. This series of annual workshops now having the 11th event was initiated in 1992 in Slovenia (Portoroz) by a relatively small community of approximately 25 members active in the Alpe-Adria Region. Consecutive events were organized in 1993 in Krems (Austria), 1994 Bled (Slovenia), 1995 Pörtschach (Austria), 1996 Budapest (Hungary), 1997 Cassino (Italy), 1998 Smolenice (Slovakia), 1999 Munich (Germany), 2000 Maribor (Slovenia), and finally in 2001 in Vienna, Austria.

Though the „regional” nature of these workshops has been conserved in the past years, on one and the region concerned has been increased via the inclusion of the other countries along the river Danube, and on the other hand, participants yearly appear from different regions and even from different continents. RAAD goes more and more international.

During the past few years application of robots suffered significant changes. While robotics conserved its significance in the traditional fields of industrial application, novel potential areas of utilization as surgery, rehabilitation, rescuing, more or less autonomous navigation and other activities in a partially unknown environment, etc. seem to emerge with increasing significance. In contrast to the conventional industrial robotics these new fields require highly intelligent, cooperative and mobile robots. While traditional robot applications need no significant research activity in our days, the emerging ones require huge intellectual efforts.

Situating in the centre of Europe Hungary is a kind of cross-point between East and West as well as North and South Europe. Its special location in both the geographic and the legal sense of the word makes this country be an appropriate host to achieve a more balanced participation from the western and from the eastern parts of the Alpe-Adria-Danube Region. Balatonfüred near the Lake Balaton (one of Europe’s greatest sweet water lakes) offers the participants ample possibilities for relaxation and regeneration in the breaks of the Workshop.

The program contains 4 plenary lectures delivered by very well known scientists in the field of robotics. This proceedings volume – available on CD-ROM and printed form too – contains 80 contributions almost covering the whole field of robotics and related areas. Human-centered robotics, humanoid robots, playing with roots, nonholonomic nature of certain class of robots, and application of special purpose robots in nuclear power plants are considered, too.

On behalf of the Steering Committee and the National Organizing Committee we would like to thank you all for participating in this event and we hope that you will enjoy the technical as well as the social program.

János F. Bitó Imre J. Rudas József K. Tar
Honorary Chair General Chair Chairman of the NOC
Table of Contents

Submitted Plenary Papers:

“Humanoid Robots: Beginnings, State and Prospects” by Miomir Vukobratovic, Branislav Borovac, Submitted Plenary Papers Page 1-10

“Playing with Robots” by Peter Kopacek, Submitted Plenary Papers Page 11-18

Regular Papers:

“A ‘Tool Kit’ for Demining Robots” by Peter Kopacek, pp. 131-136
“A JAVA Collision Detection for a WEB-based Robot Simulation” by Smiljan Sinjur, Riko Safaric, Borut Zalik, pp. 189-194
“A Low Cost 5 Axes Revolute Industrial Robot Design” by S. Pagano, C. Rossi and F. Timpone, pp. 84-89
“A Modular Development of Autonomous Mobile Robot” by András Barta, Gábor Somogyi, Zoltán Major, Márk Visontai, István Vajk, pp. 266-270
“A Novel Adaptive Control for Hydraulic Differential Cylinders” by József K. Tar, Markus Bröcker, Krzysztof Kozłowski, pp. 7-12
“A PZT Actuated Robotic Gripper for Biomedical Applications” by A. Baldi, P. Casu, A. Masala, B. Picasso, pp. 159-164
“A Robotic Haptic Interface for Kinesthetic Knee Joint Simulation” by J.Hoogen, M.Ponikvar, R.Riener, G.Schmidt, pp. 125-130


“A Tripod Parallel Robot as an Active Suspension for Low Frequencies Damping” by Roberto Bussola, Rodolfo Faglia, Giovanni Incerti, pp. 333-338


“An Approach to Multibody Simulation of Pneumo-mechanical Systems” by Paolo Righettini, Alessandro Tasora, Hermes Giberti, pp. 95-100

“Application of Experts Enablers in the Machinery Engineering Domain” by János Nacsa, pp. 248-253


“Autonomous Vehicle Navigation in Unmapped Terrain” by Danica Janglová, Svatopluk Vagner, pp. 56-60

“Bioelectric EMG-Signals at Prosthetic Arms Control” by Zdenek Kolibal, Martin Janca, pp. 230-235

“Centric Minded Imaging and GPS” by Pál Greguss, pp. 379-384

“Collision Avoidance of Mobile Robots for Moving Obstacles” by Atsushi Fujimori, Csaba Dinnyés, pp. 119-124

“Computed Torque Method for a Ball and Beam” by Suzana Uran, Karel Ježenik, pp. 310-315
“Considerations Over the Control Functions for the Mechanisms that Ensure Dragging Locomotion” by Iulian Iordachita, pp. 220-223
“Contribution to Kinematic Modelling of Wheeled Mobile Robots” by Corneliu Rădulescu, pp. 67-72
“Designing of Position Measurement System for an SMA Driven Robot Hand” by Péter Zsíros, Antal Huba, Péter Korondi, pp. 165-170
“Development of the REHAROB Upper Limb Physiotherapy System” by Gusztáv Arz, András Tóth, Gábor Fazekas, Daniel Bratanov, pp. 242-247
“Direct Drive Adaptive Controller for a Brushless DC Servo Motor” by Calin Rusu, Iulian Birou, pp. 322-326
“Distributed Control System for Autonomous Mobile Robot” by Štefan Szabó, Miloš Hammer, Radek Král, pp. 90-94
“Dynamic Analysis of a Robot Used in Thermic Conditions” by Rosca Daniela, Rosca Adrian, pp. 73-77
“Experimental Determination of Kinematic Parameters and Workspace of Human Arms” by Ottaviano Erika, Ceccarelli Marco, Sbardella Fabiola, Thomas Federico, pp. 271-276
“Fault Analysis of Mobile Robot Positioning in Respect of Amount and Displacing of the Markers” by István Nagy, Attila L. Bencsik, pp. 421-430
“Feature-Based Object Modelling in Robotics” by Theodor Borangiu, pp. 45-50
“Fuzzy Q-learning in Reduced Dynamic State-space” by Szilveszter Kovács, Péter Baranyi, pp. 260-265
“High Frame Rate Vision for Interaction Between Humans and Humanoid Robots” by Ales Ude, pp. 236-241
“Human Body Movement Animation with Regard to Phylogenetic Evolution of Walking” by E. Pajorova, K. Dobrovodsky, E. Lanyova, V. Linek, pp. 183-188


“Implementation of Symbolic Modeling in Generation of Production Processes and Systems for Customer Oriented Production” by Madarász, L., Kováč, J., Rudy, V., Liška, O., pp. 391-395

“Intelligent Control System for the Automatic Correction of Deburring and Dressing Process with Industrial Robots” by Ulrich Berger, Raffaello Lepratti, pp. 298-303


“Kinematics of a New Translational Paralel Manipulator” by Raffaele Di Gregorio, pp. 214-219

“Mechatronic Design of a 3-DOF Parallel Translational Manipulator” by Paolo Righettini, Alessandro Tasora, Hermes Giberti, pp. 367-372

“Method Used for Investigation of Influence of Number of the Buffer Tracks at the Portal Robot Aided Formation of Homogeneous Loading Units” by László Smid, József Cselényi, László Kovács, pp. 437-442

“Mobility Analysis of the 3-RRPRR Wrist” by Raffaele Di Gregorio, pp. 208-213

“Model based Adaptive Friction Compensation – Stability Issues” by Márton Lőrinc, pp. 61-66

“Modelling and Influence of Backlash in Revolute and Prismatic Pairs of Parallel Mechanisms” by V. Parenti-Castelli, S. Venanzi, pp. 327-332

“Modelling of Communication in the Automated Spinning Mill by Means of Stochastic Petri Net” by Pavel Rydlo, pp. 304-309
“Neural Network Implementation of Jacobian and Its Inverse of Serial Robot Kinematics” by Jarmila Škrinárová, Jozef Suchý, pp. 339-344


“Part Feature Driven Control of Assembly Trajectory Generation” by László Horváth, Imre. J. Rudas, H. M. Amin Shamsudin, pp. 431-436

“Path Planning Using Quadtree-based Voronoi Diagrams” by Dr. Jozef Vörös, pp. 373-378

“Process of Special Industrial Robots Development and Application” by M. Valny, P. Belohoubek, Z. Kolibal, 195-198

“Production Optimization via Dynamic Programming” by Frankovič, B., Budinská, I., Dang T-Tung, pp. 288-293

“QNX-Based Realization of the Control System of a PUMA-like Robot” by Prohászka, Zoltán, pp. 361-366

“Remarks about the Eigenfactor Quasi-coordinate Velocity Vector” by Przemysław Herman, Krzysztof Kozłowski, József K. Tar, pp. 1-6


“Robotic (micro) Mechanisms Based on Flexible Structures” by Havlík Štefan, pp. 177-182

“Robotic Guidance for Percutaneous Interventions” by Gernot Kronreif, Martin Fürst, pp. 277-281

“Robotics-oriented Human Body Animation Based on Captured Motion” by Karol Dobrovodsky, Pavel Andris, Peter Kurdel, pp. 171-176
“Robots for Assembly and Disassembly” by D. Noe, P. Kopacek, pp. 455-460

“Signal Testing and Diagnosing in CAN Communication Based Control Networks without PC” by D. Fodor, T. Bencze, V. Hauptmann, M. Molnár, K. Horváth, T. Göndör, pp. 403-408

“Some Remarks on Development of Navigation of Mobile Robots Using a Mobile Robot for Demonstrational Purposes” by Béla Kulcsár, Gábor Bohács, Balázs Gódor, Sándor Hajdu, pp. 101-106

“State Observer for Sensorless AC Induction Motor Control, Kalman Filter versus Deterministic Approach” by Pavel Vaclavek, Petr Blaha, Jaroslav Lepka, pp. 316-321

“Strategies of Inhomogeneous Formation of Loading Units (Commissioning) in a Mobile Robot System in Case of Characteristic Systems” by József Cselényi, Tamás Bányai, Attila Vernyik, pp. 449-454

“Study of the Electrotribological Behaviour on Sliding Electric Contacts Used in Mechatronic Applications” by Anca Sorana Popa, pp. 27-32

“Supporting SMEs in Software Requirement Gathering in the Field of Automation” by János Nacsa, George L. Kovács, pp. 415-420

“System For Measuring The Stress Force And Rotation Torque In Case Of Robots That Perform Polishing of Plane Surfaces” by Daniel Popescu, pp. 149-152


“The Compare of Robot Position Control with PD Controller and Parallel Model Controller” by Václav Záda, pp. 385-390


“The Jaw Profile For A Two Or Three-Fingered Gripper Type For Cylindrical Parts” by Eugen Pămîntaș, pp. 409-414
“The Precision Concept of the Parallel Kinematics” by Knut Großmann, Bernd Wunderlich, Szabolcs Szatmári, pp. 202-207

“Tracking Controller of Flexible Joint Robots by Separation Principle” by E. Gyurkovics, D. Svirko, pp. 282-287

“Trajectory Planning for an Arm Manipulator Using Geometric Entities and Dijkstra Algorithm” by Luis A. Gonzalez, Angel Parrazal, Branco Ivankovic, pp. 224-229

“Virtual Reality in Flexible Manufacturing” by S. Kopácsi, F. Sárközy, G.L. Kovács, pp. 254-259

“Vision System in Map Building for Autonomous Vehicle” by Lubomír Uher, Danica Janglová, Ivo Považan, pp. 51-55

“Voluntary Control in Robot Supported Standing–Up Training of Impaired People” by Roman Kamnik, Tadej Bajd, pp. 143-148
Abstract – This paper is an overview of characteristics and problems of architectural sites for historical analysis and survey using robotic systems. Design requirements and operation peculiarities of suitable robotic systems are outlined and discussed in general, but for a specific example. A case of study is presented to show both the engineering feasibility and architects’ interest in using robots through the proposed concepts for robot design and operation in architectural sites.

KEYWORDS: Architecture Analysis and Survey, Non-Industrial Applications of Robots

I INTRODUCTION

In this paper a study of feasibility is presented for using robots or robotic systems in novel applications concerning with activities related to analysis and survey of ancient pavements, which are of archaeological, historical-artistic or architectonic interest. The aim of this paper consists of studying and discussing on robotic systems and automatic procedures that can enhance both the activity and results of analysis and restoration of architectural historical sites. But specifically at this preliminary stage of the research the paper is focused on robot applications for architectonic survey of historical pavements. This novel application of robots is characterized by the aim to achieve photographically survey, analysis measurements, and inspection of historical pavements with enhanced operation in terms of activity velocity and accuracy.

Mobile robots are increasingly being used in difficult situations, such as the inspection of the inner layer of atomic power stations, environment inspections, home servicing, forestry and agriculture, planetary explorations and exploration of non-accessible terrain like volcano craters. An additional novel application of robots can be advised in architecture analysis and restoration that will require mobile robots to perform difficult tasks in environments with limited human supervision.

In this paper we have proposed the use of robots with suitable mechanical design for architecture analysis and restoration. In order to perform this task a mobile robot is required for motion and vision capabilities and rather limited human supervision. The basic design and operation features of robots for applications in Architecture analysis and restoration activities are outlined with a general view, but a specific application for activity on historical pavements is discussed with details. A specific robot design is proposed for analysis and survey of a specific pavement in the Montecassino Abbey even with the aim to outline practical problems and requirements.
Cultural Patrimony is usually considered as common property by this time and basic means for cultural-social evolution. Therefore, it is a good for the current society that is responsible for a suitable preservation and transmission to the future generations. Consequently, a continuous monitoring of the Cultural Patrimony is required to check and analyze its status of preservation.

Basic activity can be considered the operations of analysis and architectural survey. Architectural survey is a discipline whose aim consists of acquiring an in-depth knowledge of any architectonic site, including historical evolutions and transformations, specifically in terms both of dimensional and construction aspects. In fact, it is useful to know the preservation status of an architectonic sites by analyzing the degradation conditions and motivations as well as the static conditions of the construction [1]. Therefore, the survey activity is characterized by an acquisition of huge quantity of data from integrated viewpoints.

In addition, the measurements and data acquisitions must be obtained with high level of accuracy, mainly from graphical viewpoint for a suitable representation of the architecture, since large scaled representation can be needed for a clear historic and technical survey. By referring to a historic pavement, the requirements of data accuracy and representation quality can be critical issues, since the survey must be variable as a function of the size of components and schemes of the pavement.

An example of these constraints is shown in Fig. 1, [2], in which one can recognize different sizes of drawings and construction components, but within an available environment for human operators yet. As in the case of the pavement in Fig. 1, the study of the size and material of the used pieces characterizes the analysis of the mosaic drawing and scheme. Also the study of the assembling is important in term of the type and quality of surface roughness, the thickness and treatment of connections and the pose at large. In a correct survey, each element of a pavement must be identified both as a single unit and a surface component, with a specific attention to serial or repeated parts since their anomalies can characterize the pavement yet. In addition, particular care is required in the measurement of surface irregularities in term of global characteristics (like level variations, depressions, holes, etc.) and local void and adjustments that were made over the time. The survey process consisting of the measurement and graphical representation with different scales in the following activities can be outlined by referring to the cases of Cosmatesque pavements ¹ in Figs. 2 a to c:

1- survey and representation of a pavement as the whole within architectural site (in scale from 1:100 to 1:50), as shown in Fig. 2a;
2- survey and representation (in scale from 1:50 to 1:10) of main compositions in the mosaic, as shown in Fig. 2b;
3- survey and representation (in scale from

¹ The Cosmatesque style started at the beginning of XII-th century and it was used mainly in Rome and Lazio region up to the end of XIV-th century. Its main characteristics can be considered the assembling aspect with square or rectangular panels that are composed of marbles parts and porphyry disks. The first Cosmatesque pavement is that one in the Basilica of Montecassino Abbey that was inspired by oriental sources and ancient Roman pavements.
1:10 to 1:1) of the geometrical units that give the majority of the schemes in the mosaic, as shown in Fig. 2c.

Generally, the activity at items 1 and 2 is carried out by installing a wire-netting over the pavement with suitable resolution in agreement with the sizes of the architectural units. By using the wire-netting, the location of the pavement is determined as a whole by using the position of main elements. Successively, once the overall representation is obtained, a further survey permits to determine position and shape of single components of the mosaic. The last item 3 of the survey process is usually carried out by using the so-called “contact survey” method, which consists of operating a manual copy of single part of the composition on a sheet of suitable material that is deposited on the pavement yet [4]. Then, this drawing with 1:1 scale is elaborated in a suitable size to include it in drawing of interest.

The above-mentioned survey process gives usually two sets of results with graphical and photograpical representation. The first set of results is aimed to advise the degradation status of the whole and single units. The second set concerns with a chromatic survey for identification of tonality, grain and types of used materials. The need of more accurate and efficient survey activity requires enhancement and even development of procedures with more reliable, innovative, and advanced characteristics. Within this expectation robots and robotic systems seem to be a suitable solution for pavement survey with the purposes of:

- operating in environments that cannot be reached by human operators by using proper instrumentation for even teletransmission of data and supervision;
- detecting the degradation status by avoiding the complicate netting and inspecting any deficiency of planarity;
- achieving data storage within Informatics frames based on the robot overall design.

3 ROBOTS FOR ARCHITECTURE SITES

A historical pavement can be seen as a difficult environment that requires features that could cause robot entrapment or loss of stability. Indeed, an analysis of the State-of-Art of available mobile robots can be useful to determine what type and number of degrees of freedom (DOFs) can be suitable to perform architecture analysis of ancient pavements.

Articulated or wheeled mobile robots can be used in architectural sites. Basic survey measurements that can be carried out are based on panoramic images of the site, which can be taken by a camera installed on the robot, and measuring local pavement slope through servo-inclinometers. This operation can require a mobile robot with an inertial system to locate the robot in a world fixed frame, and proximity sensors to avoid
Basic task requirements for the robot capability can be summarized as:
- travel distance that can be estimated with maximum range of 100 meters;
- average local pavement slope can be estimated less than 5 degrees;
- DOFs of the robot can be evaluated in term of 2 DOFs for motion on the pavement and 3 DOFs for manipulation of sensor equipment;
- sensors are needed like vision system, orientation and proximity sensors.

For inspection of architectural site it is desirable to estimate pavement lay out and detect obstacles in real time. Therefore, motion planning is another important issue. Path planning methods for robots have been proposed using techniques such as graph-search methods, potential fields, fuzzy logic. But traditional motion planning methods usually cannot be successfully applied since they assume perfect knowledge of the environment and ignore pavement features.

Many mobile robots for planetary explorations have been developed with characteristics that can be recognized as suitable for the non-conventional application under consideration. Sojourner is the name given to the first robotic roving vehicle shown in Fig. 3a that will be sent to the planet Mars, [5]. Its weigh is 110 N on earth. It has six wheels and can move at speeds up to 0.6 meters per minute, with great stability and obstacle-crossing capability. The goal is to acquire measurements of some rock near the robot: the rock can be selected through an evaluation of the panoramic image of the landing site taken by a camera. A vision-based mobile robot that uses a single camera for obstacle avoidance has been developed at MIT as shown in Fig. 3b, [6].

In the past years efforts have been made to develop walking and climbing machines to open new fields of application. Compared to wheeled vehicles walking machines show the advantage that they can act in highly unstructured terrain without streets or rails. Legged robots cross obstacles more easily, and they do not depend on the surface conditions and quality and, in general, they exhibit better adaptability. However, they have also specific features which make difficult both their design and control, like:
- a biped robot design integrates a large number of joints with their actuators and transmissions in a narrow space;
- the robot must be continuously in equilibrium, either static or dynamic, which may require high peak actuating torque;
- in case of falling, the robot should not break and furthermore should be able to recover its standing position;
- the available space and payload are small, which makes small also the energetic autonomy of the system, since batteries or other kinds of power generators can be stored in small quantity.

Several walking robots with two legs can be found in literature. Illustrative examples are shown in Fig. 4. One of the first prototypes was developed at Waseda University in Tokyo, [7]. Fig. 4a). Fig. 4b) shows a prototype of Wall Climbing Robot With Scanning-Type Suction Cups II, that has been developed at Tsukuba University, [8]. Fig. 4c) shows the prototype of EPWaR-II, [9], which has been developed with electro-pneumatic actuation and two suction cups beneath each foot at the Laboratory of Robotics and Mechatronics in Cassino.

The walking locomotion requires more actuators than the wheeled method of locomotion, and the drive system is heavy; in addition it is not simple to control.

![Fig. 3: Examples of existing mobile robots for planetary explorations: a) Sojourner; [5]; b) MIT vision based mobile robot [6]](image)
However, walking machines can be used for several tasks, since they can move while selecting the point of leg contact with the ground in order to adapt the step to the shape of the terrain. They have suitable characteristics for application in architectural survey like the following: they can move over a rugged surface, and can pass over fragile objects on the ground surface without touching them; they can make holonomic omnidirectional motion without slipping or damaging the ground surface. In addition, by using four or six legs robots can perform a stable motion, because it is possible to maintain 3 or more legs in contact with the pavement.

![Biped robots](image)

Fig. 4: Examples of biped robots: a) Wabot developed at Waseda University in Tokyo; b) Wall Climbing Robot developed at Tsukuba University; c) EPWaR-II developed at LARM in Cassino.

![Four legged robots](image)

Fig. 5: Examples of four legged robots: a) TITAN VIII, [10]; b) roller walker; c) ARLScout II, [11].

![Six legged robots](image)

Fig. 6: Examples of 6-legged walking robots: a) LAURON III, [12]; b) Eye Walker, [13].

<table>
<thead>
<tr>
<th>robot</th>
<th>Size (cm)</th>
<th>Weight (N)</th>
<th>Payload (N)</th>
<th>Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig.4a</td>
<td>43x27x21</td>
<td>85</td>
<td>20</td>
<td>0.3</td>
</tr>
<tr>
<td>Fig.4c</td>
<td>40x120x60</td>
<td>300</td>
<td>100</td>
<td>1.0</td>
</tr>
<tr>
<td>Fig.5a</td>
<td>60x25x40</td>
<td>190</td>
<td>70</td>
<td>0.9</td>
</tr>
<tr>
<td>Fig.5c</td>
<td>46x40x45</td>
<td>270</td>
<td>--</td>
<td>1.4</td>
</tr>
<tr>
<td>Fig.6a</td>
<td>50x30x80</td>
<td>180</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>Fig.6b</td>
<td>35x20x30</td>
<td>20</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Table 1. Main characteristics of examples of legged mobile robots of Figs. 4 to 6.

Illustrative examples of four legged robots are shown in Fig.5; Fig. 5b) shows the hybrid mobile robot named roller walker, that has been developed as a new version of the TITAN-VIII. Illustrative examples of six legged robots are shown in Fig.6. Characteristics are summarized in Table 1 to compare the legged robots of Figs. 4 to 6.

4 A CASE OF STUDY: THE PAVEMENT OF THE MONTECASSINO ABBEY

The above-mentioned considerations and concepts can be applied to a specific case of study in order to verify the feasibility of using a proposed robot in a survey activity of a historical pavement. The case of study refers to the pavement of the Basilica of Montecassino Abbey that was built between 1066 and 1071. Today is located beneath the pavement of the current Basilica that has been rebuilt in agreement of XVIIIth century design between 1948 and 1952 after the destruction during the II world war [14].

In Fig. 7a) a graphical representation of the survey carried out in 1951-52 is reported to show the medieval pavement status before the reconstruction of the Basilica. Some parts of the pavement were moved to other location in Montecassino Abbey as shown in Fig. 7b), but most of the pavement is still located at 1 meter beneath the current pavement as shown in Fig. 8. A limited room is available for inspection and the environment is not suitable for human operators since lack of light and air.
5 CONCLUSIONS
This paper has presented a study of feasibility of using a robot in an architecture survey activity for the ancient pavement of the Basilica in Montecassino Abbey.

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