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Fast Aerial Video Stitching
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Research on one Bio-inspired Jumping Locomotion Robot for Search and Rescue
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Accuracy Analysis of a Robot System for Closed Diaphyseal Fracture Reduction
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CPG-based Sensory Feedback Control for Bio-inspired Multimodal Swimming
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Towards Automated and Objective Assessment of Fabric Pilling
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Biologically-inspired Control Architecture for Musical Performance Robots
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Stiffness Model of a 3-DOF Parallel Manipulator with Two Additional Legs
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Research on a New Bilateral Self-locking Mechanism for an Inchworm Micro In-pipe Robot with Large Traction
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Design and Rolling Analysis of a Novel Deformable Mobile Polyhedron Robot
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Predicting the Motion of a Robot Manipulator with Unknown Trajectories Based on an Artificial Neural Network
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Particle-filter-based Pose Estimation from Controlled Motion with Application to Visual Servoing
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A Flying Robot Localization Method Based on Multi-sensor Fusion
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On the Numerical Modelling and Error Compensation for General Gough-Stewart Platform
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Global Finite-time Stabilization for Nonholonomic Mobile Robots Based on Visual Servoing
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Recent Advances in the Control of Piezoelectric Actuators
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Emulating Upper Limb Disorder for Therapy Education
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Optimization of PI and Fuzzy-PI Controllers on Simulation Model of Szabad(ka)-II Walking Robot
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A Dual-Axis Electrostatically Driven MEMS Microgripper
Yukun Jia, Minping Jia and Qingsong Xu

SMAC — Modular Open Source Architecture for Medical Capsule Robots
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Miniature Mobile Bristled In-Pipe Machine
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Design and Kinematic Analysis of a New End-Effector for a Robotic Needle Insertion-Type Intervention System
Youngjin Moon, Hyuk Jae Choi, Joon Beom Seo and Jaesoon Choi

A Crawler Climbing Robot Integrating Electroadhesion and Electrostatic Actuation
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New Structural Design of a Compliant Gripper Based on the Scott-Russell Mechanism
Wenji Ai and Qingsong Xu

A Robust and Efficient Algorithm for Tool Recognition and Localization for Space Station Robot
Lingbo Cheng, Zhihong Jiang, Hui Li and Qiang Huang

A Collision-Free $G^2$ Continuous Path-Smoothing Algorithm Using Quadratic Polynomial Interpolation
Seong-Ryong Chang and Uk-Youl Huh
Book of Abstracts
Modelling, Design and Robust Control of a Remotely Operated Underwater Vehicle

Luis Govinda García-Valdovinos, Tomás Salgado-Jiménez, Manuel Bandala-Sánchez, Luciano Nava-Balanzar, Rodrigo Hernández-Alvarado and José Antonio Cruz-Ledesma

Abstract:
Underwater remotely operated vehicles (ROVs) play an important role in a number of shallow and deep-water missions for marine science, oil and gas extraction, exploration and salvage. In these applications, the motions of the ROV are guided either by a human pilot on a surface support vessel through an umbilical cord providing power and telemetry, or by an automatic pilot. In the case of automatic control, ROV state feedback is provided by acoustic and inertial sensors and this state information, along with a controller strategy, is used to perform several tasks such as station-keeping and auto-immersion/heading, among others. In this paper, the modelling, design and control of the Kaxan ROV is presented: 1) The complete six degrees of freedom, non linear hydrodynamic model with its parameters, 2) the Kaxan hardware/software architecture, 3) numerical simulations in Matlab/Simulink platform of a model-free second order sliding mode control along with ocean currents as disturbances and thruster dynamics, 4) a virtual environment to visualize the motion of the Kaxan ROV and 5) experimental results of a one degree of freedom underwater system.

Keywords: ROV Control, High Order Sliding Mode Control, Model-Free, Ocean Currents

Stitching Images with Arbitrary Lens Distortions

Myung-Ho Ju and Hang-Bong Kang

Abstract:
In this paper, we propose a new method to compensate for lens distortions in image stitching. Lens distortions that arise from the nonlinearity of a lens are the main cause for mismatches in stitching images. We estimate the distortion factors for each image using the Division Model and linearize the projected relationships between matching distorted feature points. Because our method works at the RANSAC stage, the estimated distortion factors are further refined during the bundle adjustment phase and thus accurate distortion factors are obtained. Applications based on estimated lens distortion factors show that our method is more efficient and that the stitched results are more accurate than other previous methods.

Keywords: Panorama, Image Stitching, Lens Distortion
An Adaptive Neural Network Learning-Based Solution for the Inverse Kinematics of Humanoid Fingers

Byoung-Ho Kim

Abstract:
This paper presents an adaptive neural network learning-based solution for the inverse kinematics of humanoid fingers. For the purpose, we specify an effective finger model by considering the interphalangeal joint coordination inherent in human fingers. In order to find a proper joint combination for any fingertip trajectory, we propose an adaptive learning scheme by using a multi-layered neural network. It is interesting to use an adaptive learning rate algorithm that leads the neural network to get the inverse kinematic solution quickly. The usefulness of the proposed approach is verified by exemplary simulations for the general motion of humanoid fingers.

Keywords  Adaptive Neural Network Learning, Inverse Kinematics, Humanoid Fingers

An Efficient Ceiling-view SLAM Using Relational Constraints Between Landmarks

Hyukdoo Choi, Ryunseok Kim and Euntai Kim

Abstract:
In this paper, we present a new indoor ‘simultaneous localization and mapping’ (SLAM) technique based on an upward-looking ceiling camera. Adapted from our previous work [17], the proposed method employs sparsely-distributed line and point landmarks in an indoor environment to aid with data association and reduce extended Kalman filter computation as compared with earlier techniques. Further, the proposed method exploits geometric relationships between the two types of landmarks to provide added information about the environment. This geometric information is measured with an upward-looking ceiling camera and is used as a constraint in Kalman filtering. The performance of the proposed ceiling-view (CV) SLAM is demonstrated through simulations and experiments. The proposed method performs localization and mapping more accurately than those methods that use the two types of landmarks without taking into account their relative geometries.

Keywords  Extended Kalman Filter, Relational Constraint, Ceiling-view, Visual Simultaneous Localization and Mapping (vSLAM)
A Comparison Study on Motion/Force Transmissibility of Two Typical 3-DOF Parallel Manipulators: The Sprint Z3 and A3 Tool Heads

Xiang Chen, Xin-Jun Liu, FuGui Xie and Tao Sun

Abstract:
This paper presents a comparison study of two important three-degree-of-freedom (DOF) parallel manipulators, the Sprint Z3 head and the A3 head, both commonly used in industry. As an initial step, the inverse kinematics are derived and an analysis of two classes of limbs is carried out via screw theory. For comparison, three transmission indices are then defined to describe their motion/force transmission performance. Based on the same main parameters, the compared results reveal some distinct characteristics in addition to the similarities between the two parallel manipulators. To a certain extent, the A3 head outperforms the common Sprint Z3 head, providing a new and satisfactory option for a machine tool head in industry.

Keywords  Parallel Manipulators, Sprint Z3 Head, A3 Head, Comparison, Motion/Force Transmissibility

Design of a Wildlife Avoidance Planning System for Autonomous Harvesting Operations

Dionysis D. Bochtis, Claus G. Sørensen, Ole Green, Ibrahim A. Hameed and Remigio Berruto

Abstract:
Harvesting and mowing operations are among the main potential stressors affecting wildlife within agricultural landscapes, leading to large animal losses. A number of studies have been conducted on harvesting practices to address the problem of wildlife mortality, providing a number of management actions or field area coverage strategies. Nevertheless, these are general rules limited to simple-shaped fields, and which are not applicable to more complex operational situations. The objectives of the present study were to design a system capable of deriving a wildlife avoidance driving pattern for any field shape complexity and field boundary conditions (in terms of escape and non-escape areas) and applicable to different animal behaviours. The assumed animal escape reactions are the result of the parameterization of a series of developed behavioural functions. This parameterization will be able to adapt any knowledge that is or might become available as a result of dedicated future experiments on animal behaviour for different species or different animal ages.

Keywords  Operations Management, Field Robotics, Path Planning
Design of Neural Network Control System for Controlling Trajectory of Autonomous Underwater Vehicles

İkbal Eski and Şahin Yıldırım

Abstract:
A neural network based robust control system design for the trajectory of Autonomous Underwater Vehicles (AUVs) is presented in this paper. Two types of control structure were used to control prescribed trajectories of an AUV. The vehicle was tested with random disturbances while taxiing underwater. The results of the simulation showed that the proposed neural network based robust control system has superior performance in adapting to large random disturbances such as underwater flow. It is proved that this kind of neural predictor could be used in real-time AUV applications.

Keywords  Neural Network Control, Robust Control, Autonomous Underwater Vehicles, Trajectory Control

Authentication and Secure Robot Communication

Evangelos A. Yfantis and Ahmad Fayed

Abstract:
In many cases robots are connected wirelessly with a file server and often with one another, either directly, or via the file server. The network connections form a subnet where the router has the static IP address visible to the outside world and the server along with the robots form a subnet with local IP addresses. Often however, each robot has its own static IP address. In addition, each robot has a NIC card and a unique NIC address, as well as other hardware identifiers depending on the functionality and complexity of the robot. The non-electronic part of the robot hardware usually represents mature technology that has been understood for a long time. The electronic hardware has evolved to the point that the embedded software can provide the needed intelligence for the robot to perform sophisticated tasks previously performed by one or more human beings. However, in previous research emphasis has been placed on the tasks performed by the robots, neglecting any security issues or liabilities that may arise due to lack of security. In this paper, we provide an algorithm for secure key management, and secure communication in an insecure wireless and noisy environment in which the robots operate.

Keywords  Digital Transmission, UDP, Wireless Transmission, Noisy Channels
Simulation Research on Adaptive Control of a Six-degree-of-freedom Material-testing Machine

Dan Wang, Rui Fan and Wuyi Chen

Abstract:
This paper presents an adaptive controller equipped with a stiffness estimation method for a novel material-testing machine, in order to alleviate the performance depression caused by the stiffness variance of the tested specimen. The dynamic model of the proposed machine is built using the Kane method, and the kinematic model is established with a closed-form solution. The stiffness estimation method is developed based on the recursive least-squares method and the proposed stiffness equivalent matrix. Control performances of the adaptive controller are simulated in detail. The simulation results illustrate that the proposed controller can greatly improve the control performance of the target material-testing machine by online stiffness estimation and adaptive parameter tuning, especially in low-cycle fatigue (LCF) and high-cycle fatigue (HCF) tests.

Keywords  6-DOF Material-testing Machine, Parallel Robot, Adaptive Control, Stiffness Estimation

An Extension of the Interscale SURE-LET Approach for Image Denoising

Lihong Cui, Zhan Wang, Yigang Cen, Xuguang Li and Jianjun Sun

Abstract:
In this paper, an extension of the interscale SURE-LET approach exploiting the interscale and intrascale dependencies of wavelet coefficients is proposed to improve denoising performance. This method incorporates information on neighbouring coefficients into the linear expansion of thresholds (LETs) without additional parameters to capture the texture characteristics of this image. The resulting interscale-intrascale wavelet estimator consists of a linear expansion of multivariate thresholding functions, whose parameters are optimized thanks to a multivariate Stein’s unbiased risk estimate (SURE). Some experimental results are given to demonstrate the strength of the proposed method.

Keywords  Orthonormal Wavelet, Multivariate SURE-LET, Interscale and Intrascale Dependence, Multivariate Stein’s Unbiased Risk Estimate, Image Denoising
Improved Laser Manipulation for On-chip Fabricated Microstructures Based on Solution Replacement and Its Application in Single Cell Analysis

Tao Yue, Masahiro Nakajima, Masaru Takeuchi and Toshio Fukuda

Abstract:
In this paper, we present the fabrication and assembly of microstructures inside a microfluidic device based on a photocrosslinkable resin and optical tweezers. We also report a method of solution replacement inside the microfluidic channel in order to improve the manipulation performance and apply the assembled microstructures for single cell cultivation. By the illumination of patterned ultraviolet (UV) through a microscope, microstructures of arbitrary shape were fabricated by the photocrosslinkable resin inside a microfluidic channel. Based on the microfluidic channel with both glass and polydimethylsiloxane (PDMS) surfaces, immovable and movable microstructures were fabricated and manipulated. The microstructures were fabricated at the desired places and manipulated by the optical tweezers. A rotational microstructure including a microgear and a rotation axis was assembled and rotated in demonstrating this technique. The improved laser manipulation of microstructures was achieved based on the on-chip solution replacement method. The manipulation speed of the microstructures increased when the viscosity of the solvent decreased. The movement efficiency of the fabricated microstructures inside the lower viscosity solvent was evaluated and compared with those microstructures inside the former high viscosity solvent. A novel cell cage was fabricated and the cultivation of a single yeast cell (w303) was demonstrated in the cell cage, inside the microfluidic device.

Keywords  Laser Manipulation, On-chip Fabrication, Microstructures, Solution Replacement, Single Cell Analysis

Terrain-surface Estimation from Body Configurations of Passive Linkages

Daisuke Chugo, Kuniaki Kawabata, Hayato Kaetsu, Hajime Asama and Taketoshi Mishima

Abstract:
A passive linkage mechanism is used for increasing the mobile performance of a wheeled vehicle on uneven ground. The mechanism changes its shape according to the terrain and enables all the wheels to remain grounded while the vehicle operates over rough terrain. This means that the shape of the passive linkage mechanism must correspond to that of the terrain surface, so that the vehicle can estimate the shape of the surface while passing over it. This paper proposes a new terrain-surface estimation scheme that uses a passive linkage mechanism. Our key concept is to enable changes in the vehicle body’s configuration to correspond to those in the terrain’s shape. Using this concept, our mobile platform estimates the shape of terrain surfaces without using external sensors; the estimated surface shapes are used to adjust the reference velocities of individual wheels, thereby improving the mobile performance of the vehicle. We test our proposed scheme by experiments using a prototype vehicle.

Keywords  Passive Linkage Mechanism, Terrain-Surface Estimation, Non-Flat Ground, Omnidirectional Wheeled Vehicle
Optimization of Rules Selection for Robot Soccer Strategies
Václav Snášel, Václav Svatoň, Jan Martinovič and Ajith Abraham

Abstract:
Mobile embedded systems belong among the typical applications of distributed systems control in real-time. An example of a mobile control system is a robotic system. The proposal and realization of such a distributed control system represents a demanding and complex task for real-time control. In the process of robot soccer game applications, extensive data is accumulated. The reduction of such data is a possible win in a game strategy. The main topic of this article is a description of an efficient method for rule selection from a strategy. The proposed algorithm is based on the geometric representation of rules. A described problem and a proposed solution can be applied to other areas dealing with effective searching of rules in structures that also represent coordinates of the real world. Because this construed strategy describes a real space and the stores physical coordinates of real objects, our method can be used in strategic planning in the real world where we know the geographical positions of objects.

Keywords Robot Soccer, Strategy, Rule

An Optimal Calibration Method for a MEMS Inertial Measurement Unit
Bin Fang, Wusheng Chou and Li Ding

Abstract:
An optimal calibration method for a micro-electro-mechanical inertial measurement unit (MIMU) is presented in this paper. The accuracy of the MIMU is highly dependent on calibration to remove the deterministic errors of systematic errors, which also contain random errors. The overlapping Allan variance is applied to characterize the types of random error terms in the measurements. The calibration model includes package misalignment error, sensor-to-sensor misalignment error and bias, and a scale factor is built. The new concept of a calibration method, which includes a calibration scheme and a calibration algorithm, is proposed. The calibration scheme is designed by D-optimal and the calibration algorithm is deduced by a Kalman filter. In addition, the thermal calibration is investigated, as the bias and scale factor varied with temperature. The simulations and real tests verify the effectiveness of the proposed calibration method and show that it is better than the traditional method.

Keywords Calibration, MIMU, D-optimal, Kalman Filter, Thermal
An Infant Development-inspired Approach to Robot Hand-eye Coordination
Fei Chao, Mark H. Lee, Min Jiang and Changle Zhou

Abstract:
This paper presents a novel developmental learning approach for hand-eye coordination in an autonomous robotic system. Robotic hand-eye coordination plays an important role in dealing with real-time environments. Under the approach, infant developmental patterns are introduced to build our robot’s learning system. The method works by first constructing a brain-like computational structure to control the robot, and then by using infant behavioural patterns to build a hand-eye coordination learning algorithm. This work is supported by an experimental evaluation, which shows that the control system is implemented simply, and that the learning approach provides fast and incremental learning of behavioural competence.

Keywords Developmental Robotics, Robotic Hand-eye Coordination, Infant Developmental Pattern, Brain-like Computational Structure

A New Profile Shape Matching Stereovision Algorithm for Real-time Human Pose and Hand Gesture Recognition
Dong Zhang, Dah-Jye Lee and Yung-Ping Chang

Abstract:
This paper presents a new profile shape matching stereovision algorithm that is designed to extract 3D information in real time. This algorithm obtains 3D information by matching profile intensity shapes of each corresponding row of the stereo image pair. It detects the corresponding matching patterns of the intensity profile rather than the intensity values of individual pixels or pixels in a small neighbourhood. This approach reduces the effect of the intensity and colour variations caused by lighting differences. As with all real-time vision algorithms, there is always a trade-off between accuracy and processing speed. This algorithm achieves a balance between the two to produce accurate results for real-time applications. To demonstrate its performance, the proposed algorithm is tested for human pose and hand gesture recognition to control a smart phone and an entertainment system.

Keywords Profile Shape Matching, Real-Time Stereovision, Human Pose and Gesture Estimation, Resource-Limited Systems
A Simulation Environment for Bio-inspired Heterogeneous Chained Modular Robots

Alberto Brunete, Miguel Hernando and Ernesto Gambao

Abstract:
This paper presents a new simulation environment aimed at heterogeneous chained modular robots. This simulator allows for the testing of the feasibility of the design, the checking of how the modules will perform in the field, and the verifying of the hardware, electronics and communication designs before the prototype is built, saving time and resources. The paper shows how the simulator is built and how it can be set up to adapt to new designs. It also gives some examples of its use showing different heterogeneous modular robots running in different environments.

Keywords Modular Robots, Heterogeneous, Simulation, Bio-inspired

A Novel Robust Scene Change Detection Algorithm for Autonomous Robots Using Mixtures of Gaussians

Luis J. Manso, Pedro Núñez, Sidnei da Silva and Paulo Drews-Jr

Abstract:
Interest in change detection techniques has considerably increased during recent years in the field of autonomous robotics. This is partly because changes in a robot’s working environment are useful for several robotic skills (e.g., spatial cognition, modelling or navigation) and applications (e.g., surveillance or guidance robots). Changes are usually detected by comparing current data provided by the robot’s sensors with a previously known map or model of the environment. When the data consists of a large point cloud, dealing with it is a computationally expensive task, mainly due to the amount of points and the redundancy. Using Gaussian Mixture Models (GMM) instead of raw point clouds leads to a more compact feature space that can be used to efficiently process the input data. This allows us to successfully segment the set of 3D points acquired by the sensor and reduce the computational load of the change detection algorithm. However, the segmentation of the environment as a Mixture of Gaussians has some problems that need to be properly addressed. In this paper, a novel change detection algorithm is described in order to improve the robustness and computational cost of previous approaches. The proposal is based on the classic Expectation Maximization (EM) algorithm, for which different selection criteria are evaluated. As demonstrated in the experimental results section, the proposed change detection algorithm achieves the detection of changes in the robot’s working environment faster and more accurately than similar approaches.

Keywords Change Detection, Gaussian Mixture Models
Online Joint Trajectory Generation of Human-like Biped Walking

Jong-Wook Kim

Abstract:
Biped walking has long been studied in the area of gait analysis and robotic locomotion. The goal of this paper is to establish a systematic methodology for human-like natural walking by fusing the measured human joint data and optimal pattern generation techniques based on a full-body humanoid model. To this end, this paper proposes an adaptive two-stage gait pattern by which the step length and walking velocity can be changed with two scaling factors. In addition, to cope with the situations involving passing over a small obstacle, the joint trajectories of the swing foot can be adjusted with a novel concept of differential angle trajectory using a reliable optimization method, viz. particle swarm optimization. The feasibility of the proposed walking scheme is validated by walking experiments with the robot platform DARwIn-OP.

Keywords  Biped Walking, Trajectory Generation, Humanoid Robot, Particle Swarm Optimization

An Underactuated Multi-finger Grasping Device

Cesare Rossi and Sergio Savino

Abstract:
In this paper, a mechanical model for an underactuated multi-finger grasping device is presented. The device has single-tendon, three-phalanx fingers, all moved by only one actuator. By means of the model, both the kinematic and dynamical behaviour of the finger itself can be studied. The finger is part of a more complex mechanical system that consists of a four-finger grasping device for robots or a five-finger human hand prosthesis. Some results of both the kinematic and dynamical behaviour are also presented.

Keywords  Mechanical Finger, Robotic Hand, Gripper
Quantile Acoustic Vectors vs. MFCC Applied to Speaker Verification

Mayorga-Ortiz Pedro, Olguín-Espinoza J. Martín, González-Arriaga O. Hugo, Nylsa Flores and Vizcarra-Corral Luis

Abstract:
In this paper we describe speaker and command recognition related experiments, through quantile vectors and Gaussian Mixture Modelling (GMM). Over the past several years GMM and MFCC have become two of the dominant approaches for modelling speaker and speech recognition applications. However, memory and computational costs are important drawbacks, because autonomous systems suffer processing and power consumption constraints; thus, having a good trade-off between accuracy and computational requirements is mandatory. We decided to explore another approach (quantile vectors in several tasks) and a comparison with MFCC was made. Quantile acoustic vectors are proposed for speaker verification and command recognition tasks and the results showed very good recognition efficiency. This method offered a good trade-off between computation times, characteristics vector complexity and overall achieved efficiency.

Keywords Quantile Vectors, Gaussian Mixture Models (GMM), Speaker Verification

2D Hand Tracking Based on Flocking with Obstacle Avoidance

Zihong Chen, Lingxiang Zheng, Yuqi Chen and Yixiong Zhang

Abstract:
Hand gesture-based interaction provides a natural and powerful means for human-computer interaction. It is also a good interface for human-robot interaction. However, most of the existing proposals are likely to fail when they meet some skin-coloured objects, especially the face region. In this paper, we present a novel hand tracking method which can track the features of the hand based on the obstacle avoidance flocking behaviour model to overcome skin-coloured distractions. It allows features to be split into two groups under severe distractions and merge later. The experiment results show that our method can track the hand in a cluttered background or when passing the face, while the Flocking of Features (FoF) and the Mean Shift Embedded Particle Filter (MSEPF) methods may fail. These results suggest that our method has better performance in comparison with the previous methods. It may therefore be helpful to promote the use of the hand gesture-based human-robot interaction method.

Keywords Human-Computer Interaction, Human-Robot Interaction, Hand Tracking, Flocking Behaviour, Obstacle Avoidance
Delay-range-dependent Stability Criteria of Neural Networks with Time-varying Discrete and Distributed Delays

Kai Hu, AiGuo Song, YingChao Zhang and WeiLiang Wang

Abstract:
This article deals with the global asymptotic stability problem for a class of neural networks with time-varying discrete and distributed delays. The activation functions are assumed to be neither monotonic nor differentiable, and two types of time-varying discrete delays are considered: one is differentiable and has bounded derivatives, and the other is continuous and may vary very fast. By constructing an appropriate Lyapunov-Krasovskii functional and employing a tighter inequality, new stability criteria dependent on both the lower bound and upper bound of the time-varying time delays are established to guarantee asymptotic stability for the addressed neural networks. It is shown that the new criteria improve some results from previous studies. Two simulation examples are given to show the effectiveness and the reduced conservatism of the proposed criteria.

Keywords Delay-Dependent, Global Asymptotic Stability, Neural Networks (NNs), Time-Varying Delays, Linear Matrix Inequality (LMI)

Evaluation of an Efficient Approach for Target Tracking from Acoustic Imagery for the Perception System of an Autonomous Underwater Vehicle

Sebastián A. Villar, Gerardo G. Acosta, André L. Sousa and Alejandro Rozenfeld

Abstract:
This article describes the core algorithms of the perception system to be included within an autonomous underwater vehicle (AUV). This perception system is based on the acoustic data acquired from side scan sonar (SSS). These data should be processed in an efficient time, so that the perception system is able to detect and recognize a predefined target. This detection and recognition outcome is therefore an important piece of knowledge for the AUVs dynamic mission planner (DMP). Effectively, the DMP should propose different trajectories, navigation depths and other parameters that will change the robot's behaviour according to the perception system output. Hence, the time in which to make a decision is critical in order to ensure safe robot operation and to acquire good quality data; consequently, the efficiency of the on-line image processing from acoustic data is a key issue. Current techniques for acoustic data processing are time and computationally intensive. Hence, it was decided to process data coming from a SSS using a technique that is used for radars, due to its efficiency and its amenability to on-line processing. The engineering problem to solve in this case was underwater pipeline tracking for routine inspections in the off-shore industry. Then, an automatic oil pipeline detection system was developed borrowing techniques from the processing of radar measurements. The radar technique is known as Cell Average – Constant False Alarm Rate (CA – CFAR). With a slight variation of the algorithms underlying this radar technique, which consisted of the previous accumulation of partial sums, a great improvement in computing time and effort was achieved. Finally, a comparison with previous approaches over images acquired with a SSS from a vessel in the Salvador de Bahia bay in Brazil showed the feasibility of using this on-board technique for AUV perception.

Keywords Autonomous Underwater Vehicles, Side Scan Sonar, Acoustic Image Processing
A $G^2$ Continuous Path-smoothing Algorithm Using Modified Quadratic Polynomial Interpolation

Uk-Youl Huh and Seong-Ryong Chang

Abstract:
Path searching algorithm is one of the main topics in studies on path planning. These algorithms are used to avoid obstacles and finding paths from starting point to target point. There are dynamic problems that must be addressed when these paths are applied in real environments. In order to be applicable in actual situations, the path must be a smooth path. A smooth path is a path that maintains continuity. Continuity is decided by the differential values of the path. In order to be $G^2$ continuous, the secondary differential values of the path must be connected throughout the path. In this paper, the interpolation method is used to construct continuous paths. The quadratic polynomial interpolation is a simple method for obtaining continuous paths about three points. The proposed algorithm makes a connection of three points with curves and the proposed path is rotated using the parametric method in order to make the path optimal and smooth. The polynomials expand to the next three points and they merge into the entire path using the membership functions with $G^2$ continuity.

Keywords: Continuous Path, Curve Fitting, Function Approximation, Interpolation, Path Planning, Robot Motion, Smoothing Algorithm, Smooth Path, Vehicle Navigation

3D Visual Sensing of the Human Hand for the Remote Operation of a Robotic Hand

Pablo Gil, Carlos Mateo and Fernando Torres

Abstract:
New low cost sensors and open free libraries for 3D image processing are making important advances in robot vision applications possible, such as three-dimensional object recognition, semantic mapping, navigation and localization of robots, human detection and/or gesture recognition for human-machine interaction. In this paper, a novel method for recognizing and tracking the fingers of a human hand is presented. This method is based on point clouds from range images captured by a RGBD sensor. It works in real time and it does not require visual marks, camera calibration or previous knowledge of the environment. Moreover, it works successfully even when multiple objects appear in the scene or when the ambient light is changed. Furthermore, this method was designed to develop a human interface to control domestic or industrial devices, remotely. In this paper, the method was tested by operating a robotic hand. Firstly, the human hand was recognized and the fingers were detected. Secondly, the movement of the fingers was analysed and mapped to be imitated by a robotic hand.

Keywords: RGB-D, Kinect, Hand Recognition, Interaction Human-Robot
LEGO-based Robotics in Higher Education: 15 Years of Student Creativity

Ethan Danahy, Eric Wang, Jay Brockman, Adam Carberry, Ben Shapiro and Chris B. Rogers

Abstract:
Our goal in this article is to reflect on the role LEGO robotics has played in college engineering education over the last 15 years, starting with the introduction of the RCX in 1998 and ending with the introduction of the EV3 in 2013. By combining a modular computer programming language with a modular building platform, LEGO Education has allowed students (of all ages) to become active leaders in their own education as they build everything from animals for a robotic zoo to robots that play children’s games. Most importantly, it allows all students to develop different solutions to the same problem to provide a learning community. We look first at how the recent developments in the learning sciences can help in promoting student learning in robotics. We then share four case studies of successful college-level implementations that build on these developments.

Keywords: Constructionism, Educational Robotics, LEGO Robotics, Student-led Learning

A Generalized Visual Aid System for Teleoperation Applied to Satellite Servicing

Guoliang Zhang, Zhanni Wang, Jixiang Du, Tian Wang and Zainan Jiang

Abstract:
This paper presents the latest results of a newly developed visual aid system for direct teleoperation. This method is extended to visual control to make an efficient teleoperation system by combining direct teleoperation and automatic control. On the one hand, an operator can conduct direct teleoperation with 3D graphic prediction simulation established by the VR technique. In order to remove inconsistencies between the virtual and real environments, a practical model-matching method is investigated. On the other hand, to realize real-time visual servoing control, a particular object recognition and pose estimation algorithm based on polygonal approximation is investigated to ensure a low computational cost for image processing. To avoid undesired forces involved in contact operation, 3D visual servoing incorporating a compliant control based on impedance control is developed. Finally, in a representative laboratory environment, a typical satellite servicing experiment is carried out based on this combined system. Experimental results demonstrate the feasibility and the effectiveness of the proposed method.

Keywords: Satellite Servicing, 3D Graphic Prediction Simulation, Pose Estimation, Visual Servoing, Compliance Control
On the Design of a Wearable Multi-sensor System for Recognizing Motion Modes and Sit-to-stand Transition

Enhao Zheng, Baojun Chen, Xuegang Wang, Yan Huang and Qining Wang

Abstract:
Locomotion mode recognition is one of the key aspects of control of intelligent prostheses. This paper presents a wireless wearable multi-sensor system for locomotion mode recognition. The sensor suit of the system includes three inertial measurement units (IMUs) and eight force sensors. The system was built to measure both kinematic (tilt angles) and dynamic (ground contact forces) signals of human gaits. To evaluate the recognition performance of the system, seven motion modes and sit-to-stand transition were monitored. With a linear discriminant analysis (LDA) classifier, the proposed system can accurately classify the current states. The overall motion mode recognition accuracy was 99.9% during the stance phase and 98.5% during the swing phase. For sit-to-stand transition recognition, the average accuracy was 99.9%. These promising results show the potential of the designed system for the control of intelligent prostheses.

Keywords: Locomotion Mode Recognition, Multi-sensor system, Inertial Sensors, Ground Contact Force

Depth Control for Micro-autonomous Underwater Vehicles (μAUVs): Simulation and Experimentation

Simon A. Watson and Peter N. Green

Abstract:
Swarms of micro-autonomous underwater vehicles (μAUVs) are an attractive solution to the problem of nuclear storage pond monitoring. Independent movement in the horizontal and vertical planes is necessary to maximize manoeuvrability. This paper presents a comparison of different control strategies for independent depth control using both simulations and real experimental results. PID, sliding mode and a simplification of sliding mode (called ‘bounded PD’) are simulated using a MATLAB/SIMULINK model and are then compared to experimental results obtained when the controllers were implemented on a prototype μAUV.

Keywords: Autonomous Underwater Vehicles (AUVs), PID Control, Sliding Mode Control
Tuning a PD Controller Based on an SVR for the Control of a Biped Robot Subject to External Forces and Slope Variation

João P. Ferreira, Manuel Crisóstomo and A. Paulo Coimbra

Abstract:
Real-time balance control of an eight-link biped robot using a zero moment point (ZMP) dynamic model is difficult to achieve due to the processing time of the corresponding equations. To overcome this limitation an intelligent computing technique based on Support Vector Regression (SVR) is developed and presented in this paper. To implement a PD controller the SVR uses the ZMP error relative to a reference and its variation as inputs, and the output is the correction of the angle of the robot’s torso, necessary for its sagittal balance. The SVR was trained based on simulation data generated using a PD controller. The initial values of the parameters of the PD controller were obtained by the second Ziegler-Nichols method. In order to evaluate the balance performance of the biped robot, three performance indexes are used. The ZMP is calculated by reading four force sensors placed under each of the robot’s feet. The gait implemented in this biped is similar to a human gait, which is acquired and adapted to the robot’s size. The main contribution of this paper is the fine-tuning of the ZMP controller based on the SVR. To implement and test this, the biped robot was subjected to external forces and slope variation. Some experiments are presented and the results show that the implemented gait combined with the correct tuning of the SVR controller is appropriate for use with this biped robot. The SVR controller runs at 0.2 ms, which is about 50 times faster than a corresponding first-order TSK neural-fuzzy network.

Keywords: Tuning, PD, SVR, Biped Robot, Balance, ZMP

A Hierarchical Fuzzy Control Design for Indoor Mobile Robot

Foudil Abdessemed, Mohammed Faisal, Muhammed Emmadeddine, Ramdane Hedjar, Khalid Al-Mutib, Mansour Alsulaiman and Hassan Mathkour

Abstract:
This paper presents a motion control for an autonomous robot navigation using fuzzy logic motion control and stereo vision based path-planning module. This requires the capability to maneuver in a complex unknown environment. The mobile robot uses intuitive fuzzy rules and is expected to reach a specific target or follow a prespecified trajectory while moving among unforeseen obstacles. The robot’s mission depends on the choice of the task. In this paper, behavioral-based control architecture is adopted, and each local navigational task is analyzed in terms of primitive behaviors. Our approach is systematic and original in the sense that some of the fuzzy rules are not triggered in face of critical situations for which the stereo vision camera can intervene to unblock the mobile robot.

Keywords: Powerbot, Mobile Robot, Hierarchical Fuzzy Control, FLMC, Obstacle Avoidance, SVPPM
The Path Planning of AUV Based on D-S Information Fusion Map Building and Bio-inspired Neural Network in Unknown Dynamic Environment

Daqi Zhu, Weichong Li, Mingzhong Yan and Simon X. Yang

Abstract:
In this paper a biologically inspired neural dynamics and map planning based approach are simultaneously proposed for AUV (Autonomous Underwater Vehicle) path planning and obstacle avoidance in an unknown dynamic environment. Firstly the readings of an ultrasonic sensor are fused into the map using the D-S (Dempster-Shafer) inference rule and a two-dimensional occupancy grid map is built. Secondly the dynamics of each neuron in the topologically organized neural network is characterized by a shunting equation. The AUV path is autonomously generated from the dynamic activity landscape of the neural network and previous AUV location. Finally, simulation results show high quality path optimization and obstacle avoidance behaviour for the AUV.

Keywords  AUV (Autonomous Underwater Vehicle), Map Building, D-S Information Fusion, Path Planning, Biologically Inspired Neural Dynamics, Neural Network, Obstacle Avoidance

Variable Structure Control for Space Robots Based on Neural Networks

Yaming Fang, Wenhui Zhang and Xiaoping Ye

Abstract:
Problems of trajectory tracking for a class of free-floating robot manipulators with uncertainties are considered. Two neural network controls are designed. The first scheme consists of a PD feedback and a dynamic compensator which is an RBF neural network controller. The second scheme syncretizes neural networks with variable structures using a saturation function. Neutral networks are used to adaptively learn about and compensate for the unknown system. Approach errors are eliminated as disturbances by using the variable structure controller. The shortcomings of local networks are considered. The control is based on dividing aspects into three sections with classification and integration: state dimensional, neural network and variable structure separate control. When invalidations of the neutral network appeared, the controller was able to guarantee good robustness as well as the stability of the closed-loop system. The simulation results show that the methods presented are effective.

Keywords  Neural Network, Variable Structure, Space Robot, Adaptive Control
2D-3D Face Recognition Method Based on a Modified CCA-PCA Algorithm

Patrik Kamencay, Robert Hudec, Miroslav Benco and Martina Zachariasova

Abstract:
This paper presents a proposed methodology for face recognition based on an information theory approach to coding and decoding face images. In this paper, we propose a 2D-3D face-matching method based on a principal component analysis (PCA) algorithm using canonical correlation analysis (CCA) to learn the mapping between a 2D face image and 3D face data. This method makes it possible to match a 2D face image with enrolled 3D face data. Our proposed fusion algorithm is based on the PCA method, which is applied to extract base features. PCA feature-level fusion requires the extraction of different features from the source data before features are merged together. Experimental results on the TEXAS face image database have shown that the classification and recognition results based on the modified CCA-PCA method are superior to those based on the CCA method. Testing the 2D-3D face match results gave a recognition rate for the CCA method of a quite poor 55% while the modified CCA method based on PCA-level fusion achieved a very good recognition score of 85%.

Keywords  Face Recognition, PCA, CCA, CCADouble, KCCA, TEXASdatabase, Image Fusion

Human Hand Motion Analysis and Synthesis of Optimal Power Grasps for a Robotic Hand

Francesca Cordella, Loredana Zollo, Antonino Salerno, Dino Accoto, Eugenio Guglielmelli and Bruno Siciliano

Abstract:
Biologically inspired robotic systems can find important applications in biomedical robotics, since studying and replicating human behaviour can provide new insights into motor recovery, functional substitution and human-robot interaction. The analysis of human hand motion is essential for collecting information about human hand movements useful for generalizing reaching and grasping actions on a robotic system. This paper focuses on the definition and extraction of quantitative indicators for describing optimal hand grasping postures and replicating them on an anthropomorphic robotic hand. A motion analysis has been carried out on six healthy human subjects performing a transverse volar grasp. The extracted indicators point to invariant grasping behaviours between the involved subjects, thus providing some constraints for identifying the optimal grasping configuration. Hence, an optimization algorithm based on the Nelder-Mead simplex method has been developed for determining the optimal grasp configuration of a robotic hand, grounded on the aforementioned constraints. It is characterized by a reduced computational cost. The grasp stability has been tested by introducing a quality index that satisfies the form-closure property. The grasping strategy has been validated by means of simulation tests and experimental trials on an arm-hand robotic system. The obtained results have shown the effectiveness of the extracted indicators to reduce the non-linear optimization problem complexity and lead to the synthesis of a grasping posture able to replicate the human behaviour while ensuring grasp stability. The experimental results have also highlighted the limitations of the adopted robotic platform (mainly due to the mechanical structure) to achieve the optimal grasp configuration.

Keywords  Human Hand Motion Analysis, Grasping Indicators, Hand Kinematics, Human-like Grasping Strategy, Arm-hand Robotic System
Linear Determination of a Camera’s Intrinsic Parameters Using Two Intersecting Circles

Xu Chen, Yue Zhao and Fu ShengNan

Abstract:
An approach using two intersecting circles is proposed as a linear approach for determining a camera’s intrinsic parameters. The two intersecting coplanar circles have four intersection points in the projective plane: two real points and two circular points. In the image plane, the diagonal triangle - on which the image of the four intersection points composes a complete quadrangle - is a self-polar triangle for the projection curves of the circles. The vertex of the self-polar triangle is the null space of the degenerate conic formed by the image of the four intersection points. By solving the three vertices of the self-polar triangle using the image coordinates of the two real intersection points, the degenerate conic can be obtained. The image of the two circular points is then computed from the intersection points of the degenerate conic. Using the image of the circular points from the three images of the same planar pattern with different directions, the intrinsic parameters can be linearly determined.

Keywords: Camera Intrinsic Parameters, Circular Points, 3D Reconstruction, Computer Vision

Intersection Recognition and Guide-path Selection for a Vision-based AGV in a Bidirectional Flow Network

Wu Xing, Lou Peihuang, Yu Jun, Qian Xiaoming and Tang Dunbing

Abstract:
Vision recognition and RFID perception are used to develop a smart AGV travelling on fixed paths while retaining low-cost, simplicity and reliability. Visible landmarks can describe features of shapes and geometric dimensions of lines and intersections, and RFID tags can directly record global locations on pathways and the local topological relations of crossroads. A topological map is convenient for building and editing without the need for accurate poses when establishing a priori knowledge of a workplace. To obtain the flexibility of bidirectional movement along guide-paths, a camera placed in the centre of the AGV looks downward vertically at landmarks on the floor. A small visual field presents many difficulties for vision guidance, especially for real-time, correct and reliable recognition of multi-branch crossroads. First, the region projection and contour scanning methods are both used to extract the features of shapes. Then LDA is used to reduce the number of the features’ dimensions. Third, a hierarchical SVM classifier is proposed to classify their multi-branch patterns once the features of the shapes are complete. Our experiments in landmark recognition and navigation show that low-cost vision systems are insusceptible to visual noises, image breakages and floor changes, and a vision-based AGV can locate itself precisely on its paths, recognize different crossroads intelligently by verifying the conformance of vision and RFID information, and select its next pathway efficiently in a bidirectional flow network.

Keywords: Automated Guided Vehicle, Vision Guidance, Landmark Recognition, Navigation Control
Experimental and Simulation Results for the Impact of a Rotating Flexible Link with a Granular Material

Dan Marghitu, Seunghun Lee and Daniela Marghitu

Abstract:
In this paper, a rotating flexible link impacting a granular media is studied. The influences of initial impact velocity and impact angle are examined. The resistance forces are expressed as the sum of a dynamic frictional force (velocity-dependent) and a static resistance force (depth dependent). The penetrating angle increases with initial impact velocity as expected. However, the stopping time decreases with initial impact velocity for all initial impact angles for the considered system.

Keywords  Impact, Rotating Link, Granular Media, Stopping Time

Hybrid Architecture for Coordination of AGVs in FMS

Eduardo G. Hernandez-Martinez, Sergio A. Foyo-Valdes, Erika S. Puga-Velazquez and Jeús A. Meda-Campaña

Abstract:
This paper presents a hybrid control architecture that coordinates the motion of groups of automated guided vehicles in flexible manufacturing systems. The high-level control is based on a Petri net model, using the industrial standard ISA-95, obtaining a task-based coordination of equipment and storage considering process restrictions, logical precedences, shared resources and the assignment of robots to move workpieces individually or in subgroups. On the other hand, in the low-level control, three basic control laws are designed for unicycle-type robots in order to achieve desired formation patterns and marching behaviours, avoiding inter-robot collisions. The control scheme combines the task assignment for the robots obtained from the discrete-event model and the implementation of formation and marching continuous control laws applied to the motion of the mobile robots. The hybrid architecture is implemented and validated for the case of a flexible manufacturing system and four mobile robots using a virtual reality platform.

Keywords  Petri Nets, Multi-robot Systems, Formation Control, Marching Control, Unicycles
Mobile Robot Aided Silhouette Imaging and Robust Body Pose Recognition for Elderly-fall Detection

Tong Liu and Jun Liu

Abstract:
This article introduces a mobile infrared silhouette imaging and sparse representation-based pose recognition for building an elderly-fall detection system. The proposed imaging paradigm exploits the novel use of the pyroelectric infrared (PIR) sensor in pursuit of body silhouette imaging. A mobile robot carrying a vertical column of multi-PIR detectors is organized for the silhouette acquisition. Then we express the fall detection problem in silhouette image-based pose recognition. For the pose recognition, we use a robust sparse representation-based method for fall detection. The normal and fall poses are sparsely represented in the basis space spanned by the combinations of a pose training template and an error template. The l1 norm minimizations with linear programming (LP) and orthogonal matching pursuit (OMP) are used for finding the sparsest solution, and the entity with the largest amplitude encodes the class of the testing sample. The application of the proposed sensing paradigm to fall detection is addressed in the context of three scenarios, including: ideal non-obstruction, simulated random pixel obstruction and simulated random block obstruction. Experimental studies are conducted to validate the effectiveness of the proposed method for nursing and homeland healthcare.

Keywords
Elderly-fall Detection, Healthcare, Pyroelectric Infrared Sensor, Mobile Robot Aided Silhouette Imaging, Sparse Representation

A Fast Approach to Arm Blind Grasping and Placing for Mobile Robot Transportation in Laboratories

Hui Liu, Norbert Stoll, Steffen Junginger and Kerstin Thurow

Abstract:
This paper presents a fast approach to organizing arm grasping and placing manipulations for mobile robot transportation systems in life science laboratories. The approach builds a blind framework to realize the robot arm operations without integrating any other sensors or recognizing computation, but only adopting the robot’s existing on-board ultrasonic sensors originally installed for collision avoidance. To achieve high-precision indoor positioning performance for the proposed blind arm strategy, a hybrid method is proposed, including a StarGazer system for all laboratory environments and an ultrasonic sensor-based component for the local areas where the arm operations are expected. At the same time, two error-correcting algorithms are presented for the improvement of the high-precision localization and the selection of the robot arm operations. In addition, the architecture of all the robotic controlling centres and their key APIs are also explained. Finally, an experiment proves that the proposed blind strategy is effective and economically viable for the laboratory automation.

Keywords
Mobile Robot, Life Science Automation, Laboratory Indoor Transportation, Arm Blind Manipulation, Ultrasonic Sensors
Fast and Low-cost Mechatronic Recognition System for Persian Banknotes

Majid Behjat and Payman Moallem

Abstract:
In this paper, we designed a fast and low-cost mechatronic system for recognition of eight current Persian banknotes in circulation. Firstly, we proposed a mechanical solution for avoiding extra processing time caused by detecting the place of banknote and paper angle correction in an input image. We also defined new parameters for feature extraction, including colour features (RGBR values), size features (LWR) and texture features (CRLVR value). Then, we used a Multi-Layer Perceptron (MLP) neural network in the recognition phase to reduce the necessary processing time. In this research, we collected a perfect database of Persian banknote images (about 4000 double-sided prevalent images). We reached about 99.06% accuracy (average for each side) in final banknote recognition by testing 800 different worn, torn and new banknotes which were not part of the initial learning phase. This accuracy could increase to 99.62% in double-sided decision mode. Finally, we designed an ATmega32 microcontroller-based hardware with 16MHz clock frequency for implementation of our proposed system which can recognize sample banknotes at about 480ms and 560ms for single-sided detection and double-sided detection respectively, after image scanning.

Keywords: Fast and Intelligent Mechatronic System, Persian Banknote Recognition, Colour Image Processing, Multi-layer Perceptron

An Overview on Gripping Force Measurement at the Micro and Nano-scales Using Two-fingered Microrobotic Systems

Mokrane Boudaoud and Stephane Regnier

Abstract:
Two-fingered micromanipulation systems with an integrated force sensor are widely used in robotics to sense and control gripping forces at the micro and nano-scales. They became of primary importance for an efficient manipulation and characterization of highly deformable biomaterials and nanostructures. This paper presents a chronological overview of gripping force measurement using two-fingered micromanipulation systems. The work summarizes the major achievements in this field from the early 90s to the present, focusing in particular on the evolution of measurement technologies regarding the requirements of microrobotic applications. Measuring forces below the microNewton for the manipulation of highly deformable materials, embedding force sensors within microgrippers to increase their dexterity, and reducing the influence of noise to improve the measurement resolution are among the addressed challenges. The paper shows different examples of how these challenges have been addressed. Resolution, operating range and signal/noise ratio of gripping force sensors are reported and compared. A discussion about force measurement technologies and gripping force control is performed and future trends are highlighted.

Keywords: Microrobotics, Microgrippers, Force Measurement, Control
Flexible-link Robot Control Using a Linear Parameter Varying Systems Methodology

Houssem Halalchi, Edouard Laroche and Gabriela Iuliana Bara

Abstract:
This paper addresses the issues of the Linear Parameter Varying (LPV) modelling and control of flexible-link robot manipulators. The LPV formalism allows the synthesis of nonlinear control laws and the assessment of their closed-loop stability and performances in a simple and effective manner, based on the use of Linear Matrix Inequalities (LMI). Following the quasi-LPV modelling approach, an LPV model of a flexible manipulator is obtained, starting from the nonlinear dynamic model stemming from Euler-Lagrange equations. Based on this LPV model, which has a rational dependence in terms of the varying parameters, two different methods for the synthesis of LPV controllers are explored. They guarantee the asymptotic stability and some level of closed-loop $L_2$-gain performance on a bounded parametric set. The first method exploits a descriptor representation that simplifies the rational dependence of the LPV model, whereas the second one manages the troublesome rational dependence by using dilated LMI conditions and taking the particular structure of the model into account. The resulting controllers involve the measured state variables only, namely the joint positions and velocities. Simulation results are presented that illustrate the validity of the proposed control methodology. Comparisons with an inversion-based nonlinear control method are performed in the presence of velocity measurement noise, model uncertainties and high-frequency inputs.

Keywords  Flexible Robots, LPV Modelling, LPV Control, LMI Conditions

Design and Implementation of a Modular Self-reconfigurable Robot

Guifang Qiao, Guangming Song, Weiguo Wang, Ying Zhang and Yali Wang

Abstract:
This paper presents the design and implementation of a new modular self-reconfigurable robot. The single module has three joints and can perform rectilinear motion, lateral shift, lateral rolling, and rotation. A flexible pin-hole-based docking mechanism is designed for self-assembly. With the proposed infrared-sensor-based docking method, multiple modules can be self-assembled to form versatile configurations. The modules communicate with each other through ZigBee protocols. The locomotion planning and geometry analysis of the single module are presented in detail and the efficiency of the single module’s mobility is also demonstrated by experimental results. In automatic docking experiments with two modules, the proposed method is shown to be able to achieve an average success rate of 78% within the effective region. The average time of the docking process is reduced to 75 s. The maximum velocity of the I-shaped robot is up to 3.6 cm/s and the maximum velocity of the X-shaped robot is 4.8 cm/s. The detach-dock method for I-to-X transformation planning is also verified. The ZigBee-based communication system can achieve 100% receiving rate at 55 ms transformation interval.

Keywords  Modular Self-Reconfigurable Robot, Wireless Sensor Network, Docking Method, Bio-inspired Robot
VFI-based Robotic Arm Control for Natural Adaptive Motion
Woosung Yang, Ji-Hun Bae and Hyungjoo Kim

Abstract:
Since neural oscillator based control methods can generate rhythmic motion without information on system dynamics, they can be a promising alternative to traditional motion planning based control approaches. However, for field application, they still need to be robust against unexpected forces or changes in environments so as to be able to generate “natural motion” like most biological systems. In this study a biologically inspired control algorithm that combines neural oscillators and virtual force is proposed. This work gives the condition with respect to parameters tuning to stably activate the neural oscillators. This is helpful to achieve motion adaptability to environmental changes keeping the motion repeatability. The efficacy and efficiency of the proposed methods are tested in the control of a planar three-linkage robotic arm. It is shown that the proposed controller generates a given circular path stably and repeatedly, even with unexpected contact with a wall. The adaptivity of motion control is also tested in control of a robotic arm with redundant degrees of freedom. The proposed control algorithm works throughout the simulations and experiments.

Keywords: Biologically Inspired Control, Robotic Arm, Natural Movement, Neural Oscillator

Development of Grousers with a Tactile Sensor for Wheels of Lunar Exploration Rovers to Measure Sinkage
Kojiro Iizuka, Tatsuya Sasaki, Mitsuhiro Yamano and Takashi Kubota

Abstract:
This paper presents a grouser developed for the wheels of lunar exploration rovers to measure sinkage. The wheels, which are intended to traverse loose soil such as lunar regolith, contain grousers that transfer thrust to the wheels and thus to the body of the rover. The interaction between the wheel (with grousers) and the loose soil can be described using a kinematic model. When traversing loose soil, the wheel sinks into the soil, which necessitates knowledge of the entrance angle needed in order to avoid this problem. If the entrance angle is known, the sinkage can be measured in real time before adverse conditions occur. Because of the importance and usefulness of detecting the entrance angle of the wheel, we herein propose a grouser with an embedded tactile sensor. A strain gauge on the surface of the grousers serves as the tactile sensor. In order to confirm the precision of the proposed grouser, we have performed tests on a rigid surface and loose soil surfaces.

Keywords: Lunar Exploration Rovers, Loose Soil, Grouser, Tactile Sensor, Strain Gauge
Localization Using Magnetic Patterns for Autonomous Mobile Robot

Won Suk You, Byung June Choi, Hyouk Ryeol Choi, Ja Choon Koo and Hyungpil Moon

Abstract:
In this paper, we present a method of localization using magnetic landmarks. With this method, it is possible to compensate the pose error \((x_e, y_e, \theta_e)\) of a mobile robot correctly and localize its current position on a global coordinate system on the surface of a structured environment with magnetic landmarks. A set of four magnetic bars forms total six different patterns of landmarks and these patterns can be read by the mobile robot with magnetic hall sensors. A sequential motion strategy for a mobile robot is proposed to find the geometric center of magnetic landmarks by reading the nonlinear magnetic field. The mobile robot first moves into the center region of the landmark where it can read the magnetic pattern, after which tracking and global localization can be easily achieved by recognizing the patterns of neighboring landmarks. Experimental results show the effectiveness of the sequential motion strategy for estimating the center of the first encountered landmark as well as the performance of tracking and global localization of the proposed system.

Keywords  Localization, Magnetic Landmark, Hall Sensor, Motion Planning, Mobile Robot

System Integration for Real-time Mobile Manipulation

Reza Oftadeh, Mohammad M. Aref, Reza Ghabcheloo and Jouni Mattila

Abstract:
Mobile manipulators are one of the most complicated types of mechatronics systems. The performance of these robots in performing complex manipulation tasks is highly correlated with the synchronization and integration of their low-level components. This paper discusses in detail the mechatronics design of a four wheel steered mobile manipulator. It presents the manipulator’s mechanical structure and electrical interfaces, designs low-level software architecture based on embedded PC-based controls, and proposes a systematic solution based on code generation products of MATLAB and Simulink. The remote development environment described here is used to develop real-time controller software and modules for the mobile manipulator under a POSIX-compliant, real-time Linux operating system. Our approach enables developers to reliably design controller modules that meet the hard real-time constraints of the entire low-level system architecture. Moreover, it provides a systematic framework for the development and integration of hardware devices with various communication mediums and protocols, which facilitates the development and integration process of the software controller.

Keywords  Mobile Manipulators, Real-time Systems, Autonomous Vehicles, Mechatronic Design
Abstract:
This paper establishes an approach to external force estimation for telerobotic control in radioactive environments by the use of an identified manipulator model and pressure sensors, without employing a force/torque sensor. The advantages of - and need for - force feedback have been well-established in the field of telerobotics, where electrical and back-drivable manipulators have traditionally been used. This research proposes a methodology employing hydraulic robots for telerobotics tasks based on a model identification scheme. Comparative results of a force sensor and the proposed approach using a hydraulic telemanipulator are presented under different conditions. This approach not only presents a cost effective solution but also a methodology for force estimation in radioactive environments, where the dose rates limit the use of electronic devices such as sensing equipment.

Keywords  Force Estimation, Telerobotics, Hydraulic Manipulator, Parameter Identification

Obstacles and Pedestrian Detection on a Moving Vehicle
Yang Yang, Ren Mingwu and Yang Jingyu

Abstract:
We present a new method for obstacle and pedestrian detection with lower computation complexity and higher detection performance on a small target. By calculating stereo disparity according to the road parameters, our system efficiently detects objects above the ground. Experiments on over 10,000 images captured in urban areas demonstrate our method’s effectiveness. We also propose a multi-scale compatible pedestrian detector. Detection speed is improved by avoiding size adjustment of input. Experiments on three public pedestrian databases and our HENU database show that our detector achieves better results than the state-of-the-art detection quality at equal speed, especially on pedestrian target with small size.

Keywords  Pedestrian Detection, Obstacle Detection, Support Vector Machine, Adaboost, Surface Parallax Map
Global Observer-based Attitude Controller Using Direct Inertial Measurements

Saâdi Bouhired, Mouloud Bouchoucha and Mohamed Tadjine

Abstract:
In this work, we address the problem of global attitude control using direct inertial measurements. When using direct inertial measurement to observe the rigid body attitude, it is shown that due to a geometrical obstruction, it is impossible to achieve global asymptotic stability. In fact, for a particular initial condition the tracking error quaternion converges to a pure imaginary quaternion formed by an eigenvector of a characteristic matrix related to the inertial constant and known vectors. Our proposition consists of adding a dynamic signal to force the rigid body to escape from such a situation. The proposed observer-based controller is synthesized based on a single Lyapunov function and a stability analysis shows that the controller stabilizes globally and asymptotically the rigid body attitude at the desired one. The effectiveness of the proposed observer-based controller is confirmed by simulation results.

Keywords Attitude Control, Inertial Measurements, Quaternion, Global Stability

A Panoramic 3D Reconstruction System Based on the Projection of Patterns

Diana-Margarita Córdova-Esparza, José-Joel González-Barbosa, Juan-Bautista Hurtado-Ramos and Francisco-Javier Ornelas-Rodríguez

Abstract:
This work presents the implementation of a 3D reconstruction system capable of reconstructing a 360-degree scene with a single acquisition using a projection of patterns. The system is formed by two modules: the first module is a CCD camera with a parabolic mirror that allows the acquisition of catadioptric images. The second module consists of a light projector and a parabolic mirror that is used to generate the pattern projections over the object that will be reconstructed. The projection system has a 360-degree field of view and both modules were calibrated to obtain the extrinsic parameters. To validate the functionality of the system, we performed 3D reconstructions of three objects, and show the reconstruction error analysis.

Keywords Panoramic 3D Reconstruction, Calibration, Catadioptric Camera, Catadioptric Projector
Flexible Robotic Spine Actuated by Shape Memory Alloy

Shiquan Wang, Qiuguo Zhu, Rong Xiong and Jian Chu

Abstract:
A flexible robotic spine actuated by shape memory alloy (SMA) can achieve both bending motion and impact absorption, which will allow robots to realize a variety of postures. In this paper, the robotic spine is designed and simplified into a multi-segment dynamic model based on several verified assumptions. The SMA wire is modelled using the Seelecke-Muller-Acenbach theory. An iterative algorithm is developed to address the external forces distributed along the spine and compute the spine’s bending angle. Based on the dynamic model, we improve the simulation structure and search algorithm to achieve good efficiency and stable solutions. Experiments are conducted to verify the simulation and the results fit the simulation prediction well, with error of less than five degrees. Design optimization with our simulation tool based on several parameters is also discussed in this paper.

Keywords Flexible Robotic Spine, Shape Memory Alloy, Dynamic Model, Search Algorithm

A Hybrid System of Hierarchical Planning of Behaviour Selection Networks for Mobile Robot Control

Young-Seol Lee and Sung-Bae Cho

Abstract:
An office delivery robot receives a large amount of sensory data and there is uncertainty in its action outcomes. The robot should not only accomplish its goals using environmental information, but also consider various exceptions simultaneously. In this paper, we propose a hybrid system using hierarchical planning of modular behaviour selection networks to generate autonomous behaviour in the office delivery robot. Behaviour selection networks, one of the well-known behaviour-based methods suitable for goal-oriented tasks, are made up of several smaller behaviour modules. Planning is attached to the construct and adjust sequences of the modules by considering the sub-goals, the priority in each task and the user feedback. This helps the robot to quickly react in dynamic situations as well as achieve global goals efficiently. The proposed system is verified with both the Webot simulator and a Khepera II robot that runs in a real office environment carrying out delivery tasks. Experimental results have shown that a robot can achieve goals and generate module sequences successfully even in unpredictable situations. Additionally, the proposed planning method reduced the elapsed time during tasks by 17.5% since it adjusts the behaviour module sequences more effectively.

Keywords Office Delivery Robot, Hybrid Robot Control, Behaviour Selection Networks
A Novel Hybrid Safety-control Strategy for a Manipulator

Jing Xia, Zainan Jiang, Hong Liu, Hegao Cai and Guangxin Wu

Abstract:
As robots tend to work cooperatively with humans in shared workplaces, safety as regards robot-human interactions has caused a great deal of concern in the robot community, and control strategies have become a hot topic in robotics research. In order to guarantee the robot’s safety and continuous motions, this paper proposes a novel safety-control strategy, which is strictly conservative and which consists of a pre-contact and post-contact safety strategy. We adopt an optimal motion trajectory-planning method, by use of which the jerk, acceleration and velocity of the robot’s motion can be limited and a time-optimal motion can be obtained as a post-contact safety strategy for a position-controlled manipulator. The optimal motion trajectory planning not only reduces the impact forces during the collision period, but also maintains the efficiency of the manipulator and preserves continuous motions. Next, we describe a novel collision detection method as a pre-contact safety strategy to avoid collisions. The method proposed here can compute security warning region to handle the effect of robot motion on collision detection and detect collisions between non-convex polygon soups. Finally, the control strategy is implemented for a 7-DOF humanoid manipulator and the experimental results demonstrate the validity of this novel hybrid safety-control strategy.

Keywords  Safety Strategy, Trajectory Planning, Collision Detection, Humanoid Manipulator

An Efficient Hybrid Face Recognition Algorithm Using PCA and GABOR Wavelets

Hyunjong Cho, Rodney Roberts, Bowon Jung, Okkyung Choi and Seungbin Moon

Abstract:
With the rapid development of computers and the increasing, mass use of high-tech mobile devices, vision-based face recognition has advanced significantly. However, it is hard to conclude that the performance of computers surpasses that of humans, as humans have generally exhibited better performance in challenging situations involving occlusion or variations. Motivated by the recognition method of humans who utilize both holistic and local features, we present a computationally efficient hybrid face recognition method that employs dual-stage holistic and local feature-based recognition algorithms. In the first coarse recognition stage, the proposed algorithm utilizes Principal Component Analysis (PCA) to identify a test image. The recognition ends at this stage if the confidence level of the result turns out to be reliable. Otherwise, the algorithm uses this result for filtering out top candidate images with a high degree of similarity, and passes them to the next fine recognition stage where Gabor filters are employed. As is well known, recognizing a face image with Gabor filters is a computationally heavy task. The contribution of our work is in proposing a flexible dual-stage algorithm that enables fast, hybrid face recognition. Experimental tests were performed with the Extended Yale Face Database B to verify the effectiveness and validity of the research, and we obtained better recognition results under illumination variations not only in terms of computation time but also in terms of the recognition rate in comparison to PCA- and Gabor wavelet-based recognition algorithms.

Keywords  Face Recognition, Confidence Level, PCA, Gabor Wavelet, Hybrid
Convergence Analysis of an Iterative Targeting Method for Keyhole Robotic Surgery

Mirko Daniele Comparetti, Elena De Momi, Tim Beyl, Mirko Kunze, Jörg Raczkowsky and Giancarlo Ferrigno

Abstract:
In surgical procedures, robots can accurately position and orient surgical instruments. Intraoperatively, external sensors can localize the instrument and compute the targeting movement of the robot, based on the transformation between the coordinate frame of the robot and the sensor. This paper addresses the assessment of the robustness of an iterative targeting algorithm in perturbed conditions. Numerical simulations and experiments (with a robot with seven degrees of freedom and an optical tracking system) were performed for computing the maximum error of the rotational part of the calibration matrix, which allows for convergence, as well as the number of required iterations. The algorithm converges up to 50 degrees of error within a large working space. The study confirms the clinical relevance of the method because it can be applied on commercially available robots without modifying the internal controller, thus improving the targeting accuracy and meeting surgical accuracy requirements.

Keywords  Robotic Surgery, Iterative Targeting, Neurosurgery

Real-time Lane Detection on Suburban Streets using Visual Cue Integration

Shehan Fernando, Lanka Udawatta, Ben Horan and Pubudu Pathirana

Abstract:
The detection of lane boundaries on suburban streets using images obtained from video constitutes a challenging task. This is mainly due to the difficulties associated with estimating the complex geometric structure of lane boundaries, the quality of lane markings as a result of wear, occlusions by traffic, and shadows caused by road-side trees and structures. Most of the existing techniques for lane boundary detection employ a single visual cue and will only work under certain conditions and where there are clear lane markings. Also, better results are achieved when there are no other on-road objects present. This paper extends our previous work and discusses a novel lane boundary detection algorithm specifically addressing the abovementioned issues through the integration of two visual cues. The first visual cue is based on stripe-like features found on lane lines extracted using a two-dimensional symmetric Gabor filter. The second visual cue is based on a texture characteristic determined using the entropy measure of the predefined neighbourhood around a lane boundary line. The visual cues are then integrated using a rule-based classifier which incorporates a modified sequential covering algorithm to improve robustness. To separate lane boundary lines from other similar features, a road mask is generated using road chromaticity values estimated from CIE L*a*b* colour transformation. Extraneous points around lane boundary lines are then removed by an outlier removal procedure based on studentized residuals. The lane boundary lines are then modelled with Bezier spline curves. To validate the algorithm, extensive experimental evaluation was carried out on suburban streets and the results are presented.

Keywords  Mahalanobis Distance, Entropy Measure, Gabor Filter, Visual Cue Integration, Studentized Residuals
A Practical Method for Implementing an Attitude and Heading Reference System

Rodrigo Munguía and Antoni Grau

Abstract:
This paper describes a practical and reliable algorithm for implementing an Attitude and Heading Reference System (AHRS). This kind of system is essential for real time vehicle navigation, guidance and control applications. When low cost sensors are used, efficient and robust algorithms are required for performance to be acceptable. The proposed method is based on an Extended Kalman Filter (EKF) in a direct configuration. In this case, the filter is explicitly derived from both the kinematic and error models. The selection of this kind of EKF configuration can help in ensuring a tight integration of the method for its use in filter-based localization and mapping systems in autonomous vehicles. Experiments with real data show that the proposed method is able to maintain an accurate and drift-free attitude and heading estimation. An additional result is to show that there is no ostensible reason for preferring that the filter have an indirect configuration over a direct configuration for implementing an AHRS system.

Keywords: Attitude Estimation, Sensor Fusion, Vehicle Navigation, Inertial Measurement, Kalman Filtering

Self-excited Vibration Analysis for the Feed Support System in FAST

Xiaoqiang Tang, Zhihua Liu, Zhufeng Shao and Liping Wang

Abstract:
China is currently building the largest single dish radio telescope in the world, which is called the Five-hundred meter Aperture Spherical radio Telescope (FAST). The feed support system in the FAST is composed of a cable-driven parallel manipulator, an A-B rotator, and a Stewart platform. Since the stiffness of the cable-driven parallel manipulator is low, the feed support system is prone to vibrate under the action of the Stewart platform. The main purpose of this paper is to study the self-excited vibration of the feed support system. Self-excited vibration involves the natural frequencies of the system and the resultant forces produced by the motion of the Stewart platform. This paper linearizes the dynamic equations of the system at an operating point and determines the configuration-dependent natural frequencies in the given workspace. This paper obtains the resultant forces from the legs due to the motion of the Stewart platform by using the numerical method. According to the natural frequencies and the resultant forces, the condition of self-excited vibration is given and verified by simulations. In order to verify the linearization method, an experimental platform of a cable-driven parallel manipulator is set up. The experimental results match well with the theoretical arithmetic. This paper provides a reference point for further studies on vibration suppression in the FAST.

Keywords: Self-excited Vibration, Parallel Manipulator, Natural Frequency, Resonance, FAST
Performance Evaluation of the Various Training Algorithms and Network Topologies in a Neural-network-based Inverse Kinematics Solution for Robots

Yavuz Sarı

Abstract:
Recently, artificial neural networks have been used to solve the inverse kinematics problem of redundant robotic manipulators, where traditional solutions are inadequate. The training algorithm and network topology affect the performance of the neural network. There are several training algorithms used in the training of neural networks. In this study, the effect of various learning algorithms on the learning performance of the neural networks on the inverse kinematics model learning of a seven-joint redundant robotic manipulator is investigated. After the implementation of various training algorithms, the Levenberg-Marquardth (LM) algorithm is found to be significantly more efficient compared to other training algorithms. The effect of the various network types, activation functions and number of neurons in the hidden layer on the learning performance of the neural network is then investigated using the LM algorithm. Among different network topologies, the best results are obtained for the feedforward network model with logistic sigmoid-activation function (logsig) and 41 neurons in the hidden layer. The results are presented with graphics and tables.

Keywords: Robotics, Neural Networks, Training Algorithms, Machine Learning, Inverse Kinematics Solution


Augustin Manecy, Nicolas Marchand and Stéphane Viollet

Abstract:
Hovering flies are able to stay still in place when hovering above flowers and burst into movement towards a new object of interest (a target). This suggests that sensorimotor control loops implemented onboard could be usefully mimicked for controlling Unmanned Aerial Vehicles (UAVs). In this study, the fundamental head-body movements occurring in free-flying insects was simulated in a sighted twin-engine robot with a mechanical decoupling inserted between its eye (or gaze) and its body. The robot based on this gaze control system achieved robust and accurate hovering performances, without an accelerometer, over a ground target despite a narrow eye field of view (±5°). The gaze stabilization strategy validated under Processor-In-the-Loop (PIL) and inspired by three biological Oculomotor Reflexes (ORs) enables the aerial robot to lock its gaze onto a fixed target regardless of its roll angle. In addition, the gaze control mechanism allows the robot to perform short range target to target navigation by triggering an automatic fast “target jump” behaviour based on a saccadic eye movement.

Keywords: Micro Aerial Vehicle, Automatic Navigation, Gaze Control, Visual Control, Hover Flight, Eye Movement, Oculomotor Control, Biorobotics

Full Article

Full Article
Real-time Obstacle Avoidance for a Swarm of Autonomous Mobile Robots

Ramdane Hedjar and Messaoud Bounkhel

Abstract:
In this paper, we propose a computational trajectory generation algorithm for swarm mobile robots using local information in a dynamic environment. The algorithm plans a reference path based on constrained convex nonlinear optimization which avoids both static and dynamic obstacles. This algorithm is combined with one-step-ahead predictive control for a swarm of mobile robots to track the generated paths and reach the goals without collision. The numerical simulations and experimental results demonstrate the effectiveness of the proposed free-collision path planning algorithm.

Keywords  Obstacle Avoidance, Smooth Motion, Swarm Mobile Robots, Sweeping Process, Predictive Control

Robust Tracking with Discriminative Ranking Middle-level Patches

Hong Liu, Zilin Liang and Qianru Sun

Abstract:
The appearance model has been shown to be essential for robust visual tracking since it is the basic criterion to locating targets in video sequences. Though existing tracking-by-detection algorithms have shown to be greatly promising, they still suffer from the drift problem, which is caused by updating appearance models. In this paper, we propose a new appearance model composed of ranking middle-level patches to capture more object distinctiveness than traditional tracking-by-detection models. Targets and backgrounds are represented by both low-level bottom-up features and high-level top-down patches, which can compensate each other. Bottom-up features are defined at the pixel level, and each feature gets its discrimination score through selective feature attention mechanism. In top-down feature extraction, rectangular patches are ranked according to their bottom-up discrimination scores, by which all of them are clustered into irregular patches, named ranking middle-level patches. In addition, at the stage of classifier training, the online random forests algorithm is specially refined to reduce drifting problems. Experiments on challenging public datasets and our test videos demonstrate that our approach can effectively prevent the tracker drifting problem and obtain competitive performance in visual tracking.

Keywords  Middle-level Patches, Selective Feature Attention, Random Forests, Tracking-by-detection
Analysis of Coordinated Motions of Humanoid Robot Fingers Using Interphalangeal Joint Coordination

Byoung-Ho Kim

Abstract:
In this study, we analyse the coordinated motions of humanoid robot fingers using an interphalangeal joint coordination. For this purpose, four humanoid robot fingers with different sizes have been considered. A biomimetic interphalangeal joint coordination (IJC) formulation based on the grasp configuration of human fingers has been presented for humanoid robot fingers. The usefulness of the specified IJC formulation for human-like finger motion has been verified through comparative demonstrations. As a result, a proper coordination of humanoid robot fingertips can be achieved by applying our IJC formulation. Also the IJC formulation can be used to design of humanoid robot fingers.

Keywords  Interphalangeal Joint Coordination, Human-like Finger Motion, Humanoid Robot Fingers

Dynamical Modelling and Controllability Analysis of an Underactuated 2-Dimensional TORA System on a Slope

Bingtuan Gao and Jianguo Zhao

Abstract:
The 2-Dimensional Translational Oscillators with Rotating Actuator (2DTORA) is a novel underactuated system which has one actuated rotor and two unactuated translational carts. This paper focuses on dynamical modelling and simulation analysis of the underactuated 2DTORA on a slope. Based on Lagrange equations, the dynamics of the 2DTORA is achieved by selecting a transverse position of a cart, a travelling position of a cart, and the rotor angle as the general coordinates and torque acting on the rotor as the general force. When the slope angle is set to zero, the dynamics of 2DTORA on a slope is reduced to that of 2DTORA on the horizontal plane. Moreover, by eliminating one degree of translational cart motion, the dynamics of 2DTORA is reduced to that of TORA which is a benchmark of underactuated systems. In addition, the equilibrium and controllability of the 2DTORA system on a slope are discussed. Finally, numerical simulations are performed to verify the feasibility of the developed dynamic models.

Keywords  Underactuated System, 2DTORA, Dynamic Modelling, Controllability, TORA
A Study on the Education Assistant System Using Smartphones and Service Robots for Children

Gu-Min Jeong, Chang-Woo Park, Sujeong You and Sang-Hoon Ji

Abstract:
In this paper, we propose a new education assistant system model using both smartphones and service robots for children’s learning. Through the interaction between a smartphone and a robot, various use cases can be derived. For example, we can control the movement of the robot remotely, watch the status of the children using real-time streaming, or read the answer on the smartphone while only the question is displayed on the robot. Considering these facts, we present three use cases, namely ‘remote control’, ‘streaming’ and ‘N-screen’ for robot-based learning with smartphones. The proposed learning model is implemented in Android-based smartphones and a service robot using the OPRoS platform, and we show that the proposed model works well.

Keywords  Children’s Learning, Robot-based Learning, Remote Control, Streaming, N-screen

A Motion System for Social and Animated Robots

Jelle Saldien, Bram Vanderborght, Kristof Goris, Michael Van Damme and Dirk Lefeber

Abstract:
This paper presents an innovative motion system that is used to control the motions and animations of a social robot. The social robot Probo is used to study Human-Robot Interactions (HRI), with a special focus on Robot Assisted Therapy (RAT). When used for therapy it is important that a social robot is able to create an “illusion of life” so as to become a believable character that can communicate with humans. The design of the motion system in this paper is based on insights from the animation industry. It combines operator-controlled animations with low-level autonomous reactions such as attention and emotional state. The motion system has a Combination Engine, which combines motion commands that are triggered by a human operator with motions that originate from different units of the cognitive control architecture of the robot. This results in an interactive robot that seems alive and has a certain degree of “likeability”. The Godspeed Questionnaire Series is used to evaluate the animacy and likeability of the robot in China, Romania and Belgium.

Keywords  Social Robot, HRI, Animation, Motion Control
System Design of a Cheetah Robot Toward Ultra-high Speed

Mantian Li, Xin Wang, Wei Guo, Pengfei Wang and Lining Sun

Abstract:
High-speed legged locomotion pushes the limits of the most challenging problems of design and development of the mechanism, also the control and the perception method. The cheetah is an existence proof of concept of what we imitate for high-speed running, and provides us lots of inspiration on design. In this paper, a new model of a cheetah-like robot is developed using anatomical analysis and design. Inspired by a biological neural mechanism, we propose a novel control method for controlling the muscles' flexion and extension, and simulations demonstrate good biological properties and leg's trajectory. Next, a cheetah robot prototype is designed and assembled with pneumatic muscles, a musculoskeletal structure, an antagonistic muscle arrangement and a J-type cushioning foot. Finally, experiments of the robot legs swing and kick ground tests demonstrate its natural manner and validate the design of the robot. In the future, we will test the bounding behaviour of a real legged system.

Keywords  Biomimetic, Legged Robots, Artificial Pneumatic Muscle, Musculoskeletal Structure

Decrease in Accuracy of a Rotational SINS Caused by its Rotary Table’s Errors

Pin Lv, Jianye Liu, Jizhou Lai and Ling Zhang

Abstract:
We call a strapdown inertial navigation system (SINS) that uses the rotation auto-compensation technique (which is a common method to reduce the effect of the bias errors of inertial components) a ‘rotational SINS’. In a rotational SINS, the rotary table is an important component, rotating the inertial sensor assembly back and forth in azimuth to accomplish error modulation. As a consequence of the manufacturing process, errors may exist in rotary tables which decrease the navigation accuracy of rotational SINSs. In this study, the errors of rotary tables are considered in terms of installation error, wobble error and angular error, and the models of these errors are established for the rotational SINS. Next, the propagation characteristics of these errors in the rotational SINS are analysed and their effects on navigation results are discussed. Finally, the theoretical conclusions are tested by numerical simulation. This paper supplies a good reference for the development of low-cost rotational SINSs, which usually have low accuracy rotary tables and which may be used in robots, intelligent vehicles and unmanned aerial vehicles (UAVs).

Keywords  Strapdown Inertial Navigation System (SINS), Rotation Technique, Rotary Table Error, Robot Navigation
Robust Tracking Control Using Fuzzy Disturbance Observer for Wheeled Mobile Robots with Skidding and Slipping

Hyo-Seok Kang, Chang-Ho Hyun and Seungwoo Kim

Abstract:
This paper proposes a robust tracking controller based on the Fuzzy Disturbance Observer (FDO) for a Wheeled Mobile Robot (WMR) with unknown skidding and slipping. The proposed method provides disturbance-free techniques for stability analysis. In our previous work [1], we proposed an extended state-observer approach to robust tracking control for wheeled mobile robots with skidding and slipping. Even though satisfying performances were shown and the proposed method was verified in [1], the derivatives of disturbance should go to zero as time passes in order to guarantee performance. This is a very critical assumption. The method proposed in this paper overcomes this problem using universal approximation with a fuzzy model. Thus, the condition that disturbance should disappear with time is not required anymore. Furthermore, the proposed method can be used more widely than that shown in the previous work. This is guaranteed by a Lyapunov-theory-based stability analysis, and performance is verified by simulation results.

Keywords Wheeled Mobile Robot, Skidding, Slipping, Robust Tracking Control, Fuzzy Disturbance Observer

Using a 3DOF Parallel Robot and a Spherical Bat to Hit a Ping-Pong Ball

Alberto Trasloheros, José M. Sebastián, Jesús Torrijos, Ricardo Carelli and Flavio Roberti

Abstract:
Playing the game of Ping-Pong is a challenge to human abilities since it requires developing skills, such as fast reaction capabilities, precision of movement and high speed mental responses. These processes include the utilization of seven DOF of the human arm, and translational movements through the legs, torso, and other extremities of the body, which are used for developing different game strategies or simply imposing movements that affect the ball such as spinning movements. Computationally, Ping-Pong requires a huge quantity of joints and visual information to be processed and analysed, something which really represents a challenge for a robot. In addition, in order for a robot to develop the task mechanically, it requires a large and dexterous workspace, and good dynamic capacities. Although there are commercial robots that are able to play Ping-Pong, the game is still an open task, where there are problems to be solved and simplified. All robotic Ping-Pong players cited in the bibliography used at least four DOF to hit the ball. In this paper, a spherical bat mounted on a 3-DOF parallel robot is proposed. The spherical bat is used to drive the trajectory of a Ping-Pong ball.

Keywords Parallel Robot, Visual Servoing, Robot Ping-Pong Playing
A Fault-tolerable Control Scheme for an Open-frame Underwater Vehicle

Huang Hai, Wan Lei, Chang Wen-tian, Pang Yong-jie and Jiang Shu-qiang

Abstract:
Open-frame is one of the major types of structures of Remote Operated Vehicles (ROV) because it is easy to place sensors and operations equipment on-board. Firstly, this paper designed a petri-based recurrent neural network (PRFNN) to improve the robustness with response to nonlinear characteristics and strong disturbance of an open-frame underwater vehicle. A threshold has been set in the third layer to reduce the amount of calculations and regulate the training process. The whole network convergence is guaranteed with the selection of learning rate parameters. Secondly, a fault tolerance control (FTC) scheme is established with the optimal allocation of thrust. Infinity-norm optimization has been combined with 2-norm optimization to construct a bi-criteria primal-dual neural network FTC scheme. In the experiments and simulation, PRFNN outperformed fuzzy neural networks in motion control, while bi-criteria optimization outperformed 2-norm optimization in FTC, which demonstrates that the FTC controller can improve computational efficiency, reduce control errors, and implement fault tolerable thrust allocation.

Keywords  Open-frame Underwater Vehicle, Recurrent Neural Network, Bi-criteria Control, Fault Tolerance Control

Structure Design and Stable-balancing Control of a Kind of Wire-moving Robot

Lei Guo, Guanglei Lu, Qizheng Liao, Yanbo Cui, Dongqiang Liu, Deng Guo and Zeyan Hu

Abstract:
Wire-moving robots are mechanical systems that can maintain their balance and move on tightropes. Their name comes from the manner in which tightrope walkers maintain their balance by rolling or moving a pole from left to right. In order to investigate the internal laws of these systems and to apply a mechanism of self-balance control to them, a new mechanical structure for wire-moving robots is presented here. This structure consists of a rotational pole and a translational pole coupled with each other in a parallelogram. The robot is an underactuated system. A dynamic model of the robot is established here based on the Lagrange method, and the controller of the system was designed using a partial feedback linearization control algorithm. Finally, the efficiency of the algorithm and the stabilization were verified by computer simulation and experimentation using a prototype.

Keywords  Wire-moving Robot, Balancing Pole, Dynamic Model, Self-balance
A Deployment Method Based on Spring Force in Wireless Robot Sensor Networks

Xiangyu Yu, Ninghao Liu, Xin Qian and Tao Zhang

Abstract:
Robotic sensor deployment is fundamental for the effectiveness of wireless robot sensor networks - a good deployment algorithm leads to good coverage and connectivity with low energy consumption for the whole network. Virtual force-based algorithms (VFAs) is one of the most popular approaches to this problem. In VFA, sensors are treated as points subject to repulsive and attractive forces exerted among them - sensors can move according to imaginary force generated in algorithms. In this paper, a virtual spring force-based algorithm with proper damping is proposed for the deployment of sensor nodes in a wireless sensor network (WSN). A new metric called Pair Correlation Diversion (PCD) is introduced to evaluate the uniformity of the sensor distribution. Numerical simulations showed that damping can affect the network coverage, energy consumption, convergence time and general topology in the deployment. Moreover, it was found that damping effect (imaginary friction force) has significant influence on algorithm outcomes. In addition, when working under approximate critical-damping condition, the proposed approach has the advantage of a higher coverage rate, better configurational uniformity and less energy consumption.

Keywords  Robot Sensors, Wireless Sensor Networks, Sensor Deployment, Virtual Force, Spring Force

A Kinect-sensor-based Tracked Robot for Exploring and Climbing Stairs

I-Hsum Li, Wei-Yen Wang and Chien-Kai Tseng

Abstract:
This paper focuses on the stair-climbing problem for a tracked robot. The tracked robot designed in this paper has the ability to explore stairs in an unknown indoor environment, climbing up and down the stairs, keeping balance while climbing, and successfully landing on the stair platform. Intelligent algorithms are proposed to explore and align stairs, and a fuzzy controller is introduced to stabilize the tracked robot’s movement during the exploration. An inexpensive Kinect depth sensor is the only equipment needed for all the control modes. Finally, experiments illustrate the effectiveness of the proposed approach for climbing stairs.

Keywords  Tracked Robot, Stair-climbing, Autonomous Robot
Steps Towards Scalable and Modularized Flight Software for Unmanned Aircraft Systems

Johann C. Dauer, Lukas Goormann and Christoph Torens

Abstract:
Unmanned aircraft (UA) applications impose a variety of computing tasks on the on-board computer system. From a research perspective, it is often more convenient to evaluate algorithms on bigger aircraft as they are capable of lifting heavier loads and thus more powerful computational units. On the other hand, smaller systems are often less expensive and operation is less restricted in many countries. This paper thus presents a conceptual design for flight software that can be evaluated on the UA of convenient size. The integration effort required to transfer the algorithm to different sized UA is significantly reduced. This scalability is achieved by using exchangeable payload modules and a flexible process distribution on different processing units. The presented approach is discussed using the example of the flight software of a 14 kg unmanned helicopter and an equivalent of 1.5 kg. The proof of concept is shown by means of flight performance in a hardware-in-the-loop simulation.

Keywords: UAV, UAS, Flight Control Software, Unmanned Helicopter

Path-tracking Algorithm for Aircraft Fuel Tank Inspection Robots

Niu Guochen, Wang Li, Gao Qingji and Hu Dandan

Abstract:
A 3D path-tracking algorithm based on end-point approximation is proposed to implement the path traversal of robots designed to inspect aircraft fuel tanks. Kinematic models of single-joint segments and multiple-joint segments were created. First, each joint segment of the path was divided into many equal sections and the rotation angle was computed. The rotation angle was found for the plane determined by one divided point and the secondary terminal joint segment. Second, the shortest distance search strategy was used to calculate the bending angle of the joint segment. The main advantage of the algorithm was that only the terminal joint segment variables needed to be solved, the joint variables of other joint segments were copied from the adjacent front-end joint segment variables in turn. Finally, evaluation indexes of path tracking performance were proposed to evaluate the effect of the algorithm. Simulations of planar and space path tracking were carried out using MATLAB, and the effectiveness and stability of the tracking algorithm were verified.

Keywords: Continuum Robot, Aircraft Fuel Tank, Inspection Robot, Path-tracking, Endpoint Approximation, Evaluation Index
Calibration of the Multi-camera Registration System for Visual Navigation Benchmarking
Adam Schmidt, Andrzej Kasiński, Marek Kraft, Michał Fularz and Zuzanna Domagała

Abstract:
This paper presents the complete calibration procedure of a multi-camera system for mobile robot motion registration. Optimization-based, purely visual methods for the estimation of the relative poses of the motion registration system cameras, as well as the relative poses of the cameras and markers placed on the mobile robot were proposed. The introduced methods were applied to the calibration of the system and the quality of the obtained results was evaluated. The obtained results compare favourably with the state of the art solutions, allowing the use of the considered motion registration system for the accurate reconstruction of the mobile robot trajectory and to register new datasets suitable for the benchmarking of indoor, visual-based navigation algorithms.

Keywords  Visual Navigation, Calibration, Motion Capture, Benchmarking, Multi-camera System

Autonomous Navigation with Constrained Consistency for C-Ranger
Shujing Zhang, Bo He, Lulu Ying, Minghui Li and Guang Yuan

Abstract:
Autonomous underwater vehicles (AUVs) have become the most widely used tools for undertaking complex exploration tasks in marine environments. Their synthetic ability to carry out localization autonomously and build an environmental map concurrently, in other words, simultaneous localization and mapping (SLAM), are considered to be pivotal requirements for AUVs to have truly autonomous navigation. However, the consistency problem of the SLAM system has been greatly ignored during the past decades. In this paper, a consistency constrained extended Kalman filter (EKF) SLAM algorithm, applying the idea of local consistency, is proposed and applied to the autonomous navigation of the C-Ranger AUV, which is developed as our experimental platform. The concept of local consistency (LC) is introduced after an explicit theoretical derivation of the EKF-SLAM system. Then, we present a locally consistency-constrained EKF-SLAM design, LC-EKF, in which the landmark estimates used for linearization are fixed at the beginning of each local time period, rather than evaluated at the latest landmark estimates. Finally, our proposed LC-EKF algorithm is experimentally verified, both in simulations and sea trials. The experimental results show that the LC-EKF performs well with regard to consistency, accuracy and computational efficiency.

Keywords  AUV, SLAM, EKF, Filter Consistency
STRIDE II: A Water Strider-inspired Miniature Robot with Circular Footpads

Onur Ozcan, Han Wang, Jonathan D. Taylor and Metin Sitti

Abstract:

Water strider insects have attracted the attention of many researchers due to their power-efficient and agile water surface locomotion. This study proposes a new water strider insect-inspired robot, called STRIDE II, which uses new circular footpads for high lift, stability and payload capability, and a new elliptical leg rotation mechanism for more efficient water surface propulsion. Using the advantage of scaling effects on surface tension versus buoyancy, similar to water strider insects, this robot uses the repulsive surface tension force on its footpads as the dominant lift principle instead of creating buoyancy by using very skinny (1 mm diameter) circular footpads coated with a superhydrophobic material. The robot and the insect propel quickly and power efficiently on the water surface by the sculling motion of their two side-legs, which never break the water surface completely. This paper proposes models for the lift, drag and propulsion forces and the energy efficiency of the proposed legged robot, and experiments are conducted to verify these models. After optimizing the robot design using the lift models, a maximum lift capacity of 55 grams is achieved using 12 footpads with a 4.2 cm outer diameter, while the robot itself weighs 21.75 grams. For this robot, a propulsion efficiency of 22.3% was measured. The maximum forward and turning speeds of the robot were measured as 71.5 mm/sec and 0.21 rad/sec, respectively. These water strider robots could be used in water surface monitoring, cleaning and analysis in lakes, dams, rivers and the sea.

Keywords  Biologically-inspired Robots, Water Strider, Surface Tension, Miniature Robots

Distributed Fault Detection and Isolation for Flocking in a Multi-robot System with Imperfect Communication

Shao Shiliang, Wang Ting, Yao Chen, Li Xiaofan and Zhao Hai

Abstract:

In this paper, we focus on distributed fault detection and isolation (FDI) for a multi-robot system where multiple robots execute a flocking task. Firstly, we propose a fault detection method based on the local-information-exchange and sensor-measurement technologies to cover cases of both perfect communication and imperfect communication. The two detection technologies can be adaptively selected according to the packet loss rate (PLR). Secondly, we design a fault isolation method, considering a situation in which faulty robots still influence the behaviours of other robots. Finally, a complete FDI scheme, based on the proposed detection and isolation methods, is simulated in various scenarios. The results demonstrate that our FDI scheme is effective.

Keywords  Multi-Robot, Flocking, Fault Detection, Isolation
CPG-based Locomotion Controller Design for a Boxfish-like Robot
Wei Wang and Guangming Xie

Abstract:
This paper focuses on a Central Pattern Generator (CPG)-based locomotion controller design for a boxfish-like robot. The bio-inspired controller is aimed at flexible switching in multiple 3D swimming patterns and exact attitude control of yaw and roll such that the robot will swim more like a real boxfish. The CPG network comprises two layers, the lower layer is the network of coupled linear oscillators and the upper is the transition layer where the lower-dimensional locomotion stimuli are transformed into the higher-dimensional control parameters serving for all the oscillators. Based on such a two-layer framework, flexible switching between multiple three-dimensional swimming patterns, such as swimming forwards/backwards, turning left/right, swimming upwards/downwards and rolling clockwise/counter-clockwise, can be simply realized by inputting different stimuli. Moreover, the stability of the CPG network is strictly proved to guarantee the intrinsic stability of the swimming patterns. As to exact attitude control, based on this open-loop CPG network and the sensory feedback from the Inertial Measurement Unit (IMU), a closed-loop CPG controller is advanced for yaw and roll control of the robotic fish for the first time. This CPG-based online attitude control for a robotic fish will greatly facilitate high-level practical underwater applications. A series of relevant experiments with the robotic fish are conducted systematically to validate the effectiveness and stability of the open-loop and closed-loop CPG controllers.

Keywords Robotic Fish, Open-loop CPG, Closed-loop CPG, Attitude Control, Sensory Feedback

Isotropic Optical Mouse Placement for Mobile Robot Velocity Estimation
Sungbok Kim

Abstract:
This paper presents the isotropic placement of multiple optical mice for the velocity estimation of a mobile robot. It is assumed that there can be positional restriction on the installation of optical mice at the bottom of a mobile robot. First, the velocity kinematics of a mobile robot with an array of optical mice is obtained and the resulting Jacobian matrix is analysed symbolically. Second, the isotropic, anisotropic and singular optical mouse placements are identified, along with the corresponding characteristic lengths. Third, the least squares mobile robot velocity estimation from the noisy optical mouse velocity measurements is discussed. Finally, simulation results for several different placements of three optical mice are given.

Keywords Optical Mice, Mobile Robot, Velocity Estimation, Isotropic Optical Mouse Placement, Optimal Characteristic Length
Genetic Algorithm-based Affine Parameter Estimation for Shape Recognition

Yuxing Mao, Yan Wang, Quanlin Wang and Wei He

Abstract:
Shape recognition is a classically difficult problem because of the affine transformation between two shapes. The current study proposes an affine parameter estimation method for shape recognition based on a genetic algorithm (GA). The contributions of this study are focused on the extraction of affine-invariant features, the individual encoding scheme, and the fitness function construction policy for a GA. First, the affine-invariant characteristics of the centroid distance ratios (CDRs) of any two opposite contour points to the barycentre are analysed. Using different intervals along the azimuth angle, the different numbers of CDRs of two candidate shapes are computed as representations of the shapes, respectively. Then, the CDRs are selected based on predesigned affine parameters to construct the fitness function. After that, a GA is used to search for the affine parameters with optimal matching between candidate shapes, which serve as actual descriptions of the affine transformation between the shapes. Finally, the CDRs are resampled based on the estimated parameters to evaluate the similarity of the shapes for classification. The experimental results demonstrate the robust performance of the proposed method in shape recognition with translation, scaling, rotation and distortion.

Keywords Shape Recognition, Affine Transformation, Centroid Distance Ratio, Genetic Algorithm, Fitness Function

Kinodynamic Motion Planning for Autonomous Vehicles

Jiwung Choi

Abstract:
This article proposes a computationally effective motion planning algorithm for autonomous ground vehicles operating in a semi-structured environment with a mission specified by waypoints, corridor widths and obstacles. The algorithm switches between two kinds of planners, (i) static planners and (ii) moving obstacle avoidance manoeuvre planners, depending on the mobility of any detected obstacles. While the first is broken down into a path planner and a controller, the second generates a sequence of controls without global path planning. Each subsystem is implemented as follows. The path planner produces an optimal piecewise linear path by applying a variant of cell decomposition and dynamic programming. The piecewise linear path is smoothed by Bézier curves such that the maximum curvatures of the curves are minimized. The controller calculates the highest allowable velocity profile along the path, consistent with the limits on both tangential and radial acceleration and the steering command for the vehicle to track the trajectory using a pure pursuit method. The moving obstacle avoidance manoeuvre produces a sequence of time-optimal local velocities, by minimizing the cost as determined by the safety of the current velocity against obstacles in the velocity obstacle paradigm and the deviation of the current velocity relative to the desired velocity, to satisfy the waypoint constraint. The algorithms are shown to be robust and computationally efficient, and to demonstrate a viable methodology for autonomous vehicle control in the presence of unknown obstacles.

Keywords Path Planning, Moving Obstacle Avoidance, Autonomous Vehicles
**Human-robot Team Coordination That Considers Human Fatigue**

*Kai Zhang and Xiaobo Li*

**Abstract:**

Many applications for robots require them to work alongside people as capable members of human-robot teams and to collaborate in order to perform tasks and achieve common goals. These tasks can induce strain on the human due to time constraints. Additionally, humans can become highly stressed due to fatigue, resulting in decreased efficiency. The contribution of this paper is in the introduction of a human fatigue model and the application of this model to a mixed team coordination framework in order to predict team performance given the constraints of human fatigue. The human fatigue model - namely a FAtigue Prediction (FAP) model - is used to conduct numerical simulations that predict mixed team performances. Specifically, extensive simulations are performed to determine how human fatigue influences the choice of the number of agents for a given number of tasks. The novel mixed team coordination framework is a Stochastic Clustering Auction (SCA), which is based on a modification of the Swendsen-Wang method, called SW$^2$SCA. It enables complex and efficient movement between clusters by connecting tasks that appear to be synergistic and then stochastically reassigning these connected tasks. In SW$^2$SCA, the auctioneer makes stochastic movements with homogeneous or heterogeneous agents. The final discussion outlines a systematic procedure to predict the performance of human-robot systems with the FAP model in SCA.

**Keywords**  Human-robot Interaction, Auctions and Market-based Systems, Human Fatigue

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**A Markov Random Field Model for the Restoration of Foggy Images**

*Fan Guo, Jin Tang and Hui Peng*

**Abstract:**

This paper presents an algorithm to remove fog from a single image using a Markov random field (MRF) framework. The method estimates the transmission map of an image degradation model by assigning labels with a MRF model and then optimizes the map estimation process using the graph cut-based $\alpha$-expansion technique. The algorithm employs two steps. Initially, the transmission map is estimated using a dedicated MRF model combined with a bilateral filter. Next, the restored image is obtained by taking the estimated transmission map and the ambient light into the image degradation model to recover the scene radiance. The algorithm is controlled by just a few parameters that are automatically determined by a feedback mechanism. Results from a wide variety of synthetic and real foggy images demonstrate that the proposed method is effective and robust, yielding high-contrast and vivid defogging images. In addition to image defogging, surveillance video defogging based on a universal strategy and the application of a transmission map are also implemented.

**Keywords**  Foggy Image, Defogging, Markov Random Field, Label Assignment, Transmission Map
Cellular Automata Based Real-time Path-planning for Mobile Robots

Usman Ahmed Syed and Faraz Kunwar

Abstract:
Intelligent mobile robotic agents demand optimal motion planners with minimal query time. Most contemporary algorithms lack one of these two required aspects. This paper proposes an efficient path-planning scheme based on cellular automata (CA) that generates optimal paths in the minimum time. A Cellular automaton is evolved over the entire search space and subsequently used for the determination of the shortest path. This approach generates a parent-child relationship for each cell in order to minimize the search time. Performance comparisons with A*, Dijkstra’s, D* and MPCNN have proven it to be time-efficient. Analysis, simulation and experimental results have proven it to be a robust and complete path-planning scheme. Also it has demonstrated to be time-efficient in both static and dynamic environments.

Keywords  Cellular Automata, Path-planning, Obstacle Avoidance

SmartPATH: An Efficient Hybrid ACO-GA Algorithm for Solving the Global Path Planning Problem of Mobile Robots

Imen Châari, Anis Koubâa, Sahar Trigui, Hachemi Bennaceur, Adel Ammar and Khaled Al-Shalfan

Abstract:
Path planning is a fundamental optimization problem that is crucial for the navigation of a mobile robot. Among the vast array of optimization approaches, we focus in this paper on Ant Colony Optimization (ACO) and Genetic Algorithms (GA) for solving the global path planning problem in a static environment, considering their effectiveness in solving such a problem. Our objective is to design an efficient hybrid algorithm that takes profit of the advantages of both ACO and GA approaches for the sake of maximizing the chance to find the optimal path even under real-time constraints. In this paper, we present smartPATH, a new hybrid ACO-GA algorithm that relies on the combination of an improved ACO algorithm (IACO) for efficient and fast path selection, and a modified crossover operator to reduce the risk of falling into a local minimum. We demonstrate through extensive simulations that smartPATH outperforms classical ACO (CACO), GA algorithms. It also outperforms the Dijkstra exact method in solving the path planning problem for large graph environments. It improves the solution quality up to 57% in comparison with CACO and reduces the execution time up to 83% as compared to Dijkstra for large and dense graphs. In addition, the experimental results on a real robot shows that smartPATH finds the optimal path with a probability up to 80% with a small gap not exceeding 1m in 98%.

Keywords  Mobile Robots, Path Planning, Ant Colony Optimization, Genetic Algorithms
A Novel Design of a Quadruped Robot for Research Purposes
Yam Geva and Amir Shapiro

Abstract:
This paper presents the design of a novel quadruped robot. The proposed design is characterized by a simple, modular design, and easy interfacing capabilities. The robot is built mostly from off-the-shelf components. The design includes four 3-DOF legs, the robot body and its electronics. The proposed robot is able to traverse rough terrain while carrying additional payloads. Such payloads can include both sensors and computational hardware. We present the robot design, the control system, and the forward and inverse kinematics of the robot, as well as experiments that are compared with simulation results.

Keywords  Quadruped Robot, Robot Design, Research Platform

Contact Estimation in Robot Interaction
Filippo D’Ippolito, Francesco Alonge and Elisa Cucco

Abstract:
In the paper, safety issues are examined in a scenario in which a robot manipulator and a human perform the same task in the same workspace. During the task execution, the human should be able to physically interact with the robot, and in this case an estimation algorithm for both interaction forces and a contact point is proposed in order to guarantee safety conditions. The method, starting from residual joint torque estimation, allows both direct and adaptive computation of the contact point and force, based on a principle of equivalence of the contact forces. At the same time, all the unintended contacts must be avoided, and a suitable post-collision strategy is considered to move the robot away from the collision area or else to reduce impact effects. Proper experimental tests have demonstrated the applicability in practice of both the post-impact strategy and the estimation algorithms; furthermore, experiments demonstrate the different behaviour resulting from the adaptation of the contact point as opposed to direct calculation.

Keywords  Physical Human-robot Interaction, Contact Force Estimation, Collision Detection
Detection and Tracking Strategies for Autonomous Aerial Refuelling Tasks Based on Monocular Vision

Yingjie Yin, De Xu, Xingang Wang and Mingran Bai

Abstract:
Detection and tracking strategies based on monocular vision are proposed for autonomous aerial refuelling tasks. The drogue attached to the fuel tanker aircraft has two important features. The grey values of the drogue’s inner part are different from the external umbrella ribs, as shown in the image. The shape of the drogue’s inner dark part is nearly circular. According to crucial prior knowledge, the rough and fine positioning algorithms are designed to detect the drogue. Particle filter based on the drogue’s shape is proposed to track the drogue. A strategy to switch between detection and tracking is proposed to improve the robustness of the algorithms. The inner dark part of the drogue is segmented precisely in the detecting and tracking process and the segmented circular part can be used to measure its spatial position. The experimental results show that the proposed method has good performance in real-time and satisfied robustness and positioning accuracy.

Keywords  Positioning, Monocular Vision, Visual Detection, Visual Tracking, Particle Filter, Aerial Refuelling

Evaluating the Fin-ray Trajectory Tracking of Bio-inspired Robotic Undulating Fins via an Experimental-numerical Approach

Xiaojia Xiang, Tianjiang Hu, Han Zhou and Zhaowei Ma

Abstract:
In the past decade, biomimetic undulating fin propulsion has been one of the main topics considered by scientists and researchers in the field of robotic fish. This technology is inspired by the biological wave-like propulsion of ribbon-finned fish. The swimming modes have aquatic application potentials with greater manoeuvrability, less detectable noise or wake and better efficiency at low speeds. The present work concentrates on the evaluation of fin-ray trajectory tracking of biorobotic undulating fins at the levels of kinematics and hydrodynamics by using an experimental-numerical approach. Firstly, fin-ray tracking inconsistence between the desired and actual undulating trajectories is embodied with experimental data of the fin prototype. Next, the dynamics’ nonlinearity is numerically and analytically unveiled by using the computational fluid dynamics (CFD) method, from the viewpoint of vortex shedding and the hydro-effect. The evaluation of fin-ray tracking performance creates a good basis for control design to improve the fin-ray undulation of prototypes.

Keywords  Biomimetics, Robotic Fish, Fin-ray Trajectory Tracking, Hysteresis, Undulating Fins, Computational Fluid dynamics (CFD)
A Millimetre-sized Robot Realized by a Piezoelectric Impact-type Rotary Actuator and a Hardware Neuron Model

Minami Takato, Masaki Tatani, Hirozumi Oku, Yuki Okane, Junichi Tanida, Shinpei Yamasaki, Ken Saito and Fumio Uchikoba

Abstract:
Micro-robotic systems are increasingly used in medicine and other fields requiring precision engineering. This paper proposes a piezoelectric impact-type rotary actuator and applies it to a millimetre-size robot controlled by a hardware neuron model. The rotary actuator and robot are fabricated by micro-electro-mechanical systems (MEMS) technology. The actuator is composed of multilayer piezoelectric elements. The rotational motion of the rotor is generated by the impact head attached to the piezoelectric element. The millimetre-size robot is fitted with six legs, three on either side of the developed actuator, and can walk on uneven surfaces like an insect. The three leg parts on each side are connected by a linking mechanism. The control system is a hardware neuron model constructed from analogue electronic circuits that mimic the behaviour of biological neurons. The output signal ports of the controller are connected to the multilayer piezoelectric element. This robot system requires no specialized software programs or A/D converters. The rotation speed of the rotary actuator reaches 60 rpm at an applied neuron frequency of 25 kHz during the walking motion. The width, length and height of the robot are 4.0, 4.6 and 3.6 mm, respectively. The motion speed is 180 mm/min.

Keywords: Piezoelectric Actuator, Impact Type, MEMS, Millimetre-size Robot, Hardware Neuron Model

Reactive Robot Navigation Utilizing Nonlinear Control

Lei Ting, Chris J.B. Macnab and Sebastian Magierowski

Abstract:
In this paper, we propose a computationally efficient heuristic solution to choosing a path around obstacles in the face of limited sensor information. Specifically, we propose a navigation algorithm for a mobile robot that reaches a measured target position while avoiding obstacles, making decisions in real-time (without stopping) and relying strictly on information obtained from limited and noisy robot-mounted sensors to determine the location and severity of obstacles. The solution utilizes fuzzy processing to encode the environment - the fuzzy encoding is used both in deciding on an intermediate target direction and in a collision-avoidance strategy. A closed-loop nonlinear feedback control provides a smooth motion with stability guarantees. Simulation results in a corridor environment demonstrate expected collision-free trajectories.

Keywords: Mobile Robot Navigation, Reactive Control, BEAM Robotics, Lyapunov Backstepping Control
Structural Synthesis of 3-DoF Spatial Fully Parallel Manipulators

Alfonso Hernandez, Jose Ignacio Ibarreche, Victor Petuya and Oscar Altuzarra

Abstract:
In this paper, the architectures of three degrees of freedom (3-DoF) spatial, fully parallel manipulators (PMs), whose limbs are structurally identical, are obtained systematically. To do this, the methodology followed makes use of the concepts of the displacement group theory of rigid body motion. This theory works with so-called ‘motion generators’. That is, every limb is a kinematic chain that produces a certain type of displacement in the mobile platform or end-effector. The laws of group algebra will determine the actual motion pattern of the end-effector. The structural synthesis is a combinatorial process of different kinematic chains’ topologies employed in order to get all of the 3-DoF motion pattern possibilities in the end-effector of the fully parallel manipulator.

Keywords: Parallel Manipulator, Structural Synthesis, Group of Displacement, Kinematic Bond, Motion Pattern

On the Necessity of Including Joint Passive Dynamics in the Impedance Control of Robotic Legs

Juan Carlos Arevalo, Manuel Cestari, Daniel Sanz-Merodio and Elena Garcia

Abstract:
Bioinspired quadruped robots are among the best robot designs for field missions over the complex terrain encountered in extraterrestrial landscapes and disaster scenarios caused by natural and human-made catastrophes, such as those caused by nuclear power plant accidents and radiological emergencies. For such applications, the performance characteristics of the robots should include high mobility, adaptability to the terrain, the ability to handle a large payload and good endurance. Nature can provide inspiration for quadruped designs that are well suited for traversing complex terrain. Horse legs are an example of a structure that has evolved to exhibit good performance characteristics. In this paper, a leg design exhibiting the key features of horse legs is briefly described. This leg is an underactuated mechanism because it has two actively driven degrees of freedom (DOFs) and one passively driven DOF. In this work, two control laws intended to be use in the stance phase are described: a control law that considers passive mechanism dynamics and a second law that neglects these dynamics. The performance of the two control laws is experimentally evaluated and compared. The results indicate that the first control law better achieves the control goal; however, the use of the second is not completely unjustified.

Keywords: Bioinspired Robots, Impedance Control, Agile Locomotion, Underactuated Robots
Generating a Style-adaptive Trajectory from Multiple Demonstrations

Yue Zhao, Rong Xiong, Li Fang and Xiaohe Dai

Abstract:
Trajectory learning and generation from demonstration have been widely discussed in recent years, with promising progress made. Existing approaches, including the Gaussian Mixture Model (GMM), affine functions and Dynamic Movement Primitives (DMPs) have proven their applicability to learning the features and styles of existing trajectories and generating similar trajectories that can adapt to different dynamic situations. However, in many applications, such as grasping an object, shooting a ball, etc., different goals require trajectories of different styles. An issue that must be resolved is how to reproduce a trajectory with a suitable style. In this paper, we propose a style-adaptive trajectory generation approach based on DMPs, by which the style of the reproduced trajectories can change smoothly as the new goal changes. The proposed approach first adopts a Point Distribution Model (PDM) to get the principal trajectories for different styles, then learns the model of each principal trajectory independently using DMPs, and finally adapts the parameters of the trajectory model smoothly according to the new goal using an adaptive goal-to-style mechanism. This paper further discusses the application of the approach on small-sized robots for an adaptive shooting task and on a humanoid robot arm to generate motions for table tennis-playing with different styles.

Keywords  Dynamic Movement Primitives, SADMPs, Trajectory Learning

An Advanced Approach to Extraction of Colour Texture Features Based on GLCM

Miroslav Benco, Robert Hudec, Patrik Kamencay, Martina Zachariasova and Slavomir Matuska

Abstract:
This paper discusses research in the area of texture image classification. More specifically, the combination of texture and colour features is researched. The principle objective is to create a robust descriptor for the extraction of colour texture features. The principles of two well-known methods for grey-level texture feature extraction, namely GLCM (grey-level co-occurrence matrix) and Gabor filters, are used in experiments. For the texture classification, the support vector machine is used. In the first approach, the methods are applied in separate channels in the colour image. The experimental results show the huge growth of precision for colour texture retrieval by GLCM. Therefore, the GLCM is modified for extracting probability matrices directly from the colour image. The method for 13 directions neighbourhood system is proposed and formulas for probability matrices computation are presented. The proposed method is called CLCM (colour-level co-occurrence matrices) and experimental results show that it is a powerful method for colour texture classification.

Keywords  Co-occurrence Matrices, Feature Extraction, GLCM, Image Texture Analysis
Orthopaedic Rehabilitation Device Actuated with Pneumatic Muscles

Ioana Petre, Andrea Deaconescu, Liliana Rogozea and Tudor Ion Deaconescu

Abstract:
Year after year recovery clinics worldwide report significant numbers of lower limb bearing joint disabilities. An effective method for the speedy rehabilitation of patients with such afflictions is Continuous Passive Motion (CPM), drawing upon a range of specific equipment. This paper presents an innovative constructive solution for such orthopaedic rehabilitation equipment, designed to ensure a swift reintegration of patients at as low a cost as possible. The absolute novelty consists in the utilization of the linear pneumatic muscle as actuator of the orthopaedic rehabilitation equipment, thus achieving a light and highly compliant construction that satisfies safety requirements related to man-machine interaction. Pneumatic muscles are bio-inspired actuation systems characterized by a passive variable compliant behaviour. This property, deployed in rehabilitation systems, enables the development of human friendly devices, which are comfortable for the patients, and capable of safe interaction. This paper presents the constructive schematic of the orthopaedic rehabilitation equipment, the structure of the actuation and positioning system, and several of its functional characteristics.

Keywords Orthopaedic Rehabilitation Equipment, CPM, Pneumatic Muscle

A Low-cost, Light-weight Climbing Robot for Inspection of Glass Curtains

Ran Liang, Meteb Altaf, Eball Ahmad, Rong Liu and Ke Wang

Abstract:
This paper presents design of a climbing robot for inspection of glass curtain walls. The double-chamber structure enables the robot to climb over grooves on the glasses. In order to reduce the weight, both number and shape of the chambers are specially considered, and the pressure structure is optimized by FEA method. The statics models of different adsorption situations are also analyzed and deduced for the operational safety. In addition, design of the working arm and the wireless control system are introduced in detail. Finally, experiments of the robot are illustrated, including adsorption on different surfaces, vertical and horizontal groove-crossing as well as glass inspection. These experiments fully prove the theoretical analysis and demonstrate the climbing performance of the robot.

Keywords Climbing Robot, Negative Pressure Adsorption, Multi-chamber Structure, Glass-inspection
External Joint Torque-based Estimation of Contact Information

Nejc Likar and Leon Žlajpah

Abstract:
In the paper, a method for the estimation of the contact force and contact location is proposed. Contact can occur at any point on the body of the robot manipulator. The contact force estimation algorithm is based on the measurement of the part of the joint torques caused by the external force. As this is a complex nonlinear problem, the proposed method is based on nonlinear constrained optimization. Using certain assumptions, the complexity of the problem is reduced. In this paper, only robots with cylindrically-shaped links are considered. The simulation and experimental results show that the proposed approach allows the estimation of the contact forces by using only the joint torque sensors, without any additional external sensory systems for the detection of contacts along the robot body-structure.

Keywords  External Torque Measurement, Global Optimization, Contact Detection

Comparison of Uncalibrated Model-free Visual Servoing Methods for Small-amplitude Movements: A Simulation Study

Josip Musić, Mirjana Bonković and Mojmir Cecić

Abstract:
The paper compares the performance of several methods used for the estimation of an image Jacobian matrix in uncalibrated model-free visual servoing. This was achieved for an eye-in-hand configuration with small-amplitude movements with several sets of system parameters. The tested methods included the Broyden algorithm, Kalman and particle filters as well as the recently proposed population-based algorithm. The algorithms were tested in a simulation environment (Peter Corke’s Robotic Toolbox for MATLAB) on a PUMA 560 robot. Several application scenarios were considered, including static point and dynamic trajectory tracking, with several characteristic shapes and three different speeds. Based on the obtained results, conclusions were drawn about the strengths and weaknesses of each method both for a particular setup and in general. Algorithm-switching was introduced and explored, since it might be expected to improve overall robot tracking performance with respect to the desired trajectory. Finally, possible future research directions are suggested.

Keywords  Visual Servoing, Model-free, Uncalibrated, Population-based, Particle Filter
Forward and Inverse Dynamics of the Biped PASIBOT
Eduardo Corral, Jesús Meneses, Cristina Castejón and Juan Carlos García-Prada

Abstract:
This article addresses the supporting foot slippage of the biped robot PASIBOT and develops its forward and inverse dynamics for simple and double support phases. To address the slippage phenomenon, we consider an additional degree of freedom at the supporting foot and also distinguish between static and kinetic friction conditions. The inverse and forward dynamics, accounting for support foot slippage, are encoded in MATLAB. The algorithm predicts the motion of the biped from the torque function given by the biped’s sole motor. Thus, the algorithm becomes an indispensable tool for studying transient states of the biped (for example, the torques required for starting and braking), as well as defining the conditions that prevent or control slippage. Since the developed code is parametric, its output can greatly assist in the design, optimization and control of PASIBOT and similar biped robots. The topology, kinematics and inverse dynamics of the one-degree-of-freedom biped PASIBOT have been previously described, but without regard to slippage between the supporting foot and the ground.

Keywords  Mechanism Analysis, Biped, Forward Dynamics, Slippage

Distributed Computation in a Quadrupedal Robotic System
Daniel Kuehn, Felix Bernhard, Armin Burchardt, Moritz Schilling, Tobias Stark, Martin Zenzes and Frank Kirchner

Abstract:
Today’s and future space missions (will) have to deal with increasing requirements regarding autonomy and flexibility in the locomotor system. To cope with these requirements, a higher bandwidth for sensor information is needed. In this paper, a robotic system is presented that is equipped with artificial feet and a spine incorporating increased sensing capabilities for walking robots. In the proposed quadrupedal robotic system, the front and rear parts are connected via an actuated spinal structure with six degrees of freedom. In order to increase the robustness of the system’s locomotion in terms of traction and stability, a foot-like structure equipped with various sensors has been developed. In terms of distributed local control, both structures are as self-contained as possible with regard to sensing, sensor preprocessing, control and communication. This allows the robot to respond rapidly to occurring events with only minor latency.

Keywords  Artificial Spine, Sensor Foot, Distributed Control, Walking Robot
A Taxonomy of Vision Systems for Ground Mobile Robots

Jesus Martínez-Gómez, Antonio Fernández-Caballero, Ismael García-Varea, Luis Rodríguez and Cristina Romero-González

Abstract:
This paper introduces a taxonomy of vision systems for ground mobile robots. In the last five years, a significant number of relevant papers have contributed to this subject. Firstly, a thorough review of the papers is proposed to discuss and classify both past and the most current approaches in the field. As a result, a global picture of the state of the art of the last five years is obtained. Moreover, the study of the articles is used to put forward a comprehensive taxonomy based on the most up-to-date research in ground mobile robotics. In this sense, the paper aims at being especially helpful to both budding and experienced researchers in the areas of vision systems and mobile ground robots. The taxonomy described is devised from a novel perspective, namely in order to respond to the main questions posed when designing robotic vision systems: why?, what for?, what with?, how?, and where? The answers are derived from the most relevant techniques described in the recent literature, leading in a natural way to a series of classifications that are discussed and contextualized. The article offers a global picture of the state of the art in the area and discovers some promising research lines.

Keywords: Ground Mobile Robots, Vision Systems, Taxonomy, Review

Robotic Services at Home: An Initialization System Based on Robots’ Information and User Preferences in Unknown Environments

Nur Safwati Mohd Nor and Makoto Mizukawa

Abstract:
One important issue in robotic services is the construction of the robotic system in the actual environment. In other words, robots must perform environment sensing or have information on real objects, such as location and 3D dimensions, in order to live together with humans. It is crucial to have a mechanism to create an actual robotic system (intelligent space) such that there is no initialization framework for the objects in the environment, or we have to perform SLAM and object recognition as well as mapping to generate a useful environmental database. In intelligent space research, normally the objects are attached to various sensors in order to extract the necessary information. However, that approach will highly depend on sensor accuracy and the robotic system will be burdened if there are too many sensors in an environment. Therefore, in this paper we present a system in which a robot can obtain information about an object and even create the furniture layout map for an unknown environment. Our approach is intended to improve home-based robotic services by taking into account the user or individual preferences for the Intelligent Space (IS). With this information, we can create an informational map of the home-based environment for the realization of robot assistance of humans in their daily activities at home, especially for disabled people. The result shows the system design and development in our approach by using model-based system engineering.

Keywords: Intelligent Space, Human-robot Interaction, Space Sensing and Mapping, Robotic Services
**Colias: An Autonomous Micro Robot for Swarm Robotic Applications**

Farshad Arvin, John Murray, Chun Zhang and Shigang Yue

**Abstract:**
Robotic swarms that take inspiration from nature are becoming a fascinating topic for multi-robot researchers. The aim is to control a large number of simple robots in order to solve common complex tasks. Due to the hardware complexities and cost of robot platforms, current research in swarm robotics is mostly performed by simulation software. The simulation of large numbers of these robots in robotic swarm applications is extremely complex and often inaccurate due to the poor modelling of external conditions. In this paper, we present the design of a low-cost, open-platform, autonomous micro-robot (Colias) for robotic swarm applications. Colias employs a circular platform with a diameter of 4 cm. It has a maximum speed of 35 cm/s which enables it to be used in swarm scenarios very quickly over large arenas. Long-range infrared modules with an adjustable output power allow the robot to communicate with its direct neighbours at a range of 0.5 cm to 2 m. Colias has been designed as a complete platform with supporting software development tools for robotics education and research. It has been tested in both individual and swarm scenarios, and the observed results demonstrate its feasibility for use as a micro-sized mobile robot and as a low-cost platform for robot swarm applications.

**Keywords**  Autonomous Robot, Swarm Robotics, Collective Behaviour, Micro-robot

**Silhouette Extraction from Street View Images**

Begüm Mutlu, Murat Hacıömeroğlu, Mehmet Serdar Guzel, Mehmet Dikmen and Hayri Sever

**Abstract:**
This study addresses the issue of silhouette extraction of a street, and proposes two novel approaches to overcome this problem. The first, namely hybrid-stitching, considers the silhouette extraction as an image stitching problem and aims to use 2D street view images. The algorithm used in this method integrates a new composition technique into a conventional image stitching pipeline. The developed software using the proposed hybrid approach results in better stitching performances when compared with the popular stitching tools in the literature. Despite the results of the proposed method are better than the state-of-the-art image stitching techniques in many cases, they are not reliable enough to handle all of the street view image sets. Accordingly, a second solution has been proposed, including 3D location information, namely, 3D Silhouette Extraction Pipeline. The pipeline involves several techniques and post-processing steps to handle both the transformation and projection of the obtained point cloud, and the elimination of misleading location information. The results reveal that compared with the 2D solutions, the proposed algorithm is very effective and more reliable in silhouette extraction of a street, which is critical in urban transformation and environmental protection.

**Keywords**  Silhouette Extraction, Image Stitching, Street Views, Urban Transformation
Micro-assembly of a Vascular-like Micro-channel with Railed Micro-robot Team-coordinated Manipulation

Huaping Wang, Qing Shi, Tao Yue, Masahiro Nakajima, Masaru Takeuchi, Qiang Huang and Toshio Fukuda

Abstract:
The 3D assembly of cellular structures is important for the fabrication of biological substitutes in tissue engineering. In particular, a micro-channel with a 200 μm diameter is of interest because of its promising ability to construct the vascular network for oxygen and nutrition delivery in thick biological substitutes in the future. In this paper, a novel rail-guided micro-robot- team system is proposed for the micro-assembly of a cellular structure. The cellular two-dimensional (2D) component was fabricated by ultraviolet (UV) illumination of a cross-linkable hydrogel. The modular rail-guided micro-robotic system was set up with multi- micromanipulators as the modules and controlled with hybrid motors to achieve an operation resolution of 30 nm. To realize the bottom-up fabrication of the cellular micro-channel, different micro-assembly strategies with multi-manipulators were developed. The micro-assembly success rate and the efficiency of the different strategies were evaluated based on the assembly of micro-donuts. Through the novel, designed, concentric movement of the multi-manipulators along the rail, arbitrary change of the approaching angle and the coordination posture was achieved to improve the micro-assembly’s flexibility. The operation range for every micromanipulator in different coordinated manipulation modes was analysed to avoid the breakdown of the assembled 3D structure. The image processing for the target location and end-effector identification was conducted to improve assembly efficiency in the micro-robot-team system. Finally, the assembly of the cellular vascular-like micro-channel was achieved with coordinated manipulation in the rail-guided micro-robot-team system.

Keywords 3D Assembly, Multi-micro-robots, Coordinated Manipulation, Vision Processing, Tissue Engineering

A Power-efficient Propulsion Method for Magnetic Microrobots

Gioia Lucarini, Stefano Palagi, Lucia Beccai and Arianna Menciassi

Abstract:
Current magnetic systems for microrobotic navigation consist of assemblies of electromagnets, which allow for the wireless accurate steering and propulsion of sub-millimetric bodies. However, large numbers of windings and/or high currents are needed in order to generate suitable magnetic fields and gradients. This means that magnetic navigation systems are typically cumbersome and require a lot of power, thus limiting their application fields. In this paper, we propose a novel propulsion method that is able to dramatically reduce the power demand of such systems. This propulsion method was conceived for navigation systems that achieve propulsion by pulling microrobots with magnetic gradients. We compare this power-efficient propulsion method with the traditional pulling propulsion, in the case of a microrobot swimming in a micro-structured confined liquid environment. Results show that both methods are equivalent in terms of accuracy and the velocity of the motion of the microrobots, while the new approach requires only one ninth of the power needed to generate the magnetic gradients. Substantial equivalence is demonstrated also in terms of the manoeuvrability of user-controlled microrobots along a complex path.

Keywords Microrobot, Magnetic Navigation, Power-efficient
A Global Obstacle-avoidance Map for Anthropomorphic Arms

Cheng Fang and Xilun Ding

Abstract:
More and more humanoid robots are used in human society, and they face a wide variety of complicated manipulation tasks, which are mainly to be achieved by their anthropomorphic arms. Obstacle avoidance for the anthropomorphic arm must be a fundamental consideration to guarantee the successful implementation of these tasks. Different from traditional methods searching for feasible or optimal collision-free solutions for the anthropomorphic arm, a global obstacle-avoidance map for the whole arm is proposed to indicate the complete set of feasible solutions. In this map, the motion of the arm can be appropriately planned to intuitively control the configuration of the arm in motion. First, the cubic spline function is adopted to interpolate some well-chosen path points to generate a smooth collision-free path for the wrist of the anthropomorphic arm. Second, based on the path function of the wrist, the time and the self-rotation angle of the arm about the "shoulder-wrist" axis are used to parameterize all possible configurations of the arm so that a global two-dimensional map considering the obstacle avoidance can be established. Subsequently, a collision-free self-rotation angle profile of the arm can be well planned. Finally, the joint trajectories of a specific anthropomorphic arm, which correspond to the planned path of the wrist and self-rotation angle profile of the arm, can be solved on the basis of the general kinematic analysis of the anthropomorphic arm and the specific structure. Several simulations are conducted to verify that the proposed collision-free motion planning method for anthropomorphic arms has some advantages and can be regarded as a convenient and intuitive tool to control the configuration of the anthropomorphic arm in motion, without collision with obstacles in its surroundings.

Keywords: Anthropomorphic Arms, Obstacle-avoidance Map, Collision-free Motion Planning

Modelling and Control of the Multi-stage Cable Pulley-driven Flexible-joint Robot

Phongsaeen Pitakwatchara

Abstract:
This work is concerned with the task space impedance control of a robot driven through a multi-stage nonlinear flexible transmission system. Specifically, a two degrees-of-freedom cable pulley-driven flexible-joint robot is considered. Realistic modelling of the system is developed within the bond graph modelling framework. The model captures the nonlinear compliance behaviour of the multi-stage cable pulley transmission system, the spring effect of the augmented counterbalancing mechanism, the major loss throughout the system elements, and the typical inertial dynamics of the robot. Next, a task space impedance controller based on limited information about the angle and the current of the motors is designed. The motor current is used to infer the transmitted torque, by which the motor inertia may be modulated. The motor angle is employed to estimate the stationary distal robot link angle and the robot joint velocity. They are used in the controller to generate the desired damping force and to shape the potential energy of the flexible joint robot system to the desired configuration. Simulation and experimental results of the controlled system signify the competency of the proposed control law.

Keywords: Cable Pulley-driven Robot, Multi-stage Flexible Transmission System, Task Space Impedance Control
zePPeLIN: Distributed Path Planning Using an Overhead Camera Network
Andreagiovanni Reina, Luca Maria Gambardella, Marco Dorigo and Gianni A. Di Caro

Abstract:
We introduce zePPeLIN, a distributed system designed to address the challenges of path planning in large, cluttered, dynamic environments. The objective is to define a sequence of instructions to precisely move a ground object (e.g., a mobile robot) from an initial to a final configuration in an environment. zePPeLIN is based on a set of wirelessly networked overhead cameras. While each camera only covers a limited environment portion, the camera set fully covers the environment through the union of its fields of view. Path planning is performed in a fully distributed and cooperative way, based on potential diffusion over local Voronoi skeletons and local message exchanging. Additionally, the control of the moving object is fully distributed: it receives movement instructions from each camera when it enters that camera’s field of view. The overall task is made particularly challenging by intrinsic errors in the overlap in cameras’ fields of view. We study the performance of the system as a function of these errors, as well as its scalability for the size and density of the camera network. We also propose a few heuristics to improve performance and computational and communication efficiency. The reported results include both extensive simulation experiments and validation using a real camera network planning for a two-robot system.

Keywords  Distributed Path Planning, Cooperative Multi-camera Network, Robot Navigation

On Consensus of Multiple High-order Uncertain Systems Based on Distributed Backstepping Framework
Jie Huang, Chen Chen, Hao Fang, Jie Chen and Lihua Dou

Abstract:
This paper focuses on the consensus problem of multiple high-order systems with uncertainties. Since it is difficult to use matrix theory approaches to design consensus controllers for a class of multiple high-order uncertain nonlinear systems, in this paper a set of consensus control laws are proposed by employing adaptive control theory and a backstepping technique. The distributed virtual control functions of the multi-agent systems are elaborately constructed by only using their local information in the recursive controller design procedure. Furthermore, the asymptotic stability of the overall interconnected system is proved relying on the Lyapunov stability analysis method. Finally, simulations are provided to verify the effectiveness of the control algorithms.

Keywords  Consensus, Backstepping, High-order Nonlinear Systems, Multi-agent, Distributed Control
Rail-guided Multi-robot System for 3D Cellular Hydrogel Assembly with Coordinated Nanomanipulation

Huaping Wang, Qing Shi, Masahiro Nakajima, Masaru Takeuchi, Tao Chen, Pei Di, Qiang Huang and Toshio Fukuda

Abstract:
The 3D assembly of micro-/nano-building blocks with multi-nanomanipulator coordinated manipulation is one of the central elements of nanomanipulation. A novel rail-guided nanomanipulation system was proposed for the assembly of a cellular vascular-like hydrogel microchannel. The system was equipped with three nanomanipulators and was restricted on the rail in order to realize the arbitrary change of the end-effectors during the assembly. It was set up with hybrid motors to achieve both a large operating space and a 30 nm positional resolution. The 2D components such as the assembly units were fabricated through the encapsulation of cells in the hydrogel. The coordinated manipulation strategies among the multi-nanomanipulators were designed with vision feedback and were demonstrated through the bottom-up assembly of the vascular-like microtube. As a result, the multi-layered microchannel was assembled through the cooperation of the nanomanipulation system.

Keywords: 3D Assembly, Multi-robot, Nanomanipulation, Vision Processing, Tissue engineering

A Reconfiguration Control Scheme for a Quadrotor Helicopter via Combined Multiple Models

Fuyang Chen, Qingbo Wu, Gang Tao and Bin Jiang

Abstract:
In this paper, an optimal reconfiguration control scheme is proposed for a quadrotor helicopter with actuator faults via adaptive control and combined multiple models. The combined models set contains several fixed models, an adaptive model and a reinitialized adaptive model. The fixed models and the adaptive model can describe the failure system under different fault conditions. Moreover, the proposed reinitialized adaptive model refers to the closest model of the current system and can improve the speed of convergence effectively. In addition, the reference model is designed in consideration of an optimal control performance index and the principle of the minimum cost to achieve perfect tracking performance. Finally, some simulation results demonstrate the effectiveness of the proposed reconfiguration control scheme for faulty cases.

Keywords: Adaptive Control, Multiple Models, Optimization, Quadrotor Helicopter, Reconfiguration Control
A Project-based Quantification of BIM Benefits

Jian Li, Lei Hou, Xiangyu Wang, Jun Wang, Jun Guo, Shaohua Zhang and Yi Jiao

Abstract:
In the construction industry, research is being carried out to look for feasible methods and technologies to cut down project costs and waste. Building Information Modelling (BIM) is certainly currently a promising technology/method that can achieve this. The output of the construction industry has a considerable scale; however, the concentration of the industry and the level of informatization are still not high. There is still a large gap in terms of productivity between the construction industry and other industries. Due to the lack of first-hand data regarding how much of an effect can be genuinely had by BIM in real cases, it is unrealistic for construction stakeholders to take the risk of widely adopting BIM. This paper focuses on the methodological quantification (through a case study approach) of BIM’s benefits in building construction resource management and real-time costs control, in contrast to traditional non-BIM technologies. Through the use of BIM technology for the dynamic querying and statistical analysis of construction schedules, engineering, resources and costs, the three implementations considered demonstrate how BIM can facilitate the comprehensive grasp of a project’s implementation and progress, identify and solve the contradictions and conflicts between construction resources and costs controls, reduce project over-spends and protect the supply of resources.

Keywords Building Information Modelling, Schedule, Resources, Costs

Benefits of Building Information Modelling in the Project Lifecycle: Construction Projects in Asia

Jian Li, Ying Wang, Xiangyu Wang, Hanbin Luo, Shih-Chung Kang, Jun Wang, Jun Guo and Yi Jiao

Abstract:
Building Information Modelling (BIM) is a process involving the creation and management of objective data with property, unique identity and relationship. In the Architecture, Engineering and Construction (AEC) industry, BIM is adopted a lot in the lifecycle of buildings because of the high integration of information that it enables. Four-dimensional (4D) computer-aided design (CAD) has been adopted for many years to improve the construction planning process. BIM is adopted throughout buildings’ lifecycles, in design, construction and operation. This paper presents five large-scale public and financial projects that adopt BIM in the design, construction and operational phases. Different uses of BIM are compared and contrasted in the context of the separate backgrounds. It is concluded that productivity is improved where BIM is used to enable easy sharing and integration of information and convenient collaboration.

Keywords Building Information Modelling, 4D, Construction, Building Lifecycle
Using BIM to Improve the Design and Construction of Bridge Projects: A Case Study of a Long-span Steel-box Arch Bridge Project

Wenping Liu, Hongling Guo, Heng Li and Yan Li

Abstract:
More and more mega-complex bridge projects are being or will be built worldwide. At the same time, the design and construction of such projects involve more and more challenges, e.g., complex structural designs, complicated construction environments, etc. This research study aims to apply BIM (Building Information Modelling) to bridge projects to improve the efficiency and effectiveness of design and construction. Through the analysis of the characteristics of bridge projects and relevant, associated problems, a BIM-based solution to improving design and construction is developed, including conceptual design optimization, detailed design optimization, the optimization of construction sequences, construction scheduling, construction management, and construction process monitoring. Furthermore, a real-life bridge project is presented to demonstrate the feasibility and validity of the BIM-aided approach to design and construction. It is shown that BIM has the potential to improve the design and construction of bridge projects. It is expected that this research could contribute to the extensive application of BIM in mega-complex bridge projects to aid in design and construction in the future.

Keywords  Bridge projects, Design, Construction, BIM

A Framework for BIM-enabled Life-cycle Information Management of Construction Project

Xun Xu, Ling Ma and Lieyun Ding

Abstract:
BIM has been widely used in project management, but on the whole the applications have been scattered and the BIM models have not been deployed throughout the whole project life-cycle. Each participant builds their own BIM, so there is a major problem in how to integrate these dynamic and fragmented data together. In order to solve this problem, this paper focuses on BIM-based life-cycle information management and builds a framework for BIM-enabled life-cycle information management. To organize the life-cycle information well, the information components and information flow during the project life-cycle are defined. Then, the application of BIM in life-cycle information management is analysed. This framework will provide a unified platform for information management and ensure data integrity.

Keywords  Life-cycle Management, Information Component, Information Flow, BIM Application
BIM-enabled Conceptual Modelling and Representation of Building Circulation

Jin Kook Lee and Mi Jeong Kim

Abstract:
This paper describes how a building information modelling (BIM)-based approach for building circulation enables us to change the process of building design in terms of its computational representation and processes, focusing on the conceptual modelling and representation of circulation within buildings. BIM has been designed for use by several BIM authoring tools, in particular with the widely known interoperable industry foundation classes (IFCs), which follow an object-oriented data modelling methodology. Advances in BIM authoring tools, using space objects and their relations defined in an IFC’s schema, have made it possible to model, visualize and analyse circulation within buildings prior to their construction. Agent-based circulation has long been an interdisciplinary topic of research across several areas, including design computing, computer science, architectural morphology, human behaviour and environmental psychology. Such conventional approaches to building circulation are centred on navigational knowledge about built environments, and represent specific circulation paths and regulations. This paper, however, places emphasis on the use of ‘space objects’ in BIM-enabled design processes rather than on circulation agents, the latter of which are not defined in the IFCs’ schemas. By introducing and reviewing some associated research and projects, this paper also surveys how such a circulation representation is applicable to the analysis of building circulation-related rules.

Keywords  Building Information Modelling (BIM), Industry Foundation Classes (IFCs), Space Object, Building circulation, Conceptual modelling, Circulation, Rules

The Information-related Time Loss on Construction Sites: A Case Study on Two Sites

Sheng Xu and Hanbin Luo

Abstract:
Information management is essential in construction projects. Existing research has identified and discussed problems in communication and information transfer among different stakeholders, such as the loss of information caused by fragmentation and information islands. However, there are few statistics about the direct time waste caused by information loss arising from poor communication and information management. Existing surveys relying on self-reporting questionnaires and interviews often contain various biases. This paper presents a direct observation of two construction sites in China in relation to wasted time and the information flows in these time-wasting events. Analysis of the observation data provides objective and comprehensive statistics on time wasted due to inconsistent information, dislocation and ambiguity. This research also analyses the correlation between participants, information carriers, information loss and the amount of time wasted. Finally, the wasting of time is analysed from the perspective of information flows and problems that cannot be addressed by information technologies are discussed.

Keywords  Information Loss, Information Management, Schedule, Observation, Waste
Application of Cloud Storage on BIM Life-cycle Management
Lieyun Ding and Xun Xu

Abstract:
Because of its high information intensity, strong consistency and convenient visualization features, building information modelling (BIM) has received widespread attention in the fields of construction and project management. However, due to large amounts of information, high integration, the need for resource sharing between various departments, the long time-span of the BIM application, challenges relating to data interoperability, security and cost all slow down the adoption of BIM. This paper constructs a BIM cloud storage concept system using cloud storage, an advanced computer technology, to solve the problem of mass data processing, information security, and cost problems in the existing application of BIM to full life-cycle management. This system takes full advantage of the cloud storage technique. Achievements are reached in four areas of BIM information management, involving security and licensing management, file management, work process management and collaborative management. The system expands the time and space scales, improves the level of participation, and reduces the cost of BIM. The construction of the BIM cloud storage system is one of the most important directions of the development of BIM, which benefits the promotion and further development of BIM to better serve construction and engineering project management.

Keywords  Full Life-cycle BIM, Mass Data Processing, Information Security, Information Collaboration

Virtual Prototyping for Construction Site Co2 Emissions and Hazard Detection
Johnny Kwok Wai Wong, Heng Li, Greg Chan, Haoran Wang, Ting Huang, Eric Luo and Vera Li

Abstract:
The need for an efficient means of managing emissions and identifying potential hazard black spots in construction processes effectively and at the lowest cost possible has been highlighted in the construction sector. This study illustrates an integrated 5D model developed for quantifying carbon emissions and simulating the pattern of emissions of construction processes as a whole using virtual prototyping technologies. The predicted construction emissions data for each activity is generated and plotted to visually demonstrate the emission rates alongside the integrated four-dimensional VP framework of the construction project. The model also consists of a pro-active construction management system (PCMS), which assist the project team to detect sources of danger to on-site workers and provide pro-active warnings to them so as to avoid fatal accidents that are often caused by falling from heights and being struck by moving objects. A Hong Kong high-rise housing development project is used to exhibit the application of the carbon emission visualisation and potential accident detection system. This tool aims to encourage construction industry practitioners to become more environmentally conscious and pro-active in carbon mitigation and safety performance.

Keywords  Carbon, Accident, Safety, Construction Process, Virtual Prototyping
Abstract:
Current building assessment methods limit themselves in their environmental impact by failing to consider the other two aspects of sustainability: the economic and the social. They tend to be complex and costly to run, and therefore are of limited value in comparing design options. This paper proposes and develops a model for the automatic assessment of a building’s sustainability life cycle with the building information modelling (BIM) approach and its enabling technologies. A 6D CAD model is developed which could be used as a design aid instead of as a post-construction evaluation tool. 6D CAD includes 3D design as well as a fourth dimension (schedule), a fifth dimension (cost) and a sixth dimension (sustainability). The model can automatically derive quantities (5D), calculate economic (5D and 6D), environmental and social impacts (6D), and evaluate the sustainability performance of alternative design options. The sustainability assessment covers the life cycle stages of a building, namely material production, construction, operation, maintenance, demolition and disposal.

Keywords  5D CAD, 6D CAD, Sustainability, Life Cycle Assessment, Building, Building Information Modelling

Abstract:
The Building Information Model (BIM) serves as a framework to align all the project-related data, providing interoperability to store and retrieve information interactively. Unfortunately, the construction site itself is excluded from this interaction as the large amount of data requires high data transfer rates and ruggedized hardware. However, advanced wireless communication technologies open radically new avenues to relay large amounts of data automatically and in near real-time. Construction could be a key beneficiary of these advancements. Wireless communication integrated with BIM, GPS and the Internet is able to provide the backbone necessary for creating intelligent systems, supporting the designer in his or her office as well as workers on the work-front. This paper presents a study that documents the development and testing of prototypes designed to facilitate information sharing at the field-level during construction. The main system constitutes an information hub, called the eCKiosk, connecting “senders and receivers” both on-site as well as off-site. The system design is discussed and some of the main modules are demonstrated. Since the electronic Kiosk depends on robust connections to the wireless devices distributed across the site, reliable connectivity is essential. For this reason, the discussion includes a study of the electronic signals behaviour in an ever-changing construction site. Measurements of the signal strengths during excavation and concrete work are presented and compared with theoretical calculations used to predict wave propagation. The results show how present models overestimate signal attenuation patterns on the construction site. This is important for designing a reliable and secure wireless site networks to link BIM to the work-front.

Keywords  BIM, Construction Automation, Field-level, Information Flow, Signal Attenuation
Optimum Tower Crane Selection and Supporting Design Management

Hyo Won Sohn, Won Kee Hong, Donghoon Lee, Chae-Yeon Lim, Xiangyu Wang and Sunkuk Kim

Abstract:
To optimize tower crane selection and supporting design, lifting requirements (as well as stability) should be examined, followed by a review of economic feasibility. However, construction engineers establish plans based on data provided by equipment suppliers since there are no tools with which to thoroughly examine a support design's suitability for various crane types, and such plans lack the necessary supporting data. In such cases it is impossible to optimize a tower crane selection to satisfy lifting requirements in terms of cost, and to perform lateral support and foundation design. Thus, this study is intended to develop an optimum tower crane selection and supporting design management method based on stability. All cases that are capable of generating an optimization of approximately 3,000 ~ 15,000 times are calculated to identify the candidate cranes with minimized cost, which are examined. The optimization method developed in the study is expected to support engineers in determining the optimum lifting equipment management.

Keywords: Tower Crane Management, Support Design, Crane Selection, Optimization, Lifting Plan

Adaptive Multi-sensor Perception for Driving Automation in Outdoor Contexts

Annalisa Milella and Giulio Reina

Abstract:
In this research, adaptive perception for driving automation is discussed so as to enable a vehicle to automatically detect driveable areas and obstacles in the scene. It is especially designed for outdoor contexts where conventional perception systems that rely on a priori knowledge of the terrain’s geometric properties, appearance properties, or both, is prone to fail, due to the variability in the terrain properties and environmental conditions. In contrast, the proposed framework uses a self-learning approach to build a model of the ground class that is continuously adjusted online to reflect the latest ground appearance. The system also features high flexibility, as it can work using a single sensor modality or a multi-sensor combination. In the context of this research, different embodiments have been demonstrated using range data coming from either a radar or a stereo camera, and adopting self-supervised strategies where monocular vision is automatically trained by radar or stereo vision. A comprehensive set of experimental results, obtained with different ground vehicles operating in the field, are presented to validate and assess the performance of the system.

Keywords: Driving Automation, Robotics Vehicles, Adaptive Learning, Multi-sensor Perception
A Cooperative Path Planning Algorithm for a Multiple Mobile Robot System in a Dynamic Environment

Wentao Yu, Jun Peng, Xiaoyong Zhang and Kuo-chi Lin

Abstract:
A practical path planning method for a multiple mobile robot system (MMRS) requires handling both the collision-free constraint and the kinematic constraint of real robots, the latter of which has to date been neglected by most path planning methods. In this paper, we present a practical cooperative path planning algorithm for MMRS in a dynamic environment. First, each robot uses an analytical method to plan an obstacle-avoidance path. Then, a distributed prioritized scheme is introduced to realize cooperative path planning. In the scheme, each robot calculates a priority value according to its situation at each instant in time, which will determine the robot’s priority. Higher-priority robots can ignore lower-priority robots, whereas lower-priority robots should avoid collisions with higher-priority robots. To minimize the path length for MMRS, a least path length constraint is added. The priority value is also calculated by a path cost function that takes the path length into consideration. Unlike other priority methods, the algorithm proposed is not time consuming; therefore, it is suitable for dynamic environments. Simulation results are presented to verify the effectiveness of the proposed algorithm.

Keywords: Analytical Path Planning, Multiple Mobile Robot System, Kinematic Constraints, Distributed Prioritized Scheme

Estimation of Cartesian Space Robot Trajectories Using Unit Quaternion Space

Aleš Ude

Abstract:
The ability to estimate Cartesian space trajectories that include orientation is of great importance for many practical applications. While it is becoming easier to acquire trajectory data by computer vision methods, data measured by general-purpose vision or depth sensors are often rather noisy. Appropriate smoothing methods are thus needed in order to reconstruct smooth Cartesian space trajectories given noisy measurements. In this paper, we propose an optimality criterion for the problem of the smooth estimation of Cartesian space trajectories that include the end-effector orientation. Based on this criterion, we develop an optimization method for trajectory estimation which takes into account the special properties of the orientation space, which we represent by unit quaternions. The efficiency of the developed approach is discussed and experimental results are presented.

Keywords: Unit Quaternions, Nonlinear Optimization, Robot Programming by Demonstration
A Validation Process for Underwater Localization Algorithms
Marc Hildebrandt, Christopher Gaudig, Leif Christensen, Sankaranarayanan Natarajan, Javier Hidalgo Carrio, Patrick Merz Paranhos and Frank Kirchner

Abstract:
This paper describes the validation process of a localization algorithm for underwater vehicles. In order to develop new localization algorithms, it is essential to characterize them with regard to their accuracy, long-term stability and robustness to external sources of noise. This is only possible if a gold-standard reference localization (GSRL) is available against which any new localization algorithm (NLA) can be tested. This process requires a vehicle which carries all the required sensor and processing systems for both the GSRL and the NLA. This paper will show the necessity of such a validation process, briefly sketch the test vehicle and its capabilities, describe the challenges in computing the localizations of both the GSRL and the NLA simultaneously for comparison, and conclude with experimental data of real-world trials.

Keywords: Localization, Under Water, Validation, Comparison, AUV, Navigation, Benchmark

Study of Bipedal Robot Walking Motion in Low Gravity: Investigation and Analysis
Aiman Omer, Kenji Hashimoto, Hun-ok Lim and Atsuo Takanishi

Abstract:
Humanoid robots are expected to play a major role in the future of space and planetary exploration. Humanoid robot features could have many advantages, such as interacting with astronauts and the ability to perform human tasks. However, the challenge of developing such a robot is quite high due to many difficulties. One of the main difficulties is the difference in gravity. Most researchers in the field of bipedal locomotion have not paid much attention to the effect of gravity. Gravity is an important parameter in generating a bipedal locomotion trajectory. This research investigates the effect of gravity on bipedal walking motion. It focuses on low gravity, since most of the known planets and moons have lower gravity than earth. Further study is conducted on a full humanoid robot model walking subject to the moon’s gravity, and an approach for dealing with moon gravity is proposed in this paper.

Keywords: Bipedal Locomotion, Planetary Exploration, Froude Number, Humanoid Robot
An Effective Approach Control Scheme for the Tethered Space Robot System

Zhongjie Meng and Panfeng Huang

Abstract:
The tethered space robot system (TSR), which is composed of a platform, a gripper and a space tether, has great potential in future space missions. Given the relative motion among the platform, tether, gripper and the target, an integrated approach model is derived. Then, a novel coordinated approach control scheme is presented, in which the tether tension, thrusters and the reaction wheel are all utilized. It contains the open-loop trajectory optimization, the feedback trajectory control and attitude control. The numerical simulation results show that the rendezvous between TSR and the target can be realized by the proposed coordinated control scheme, and the propellant consumption is efficiently reduced. Moreover, the control scheme performs well in the presence of the initial state’s perturbations, actuator characteristics and sensor errors.

Keywords  Tethered Space Robot, Approach Control, Dynamic Modelling, Coordinated Control

Bio-inspired Trajectory Generation for UAV Perching Movement Based on Tau Theory

Zhen Zhang, Pu Xie and Ou Ma

Abstract:
This paper offers a bio-inspired trajectory generation method for UAV/MAV perching (i.e., the final approach to, and landing on, a target). The method is based on tau theory, which was established based on the study of the natural motion patterns of animals (including humans) when they approach a fixed or moving object for perching or capturing prey. In our research, tau theory is applied to the trajectory generation problem of an air vehicle for perching on a target object. Three bio-inspired strategies, namely the tau in the action gap strategy, the tau coupling strategy and the intrinsic tau gravity strategy are studied for perching tasks. A key parameter of the method inspired by biological systems is discussed. Two perching scenarios, one from a flight state (with non-zero initial velocity) and one from a hovering state (with zero initial velocity), are studied. Numerical simulations with a rotary vehicle are presented as examples to demonstrate the performance of the proposed approach. The simulation results show that the resulting flight trajectories meet all the desired requirements for the vehicle in perching on an object.

Keywords  Trajectory Generation, Path Planning, Bio-inspired, Perching, Tau Theory
A Cross-domain Survey of Metrics for Modelling and Evaluating Collisions

Jeremy A. Marvel and Roger Bostelman

Abstract:
This paper provides a brief survey of the metrics for measuring probability, degree, and severity of collisions as applied to autonomous and intelligent systems. Though not exhaustive, this survey evaluates the state-of-the-art of collision metrics, and assesses which are likely to aid in the establishment and support of autonomous system collision modelling. The survey includes metrics for 1) robot arms; 2) mobile robot platforms; 3) nonholonomic physical systems such as ground vehicles, aircraft, and naval vessels, and; 4) virtual and mathematical models.

Keywords  Collision Metrics, Collision Modelling, Robot Collisions, Mobile Robot Collisions, Vehicular Collisions

Active Elbow Orthosis

Tomas Ripel, Jiri Krejsa, Jan Hrbacek and Igor Cizmar

Abstract:
This paper presents a novel approach to the design of a motorized rehabilitation device – active elbow orthosis (AEO) – inspired by the principles of robotic exoskeletons. The device is currently designed for the elbow joint, but can be easily modified for other joints as well. AEO determines the motion activity of the patient using a strain gauge and utilizes this measurement to control the actuator that drives the forearm part of the orthosis. Patient activity level is related to a free arm measurement obtained via a calibration procedure prior to the exercise. A high-level control module offers several types of exercises mimicking the physiotherapist. The device was successfully verified by tests on a number of patients, resulting in extended range of elbow-joint motion.

Keywords  Rehabilitation Robotics, Active Orthosis, Upper Limb Rehabilitation
A Novel Quad Harmony Search Algorithm for Grid-based Path Finding

Saso Koceski, Stojanche Panov, Natasa Koceska, Pierluigi Beomonte Zobel and Francesco Durante

Abstract:
A novel approach to the problem of grid-based path finding has been introduced. The method is a block-based search algorithm, founded on the bases of two algorithms, namely the quad-tree algorithm, which offered a great opportunity for decreasing the time needed to compute the solution, and the harmony search (HS) algorithm, a meta-heuristic algorithm used to obtain the optimal solution. This quad HS algorithm uses the quad-tree decomposition of free space in the grid to mark the free areas and treat them as a single node, which greatly improves the execution. The results of the quad HS algorithm have been compared to other meta-heuristic algorithms, i.e., ant colony, genetic algorithm, particle swarm optimization and simulated annealing, and it was proved to obtain the best results in terms of time and giving the optimal path.

Keywords  Heuristic Algorithms, Artificial Intelligence, Computational Intelligence, Optimization, Path Planning

The Concept of Collision-free Motion Planning Using a Dynamic Collision Map

Keum-Bae Cho and Seong-Yun Cho

Abstract:
In this paper, we address a new method for the collision-free motion planning of a mobile robot in dynamic environments. The motion planner is based on the concept of a conventional collision map (CCM), represented on the L(travel length)-T(time) plane. We extend the CCM with dynamic information about obstacles, such as linear acceleration and angular velocity, providing useful information for estimating variation in the collision map. We first analyse the effect of the dynamic motion of an obstacle in the collision region. We then define the measure of collision dispersion (MOCD). The dynamic collision map (DCM) is generated by drawing the MOCD on the CCM. To evaluate a collision-free motion planner using the DCM, we extend the DCM with MOCD, then draw the unreachable region and deadlocked regions. Finally, we construct a collision-free motion planner using the information from the extended DCM.

Keywords  Motion Planner, Collision Avoidance, Collision Map
A Multi-sensory Autonomous Docking Approach for a Self-reconfigurable Robot without Mechanical Guidance

Yanhe Zhu, Hongzhe Jin, Xueyuan Zhang, Jingchun Yin, Pijun Liu and Jie Zhao

Abstract:
The most important feature of a Self-Reconfigurable Robot (SRR) is that it is reconfigurable and self-repairing. At the centre of these capabilities is autonomous docking. One difficulty for docking is the alignment between two robots. Current strategies overcome this by integrating a mechanical guiding device within the connecting mechanism. This increases the robustness of docking but compromises the flexibility of reconfiguration. In this paper, we present a new autonomous docking strategy that can overcome the drawbacks of current approaches. The new strategy uses a novel hook-type connecting mechanism and multi-sensory guidance. The hook-type connecting mechanism is strong and rigid for reliable physical connection between the modules. The multi-sensory docking strategy, which includes visual-sensor-guided rough positioning, Hall-sensor-guided fine positioning, and the locking between moving and target modules, guarantees robust docking without sacrificing reconfigurability. The proposed strategy is verified by docking between a worm-shaped robot and one target module, and docking among three moving robots to form a T-shaped configuration. The experimental results showed that the strategy is very effective.

Keywords  Self-reconfigurable Robot (SRR), Sensory Module, Connecting Mechanism, Autonomous Docking

ROBIL: Robot Path Planning Based on PBIL Algorithm

Bo-Yeong Kang, Miao Xu, Jaesung Lee and Dae-Won Kim

Abstract:
Genetic algorithm (GAs) have attracted considerable interest for their usefulness in solving complex robot path planning problems. Specifically, researchers have combined conventional GAs with problem-specific operators and initialization techniques to find the shortest paths in a variety of robotic environments. Unfortunately, these approaches have exhibited inherently unstable performance, and they have tended to make other aspects of the problem-solving process (e.g., adjusting parameter sensitivities and creating high-quality initial populations) unmanageable. As an alternative to conventional GAs, we propose a new population-based incremental learning (PBIL) algorithm for robot path planning, a probabilistic model of nodes, and an edge bank for generating promising paths. Experimental results demonstrate the computational superiority of the proposed method over conventional GA approaches.

Keywords  Robot Path Planning, Genetic Algorithm, Population-based Incremental Learning
Development of Wireless Endoscope with Symmetrical Motion Characteristics

Jian Guo, Shuxiang Guo, Xiang Wei and Yunliang Wang

Abstract:
In the biomedical field, a wireless microrobot in a pipe which can move smoothly in water or other aqueous mediums has been urgently demanded. In this paper, several methods of designing a novel microrobot with symmetrical motion characteristics have been discussed and a new kind of wireless microrobot has been developed. According to the modelling analysis, we considered two kinds of common cases occurring in vertical motion, which required gravity compensation. Based on two groups of simulations and experiments on forward-backward motion, upward-downward motion and inclined plane motion, the results and dynamic error evaluation indicated that the wireless microrobot with symmetrical structure could realize similar kinematic characteristics in the horizontal motion. The gravity compensation played an important role in the design process, and the performance of the vertical motion had been improved by gravity compensation. With this method, we made the wireless microrobot realize symmetrical motion characteristics, and simplified the control strategies. Finally, a control panel for our system was designed, which could control the current motion states more intuitively and far more easily through the buttons. The developed wireless microrobot would be very useful in the industrial application and microsurgery application.

Keywords: Wireless Endoscope, Gravity Compensation, Symmetrical Motion Characteristics, Medical Application

A Vision-based Approach to Fire Detection

Pedro Gomes, Pedro Santana and José Barata

Abstract:
This paper presents a vision-based method for fire detection from fixed surveillance smart cameras. The method integrates several well-known techniques properly adapted to cope with the challenges related to the actual deployment of the vision system. Concretely, background subtraction is performed with a context-based learning mechanism so as to attain higher accuracy and robustness. The computational cost of a frequency analysis of potential fire regions is reduced by means of focusing its operation with an attentive mechanism. For fast discrimination between fire regions and fire-coloured moving objects, a new colour-based model of fire’s appearance and a new wavelet-based model of fire’s frequency signature are proposed. To reduce the false alarm rate due to the presence of fire-coloured moving objects, the category and behaviour of each moving object is taken into account in the decision-making. To estimate the expected object’s size in the image plane and to generate geo-referenced alarms, the camera-world mapping is approximated with a GPS-based calibration process. Experimental results demonstrate the ability of the proposed method to detect fires with an average success rate of 93.1% at a processing rate of 10 Hz, which is often sufficient for real-life applications.

Keywords: Vision Systems, Fire Detection, Smart Cameras, Computer Vision, Object Detection & Tracking
Towards Mobile Microrobot Swarms for Additive Micromanufacturing

David Cappelleri, Dimitrios Efthymiou, Ashesh Goswami, Nikolaos Vitoroulis and Michael Zavlanos

Abstract:
In this paper, a novel approach to achieving the independent control of multiple magnetic microrobots is presented. The approach utilizes a specialized substrate consisting of a fine grid of planar, MEMS-fabricated micro coils of the same size as the microrobots (≤ 500 μm). The coils can be used to generate real magnetic potentials and, therefore, attractive and repulsive forces in the workspace to control the trajectories of the microrobots. Initial work on modelling the coil and microrobot behavior is reported along with simulation results for navigating one and two microrobots along independent desired trajectories. Qualitative results from a scaled-up printed circuit board version of the specialized substrate operating on permanent magnets are presented and offer proof-of-concept results for the approach. These tests also provide insights for practical implementations of such a system, which are similarly reported. The ultimate goal of this work is to use swarms of independently controlled microrobots in advanced, additive manufacturing applications.

Keywords  Mobile Microrobotics, Multi-robot Control, Additive Manufacturing

Study of a MEMS Vibratory Gyroscope Using Adaptive Iterative Learning Control

Xiaochun Lu and Juntao Fei

Abstract:
This paper proposes a framework, namely adaptive iterative learning control (AILC), which is used in the control of a microelectromechanical system (MEMS) gyroscope, to realize high-precision trajectory tracking control. According to the characteristics of the MEMS gyroscope’s model, the proposed AILC algorithm includes an adaptive law of parametric estimation and an iteration control law, which is updated in the iterative domain without any prior knowledge of MEMS gyroscopes. The convergence of the method is proven by a Lyapunov-like approach, which shows that the designed controller can guarantee the stability of the system and make the output tracking errors to converge completely to zero while the iteration index tends to infinity. By comparing AILC and traditional PD-ILC, the simulation results demonstrate the effectiveness of AILC and its robustness against external random disturbance.

Keywords  MEMS Vibratory Gyroscopes, Adaptive Iterative Learning Control, Trajectory Tracking, Adaptive Control
**ALO4: Angle Localization and Orientation System with Four Receivers**  
*Santiago Elvira, Ángel de Castro and Javier Garrido*

**Abstract:**  
This paper presents a 2D indoor localization and orientation system based on a TDOA (Time Difference of Arrival) technique. It uses an array of receivers (four low-cost ultrasonic resonant devices in a square distribution) to implement low-computational-effort DOA (Direction of Arrival) algorithms, based on assumed plane-wave reception. The system only demands two transmitters at well-known positions on the ceiling of the room for obtaining the node position and orientation when it is deployed on the floor of the room. This system has been tested using a Xilinx Spartan-3A FPGA that implements a 52 MHz MicroBlaze. The experimental results include a total of 1,440 points, obtaining a mean localization error of 5.17 cm and a mean orientation error of 3.34°. For this system, the localization and orientation processes are executed in less than 50 us.

**Keywords**  
TDOA, Location, Orientation, Ultrasonic, DOA

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**Robust and Accurate Multiple-camera Pose Estimation Toward Robotic Applications**  
*Yong Liu, Rong Xiong and Yi Li*

**Abstract:**  
Pose estimation methods in robotics applications frequently suffer from inaccuracy due to a lack of correspondence and real-time constraints, and instability from a wide range of viewpoints, etc. In this paper, we present a novel approach for estimating the poses of all the cameras in a multi-camera system in which each camera is placed rigidly using only a few coplanar points simultaneously. Instead of solving the orientation and translation for the multi-camera system from the overlapping point correspondences among all the cameras directly, we employ homography, which can map image points with 3D coplanar-referenced points. In our method, we first establish the corresponding relations between each camera by their Euclidean geometries and optimize the homographies of the cameras; then, we solve the orientation and translation for the optimal homographies. The results from simulations and real case experiments show that our approach is accurate and robust for implementation in robotics applications. Finally, a practical implementation in a ping-pong robot is described in order to confirm the validity of our approach.

**Keywords**  
Multi-camera System, Pose Estimation, Coplanar Points, Ping-pong Robot
Facial Feature Tracking Using Efficient Particle Filter and Active Appearance Model

Durkhyun Cho, Sanghoon Lee and Il Hong Suh

Abstract:
For natural human-robot interaction, the location and shape of facial features in a real environment must be identified. One robust method to track facial features is by using a particle filter and the active appearance model. However, the processing speed of this method is too slow for utilization in practice. In order to improve the efficiency of the method, we propose two ideas: (1) changing the number of particles situationally, and (2) switching the prediction model depending upon the degree of the importance of each particle using a combination strategy and a clustering strategy. Experimental results show that the proposed method is about four times faster than the conventional method using a particle filter and the active appearance model, without any loss of performance.

Keywords  Facial Feature Tracking, Particle Filter, Active Appearance Model, Robot Vision, Human-robot Interaction

Optimal Trajectory Planning and Coordinated Tracking Control Method of Tethered Space Robot Based on Velocity Impulse

Panfeng Huang, Xiudong Xu and Zhongjie Meng

Abstract:
The tethered space robot (TSR) is a new concept of space robot which consists of a robot platform, space tether and operation robot. This paper presents a multi-objective optimal trajectory planning and a coordinated tracking control scheme for TSR based on velocity impulse in the approaching phase. Both total velocity impulse and flight time are included in this optimization. The non-dominated sorting genetic algorithm is employed to obtain the optimal trajectory Pareto solution using the TSR dynamic model and optimal trajectory planning model. The coordinated tracking control scheme utilizes optimal velocity impulse. Furthermore, the PID controller is designed in order to compensate for the distance measurement errors. The PID control force is optimized and distributed to thrusters and the space tether using a simulated annealing algorithm. The attitude interferential torque of the space tether is compensated using time-delay algorithm through reaction wheels. The simulation results show that the multi-objective optimal trajectory planning method can reveal the relationships among flight time, fuel consumption, planar view angle and velocity impulse number. This method can provide a series of optimal trajectory according to a number of special tasks. The coordinated control scheme can significantly save thruster fuel for tracking the optimal trajectory, restrain the attitude interferential torque produced by space tether and maintain the relative attitude stability of the operation robot.

Keywords  Tethered Space Robot, Velocity Impulse, Optimal Trajectory, Pareto Optimal Solutions, Coordinated Control, Time-delay
Vision-based Detection and Tracking of a Mobile Ground Target Using a Fixed-wing UAV

Xun Wang, Huayong Zhu, Daibing Zhang, Dianle Zhou and Xiangke Wang

Abstract:
This paper presents a framework for tracking a mobile ground target (MGT) using a fixed-wing unmanned aerial vehicle (UAV). Challenges from pure theories to practical applications, including varying illumination, computational limits and a lack of clarity are considered. The procedure consists of four steps, namely: target detection, target localization, states estimation and UAV guidance. Firstly, the MGT in the wild is separated from the background using a Laplacian operator-based method. Next, the MGT is located by performing coordinate transformations with the assumption that the altitude of the ground is invariant and known. Afterwards, a Kalman filter is used to estimate the location and velocity of the MGT. Finally, a modified guidance law is developed to guide the UAV to circle and track the MGT. The performance of our framework is validated by simulations and a number of actual flight tests. The results indicate that the framework is effective and of low computational complexity, and in particular our modified guidance law can reduce the error of the tracking distance by about 75% in specified situations. With the proposed framework, such challenges caused by the actual system can be tackled effectively, and the fixed-wing UAV can track the MGT stably.

Keywords  Fixed-wing UAV, MGT Tracking, Target Detection, Target Localization

Arbitrary Finite-time Tracking Control for Magnetic Levitation Systems

Xuan-Toa Tran and Hee-Jun Kang

Abstract:
In this paper, an arbitrary finite-time tracking control (AFTC) method is developed for magnetic levitation systems with uncertain dynamics and external disturbances. By introducing a novel augmented sliding-mode manifold function, the proposed method can eliminate the singular problem in traditional terminal sliding-mode control, as well as the reaching-phase problem. Moreover, the tracking errors can reach the reference value with faster convergence and better tracking precision in arbitrarily determined finite time. In addition, a fuzzy-arbitrary finite-time tracking control (F-AFTC) scheme that combines a fuzzy technique with AFTC to enhance the robustness and sliding performance is also proposed. A fuzzy logic system is used to replace the discontinuous control term. Thus, the chattering phenomenon is resolved without degrading the tracking performance. The stability of the closed-loop system is guaranteed by the Lyapunov theory. Finally, the effectiveness of the proposed methods is illustrated by simulation and experimental study in a real magnetic levitation system.

Keywords  Finite-time Control, Magnetic Levitation Systems, Sliding-mode Control, Fuzzy Logic System
Convergence of Object Focused Simultaneous Estimation of Optical Flow and State Dynamics

Nicholas Bauer, Pubudu Pathirana, Samitha Ekanayake and Mandyam Srinivasan

Abstract:
The purpose of this study is to prove the convergence of the simultaneous estimation of the optical flow and object state (SEOS) method. The SEOS method utilizes dynamic object parameter information when calculating optical flow in tracking a moving object within a video stream. Optical flow estimation for the SEOS method requires the minimization of an error function containing the object’s physical parameter data. When this function is discretized, the Euler-Lagrange equations form a system of linear equations. The system is arranged such that its property matrix is positive definite symmetric, proving the convergence of the Gauss-Seidel iterative methods. The system of linear equations produced by SEOS can alternatively be resolved by Jacobi iterative schemes. The positive definite symmetric property is not sufficient for Jacobi convergence. The convergence of SEOS for a block diagonal Jacobi is proved by analysing the Euclidean norm of the Jacobi matrix. In this paper, we also investigate the use of SEOS for tracking individual objects within a video sequence. The illustrations provided show the effectiveness of SEOS for localizing objects within a video sequence and generating optical flow results.

Keywords Optical Flow, Simultaneous Estimation, Tracking

Volumetric Next-best-view Planning for 3D Object Reconstruction with Positioning Error

J. Irving Vasquez-Gomez, L. Enrique Sucar, Rafael Murrieta-Cid and Efrain Lopez-Damian

Abstract:
Three-dimensional (3D) object reconstruction is the process of building a 3D model of a real object. This task is performed by taking several scans of an object from different locations (views). Due to the limited field of view of the sensor and the object’s self-occlusions, it is a difficult problem to solve. In addition, sensor positioning by robots is not perfect, making the actual view different from the expected one. We propose a next best view (NBV) algorithm that determines each view to reconstruct an arbitrary object. Furthermore, we propose a method to deal with the uncertainty in sensor positioning. The algorithm fulfills all the constraints of a reconstruction process, such as new information, positioning constraints, sensing constraints and registration constraints. Moreover, it improves the scan’s quality and reduces the navigation distance. The algorithm is based on a search-based paradigm where a set of candidate views is generated and then each candidate view is evaluated to determine which one is the best. To deal with positioning uncertainty, we propose a second stage which re-evaluates the views according to their neighbours, such that the best view is that which is within a region of the good views. The results of simulation and comparisons with previous approaches are presented.

Keywords View Planning, Sensor Planning, Next Best View, Object Reconstruction
Real-time Walking Pattern Generation for a Biped Robot with Hybrid CPG-ZMP Algorithm

Bin He, Zhipeng Wang, Runjie Shen and Sanqing Hu

Abstract:
Biped robots have better mobility than conventional wheeled robots. The bio-inspired method based on a central pattern generator (CPG) can be used to control biped robot walking in a manner like human beings. However, to achieve stable locomotion, it is difficult to modulate the parameters for the neural networks to coordinate every degree of freedom of the walking robot. The zero moment point (ZMP) method is very popular for the stability control of biped robot walking. However, the reference trajectories have low energy efficiency, lack naturalness and need significant offline calculation. This paper presents a new method for biped real-time walking generation using a hybrid CPG-ZMP control algorithm. The method can realize a stable walking pattern by combining the ZMP criterion with rhythmic motion control. The CPG component is designed to generate the desired motion for each robot joint, which is modulated by phase resetting according to foot contact information. By introducing the ZMP location, the activity of the CPG output signal is adjusted to coordinate the limbs' motion and allow the robot to maintain balance during the process of locomotion. The numerical simulation results show that, compared with the CPG method, the new hybrid CPG-ZMP algorithm can enhance the robustness of the CPG parameters and improve the stability of the robot. In addition, the proposed algorithm is more energy efficient than the ZMP method. The results also demonstrate that the control system can generate an adaptive walking pattern through interactions between the robot, the CPG and the environment.

Keywords  Biped Robots, Motion Control, Central Pattern Generator, Zero Moment Point

Multi-agent Orbit Design for Visual Perception Enhancement Purpose

Hamidreza Nourzadeh and John McInroy

Abstract:
This paper develops a robust optimization-based method to design orbits on which the sensory perception of the desired physical quantities are maximized. It also demonstrates how to incorporate various constraints imposed by many spacecraft missions, such as collision avoidance, co-orbital configuration, altitude and frozen orbit constraints along with Sun-synchronous orbit constraints. The paper specifically investigates designing orbits for constrained visual sensor planning applications as its case study. For this purpose, the key elements to form an image in such vision systems are considered and effective factors are taken into account to define a metric for perception quality. The method employs a max-min model to ensure robustness against possible perturbations and model uncertainties. While fulfilling the mission requirements, the algorithm devises orbits on which a higher level collective observation quality for the desired sides of the targets is available. The simulation results confirm the effectiveness of the proposed method for several scenarios involving low and medium Earth orbits as well as a challenging space-based space surveillance program application.

Keywords  Orbit Design, Perception Enhancement, Sensor Network, Multi-agent System
Adaptive Control of Quadruped Locomotion Through Variable Compliance of Revolute Spiral Feet

Alan Mutka, Edin Kočo and Zdenko Kovačić

Abstract:
In this article we present a novel mechanical design of a robot leg that possesses active and variable passive compliance properties. The hip and knee joints provide active compliance, while the variable passive compliance comes from the spiral foot spring, mounted on the ankle joint, which changes its stiffness by rotating and changing contact angle with the ground. The stiffness of the foot for various contact angles was identified experimentally by using the strength tester measurement system. The method for damping coefficient identification, based on the observation of energy losses during the stance phase of leg hopping motion, is described and used to obtain the foot damping model. The adaptation of spiral foot stiffness to varying ground stiffness is achieved by extracting a leg contact time from a feedback signal provided by a flex sensor mounted on the foot. The experiments on a single leg and quadruped platforms have confirmed that the presented spiral foot design provides stiffness adaptability, partial recovery of the energy from the previous hop and restriction of stance contact time, which are all necessary conditions to obtain more efficient quadruped locomotion.

Keywords  Passive Variable Compliance, Quadruped Locomotion, Adaptive Stiffness Control

A Modified Prandtl-Ishlinskii Model for Rate-dependent Hysteresis Nonlinearity Using $m$th-power Velocity Damping Mechanism

Mei-Ju Yang, Chun-Xia Li, Guo-Ying Gu and Li-Min Zhu

Abstract:
Hysteresis of piezoelectric actuators is rate-dependent at high frequencies, but most of the hysteresis models are rate-independent and cannot describe the rate-dependent hysteresis nonlinearity independently. In this paper, a modified Prandtl-Ishlinskii (P-I) model is proposed to characterize the rate-dependent hysteresis of piezoelectric actuators under sinusoidal excitation. This model is formulated by a $m$th-power velocity damping model in conjunction with the rate-independent P-I model. The parameter identification of this model is divided into two steps using different experimental data and algorithms. The particle swarm optimization is introduced first to identify the rate-independent parameters, and the nonlinear least square method is adopted afterwards to identify the rate-dependent parameters which are functions of the excitation frequency. Moreover, the proposed P-I model is developed to describe hysteresis nonlinearity under triangular excitation by introducing weighted functions, i.e., $\lambda$. Finally, the model results attained under the sinusoidal and triangular inputs at different frequencies are compared with the corresponding experimental data. The comparisons demonstrate that the proposed P-I model can well describe hysteresis nonlinearity under sinusoidal excitation up to 1,500 Hz and triangular excitation up to 250 Hz, respectively.

Keywords  Piezoelectric Actuators, Hysteresis Modelling, Rate-dependent, Prandtl-Ishlinskii
Development of a Survivable Cloud Multi-robot Framework for Heterogeneous Environments

Isaac Osunmakinde and Vikash Ramharuk

Abstract:
Cloud robotics is a paradigm that allows for robots to offload computationally intensive and data storage requirements into the cloud by providing a secure and customizable environment. The challenge for cloud robotics is the inherent problem of cloud disconnection. A major assumption made in the development of the current cloud robotics frameworks is that the connection between the cloud and the robot is always available. However, for multi-robots working in heterogeneous environments, the connection between the cloud and the robots cannot always be guaranteed. This work serves to assist with the challenge of disconnection in cloud robotics by proposing a survivable cloud multi-robotics (SCMR) framework for heterogeneous environments. The SCMR framework leverages the combination of a virtual ad hoc network formed by robot-to-robot communication and a physical cloud infrastructure formed by robot-to-cloud communications. The quality of service (QoS) on the SCMR framework was tested and validated by determining the optimal energy utilization and time of response (ToR) on drivability analysis with and without cloud connection. The design trade-off, including the result, is between the computation energy for the robot execution and the offloading energy for the cloud execution.

Keywords Multi-robotics, Cloud, Drivability, Disconnection, R2C, R2R, SRM, Survivability

Adaptive Backstepping Self-balancing Control of a Two-wheel Electric Scooter

Nguyen Ngoc Son and Ho Pham Huy Anh

Abstract:
This paper introduces an adaptive backstepping control law for a two-wheel electric scooter (eScooter) with a nonlinear uncertain model. Adaptive backstepping control is integrated with feedback control that satisfies Lyapunov stability. By using the recursive structure to find the controlled function and estimate uncertain parameters, an adaptive backstepping method allows us to build a feedback control law that efficiently controls a self-balancing controller of the eScooter. Additionally, a controller area network (CAN bus) with high reliability is applied for communicating between the modules of the eScooter. Simulation and experimental results demonstrate the robustness and good performance of the proposed adaptive backstepping control.

Keywords Adaptive Backstepping Control, Embedded System, Kalman Filter, Self-balancing Two-wheel Electric Scooter, CAN bus, Lyapunov Stability
An Adaptive Image-stitching Algorithm for an Underwater Monitoring System

Hengyu Li, Jun Luo, Chaojiong Huang, Yi Yang and Shaorong Xie

Abstract:
Against the narrow range of sonar images for underwater monitoring, an adaptive sonar image-stitching algorithm is proposed in this paper. Compared with conventional sonar image-stitching algorithms, this algorithm can be applied to stitch sonar images with fewer features and better results. This paper first introduces the hardware platform of the underwater monitoring system and a 3D model of the underwater rotational mechanism. Next, related image pre-processing is conducted to improve its accuracy. A SURF algorithm is then applied to extract the speeded-up robust feature (SURF) points. Compared with a threshold, if the number of SURF points is larger, the SURF algorithm is applied to stitch the sonar images or else the phase correlation method is selected to mosaic the sonar images. Finally, a weighted smoothing fusion algorithm based on a maintained boundary is proposed to fuse the sonar images. The algorithm is verified to give good performance in mosaicing sonar images by an experimental study.

Keywords: Underwater Monitoring System, SURF, Phase Correlation Method, Fusion Algorithm

Fast Aerial Video Stitching

Jing Li, Tao Yang, Jingyi Yu, Zhaoyang Lu, Ping Lu, Xia Jia and Wenjie Chen

Abstract:
The highly efficient and robust stitching of aerial video captured by unmanned aerial vehicles (UAVs) is a challenging problem in the field of robot vision. Existing commercial image stitching systems have seen success with offline stitching tasks, but they cannot guarantee high-speed performance when dealing with online aerial video sequences. In this paper, we present a novel system which has an unique ability to stitch high-frame rate aerial video at a speed of 150 frames per second (FPS). In addition, rather than using a high-speed vision platform such as FPGA or CUDA, our system is running on a normal personal computer. To achieve this, after the careful comparison of the existing invariant features, we choose the FAST corner and binary descriptor for efficient feature extraction and representation, and present a spatial and temporal coherent filter to fuse the UAV motion information into the feature matching. The proposed filter can remove the majority of feature correspondence outliers and significantly increase the speed of robust feature matching by up to 20 times. To achieve a balance between robustness and efficiency, a dynamic key frame-based stitching framework is used to reduce the accumulation errors. Extensive experiments on challenging UAV datasets demonstrate that our approach can break through the speed limitation and generate an accurate stitching image for aerial video stitching tasks.

Keywords: Aerial Video Stitching, UAV Video Surveillance, Outlier Removal
Research on one Bio-inspired Jumping Locomotion Robot for Search and Rescue

Dunwen Wei and Wenjie Ge

Abstract:
Jumping locomotion is much more effective than other locomotion means in order to tackle the unstructured and complex environment in research and rescue. Here, a bio-inspired jumping robot with a closed-chain mechanism is proposed to achieve the power amplification during taking-off. Through actuating one variable transmission mechanism to change the transmission ratio, the jumping robot reveals biological characteristics in the phase of posture adjustment when adjusting the height and distance of one jump. The kinematics and dynamics of the simplified jumping mechanism model in one jumping cycle sequence are analysed. A compliant contact model considering nonlinear damping is investigated for jumping performance under different terrain characteristics. The numerical simulation algorithm with regard to solving the dynamical equation is described and simulation results are discussed. Finally, one primary prototype and experiment are described. The experimental results show the distance of jumping in the horizontal direction increases with the increasing gear ratio, while the height of jumping decreases in reverse. The jumping robot can enhance the capability to adapt to unknown cluttered environments, such as those encountered in research and rescue, using this strategy.

Keywords: Robotics, Bio-inspired Robot, Jumping Robot, Hopping Robot, Research and Rescue Robot, Variable Transmission Mechanism, Compliant Contact Model

Accuracy Analysis of a Robot System for Closed Diaphyseal Fracture Reduction

Changsheng Li, Tianmiao Wang, Lei Hu, Lihai Zhang, Hailong Du, Lifeng Wang, Sheng Luan and Peifu Tang

Abstract:
We have developed a robot system for closed diaphyseal fracture reduction. Because accuracy is essential for the treatment effects of the robot system and for the safety of both the patients and surgeons, we analysed accuracy in a systematic way. Both the structure of the robot and the operation procedure are described. Using the transfer model of errors in series and the error differential solving method for parallel mechanisms, an error model was established, and the main influencing factors of errors were considered. The Monte Carlo method was used to perform the simulation based on the error model. Experiments of image registration, of the mechanism and of the whole robot system were tested in different aspects to verify that the results of the simulation are correct. The system accuracy was compared with clinical standards to show that the robot system fulfilled the requirements for closed diaphyseal fracture reduction. The accuracy analysis method also provides an efficient path for other medical robots.

Keywords: Fracture Reduction Robot, Accuracy Analysis, Image Registration, Parallel Mechanism, Error Model
Abstract:
Sensory feedback plays a very significant role in the generation of diverse and stable movements for animals. In this paper, we describe our effort to develop a Central Pattern Generator (CPG)-based sensory feedback control for the creation of multimodal swimming for a multi-articulated robotic fish in the context of neurocomputing. The proposed control strategy is composed of two phases: the upper decision-making and the automatic adjustment. According to the upper control commands and the sensory inputs, different swimming gaits are determined by a finite state machine algorithm. At the same time, the sensory feedback is exploited to shape the CPG coupling forms and control parameters. In the automatic adjustment phase, the CPG model with sensory feedback will adapt the environment autonomously. Simulation and underwater tests are further conducted to verify the presented control scheme. It is found that the CPG-based sensory feedback control method can effectively improve the maneuverability and adaptability of the robotic fish in water.

Keywords: Central Pattern Generator (CPG), Sensory Feedback, Robotic Fish, Neurocomputing, Swimming Control

Towards Automated and Objective Assessment of Fabric Pilling

Abstract:
Pilling is a complex property of textile fabrics, representing, for the final user, a non-desired feature to be controlled and measured by companies working in the textile industry. Traditionally, pilling is assessed by visually comparing fabrics with reference to a set of standard images, thus often resulting in inconsistent quality control. A number of methods using machine vision have been proposed all over the world, with almost all sharing the idea that pilling can be assessed by determining the number of pills or the area occupied by the pills on the fabric surface. In the present work, a different approach is proposed: instead of determining the number of pills, a machine vision-based procedure is devised with the aim of extracting a number of parameters characterizing the fabric. These are then used to train an artificial neural network to automatically grade the fabrics in terms of pilling. Tested against a set of differently pilled fabrics, the method shows its effectiveness.

Keywords: Textile Industry, Pilling, Computational Vision, Neural Networks, Image Processing, Machine Vision System
Biologically-inspired Control Architecture for Musical Performance Robots

Jorge Solis, Kenichiro Ozawa, Maasaki Takeuchi, Takafumi Kusano, Shimpei Ishikawa, Klaus Petersen and Atsuo Takanishi

Abstract:
At Waseda University, since 1990, the authors have been developing anthropomorphic musical performance robots as a means for understanding human control, introducing novel ways of interaction between musical partners and robots, and proposing applications for humanoid robots. In this paper, the design of a biologically-inspired control architecture for both an anthropomorphic flutist robot and a saxophone playing robot are described. As for the flutist robot, the authors have focused on implementing an auditory feedback system to improve the calibration procedure for the robot in order to play all the notes correctly during a performance. In particular, the proposed auditory feedback system is composed of three main modules: an Expressive Music Generator, a Feed Forward Air Pressure Control System and a Pitch Evaluation System. As for the saxophone-playing robot, a pressure-pitch controller (based on the feedback error learning) to improve the sound produced by the robot during a musical performance was proposed and implemented. In both cases studied, a set of experiments are described to verify the improvements achieved while considering biologically-inspired control approaches.

Keywords  Biologically-inspired Robotics, Feedback Error Learning Control, Music

Stiffness Model of a 3-DOF Parallel Manipulator with Two Additional Legs

Guang Yu, Jun Wu and Liping Wang

Abstract:
This paper investigates the stiffness modelling of a 3-DOF parallel manipulator with two additional legs. The stiffness model in six directions of the 3-DOF parallel manipulator with two additional legs is derived by performing condensation of DOFs for the joint connection and treatment of the fixed-end connections. Moreover, this modelling method is used to derive the stiffness model of the manipulator with zero/one additional legs. Two performance indices are given to compare the stiffness of the parallel manipulators with two additional legs with those of the manipulators with zero/one additional legs. The method not only can be used to derive the stiffness model of a redundant parallel manipulator, but also to model the stiffness of non-redundant parallel manipulators.

Keywords  Stiffness, Actuation Redundancy, Parallel Manipulator, Comparison Study
Research on a New Bilateral Self-locking Mechanism for an Inchworm Micro In-pipe Robot with Large Traction
Junhong Yang, Yong Xue, Jiangzhong Shang and Zirong Luo

Abstract:
In this paper, we present an innovative bilaterally-controllable self-locking mechanism that can be applied to the micro in-pipe robot. The background and state of the art of the inchworm micro in-pipe robot is briefly described in the very beginning of the paper, where the main factors that influence the traction ability are also discussed. Afterwards, the micro in-pipe robots’ propulsion principle based on a unidirectional self-locking mechanism is discussed. Then, several kinds of self-locking mechanisms are compared, and a new bilaterally-controllable self-locking mechanism is proposed. By implementing the self-locking mechanism, the robot’s tractive force is no longer restricted by the friction force, and both two-way motion and position locking for the robot can be achieved. Finally, the traction experiment is conducted using a prototype robot with the new bilaterally-controllable self-locking mechanism. Test results show that this new self-locking mechanism can adapt itself to a diameter of Φ17~Φ20 mm and has a blocking force up to 25N, and the maximum tractive force of the in-pipe robot based on such a locking mechanism is 12N under the maximum velocity of 10mm/s.

Keywords  Micro In-Pipe Robot, Traction Ability, Self-Locking Mechanism, Two-Way Motion, Position Locking

Design and Rolling Analysis of a Novel Deformable Mobile Polyhedron Robot
Yaobin Tian, Xiangzhi Wei, Ajay Joneja and Yan-An Yao

Abstract:
In this paper, a new rolling robot is proposed. The mechanism of the robot consists of eight links with three degrees of freedom (DOFs). The shape of each link of the robot is an equilateral triangle. The robot realizes its direction switching function by deforming into different modes of planar parallelogram mechanisms (PPM). In any deterministic mode, the robot can roll on the ground. The motion of the robot is studied based on the kinematic and zero moment point (ZMP) analyses. Though the robot has three DOFs, we show that it can realize flexible mobility via direction switching and rolling functions with two DOFs and one DOF, respectively. A prototype robot was manufactured. A series of simulations and experiments done using this prototype is reported, verifying the feasibility of the design.

Keywords  Rolling Locomotion, Folding Function, Mobile Robot, ZMP Analysis
Predicting the Motion of a Robot Manipulator with Unknown Trajectories Based on an Artificial Neural Network

Sai Hong Tang, Chun Kit Ang, Mohd Khairil Anuar Bin Mohd Ariffin and Syamsiah Binti Mashohor

Abstract:
Mathematically, the motion of a robot manipulator can be computed through the integration of kinematics, dynamics, and trajectories calculations. However, the calculations are complex and only can be applied if the configuration of the robot and the characteristics of the joint trajectories are known. This paper introduces the use of artificial neural networks (ANN) to overcome these shortcomings by solving nonlinear functions and adapting the characteristics of unknown trajectories. A virtual six-degree-of-freedom (DOF) robot manipulator is exploited as an example to show the robustness of the developed ANN topology.

Keywords  Artificial Neural Networks, Robotic Manipulator, Unknown Trajectory

Particle-filter-based Pose Estimation from Controlled Motion with Application to Visual Servoing

Abdul Hafez Abdul Hafez and Enric Cervera

Abstract:
In this paper, we present a Bayesian algorithm based on particle filters to estimate the camera pose for vision-based control. The state model is represented as a relative camera pose between the current and initial camera frames. The particles in the prior motion model are drawn using the velocity control signal collected from the visual controller of the robot. The pose samples are evaluated using an epipolar geometry measurement model and a suitable weight is associated with each sample. The algorithm takes advantage of the a priori knowledge about motion, i.e., the velocity computed by the visual servo control, to estimate the magnitude of the translation in addition to its direction, hence producing a full camera motion estimate. Its application to position-based visual servoing is demonstrated. Experiments are carried out using a real robot setup. The results show the efficiency of the proposed filter over the motion measurements of the robot. In addition, the filter was able to recover the split performed by the robot joints.

Keywords  Visual Servoing, Particle Filter, Pose Estimation, Controlled Motion
A Flying Robot Localization Method Based on Multi-sensor Fusion

Changan Liu, Sheng Zhang, Hua Wu and Ruifang Don

Abstract:
This paper proposes a novel localization method for a power-tower-inspection flying robot based on fusion of vision, IMU and GPS. First, the research background is introduced in relation to a visual localization algorithm derived from 3D-model-based tracking and a coordinate transformation model for related coordinate frames. Then, a multi-sensor fusion-based localization method is presented, in which two collaborative Kalman filters are designed to fuse IMU/GPS and visual information. Finally, experimental results are presented to show the robustness and precision of the proposed method.

Keywords  Flying Robot, Power-tower Inspection, Multi-sensor Fusion-based Localization

On the Numerical Modelling and Error Compensation for General Gough-Stewart Platform

Eusebio Hernandez, Sergio Ivvan Valdez and Eduardo Sanchez

Abstract:
Parallel robots are specially designed to perform high-precision tasks. Nevertheless, manufacturing, assembling and control issues can reduce their capacity to perform adequately. Observing the acquired measurement data with high-precision devices - such as laser-based instruments - it is not surprising that the error data follows patterns or have a structure because, in many cases, the greatest error comes from a mechanical bias introduced by manufacturing issues. Even though we cannot determine with certainty where the error comes from, a pattern in the measured data suggests that it is feasible that it can be modelled and corrected - in a significant proportion - by purely software applications, without the need of disassembling or re-manufacturing any component. This work deals with the problem of finding a mathematical model which adequately fits the error data from the legs of a general Gough-Stewart platform. Hence, we obtain an expression which can be subtracted from the control parameters in order to compensate the inherent mechanical error in the legs. The purpose of this article is two-fold: 1) to present numerical results of the beneficial effects of the error compensation in the legs as well as in the end-effector, and 2) to introduce a numerical methodology to find a model for error compensation and to numerically simulate its effects. Numerical, graphical and statistical evidence of the error improvements, according this methodology, is provided.

Keywords  Parallel Robots, Modelling, Error Simulation, Compensation
Global Finite-time Stabilization for Nonholonomic Mobile Robots Based on Visual Servoing

Hua Chen, Shihong Ding, Xi Chen, Lihua Wang, Changping Zhu and Wen Chen

Abstract:
In this paper, the global finite-time stabilization problem is considered for nonholonomic mobile robots based on visual servoing with uncalibrated visual parameters, control direction and unmatched external disturbances. Firstly, the simple dynamic chained-form systems is obtained by using a state and input transformation of the kinematic robot systems. Secondly, a new discontinuous switching controller is presented in the presence of uncertainties and disturbances, it is rigorously proved that the corresponding closed-loop system can be stabilized to the origin equilibrium point in a finite time. Finally, the simulation results show the effectiveness of the proposed control design approach.

Keywords: Nonholonomic Mobile Robots, Chained-form System, Visual Servoing, Finite-time Stabilization, Switching Control

Recent Advances in the Control of Piezoelectric Actuators

Ziqiang Chi and Qingsong Xu

Abstract:
The micro/nano positioning field has made great progress towards enabling the advance of micro/nano technology. Micro/nano positioning stages actuated by piezoelectric actuators are the key devices in micro/nano manipulation. The control of piezoelectric actuators has emerged as a hot topic in recent years. Piezoelectric materials have inherent hysteresis and creep nonlinearity, which can reduce the accuracy of the manipulation, even causing the instability of the whole system. Remarkable efforts have been made to compensate for the nonlinearity of piezoelectric actuation through the mathematical modelling and control approaches. This paper provides a review of recent advances on the control of piezoelectric actuators. After a brief introduction of basic components of typical piezoelectric micro/nano positioning platforms, the working principle and modelling of piezoelectric actuators are outlined in this paper. This is followed with the major control method and recent progress is presented in detail. Finally, some open issues and future work on the control of piezoelectric actuators are extensively discussed.

Keywords: Piezoelectric Actuator, Micro/Nano Positioning Stage, Hysteresis Nonlinearity, Control Algorithm, Dynamic Modelling
**Emulating Upper Limb Disorder for Therapy Education**

*Noor Ayuni binti Che Zakaria, Takashi Komeda, Cheng Yee Low and Kaoru Inoue*

**Abstract:**

Robotics not only contributes to the invention of rehabilitation devices, it can also enhance the quality of medical education. In recent years, the use of patient simulators and part-task trainers in the medical education field has brought meaningful improvements in the training of medical practitioners. Nevertheless, in the context of therapy training for upper limb disorders, trainee therapists still have to engage directly with the patients to gain experience of the rehabilitation of physical diseases. In this work, a high-fidelity part-task trainer that is able to reproduce the stiffness of spasticity and rigidity symptoms of the upper limb, such as those observed in post-stroke patients and Parkinson's disease patients, has been developed. Based on the evaluation carried out by two experienced therapists, the developed part-task trainer is able to simulate different patient cases and help trainee therapists gain pre-clinical experience in a safe and intuitive learning environment.

**Keywords**  Part-task Trainer, Therapy Education, Upper Limb Disorder, Artificial Human Arm

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**Optimization of PI and Fuzzy-PI Controllers on Simulation Model of Szabad(ka)-II Walking Robot**

*István Kecskés and Péter Odry*

**Abstract:**

The Szabad(ka)-II 18 DOF walking robot and its simulation model is suitable for research into hexapod walking algorithm and motion control. The complete dynamic model has already been built, and is used as a black box for walking optimization in this research. First, optimal straight line walking was chosen as our objective, since the robot mainly moves in this mode. This case can be tested and validated as well on the current version of our robot. An ellipse-based leg trajectory has been generated for this low-cost straight line walking. Currently a simple new Fuzzy-PI controller with three input variables is being constructed and compared with an previously used PI controller. The purpose of defining the rules and its optimization are to obtain a controller that provides walking with higher quality. Both the compared controllers have been optimized together with the parameters of the leg trajectory. The particle swarm optimization (PSO) method was chosen from several methods with our benchmark-based selection research and the help of specific test functions; moreover the previous research (the comparison of genetic algorithm (GA) and PSO) also led to this conclusion.

**Keywords**  Hexapod Robot, Optimization Method Selection, Walking Optimization, PSO, Fuzzy Control
A Dual-Axis Electrostatically Driven MEMS Microgripper

Yukun Jia, Minping Jia and Qingsong Xu

Abstract:
This paper presents the design of a new monolithic two-axis electrostatically actuated MEMS microgripper with integrated capacitive position and force sensors working at the micro-scale level. Each of the two jaws of the microgripper possesses two degrees-of-freedom (DOF) and is capable of positioning in both x- and y-axes. Unlike existing works, where one gripper arm is actuated and other one is sensed, both arms of the proposed microgripper are actuated and sensed independently. A sensing scheme is constructed to provide the position and force signals in the noncontact and contact phases, respectively. By applying a 120V driving voltage, the jaw can provide 70 μm x-axis and 18 μm y-axis displacements with the force of 190 μN. By this design, the real-time position and grasping force information can be obtained in the dual sensing mode. Both analytical calculation and finite-element analysis (FEA) were performed to verify the performance of the proposed design. A scaled-up prototype is designed, fabricated and tested through the experiment to verify the structure design of the microgripper.

Keywords: MEMS, Microgripper, Electrostatic actuator, Capacitive sensor

SMAC — Modular Open Source Architecture for Medical Capsule Robots

Marco Beccani, Ekawahyu Susilo, Christian Di Natali and Pietro Valdastri

Abstract:
The field of Medical Capsule Robots (MCRs) is gaining momentum in the robotics community, with applications spanning from abdominal surgery to gastrointestinal (GI) endoscopy. MCRs are miniature multifunctional devices usually constrained in both size and on-board power supply. The design process for MCRs is time consuming and resource intensive, as it involves the development of custom hardware and software components. In this work, we present the STORM Lab Modular Architecture for Capsules (SMAC), a modular open source architecture for MCRs aiming to provide the MCRs research community with a tool for shortening the design and development time for capsule robots. The SMAC platform consists of both hardware modules and firmware libraries that can be used for developing MCRs. In particular, the SMAC modules are miniature boards of uniform diameter (i.e., 9.8 mm) that are able to fulfill five different functions: signal coordination combined with wireless data transmission, sensing, actuation, powering and vision/illumination. They are small in size, low power, and have reconfigurable software libraries for the Hardware Abstraction Layer (HAL), which has been proven to work reliably for different types of MCRs. A design template for a generic SMAC application implementing a robust communication protocol is presented in this work, together with its finite state machine abstraction, capturing all the architectural components involved. The reliability of the wireless link is assessed for different levels of data transmission power and separation distances. The current consumption for each SMAC module is quantified and the timing of a SMAC radio message transmission is characterized. Finally, the applicability of SMAC in the field of MCRs is discussed by analysing examples from the literature.

Keywords: Medical capsule robots, robotic capsule endoscopy, advanced capsule endoscopy, open source robot design, Minimally Invasive Surgery (MIS), Natural Orifices Transluminal Endoscopic Surgery (NOTES)
Miniature Mobile Bristled In-Pipe Machine

Oskar Ostertag, Eva Ostertagová, Michal Kelemen, Tatiana Kelemenová, Ján Buša and Ivan Virgala

Abstract:
The in-pipe machine locomotes in the pipe on the principle of differential friction between the bristles and the pipe wall during the movement of the bristle forwards and backwards. These bristles are very important construction parts of the in-pipe machine. In order to define the locomotion of movement it is important to know the force situation on the bristles caused by its high deformation in the pipe. The determination of force situation brought us to a non-linear differential equation of the second order and determination of conditions for its solution. By this equation it is possible to describe the outline of large deformations of the construction part and to determine the forces affecting this part.

Keywords  In-Pipe Machine, Bristle, Locomotion, Friction Difference

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Design and Kinematic Analysis of a New End-Effector for a Robotic Needle Insertion-Type Intervention System

Youngjin Moon, Hyuk Jae Choi, Joon Beom Seo and Jaesoon Choi

Abstract:
This paper presents a new end-effector as a key component for a robotic needle insertion-type intervention system and its kinematic analysis. The mechanism is designed as a spherical mechanism with a revolute joint and a curved sliding joint, and its links always move on the surface of a sphere. The remote centre of motion (RCM) of the designed mechanism is placed below the base of the mechanism to avoid contact with the patient’s body, unlike the conventional end-effectors developed for needle insertion. For the proposed mechanism, the forward kinematics are solved in terms of input joint parameters and then the reverse kinematics are solved by using the cross-product relationship between each joint vector and a vector mutually perpendicular to the vectors. The kinematic solutions are confirmed by numerical examples.

Keywords  Needle Insertion Type Intervention, End-effector, Remote center of motion, Medical robot, Spherical mechanism, Kinematics
A Crawler Climbing Robot Integrating Electroadhesion and Electrostatic Actuation

Hongqiang Wang, Akio Yamamoto and Toshiro Higuchi

Abstract:
Previous electroadhesive climbing robots generally employed typical electromagnetic motors, which spoiled some of the advantages of electroadhesion such as it being light, thin and flexible. To improve these, an integration of electrostatic actuation and adhesion was utilized in this work. By using FEM analyses, the present paper analysed the effect of design parameters on adhesive and driving forces respectively, and examined the possible interference between electrostatic actuation and adhesion inside the integration. Then this article discussed the driving force, payload capacity and torque balance of the robot with the integration. Based on these analyses, we designed and fabricated a lightweight (94 g) and low-height (15 mm) prototype with electrode films made by screen printing. Experiments on the prototype demonstrated that it can adhere to a vertical wall stably and move at a maximum speed of 35.3 mm/s.

Keywords Climbing robot, Electroadhesion, Electrostatic actuator

New Structural Design of a Compliant Gripper Based on the Scott-Russell Mechanism

Wenji Ai and Qingsong Xu

Abstract:
This paper presents the structural design and analysis of a novel compliant gripper based on the Scott-Russell (SR) mechanism. The SR mechanism in combination with a parallelogram mechanism enables the achievement of a pure translation of the gripper tips, which is attractive for practical micro-manipulation and microassembly applications. Unlike traditional pure-translation grippers, the reported SR-based gripper exhibits a simple structure as well as compact dimension because the in-plane space is fully used. The kinematics, statics and dynamics models of the gripper mechanism are established, and finite element analysis (FEA) simulations are carried out to verify the structure design. A prototype has been developed for experimental testing. The results not only demonstrate the feasibility of the proposed SR-based gripper design but also reveal a promising performance of the gripper when driven by piezoelectric stack actuators. Moreover, several variations of the gripper structure are presented as well.

Keywords Microgripper, mechanism design, Scott-Russell mechanism, FEA simulation
A Robust and Efficient Algorithm for Tool Recognition and Localization for Space Station Robot

Lingbo Cheng, Zhihong Jiang, Hui Li and Qiang Huang

Abstract:
This paper studies a robust target recognition and localization method for a maintenance robot in a space station, and its main goal is to solve the target affine transformation caused by microgravity and the strong reflection and refraction of sunlight and lamplight in the cabin, as well as the occlusion of other objects. In this method, an Affine Scale Invariant Feature Transform (Affine-SIFT) algorithm is proposed to extract enough local feature points with a fully affine invariant, and the stable matching point is obtained from the above point for target recognition by the selected Random Sample Consensus (RANSAC) algorithm. Then, in order to localize the target, the effective and appropriate 3D grasping scope of the target is defined, and we determine and evaluate the grasping precision with the estimated affine transformation parameters presented in this paper. Finally, the threshold of RANSAC is optimized to enhance the accuracy and efficiency of target recognition and localization, and the scopes of illumination, vision distance and viewpoint angle for robot are evaluated to obtain effective image data by Root-Mean-Square Error (RMSE). An experimental system to simulate the illumination environment in a space station is established. Enough experiments have been carried out, and the experimental results show both the validity of the proposed definition of the grasping scope and the feasibility of the proposed recognition and localization method.

Keywords
Space station, maintenance robot, target recognition and localization, ASIFT & RANSAC, illumination simulation, parameters estimation

A Collision-Free G² Continuous Path-Smoothing Algorithm Using Quadratic Polynomial Interpolation

Seong-Ryong Chang and Uk-Youl Huh

Abstract:
Most path-planning algorithms are used to obtain a collision-free path without considering continuity. On the other hand, a continuous path is needed for stable movement. In this paper, the searched path was converted into a G continuous path using the modified quadratic polynomial and membership function interpolation algorithm. It is simple, unique and provides a good geometric interpretation. In addition, a collision-checking and improvement algorithm is proposed. The collision-checking algorithm can check the collisions of a smoothed path. If collisions are detected, the collision improvement algorithm modifies the collision path to a collision-free path. The collision improvement algorithm uses a geometric method. This method uses the perpendicular line between a collision position and the collision piecewise linear path. The sub-waypoint is added, and the QPMI algorithm is applied again. As a result, the collision-smoothed path is converted into a collision-free smooth path without changing the continuity.

Keywords
Continuous path, Function approximation, Interpolation, Path planning, Path smoothing, Robot motion, Smoothing algorithm, Smooth path, Vehicle navigation