# 1. A real-time path planning approach without the computation of Cspace obstacles

Yongji Wang, Liu Han, Mingshu Li, Qing Wang, Jinhui Zhou, Matthew Cartmel

An important concept proposed in the early stage of robot path planning field is the shrinking of the robot to a point and meanwhile expanding of the obstacles in the workspace as a set of new obstacles. The resulting grown obstacles are called the Configuration Space (Cspace) obstacles. The find-path problem is then transformed into that of finding a collision free path for a point robot among the Cspace obstacles.

# 2.  Ultrasonic classification and location of 3D room features using maximum likelihood estimation - Part II

Mun-Li Hong, Lindsay Kleeman

Full text available:  pdf(302.50 KB)

This paper is part II of a paper published in the previous issue of Robotica. This part proceeds from the assumption that 3D features have been calssified into either a plane, a 2D corner type I or II, or a 3D corner using the Maximum Likelihood Estimator. The location of the 3D features from the results of the Maximum Likelihood Estimation are derived here. Experimental results characterising the ultrasonic sensor and its application to a robot localisation problem are presented in this ...

# 3.Behaviour-based robot program invariance

Giovanni C. Pettinaro

Despite the numerous technical improvements, robot programming is still today a very tedious activity requiring considerable efforts for fine tuning programs written off-line. Moreover, such programs are usually not particularly portable from one robot to another, sometimes even when the robots are from the same maker.

## 4. Optimal kinematic design of a three translational DoFs parallel manipulator

Xin-Jun Liu

In this paper, an optimal kinematic design method of a three translational DoFs parallel manipulator is presented. The design is based on the concept of performance chart, which can show the relationship between a criterion and design parameters graphically and globally. The normalization on the design parameters of the studied manipulator makes it possible that the design space, which is made up of the normalized parameters, is limited.

## 5. PD control with feedforward compensation for robot manipulators: analysis and experimentation

Victor Santibañez, Rafael Kelly

One of the simplest and natural appealing motion control strategies for robot manipulators is the PD control with feedforward compensation. Although successful experimental tests of this control scheme have been published since the beginning of the eighties, the proof of global asymptotic stability has remained unattended until now.

## 6 An optimum robot path planning with payload constraints

Sezimaria F. P. Saramago, Marco Ceccarelli

This paper presents a general methodology for the off-line planning of optimal trajectory of robot manipulators by taking into account the grasping forces in the manipulator gripper. The mechanical energy of the actuators has been considered for the formulation of the objective function. The optimization problem has been formulated as subject to physical constraints, input torque/force constraints and payload constraints.

## 7  HANA: a novel spatial parallel manipulator with one rotational and two translational degrees of freedom

Xin-Jun Liu, Xiaoqiang Tang, Jinsong Wang

Publisher: Cambridge University Press

This paper concerns the proposal and analysis of HANA, a novel spatial parallel manipulator with over constraint. The parallel manipulator consists of a base plate, a movable platform, and three connecting legs. The moving platform has three degrees of freedom (DoFs), which are two degrees of translational freedom and one degree of rotational freedom, with respect to the base plate.
Keywords: Kinematics, Parallel manipulator, Rotational capability, Singularity, Workspace

## 8  Guest Editors' Introduction: Graphics for Robotica and CAD/CAM/CIM Planning

Jose Encarnacao, Ulrich Rembold
January 1989   IEEE Computer Graphics and Applications,  Volume 9 Issue 1
Publisher: IEEE Computer Society Press

Full text available:  Publisher Site

## 9 Learning control of robot manipulators by interactive simulation

Rafael Kelly, Sebastian Dormido, Carmen Monroy, Elizabeth Díaz
July 2005   Robotica,  Volume 23 Issue 4
Publisher: Cambridge University Press

Control systems of robot manipulators offer many challenges in education where the students must learn robot dynamics and control structures, and understand relations between the control parameters and the systems performance. Interactive simulation is aimed at improving the understanding of and intuition for the abstract parts of the control of robot courses. This paper presents an application of interactive simulation to teach control systems of robots.

Keywords: Control systems, Education, Interactive simulation, Robot control, Robotics

## 10  Objectives and technological approach to the development of the multifunctional MANUS upper limb prosthesis

J. L. Pons, R. Ceres, E. Rocon, D. Reynaerts, B. Saro, S. Levin, W. Van Moorleghem
May 2005   Robotica,  Volume 23 Issue 3
Publisher: Cambridge University Press

The design of multifunctional upper limb prosthetics has been investigated in recent years. In 1998, the MANUS consortium was set up on the basis of multidisciplinary skills of the partners in order to provide a global approach to the problem of upper limb prosthetics. In the framework of this approach, the consortium addressed the development of appropriate hand mechanics, the analysis and implementation of control electronics, the development of advanced control strategies and the implementations.

Keywords: MANUS, Multifunctional, Prosthesis

## 11.Two novel approaches for unmanned underwater vehicle path planning: constrained optimisation and semi-infinite constrained optimisation

Yongji Wang, David M. Lane, Gavin J. Falconer

In this paper, two novel approaches to unmanned underwater vehicle path planning are presented. The main idea of the first approach, referred to as Constrained Optimisation (CO) is to represent the free space of the workspace as a set of inequality constraints using vehicle configuration variables. The second approach converts robot path planning into a Semi-infinite Constrained Optimisation (SCO) problem.

Keywords: Non-linear programming, Robotics, Autonomous underwater vehicle, Semi-infinite constrained optimisation, obstacle avoidance, path planning

## 12 Behavioural approach for a bipedal robot stepping motion gait

F. El Hafi, P. Gorce

This paper deals with the decision mechanism analysis and the design of bipedal trajectories, for the stepping motion. For that we have used biomechanical model of the human body and dynamic control scheme previously developed by Gorce. We based our study on an experimental protocol, in order to determine behavioural laws for the task execution. We have developed a biped trajectory generation process, taking into account the biped height and the obstacle dimensions.

Keywords: Admissible control domain, Behavioural, Bipedal robot, Stepping motion

## 13.Mixing input-output pseudolinearization and gain scheduling techniques for stabilization of mobile robots with two independently driven wheels

Jin-Tsong Jeng, Ching-Long Shih, Tsu-Tian Lee

In this paper, we propose a two-loop structure to transform and stabilize the kinematic model of a nonholonomic mobile robot with two independently driven wheels. This two-loop structure consists of input-output pseudolinearization and gain scheduling techniques. A comparison with previous methods is included.

Keywords: Gain scheduling, Input-output pseudolinearization, Linear parameter-varying system, Mobile robot

### 14. Ultrasonic classification and location of 3D room features using maximum likelihood estimation - Part I

Hong Mun-Li, Lindsay Kleeman

Current mobile robot ultrasonic localisation techniques use sensor systems which rely on features in a horizontal plane. The implicit assumption is that the room boundary on the horizontal plane is not obstructed by objects such as furniture. This assumption is often not realistic and restricts the versatility and portability of these systems. The solution proposed in this paper is the provision of sensing flexibility to use other 3D room boundaries (e.g. ceiling-wall intersections)

Keywords: 3D room features, Localisation, Maximum likelihood estimation, Ultrasonic sensors

### 15  News from the international federation of robotics for robotica
**Anonymous**

JAPAN new challenges face the robot industry of tomorrow. 'It is estimated that the Japanese robot industry increased its production to Yen550billion in 1997,' writes Seiuemon Inaba, Chairman of the Japan Robot Association in his New Year message . 'This is 17&percnt; up over the preceding year, due chiefly to the rapid recovery of exports, in addition to the active domestic demand that has continued since 1996.

16  News from the international federation of robotics for robotica
Anonymous

17  News from the International Federation of Robotics for Robotica
Anonymous

UNITED KINGDOM29th ISR and Automation and Robotics '98By IFR Vice Chairman and President of the B.R.A., Mike Wilson

**18 News from the International Federation of Robotics for Robotica**
**Anonymous**

**19.News from the international federation of robotics for robotica**

Michael Kassler

**20** The International Federation of Robotics expects to have a presence on the World Wide Web by the time this issue of Robotica is published. The URL will be http://www.ifr.org. The IFR Web pages will include information about the Federation's activities as well as links to its member associations in Europe, Asia, North America and Australia.


**21.Integrating mathematica with C++ for the development of a computational geometry problem solver**

Mufid Abudiab, Michael Starek

Mathematica employs a communication protocol called MathLink to interact with external programs written in programming languages such as C, C++, and others. MathLink allows Mathematica to be integrated with other packages like Robotica, Prolog, and Discover. This integration process is triggered by the flexibility and usability of outside languages and packages and the computing power and pre-developed algorithms and functions of Mathematica.

**22. Beginnings of robotics as a separate discipline of technical sciences and some fundamental results - a personal view**

Miomir Vukobratovic

Based on the author's knowledge the paper gives a brief account of some of the scientific achievements of robotics that were of crucial importance to its development. In a rough chronological order these are: zero-moment concept and semi-inverse method; recursive formulation of robot dynamics; computer-aided derivation of robot dynamics in symbolic form; dynamic approach to

generation of trajectories of robotic manipulators; centralized feedforward control in robotics; robot dynamic control; dece ...

### 23. A comparison of rehabilitation robotics languages and software

William S. Harwin, Ray G. Gosine, Zunaid Kazi, David S. Lees, John L. Dallaway

There is a wide diversity in the functioning and programming of robots designed and programmed to assist individuals with disabilities. The planning and structure of four rehabilitation robot implementations is presented. The first is the CURL language developed for human interface and the most widely used in this field. The second, MUSIIC, explores methods for direct manipulation of objects. RoboGlyph uses symbolic constructs to assist with the direction and programming of rehabilitation robots.

### 24. A simplified hybrid force/position controller method for the walking robots

Jun Song, K. H. Low, Weimiao Guo

Force and position sensors have been widely used in robots to realize compliance and precise control. Traditional force/position control methods were studied and developed by the inverse dynamics for decades. Generally speaking, the controller contains two parts: One is the error-driven part that guarantees system stability; another is the identification model of inverse dynamics that can compensate for system influence.

### 25  Collision-free path planning for nonholonomic mobile robots using a new obstacle representation in the velocity space

Gabriel Ramírez, Saïd Zeghloul

This paper presents a collision-free path planner for mobile robot navigation in an unknown environment subject to nonholonomic constraints. This planner is well adapted for use with embarked sensors, because it uses only the distance information between the robot and the obstacles. The collision-free path-planning is based on a new representation of the obstacles in the velocity space.

Keywords: Collision avoidance, Mobile robots, Nonholonomic systems


## 26  Generating globally optimised sagittal gait cycles of a biped robot

Tarik Saidouni, Guy Bessonnet
March 2003    Robotica,  Volume 21 Issue 2
Publisher: Cambridge University Press

The paper is aimed at generating optimal gait cycles in the sagittal plane of a biped, the locomotion system of which has anthropomorphic characteristics. Both single and double support phases are globally optimised, considering incompletely specified transition postural configurations from one phase to the other. An impactless heel-touch is prescribed. Full dynamic models are developed for both gait phases.

Keywords: Cubic spline interpolation, Gait optimisation, Impactless gait, Parametric optimisation, Sagittal gait


27  Synthesis of a complete sagittal gait cycle for a five-link biped robot

Xiuping Mu, Qiong Wu
October 2003    Robotica,  Volume 21 Issue 5
Publisher: Cambridge University Press

This paper presents a method for synthesising the joint profiles for a planar five-link biped walking on flat ground. Both single support and double support phases are considered. The joint profiles have been determined based on constraint equations cast in terms of step length, step period, maximum step height and so on. A special constraint equation is developed to eliminate the destabilising effect of the impact (heel strike) occurring in the system.

Keywords: Biped robot, Gait cycle, Hip trajectory, Joint profile generation, Single and double support phases, Stability and repeatability of walking, Swing limb trajectory

## 28  On the planar stability of rigid-link binary walking robots

Yu Zhou
December 2003    Robotica,  Volume 21 Issue 6
Publisher: Cambridge University Press

A binary walking robot moves as a result of bi-state actuator transitions. Because of the bi-state nature of binary joints, many research results about continuous walking robots cannot be applied to binary walking robots directly. In this paper, a new and simple model of rigid-link binary walking robot is proposed, around which related concepts are introduced, and formulas are derived. Based on this model, general characteristics and limitations of periodic gaits are discussed, and the stability ...

Keywords: Periodic gaits, Planar stability, Rigid link, Walking robots

## 29  Optimal design of a micro parallel positioning platform. Part II: Real machine design

Kun-Ku Oh, Xin-Jun Liu, Deuk Soo Kang, Jongwon Kim

In part I of this paper (previous issue of Robotica) a dual stage system with the coarse and fine actuators is adopted to achieve sub-micron accuracy with a large working space for the proposed new three degree-of-freedom (DOF) miniaturized micro parallel mechanism with high mobility and one type of the architecture with vertical actuator locations in all three legs (C-VV type) among six possible coarse actuator architectures is selected for the coarse actuator architecture.

Keywords: Design optimization, Dual stage system, Micro positioning platform, Parallel mechanism

## 30  Passive dynamic walking model with upper body

M. Wisse, A. L. Schwab, F. C. T. Van Der Helm

This paper presents the simplest walking model with an upper body. The model is a passive dynamic walker, i.e. it walks down a slope without motor input or control. The upper body is confined to the midway angle of the two legs. With this kinematic constraint, the model has only two degrees of freedom. The model achieves surprisingly successful walking results: it can handle disturbances of 8% of the initial conditions and it has a specific resistance of only 0.0725(−).

Keywords: Biped, Passive dynamic walking, Passive upper body

## 31  Optimal design of a micro parallel positioning platform. Part I: Kinematic analysis

Kun-Ku Oh, Xin-Jun Liu, Deuk Soo Kang, Jongwon Kim

Using a coarse-and-fine actuator combination (dual stage system), a new design of the three degree-of-freedom (DOF) micro parallel positioning platform with high mobility, high accuracy, and a large working space is proposed. To achieve these three DOFs and implement the dual stage system, there are six possible architectures for the coarse and fine actuators, respectively. This paper is organized in two parts. Part I treats the kinematic analysis of each architecture and the problem of selec ...

## 32  Global robust output feedback tracking control of robot manipulators

W. E. Dixon, E. Zergeroglu, D. M. Dawson

This paper addresses the problem of global output feedback, link position tracking control of robot manipulators. Specifically, a robust, Lyapunov-based controller is designed to ensure that the link position tracking error is globally uniformly ultimately bounded despite the fact that only link position measurements are available in the presence of incomplete model information (i.e., parametric uncertainty and additive bounded disturbances).

## 33.A complete analytical solution to the inverse kinematics of the Pioneer 2 robotic arm

John Q. Gan, Eimei Oyama, Eric M. Rosales, Huosheng Hu

For robotic manipulators that are redundant or with high degrees of freedom (dof), an analytical solution to the inverse kinematics is very difficult or impossible. Pioneer 2 robotic arm (P2Arm) is a recently developed and widely used 5-dof manipulator. There is no effective solution to its inverse kinematics to date. This paper presents a first complete analytical solution to the inverse kinematics of the P2Arm, which makes it possible to control the arm.

## 34  Important role of force/velocity characteristics in sensory-motor coordination for control design of object manipulation by a multi-fingered robot hand

J.-H. Bae, S. Arimoto

The purpose of this paper is in duplicate to present computer simulation results of concurrent grasp and object manipulation by a pair of three degrees of freedom (3-dof) robot fingers with rigid hemispherical finger-ends that induce rolling contacts with an object and propose a guidance of gain tuning. Although the existence of a class of sensory feedback signals that realize stable grasp and orientation control of the object concurrently has been shown theoretically

Keywords: Force-velocity characteristics, Gain tuning, Robot fingers, Rolling contact, Sensory feedback, Stable grasp


## 35  Modelling and simulation of artificial locomotion systems

Manuel F. Silva, J. A. Tenreiro Machado, António M. M. Lopes

This paper describes a simulation model for a multi-legged locomotion system with joints at the legs having viscous friction, flexibility and backlash. For that objective the robot prescribed motion is characterized in terms of several locomotion variables. Moreover, the robot body is divided into several segments in order to emulate the behaviour of an animal spine.

Keywords: Backlash, Dynamic modelling, Fractional calculus, Friction, Kinematics, Robotics, Saturation, Simulation, Walking

## 35  Gait synthesis for hexapod robots with a locked joint failure

Jung-Min Yang

This paper presents a strategy for generating fault-tolerant gaits of hexapod walking robots. A multi-legged robot is considered to be fault-tolerant with respect to a given failure if it is capable of continuing its walking after the occurrence of a failure, maintaining its static stability. The failure concerned in this paper is a locked joint failure for which a joint in a leg cannot move and is locked in place.

Keywords: Fault-tolerant walking, Gait study, Hexapod robots, Locked joint failure

## 36  A Parametric Optimization Approach to Walking Pattern Synthesis

G. Bessonnet, P. Seguin, P. Sardain

Walking pattern synthesis is carried out using a spline-based parametric optimization technique. Generalized coordinates are approximated by spline functions of class C3fitted at knots uniformly distributed along the motion time. This high-order differentiability eliminates jerky variations of actuating torques. Through connecting conditions, spline polynomial coefficients are determined as a linear function of the joint coordinates at knots.

## 37  Manipulation with a polyarticulated mechanical hand: a new efficient real-time method for computing fingertip forces for a global manipulation strategy

J. P. Gazeau, S. Zeghloul, G. Ramirez

This paper proposes an efficient algorithm for computing finger forces involved in a three-dimensional objects grasp. Effective finger force computation is necessary for the successful manipulation on an object by a multifingered robot hand. Based on previous works, the stability forces are computed as a solution of an optimization problem. This optimization problem is mapped into a linear quadratic problem under inequality constraints.

## 38  Sonar Based Systematic Exploration Method for an Autonomous Mobile Robot Operating in an Unknown Environment

Jong Hwan Lim, Dong Woo Choo

A new systematic exploration method is addressed that permits a mobile robot to effectively acquire the information on an unknown environment without wasting time. The algorithm is composed of following three modules: the first is the decomposition of a workspace into several sub-nodes by employing the concept of Quadtree. These nodes are chosen as sub-goals to be reached successively.

## 39  Introduction to the special issue on rehabilitation robotics

M. Hillman

This special issue of "Robotica" gives an opportunity to present a cross-section of the wide range of research and development projects in rehabilitation robotics. Rehabilitation Robotics (RR) is the application of robotic technology to the rehabilitative needs of people with disabilities as well as the growing elderly population. The papers were originally presented at the ICORR'97 conference, organised by the Bath Institute of Medical Engineering

**40 Introduction to the special issue on Design and Applications in Robotics**

It is, indeed, a pleasure to edit this special issue of Robotica entitled Design and Applications. This consists of revised and updated papers presented during the 26th International Symposium on Industrial Robots (ISIR), which was held on 4–6 October, 1995, in Singapore. The theme of the symposium was "Competitive Automation: New Frontiers, New Opportunities". Ninety-six papers were presented by authors from twenty-five countries around the world.

**41 A successive approximation algorithm for the inverse position analysis of serial manipulators**

Xinhua Zhao, Shangxian Peng

A new numerical method for the solution of the inverse position analysis of serial manipulators is presented. The main feature of the method that makes it attractive with respect to the method available in the literature, is its ability to search out the inverse solution of any precision quickly.

**42 Neural network sliding mode robot control**

Karel Jezernik, Miran Rodič, Riko Šafarič, Boris Curk

This paper develops a method for neural network control design with sliding modes in which robustness is inherent. Neural network control is formulated to become a class of variable structure (VSS) control. Sliding modes are used to determine best values for parameters in neural network learning rules, thereby robustness in learning control can be improved.

**43 Minimum cost, fixed time trajectory planning in robot manipulators. A suboptimal solution**

Ignacy Duleba

In this paper the minimum cost trajectory planning problem with fixed time in robot manipulators is considered. The task is solved by transforming the problem to a set of free right-end time optimal problems, leading to a suboptimal solution. Each problem of the optimal cost trajectory planning with a free time is effectively solved by the method of minimal neighbourhood.

Keywords: Multi-robot systems, Optimization, Robot manipulator, Trajectory planning

## 44 Obstacle avoidance motion planning for mobile robots in a dynamic environment with moving obstacles

Chia-Pin Wu, Tsu-Tian Lee, Chau-Ren Tsai

A new real-time obstacle avoidance method for mobile robots has been developed. This method, namely the vector-distance function method, permits the detection of obstacles (both moving and stationary) and generates a path that can avoid collisions. The proposed approach expresses the distance information in a vector form. Then the notion of weighting is introduced to describe relationship between sensors of mobile robots and the target to be reached.
Keywords: Dynamic environment, Mobile robots, Moving obstacles, Vector-distance function

## 45  Obituary: Professor Edmond Nicolau

J. Rose

On September 2 1996, Professor Edmond Nicolau, an eminent cybernetician and great intellect, died aged 74. This was, indeed, a great loss to the world of science. I have also lost a devoted friend and active collaborator in the fields of cybernetics and systems, as well as a valuable member of the Editorial Board of Robotica.

## 46  Reports and Surveys: DEVELOPMENT PROGRAMMES FOR BUSINESS AUTOMATION

B. H. Rudall

Joint Venture Prograamme at Cranfield (UK)The Joint Venture Programme, newly launched by the Cranfield School of Management, offers help to companies that are looking to expand their business in developing countries. It is claimed that valuable European Community (EU) grants are being lost, and the Cranfield initiative offers a fast track through what they describe as the bureaucracy involved in making applications for aid to develop partnerships abroad.

**47 Generation of robotic assembly sequences with consideration of line balancing using simulated annealing**

An assembly sequence is considered to be optimal when the sequence satisfies assembly constraints and yields the minimum assembly cost. While, a line balancing solution is considered to be optimal when the solution has the minimum idle time of the line, i.e. the minimum number of workstations for a given cycle time. Although optimal assembly sequences are generated without considering line balancing, they may not guarantee the minimum number of workstations.

**48  Sagittal gait of a biped robot during the single support phase. Part 2: optimal motion**

The paper is aimed at generating optimal swing motions during the single-support phase of sagittal gait. Unlike the previous Part 1 which deals with passive motions, all joints of the biped are assumed to be active in the present Part 2. The final conditions specify an impactless heel-touch in order to avoid a destabilizing effect on the biped motion. As the biped is essentially submitted to gravity forces, the motion is generated by minimizing the joint actuating torques.

**49  Fast and accurate collision detection based on enclosed ellipsoid**

A fast and accurate method for detecting the collisions of convex polyhedra in a graphical simulation environment based on a newly developed method of distance estimate is presented. By the simultaneous use of the enclosing and the enclosed ellipsoids of convex polyhedra, potential collisions can be detected more accurate than those methods using only bounding volume for object representation, and more efficient than the polyhedral methods.

## 50  Nonholonomic path planning among obstacles subject to curvature restrictions

Wilson D. Esquivel, Luciano E. Chiang

This paper addresses the problem of finding a nonholonomic path subject to a curvature restriction, to be tracked by a wheeled autonomous navigation vehicle. This robot is able to navigate in a structured environment, with obstacles modeled as polygons, thus constituting a model based system. The path planning methodology begins with the conditioning of the polygonal environment by offsetting each polygon in order to avoid the possibility of collision with the mobile.

## 51  A stability theory of a manifold: concurrent realization of grasp and orientation control of an object by a pair of robot fingers

S. Arimoto, K. Tahara, J.-H. Bae, M. Yoshida

This paper is concerned with a stability theory of motion governed by Lagrange's equation for a pair of multi-degrees of freedom robot fingers with hemi-spherical finger ends grasping a rigid object under rolling contact constraints. When a pair of dual two d.o.f. fingers is used and motion of the overall fingers-object system is confined to a plane, it is shown that the total degree of freedom of the fingers-object system is redundant for realization of stable grasping.

## 52  A three translational DoFs parallel cube-manipulator

Xin-Jun Liu, Jay Il Jeong, Jongwon Kim

This paper concerns the presentation and analysis of a type of three translational degrees of freedom (DoFs) parallel cube-manipulator. The parallel manipulators are the topology architectures of the DELTA robot and Tsai's manipulator, respectively, which have three translational DoFs. In the design, the three actuators are arranged according to the Cartesian coordinate system, which means that the actuating directions are normal to each other

## 53 Open-loop stable running

Katja D. Mombaur, Richard W. Longman, Hans Georg Bock, Johannes P. Schlöder

We present simulated monopedal and bipedal robots that are capable of open-loop stable periodic running motions without any feedback even though they have no statically stable standing positions. Running as opposed to walking involves flight phases which makes stability a particularly difficult issue. The concept of open-loop stability implies that the actuators receive purely periodic torque or force inputs that are never altered by any feedback in order to prevent the robot from falling.

## 54 Practical robot calibration with ROSY

Lukas Beyer, Jens Wulfsberg

The accuracy of pose of industrial robots is often unsatisfactory for advanced applications. Particularly regarding off-line programming, exchangeability and high precision tasks problems may occur which can be very time-consuming and costly to solve. Therefore a calibration system ROSY has been developed in order to increase the accuracy of standard robots and parallel-kinematic structures, like the Tricept robots.

## 45 Observer-based control of a walking biped robot without orientation measurement

V. Lebastard, Y. Aoustin, F. Plestan

Two observers based on high order sliding mode approach are proposed to determine the absolute orientation of a walking biped robot without feet. Contrary to velocities observers which have been often designed for robot control, very few works have been proposed for the orientation estimation: in this paper, the estimation of all state variables are derived from only the actuated joint variables. Then the technology problem of the absolute measurement is avoided. This latter point is an o ...

## 46 A new numerical algorithm for the inverse position analysis of all serial manipulators

Yongjie Zhao, Tian Huang, Zhiyong Yang

A new fast successive approximation algorithm for the solution of the inverse position analysis of a general serial manipulator is presented. With the algorithm, we can search out the inverse solution of the serial manipulator quickly under the desired precision when the position of the three non-collinear end effector points is given. The position analysis of the 7R redundant serial manipulator is illustrated in the literature as an example. The simulation results verify the efficiency of the p ...

## 47  Simple two degree of freedom structures and their properties

Rafael Osypiuk, Bernd Finkemeyer, Stanislaw Skoczowski

A two-degree of freedom control system that is most frequently encountered in practice is the so-called Internal Model Control (IMC) structure. However, the design procedure of such a structure does not present an easy task, which implies a limited utility of IMC. In this paper two alternative solutions are proposed that may be lumped together as Model-Following Control (MFC). These are two-loop control systems being easy to implement and offering interesting properties.

## 48  Fault-tolerant crab gaits and turning gaits for a hexapod robot

Jung-Min Yang

This paper studies crab gaits and turning gaits of a hexapod robot with a locked joint failure. Due to the reduced workspace of a failed leg, fault-tolerant gaits have limitations in their mobility. Based on the principles of fault-tolerant gait planning, periodic crab gaits and turning gaits are proposed in which a hexapod robot carries out tripod walking after a locked joint failure, having a reasonable stride length and stability margin.

## 49  Comparative experiments with a multiple model based adaptive controller for a SCARA type direct drive manipulator

M. Kemal Ciliz, M. Ömer Tuncay

In this paper, different adaptive control algorithms will be experimentally tested on a two axis SCARA type direct drive robot arm, and the performance of these algorithms will be compared. Being a direct drive system, the nonlinear effects, arising from the dynamics of the manipulator under high velocities, are directly reflected in the control of the manipulator. This makes the manipulator a more efficient test bed for testing the efficiency of the proposed adaptive schemes.

Keywords: Adaptive controller, Direct drive, Multiple models, Non-linear effects, SCARA robot

## 50  A real-time joint trajectory planner for dynamic walking bipeds in the sagittal plane

J. Vermeulen, B. Verrelst, D. Lefeber, P. Kool, B. Vanderborght

A real-time joint trajectory generator for planar walking bipeds is proposed. This trajectory planner generates dynamically stable motion patterns by using a set of objective locomotion parameters as its input, and by tuning and exploiting the natural upper body dynamics. The latter can be determined and manipulated by using the angular momentum equation. Basically, trajectories for hip and swing foot motion are generated

Keywords: Angular momentum, Natural dynamics, Objective locomotion parameters, Real-time trajectory planning, Walking biped

## 51  A novel ultra-precision integrated robotic system

Shaowei Gong

An ultra-precision integrated robotic system is developed, which integrates a passive robotic measurement system (shadow system) with an industrial robot. The shadow system is built almost ideal. In a working process, when the end-effecter of integrated robot is driven to a target with errors which are caused by degrading factors associated with the robot, the shadow system will independently detect the end-effecter frame instantly with ultra-precision kinematic accuracy

Keywords: 6-D robot, Kinematic accuracy, RYLDA, Shadow system, Ultra-precision

**52**  COMPUTATIONAL VISION – INFORMATION PROCESSING IN PERCEPTION AND VISUAL BEHAVIOR, by H. A. Mallot (translated from German by J. S. Allen), Bradford Book, MIT Press, Cambridge, MA, 296 pp., 2001, ISBN 0-262-13381-4, 2001 (Hardback, £34.50)

COMPUTATIONAL VISION INFORMATION PROCESSING IN PERCEPTION AND VISUAL BEHAVIOR, by H. A. Mallot (translated from German by J. S. Allen), Bradford Book, MIT Press, Cambridge, MA, 296 pp., 2001, ISBN 0-262-13381-4, 2001 (Hardback, £34.50)

## 53  Virtual reality training and EMG control of the MANUS hand prosthesis

J. L. Pons, R. Ceres, E. Rocon, S. Levin, I. Markovitz, B. Saro, D. Reynaerts, W. Van Moorleghem, L. Bueno

The design of multifunctional upper limb prosthetics has been investigated in recent years. Several areas or research need to be developed for successful implementation of dextrous upper limb prosthesis, in particular better EMG interfaces for implementing command languages.This article introduces a novel three-bit EMG command language concept as a user interface for the multifunctional MANUS prosthesis prototype. Following the global approach proposed by MANUS, a training process and the suppor ...

Keywords: EMG control, MANUS, Prosthesis, Virtual reality

## 54  Residual kinetic imaging: a versatile interface for prosthetic control

Sam L. Phillips, William Craelius

We studied the pressure patterns in the residual limbs of transradial amputees during their voluntary commands for finger taps. Topographic maps of pressures exerted against the hard prosthetic socket were registered with an array of 32 pressure sensors, to produce residual kinetic images (RKIs) of the limb. Results with 2 untrained subjects demonstrated that RKIs are reliable decoders of efferent commands.

Keywords: Controller, Dexterity, Prosthetic, Upper-limb

## 55  The principle of superposition in human prehension

Vladimir M. Zatsiorsky, Mark L. Latash, Fan Gao, Jae Kun Shim

The experimental evidence supports the validity of the principle of superposition for multi-finger prehension in humans. Forces and moments of individual digits are defined by two independent commands: "Grasp the object stronger/weaker to prevent slipping" and "Maintain the rotational equilibrium of the object". The effects of the two commands are summed up.

Keywords: Human prehension, Robotics, Superposition principle

56 Experimental evaluation of generalized predictive control applied to a hydraulic actuator

N. Sepehri, G. Wu

This paper reports the results of an experimental study, which was conducted to evaluate the performance and implementation aspects of a generalized predictive control (GPC) technique to an electro-hydraulic positioning actuator. Poor dynamics and high nonlinearities form part of the difficulty in the control of hydraulic functions which make the application of adaptive controls an attractive solution.

## 57  Trajectory generation for a four wheel steering tractor-trailer system: a two-step method

Yongji Wang, M. P. Cartmell

A basic problem in the development of an intelligent vehicle/highway system (IVHS), or an autonomous mobile robot system (AMRS) is to find suitable input controls which can be used to drive the vehicle between any two configurations. In this paper a trajectory generation problem for a four-wheel-steering tractor/semi-trailer system is investigated

## 58  Contact Point identification in robot assembly strategies under uncertainty

C. J. Tsaprounis, N. Aspragathos

In this paper a method for the reduction of the uncertainties in robotised assembly process is presented. The generated assembly strategies are based on the determination of the contact points. The assembly task is divided in two main subtasks, the initial and the main. To reduce the uncertainty of the process a deliberate misalignment of the peg is used.This paper is focused on the determination of the position and the forces at the contact points between the peg and hole under uncertainty.

## 59  Behaviour-based peg-in-hole

Giovanni C. Pettinaro

Given the high occurence rate in assembly industry, mating a peg into a hole can be considered as one of the most classic problem in robotics. Such a task has been extensively examined by many researchers who have repeatedly attempted to find out a general solution for it. Peg in hole, which is, needlessly to mention, extremely trivial for any human operator, is surprisingly difficult to have it carried out by a robot manipulator.

## 60  A configuration space approach to collision avoidance of a two-robot system

S. W. Lee, B. H. Lee, K. D. Lee

This paper suggests an efficient approach to collision avoidance of a practical two-robot system. The approach is based on the C-space of one robot, and we consider only two and three dimensional C-space in which nearly all industrial manipulators can be reasonably represented for collision avoidance problems. The C-space of one robot is discretized with the concentric circles or spheres centered at the goal configuration.

## 61  Extension of Usable Workspace of Rotational Axes in Robot Planning

Zhen Huang, Y. Lawrence Yao

Singularity of a robot manipulator is one of the obstacles that influences its capabilities. This paper discusses constrained and allowable rotational motion resulting from lost translational freedom when the robot is singular. A convenient method and simple and clear expression to determine the allowable rotational axes and the subspace that they form, under Jacobian singularity, is analyzed and presented. Different configurations

## 62  Control of nonholonomic mechanical systems using reduction and adaptation

R. Colbaugh, E. Barany, M. Trabatti

This paper considers the problem of controlling the motion of nonholonomic mechanical systems in the presence of uncertainty regarding the system model and state. It is proposed that a simple and effective solution to this problem can be obtained by first using a reduction procedure to obtain a lower dimensional system which retains the mechanical system structure of the original system

Keywords: Adaptation, Motion control, Nonholonomic systems, Reduction

## 63  The Tricept robot: Inverse kinematics, manipulability analysis and closed-loop direct kinematics algorithm

Bruno Siciliano

This paper is aimed at presenting a study on the kinematics of the Tricept robot, which comprises a three-degree-of-freedom (dof) parallel structure having a radial link of variable length. The robot workspace is characterized and the inverse kinematics equation is obtained by using spherical coordinates. The inverse differential kinematics and statics are derived in terms of both an analytical and a geometric Jacobina and a manipulability analysis along the various workspace directions

Keywords: Direct kinematics algorithms, Inverse kinematics, Jacobian, Manipulability ellipsoids, Parallel robots

## 64  Adaptive gait planning for multi-legged robots with an adjustment of center-of-gravity

Wenjie Chen, K. H. Low, S. H. Yeo

Adaptive gait planning is an important aspect in the development of control systems for multi-legged robots traversing on rough terrain. The problem of adaptive gait generation can be viewed as one of finding a sequence of suitable foothold on rough terrain so that legged systems maintain static stability and motion continuity. Due to the limit of static stability, deadlock situation may occur in the process of searching for a suitable foothold

Keywords: CG adjustment, Gait planning, Motion planning, Multi-legged robots

## 65  Resolving kinematic redundancy of a robot using a quadratically constrained optimization technique

Woong Kwon, Beom Hee Lee, Myoung Hwan Choi

The constraints on the physical limit should be considered in a kinematic redundancy resolution problem of a robot. This paper proposes a new optimization scheme to resolve kinematic redundancy of the robot while considering physical constraints. In the proposed scheme, quadratic inequality constraints are used in place of linear inequality constraints, thus a quadratically constrained optimization technique is applied to resolve the redundancy.

## 66  Reports and Surveys

B. H. Rudall

ADVANCES IN ROBOTIC TECHNIQUES1. Robotics in MedicineThere have been a number of reports in this section of the progress being made in applying robotic techniques to medical processes. High on the list of achievements in this area have been the attempts to help in surgical operations. Already reports here have dealt with improved aids for surgeons with increased facilities for viewing and of producing images of the patient's progress.

## 67  Dynamic control of pushing operations

N. Rezzoug, P. Gorce

The goal of this paper is to present a new method to control pushing operations with several fingers. We take into account some dynamical aspects that have not yet been investigated in pushing studies such as the object's center of mass acceleration correction and optimal force distribution. To do this, we use a general method for multi-chain mechanisms based on a dynamical control with finger coordination.

## 68  Clarifying the definition of redundancy as used in robotics

E. Sahin Conkur, Rob Buckingham

Several descriptions of redundancy are presented in the literature, often from widely different perspectives. Therefore, a discussion of these various definitions and the salient points would be appropriate. In particular, any definition and redundancy needs to cover the following issues; the difference between multiple solutions and an infinite number of solutions; degenerate solutions to inverse kinematics; task redundancy; and the distinction between non-redundant, redundant and highly

## 69  An overview of robot force control

Ganwen Zeng, Ahmad Hemami

This paper reports on the existing robot force control algorithms and their composition based on the review of 75 papers on this subject. The objective is to provide a pragmatic exposition with speciality on their differences and different application conditions, and to give a guide of the existing robot force control algorithms. The previous work can be categorized into discussion, design and/or application of fundamental force control techniques

## 70  On an effective design approach of cartesian space neural network control for robot manipulators

Seul Jung, T. C. Hsia

It is well known that computed torque robot control is subjected to performance degradation due to uncertainties in robot model, and application of neural network (NN) compensation techniques are promising. In this paper we examine the effectiveness of neural network (NN) as a compensator for the complex problem of Cartesian space control. In particular we examine the differences in system performance of accurate position control when the same NN compensator is applied at different locations