INTERNATIONAL JOURNAL OF ADVANCED ROBOTIC SYSTEMS

HIGHLIGHTS

From the Managing Editor

Dear Reader,

My publishing team and I are delighted to present to you the International Journal of Advanced Robotic Systems' (IJARS) Highlights, a promotional feature showcasing all IJARS's activities and goals for the years 2012/2013. The feature includes a selection of papers by some of our most prominent authors which you can browse through starting from the back cover.

With the Highlights feature we wanted to draw your attention to the invaluable experience we gained through the years, the changes we introduced to the journal, the people we met, the research we published and disseminated freely. Above all, we wanted to unveil the hard work "behind the scene" of such a fast growing project.

IJARS would not be such a successful publication without the continuous support of our authors and reviewers, our international Editorial Board and the Publishing Staff (Anja Filipovic, Ivana Zec), the very backbone of this project.

"... you just can't differentiate between a robot and the very best of humans."

-Isaac Asimov, I, Robot

All of our staff and collaborators are doing their very best to make this journal a one-of-a-kind Robotics resource, and for that I am thankful. With an eye to the future, I am confident these fruitful collaborations will continue and grow, serving the journal's mission in the years to come.

Natalia Reinic

Contents

A Reversed Approach to Covering the Science of Robotics

THE INTERNATIONAL JOURNAL OF ADVANCED ROBOTIC SYSTEMS IS THE ONLY ISI CREDENTIALED OPEN ACCESS JOURNAL IN THE FIELD OF ROBOTICS, DEDICATED TO FREELY ELEVATING SCIENCE WITHIN THE COMMUNITY

Currently in its 10th consecutive year and volume, this cross-field journal covers all aspects of Robotics sciences with original articles that include invited feature articles, review articles and regular papers. By making all articles freely available and reducing the barriers that restrict access to knowledge, IJARS maximises its scientific dissemination and impact within scientific communities worldwide.

In 2012, the International Journal of Advanced Robotic Systems lived through several developments that strengthened its scientific impact and caught the attention of leading roboticists exploiting established research fields, as well as emerging trends and cross-discipline applications.

With the aim to align the journal's scope and topics to the robotic communities' demand for a comprehensive yet in-depth publication, a new approach to subjects featured in the journal was set down. The hard working team behind this unrivalled journal introduced topics related to distinct areas of research within Robotics, united in a single cross-subject journal. Ranging from purely mechanical aspects of robot research for industrial development and application to designs, softwares and engineering of assistive and personal robots, readers are now given an unprecedented take on Robotics sciences for a multifaceted approach to the latest trends in the field.

The changes introduced in 2012 have set new standards of quality in terms of published articles, peer-review process, and scientific relevance.

By acknowledging the invaluable feedback of our editors, authors, readers and industry professionals, the team behind IJARS was able to translate the input provided by all stakeholders into a successful business model reflecting a reversed approach to traditional Robotics journals.

In 2013, to push further IJARS's novel concept, 14 topics have been introduced now grouping together singular subjects concerning a research area. Moreover, topic specific Editorial Boards comprised of field specialists were formed to funnel original and relevant research in their field of action. The new formula is proving to be as successful as ever, making this journal an excellent resource for an already wide readership spread across all continents and active in Robotics labs, companies and academia.

Valuing the positive feedback on the journal's new format, the team now brands its philosophy upon readership demands for multidisciplinary quality research and current industry interests. That's what brought further assessments on defining this year's topics according to the latest research trends and newly developed areas of Robotics application.

In 2013, IJARS introduces 14 topics that group into single units a variety of subject-related areas of theory and application.

Topics for 2013

- Vision Systems
- Robot Manipulation and Control
- Human Robot/Machine Interaction
- Micro-Nano Robotics
- Humanoid Robotics
- Multi-Robot Systems
- Field Robotics
- Medical Robotics
- AI in Robotics
- Climbing and Walking Robots
- Service Robotics
- Bioinspired Robotics
- Robot Sensors
- Mobile and Distributed Robotics

2012 in numbers

42 Topics

54 Topic Editors + Co-Editors

376 Editorial Board Members

598 Reviewers

2012 in numbers

262
published papers

Collaborators from
56
different countries

In this view, the journal now enables submitting authors to choose a specific topic of interest to contribute their latest research to and provides its readers with a platform that grants free access to a large database of highest quality articles to be filtered by listed Robotics subjects. As a result of such effort, IJARS has published online a total of 468 up-to-date (2012/2013), including articles from some of the most authoritative professionals in Robotics as highlighted in the Selection of Papers section. Compared to the journal's article output in previous years, this number is to grow exceeding both the team's and industry expectations now provided with an invaluable and ample resource for Robotics research papers. To facilitate science dissemination beyond traditional platforms comprising databases and repositories, new ways of communication are looked upon and endorsed.

By actively taking part to social media communities to exchange opinions, news, overviews of some of the most exciting research articles, IJARS placed itself on the forefront of new media science dissemination.

Networking with the Robotics Community on Social Media

IEEE @IEEEorg 27 Mar
RT **@ARS_Journal** Harnessing **#robot** research a searching task http://bit.ly/11Gc5Kf—**@physorg_com**

Fabio Tampalini @tampalini 14 Mar
The RoboTechnology Chronicle is out! http://paper.li/tampalini/1308390033… > Top stories today via **@NAOAcademics @ARS_Journal @robotsblog**

Joao Fabro @joaofabro 29 Jan
Interesting question....RT **@ARS_Journal**: Roboethics: Liability Concerns Put the Brakes on Driverless Cars http://flip.it/ey8J6 via **@WSJ**

Ars Journal @ARS_Journal 14 Mar
Hooman Samani On Kissing With Robots http://huff.to/YaTJhq—**@HuffPost**. Ars J's **#OA** Lovotics paper by Dr Samani http://bit.ly/JImzOo **#win**

Ars Journal @ARS_Journal 7 Feb
New paper in ARS: 'Passive Ankle-Foot Prosthesis Prototype with Extended Push-Off' http://bit.ly/YVvkBR—free to read and download!

IJARS Team

IJARS's team keeps looking for opportunities to work together and collaborate on a personal level with science communities and Robotics labs

This gives trade media a direct gateway to harvest IJARS's content, resulting in news articles and interviews with authors featured in Robotics media outlets.

The business growth incentivizes the team to raise the stakes and set the quality bar higher as only sky is the limit. The goals for 2013 are high reaching than ever in terms of utmost quality output, also expecting the journal's current impact factor of 0,375 to increase. Wishing to explore all ongoing trends and meet industry's current needs within topical research areas, IJARS's team keeps looking for opportunities to work together and collaborate on a personal level with science communities and Robotics labs. To encourage even stronger ties with its Editorial Board members, reviewers and all authors, members of the team will be attending international Robotics conferences and meetings to showcase the journal's latest edition and meet personally with its international scientific collaborators.

The team has successfully built professional relationships with IJARS's Editorial Board, the very backbone of this project.

To view the complete list of IJARS's Editorial Board members, please visit our official website.

NATALIA REINIC
Managing Editor

IVANA ZEC
Publishing Process Manager

ANA NODILO
External Relations

SASA MARCAN
Library and Information Service Coordinator

VIKTORIJA ZGELA
Senior Commissioning Editor

PETRA NENADIC
Senior Commissioning Editor

ANJA FILIPOVIC
Publishing Process Manager

MARTINA SIROTIC
Graphic Designer

BOJAN BAJIC
Marketing Manager

SARA UHAC
Managing Director

Our Collaborators

The International Journal of Advanced Robotic Systems relies upon a worldwide network of collaborators actively involved in making this journal a highly successful publication within the field of Robotics.

Throughout the years, the hard-working team behind IJARS has successfully built professional relationships with collaborators comprising Editorial Board members, reviewers and authors to whom this journal's team is thankful and proud of.

Taking a personal approach to all communication with stakeholders and inviting collaborators to share their feedback on all things, IJARS's team is enabled to support and be supported in all efforts to raise the journal's profile.

To promote further this mutual engagement, a series of special activities have been taking place in the past year.

Connecting our collaborators with trade media

More than ever before, the latest developments within Robotics have caught the attention of many outside the realm of this exciting science field. From mainstream media and those interested in what novel Robotics applications are all about to fellow roboticists looking at their peers' work, interviews with professionals in the field shed light on the latest developments in particular research areas. In this view, the team encourages and facilitates authors, editors, members of IJARS's Editorial Board to share their insights and views on Robotics and their latest research effort through interviews published in Robotics magazines, science news outlets and shared via IJARS's owned social media channels.

Promoting Robotics to our local community

In the spirit of promoting free knowledge and the latest advancements in Human-Robot Interaction, the team behind IJARS organized Interact2012, a one-day event held on September 3rd, 2012, in Rijeka, Croatia. The primary scientific objectives of Interact2012 concerned the exposition of an extensive and comprehensive overview of current advances made in the field of HRI by 3 of the top tier HRI roboticists worldwide. The event was attended by a large number of professionals involved in Robotics as well as those interested in robot-related applications.

Q&A

JÜRGEN LEITNER

Visual Object Localisation in Humanoid Robots

An Interview with Mr Jürgen Leitner

Mr. Jürgen Leitner at the Dalle Molle Institute for Artificial Intelligence (IDSIA) in Lugano, Switzerland, talks to AZoRobotics about visual object localisation in humanoid robots. Mr. Leitner's study was published in the peer-reviewed International Journal of Advanced Robotic Systems by the open access publisher InTech.

Interview conducted by Kal Kaur on
azorobotics.com

Can you tell us about your on-going research at IDSIA?
At the IDSIA Robotics Lab, we are proud owners of the European-developed iCub humanoid robot.
The platform provides an anthropomorphically designed system with high degrees of freedom (DOF), which allows for interesting research into topics such as artificial intelligence, robot learning and more practically object manipulation.
This research is part of the European Commission-funded IM-CLeVeR FP7 project and is placed at the intersection of neuroscience, machine learning, computer vision and robot control.

What makes the iCub humanoid robot a good platform for object manipulation research?
The design of the iCub comprises a package that tightly integrates sensors and actuators. For example, the arm and hand provide a very detailed human-like design with almost as many DOFs.
The tight integration of artificial intelligence (AI) with a "body"—known as embodiment—allows us to draw more parallels with humans. For example, in the field of chess playing, researchers have made significant advances in the field of AI (e.g., IBM's Deep Blue computer).
These computers have been able to match (and even eclipse) human performance. If you contrast this with the physical movement of chess pieces across a board, you notice that there is plenty of room to improve robot abilities.
Currently, virtually no robots are able to perceive the chessboard, plan and then execute motions to move one chess piece to another position. But every child can perform this action without a problem.

Why is perception for robotic systems a difficult issue to solve in robotic systems?
To allow for manipulation, the object first needs to be detected and localised. Usually this localisation is performed by using stereo vision approaches, which will give a position estimate with respect to the eyes. In a humanoid robot, the eyes are usually not at the same position as the starting point of the arm. Therefore, a transformation based on the kinematics of the robot is necessary to calculate the position relative to a common reference frame. In the iCub, the origin of this global frame is in the hip.

Why is spatial understanding critical for perception and reasoning in robots?
Perception generally is very important in creating autonomous robots. A robot needs to sense its environment in order to make decisions and perform the right actions.
Spatial perception is of importance for obstacle avoidance, navigation and planning. This has been mostly of interest for mobile robots, but it is also important for a humanoid robot.
Take, for example, a humanoid robot that should clean a table in your house. This robot needs to have some understanding of how far things are away (Do I have to move to pick something up?) and how the objects are placed relatively to each other (Can I pick up the tea box or do I have to first remove the cup which is blocking my reach?).

Can you discuss the approach to your latest research on learning object localisation from vision on a humanoid robot?
The novelty of our approach is to use machine learning techniques to "learn" a direct correlation between the pixels in the two cameras and the robot's position in a useful, global reference frame.

Can you discuss the two main biologically-inspired approaches for position estimates?
In our resent research, we used two different methods to "learn" the direct correlation. One is called Genetic Programming (GP), which is based on the principles of evolution in biological systems.
The other method is based on Artificial Neural Networks (ANNs), which are a simplified model of how the neurons in our brain might work. Both of these methods are generally able to represent arbitrary functions that correlate the system inputs with its outputs.
By providing these systems a given dataset with known inputs and outputs, the systems are able to train and therefore "learn" the correlation.

What are the advantages to applying ANN and GP and for position estimates?
By using these machine-learning methods we are able to find the correlation of pixels to 3D Cartesian coordinates without any knowledge of the camera parameters (which are usually determined by calibration) and without the need of a kinematic model.
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control tend to have errors of a few centimeters, even with thorough camera and kinematic model calibration. Our approach on the other hand requires a given training set.
This takes quite a long time to collect by a human; therefore, we used another robot—a very precise industrial robot arm—to provide the ground truth to our humanoid. In the future we hope that the humanoid can learn completely autonomously by using either haptic feedback or landmarks.

Can you discuss the 'stereo vision' problem and how you have used this in your current approach to learning spatial object localisation from vision?
The stereo vision problem is to estimate the position of an object relative to the camera, given that you have multiple images from different angles.
These images can come from multiple cameras or from one camera that is moved between shots. However, the usual approach has some issues with the camera setup on the iCub, which allows the vergence of the eyes to change.

What makes the 'stereo vision' module the most accurate localisation tool for the iCub?
The stereo vision module provided by the Italian Institute of Technology in Genoa uses various interconnected modules to provide 'accurate' estimates.
First, it uses calibrated models of both the eyes and the kinematics of the robot. Second, it uses a feature-tracking approach to improve motion detection. Finally, it uses a stereo disparity map to further improve the correlation and to estimate the motion of the head.
All of these things together are a nice feat of engineering but do require a lot of computational resources.

What calibration tasks have you used to investigate special perception in your current study?
As mentioned before, we have not performed a precise kinematic model or camera parameter calibration. In our approach the two learning systems (GP and ANN) do not have any prior knowledge about these.
In fact, through training, they learn to estimate a function that contains both of these models. Of course, to collect the ground truth we have to first measure the distance of the industrial arm to the robot.

How does the robot collect data about object localisation and how is it interpreted?
The iCub tries to locate a small and bright red object. This is done to reduce the computer vision burden during the training.
The object is placed in a shared workspace by

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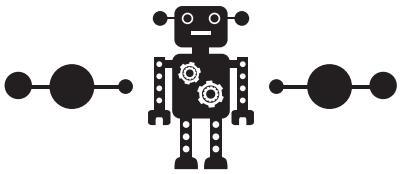
a Katana industrial robot arm with millimeter accuracy. (This introduces a few more challenges, like preventing the two robots from colliding).
While the iCub moves about it collects the data of its encoders (joint positions) of the 9 relevant joints (hip, neck, eyes, etc.) and the position of the red object in both the left and right images.
It combines these with the location ground truth provided by the Katana and this way builds a training set.
Once the learning is finished, the iCub uses the learned ANN- or GP-generated formula to localise any object in its visual space.

What were the main findings from your research?
We have a method that allows the robot to estimate its internal models (kinematics and camera) in a way to use with object localisation.
The main point was to see that this is possible to learn without the need of external calibration, and can achieve very similar results with our lightweight approach.

How do you plan on improving this approach for more accurate localisation of objects in a 3D space by using humanoid robots?
There are a few ideas, we have to improve the system's accuracy. One obvious way is to create better datasets to learn from, e.g., more data, less outliers, more positions. Another way would be to improve the learning (e.g., by knowing where the errors are large and where they are small and to take this knowledge into account).
In the end, we would like to have our iCub learn online while the robot is controlled by a human or any controller or even just by itself like a human.
Another idea is to change the frame to localise in. Currently this is operational space of the robot (Cartesian 3D space). This comes from the very well-implemented operational space controller that runs on the iCub and is the de facto standard of operation.
On the other hand, if you look at humans, we do not have a very precise Cartesian world model, we have trouble estimating distances (even of positions of a glass on a table), yet we don't have trouble picking it up.
So one thing we are looking into is combining the sensory side with the motor side and predict the position, e.g., in an ego-sphere around the robot, or even in the joint space of the robot.

How do you see this technological advancement extending the use of robotic systems into areas of application that will allow humanoids to co-exist and work with humans?
Very interesting question. It's hard to predict the future, but I strongly believe that for robots to enter domains where they need to co-exist or co-work with humans, better sensorimotor coordination is required. This will allow them to adjust to the environment in a more natural and more predictable way (for the human).
I hope that my research on spatial perception, together with other research at IDSIA and the whole iCub community, will improve some of the issues pertaining to object manipulation and interaction.

VELJKO POTKONJAK



Topic Editor of Biomechanics and Robotics (2012)

Why did you decide to dedicate your career to researching Robotics, Biomechanics in particular?
This is a rather interesting question—why people are so fascinated with robots. It really deserves an answer going beyond my own research interests. One can notice that this fascination, regardless of being positive or negative, deepens as robots become more human-like. In ancient myths one finds stories about artificial men. For instance, a Greek legend speaks about the giant Talus, made of brass, who guarded Crete against the intruders. Later on in history, the craftsmen used to demonstrate their skills by creating human-like mechanisms—dolls moving in a human manner, such as a violin player; they even created walking machines. The term robot was first used to denote an artificial man. More recently, in the sixties and the seventies, the world's first truly scientific project in Robotics was conducted by the Institute M. Pupin in Belgrade and financed by the American NSF. It concerned anthropomorphic robots, bipedal gait, and related issues which all fitted the scope of artificial man. Later, the fact that various industries were recognized as a promising and profitable marketplace to apply Robotics expertise and gained experience within research areas, turned the interests of the Robotics community and the focus of research towards a more commercial pathway to development. Anthropomorphic robots were almost forgotten except in a few research centers, like the Waseda University in Japan. Just when HONDA presented its humanoid to the public many roboticists regained interest in human-like systems. It opened the eyes of the Robotics

community and at that moment the race within the field of humanoid robot development kicked off. Robots are becoming more and more human-like, hence the interest for Biomechanics and neurosciences is rapidly increasing. Also, this chase towards human resemblance is currently forced to limits where it is reasonable and ethical to question this tendency.

One may finally conclude that deep within the human nature there is an always present, built-in, desire to create the copy of himself. Perhaps I was driven by the same instinct transformed into rational scientific work.

Talking about Biomechanics as a discipline, it appears it partially overlaps with other disciplines closely interlinked to Biomechanics, such as Biomimetics, Biological Engineering or Mechanobiology. Can you tell us what are the characteristics that distinguishes Biomechanics from closely-related fields of research?
This is a tricky but important question. There are multiple terms to describe some fields of research within Robotics, sometimes these terms are necessary and sometimes it's just fancy words used without a defined purpose. Let me mention a few terms that in some cases overlap, depending on how someone understands them: anthropomorphic robot, humanoid robot, anthropomimetic robot, musculoskeletal robot...

The same thing applies to those terms you mentioned in your question. Perhaps this is normal in situations when new scientific fields are being exploited and are still undefined.

So, let me explain how I understand Biomechanics. Mechanics (with its branches kinematics and dynamics) is the science that explores the phenomenon of motion. Biomechanics studies the motion in biological systems. This includes the "external" motion of human or animal body, i.e. movements of the skeleton driven by muscles, and the "internal" motions like the bloodstream, heart, etc.

At this level of development, Robotics is interested in mimicking external human motions in order to achieve better maneuverability and efficiency in manipulation, better stability in walking, and enhanced performances during coordinated movement activities present in every-day living, sports, etc.

In Biomechanics, detailed models of human kinematic and dynamic properties of arms, hands, fingers, and legs are created. These models are needed to understand which properties of human movement are intrinsic—caused by muscles, tendons, ligaments and bones—and which are controlled by the nervous system. Resulting models are used in the construction and control of novel robotic systems, including prosthetic hands and robotic arms and legs. Commercially, what are these novel robotic systems used for?
The "standard" robotic construction follows the machine-building principles. It consists of a number of single-degree-of-freedom joints, each joint being driven by a standard bidirectional motor. For such systems, roboticists developed computer procedures for the formation and solution of the kinematic and dynamic models. These algorithms were based on generalized coordinates and Analytical Mechanics. They opened the way to efficient simulation, model-based control, and CAD. The control was rather advanced but still following classical engineering methods.

When the researchers turned to robot structures that mimicked the human paragon, the anthropomimetic robots, new and difficult problems came to life—bio-inspired skeletons and muscle systems did not obey to any engineering principles.

Multi-degree-of-freedom joints introduced problems in measuring

It will be soon when robots will feature some human-like reactions, something that could resemble emotions. But all these abilities will still be a matter of programming.

the position. Artificial muscles, based either on electrical motors or pneumatics, generated difficulties in control. Issues resulted from the features of the bio-inspired muscle system: first of all, the fact that one muscle crosses over several rotation axes directly affects them; secondly, some motion can be equally performed using different muscles. Thus, the "unpleasant" problem of kinematic and drive redundancy appears. To model such systems, researchers had to give up the "classical" approach based on generalized coordinates and Analytical Mechanics and turn to general-purpose software packages: for instance, Blender to shape the bones and Bullet to solve the skeleton dynamics. Of course, this possibility implies an immense amount of work during the preparatory stage. In addition, the used algorithms are purely numerical allowing for simulation, but the absence of analytical features prevents any model-based control. Hence, the control of the bio-inspired robots could not be developed based on classical approaches. It needed the cognitive approach based on learning, where the researchers entered the AI field with all its open questions. The definite answers to complex problems of modeling and controlling the anthopomimetic robots are still looked for. This is the reason for increased interest in Biomechanics, a field expected to provide the answers.

In spite of all mentioned serious problems, the idea to make a truly human-like robot is sufficiently inspiring to keep the researchers on this track. It is expected that future robots will move in human-oriented environment, closely cooperating with humans. It is assumed that for such tasks the human-likeness is an ultimate solution.

Biomechanic systems impact and directly contribute to science and society. For example, its applications in the medical field enable executions of new procedures that were not possible before; its employment in search and rescue Robotics facilitates a faster detection of survivors while reducing the risk of injury for the search and rescue personnel. What other industries rely on Biomechanic principles or applications?
Note that Biomechanics is not the only bio science whit an influence on engineering developments and solutions. When control issues in different technical fields became extremely complex and hard to handle applying standard methods, the idea was to use the principles that the Central Nervous System uses when addressing motion and beyond. That is how scientists came to rely on Artificial Intelligence. AI elements, just like expert or knowledge-based systems, neural networks, neuro-fuzzy systems, machine learning, etc. are now present in many engineering applications. So, the "learn-from-humans" principle is widely promoted, thus the rising interest for bio sciences.

Can we say we are using nature's genius to create advance robotic lives? Does that mean we will soon have robots capable of imitating human actions, reactions, even emotions?
The answer to the first question

is positive just in part—the biological principles are mimicked in order to achieve enhanced performances but the systems we currently create are still very far from the perception of having "robotic lives" around us.

The answer to the second question is fortunately negative. It will be soon when robots will feature some human-like reactions, something that could resemble emotions. But all these abilities will still be a matter of programming.

So, there is no threat that robots will replace or eliminate humans. Let me elaborate this. The article "How Far Away is Artificial Man", published in IEEE Robotics and Automation Magazine, in March 2001, by T. Fukuda, R. Michelini, V. Potkonjak, S. Tzafestas, K. Valavanis, and M. Vukobratovic, states the three key features of the future artificial man: human-like motion, human-like intelligence, and human-like communication. Regarding the first feature, human-like motion, in order to achieve a truly competing artificial body, new motor systems and their control have to be developed to allow the creation of efficient artificial muscles. Such motor units are still not available but it is a matter of time before they do become available. New control concepts will also be necessary. Biomechanics can teach roboticists a lot in this sense. The third feature, human-like communication, although closely related to human-like intelligence, can be discussed separately. This feature does not impose insolvable problems. Speech communication, meaning speech recognition and generation, is close to reality. Gestural communication is a tougher hurdle to overcome but advanced vision systems that can recognize the position of the body (arms, head, etc) and the facial expressions, will soon provide the foundation for such human-like communication. The emotions mentioned in your question can be mimicked, as part of gestural language, while the true emotions based on chemistry will not be achieved. Finally, one sees that the second feature, human-like intelligence, is the weak point, the bottleneck. In spite of high expectations, artificial intelligence is progressing slowly. Although it is not popular to say, artificial intelligence is still and probably will keep being a matter of searching databases.

The larger the database capacity and efficient search algorithms, the more intelligent the system is.

It seems that the key breakthrough in this field hasn't been achieved yet. That is why a lot of effort is being invested in exploring the functions of the Central Nervous System.

The above mentioned article on artificial man identifies a threat resulting from this delayed engineering progress towards the "perfect robot", also addressing

the fast progress of some other sciences like biology with all its branches. The authors state that engineers have to hurry up since it is not long before biologists create perfect robots, cloned and genetically engineered to be skilled house helpers, strong manual workers, efficient and merciless soldiers... Although I am aware of all related ethical problems, I think that such situation is still possible. Who is going to win this race, engineers or biologists?

AMIR SHAPIRO

IJARS Editorial Board Member

You are the director of the Robotics Lab at Ben-Gurion University in Israel and with your team you have designed some amazing robots. How did your career start? What is it that made you choose Robotics as your career path?
The field of Robotics is a multidisciplinary field, where a roboticist gets to work both on the mechanical and electrical hardware and on the software of the robot. It is a field where one can build an entire system and finally watch it move. This is basically what drew me towards Robotics: the ability to work on different interesting and challenging subjects while at the end of the process there is a result —a fully functioning robot. The satisfaction of watching the robot complete its task gives me the drive to start a new project.

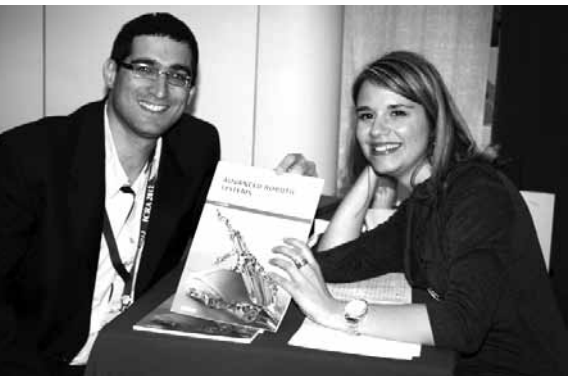
What do you consider to be your biggest achievement in the field of Robotics?
I think my main contributions to the science of Robotics are within the areas of motion planning and control of legged robots, as well as within modeling, stability analysis and synthesis of Robotics grasps.

You graduated Mechanical Engineering, a core discipline in Robotics. Other disciplines such as Biomimetics, Biomechanics, Mechatronics, Biological Engineering are key in robot design and projection and there seems to be no clear distinction between these research areas in Robotics but quite a bit of overlapping among these different domains.
You are correct. The beauty of Robotics is that it is composed of so many fields and disciplines. One can always learn more and investigate both deeper and wider in this never-ending field.

Many of your robots are inspired by animals mimicking their biomechanic functions. Your Snake-bot, Spiderman-inspired robot or llama-resembling robot have gotten a lot of attention; no surprise there as these robots amaze us. Why do you keep going back to nature's genius for inspiration and further projects?
As a roboticist I am amazed by

I definitively support and encourage everyone to build and program their own robot.

what nature's creatures can do. How a lizard climbs vertically walls. How four-legged animals can traverse rough terrains and jump from one rock to another, and how a snake can crawl through holes or tunnels and climb a tree. All these serve us as a source of inspiration. I learned from Prof. Howie Choset that in Robotics we cannot copy nature but we can do our best to mimic it using the available materials, actuators, and computation power. And if I may add I do believe that the "Engineer" who created nature did a marvelous job and we have a lot to learn from him.



Can we say we are using nature's genius to create advanced robotic lives?
I would not phrase it like this. We use nature's genius as a source of inspiration for creating robots. However, we have different limitations unlike nature. For example, in nature there is no joint that can turn 360 degrees, but we can use wheels. On the other hand, we still have a low force to weight ratio of the actuators in comparison to nature, and we still have no self-repair and-self built robots.

In the past, you have stated you couldn't choose a favorite one among all your robots. Did you change your mind in the mean time?
No! They are all my sons. It is like asking a father the child he loves more. I equally love all of my five children, but the robots still come after my family.

You stated that robots are here to benefit humankind and provide solutions to many different industries. When you start a new project, how does it work exactly?

Do you think of a specific problem you want to provide a solution to or you come up with a new concept for a robot and then think about what purpose it might have?
Usually we first find a problem which is challenging and interesting enough, then we brainstorm to find a solution.

Are you currently working or thinking of designing and projecting humanoid robots?
Humanoids are very interesting and challenging. However, there are many international groups working on this subject. Currently I have no funding source for developing humanoids, but some of our theories that were developed for other walking robots can be applied to humanoids.

Robotics has been quite a popular scientific field in general. Not only it attracts attention from diverse research areas, but also, more and more people seem to be interested in DIY (do it yourself) robot applications. In your view, this popularisation of Robotics as a hobby, can it be taken seriously from a research point of view? Do you think innovations could be generated even from those who are not professionals in the field of Robotics?
I definitively support and encourage everyone to build and program their own robot. I believe each person has a slightly different view of a problem and if many people are working on the same problem some will come to a creative genuine solution. There is no need to be professional in order to be creative. However, it does help!

SYLVAIN MARTEL

Magnetic Resonance Navigation for Nanorobotic Cancer Therapies

An Interview with Mr Sylvain Martel

Professor Sylvain Martel from the Department of Computer Engineering at Polytechnique Montréal talks to Kal Kaur from AZoNano about Magnetic Resonance Navigation for Nanorobotic Cancer Therapies. Dr. Martel's study was published in the peer-reviewed International Journal of Advanced Robotic Systems by the open access publisher InTech.

Interview conducted by Kal Kaur on
azorobotics.com

Please can you provide us with a brief overview of magnetic resonance navigation?
Magnetic Resonance Navigation (MRN) is a medical robotic approach that relies on Magnetic Resonance Imaging (MRI) technology to navigate therapeutic, surgical, imaging, or diagnostic micro-agents to a targeted location typically accessible through the vascular network.
More specifically, the strong, uniform magnetic field of a clinical MRI scanner, usually used to align the spin of protons (hydrogen nuclei) in the body of a patient for imaging purposes, is exploited during MRN to significantly increase the magnetization level of nanoparticles embedded in these micro-agents. In this "super-magnetization" state, the untethered micro-agents become much more responsive to the displacement force induced by a directional magnetic gradient. Such a directional magnetic gradient can be provided by the same coil typically used for spatial encoding during MR-imaging. After retrieving an image of the blood vessels to be navigated, a trajectory is plotted from the injection site to the final destination along the selected blood vessels. Once injected, a computer controls the generation of the 3D gradients in order to maintain the micro-agents along the planned trajectory.
The magnetic nanoparticles embedded in the micro-agents are not only used to induce a directional propelling or steering force from the gradients - they also create image artefacts in the homogenous field, allowing the position of the micro-agents to be tracked by MRI.
Unlike the use of an external magnet, where the gradient field decays rapidly with distance, the efficacy of MRN is depth independent, i.e., targeting deep into the body is as effective as near the skin surface, while providing the added advantages of computer-controlled navigation combined with a higher magnetization of the magnetic micro-agents to achieve enhanced targeting efficacy.

How much modification to a standard MRI scanner is required for this technique?
It really depends on the overall sizes of the micro-agents. In all cases, special software modules allowing MRN operations must be added or linked to the software platform of a clinical MRI scanner. In this case, larger agents such as the ones intended for navigation in larger arteries can be supported without hardware upgrades or modifications.
For smaller agents intended to transit in narrower vessels beyond the arteries, the gradient strengths of typical clinical MRI scanners are not sufficient. In such a case, the MRI scanner must be upgraded with a dedicated coil, or an imaging coil capable of generating higher gradients.
This additional coil can be inserted into the tunnel of a clinical MRI scanner, and then retrieved when MRN operations are no longer required. This special insert has the advantage of not requiring any hardware modifications to the MRI scanner itself, and because of the smaller inner diameter, it is still suitable for conducting MRN interventions on small animals or in regions of the body such as the head that can fit in the smaller diameter insert.

For full body MRN interventions beyond the arteries, a larger inner diameter is required and as such, there are two main alternatives. One is to replace or upgrade the gradient coil of an existing MRI scanner. The other is to develop a dedicated MRN platform.

What kind of micro-agents can this technique be applied to?
Any type of micro-agents synthesized with any type of biocompatible materials and dedicated to target surgeries, therapies, diagnostics, or for imaging purposes can be considered for MRN interventions provided that they contain a certain quantity of magnetic nanoparticles.
For example, MRN-compatible Therapeutic Magnetic MicroCarriers (TMMC) made of magnetic nanoparticles, encased with a therapeutic drug (Doxorubicin) in a biodegradable polymer (PLGA) sphere, with an overall diameter of approximately half the thickness of a human hair (approx. 50 micrometers), have showed targeting efficacy for releasing the drug into specific regions of the liver in rabbit models.

How accurately can you control the micro-agents?
MRN has proven to be sufficiently accurate to steer micro-agents to the proper branches when transiting through the first vessel bifurcations. As the number of bifurcations being transited gets higher, the distance between successive bifurcations decreases substantially, and as such, the directional gradients need to be changed at a faster rate.
Due to technological and physiological constraints, the maximum rate of such directional changes is limited and as such, while considering the small effective volume of magnetic nanoparticles in each micro-agent, it becomes difficult to perform MRN past the arterioles.

What were the benefits of using this technique found in your recent study?
In cancer therapy, MRN is presently the only approach that can deliver therapeutics to the specific site to be treated while avoiding systemic circulation. Avoiding systemic injections of highly toxic drugs can lead to a potential elimination or at least a significant reduction of the level of toxicity in healthy organs and an increase in the amount of therapeutics being delivered to the targeted site, whilst lowering the injected dose.

What technical challenges did you encounter?
There were many technical challenges. For instance, scaling of the gradient coils for whole-body MRN past the arteries, although feasible, was and still is a significant technical challenge. The cooling of the gradient coils limits the total time for which MRN can be performed, so that is another technical issue that was taken into consideration in developing the interventional protocol.
Real-time performance in MRI tracking of the micro-agents in order to gather sufficient positional data for the computer to maintain them along the planned trajectory was limited and as such, MRN operations had to be adjusted and modified accordingly.

Does MRN have any additional health implications for the patient compared to standard MRI?
MRN, if operated correctly, will prove to be safe for the patients. The same high magnitude uniform field as used in clinical MRI scanners has shown to be safe for the patients unless they have a ferromagnetic object such as an implant.
Because the magnitude of the gradients for MRN is higher than the ones used for MRI, the slew rate or rate of changes of the magnetic gradients is reduced to minimize or to avoid Peripheral Nerve Stimulation (PNS). The rate of changes is automatically adjusted by the system to ensure safe operation.
Other risks are related to the micro-agents themselves, so MRN should not introduce a higher level of risks than other therapies relying on the injection of substances into the blood stream.

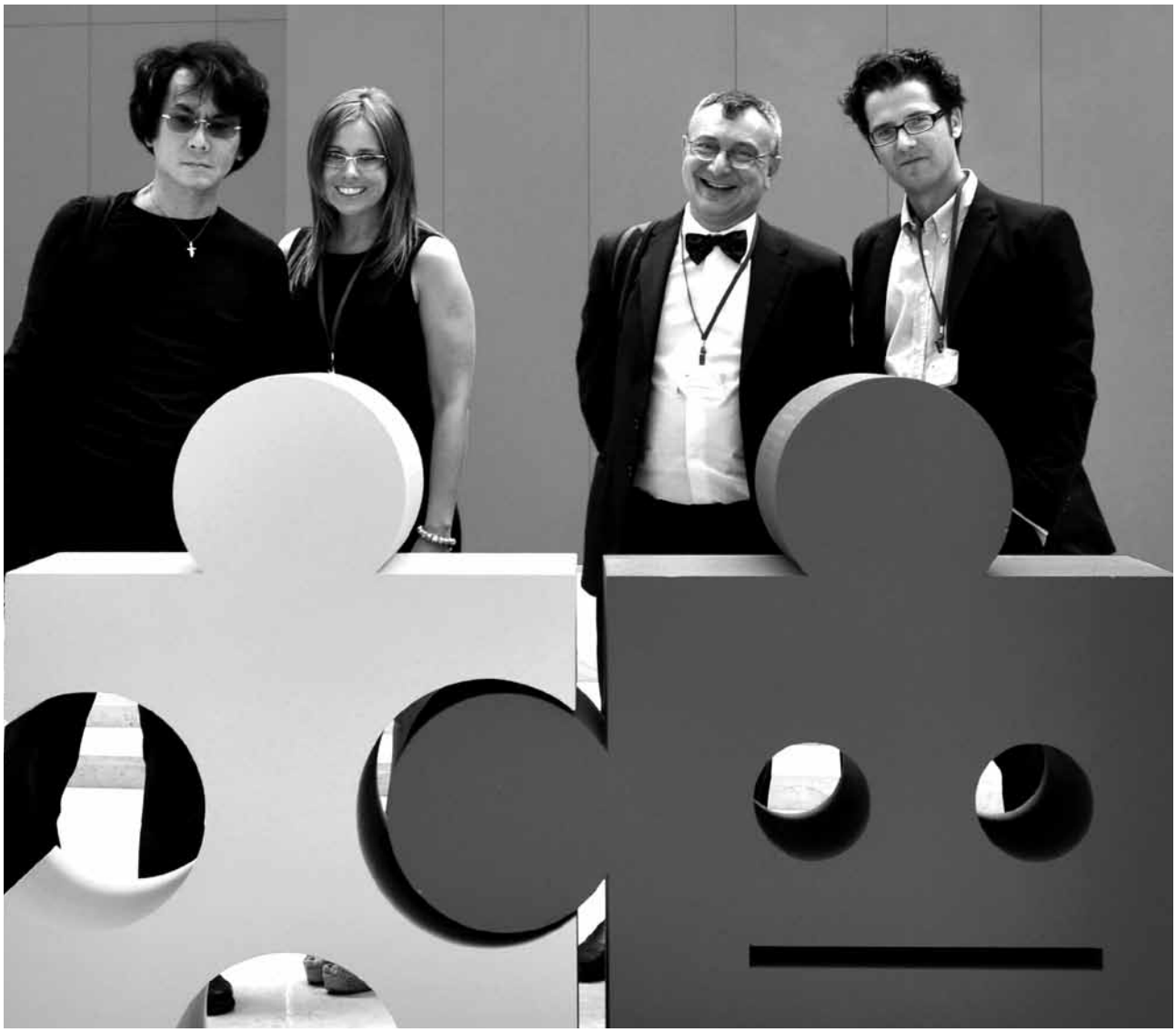
What additional technology could help circumvent these challenges?
A faster and more precise MRI sequence or a medical imaging modality capable of operating in a high magnetic field to track the micro-agents would certainly improve MRN operations.
Materials or nanoparticles with a higher magnetization level would allow higher force to be induced on the micro-agents, or a higher density of therapeutics compensated by a smaller amount of nanoparticles per micro-agent.
Better cooling systems and improvement in gradient coil technologies are other technical advances that would have a profound impact on the efficacy of MRN.
These are just a few examples among many others.

How far away is this technique from real world application?
From an engineering point of view, the platform is already functional. One interventional platform relying on a clinical MRI scanner has already been developed, and has been used by medical specialists—with the help of engineers—to evaluate and confirm the gained efficacy of the method for target chemoembolization and drug delivery in the liver, which could be adapted to other types of targets.
Although more developments such as a more user friendly interface for the medical staff could be developed, the main delay in making this technology accessible will mostly depend on regulatory issues and its acceptance in the medical community.
Also, some level of interest from medical instruments manufacturers and the pharmacology industry would certainly help in making such technology available in the shorter term.

What additional nanorobotic targeting methods have been proposed and how does MRN compare to these?
After the first successful demonstration of MRN by our group in 2006, performed in the carotid artery of a living swine, some other research groups have proposed custom platforms capable of generating comparable high gradient fields with x-ray being used as the imaging modality.
In these platforms, the lack of a high magnitude field to magnetize the micro-agents in the interventional space substantially reduces the force induced from the magnetic gradients.
This means that compared to MRN, the minimum size of the micro-agents that could be navigated is likely to be much larger, therefore limiting efficient interventions to larger arteries only.
X-ray is also an invasive imaging modality and its usage must be limited, which is not the case for MRI. Furthermore, because the magnetization of the micro-agents is constant with MRN, but varies with other approaches, navigation control is greatly simplified for MRN.
Last but not the least, because a magnetic micro-agent can create an image artefact in the uniform field during MRN interventions that can be much larger than the size of the agent itself, a smaller magnetic agent undetectable with x-ray could be detected with MRI, allowing the medical staff to assess the targeting efficacy, and offering the possibility to estimate the quantity of drug delivered at a specific location during cancer therapy.
But due to various technical and physiological constraints, and although MRN operations can be conducted in smaller vessels compared to other proposed approaches, MRN is still limited to the arterioles, without the possibility of navigation in narrower capillary vessels like the capillary angiogenesis network connecting to a tumour.
To overcome this limitation, our group has developed a self-propelled micro-agent in the form of a flagellated magnetotactic bacterium capable of transiting through the tiniest blood vessels found in humans.
A special platform, dubbed the magnetotaxis system, has been developed to create a "artificial magnetic pole" located at the site to be treated, in order to force the bacteria to migrate towards it.
Each bacterial cell contains a chain of nanoparticles known as magnetosomes that acts like a nanoscale compass needle, or a nano-steering system, that can be controlled by such magnetotaxis system.
Presently, approximately 70 nanoscale bags—known as liposomes—containing the therapeutic cargo, are attached to the surface of each bacterial cell. This approach is presently under investigation for treating colorectal cancer in humans.
Since the bacteria are much less effective in larger blood vessels because of the higher blood flow rate, special MRN-compatible micro-carriers are under development, to encapsulate the bacterial agents in order to release them closer to the microvasculature, which should allow us to target other regions in the body only accessible through small capillary vessels.

Where can we find more information about your research?
There are several scientific papers and book chapters that have been published on various aspects of this technology. The readers can also go to the NanoRobotics Laboratory web site. For a more general description, other sources are also available on the web, such as this article in IEEE Spectrum entitled "magnetic microrobots to fight cancer", providing a general description of the approach with supporting figures, and this short TEDx presentation given in French with subtitles in English.

Interact2012



THE INTERNATIONAL JOURNAL OF ADVANCED ROBOTIC SYSTEMS' INTERACT2012 – HUMAN ROBOT INTERACTION (HRI) PRESENTED HIROSHI ISHIGURO, ANDREA BONARINI AND PERICLE SALVINI'S LATEST RESEARCH EFFORTS

Interact2012, organised by InTech open access publisher and the team behind the International Journal of Advanced Robotic Systems , in collaboration with the University of Rijeka, was a free-atendance series of workshops that took place on September 3rd, 2012, in Rijeka, Croatia. Worldwide renowned Professors Hiroshi Ishiguro (University of Osaka), Andrea Bonarini (Politecnico di Milano), and Pericle Salvini (Scuola Superiore Sant'Anna) took Interact's main stage giving the audience the best of HRI currently developed in their laboratories.
The principal goal of Interact2012 was to give an overview of the latest and future developments, applications, and frontiers to overcome in the Robotics research area of HRI, leading to the full immersion of robot companions in our lives. An audience comprised of academics, professionals and the lay public interested in the latest of technology was provided with a fully comprehensive overview of humanoid robots—leading to a change in perceiving culture as a whole. In an attempt to a 360 degree analysis of HRI's latest novelties, Interact2012 proved its scope by creating fertile ground for new enthusiastic collaborations, sharing of ideas and future research paths.

Interact2012, being conceived as a free event open to all public, promoted the latest science and delivered it to every person interested in scientific yet popular research specifically within Robotics, also providing the chance to join open conversations initiated on the spot with a panel of HRI experts and academics

The speakers included the following roboticists

HIROSHI ISHIGURO

University of Osaka

Professor Hiroshi Ishiguro, director of the Intelligent Robotics Laboratory, department of Systems Innovation at Osaka University, is notably known for his commitment and achievements in humanoid robotics. Professor Ishiguro's efforts focus on the design and engineering of humanoid robots replicating human-like appearances and behaviors.

in humanities and Robotics. The core of the scientific program was built around 3 scientific sessions, each one followed by an interactive discussion with attendees. Time for interaction through extensive breaks and a technology exhibition was provided in order to give the possibility to all participants and public to discuss further all topics presented during the scientific sessions.

ANDREA BONARINI

Politecnico di Milano

Professor Andrea Bonarini holds an MA in Electronics Engineering and a PhD in Computer and System Engineering.
He is currently employed as full-time Professor at the Department of Electronics and Information at the Politecnico di Milano and he proudly occupies the role of coordinator of the Politecnico di Milano's Artificial Intelligence and Robotics Lab. He is in charge of Informatics, Artificial Intelligence and Soft Computing courses at the Politecnico, as well as the coordinator of the Computer Engineering section PHD track.
His main research efforts focus on intelligent data interpretation, autonomous robotic agents, affective robotics, reinforcement learning and fuzzy systems.

PERICLE SALVINI

Scuola Superiore Sant'Anna

Dr Pericle Salvini, post doc fellow working since 2005 at the ARTS Lab of Scuola Superiore Sant'Anna, holds a PhD in Biorobotic Science and Engineering. He also graduated Foreign Languages and Literatures and getting a MA of Research Degree in Theatre Studies.
His research focus lies in social robotics, legal and safety regulations, robotics, educational robotics, robotic and telepresence art, reflecting the polyhedric nature of his studies and merging robotics with arts.

Compared to other Robotics gatherings, the peculiarity and originality of Interact2012 consisted in promoting the latest of technological advances in the field both to an audience of academics and researchers and the general public. The team strongly felt that talking directly to such different audiences was key for a better understanding of new technologies on the horizon. This one-of-a kind gathering resulted in highly engaging and interactive workshops that delivered some of the best Robotics science and research featured in the International Journal of Advanced Robotic Systems.