EUROPEAN COMMISSION
Community Research

COGNITIVE SYSTEMS
ROBOTICS
SEVENTH FRAMEWORK PROGRAMME

Large-scale integrating project

Deliverable D7.6
Summary of DEXMART Publications

Project acronym: **DEXMART**

Project full title: **DEXterous and autonomous dual-arm/hand robotic manipulation with sMART sensory-motor skills: A bridge from natural to artificial cognition**

Grant agreement no: **FP7 216239**

Project web site: **www.dexmart.eu**

Due date: 31 January 2012	Submission date: 31 January 2012
Start date of project: 1 February 2008	Duration: 48 months
Lead beneficiary: USAAR	Revision: 3

Nature: R/P/D/O	Dissemination level: PU/PP/RE/CO
R = Report P = Prototype D = Demonstrator O = Other	**PU = Public** PP = Restricted to other programme participants (including the Commission Services) RE = Restricted to a group specified by the consortium (including the Commission Services) CO = Confidential, only for members of the consortium (including the Commission Services)

Short project overview

The DEXMART project is focused on artificial systems reproducing smart sensory-motor human skills, which operate in unstructured real-world environments. The emphasis is on manipulation capabilities achieved by dexterous and autonomous, and also human aware dual-arm/hand robotic systems.

The challenge is to allow a dual-arm robot including two multi-fingered redundant hands to grasp and manipulate the same objects used by human beings. The objects can be of different shape, dimension and weight. The manipulation has to take place in an unsupervised, robust and dependable manner so as to allow the robot to safely cooperate with humans for the execution of given tasks. This goal has always been one of the most critical issues in the design of robotic systems as it has been clear since the early days in robotics.

Successful achievement of this goal requires a significant advancement over the existing robotic manipulation solutions, concerning on one side the development of skills and manipulation procedures at a high cognitive level, the control modalities and, on the other, the mechanical structure, the kinematic configuration, the actuation and sensing system. Within the DEXMART project, research efforts have been devoted to contribute to all these challenging research questions.

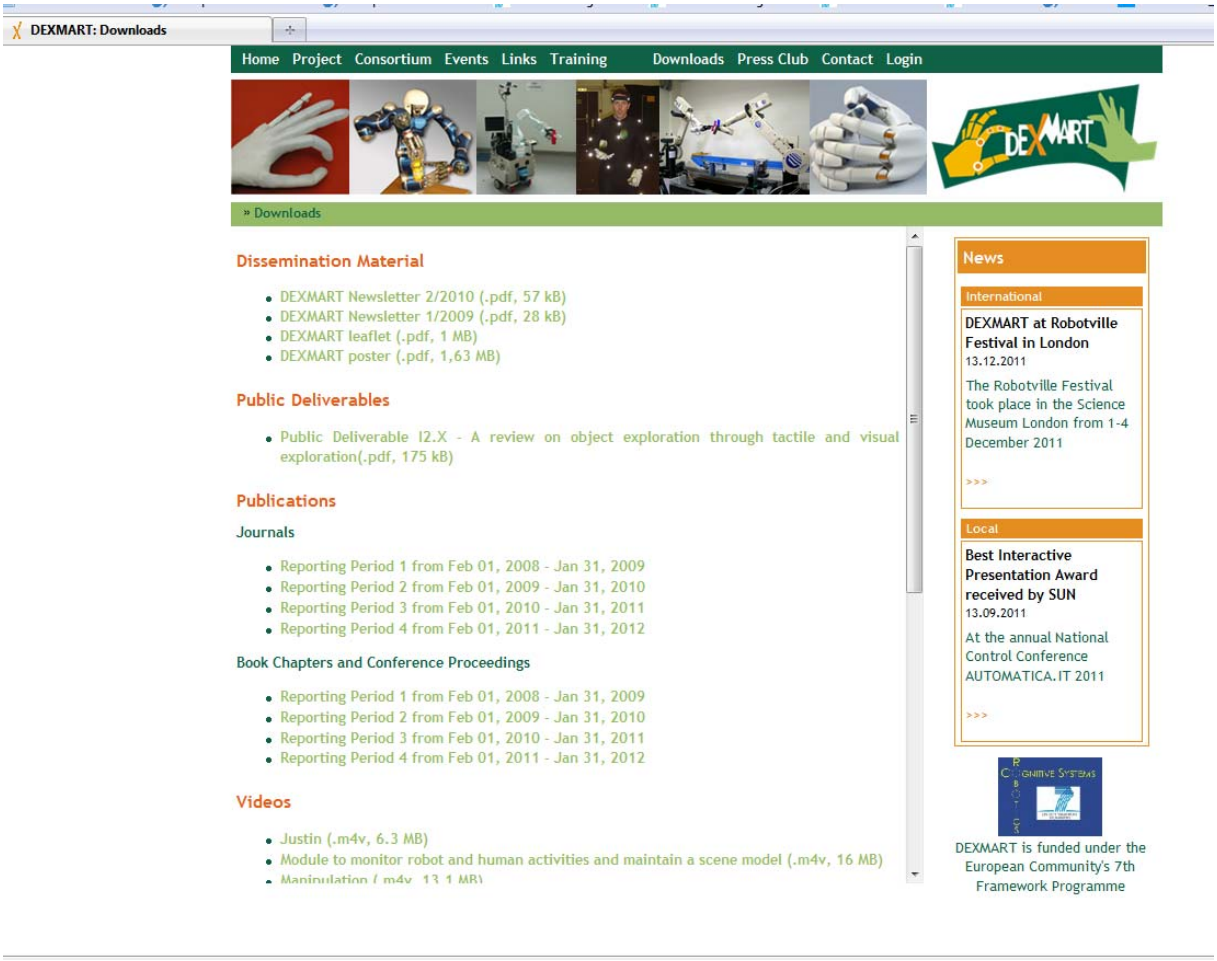
Dual-hand/arm manipulation of objects in an unstructured environment is a complex task which is a compound of different strategies, constraints, goals and actions at the same time. The robotic system has to possess the ability to autonomously decide between different manipulation options. It has to properly and quickly react to unexpected situations and events as well as understand changes in the behaviour of humans cooperating with it. Moreover, in order to act in a changing scenario, the robot should be able to acquire knowledge by learning new action sequences so as to create a consistent and comprehensive manipulation knowledge base through an actual reasoning process.

Cognitive and control aspects of the robotic system have played a key role within the project. On the other hand worldwide trends on manipulation systems, especially for humanoid robots, demand the development of a new technology, possibly bio-mimetic both for advanced actuation and sensing systems. In fact, the artificial hands proposed so far exhibit a wide range of acceptable solutions as far as their functionality is concerned, but most of them are too complex, bulky, expensive or unreliable for practical use outside a research laboratory. To overcome these limitations, the possibility to exploit the high power-to-weight ratio of smart materials and structures has been explored, and research efforts have been devoted to the design of new hand components (finger, thumb, wrist) and sensors that will pave the way for the next generation of dexterous robotic hands.

Scope

The DEXMART consortium produced a very high number of publications during the project's lifetime (1 February 2008 — 31 January 2012).

These DEXMART publications are summarised in the present document. The deliverable has been set up under Work Package 7 — Dissemination, Training and Exploitation. Scientific publications of the DEXMART consortium are submitted, approved by the other beneficiaries and archived in the internal part of the website, which is reserved for publications. Moreover, the publications are listed on the public project website and were regularly updated during project duration:

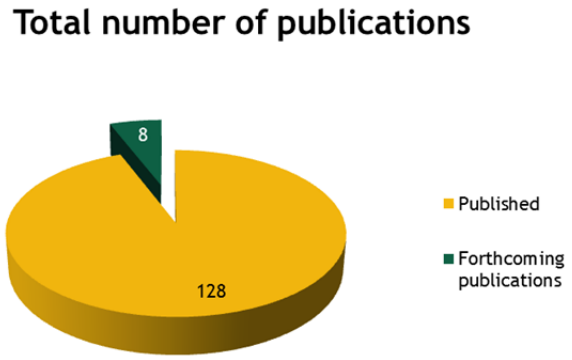


The document is structured as follows:

- A statistical overview
- A synopsis of publications according to research domains

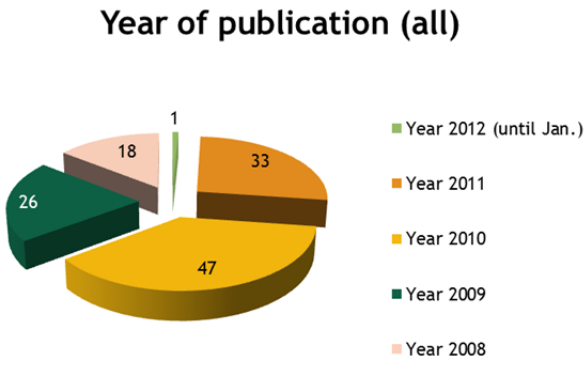
A statistical overview

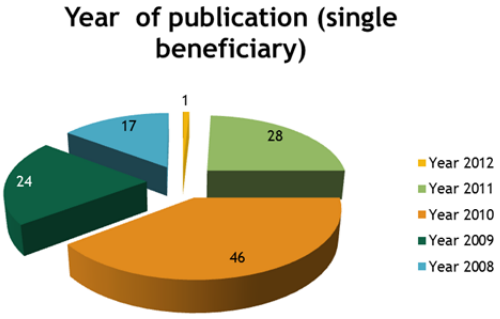
Altogether, 137 scientific publications have been and are being produced within the DEXMART project. Several publications will also appear after the end of the project (see page 136). The total number of publications is reported in the figure below.

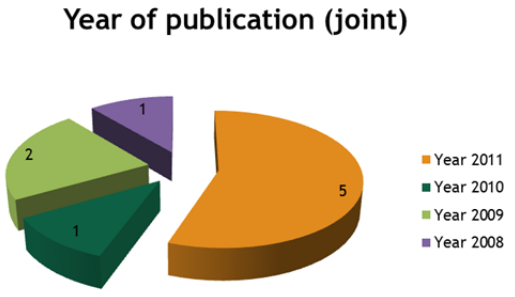


In this diagram, no differentiation is made as to how many beneficiaries have been involved in a joint publication. The relatively large number of publications made by a single beneficiary compared to the number of joint publications has to be seen against the background of the different research domains in the DEXMART project and its inherent structure making joint publications less likely to happen.

The last two years of the project (2010 and 2011) have been the most important ones as far as the number of publications is concerned. The following diagrams do not take into account the forthcoming publications for 2012.



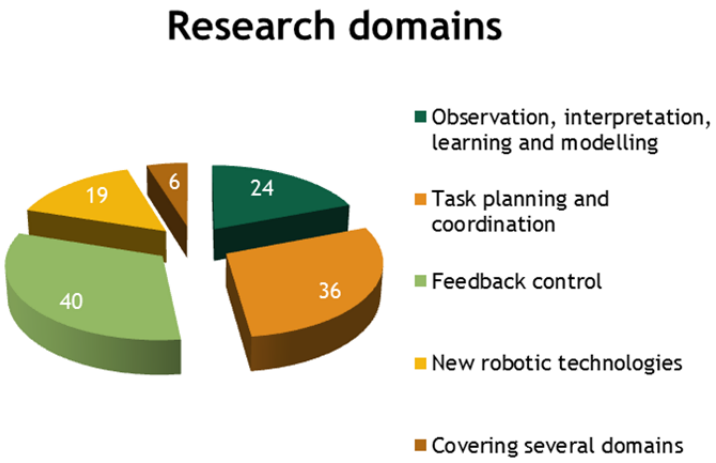




The DEXMART project can be divided into 4 research domains:

- Observation, interpretation, learning and modelling
- Task planning and coordination
- Feedback control
- New robotic technologies

The diagram below shows the number of publications in the single research domains. Several publications cover more than one research domain.



On the following pages you will find a short description of the main results achieved in the four research domains as well as the publications on which these diagrams are based with title, abstract, contact person and authors, the involved institution(s), publication date and reference. Whenever available, a DOI (Digital Object Identifier) is assigned to the publication so that interested people can access a publication fast and easily. Alternatively, the hyperlinks to those publications with direct access for download are given.

Classifying the publications offers the reader the possibility to quickly check on the research domain(s) (s)he is interested in without having to read the complete list of publications. Also, within the single research domains, the publications are listed in inverse chronological order.

A synopsis of publications according to research domains

The DEXMART project is composed of four different scientific research domains, which are listed below along with the main results achieved within each domain.

Observation, interpretation, learning and modelling

- Multi-modal sensor fusion architecture to observe humans performing manipulation activities and learn bimanual manipulation strategies
- Observation of human-robot object exchanges through sensorised object with contact force measurements
- Integration of attentional module into control system for safe and aware human-robot interaction

Task planning and coordination

- Development of new tools to represent objects, obstacles and scene dynamics
- Artificial cognitive system learning probabilistic mission planning models from human demonstrations
- Representation of obstacles using graspability and capability maps for motion planning and robust grasping

Feedback control

- Grasping optimisation algorithm using finger tactile information and contact force measurements for the DEXMART hand
- Computation of three predominant postural synergies of the DEXMART hand for simplifying grasp synthesis and control

New robotic technologies

- Design of novel tactile sensors based on LED-phototransistor couples and deformable elastic layer (Italian and European patents pending)
- Development of novel twisted string actuation concept (German utility patent)
- Version IV of the University of Bologna dexterous anthropomorphic hand (DEXMART hand) with two fully-actuated and sensorised fingers

Title **Using SVD for segmentation and classification of human hand actions**

Abstract An automated strategy for decomposing time series into small, elementary subsequences is proposed. This is accomplished in two steps: first the time series must be decomposed into simpler sub-series (segmentation), next each subseries has to be suitably modeled or uniquely characterized (classification). In this paper, an approximation employing the first right singular vector of the data matrix is considered, and two new criteria for segmenting data are proposed and compared. The effectiveness of the proposed strategy is shown on a time series resulting from sensory data on a data-glove when a human picks a tin can. The strategy proves to be simple and reliable, and can be used as a basic ingredient for real-time detection and interpretation of human gestures.

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Publication date 18 December 2011

Reference 10th IEEE International Conference on Machine Learning and Applications

DOI http://doi.ieeecomputersociety.org/10.1109/ICMLA.2011.155

Title **Improvement of human hand motion observation by exploiting contact force measurements**

Abstract The aim of this paper is to present a novel method to improve the observation of the human hand motion, exploiting the measurements of fingertip contact forces. The core idea of the proposed algorithm is to compare the fingertip contact information, obtained by commercial tactile sensors, with the contact information computed in a virtual environment that reproduces the real environment in which the observation is carried out. In case the estimation of the joint angles and the relative pose between the hand and the object are accurate, the contact information in the virtual and in the real environment is consistent. On the other hand, when the two sources of information are not consistent, a correction of the hand posture is applied. The algorithm has been designed to work on-line. In general, this feature is particularly important for Programming by Demonstration (PbD) applications, since it allows the trainer to actively adapt the demonstration to measurement noise and model errors. The effectiveness of the proposed method has been tested in three different tasks: grasping a cup, unscrewing a bottle, grasping a plate.

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Publication date 26 October 2011

Reference 11th IEEE-RAS International Conference on Humanoid Robots

DOI 10.1109/Humanoids.2011.6100858

Title **Primitive actions extraction for a human hand by using SVD**

Abstract The use of singular values for classification of elementary actions performed by human hands is known in the literature. However, usually only the first singular right-vector is used. This approach is well-suited when a single elementary action is performed, thus it is used for classification, as it reduces a large set of data to a single vector with as many entries as the number of features. However, when considering complex actions, the second singular value may increase its importance with respect to the first one. This suggests a strategy for segmentation of elementary actions based on the analysis of the second-to-first singular value ratio. The idea is first discussed on a simple 2D example and then tested on an experimental set-up employing a data-glove with 18 markers and 5 infra-red cameras, resulting into samples of 54 data (3D-data for each marker). Different manoeuvres are executed, a flow of 600 samples (on the average) is stored and processed, resulting in segmentation of the complete action into a suitable number of elementary actions. What is worth noticing is that the procedure is fully data-driven, no prior human knowledge is required to produce segmentation, classification and motion interpretation. The results of experiments show the effectiveness of the proposed procedure, both in segmenting and in classifying and recognizing complex manoeuvres.

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Publication date 10 October 2011

Reference 9th IEEE International Symposium on Intelligent Systems and Informatics

DOI 10.1109/SISY.2011.6034363

Title	**Distributed generalization of learned planning models in robot Programming by Demonstration**
Abstract	In Programming by Demonstration (PbD), one of the key problems for autonomous learning is to automatically extract the relevant features of a manipulation task, which has a significant impact on the generalization capabilities. In this paper, task features are encoded as constraints of a learned planning model. In order to extract the relevant constraints, the human teacher demonstrates a set of tests, e.g. a scene with different objects, and the robot tries to execute the planning model on each test using constrained motion planning. Based on statistics about which constraints failed during the planning process multiple hypotheses about the correct set of constraints are refined in parallel using an evolutionary algorithm, which has the goal to maximize the number of learned constraints while finding a solution in all tests. The algorithm was tested on 7 experiments and two different robot systems.
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Authors	Rainer Jäkel, Pascal Meißner, Sven R. Schmidt-Rohr, Rüdiger Dillmann
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Publication date	30 September 2011
Reference	2011 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2011.6094717

Title	**Modelling of joint angle limits for ICP-based body tracking**
Abstract	Human Motion Capture (HMC) is an active topic of research with applications in diverse domains. The robotics community is in particular interested in methods which allow the tracking of human movements on autonomous robotic systems with their constrained perception and processing capabilities. One approach for such a tracking is based on the Iterative Closest Points (ICP) algorithm. A specific problem of ICP-based tracking systems is the modelling of constraints and limits to limb movements, which are necessary to make sure that only anatomically possible body configurations are found. In this paper, we will present an approach to model joint limits in a way which allows the direct integration into an ICP-based tracking framework. This way, the compliance of the tracking results with e.g. anatomical limits of human body configurations is intrinsically ensured. The results show that this method provides a fast and robust way to achieve more consistent results.
Contact person	Martin Lösch **e-mail:** loesch@ira.uka.de
Authors	Dirk Mayer, Sven R. Schmidt-Rohr, Rainer Jäkel, Rüdiger Dillmann
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Publication date	22 June 2011
Reference	15th International Conference on Advanced Robotics
DOI	10.1109/ICAR.2011.6088587

Title **From motor to sensory processing in mirror neuron computational modelling**

Abstract Typical patterns of hand-joint covariation arising in the context of grasping actions enable one to provide simplified descriptions of these actions in terms of small sets of hand-joint parameters. The computational model of mirror mechanisms introduced here hypothesizes that mirror neurons are crucially involved in coding and making this simplified motor information available for both action recognition and control processes. In particular, grasping action recognition processes are modeled in terms of a visuo-motor loop enabling one to make iterated use of mirror-coded motor information. In simulation experiments concerning the classification of reach-to-grasp actions, mirror-coded information was found to simplify the processing of visual inputs and to improve action recognition results with respect to recognition procedures that are solely based on visual processing. The visuo-motor loop involved in action recognition is a distinctive feature of this model which is coherent with the direct matching hypothesis. Moreover, the visuo-motor loop sets the model introduced here apart from those computational models that identify mirror neuron activity in action observation with the final outcome of computational processes unidirectionally flowing from sensory (and usually visual) to motor systems.

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Authors Giovanni Tessitore, Roberto Prevete, Ezio Catanzariti, Guglielmo Tamburrini

Involved institution(s) UNINA

Publication date 17 December 2010

Reference Biological Cybernetics

DOI 10.1007/s00422-010-0415-5

Title	**Learning of generalized manipulation strategies in the context of Programming by Demonstration**
Abstract	In Programming by Demonstration, abstract manipulation knowledge has to be learned, that can be used by an autonomous robot system in different environments with arbitrary obstacles. In this work, manipulation strategies are learned by observation of a human teacher and represented as a flexible, constraint-based representation of the search space for motion planning. The learned manipulation strategy contains a large set of automatically generated features, which are generalized using additional demonstrations of the teacher. The generalized manipulation strategy is executed on a real bimanual anthropomorphic robot system in different environments with arbitrary obstacles using constrained motion planning.
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Publication date	6 December 2010
Reference	10th IEEE-RAS International Conference on Humanoid Robots
DOI	10.1109/ICHR.2010.5686305

Title **Designing structured sparse dictionaries for sparse representation modeling**

Abstract Linear approaches to the problem of unsupervised data dimensionality reduction consist in finding a suitable set of factors, which is usually called dictionary, on the basis of which data can be represented as a linear combination of the dictionary elements. In recent years there have been relevant efforts for searching data representation which are based on sparse dictionary elements or a sparse linear combination of the dictionary elements. Here we investigate the possibility to combine the advantages of both sparse dictionary elements and sparse linear combination. Notably, we also impose a structure on the dictionary elements. We compare our algorithm with two other different approaches presented in literature which impose either sparse structured dictionary elements or sparse linear combination. These (preliminary) results suggest that our approach presents some promising advantages, in particular a greater possibility of interpreting the data representation.

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Publication date 30 November 2010

Reference Advances in Intelligent and Soft Computing

DOI 10.1007/978-3-642-20320-6_17

Title	**An action-tuned neural network architecture for hand pose estimation**
Abstract	There is a growing interest in developing computational models of grasping action recognition. This interest is increasingly motivated by a wide range of applications in robotics, neuroscience, HCI, motion capture and other research areas. In many cases, a vision-based approach to grasping action recognition appears to be more promising. For example, in HCI and robotic applications, such an approach often allows for simpler and more natural interaction. However, a vision-based approach to grasping action recognition is a challenging problem due to the large number of hand self-occlusions which make the mapping from hand visual appearance to the hand pose an inverse ill-posed problem. The approach proposed here builds on the work of Santello and co-workers which demonstrate a reduction in hand variability within a given class of grasping actions. The proposed neural network architecture introduces specialized modules for each class of grasping actions and viewpoints, allowing for a more robust hand pose estimation. A quantitative analysis of the proposed architecture obtained by working on a synthetic data set is presented and discussed as a basis for further work.
Contact person	Roberto Prevete **e-mail:** roberto.prevete@unina.it
Authors	Giovanni Tessitore, Francesco Donnarumma, Roberto Prevete
Involved institution(s)	UNINA
Publication date	24 October 2010
Reference	International Conference on Fuzzy Computation and 2nd International Conference on Neural Computation
DOI	10.5220/0003086403580363

Title	**Programming by Demonstration of probabilistic decision making on a multi-model service robot**
Abstract	In this paper we propose a process which is able to generate abstract service robot mission representations, utilized during execution for autonomous, probabilistic decision making, by observing human demonstrations. The observation process is based on the same perceptive components as used by the robot during execution, recording dialog between humans, human motion as well as objects poses. This leads to a natural, practical learning process, avoiding extra demonstration centers or kinesthetic teaching. By generating mission models for probabilistic decision making as Partially observable Markov decision processes, the robot is able to deal with uncertain and dynamic environments, as encountered in real world settings during execution. Service robot missions in a cafeteria setting, including the modalities of mobility, natural human-robot interaction and object grasping, have been learned and executed by this system.
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Authors	Sven R. Schmidt-Rohr, Martin Lösch, Rainer Jäkel, Rüdiger Dillmann
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Publication date	18 October 2010
Reference	2010 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2010.5652268

Title	**A new data glove equipped with joint displacement sensors based on optoelectronic technology**
Abstract	In this paper a novel data glove is described, which allows to estimate the extension-flexion joint angles of the hand, through low-cost optoelectronic angular sensors. The data glove can be used in stand-alone mode when the estimation of a joint angle subset is needed, or within a wider sensor fusion system for tracking all the joint angles and the pose of the hand dorsum in the space, during complex one-hand or bimanual manipulation tasks.
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Authors	Pietro Falco, Salvatore Pirozzi
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Publication date	14 October 2010
Reference	1st International Conference on Applied Bionics and Biomechanics
DOI	-

Title	**A sensor fusion approach to observation of human hand motion**
Abstract	In advanced robotics the adoption of the human observation is getting more and more frequent within the imitation learning and programming by demonstration (PbD) approaches to the robot programming. When the robot is constituted by a robotic arm equipped with an anthropomorphic hand to be used for grasping and manipulation of objects, the observation phase becomes very challenging, and, at the state of the art, no ultimate solution exists. This work proposes a novel approach to the observation of human hand motion during manipulation tasks. The strategy is based on the combined use of an optical motion capture system and a data glove equipped with joint angle sensors. The combination of the two information sources is carried out by resorting to a sensor fusion algorithm based on the Extended Kalman Filter (EKF) suitably modified to tackle the well-known problem of marker occlusions typical of optical motion capture systems. In order to use a sensor fusion approach, a kinematic model of the human hand is required. A key contribution of the paper is a new method to calibrate this model that usefully exploits the recursive nature of open kinematic chains.
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Authors	Ciro Natale, Pietro Falco
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Publication date	14 October 2010
Reference	1st International Conference on Applied Bionics and Biomechanics
DOI	-

Title	**Naturalness criterion for robot hand motion**
Abstract	Generating robot motion that appears humanlike is a longstanding problem in the anthropomorphic robot implementation, and to develop a new approach to robot motion generation, a naturalness measure, which could allow to classify the movement as natural or not, should be useful. This paper presents on the base of statistical and wavelet analysis a criterion to evaluate the naturalness (i.e. human-like appearance) of the motion of robotic hands. A classification analysis will be conducted on the movements captured in a series of grasp of objects with the right hand of many performers. Due to different styles of execution, the captured movements of different performers could constitute a limit for the process of movement classification. To this end, data will be "depersonalized" through a decomposition process based on wavelets in such a way to obtain a separation of the information present in the human motion: low frequencies (physical content), high frequencies (stylistic content). The training phase of the classifier will be initially implemented as an EM (expectation-maximization) optimization of a Gaussian mixture model. The estimation of naturalness score will be represented by the negative-log likelihood of the mixture. The motivation of a learn algorithm model parameters, like EM, is to produce a simple and efficient method of classification starting from a data set of motion characteristics. The performance of the classifier will be evaluated by the ROC curve (Receiver Operating Characteristic), analyzing the probability of obtaining truepositive and false-positive results. The results showing just over 90% confidence level seem to encourage our choice naturalness criterion. A key contribution of the paper is a new method to compute a naturalness score for robot motion. The measure of naturalness will be useful to check if synthetically generated movement can be classified as natural motions.
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Publication date	14 October 2010
Reference	1st International Conference on Applied Bionics and Biomechanics
DOI	-

Title	**A singular values based approach to segmentation and classification of primitive actions for a human hand**
Abstract	The use of singular values for classification of elementary actions performed by human hands is known in the literature. However, only the first singular value is used, and the related first singular right-vector, being the one that conveys most of the information. This approach is well-suited when a single elementary action is performed, thus it is used for classification, as it reduces a large set of data to a single vector with so many entries as the number of sensors. However, when considering general actions, the second singular value may increase with respect to the first one. This suggests a strategy for segmentation of elementary actions based on the analysis of the second-to-first singular value ratio. The idea is first discussed on a musical example and then tested on an experimental set-up employing a glove with 18 markers and 5 infra-red cameras (in order to compensate for possible occlusions), resulting into frames of 54 data (3D-data for each marker). Different manoeuvres are executed, a flow of 600 frames (on the average) is stored and processed, resulting in segmentation of the complete action into a suitable number of elementary actions. What is worth noticing is that the procedure is fully data-driven, no prior human knowledge is required to produce segmentation, classification and motion interpretation. The results of experiments show the effectiveness of the proposed procedure.
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Publication date	14 October 2010
Reference	1st International Conference on Applied Bionics and Biomechanics
DOI	-

RTitle	**Learning flexible, multi-modal human-robot interaction by observing human-human interaction**
Abstract	This paper presents a technique to learn flexible action selection in autonomous, multi-modal human-robot interaction (HRI) from observing multi-modal human-human interaction (HHI). A model is generated using the proposed technique with symbolic states and actions, representing the scope of the observed mission. Variations in human behavior can be learned as stochastic action effects while execution time perception noise is taken into account, using likelihood models. During execution, the model is used for dynamic action selection in HRI situations. The model as well as the evaluation system integrate the interaction elements of spoken dialog, human body configuration and exchanged objects. The technique is evaluated on a multi-modal service robot which is both able to observe the demonstration of two humans as well as execute the generated mission autonomously.
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Publication date	12 September 2010
Reference	19th IEEE International Symposium in Robot and Human Interactive Communication
DOI	10.1109/ROMAN.2010.5598670

Title **Perceiving affordances: A computational investigation of grasping affordances**

Abstract The Grasping Affordance Model (GAM) introduced here provides a computational account of perceptual processes enabling one to identify grasping action possibilities from visual scenes. GAM identifies the core of affordance perception with visuo-motor transformations enabling one to associate features of visually presented objects to a collection of hand grasping configurations. This account is coherent with neuroscientific models of relevant visuo-motor functions and their localization in the monkey brain. GAM differs from other computational models of biological grasping affordances in the way of modeling focus, functional account, and tested abilities. Notably, by learning to associate object features to hand shapes, GAM generalizes its grasp identification abilities to a variety of previously unseen objects. Even though GAM information processing does not involve semantic memory access and full-fledged object recognition, perceptions of (grasping) affordances are mediated there by substantive computational mechanisms which include learning of object parts, selective analysis of visual scenes, and guessing from experience. Keywords: Affordances; Grasping actions; Computational model; Brain; Visuo-motor transformation

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Publication date 4 August 2010

Reference Cognitive Systems Research

DOI 10.1016/j.cogsys.2010.07.005

Title	**Representation and constrained planning of manipulation strategies in the context of Programming by Demonstration**
Abstract	In Programming by Demonstration, a flexible representation of manipulation motions is necessary to learn and generalize from human demonstrations. Calinon et al. employ a subsymbolic representation of trajectories based on a Gaussian Mixture Model to deduce constraints in task and joint space. In this work, a partially symbolic representation of manipulation strategies based on a temporal satisfaction problem with domain constraints is developed. By using a geometric constraint representation, generalization to different robot systems and new environments is achieved. In order to plan learned manipulation strategies the RRT-based algorithm by Stilman et al. for constrained motion planning is extended to consider, that multiple sets of constraints are possible during the extension of the search tree.
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Publication date	3 May 2010
Reference	2010 IEEE International Conference on Robotics and Automation
DOI	10.1109/ROBOT.2010.5509959

Title **Learning of probabilistic grasping strategies using Programming by Demonstration**

Abstract The planning of grasping motions is demanding due to the complexity of modern robot systems. In Programming by Demonstration, the observation of a human teacher allows to draw additional information about grasping strategies. Rosell showed that the motion planning problem can be simplified by globally restricting the set of valid configurations to a learned subspace. In this work, the transformation of a humanoid grasping strategy to an anthropomorphic robot system is described by a probabilistic model, called variation model, in order to account for modeling and transformation errors. The variation model resembles a soft preference for grasping motions similar to the demonstration and therefore induces a non-uniform sampling distribution on the configuration space. The sampling distribution is used in a standard probabilistic motion planner to plan grasping motions efficiently for new objects in new environments.

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Publication date 3 May 2010

Reference 2010 IEEE International Conference on Robotics and Automation

DOI 10.1109/ROBOT.2010.5509958

Title	**How direct is perception of affordances? A computational investigation of grasping affordances**
Abstract	The computational model presented here, Grasping Affordances (GA) model, provides a precise explication of the notion of affordance in the context of grasping actions carried out by monkeys. This explication is consistent with both direct perception theories and neuroscientific models of monkey brains, insofar as the identification of grasping affordances requires, according to this model, neither object recognition processes nor access to semantic memory. Nevertheless, this model posits a cascade of complicated computational pro- cesses, in the way of visuo-motor transformations, which suggest the advisability of qualifying and re-interpreting the claim that (grasping) affordances are directly available to an acting biological system. This re-interpretation undermines the alleged alternative between direct and indirect perception theories, to the extent that substantive visuo-motor transformations have to be posited in order to identify grasping affordances.
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Publication date	24 July 2009
Reference	9th International Conference on Cognitive Modeling
DOI	http://people.na.infn.it/~tamburrini/pub/ICCM09.pdf

Title	**Original approaches to interpretation, learning and modelling, from the observation of human manipulation**
Abstract	The DEXMART project is focused on artificial systems reproducing smart sensory-motor human skills, which operate in unstructured real-world environments. The emphasis is on manipulation capabilities achieved by dexterous and autonomous, and also human aware dual-arm/hand robotic systems. Manipulation cannot be fully planned without human interaction and intervention. Even then, human demonstration, advice and correction are important parts of robot manipulation learning and execution. Research targets methods and mechanisms to observe human manipulations in a way that the observed actions enhance the robots skills (e.g. by new or optimized skills) and tasks (e.g. due to the optimized, context and goal depending combination of skills).
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Publication date	28 June 2009
Reference	Workshop on “Understanding the human hand for advancing robotics manipulation” at Robotics: Science and Systems 2009
DOI	-

Title	**A human body model initialization approach made real-time capable through heuristic constraints**
Abstract	Current research in service robotics is more and more aimed at applications in real home environments. In such context, the ability to track and understand human movements is very important for a robot, for human-robot-interaction as well as other purposes, e.g. proactive behavior, gestures and motions are an important channel of information about the humans intentions. Before actual motion tracking can take place, it is necessary to initialize the tracking system with a hypothesis about the position and pose of the person who shall be tracked. For collaboration with humans in an unknown environment, the system should perform this step automatically. Therefore, we propose an approach to initialize a usable model of a human standing in front of the system by determining the position and height of a human from its silhouette with a cascade of simple metrics, e.g. compactness and position of the neck.
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Publication date	24 June 2009
Reference	14th International Conference on Advanced Robotics
DOI	http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5174716

Title	**Bridging the gap of abstraction for probabilistic decision making on a multi-modal service robot**
Abstract	This paper proposes a decision making and control supervision system for a multi-modal service robot. With partially observable Markov decision processes (POMDPs) utilized for scenario level decision making, the robot is able to deal with uncertainty in both observation and environment dynamics and can balance multiple, conflicting goals. By using a flexible task sequencing system for fine grained robot component coordination, complex sub-activities, beyond the scope of current POMDP solutions, can be performed. The sequencer bridges the gap of abstraction between abstract POMDP models and the physical world concerning actions, and in the other direction multi-modal perception is filtered while preserving measurement uncertainty and model-soundness. A realistic scenario for an autonomous, anthropomorphic service robot, including the modalities of mobility, multi-modal human-robot interaction and object grasping, has been performed robustly by the system for several hours. The proposed filter-POMDP reasoner is compared with classic POMDP as well as MDP decision making and a baseline finite state machine controller on the physical service robot, and the experiments exhibit the characteristics of the different algorithms.
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Publication date	1 September 2008
Reference	2008 Robotics: Science and Systems
DOI	http://www.roboticsproceedings.org/rss04/p14.pdf

Title	**Human and robot behavior modeling for probabilistic cognition of an autonomous service robot**
Abstract	This paper presents an approach to model multi-modal human-robot interaction as partially observable Markov decision processes (POMDPs) for a service robot in realistic settings. Interaction modalities include spoken dialog and non-verbal human activities like gestures and general body postures. By using POMDPs which can model uncertainties in robot perception as well as human behavior, robustness and flexibility concerning autonomous decision making are improved in real world settings. This paper presents strategies to express perception uncertainties, stochastic human behavior and typical mission objectives in explicit POMDP models. Additionally, a system is presented to compile models from more compact representations. Finally, models are actually evaluated on a physical, autonomous service robot, controlled by POMDP decision making and compared to a classical baseline controller in typical domestic missions.
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Publication date	3 August 2008
Reference	17th International Symposium on Robot and Human Interactive Communication
DOI	10.1109/ROMAN.2008.4600738

Title **Making feature selection for human motion recognition more interactive through the use of taxonomies**

Abstract Human activity recognition is an essential ability for service robots and other robotic systems which interact with human beings. To be proactive, the system must be able to evaluate the current state of the user it is dealing with. Also future surveillance systems will benefit from robust activity recognition if real time constraints are met, allowing to automate tasks that have to be fulfilled by humans yet. In this paper, a novel approach for the integration of a feature selection in human motion recognition is proposed. Typically, the features are chosen with respect to the relevance of the features for the classification of the activity which shall be recognized. Our new approach extends this process by involving background knowledge about the features and active user engagement. Using taxonomies built on the complete feature set, users can be provided with an interface to guide and refine the selection process. Thereby, certain problems can be avoided which are common if noisy or small amounts of training data are used to train the system.

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Publication date 3 August 2008

Reference 17th International Symposium on Robot and Human Interactive Communication

DOI 10.1109/ROMAN.2008.4600722

Title **Knowledge representations for planning manipulation tasks**

Abstract In this book, the capability map, a novel general representation of the kinematic capabilities of a robot arm, is introduced. The capability map allows to determine how well regions of the workspace are reachable for the end effector in different orientations. It is a representation that can be machine processed as well as intuitively visualized for the human. The capability map and the derived algorithms are a valuable source of information for high- and low-level planning processes. The versatile applicability of the capability map is shown by examples from several distinct application domains. In human-robot interaction, a bi-manual interface for tele-operation is objectively evaluated. In low-level geometric planning, more human-like motion is planned for a humanoid robot while also reducing the computation time. And in high-level task reasoning, the suitability of a robot for a task is evaluated.

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Expected publication date 28 February 2012

Reference Cognitive Systems Monographs

DOI ISBN 978-3-642-25181-8

Research domain covered Task planning and coordination

Title **Efficient models for grasp planning with a multi-fingered hand**

Abstract This paper presents a simple grasp planning method for a multi-fingered hand. Its purpose is to compute a context-independent and dense set or list of grasps, instead of just a small set of grasps regarded as optimal with respect to a given criterion. By context-independent, we mean that only the robot hand and the object to grasp are considered. The environment and the position of the robot base with respect to the object are considered in a further stage. Such a dense set can be computed offline and then used to let the robot quickly choose a grasp adapted to a specific situation. This can be useful for manipulation planning of pick-and-place tasks. Another application is human-robot interaction when the human and robot have to hand over objects to each other. If human and robot have to work together with a predefined set of objects, grasp lists can be employed to allow a fast interaction. The proposed method uses a dense sampling of the possible hand approaches based on a simple but efficient shape feature. As this leads to many finger inverse kinematics tests, hierarchical data structures are employed to reduce the computation times. The data structures allow a fast determination of the points where the fingers can realize a contact with the object surface. The grasps are ranked according to a grasp quality criterion so that the robot will first parse the list from best to worse quality grasps, until it finds a grasp that is valid for a particular situation.

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Publication date March 2012

Reference Robotics and Autonomous Systems

DOI 10.1016/j.robot.2011.07.019

Title	**A bio-inspired grasp optimization algorithm for an anthropomorphic robotic hand**
Abstract	A fundamental requirement for assistive robots is to guarantee a safe and human-like way to perform their tasks. In particular, the ability to realize smooth movements and obtain a stable grasp is of primary importance. In this perspective, this paper aims at studying human grasping and developing a bio-inspired method for power-grip posture prediction and nger trajectory planning for a robotic hand. The developed method is based on neuroscientific assumptions and experimental evidence coming from the observation of the human behavior during power grip. It is based on the minimization of a suitably defined function to identify the optimal grasp configuration and the choice of a logarithmic spiral trajectory for moving the fingers. The behavior of ten different subjects during the grasping action has been analyzed with the CyberGlove motion capture data glove. A common thumb posture has been observed and has been introduced in the grasping algorithm. The algorithm performance has been tested on an anthropomorphic robotic hand by means of simulation trials. The results demonstrate the effectiveness of the approach and pave the way for the implementation on a real robotic hand.
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Publication date	4 March 2012
Reference	International Journal on Interactive Design and Manufacturing
Research domain covered	Task planning and coordination
DOI	10.1007/s12008-012-0149-9

Title	**Graspability map: A tool for evaluating grasp capabilities**
Abstract	This paper presents the graspability map, a novel approach to represent for a particular object the positions and orientations that a given mechanical hand can adopt to achieve a force closure precision grasp. The algorithm is based on the intersection between the fingertip workspaces and the object, plus the verification of a necessary condition for force closure grasps. The maps are computed offline and can be used for comparing the grasp capabilities of different mechanical hands with respect to some benchmark objects. The maps have also potential applications in online grasp and manipulation planning.
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Publication date	25 September 2011
Reference	2011 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2011.6094957

Title	**Experimental validation of a reach-and grasp optimization algorithm inspired to human arm-hand control**
Abstract	Taking inspiration from neurophysiological studies on synergies in the human grasping action, this paper tries to demonstrate that it is possible to find a general rule for performing a stable, human-like cylindrical grasp with a robotic hand. To this purpose, the theoretical formulation and the experimental validation of a reach-and-grasp algorithm for determining the optimal hand position and the optimal finger configuration for grasping a cylindrical object with known features are presented. The proposed algorithm is based on the minimization of an objective function expressed by the sum of the distances of the hand joints from the object surface. Algorithm effectiveness has preliminarily been tested by means of simulation trials. Experimental trials on a real arm-hand robotic system have then been carried out in order to validate the approach and evaluate algorithm performance
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Reference	33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society
DOI	10.1109/IEMBS.2011.6092010

Title **Generating a symbolic scene description for robot manipulation using physics simulation**

Abstract For complex manipulation with multiple objects a service robot needs information about its environment, especially about the objects in it and how they interact. Numerical representations are hard to be transfered to new execution environments. In order to allow a flexible use, a symbolic representation of a scene to be manipulated is required. In this paper, we propose a symbolic, relational description of the mechanical object interaction in a static scene. It consists of the Supports and Unstableize relation. It is shown how those relations can be generated automatically from a geometric scene model using an open-source physics engine as used in computer games. The generated relations are used in a symbolic planner to decompose a manipulation task into multiple atomic actions. The approach is evaluated in simulated experiments.

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Publication date 4 July 2011

Reference Multibody Dynamics 2011

DOI http://www.fzi.de/downloads/ids/publications/RühlWuXueDillmann.pdf

Title	**Knowledge representations for high-level and low-level planning**
Abstract	Logical planners need to be able to determine the feasibility of action to determine the truth value of the associated labels. To be able to use logical planning to efficiently solve service robotics tasks, knowledge representations like the capability map are needed to reduce the search space dimensionality and provide an intermediate layer between logical planning, geometrical planning and robotics.
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Reference	4th International Workshop on Scheduling and Planning Applications
DOI	http://icaps11.icaps-conference.org/proceedings/spark/zacharias-borst.pdf

Title **Finding enveloping grasps by matching continuous surfaces**

Abstract This paper presents a new method to compute enveloping grasps with a multi-fingered robotic hand. The method is guided by the idea that a good grasp should maximize the contact surface between the held object and the hand's palmar surface. Starting from a given hand pregrasp configuration, the proposed method finds the hand poses that maximize this surface similarity. We use a surface descriptor that is based on a geodesic measure and on a continuous representation of the surfaces, unlike previous shape matching methods that rely on the Euclidean distance and/or discrete representation (e.g. random point set). Using geodesic contours to describe local surfaces enables us to detect details such as a handle or a thin part. Once the surface matching returns a set of hand poses, sorted by similarity, a second step is performed to adjust the hand configuration with the purpose of eliminating penetration of the object. Lastly, the grasp stability is tested in order to definitely validate the candidate grasps.

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Publication date 9 May 2011

Reference 2011 IEEE International Conference on Robotics and Automation

DOI 10.1109/ICRA.2011.5979614

Title	**Making planned paths look more human-like in humanoid robot manipulation planning**
Abstract	It contradicts the human's expectations when humanoid robots move awkwardly during manipulation tasks. The unnatural motion may be caused by awkward start or goal configurations or by probabilistic path planning processes that are often used. This paper shows that the choice of an arm's target configuration strongly effects planning time and how human-like a planned path appears. Human-like goal configurations are found using a criterion from ergonomics research. The knowledge which pose of the Tool Center Point (TCP) can be reached in a natural manner is encapsulated in a restricted reachability map for the robot arm.
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Publication date	9 May 2011
Reference	2011 IEEE International Conference on Robotics and Automation
DOI	10.1109/ICRA.2011.5979553

Title	**Reachable independent contact regions for precision grasps**
Abstract	Independent Contact Regions allow a robust finger placement on the object, despite of potential errors in finger position. They are computed without considering the kinematics of the end-effector, and are usually applied to off-line grasp planners. This paper presents an approach to obtain Reachable Independent Contact Regions by including the hand kinematics in the computational loop. The regions are computed in a short time, which allows real-time applications in virtual grasping. Potential applications of the proposed approach include regrasp planning, and dual-hand manipulation of objects.
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Publication date	9 May 2011
Reference	2011 IEEE International Conference on Robotics and Automation
DOI	10.1109/ICRA.2011.5980341

Title	**Graspability: A description of work surfaces for planning of robot manipulation sequences**
Abstract	For complex manipulation with multiple objects a service robot needs information about the structure of its environment including how and where it can manipulate in it. For this purpose, we introduce the Graspability. It is a measure describing the quality of a pose in Cartesian space for grasping or placing an object. The graspability considers kinematic reachability for a grasping robot and available grasps for the object. It is based on the observation, that in manipulation tasks, objects tend to be located on a planer surface and have to be graspable from that object. Using that observation, we develop a discrete map of the environment which enables the use of the graspability in an autonomous planning system for complex manipulation tasks with multiple objects. Generated plans are evaluated on a real world robot.
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Publication date	9 May 2011
Reference	2011 IEEE International Conference on Robotics and Automation
DOI	10.1109/ICRA.2011.5979779

Title **An autonomous ice-cream serving robot**

Abstract An autonomous ice cream serving robot is presented in this video. The video was filmed during the Automatica 2010 trade fair in Munich. Within four days, approximately 250 scoops of different kinds of ice cream have been served to visitors during the fair. Using the KUKA Light-weighted robotic arms and the DLR/HIT robotic hands, two scientific aspects are shown in this video: stable grasping of fragile objects and manipulation of cream-like mass using a time-of-flight camera. Impedance control is intensively used both by grasping and manipulation. The video shows an autonomous service robot scenario beyond simple fetch-and-carry chores.

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Publication date 9 May 2011

Reference 2011 IEEE International Conference on Robotics and Automation

DOI 10.1109/ICRA.2011.5980335

Title	**Planning human-aware motions using a sampling-based costmap planner**
Abstract	This paper addresses the motion planning problem while considering Human-Robot Interaction (HRI) constraints. The proposed planner generates collision-free paths that are acceptable and legible to the human. The method extends our previous work on human-aware path planning to cluttered environments. A randomized cost-based exploration method provides an initial path that is relevant with respect to HRI and workspace constraints. The quality of the path is further improved with a local path-optimization method. Simulation results on mobile manipulators in the presence of humans demonstrate the overall efficacy of the approach.
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Publication date	9 May 2011
Reference	2011 IEEE International Conference on Robotics and Automation
DOI	10.1109/ICRA.2011.5980048

Title	**Efficient grasp planning with reachability analysis**
Abstract	Grasping can be performed as placing the hand to a grasping pose and finger closing. In this paper, we introduce an efficient algorithm for grasping pose generation. Depend on hand kinematic, boxes of different sizes are sampled. The reachability for grasping is represented by the information, from which pose can the hand grasp the box firmly. These boxes represent the real object, which at run-time will be decomposed into such boxes, so that the grasping poses for the real object can be generated. The concrete grasp at the grasping pose will be further checked, grasping forces will be optimized for stable grasps with high grasp quality and it can be performed to grasp the real object. Real experiments with two different robotic hands show the efficiency and feasibility of our method.
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Publication date	10 November 2010
Reference	Lecture Notes in Artificial Intelligence
DOI	10.1007/978-3-642-16584-9_3

Title	**Workspace comparisons of setup configurations for human-robot interaction**
Abstract	In virtual assembly verification or remote maintenance tasks, bimanual haptic interfaces play a crucial role in successful task completion. This paper proposes a method for objectively comparing how well a haptic interface covers the reachable workspace of human arms. Two system configurations are analyzed for a recently introduced haptic device that is based on two DLR-KUKA light weight robots: the standard configuration, where the device is opposite the human operator, and the ergonomic configuration, where the haptic device is mounted behind the human operator. The human operator directly controls the robotic arms using handles. The analysis is performed using a representation of the robot arm workspace. The merits of restricting the comparisons to the most significant regions of the human workspace are discussed. Using this method, a greater workspace correspondence for the ergonomic configuration was shown.
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Reference	2010 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2010.5649207

Title **Exploiting structure in two-armed manipulation tasks for humanoid robots**

Abstract In autonomous bimanual operation of a robot, parallelized planning and execution of a task is essential. Elements of a task have different functional and spatial relationships. They may depend on each other and have to be executed in a specific order or they may be independent and their order can be determined freely. Consequently, individual actions can be planned and executed in parallel or not. In a proof of concept, this paper shows that the structure of a task and its mapping onto subordinate planners can significantly influence planning speed and task execution. Independent tasks are planned using two parallel path planners. Dependent tasks are planned using one path planner for both arms. Using a simple, yet expandable experimentation scenario, the resulting recommendations for parameterizing path planners are verified on a humanoid robot. For execution on the real robot a violation of the rigid body model used in path planners had to be addressed.

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Publication date 18 October 2010

Reference 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems

DOI 10.1109/IROS.2010.5651121

Title	**Planning pick-and-place tasks with two-handed regrasping**
Abstract	This paper proposes a planning framework to deal with the problem of computing the motion of a robot with dual arm/hand, during an object pick-and-place task. We consider the situation where the start and goal configurations of the object constrain the robot to grasp the object with one hand, to give it to the other hand, before placing it in its final configuration. To realize such a task, the proposed framework treats the grasp computation, for one or two multi-fingered hands, of an arbitrarily-shaped object, the exchange configuration and finally the motion of the robot arms and body. In order to improve the planner performance, a context- independent grasp list is computed offline for each hand and for the given object as well as computed offline roadmap that will be adapted according to the environment composition. Simulation results show the planner performance on a complex scenario.
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Reference	2010 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2010.5649021

Title **An approach for optimal grasp determination and finger trajectory planning of a robotic hand by imitating human behavior**

Abstract Biologically inspired robotic systems are becoming increasingly popular. Especially in the field of medical robotics, building robotic devices inspired by human behavior allows sometimes overcoming human capabilities. This is the case of augmented reality applications in surgery or of repeatability improvement in rehabilitation. However, there are still a lot of human capabilities that are very hard to reproduce with a robotic device. Grasping is one of the human skills that robotic researchers mostly attempt at imitating. In assistive robotics, as well as in the field of hand prostheses, the ability of performing smooth movements and obtaining a stable grasp is essential. In this paper, a bio-inspired approach for power-grip posture prediction and finger trajectory planning of a robotic hand is proposed. On the basis of human behavior, the implemented method implies a logarithmic spiral trajectory and the minimization of an appropriate objective function. The method has been tested by means of simulation trials on a robotic hand.

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Publication date 14 October 2010

Reference 1st International Conference on Applied Bionics and Biomechanics

DOI -

Title	**Towards automatic manipulation action planning for service robots**
Abstract	A service robot should be able to automatically plan manipulation actions to help people in domestic environments. Following the classic sense-plan-act cycle, in this paper we present a planning system based on a symbolic planner, which can plan feasible manipulation actions and execute it on a service robot. The approach consists of five steps. Scene Mapping formulates object relations from the current scene for the symbolic planner. Discretization generates discretized symbols for Planning. The planned manipulation actions are checked by Verification, so that it is guaranteed that they can be performed by the robot during Execution. Experiments of planned pick-and-place and pour-in tasks on real robot show the feasibility of our method.
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Publication date	21 September 2010
Reference	Lecture Notes in Artificial Intelligence
DOI	10.1007/978-3-642-16111-7

Title	**Reactive grasping for human-robot interaction**
Abstract	This paper presents solutions to some of the problems related to the realization of a robotic system that is able to interactively grasp an object given by a human. By interactively, we mean that the robot should be able to adapt both the target grasp and the approach movement of its arm. If the human decides to change the way he/she presents the object, the robot should possibly choose a grasp different from the one that was previously selected and use a different motion to reach the object. Such reactive capacities could be of great interest in the field of assistive robotics and, more generally, human-robot interaction. The paper focused on some points: Grasp planning to re- actively select how to grasp the object from the human hand, trajectory planning to compute a comfortable approach motion and interpretation of the interaction forces during the object exchange. For the latter point, a smart device was specially conceived and realized to measure the interaction forces. Some preliminary results are presented as well as the future developments we plan.
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Publication date	27 June 2010
Reference	Workshop “Representations for object grasping and manipulation in single and dual arm tasks” at Robotics: Science and Systems 2010
DOI	http://homepages.laas.fr/jmainpri/Papers/rssws2010.pdf

Title	**Performances of the central-axis approach in grasp analysis**
Abstract	In this paper, we consider a 3D grasping problem. In previous work, we have presented the central-axis approach and proven its capability to analyse multifingered grasps. In the present paper, we extend our study by developing and analysing modified force-closure algorithms, and giving rigorous theoretical demonstrations. Through numerical simulations, we show that the proposed approach is computationally efficient when comparing with the classical qualitative ray-shooting algorithm. The proposed quantitative force-closure test offers a better quality measure without computing the six-dimensional convex hull of the primitive contact wrenches, which reduce efficiently the computational cost. Several simulation examples showing the efficiency of the proposed approach are included in the paper.
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Publication date	3 May 2010
Reference	2010 IEEE International Conference on Robotics and Automation
DOI	10.1109/ROBOT.2010.5509665

Title	**Synthesizing robot motions adapted to human presence**
Abstract	With the robotics hardware becoming more and more safe and compliant, the robots are not far from entering our homes. Yet in order to obtain a safe, comfortable and socially acceptable interaction, the presence of the human needs to be considered in all stages of robot design. In this paper we present a complete motion synthesis framework from planning to execution that is especially designed for a robot that interacts with humans. This framework, composed of Persperctive Placement, Human Aware Manipulation Planner and Soft Motion Trajectory Planner, generates natural robot motions by taking into account human's safety; his vision field and his perspective; his kinematics and his posture along with the task's constraints. Finally the whole system is integrated and illustrated in a mobile manipulator robot.
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Publication date	1 April 2010
Reference	International Journal of Social Robotics
DOI	10.1007/s12369-010-0059-6

Title	**Stochastic optimization-based approach for multifingered grasps synthesis**
Abstract	In this paper, we propose an approach for computing suboptimal grasps of polyhedral objects. Assuming n hard-finger contact with Coulomb friction model and based on central axes of the grasp wrench, we develop a new necessary and sufficient condition for n-finger grasps to achieve force-closure property. Accordingly, we reformulate the proposed force-closure test as a new linear programming problem, which we solve using an interior point method. Furthermore, we present an approach for finding appropriate stable grasps for a robotic hand on arbitrary objects. We use the simulated annealing technique for synthesizing suboptimal grasps of 3D objects. Through numerical simulations on arbitrary shaped objects, we show that the proposed approach is able to compute good grasps for multifingered hands within a reasonable computational time.
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Publication date	18 January 2010
Reference	Robotica
DOI	10.1017/S0263574709990889

Title **Integration of a loop based and an event based framework for control of a bimanual dextrous service robot**

Abstract Different components are needed to control a service robot, which helps people in the household environment to do daily tasks. Controllers in closed loop are needed to control the actuators and sensors to provide actions. A sequencer schedules and coordinates these actions to finish a given task. And an AI planner is also needed to generate the sequence of the actions. Followed this well-known three-layer architecture, we have developed a robotic framework for service robots. The controller is implemented in the \mca (Modular Control Architecture), developed by our institute. A component-based interface converts the events like start or finished signals to an event-based system, where the tasks are decomposed and organized in a task-tree. This task-tree can be automatically generated by an AI planner or learned from human demonstrations. We have evaluated the introduced control framework on a service robot with two arms and two hands. Experimental results show that our system is modular, flexible and fulfills the requirements for robotic control software development.

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Publication date 19 December 2009

Reference 2009 IEEE International Conference on Robotics and Biomimetics

DOI 10.1109/ROBIO.2009.5420642

Title	**Using a model of the reachable workspace to position mobile manipulators for 3-d trajectories**
Abstract	Humanoid robots are envisioned in general household tasks. To be able to fulfill a given task the robot needs to be equipped with knowledge concerning the manipulation and interaction in the environment and with knowledge about its own capabilities. When performing actions, e.g. opening doors or imitating human reach to grasp movements special 3-d trajectories are followed with the robot's end-effector. These trajectories cannot be executed in every part of the robot's arm workspace. Therefore a task planner has to determine if and how additional degrees of freedom such as the robot's upper body or the robot's base can be moved in order to execute the task-specific trajectory. An approach is presented that computes placements for a mobile manipulator online given a task-related 3-d trajectory. A discrete representation of the robot arm's reachable workspace is used. Task-specific trajectories are interpreted as patterns and searched in the reachability model using multi-dimensional correlation. The relevance of the presented approach is demonstrated in simulated positioning tasks.
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Publication date	7 December 2009
Reference	9th IEEE-RAS International Conference on Humanoid Robots
DOI	10.1109/ICHR.2009.5379601

Title **Combining analysis, imitation, and experience-based learning to acquire a concept of reachability in robot mobile manipulation**

Abstract Analytic modeling, imitation, and experience-based learning are three approaches that enable robots to acquire models of their morphology and skills. In this paper, we combine these three approaches to efficiently gather training data to learn a model of reachability for a typical mobile manipulation task: approaching a work-surface in order to grasp an object. The core of the approach is experience-based learning. For more effective exploration, we use capability maps as analytic models of the robot's dexterity to constrain the area in which the robot gathers training data. Furthermore, we acquire a human model of reachability from human motion data and use it to bias exploration. The acquired training data is used to learn Action-Related Places. In an empirical evaluation we demonstrate that combining the three approaches enables the robot to acquire accurate models with far less data than with our previous exploration strategy.

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Publication date 7 December 2009

Reference 9th IEEE-RAS International Conference on Humanoid Robots

DOI 10.1109/ICHR.2009.5379584

Title	**An efficient grasp planning system using impulse-based dynamic simulation**
Abstract	Grasping and manipulation are the most important functions for service robots. To grasp an object with a robotic hand, the finger joint positions and the relative pose between hand and the object need to be considered. This high dimensional space is explored efficiently using an impulse-based dynamic simulation in this paper. The graspable region of the robotic hand is analyzed. The sampled Cartesian poses build a trajectory in this graspable region, along which the object moves in the impulse-based dynamic simulation by applying impulses onto it. During the whole simulation process, the fingers try to close to grasp the object. If at least three contact points are found between the hand and the object, the grasp quality is evaluated. Stable grasps are saved into a grasp database, which can be accessed during the real execution to grasp the object with the real robotic hand. We have tested the simulation process with different objects,
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Publication date	26 June 2009
Reference	Multibody Dynamics 2009
DOI	-

Title	**An automatic grasp planning system for service robots**
Abstract	Service robots need many different information about the objects, they want to grasp and manipulate. Besides the physical information such as geometry and weight, semantic information about the objects is also needed. To model both of these types of information, we have constructed a multimodal object modeling center. It enables the modeling of physical properties of the object, such as the textures and the 3D geometry, with a digitizer and a pair of movable stereo cameras. Other properties of the objects relevant for grasping can also be automatically computed. Furthermore, a human teacher can communicate with the system through multimodal techniques to introduce the semantic information relevant grasping to the system. We have implemented a grasp planning system based on the grasp simulator "GraspIt!" to plan high quality grasps. The semantic information is represented as shape primitives, which are treated by the grasp planning as obstacles or must-touch regions of the object to influence the resulting grasps. The modeled physical, semantic and automatically computed information, together with the computed grasps are saved in a database, which provides the service robot the needed knowledge to grasp and manipulate various household objects.
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Publication date	22 June 2009
Reference	14th International Conference on Advanced Robotics
DOI	http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5174759

Title	**Online generation of reachable grasps for dexterous manipulation using a representation of the reachable workspace**
Abstract	In service robotic tasks, the ability to grasp and handle objects is mandatory. Short response times w.r.t to execution of commanded tasks are necessary. Planning in general and grasp planning in particular should happen online. We extend the online grasp planner by Borst et al. to generate reachable grasps while preserving the integrity and modularity of the grasp planner. To achieve this representation of the reachable space of a robot arm is used to determine a grasp's reachability. Furthermore we show the influence of obstacles on the reachability throughout the workspace. A method to include obstacles into the representation of reachability is sketched. The resulting representation is used by the grasp planner. The performance of the algorithms is evaluated by measuring their computation times. Even in the worst case our grasp planner outperforms comparable state of the art approaches.
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Reference	14th International Conference on Advanced Robotics
DOI	http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5174694

Title	**Object-specific grasp maps for use in planning manipulation actions**
Abstract	Humans use learned knowledge to solve reaching tasks and to manipulate objects and tools. We believe that representations of manipulation characteristics of an object and of the reaching capabilities of a robotic arm can speed up low-level planners, like grasp planners. They also enable sophisticated scene analysis and reasoning for high-level planners, like task planners. We present object-specific grasp maps to encapsulate objects manipulation characteristics. A grasp planner is shown to use the grasps maps and a representation of the reachable workspace. The exploitation of the provided knowledge focuses the planning on regions of the object that are promising to yield high quality grasps. Speed ups of factor 2-12 are reported.
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Publication date	9 June 2009
Reference	Advances in Robotic Research: Theory, Implementation, Application
DOI	10.1007/978-3-642-01213-6_19

Title	**Efficient grasp planning using continuous collision detection**
Abstract	Grasp planning for multifingered robotic hand is still time consuming. The crucial part is to find the contact points with collision detection techniques to evaluate the grasp quality and to guarantee that the hand does not collide with other objects. Our methods to accelerate the collision detection for grasp planning are presented in this paper. Grasping is performed in two steps: hand moving and finger closing. Finger links are a-priori known for both steps. We use precomputed bounding boxes to bind the extent of the finger links' motion to cull the objects that are far from robotic hand. A state-of-the-art continuous collision detection with conservative advancement is integrated to detect collisions between moving robotic hand and objects. For pick-and-place operation the environments by grasping and by placing are merged to one environment for grasp planning to find collision-free grasps for both pick and place. Ray intersections are further used to find out hidden grasping directions. We have tested our approach with three experiments: grasping a standalone object with one hand, two hands and grasping in complex environment. Results with four-fingered SAHands in simulation show the efficiency of the introduced methods.
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Publication date	12 May 2009
Reference	2009 IEEE International Conference on Mechatronics and Automation
DOI	10.1109/ICMA.2009.5244922

Title	**Integration of a loop based and an event based framework for control**
Abstract	Different components are needed to control a service robot, which helps people in the household environment to do daily tasks. Controllers in closed loop are needed to control the actuators and sensors to provide actions. A sequencer schedules and coordinates these actions to finish a given task. And an AI planner is also needed to generate the sequence of the actions. Followed this well-known three-layer architecture, we have developed a robotic framework for service robots. The controller is implemented in the MCA (Modular Control Architecture), developed by our institute. A component-based interface converts the events like start or finished signals to an event-based system, where the tasks are decomposed and organized in a task-tree. This task-tree can be automatically generated by an AI planner or learned from human demonstrations. We have evaluated the introduced control framework on a service robot with two arms and two hands. Experimental results show that our system is modular, flexible and fulfills the requirements for robotic control software development.
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Reference	2009 IEEE International Conference on Robotics and Automation
DOI	http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5174682

Title	**Dexterous manipulation planning of objects with surface of revolution**
Abstract	In this paper, we propose a novel method for dexterous manipulation planning problem of rotating object with surface of revolution using a robotic multi-fingered hand. This method finds contact point trajectories from contact points between the robotic hand and the object with task-orientated manipulation quality measurement. Based on the defined manipulation quality, the pose for robotic hand relative to object can also be optimized by random sample. Experiments using Schunk Anthropomorphic Hand with 13 degrees of freedom screwing a light bulb into holder with screw thread demonstrates the feasibility and efficiency of the introduced method.
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Reference	2008 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2008.4650906

Title **Positioning mobile manipulators to perform constrained linear trajectories**

Abstract For mobile manipulators envisioned in home environments a kitchen scenario provides a challenging testbed for numerous skills. Diverse manipulation actions are required, e.g. simple pick and place for moving objects and constrained motions for opening doors and drawers. The robot kinematics and link limits however are restrictive. Therefore especially a constrained trajectory will not be executable from arbitrary placements of the mobile manipulator. A two stage approach is presented to position a mobile manipulator to execute constrained linear trajectories as needed for opening drawers. In a first stage, a representation of a robot arm.

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Publication date 22 September 2008

Reference 2008 IEEE/RSJ International Conference on Intelligent Robots and Systems

DOI 10.1109/IROS.2008.4650617

Title	**Planning regrasp operations for a multifingered robotic hand**
Abstract	Regrasp operations consist of a sequence of pick-and-place operations, which are very useful to avoid collisions with the environment and to overcome the kinematic limitations in some cases. In this work, we propose an automatic planning system for regrasp operations for a multifingered robotic hand. The stable planes of the object to be grasped are automatically found. The minimal angle allowed to rotate the object without tipping it over is expressed using solid angles to quantify the stability of each stable plane. The grasp for the multifingered hand is generated in the simulation using hand preshapes and approach directions. The stable planes are placed in the simulation as obstacles to plan grasps that do not collide with such stable planes. After a grasp is found, collisions between the grasp and each stable plane are checked. This information and the found grasps computed off-line are saved in a grasp database. During on-line execution, regrasp operations are planned by a breadth-first search using the grasp database. The collision and kinematic feasibility are also considered by the planner.
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Publication date	25 August 2008
Reference	2008 IEEE Conference on Automation Science and Engineering
DOI	10.1109/COASE.2008.4626569

Title	**Internal force computation of grasped object using joint torques**
Abstract	Grasping and manipulation are the most important key functions for service robots to help people to handle the everyday tasks in household. After the object is grasped, the internal force between the hand and object is very important for fine manipulation. In this paper, we present the computation of internal force of grasped objects using joint torques. An automatic grasp planning system is used to generate grasps with high grasp quality for Schunk Anthropomorphic Hand with 13 degrees of freedom. Optimal grasp forces are computed as a linear matrix inequalities problem, and are exerted using embedded joint torque based finger impedance control. Computation of force at the fingertip, the internal force for grasps with multiple contact points and the external forces exerted onto the object after grasping are introduced. In case of multiple contact points, it is assumed that the external force is distributed equally among all contact points on one finger. Experimental results show the feasibility of our methods.
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Publication date	22 August 2008
Reference	SICE Annual Conference 2008 International Conference on Instrumentation, Control and Information Technology
DOI	10.1109/SICE.2008.4655140

Title	**Automatic optimal grasp planning based on found contact points**
Abstract	Automatic grasp planning systems are very important for service robots, which compute what forces should be exerted onto the object and how those forces can be applied by robotic hands. In this paper, a highly integrated grasp planning system is introduced. Initial grasp is computed in the grasp simulator GraspIt! combining hand preshapes and automatically generated approach directions. With fixed relative position and orientation between the robotic hand and object as by the initial grasp, all the contact points between the fingers and the object are efficiently found. A search process tries to improve the grasp quality by moving the fingers to its neighbored joint positions, and uses the corresponding contact points to the joint position to evaluate the grasp quality, until local maximum grasp quality is reached. Optimal forces for the found grasp is computed as a linear inequalities matrix problem, which are exerted onto the object using torque based finger impedance control during execution. Experiments on Schunk Anthropomorphic Hand with 13 degrees of freedom show that, using the introduced grasp planning system, the object can be grasped solidly with shift errors of only some millimeters.
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Publication date	4 July 2008
Reference	2008 IEEE/ASME International Conference on Advanced Intelligent Mechatronics
DOI	10.1109/AIM.2008.4601807

Title **Central axis approach for computing n-finger force-closure grasps**

Abstract In this paper, we propose a new approach for computing force-closure grasps of two-dimensional and three-dimensional objects. Assuming n hard-finger contact with Coulomb friction model and based on central axes of the grasp wrench (i.e., force and torque), we develop a new necessary and sufficient condition for n-finger grasps to achieve force-closure. We demonstrate that a grasp is force-closure if and only if, its wrench can generate any arbitrary central axis. According to this condition, we reformulate the force-closure test as a linear programming problem without computing the convex hull of the primitive contact wrenches. Therefore, we present an efficient algorithm for computing n-finger force-closure grasps. Finally, we have implemented the proposed algorithm and verified its efficiency through some examples.

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Reference 2008 IEEE International Conference on Robotics and Automation

DOI 10.1109/ROBOT.2008.4543362

Title **Multi-priority control in redundant robotic systems**

Abstract This paper presents a dynamic level control algorithm to meet simultaneously multiple desired tasks based on allocated priorities for redundant robotic systems. It is shown that this algorithm can be treated as a general framework to achieve control over the whole body of the robot and some of the previously developed results are formalized using this approach. Null-space impedance control is proposed as one of the main results of using this method and is evaluated by means of computer simulation.

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Publication date 25 September 2011

Reference 2011 IEEE/RSJ International Conference on Intelligent Robots and Systems

DOI 10.1109/IROS.2011.6094609

Title	**Kinematic control with force feedback for a redundant bimanual manipulation system**
Abstract	In this paper, a kinematic model for motion coordination and control of a redundant robotic dual-arm/hand system is derived, which allows to compute the object pose from the joint variables of each arm and each finger as well as from a suitable set of contact variables. This model is used to design a two-stage control scheme to achieve a desired object motion and maintain desired normal contact forces applied to the object. Several secondary tasks are accomplished through a prioritized task sequencing management of the whole system redundancy. A simulation case study is presented to demonstrate the effectiveness of the proposed approach.
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Publication date	25 September 2011
Reference	2011 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2011.6094865

Title	**Interaction force control of robots with variable stiffness actuation**
Abstract	In this paper, the control of the force due to the interaction with the environment of a robotic manipulator with relevant and adjustable joint stiffness is addressed. It is assumed that the interaction force is not directly measurable and a controller able to estimate this force is proposed. Also the problem of controlling simultaneously both the position and the stiffness trajectory in the robot workspace is investigated. Moreover, the proposed controller provides useful information for the implementation of collision detection/reaction strategies. The proposed control approach has been validated by means of the simulation of a two-link planar manipulator
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Reference	18th IFAC World Congress
DOI	10.3182/20110828-6-IT-1002.03271

Title	**Output-based control of robots with variable stiffness actuation**
Abstract	In this paper, the output-based control of a redundant robotic manipulator with relevant and adjustable joint stiffness is addressed. The proposed controller is configured as a cascade system that allows the decoupling of the actuators dynamics from the arm dynamics and the consequent reduction of the order of the manipulator dynamic model. Moreover, the proposed controller does not require the knowledge of the whole robot state: only the positions of the actuators and of the joints are necessary. This approach represents a significant simplification with respect to previously proposed state feedback techniques. The problem of controlling simultaneously the position trajectory and the desired stiffness in both the joint and work space is investigated, and the relations between the manipulator redundancy and the selection of both the joint and work space stiffness of the manipulator are discussed. The effectiveness of the proposed approach is verified by simulations of a 3 degrees of freedom planar manipulator.
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Reference	Journal of Robotics
DOI	10.1155/2011/735407

Title	**A grasping force optimization algorithm with dynamic torque constraints for multi-fingered robotic hands**
Abstract	The problem of grasping force optimization (GFO) for a multi-fingered robotic hand is considered in this paper. The GFO problem is cast in a convex optimization problem, considering also joint torque constraints. A new algorithmic solution is proposed here, which is suitable to be implemented in real time. The proposed formulation allows a substantial reduction of the computational load of the problem by dynamically decreasing the number of active torque constraints. Moreover, differently from other approaches, the algorithm does not require the evaluation of a new initial point at the beginning of each optimization cycle. The effectiveness of the proposed method has been tested in a simulation case study where the grasping forces of a five-fingers robotic hand are modified in real time to cope with time-varying external forces applied to the object.
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Reference	2011 American Control Conference
DOI	ISSN: 0743-1619

Title **Cognitive control in cognitive robotics: Attentional executive control**

Abstract We present an attentional control architecture for a robotic agent capable of adapting its deliberative and executive behavior to internal and external processes. In this framework, the agent is endowed with simple attentional mechanisms regulating the sensors sampling rates and action activations. The process of changing the frequency of sensors readings is interpreted as an increase or decrease of attention towards relevant tasks, activities, and processes. We propose a hybrid control architecture where these mechanisms are deployed at different levels of abstraction to regulate behavioral executions, execution monitoring, and dynamic planning. We also propose a benchmark scenario providing some empirical results showing the effectiveness of the attentional regulation.

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Publication date 20 June 2011

Reference 15th International Conference on Advanced Robotics

DOI 10.1109/ICAR.2011.6088636

Title	**Experimental evaluation of the UB Hand IV postural synergies**
Abstract	In this paper, the postural synergies configuration subspace given by the fundamental eigengrasps of the UB Hand IV (University of Bologna Hand, version IV) is derived through experiments. This study is based on the kinematic structure of the robotic hand and on the taxonomy of the grasps of common objects. Experimental results show that it is possible to obtain grasp synthesis for a large set of objects both in the case of precision and of power grasps by using only a very limited set of dominant eigengrasps. The tasks here presented are planned with an initial hold of the hand followed by reach and grasp phases, that are unique for each object/grasp combination, during which the robotic hand posture evolves continuously within a subset of the hand configuration space given by the two predominant eigenpostures. The paper reports the method adopted to define from experiments the postural synergies for the UB Hand IV and the results of the grasp tasks performed adopting the defined synergies.
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Publication date	13 May 2011
Reference	Workshop on “Autonomous Grasping” at 2011 IEEE International Conference on Robotics and Automation
DOI	http://media.isr.uc.pt/autonomousgrasping/submissions/16_CR_sinergie_long.pdf

Title	**Online dexterous hand grasping force optimization with dynamic torque constraints selection**
Abstract	In this paper, a new algorithm for online grasping force optimization (GFO) of a dextrous robotic hand is presented. The GFO problem is cast in a convex optimization problem, considering also torque joint constraints. The proposed formulation allows to simplify the computational complexity of the problem by dynamically reducing the number of active torque constraints. Moreover, differently from other approaches, it does not require the evaluation of a new initial point at the beginning of each iteration. The effectiveness and the performance of the proposed method have been tested in a simulation case study where the hand manipulates a load with time-varying mass.
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Publication date	9 May 2011
Reference	2011 IEEE International Conference on Robotics and Automation
DOI	10.1109/ICRA.2011.5979674

Title	**Friction compensation and virtual force sensing for robotic hands**
Abstract	This paper presents the latest results in the development of the low-level controller of the robotic hand UBH-IV (University of Bologna Hand, version IV). In particular, a LuGre-like model has been used to model the friction effects acting at joint level and a procedure for the identification of the friction model parameters is described. With the aim of providing an online estimation of the effects due to the interaction of the robotic hand with the environment, a controller able to evaluate the overall external torque acting on the finger joints and to discern between friction and torques generated by the external interaction force without using direct measures of the contact forces is proposed. The identification and control tests are carried over on an experimental setup composed by a single finger phalanx, manufactured with the same material and techniques of the hand itself.
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Reference	2011 IEEE International Conference on Robotics and Automation
DOI	10.1109/ICRA.2011.5980231

Title	**Thresholds tuning of a neuro-symbolic net controlling a behaviour-based robotic system**
Abstract	In this paper we present the results obtained by adopting an evolutionary approach to tune some critical neuron thresholds of a neuro-symbolic net that regulates the overall emergent behavior of a behavior-based robotic system.
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Publication date	1 May 2011
Reference	18th European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning
DOI	ISBN 978-2-87419-044-5

Title	**Kinematic motion control for visual grasp of unknown objects**
Abstract	In this paper a kinematic motion control algorithm for the fast visual grasp of unknown objects with a multi-fingered hand is investigated. The algorithm is composed of an object surface reconstruction algorithm and a kinematic motion control, evolving in parallel, providing the input for the low-lever interaction controller. The reconstruction algorithm makes use of images taken by a camera carried by the robot, and virtually places an elastic elliptical reconstruction surface, whose axes and dimensions are assigned by a preshaping process, around the object. The surface is let to evolve dynamically under the action of reconstruction forces so as to shrink toward the object until some parts of the surface intercept the object visual hull. This process shapes the surface around the unknown object. At the same time, the kinematic motion control moves the fingertips on the current available reconstruction surface, achieving a planar equilateral grasp according to suitable hand kinematic indices. The fingers keep moving towards local minima depending on the evolution of the reconstruction surface deformation. The control module must ensure that the references given by the planner are correctly followed by the robotic hand. Experiments are presented, showing the effectiveness of the proposed algorithm.
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Publication date	11 November 2010
Reference	Motion Control 2010
DOI	-

Title	**Exploiting redundancy in kinematic motion control for dexterous object manipulation**
Abstract	The advantage of using redundancy in a kinematic motion control framework for dexterous object manipulation is investigated in this paper. A kinematic model for motion coordination of a redundant multi-fingered robotic hand is derived, which allows to compute the object pose from the joint variables of each finger as well as from a suitable set of contact variables. Then, a prioritized inverse kinematics scheme with redundancy resolution, both with inverse and transpose Jacobian matrix, is developed. This algorithm can be used for kinematic control as well as a local planning method for dexterous manipulation. A simulation case study is presented to demonstrate the effectiveness of the proposed approach.
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DOI	-

Title	**Port-Hamiltonian modeling for soft-finger manipulation**
Abstract	In this paper, the model of a multi-fingered robotic hand with soft-pads grasping an object in a Port-Hamiltonian geometric framework is presented. A modular approach, for a complex lumped-parameter physical system, is used. Algebraic constrains of the interconnected systems are represented by a geometric object, called Dirac structure. This is a powerful way to describe non-contact to contact transition, and contact viscoelasticity, using the concept of energy flow and power preserving interconnection. Simulation results for the validation of the model, and of an internal force control, based on a simple Intrinsically Passive Controller (IPC), are presented; the 20-sim simulator with bond graph graphical representation has been used.
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Publication date	18 October 2010
Reference	2010 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2010.5650866

Title **Preshaped visual grasp of unknown objects with a multi-fingered hand**

Abstract In this paper a method for fast visual grasp of unknown objects with a multi-fingered hand is presented. The algorithm is composed of an object surface reconstruction algorithm and a local grasp planner, evolving in parallel. The reconstruction algorithm makes use of images taken by a camera carried by the robot, mounted in an eye-in-hand configuration. An elastic elliptical reconstruction surface, with axes and dimensions assigned by a preshaping process, is virtually placed around the object. The surface is let to evolve dynamically under the action of reconstruction forces. The reconstruction surface shrinks toward the object until some parts of the surface intercept the object visual hull. Then, local rejection forces are generated to compensate the reconstruction forces. This process shapes the surface around the unknown object. Running in parallel to the reconstruction algorithm, the grasp planner moves the fingertips on the current available reconstruction surface, towards points which are optimal (in a local sense) with respect to a number of indices weighting both the grasp quality and the kinematics configuration of the hand. Experiments are presented, showing the effectiveness of the proposed algorithm.

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Publication date 18 October 2010

Reference 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems

DOI 10.1109/IROS.2010.5650680

Title	**Antagonistically actuated compliant joint: Torque and stiffness control**
Abstract	The current research effort in the design of lightweight and safe robots is resulting in increased interest for the development of variable stiffness actuators. Antagonistic pneumatic muscle actuators (pMAs) have been proposed for this purpose, due to their inherent nonlinear spring behavior resulting from both air compressibility and their nonlinear force-length relation. This paper addresses the simultaneous torque and stiffness control of an antagonistically actuated joint with pneumatic muscles driven by compact, fast-switching solenoid valves. This strategy allows compensation of unmodeled joint dynamics while adjusting the joint stiffness depending on the task requirements. The proposed controller is based on a sliding mode force control applied to an average model of the valve-pneumatic muscle system. This was necessary to cope with both the well known model uncertainties of the pMA and the discontinuous on-off behavior of the solenoid valves. Preliminary experimental results verified the effectiveness of the proposed implementation.
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Publication date	18 October 2010
Reference	2010 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2010.5651277

Title	**Human-like visual grasp of unknown objects**
Abstract	In this paper a method to achieve a human-like grasp in unstructured environments is presented. The algorithm is composed of an object surface reconstruction algorithm and a local grasp planner, evolving in parallel. The former uses an elastic elliptical reconstruction surface, with axes and dimensions assigned by a preshaping process that is let to evolve dynamically under the action of reconstruction forces. The reconstruction surface shrinks toward the object until some parts of the surface intercept the object visual hull. The latter moves the fingertips on the current available reconstruction surface towards points which are optimal (in a local sense) with respect to a certain number of indices weighting both the grasp quality and the kinematic configuration of the hand. A control module must ensure that the references given by the planner are correctly followed by the robotic hand. Experiments are presented, showing the effectiveness of the proposed algorithm.
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Publication date	14 October 2010
Reference	1st International Conference on Applied Bionics and Biomechanics
DOI	-

Title	**An adaptive oscillatory neural architecture for controlling behavior based robotic systems**
Abstract	The introduction in Robotics of models inspired by biological clocks may be useful in order to cope with a number of problems, like, for example, an efficient resources management in the sensorial pattern elaboration, the coordination of different and parallel behaviors and the ability, for a robotic system, to adapt its emergent behavior to different contexts providing an emergent action selection mechanism. In this paper we present a general purpose neural-net able to obtain adaptive periodical controllers, described by means of the NSBL. NSBL is a Neuro-Symbolic Behavior modeling Language that allows one to express propositional logical inference and to translate them into the logically equivalent neural network. Such general periodic clocks are peculiar to each behavior, and their periods are influenced by the sensor input changing rate. In this way, the Robotic System is able to adapt its reaction time coherently to the changes occurring in the environment and to its internal state. To test our architecture we investigate the case of two conflicting behaviors.
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Publication date	1 October 2010
Reference	Neurocomputing
DOI	10.1016/j.neucom.2010.03.026

Title **Attentive monitoring strategies in a behaviour-based robotic system: An evolutionary approach**

Abstract In this paper, we propose an evolutionary approach to develop an attentive executive control system for a robotic agent. We consider a behavior-based system endowed with simple attentional mechanisms that regulate sensors sampling rates and action activations. In this context, the overall emergent attentive behavior is specified by a finite set of parameters regulating a process of adaptation w.r.t. the internal processes and the external environment. In this work, we propose the deployment of a Differential Evolution algorithm to set these parameters. As a case study, we consider an agent operating in an adaptation and survival domain. The collected results show that the generated attentional control systems perform better than the hand-tuned ones and are general enough to remain effective and robust when deployed in different environments.

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Publication date 6 September 2010

Reference 2010 IEEE International Symposium on Learning and Adaptive Behavior in Robotic Systems

DOI 10.1109/EST.2010.17

Title	**Periodic activations of behaviours and emotional adaptation in behaviour-based robotics**
Abstract	The possible modulatory influence of motivations and emotions is of great interest in designing robotic adaptive systems. In this paper, we will try to connect the concept of periodic behaviour activations to emotional modulation, in order to link the variability of behaviours to the circumstances in which they are activated. We will study the impact of emotion, described as timed controlled structures, on simple but conflicting reactive behaviours. We will show, through this approach, that the introduction of such asynchronies in the robot control system may lead to an adaptation in the emergent behaviour without having an explicit action selection mechanism. The emergent behaviours of a simple robot designed with both a parallel and a hierarchical architecture will be evaluated and compared.
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Publication date	3 September 2010
Reference	Connection Science
DOI	10.1080/09540091003749691

Title	**Task space control of robots with variable stiffness actuation**
Abstract	Physical human-robot interaction represents one of the last challenges in robotics. To this end, the development of safe and dependable robots is actually changing the way how robot are designed, introducing actuation systems and transmission elements with relevant and programmable compliance and soft covers able to emulate the human skin behaviour. From the control point of view, the definition of suitable motion control laws that take care of possible collisions and react in a safe way while preserving accuracy and performance during the motion in the free space is needed. In this paper, the workspace control of a robotic manipulator with relevant and adjustable joint stiffness is addressed. The problem of controlling simultaneously both the position and the stiffness trajectory in the robot workspace is investigated.
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Publication date	1 September 2010
Reference	8th IFAC Symposium on Nonlinear Control Systems
DOI	10.3182/20100901-3-IT-2016.00233

Title	**Attentional modulation of mutually dependent behaviors**
Abstract	In this paper, we investigate simple attentional mechanisms suitable for sensing rate regulation and action coordination in the presence of mutually dependent behaviors. We present our architecture along with a case study where a real robotic system is to manage and harmonize conflicting tasks. This research focuses on attentional mechanisms for regulating the frequencies of sensor readings and action activations in a behavior-based robotic system. Such mechanisms are to direct sensors toward the most salient sources of information and filter the available sensory data to prevent unnecessary information processing.
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Publication date	28 August 2010
Reference	11th International Conference on Simulation of Adaptive Behavior
DOI	http://www.na.infn.it/~srossi/BurattiniSAB2010.pdf

Title **Fast multi-fingered grasp synthesis based on object dynamic properties**

Abstract The grasping and manipulation of objects, especially when they are heavy with respect to the hand power capability, requires the synthesis of grasp configurations that must explicitly take into account the dynamic properties of the object. Specifically, suitable grasp configurations reducing gravitational and inertial effects during object manipulation and minimizing and equally distributing the forces required for the grasp over all the available fingers must be computed. A new method for fast synthesis of multi-fingered grasp configurations is proposed in this paper. In particular, to reduce the computational complexity, all the regions of the object surface favoring the synthesis of minimal inertia grasp are first evaluated, then a limited number of discrete grasping regions are selected on the basis of the fingertip size, model uncertainty, and surface curvature. Finally, an exhaustive search of the optimal grasp configurations with respect to the grasp quality is performed. Several case studies and comparisons with other methods are proposed to demonstrate the effectiveness of the proposed approach.

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Publication date 6 July 2010

Reference 2010 IEEE/ASME International Conference on Advanced Intelligent Mechatronics

DOI 10.1109/AIM.2010.5695953

Title	**From motion planning to trajectory control with bounded jerk for service robots**
Abstract	To build autonomous robots capable to plan and control tasks in human environments, we need a description of trajectories that allow the robot to reason on his moves. In this paper, we propose to use series of cubic polynomial curves to define the trajectories with bounded jerk, acceleration and velocity. This solution is well adapted to plan safe and acceptable moves of the robot in the vicinity of humans. It is also a simple solution to approximate any trajectory and synchronize different robots or element of the robots. These curves associated to a simple representation and to a fast computation are fitted to build controller.
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Publication date	3 May 2010
Reference	2010 IEEE International Conference on Robotics and Automation
DOI	10.1109/ROBOT.2010.5509152

Title **Design of tendon-driven robotic fingers: Modeling and control issues**

Abstract This paper reports the modeling activities related to the development of an innovative tendon-driven robotic finger, designed as the fundamental element of a new biologically-inspired artificial hand. The finger is realized in plastic material by means of 3D-printing: this production process allows a remarkable simplification of the mechanical design and makes it possible a very fast and easy implementation of solutions that can be very complex, if not impossible, to obtain with conventional manufacturing. A detailed simulation model of the robotic finger has been developed with the aim not only of designing and testing suitable control strategies for the finger, but also of investigating the benefits and the flaws of particular design solutions. As a matter of fact, this approach to design and realization of robotic fingers, that fulfills the requirements in terms of compactness, integration and simplified assembly, has a significant drawback in frictional phenomena on both tendons and joints. For this reason, an adapted LuGre friction model is proposed in order to simulate and study the finger behavior.

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Publication date 3 May 2010

Reference 2010 IEEE International Conference on Robotics and Automation

DOI 10.1109/ROBOT.2010.5509899

Title	**Attentive execution monitoring and adaptive control in cognitive robotics**
Abstract	We present an attentive control architecture for a behavior-based robotic system capable of adapting its emergent behavior to the surrounding environment and to its internal state. In this framework, the agent is endowed with simple attentional mechanisms regulating the frequencies of sensory readings and behaviour activations. The process of changing the frequency of sensory readings is interpreted as an increase or decrease of attention towards particular aspects of the agent body and the external environment. We tested the approach in different domain by considering incrementally complex settings in different scenarios. The collected results show the feasibility and the effectiveness of the approach.
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Publication date	26 February 2010
Reference	Dagstuhl Seminar Proceedings
DOI	http://drops.dagstuhl.de/opus/volltexte/2010/2632

Title	**Floating visual grasp of unknown objects**
Abstract	A new method for fast visual grasp of unknown objects using a camera mounted on a robot in an eye-inhand configuration is presented. The method is composed of a fast iterative object surface reconstruction algorithm and of a local grasp planner, evolving in a synchronized parallel way. The reconstruction algorithm makes use of images taken by a camera carried by the robot. A reconstruction sphere, virtually placed around the object, is iteratively compressed towards the object visual hull, dragging out the fingers attached to it. Between two steps of the reconstruction process, the planner moves the fingers, floating on the current reconstructed surface, according to suitable quality measures. The fingers keep moving until a local minimum is achieved, then a new object surface estimation provided by the reconstruction process is considered. Quality measures considering both hand and grasp proprieties are adopted. Simulations are presented to show the performance of the proposed algorithm.
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Publication date	11 October 2009
Reference	2009 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2009.5354350

Title	**Floating visual grasp of unknown objects using an elastic reconstruction sphere**
Abstract	In this paper a new method for fast visual grasp of unknown objects is presented. The method is composed of an object surface reconstruction algorithm and of a local grasp planner, evolving in a parallel way. The reconstruction algorithm makes use of images taken by a camera carried by the robot, mounted in an eye-in-hand configuration. An elastic reconstruction sphere, composed by masses interconnected each other by springs, is virtually placed around the object. The sphere is let to evolve dynamically under the action of external forces, which push the masses towards the object centroid. To smoothen the surface evolution, spatial dampers are attached to each mass. The reconstruction surface shrinks toward its center of mass until some pieces of its surface intercept the object visual hull, and thus local rejection forces are generated to push out the reconstruction points until they stay into the visual hull. This process shapes the sphere around the unknown object. Running in parallel to the reconstruction algorithm, the grasp planner moves the fingertips, floating on the current available reconstructed surface, according to suitable quality measures. The fingers keep moving towards local minima depending on the evolution of the reconstruction surface deformation. The process stops when the object has been completely reconstructed and the planner reaches a local minimum. Quality measures considering both hand and grasp proprieties are adopted. Simulations are presented, showing the effectiveness of the proposed algorithm.
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Publication date	31 August 2009
Reference	Springer Tracts in Advanced Robotics
DOI	10.1007/978-3-642-19457-3

Title **Monitoring strategies for adaptive periodic control in behavior-based robotic systems**

Abstract The main goal of our current research is the design of a behavior-based robotic architecture that has the capability of adapting its behaviors both to the rate of change of the environment and to changes of its internal states in order to efficiently reduce the computational costs for input processing. Inspired by research on biological clocks, we introduced a simple schema theory model where releasing mechanisms are combined with adaptive internal clocks. In this paper, we describe the design and development of a complete robotic architecture implementing this model. In particular, we considered a mobile robot domain that simulates the navigation behavior of a Catagliphys ant enhanced with simple visual capabilities.

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Publication date 22 July 2009

Reference 2nd ECSIS Symposium on Learning and Adaptive Behavior in Robotic Systems

DOI 10.1109/AT-EQUAL.2009.34

Title	**Exploiting redundancy in closed-loop inverse kinematics for dexterous object manipulation**
Abstract	In this paper, a kinematic model for motion coordination of a redundant multi-fingered robotic hand is derived, which allows to compute the object pose from the joint variables of each finger as well as from a suitable set of contact variables. Then, a prioritized inverse kinematics scheme with redundancy resolution, both with inverse and transpose Jacobian matrix, is developed. This algorithm can be used for kinematic control as well as a local planning method for dexterous manipulation. A simulation case study is presented to demonstrate the effectiveness of the proposed approach.
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Publication date	22 June 2009
Reference	14th International Conference on Advanced Robotics
DOI	http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5174728

Title	**Robust control of robots with variable joint stiffness**
Abstract	The development of safe and dependable robots for physical human-robot interaction requires the mechanical design of lightweight and compliant manipulators and the definition of motion control laws that allow to combine compliant behavior in reaction to possible collisions, while preserving accuracy and performance during the motion in the free space. For these motivations, great attention has been posed in the design of robots manipulators with relevant and programmable elasticity at the joints/transmissions. A robust control strategy for a general class of multi-dof manipulators with variable joint stiffness is reported in this paper. The proposed controller is composed by a robot dynamics plus gravity compensator, a linear controller and a smooth sliding mode control action to ensure robustness with respect to model uncertainties. The stability of the overall system is studied by using the direct Lyapunov method and the effectiveness of the proposed approach is demonstrated by simulation analysis.
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Publication date	22 June 2009
Reference	14th International Conference on Advanced Robotics
DOI	http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5174675

Title	**Inverse kinematics for object manipulation with redundant multi-fingered robotic hands**
Abstract	In this paper, the problem of motion coordination of redundant multi-fingered robotic hands is considered. A kinematic model is introduced, which allows the object pose to be computed from the joint variables of each finger as well as from a suitable set of contact variables. Hence, a local planning method for dexterous manipulation, based on a prioritized inverse kinematics scheme with redundancy resolution, is presented. A case study is developed to demonstrate the effectiveness of the proposed approach in the presence of redundant degrees of freedom.
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Publication date	1 June 2009
Reference	Robot Motion and Control
DOI	10.1007/978-1-84882-985-5

Title **Surface model reconstruction of 3D objects from multiple views**

Abstract A points surface reconstruction algorithm of 3D object models from multiple silhouettes is proposed in this paper. Some images of the target object are taken from a circular trajectory by a robot with a camera mounted in an eye-in-hand configuration. The silhouettes of the observed object are evaluated for each view using a blob analysis process, and from those a set of points that sample a reconstruction sphere surrounding the target object are estimated. The sphere sample points are attracted by the object center of mass using a variable step according to the distance from the silhouettes contours. For each point, the iterative process of constriction is stopped when all the back-projections of the point are within the corresponding silhouettes. Moreover, a new method based on a rough estimation of object dimension is proposed to reduce the disturbances due to projection and shadow cones. Simulations and experiments are presented to evaluate the performance of the proposed algorithm.

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Publication date 12 May 2009

Reference 2009 IEEE International Conference on Robotics and Automation

DOI 10.1109/ROBOT.2009.5152652

Title **Tendon-based transmission systems for robotic devices: Models and control algorithms**

Abstract Tendon-based transmission systems present many positive aspects and greatly simplify the mechanical design of small robotic devices, such as robotic fingers. On the other hand, they introduce several nonlinear effects in the actuation system that must be properly considered by the control algorithms. In this paper, some models of tendons and of the nonlinear effects arising in their use in robotic devices are discussed, and control algorithms aiming at compensating these nonlinearities are presented. Both models and control algorithms have been validated by experimental activities. In particular, in order to gain a better insight on how the tension is distributed along a tendon subject to friction, a setup able to measure the cable tension in intermediate points has been developed and employed. Once the tendon characteristics have been identified, a control scheme that allows to achieve a desired joint force/torque has been applied. This controller is based on a sliding-mode with boundary layer, where the boundary threshold is modulated in function of the magnitude of the input.

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Publication date 12 May 2009

Reference 2009 IEEE International Conference on Robotics and Automation

DOI 10.1109/ROBOT.2009.5152491

Title	**A neural network generating adaptive rhythms for controlling behavior based robotic systems**
Abstract	Influenced by the results obtained in neuroscience and biology, we have introduced a model (AIRM) that, inspired by biological rhythms, adaptively controls a behavior based robotic system (BBRS). The proposed model is implemented by means of an NSP (neuro symbolic processor). Since the NSP can be implemented on FPGA, we can take advantage of a parallel execution of the AIRM model and then an improvement of the BBRS performance.
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Publication date	1 November 2008
Reference	10th Brazilian Symposium on Artificial Neural Networks
DOI	10.1109/SBRN.2008.40

Title	**Six-dof impedance control of dual-arm cooperative manipulators**
Abstract	In this paper, the problem of impedance control of dual-arm cooperative manipulators is studied. A general impedance control scheme is adopted, which encompasses a centralized impedance control strategy, aimed at conferring a compliant behavior at the object level, and a decentralized impedance control, enforced at the end-effector level, aimed at avoiding large internal loading of the object. Remarkably, the mechanical impedance behavior is defined in terms of geometrically consistent stiffness. The overall control scheme is based on a two-loop arrangement, where a simple proportional integral derivative inner motion loop is adopted for each manipulator, while an outer loop, using force and moment measurements at the robots wrists, is aimed at imposing the desired impedance behaviors. The developed control scheme is experimentally tested on a dual-arm setup composed of two 6-DOF industrial manipulators carrying a common object. The experimental investigation concerns the four different controller configurations that can be achieved by activating/deactivating the single impedance controllers.
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Publication date	8 October 2008
Reference	IEEE/ASME Transactions on Mechatronics
DOI	10.1109/TMECH.2008.2002816

Title	**Soft motion trajectory planner for service manipulator robot**
Abstract	Human interaction introduces two main constraints: Safety and Comfort. Therefore service robot manipulator can't be controlled like industrial robotic manipulator where personnel is isolated from the robots work envelope. In this paper, we present a soft motion trajectory planner to try to ensure that these constraints are satisfied. This planner can be used on-line to establish visual and force control loop suitable in presence of human. The cubic trajectories built by this planner are good candidates as output of a manipulation task planner. The obtained system is then homogeneous from task planning to robot control. The soft motion trajectory planner limits jerk, acceleration and velocity in cartesian space using quaternion. Experimental results carried out on a Mitsubishi PA10-6CE arm are presented.
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Publication date	22 September 2008
Reference	2008 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2008.4650608

Title	**Periodic adaptive activation of behaviors in robotic systems**
Abstract	The main goal of our current research is the design of a robotic architecture that has the capability of adapting the robot's behavior to the rate of change of a dynamic environment. We present a model which takes free inspiration from some features of biological clocks. In particular, we associate the concept of Innate Releasing Mechanisms (IRM) to the concept of periodic behavior activation in order to link the variability of the behavior to the circumstances in which it is activated. We propose an architecture in which the frequency of access to the sensory system is modified in accordance to the environmental changes. To this purpose we use the Schema Theory paradigm. Some first experimental results are reported and discussed.
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Publication date	1 August 2008
Reference	International Journal of Pattern Recognition and Artificial Intelligence
DOI	10.1142/S0218001408006661

Title	**From adaptive perception to adaptive emergent behavior using rhythmic releasers**
Abstract	-
Contact person	Ernesto Burattini **e-mail:** ernb@na.infn.it
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Publication date	1 August 2008
Reference	10th International Conference on Simulation of Adaptive Behavior
DOI	http://www.cogrobotics.unina.it/LastMinuteResultsSAB08.pdf

Title	**Periodic activations of behaviors and motivational states**
Abstract	The possible modulatory influence of motivations and emotions is fundamental in designing robotic adaptive systems. In this paper, we will try to connect the concept of periodic behavior activations to emotions, in order to link the variability of behaviors to the circumstances in which they are activated. We will study the impact of emotion, described as timed controlled structures, on simple reactive behaviors. We will show, through this approach, that the emergent behaviors of a simple robot designed with a parallel or hierarchical architecture are comparable. Finally, we will see that conflicts in behaviors may be solved without an explicit action selection mechanism.
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Publication date	1 August 2008
Reference	10th International Conference on Simulation of Adaptive Behavior
DOI	http://www.cogrobotics.unina.it/Burattini-Rossi-emotion08.pdf

Title	**Interaction control of robot manipulators using force and vision**
Abstract	An approach to force and visual control of robot manipulators in contact with a partially known environment is proposed in this paper. The environment is modelled as a rigid object of known geometry but of unknown and time-varying position and orientation. An algorithm for online estimation of the object pose is adopted, based on visual data provided by a camera as well as on forces measured during the interaction. This information is used by a force/position control scheme, in charge of managing the interaction. Simulation and experimental results are presented for the case of an industrial robot manipulator.
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Publication date	1 July 2008
Reference	International Journal of Optomechatronics
DOI	10.1080/15599610802301599

Title **Force/tactile sensor for robotic applications**

Abstract The paper describes the detailed design and the prototype characterization of a novel tactile sensor for robotic applications. The sensor is based on a two-layer structure, i.e., a printed circuit board with optoelectronic components below a deformable silicon layer with a suitably designed geometry. The mechanical structure of the sensor has been optimized in terms of geometry and material physical properties to provide the sensor with different capabilities. The first capability is to work as a six-axis force/torque sensor; additionally, the sensor can be used as a tactile sensor providing a spatially distributed information exploited to estimate the geometry of the contact with a stiff external object. An analytical physical model and a complete experimental characterization of the sensor are presented.

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Reference Sensors & Actuators: A. Physical

DOI 10.1016/j.sna.2011.12.042

Research domain covered New robotic technologies

Title **A computational model for frictional effects applied to dexterous hands with soft pads**

Abstract Currently, the design of many robotics hands integrates soft pads as mechanical interface between fingers and manipulated objects. There are several good reasons for introducing soft pads, ranging from increasing safety in manipulation tasks to aesthetic issues. Among the advantages brought by soft pads, one has to mention the significant increase of friction between fingers and the object in contact, and consequently the capability of exert tangential forces with respect to the contact normal. These forces play a fundamental role in grasping and fine manipulation tasks. In this paper we propose a mathematical model able to render the tangential forces due to friction and soft pad elasticity that a finger (represented here with cylindrical and hemispherical surfaces) exerts at the contact, with the aim of simulating the interaction of a soft pad with an object. The main characteristics that this model takes into account are: the tangential elasticity of the soft pad, the relative rolling of the phalanx and the object, and the stick and slip phases. This computational model can also be adapted to haptic applications.

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Publication date 28 August 2011

Reference 18th IFAC World Congress

DOI 10.3182/20110828-6-IT-1002.00852

Title	**Miniaturized optical-based force sensors for tendon-driven robots**
Abstract	In this paper, an innovative sensor based on optoelectronic components and compliant frames for the measurement of the tendon tension is presented. With respect to conventional solutions for force sensing, like strain-gauge or Bragg-grating based force sensors, this sensor presents several advantages, mainly in terms of compactness, simplicity of the implementation and conditioning electronics. The proposed sensor exploits the properties of optoelectronic components with a narrow angle of view to measure the very small deformation of a compliant frame caused by the tendon tension. The sensor can be placed at the tendon ends as such as in any position along the tendon. The paper reports the basic working principle and a simplified procedure for the design of the sensor frame together with the results of an experimental testbench where a couple of the proposed sensors are used for the feedback control of a tendon-driven robotic joint.
Contact person	Gianluca Palli **e-mail:** gianluca.palli@unibo.it
Authors	Gianluca Palli, Salvatore Pirozzi
Involved institution(s)	UNIBO, SUN
Publication date	9 May 2011
Reference	2011 IEEE International Conference on Robotics and Automation
DOI	10.1109/ICRA.2011.5979970

Title	**Design of a variable stiffness actuator based on flexures**
Abstract	Variable Stiffness Actuators can be used in order to achieve a suitable trade-off between performance and safety in robotic devices for physical human-robot interaction. With the aim of improving the compactness and the flexibility of existing mechanical solutions, a Variable Stiffness Actuator based on the use of flexures is investigated. The proposed concept allows the implementation of a desired stiffness profile and range. In particular, this paper reports a procedure for the synthesis of a fully-compliant mechanism used as a non-linear transmission element, together with its experimental characterization. Finally, a preliminary prototype of the overall joint is depicted.
Contact person	Gianluca Palli **e-mail:** gianluca.palli@unibo.it
Authors	Gianluca Palli, Giovanni Berselli, Claudio Melchiorri, Gabriele Vassura
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Publication date	12 April 2011
Reference	ASME Journal of Mechanisms and Robotics
DOI	10.1115/1.4004228

Title

Engineering design of fluid-filled soft covers for robotic contact interfaces: Guidelines, nonlinear modeling and experimental validation

Abstract

Visco-elastic contact interfaces can be found in various robotic components covered with a compliant surface (pad) such as anthropomorphic hands, bio-mimetic tactile sensors, prosthesis and orthosis. In all those cases, it is desirable to obtain thin and resistant pads with predetermined compliance and damping properties (e.g. mimicking the human skin and pulpy tissues). In order to overcome the limits of homogeneous layers of soft visco-elastic material commonly used in the aforementioned devices, this paper suggests the adoption of soft pads composed of a continuous external layer (skin) coupled with an internal layer having fluid-filled voids. The process of designing the pad starts with the selection of a hyper-elastic medium with proper tribological features whose constitutive parameters are determined by numerically fitting nonlinear stress-strain curves under pure homogenous deformations. The optimization of the internal layer morphology is then achieved through nonlinear finite element analysis which provides an estimate of hardness and friction influence on the pad static compliance. At last, the pad is filled with a viscous fluid chosen so as to modify time-dependent phenomena and to increase damping effects. The effectiveness of the procedure is proven by designing and modeling better-behaved artificial pads which mimic the human finger dynamic properties.

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Publication date 10 May 2011

Reference IEEE Transactions on Robotics

DOI 10.1109/TRO.2011.2132970

Title **Force sensor based on discrete optoelectronic components and compliant frames**

Abstract In this paper, a novel force sensor based on commercial discrete optoelectronic components mounted on a compliant frame is described. The compliant frame has been designed through an optimization procedure to achieve a desired relation between the applied force and the angular displacement of the optical axes of the optoelectronic components. The narrow-angle characteristics of Light Emitting Diode (LED) and PhotoDetector (PD) couples have been exploited for the generation of a signal proportional to very limited deformation of the compliant frame caused by the external traction force. This sensor is suitable for applications in the field of tendon driven robots, and in particular the use of this sensor for the measurement of the actuator side tendon force in a robotic hand is reported. The design procedure of the sensor is presented together with the sensor prototype, the experimental verification of the calibration curve and of the frame deformation and the testing in a force feedback control system. The main advantages of this sensor are the simplified conditioning electronics, the very high noise-to-signal ratio and the immunity to electromagnetic fields.

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Publication date 10 January 2011

Reference Sensors & Actuators: A. Physical

DOI 10.1016/j.sna.2010.11.007

Title	**Minimally invasive force sensing for tendon-driven robots**
Abstract	The purpose of this chapter is to present a sensor solution for measurement of tendon tension or torque in force control applications of tendon-driven robots. The sensor is based on a fibre Bragg grating (FBG) used as strain sensor and owing to its minimally invasive nature typical of optical fibres, can be easily integrated in any type of tendon-driven robot. One of the most promising applications can be the integration of the sensor into anthropomorphic robotic hands for accurate impedance or compliance control. In fact, the sensing element of the proposed torque sensor can be easily bonded directly to the tendon following its natural routing with a significantly reduced invasiveness with respect to conventional sensors. These are usually based on strain gauges, which are cumbersome and require additional mechanical components and interfaces in order to provide the necessary measurement, while the Bragg sensor is embedded into the optical fibre whose typical diameter is about 125μm which allows its integration into the tendon itself. The experimental results presented here have been obtained on a simple test-bench realized by using off-the-shelf and cheap components conceived to demonstrate the potentiality of the sensor and its effectiveness in an actual compliance control scheme.
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Publication date	1 October 2010
Reference	Cutting Edge Robotics 2010
DOI	http://www.intechopen.com/articles/show/title/minimally-invasive-force-sensing-for-tendon-driven-robots

Title	**Design and modeling of variable stiffness joints based on compliant flexure**
Abstract	The development of safe and dependable robots for physical human-robot interaction is actually changing the way robot are designed introducing several new technological issues. Outstanding examples are the adoption of soft covers and compliant transmission or the definition of motion control laws that allow a compliant behavior in reaction to possible collisions, while preserving accuracy and performance during the motion in the free space. In this scenario, a growing interest is devoted to the study of variable stiffness joints. With the aim of improving the compactness and the flexibility of existing mechanical solutions, a variable stiffness joint based on the use of compliant flexures is investigated. The proposed concept allows the implementation of a desired stiffness profile and range along with the selection of the maximum joint deflection. In particular, this paper reports a systematic procedure for the synthesis of a fully-compliant mechanism used as a non-linear transmission, together with a preliminary design of the overall joint.
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Authors	Gianluca Palli, Claudio Melchiorri, Giovanni Berselli
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Publication date	15 August 2010
Reference	ASME 2010 International Design Engineering Technical Conference & Computers and Information in Engineering Conference
DOI	10.1115/DETC2010-28425

Title **On designing structured soft covers for robotic limbs with predetermined compliance**

Abstract In order to overcome the limits due to the fact that homogeneous layers of soft material placed over robotic limbs behave differently with respect to biological models, this paper suggests the adoption of soft covers (pads) with differentiated structure. In particular, it is proposed to divide the allowable pad thickness into two layers: a continuous external layer (skin) and a discontinuous internal layer, so that the overall stiffness can be adjusted by properly shaping the discontinuous layer. The methodology adopted for designing the internal layer is composed of two steps. Firstly, the covers surface is conceptually split into finite elementary triangular sub-regions. Secondly, the internal layer of each triangular element is designed in order to replicate the shape of the non-linear compression laws which is typical of endoskeletal structures covered by pulpy tissues. A series of symmetrically disposed inclined micro-beams is used for the purpose. Once the compression law of each triangular element is known, the overall pad compliance can be modulated by correctly choosing the number and size of the elements composing the pad. Equipment and results of a combined experimental and numerical analysis (FEM) are presented. The results that the proposed concept can be an effective solution when designing soft covers whose behavior needs to match the compliance of the biological counterpart. As an example, artificial pads which mimic the human finger behavior are presented.

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Publication date 15 August 2010

Reference ASME 2010 International Design Engineering Technical Conference & Computers and Information in Engineering Conference

DOI 10.1115/DETC2010-28965

Title	**Nonlinear modelling and experimental evaluation of fluid-filled soft pads for robotic hands**
Abstract	After a brief reminder about previous work, this paper addresses the dynamic characterization of fluid-filled soft pads for robotic hands. The adopted pad specimens are constituted by a single hyper-elastic material having hardness similar to that of the human thumb. The overall pad thickness is then divided into a continuous skin layer and an internal layer having communicating voids which are hermetically sealed and filled with a viscous fluid. Despite a more complicated design, it has been proven [1-3] that the pads present enhanced compliance and damping properties, a lower thickness and a higher surface hardness when compared to previously published solutions. In addition, a quasi-linear model, frequently used to describe the behavior of soft biological tissues can be applied in order to predict and control the pad interaction with the environment during grasping and manipulation tasks. In particular, the experimental tests necessary to evaluate the parameters which determine the pad dynamic response are described and discussed in detail.
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Publication date	10 July 2010
Reference	9th Youth Symposium on Experimental Solid Mechanics
DOI	-

Title	**Comparative evaluation of the selective compliance in elastic joints for robotic structures**
Abstract	After a brief reminder about advantages and problems related to the application of large displacement elastic joints in robotic structures, this paper outlines an approach for quantifying the joint's performance in terms of selective compliance (i.e. capability of providing low stiffness along a single desired direction). Local and global performance indexes are proposed which can be used to discern which joint best suits the application requirements. The approach is validated by comparing two beam-like flexures and two novel compliant joints with non trivial morphology.
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Publication date	3 May 2011
Reference	2011 IEEE International Conference on Robotics and Automation
DOI	10.1109/ICRA.2011.5980201

Title	**Tailoring the viscoelastic properties of soft pads for robotic limbs through purposely designed fluid filled structures**
Abstract	The majority of soft pads for robotic limbs studied so far were made by visco-elastic polymeric solids whose behavior is significantly influenced by the rate of application of the external loads or displacements. In particular, contact interfaces which are intrinsically visco-elastic are found, for instance, in human fingers and feet or in various robotic devices covered by a compliant surface. An outstanding instance are anthropomorphic hands where time-dependent phenomena profoundly affects the stability and sustainability of the grasp. Alternatively to homogenous solid pads, this paper proposes the use of fluid filled soft structures with differentiated layer design [1] that is the adoption of a single solid material, dividing the overall thickness of the pad into a continuous skin layer coupled with an internal layer having communicating voids. The voids are then hermetically sealed and, in case, filled with fluid. Given the allowable pad thickness, the purpose is to tailor the pad properties to the specific application by 1) selecting a skin material characterized by proper tribological features, 2) designing an inner layer geometry so as to obtain a specific static compliance, 3) filling the pad with a viscous fluid chosen so as to modify time-dependent phenomena and increase damping effects. The proposed concept is validated by designing artificial pads whose viscoelastic properties are either similar or more pronounced when compared to those of the human fingertip.
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Publication date	3 May 2010
Reference	2010 IEEE International Conference on Robotics and Automation
DOI	10.1109/ROBOT.2010.5509320

Title	**Tactile sensor based on LED-phototransistor couples**
Abstract	This paper present the preliminary results for a new tactile sensor developed within DEXMART project. The proposed tactile sensor is based on the use of LED-phototransistor couples and a deformable elastic layer. It aims to estimate both the normal and tangential components of the contact force. A prototype with 4 couples of devices has been realized and preliminary tested.
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Publication date	7 December 2009
Reference	Workshop on “Tactile Sensing” at 9th IEEE-RAS International Conference on Humanoid Robots
DOI	

Title	**Integrated mechatronic design for a new generation of robotic hands**
Abstract	In this paper, an overall description of the design of a robotic hand is discussed, with particular attention to the required sensory subsystem, its integration within the mechanical structure of the hand and the required control architecture. Different solutions for the joint configuration and the structure of the tendon network adopted for the transmission system are present together with three types of sensors applied on the finger and on the actuators. The integrated design of the hand finger and the sensors is reported and the motivations leading to this particular implementation are thoroughly addressed, taking into account both the mechanical constraints and the control requirements.
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Authors	Giovanni Berselli, Gianni Borghesan, Marco Brandi, Claudio Melchiorri, Ciro Natale, Gianluca Palli, Salvatore Pirozzi, Gabriele Vassura
Involved institution(s)	UNIBO, SUN
Publication date	9 September 2009
Reference	9th International IFAC Symposium on Robot Control
DOI	10.3182/20090909-4-JP-2010.00004

Title **Predicting the compliance of soft fingertips with differentiated layer design: A numerical and experimental investigation**

Abstract This paper describes the nonlinear Finite Elements Analysis (FEA) of soft fingertips for robotic hands in contact conditions. The purpose is to test the reliability of FEA when designing fingertips with differentiated layer design that is the adoption of a single elastic material, dividing the overall thickness of the pad into layers with different structural design (e.g. a continuous skin layer coupled with an internal layer with voids). The pads are shaped around a rigid core and their behavior is investigated under compressive contact loads. The applicability of various nonlinear hyperelastic constitutive models for predicting the pad behavior is explored under the hypothesis of large deformations. Two materials have been tested whose mechanical properties are determined experimentally. One of these materials can be used in rapid prototyping printers and its properties are presented for the first time. Experimental activity fully validates the proposed FEA models concerning homogeneous pads. At last two different and innovative pad geometries are proposed showing that FEA confirms to be a powerful tool for predicting the compliance of soft fingertips if the right hypothesis and simplifying assumptions are made.

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Publication date 22 June 2009

Reference 14th International Conference on Advanced Robotics

DOI http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5174682

Title	**Optoelectronic joint angular sensor for robotic fingers**
Abstract	The present paper reports the results of the development of a novel joint angular sensor conceived for integration in tendon-driven robotic hands and in data gloves used in virtual reality systems. The sensor is based on a couple LED/photodiode, mounted to two contiguous phalanges of a University of Bologna (UB) hand finger. When the joint between the considered phalanges flexes, the photocurrent measured by the photodetector changes with the angular displacement. An experimental model of the sensor is set up in order to select the optimal positioning of the components over the phalanges and an optical motion capture system is used to calibrate the sensor. The complete characterization of the sensor in terms of repeatability, linearity and noise presented in the paper together with its low cost confirm that the sensor can be effectively exploited both in feedback control loops for robotic systems as well as in data acquisition systems for virtual reality applications.
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Authors	Alberto Cavallo, Giuseppe De Maria, Ciro Natale, Salvatore Pirozzi
Involved institution(s)	SUN
Publication date	1 June 2009
Reference	Sensors & Actuators: A. Physical
DOI	10.1016/j.sna.2009.03.019

Title **Differentiated layer design to modify the compliance of soft pads for robotic limbs**

Abstract Most of robotic soft pads studied so far were made with a thick layer of homogeneous material shaped around a rigid core; their behavior has been widely investigated in the literature, mainly under compressive contact load, showing typical non-linear relationship between contact deformation and applied load (the so called power law). This paper proposes differentiated layer design that is the adoption of a single elastic material, dividing the overall thickness of the pad into layers with different structural design (e.g. a continuous skin layer coupled with an internal layer with voids). The purpose is to modify the actual pad compliance and the resulting power law; in particular, given the material and the allowable pad thickness, to increase the compliance with respect to a non structured pad. Some possible internal layer structures are described, compatible with rapid prototyping manufacturing. Their compressive behaviors are tested and comparatively evaluated showing that the concept can work and be exploited for useful application.

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Publication date 12 May 2009

Reference 2009 IEEE International Conference on Robotics and Automation

DOI 10.1109/ROBOT.2009.5152377

Title	**Minimally invasive torque sensor for tendon-driven robotic hands**
Abstract	The purpose of this paper is to present preliminary results on the use of a torque sensor based on a Bragg grating for torque control applications of tendon-driven mechanisms. Owing to the minimally invasive nature of optical fibres, one of the most promising applications can be the integration of the sensor into anthropomorphic robotic hands for accurate impedance or compliance control. In fact, the sensing element of the proposed torque sensor can be easily bonded directly to the tendon following its natural routing with a significantly reduced invasiveness with respect to conventional sensors. These are usually based on strain gauges, which are cumbersome and require additional mechanical components and interfaces in order to provide the necessary measurement, while the Bragg sensor is embedded into the optical fibre whose typical diameter is about 125 microns which allows its integration into the tendon itself. The experimental results presented here have been obtained on a simple test-bench realized by using off-the-shelf and cheap components conceived to demonstrate the potentiality of the sensor and its effectiveness in an actual compliance control scheme.
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Authors	Ciro Natale, Salvatore Pirozzi
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Publication date	22 September 2008
Reference	2008 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2008.4650610

Title	**Optoelectronic tactile sensor based on micromachined scattering wells**
Abstract	Preliminary prototypes of a sensing element (taxel) for a tactile sensor have been produced and calibrated. The device is based on the use of a couple of optical fibers. The first fiber emits infrared light in a well covered by a urethane foam and the second receives the light scattered by the surface of the covering foam internal to the well, whose intensity is related to the pressure applied on the external surface. The sensitivity of the taxel can be adjusted by acting on the distance between the two fibers. The minimally invasive nature of optical fibers makes the device attractive for a number of applications, e.g. virtual reality, robotics and motion capture.
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Publication date	28 June 2008
Reference	1st Mediterranean Photonics Conference
DOI	-

Title	**Advanced Bimanual Manipulation: Results from the DEXMART Project**
Abstract	**Dexterous and autonomous manipulation is a key technology for the personal and service robots of the future. Advances in Bimanual Manipulation edited by Bruno Siciliano provides the robotics community with the most noticeable results of the four-year European project DEXMART (DEXterous and autonomous dual-arm hand robotic manipulation with sMART sensory-motor skills: A bridge from natural to artificial cognition). The volume covers a host of highly important topics in the field, concerned with modelling and learning of human manipulation skills, algorithms for task planning, human-robot interaction, and grasping, as well as hardware design of dexterous anthropomorphic hands. The results described in this five-chapter collection are believed to pave the way towards the development of robotic systems endowed with dexterous and human-aware dual-arm/hand manipulation skills for objects, operating with a high degree of autonomy in unstructured real-world environments.**
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Expected publication date	26 March 2012
Reference	Springer Tracts in Advanced Robotics
DOI	ISBN 978-3-642-29040-4
Research domain covered	All

Title	**Modelling and control of the twisted string actuation system**
Abstract	The innovative actuation concept presented in this paper allows the implementation of powerful, simple, very compact and light-weight tendon-based driving systems, using as actuators small-size DC motors characterized by high speed and low torque. Due to its properties, this actuation system is very well suited for implementation in highly-integrated robotic devices like articulated robotic hands, and some preliminary design attempts for the implementation of such a device are presented in this paper. The basic working principle of this novel actuation system is introduced, and the constitutive equations of the system are given, together with their experimental validation. Driven by the necessity of controlling the actuation force in the robotic hand, the problem of tracking a desired force profile is tackled. With the aim of guaranteeing a high level of robustness against disturbances, a control algorithm based on a second-order sliding manifold has firstly been evaluated by means of simulations and then validated by experiments. The results obtained with the proposed controller prove its very low sensitivity to parameter variations and uncertainties while maintaining a low computational burden.
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Publication date	25 January 2012
Reference	IEEE/ASME Transactions on Mechatronics
DOI	10.1109/TMECH.2011.2181855
Research domains covered	New robotic technologies, Feedback control

Title	**Modeling, identification and control of tendon-based actuation systems**
Abstract	This paper deals with several aspects related to the control of tendon-based actuation systems for robotic devices. In particular, the problems of modeling, identification and control tendons sliding on curved pathways, subject to friction and visco-elastic effects, are investigated. Tendons made in polymeric materials are considered, and therefore hysteresis in the transmission system characteristic must be taken into account as an additional nonlinear effect because of the plasticity and creep phenomena typical of these materials. With the aim of reproducing these behaviors, a visco-elastic model is used for modeling the tendon compliance. Particular attention has been given to the friction effects arising from the interaction between the tendon pathway and the tendon itself. This phenomenon has been characterized by means of a LuGre-like dynamic friction model to consider the effects that cannot be reproduced employing a static friction model. A specific setup able to measure the tendon's tension in different points along its path has been designed in order to verify the tension distribution and identify the proper parameters. Finally, a simple control strategy for the compensation of these nonlinear effects and the control of the force applied by the tendon to the load is proposed and experimentally verified.
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Publication date	10 November 2011
Reference	IEEE Transactions on Robotics
DOI	10.1109/TRO.2011.2171610
Research domains covered	New robotic technologies, Feedback control

Title	**Experimental evaluation of postural synergies during reach to grasp with the UB Hand IV**
Abstract	In this paper, the postural synergies configuration subspace given by the fundamental eigengrasps of the UB Hand IV (University of Bologna Hand, version IV) is derived through experiments. This study is based on the kinematic structure of the robotic hand and on the taxonomy of the grasps of common objects. Experimental results show that it is possible to obtain grasp synthesis for a large set of objects both in the case of precision or power grasps by using only a very limited set of dominant eigengrasps. The tasks here presented are planned with an initial hold of the hand followed by reach and grasp phases, that are unique for each object/grasp combination, during which the robotic hand posture evolves continuously within a subset of the hand configuration space given by the two predominant eigenpostures. The paper reports the method adopted to define from experiments the postural synergies for the UB Hand IV and the results of the grasp tasks performed adopting the defined synergies.
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Publication date	25 September 2011
Reference	2011 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	10.1109/IROS.2011.6094671
Research domains covered	New robotic technologies, Feedback control

Title	**The twisted string actuation system: Modeling and control**
Abstract	This paper describes a novel actuation system for very compact and light-weight robotic devices, like artificial hands. The actuation concept presented here allows the implementation of powerful tendon-based driving systems, using as actuators small-size DC motors characterized by high speed and low torque. After the presentation of the basic concept of this novel actuation system, the constitutive equations of the system are given, validated by means of laboratory tests. Moreover, the problem of tracking a desired actuation force profile is taken into account, considering as load a mass-spring-damper system. A control algorithm based on a second-order sliding manifold has been firstly evaluated by means of simulations, and then validated by experiments. This output-feedback controller has been chosen to guarantee a high level of robustness against disturbances, parameters variations and uncertainties while maintaining a low computational burden.
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Publication date	6 July 2010
Reference	2010 IEEE/ASME International Conference on Advanced Intelligence Mechatronics
DOI	10.1109/AIM.2010.5695720
Research domains covered	New robotic technologies, Feedback control

PUBLICATIONS COVERING SEVERAL RESEARCH DOMAINS

Title	**Friction and visco-elasticity effects in tendon-based transmission systems**
Abstract	In this paper, the characterization of the force distribution along a tendon sliding along a curved pathway, subject to friction and visco-elastic effects, is investigated. In order to have a better understanding of the system behavior, a specific setup able to measure tension forces in different points along the tendon's path has been built. Experimental data collected by measuring the tendon tension forces during both the pulling and the release phase are presented, and theoretical models reproducing the tendon behavior with increasing fidelity are proposed. In particular, the friction arising from the interaction between the tendon pathway and the tendon itself is characterized by means of a LuGre-like dynamic friction model. The introduction of a dynamic friction model allows to reproduce in simulation some effects arising during experimental activities that cannot be reproduced employing an equivalent static friction model. Moreover, the adoption of tendons made by polymeric fibers introduces hysteresis in the tendon transmission characteristic due to the plasticity and creep phenomena typical of these materials. With the aim of reproducing this behavior, a visco-elastic model is used for modeling the tendon compliance.
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Publication date	3 May 2010
Reference	2010 IEEE International Conference on Robotics and Automation
DOI	10.1109/ROBOT.2010.5509987
Research domains covered	New robotic technologies, Feedback control

Title	**Benchmarking dexterous dual-arm/hand robotic manipulation**
Abstract	DEXMART is a European large-scale integrating project (IP) funded in the Seventh Framework Programme. The acronym stands for DEXterous and autonomous dual-arm/hand robotic manipulation with sMART sensory-motor skills: A bridge from natural to artificial cognition. The project is focused on artificial systems reproducing smart sensory-motor human skills, which operate in unstructured real-world environments. The emphasis is on manipulation capabilities achieved by dexterous and autonomous, and also human aware dual arm/hand robotic systems. The challenge is to allow a dual-arm robot including two multi-fingered redundant hands to grasp and manipulate the same objects used by human beings. The objects shall be allowed to have different shape, dimension, and weight. As compared to research and development on humanoid robots in Asia, the focus in Europe is rather on useful service tasks than pure social entertainment. Applications of robot companions range from a helper in family homes to executing tasks in offices, public environments and in professional services. Another important application area is the assistance to elderly and mobility-impaired persons that could be helped to achieve some independence from full time caring personnel. For this scenario the robot has to reach almost the same manipulation skills as a human being. The realisation of a truly dexterous and autonomous dual-arm/hand manipulation system is still an open research issue: bimanual manipulation is such a complex task combining different strategies, constraints, goals, advanced sensing and actuating technologies, requiring new concepts and design of artificial cognitive systems. In this context the question is raised how to measure and evaluate the progress of one's own research and how to compare the results with others. This is especially difficult if one wishes to evaluate the performance of real, physical, intelligent robot systems interacting with the real world.
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Publication date	26 September 2008
Reference	Workshop on "Performance Evaluation and Benchmarking for Intelligent Robots and Systems" at 2008 IEEE/RSJ International Conference on Intelligent Robots and Systems
DOI	http://elib.dlr.de/55501/
Research domains covered	All

PUBLICATIONS COVERING SEVERAL RESEARCH DOMAINS

FORTHCOMING PUBLICATIONS

Title	**A robotic joint with embedded optical position sensor for anthropomorphic robot hands**
Abstract	In this paper, the design of an optical position sensor integrated into a miniaturized tendon-driven robotic joint is presented. This joint has been conceived for the implementation of the UBH-IV (University of Bologna Hand, version IV) fingers. The position sensor working principle is based on the modulation of the light radiant power flux that goes from an InfraRed Light Emitting Diode (IR LED) to a PhotoDiode (PD) through a section-varying canal integrated into the joint itself. The LED and the PD are fixed on one of the links that compose the robotic joint, while the canal is integrated into the other link. The paper reports the details of the sensor working principle, the integrated design of the miniaturized robotic joint with embedded position sensor and the experimental evaluation of the proposed device on a force/position control loop. Finally, a preliminary prototype of the UBH-IV finger built using the proposed joint with embedded position sensor is presented.
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Reference	IEEE/ASME Transaction on Mechatronics
Research domain covered	New robotic technologies

Title	**Planning and control during reach to grasp using the three predominant UB Hand IV postural synergies**
Abstract	In this paper, the postural synergies configuration subspace given by the fundamental eigengrasps of the UB Hand IV (University of Bologna Hand, version IV) is derived. The paper reports the method, based on the kinematic structure of the robotic hand and on the taxonomy of the grasps of common objects, adopted to define the postural synergies from experiments. Moreover, the temporal weights of the first three synergies are obtained for planning grasps and the control strategy that drives the hand exploiting postural synergies is further described. The tasks here presented are planned with an initial hold of the hand followed by reach and grasp phases, that are unique for each object/grasp combination, during which the robotic hand posture evolves continuously within a subset of the hand configuration space given by the three predominant eigengrasp. The experiments confirm that it is possible to obtain grasp synthesis for a large set of objects both in the case of precision or power grasps and they show the improvement obtained by using three dominant eigengrasps instead of two.
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Research domain covered	New robotic technologies, Feedback control

Title	**A grasping force optimization algorithm for dexterous robotic hands**
Abstract	The problem of grasping force optimization for a robotic system equipped with multi-fingered hands is considered in this paper. This problem is cast in a convex optimization problem, considering also joint torque constraints. A solution suitable for an online implementation, which allows a sub- stantial reduction of the computational load by dynamically decreasing the number of active torque constraints is proposed. Moreover, for the case of a bimanual manipulation system, a sub-optimal single-hand optimization algorithm is presented and compared with the optimal one. The effectiveness of the described methods has been tested in a simulation case study.
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Research domain covered	Feedback control

Title	**Visual grasp planning of unknown objects using a multi-fingered robotic hand**
Abstract	A method for fast visual grasping of unknown objects with a multi-fingered robotic hand is presented in this paper. The algorithm is composed of an object surface reconstruction algorithm and a local grasp planner, evolving in parallel. The reconstruction algorithm makes use of images taken by a camera carried by the robot arm. A virtual elastic reconstruction surface is placed around the object. The surface shrinks toward the object until some points intercept the object visual hull. Then, local rejection forces are generated to compensate the elastic forces. At the equilibrium, the surface assumes the shape of the object. Running in parallel to the reconstruction algorithm, the grasp planner moves the fingertips on the current available reconstruction surface, towards points which are optimal (in a local sense) with respect to a number of indices weighting both the grasp quality and the kinematics configuration of the hand. This method, referred as parallel visual grasp, may represent a valid candidate for applications where online grasp planning is required. A number of experiments are presented, showing the effectiveness of the proposed approach.
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Reference	IEEE/ASME Transactions on Mechatronics
Research domain covered	Feedback control

Title	**A miniaturized optical force sensor for tendon-driven mechatronic systems: Design and experimental evaluation**
Abstract	In this paper, an innovative sensor for the control of a tendon-driven mechatronic system is presented. The proposed system measures the tendon tension using optoelectronic components properly selected and mounted on a suitably designed compliant frame. With respect to conventional solutions, like strain-gauge or Bragg-grating based force sensors, this solution presents several advantages, mainly in terms of compactness, simplicity of both implementation and conditioning electronics. The proposed sensor exploits the properties of optoelectronic components with a narrow angle of view to measure the very small deformation of a compliant frame caused by the tendon tension. The sensor can be placed at the tendon ends as such as in any position along the tendon. The paper reports the basic working principle and the procedure for the optimal design of the sensor together with the results of an experimental testbench where two of the proposed sensors are used for the feedback control of a tendon-driven mechatronic system.
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Reference	Mechatronics
Research domain covered	New robotic technologies

Title	**Attentional human-robot interaction in simple manipulation tasks**
Abstract	We present a robotic control system endowed with attentional mechanisms suitable for balancing the trade off between safe human-robot interaction and effective task execution. These mechanisms allow the robot to increase or decrease the degree of attention toward relevant activities modulating the frequency of the monitoring rate and the speed associated to the robot movements. We consider pick-and-place and give-and-receive attentional behaviors.
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Reference	7th ACM/IEEE International Conference on Human Robot Interaction
Research domain covered	Feedback control

Title	**Data fusion based on optical technology for observation of human manipulation**
Abstract	The adoption of the human observation is becoming more and more frequent within the imitation learning and programming by demonstration approaches (PbD) to robot programming. For robotic systems equipped with anthropomorphic hands, the observation phase is very challenging and no ultimate solution exists. This work proposes a novel mechatronic approach to the observation of human hand motion, during manipulation tasks. The strategy is based on the combined use of an optical motion capture system and a low-cost data glove equipped with novel joint angle sensors, based on optoelectronic technology. The combination of the two information sources is obtained through a sensor fusion algorithm based on the Extended Kalman Filter (EKF) suitably modified to tackle the problem of marker occlusions, typical of optical motion capture systems. This approach requires a kinematic model of the human hand. Another key contribution of the paper is a new method to calibrate this model.
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Expected publication date	1 March 2012
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Research domain covered	Observation, interpretation, learning and modelling

Title	**On the design of anthropomorphic dexterous robot hands: The UB Hand evolution**
Abstract	Research in the field of robot hands has a quite long tradition. Nonetheless, after more than 50 years of developments and despite the relevant number of different prototypes proposed by research centers and industrial companies, none of those is actually used for continuous and useful applications. In practice, the only manipulation devices actually employed in the industrial scenario are relatively simple grippers or complex end-effectors designed and built for a single specific task. Recently, it seems that a renewed interest for 'general purpose' devices, such as anthropomorphic hands, is growing both in the industrial and research contexts. In this paper, the authors report and briefly discuss the current trends and 'hot topics' in the design of robot hands, as derived from more than 20 years of personal experience in this fascinating, though very complex, area.
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Research domain(s) covered	New robotic technologies