



# Biologically Inspired Cognitive Architectures

Lyon, France  
6-8 November 2015





**6<sup>th</sup> International Conference on Biologically Inspired  
Cognitive Architectures**

**BICA 2015**

**6-8 november 2015  
Lyon, France**

Conference website:  
<https://liris.cnrs.fr/bica>



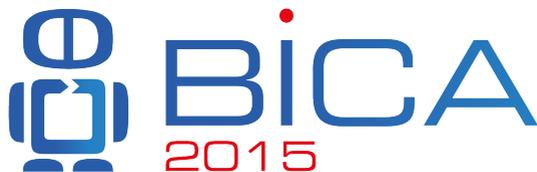
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## Welcome to BICA 2015!

Welcome to the **Sixth Annual Conference on Biologically Inspired Cognitive Architectures**, BICA 2015, which is also the Sixth Annual Meeting of the BICA Society.



Biologically Inspired Cognitive Architectures (BICAs) are computational frameworks for building intelligent agents that are inspired by biological intelligence. These agents serve both as theoretical models (e.g., in cognitive science, neuroscience, economics and social sciences), and as intelligent controllers for autonomous systems (robots, games characters, smart human/machine interfaces, health applications, etc).

Biological intelligent systems (animals, including humans) have many qualities that are often lacking in artificially designed systems; their purpose goes beyond interacting with a closed environment or solving predefined logical problems. At the time when our understanding of natural intelligence is exploding, thanks to modern brain imaging, ethological studies, and the development of cognitive models mapping brain structures with functions, our ability to learn lessons from nature and to build biologically inspired intelligent systems has never been greater. At the same time, the growth in computer science and technology has unleashed enough design creativity and computational power to generate an explosion of applications in multiple domains.

Research in Biologically Inspired Cognitive Architectures contributes to the development of these applications by addressing the numerous questions raised by the problem of replicating natural intelligence – specifically, the complexity of higher cognitive abilities of the human mind – in an artificial system (widely known as the BICA Challenge). These questions are trans-disciplinary in nature and promise to yield multi-directional flow of understanding between all the involved disciplines.

The scope of BICA 2015 covers all areas of BICA research: neuroscience; social, economic and educational science; cognitive science; artificial intelligence. In

addition to these focus topic areas, this year special thrust is on learning from experience of sensorimotor interaction. Here, the key questions are:

- Learning: how a system that has no direct ontological access to reality can construct knowledge about reality based on regularities of interaction?
- Self-motivation: what key motivational drives (e.g., emotions, behavioral preferences, social interactions) should we incorporate in models of self-motivated cognitive systems?
- Methodology: how to assess active open-ended learning? What methods can we draw from biology to define and assess intelligent behaviors beyond pre-defined tasks and pre-modeled problems?
- Models of interaction with the environment: can we define models alternative to the traditional perception-cognition-action cycle?
- What emergent mathematical foundations can support sensorimotor and other forms of learning?

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## Program

### Collocated events

Friday November 6th will welcome two collocated events in parallel with BICA:

**Morning: Technology demo/Industry meeting.** We are inviting local industries and startups interested in robotics, artificial intelligence, and cognitive science. They will showcase technology demos in parallel with some BICA participants, including Alain Mille, Peter Dominey, Sherine Antoun, Mark Waser, Ignazio Infantino. This meeting is intended to favor exchanges between academic research and industry.

**Afternoon: Symposium on Biomimetic approaches for sustainable development.** Invited speakers: Jean-Louis Deneubourg, Yves Duthen, Nour-Eddin El Faouzi. We encourage bidirectional communication with BICA.

### Symposia and tutorial

- Biological and Brain Foundations of Reservoir Computing. Chair: Peter Dominey.
- Symposium on Implication for BICA of Recent Results in Computational Narrative. Chair: Mark Finlayson.
- Symposium on Enaction, Complex Systems and Cognitive Architectures. Chair: Pierre De Loor.
- Whole Brain Architecture Initiative (WBAI) symposium. Chairs: Tarek Besold and Hiroshi Yamakawa.
- Tutorial on developmental learning. Chair: Olivier Georgeon.

### Main program

In the next pages, you will find the program of the 3 days of the conference.

Plenary sessions	Concurrent sessions	Poster session
Program numbers are given on the left of each name		*Asterisks show session chairs

Figure 1: Program legend

## Day 1: Friday November 6

8:00 am - 8:30 am: Registration

8:30 am - 10 am: Concurrent

	<i>CS1</i>	<i>CS2</i>	<i>Reservoir computing</i>
08:30	Alexei Samsonovich*	95 Jure Zabkar*	79 Peter Dominey*
09:00	64 Tarek Besold	47 Mark Waser	71 Bruno Golosio
09:30	19 Daqi Dong	63 John Tsotsos	80 Joni Dambre

10:00 am - 10:30 am: Coffee

10:30 am -12:00 pm: Concurrent

	<i>CS3</i>	<i>CS4</i>	<i>Reservoir computing</i>
10:30	81 Paul Robertson*	100 Paul Verschure*	96 Pierre Enel
11:00	60 Dane Corneil	101 Frank Ritter	33 Grégoire Pointeau
11:30	43 Junya Morita	75 Douglas Summers-Stay	Panel

12:00 pm - 1:30 pm: Lunch

1:30 pm - 3:30 pm : Plenary

	<i>Plenary 1</i>	<i>(Peter Dominey*)</i>
01:30	94 Wolf Singer	
02:00	105 Dori Derdikman	
02:30	104 Kevin O'Regan	
03:00	31 Peter Boltuc	

3:30 pm - 4:00 pm: Coffee

4:00 pm - 6:00 pm: Symposia

	<i>Computational Narrative</i>	<i>Enaction</i>	<i>Developmental learning</i>
04:00	90 Mark Finlayson*	99 Pierre De Loor*	3 Olivier Georgeon*
04:30	73 Nicolas Szilas	5 Leonardo Lana de Carvalho	93 Alain Mille
05:00	57 Carlos León	37 Ricardo Gudwin	4 Rémi Casado
05:30	Panel	22 Muneo Kitajima	69 Simon Gay

7:30pm - 8:30+ pm: Reception

## Day 2: Saturday, November 7

7:30 am - 8:00 am: Registration

8:00 am - 9:30 am: Plenary

		<i>Plenary 2</i>	<i>(Alain Mille*)</i>
08:00		a) Luc Steels	
08:30		85 Peter Gardenfors	
09:00		58 Matej Hoffman	

9:30 am - 10:00 am: Coffee

10:00 am - 12:00 am: Plenary

		<i>Plenary 3</i>	<i>(Tarek Besold*)</i>
10:00		b) Pierre-Yves Oudeyer	
10:30		27 Don Perlis	
11:00		25 Owen Holland	
11:30		9 Koichi Takahashi	

12:00 pm - 1:30 pm: Lunch

1:30 pm - 3 pm: Concurrent

	<i>Consciousness</i>	<i>Architecture</i>	<i>Creativity</i>
01:30	7 Junichi Takeno*	21 Muneo Kitajima*	14 Agnese Augello*
01:52	72 Evgenii Vityaev	18 Denis Kleyko	13 Ignazio Infantino
02:14	34 Pentti Haikonen	65 Dilhan Thilakrathne	51 Atsushi Nomura
02:36	35 André Paraense	6 Falentina Alata	Panel

3:00pm - 3:30 pm: Coffee

3:30 pm - 5:00 pm: Concurrent

	<i>Spatial cognition</i>	<i>Social interaction</i>	<i>Knowledge representation</i>
03:30	52 Amitabha Mukerjee*	53 Christopher Dancy*	40 Antonio Lieto*
03:52	8 Denis Kleyko	49 Denis Ivanov	10 Hanwen Xu
04:14	11 Haruki Ebisawa	50 Takashi Omori	15 Jean-Charles Bornard
04:36	12 Norifumi Watanabe	46 Albert Fonda	66 Tatt Wee Oong

05:00 pm - 5:15 pm: Pause

05:15 pm - 6:30 pm

		<i>Announces</i>	<i>(103 Alexei Samsonovich*)</i>
05:15		Poster pitches	
05:25		BICA Society panel	
	<i>WBAI Workshop (Tarek Besold*)</i>	<i>Poster Session</i>	
05:40	Hiroshi Yamakawa		

8:00 pm - 11:00 pm: Gala dinner

**Day 3: Sunday, November 8**

7:30 am - 8:00 am: Registration

8:00 am - 9:30 am: Plenary

	<i>Plenary 4</i>	<i>(Olivier Georjeon*)</i>
08:00	c) David Aha	
08:30	28 Igor Aleksander	
09:00	102 Rodrigo Ventura	

9:30 am - 10:00 am: Coffee

10:00 am - 12:00 am: Plenary

	<i>Plenary 5</i>
10:00	84 Patrick Shafto
10:30	16 Ricardo Gudwin
11:00	30 Peter Dominey
11:30	45 Massimo Cossentino

12:00 pm - 1:30 pm: Lunch

1:30 pm - 3 pm: Concurrent

	<i>Sensorimotor Learning</i>	<i>Emotions</i>	<i>Neural Networks</i>
01:30	39 Jacques Penders*	24 Max Talanov*	17 Andras Lorincz*
01:52	1 Daqi Dong	61 Mukta Galawat	55 Christian Huyck
02:14	38 Kota Itoda	70 Adnan Manzoor	32 Yasuo Kinouchi
02:36	88 Erwan Renaudo	62 Muh Anshar	76 Sherine Antoun

3:00pm - 3:30 pm: Coffee

3:30 pm - 4:00 pm: Plenary

	<i>Plenary 6</i>
03:30	Closing discussion

## Venue

The Novotel Gerland Conference Center is located by the beautiful Rhône river-banks across from the Musée des Confluences – Lyon’s emblematic museum of natural history and societies. The Novotel Gerland is close to the “Halle Tony Garnier” station of tramway line T1, and to the “Debourg” station of metro line B. Address: 70 avenue Leclerc, Lyon. Phone: (+33)4 72 71 11 11.



**Lunches, Coffee Breaks, and Dinner** Lunches and coffee breaks will be served at the Novotel. You will find local restaurant recommendations in the “Where to eat near the Novotel” section (see figure 2). An interactive map is also available on the venue page of our website (<https://lirs.cnrs.fr/bica>).

**Internet Access** Complimentary wireless internet access is available for the duration of the conference at the conference venue. Just connect to the wireless network and follow the instructions on your web browser.

**No Smoking Policy** Participants should be aware that smoking is banned from all public buildings in France, including in the Novotel building.

## Moving around

### About the city

With its historic center registered to the UNESCO world's heritage, Lyon is a delightful place for work and pleasure. France's second city stands at a central point, just two hours of high-speed train south of Paris, two hours driving west of the Alps, and three hours driving north of the French Riviera (Côte d'Azur).

Lyon offers an exceptional quality of life, "art de vivre", with many pedestrian streets and beautiful walkways on the Rhone and Saone riverbanks. It has efficient public transports and a pioneering public bicycle system.

Lyon is also a city of culture. It organizes many international events, ranging from a renowned music festival in the gallo-roman amphitheater to the "Lumière brothers" international film festival. You will also love the city's many museums: the new Musée des Confluences, Museum of Modern Art, Museum of Fine Art, Gallo-Roman Museum at Fourvière, etc.

Lyon is considered France's gastronomic capital. The city offers delicious cuisine for every budget from the city's "bouchons" to the world famous chef Paul Bocuse.

Lyon is a renowned cultural city. The main sights include:

- The Roman theaters on the Fourvière hill, together with a very nice Roman museum inside the hill. Cable-car "Les Minimes".
- The Old Lyon with its late Gothic and Renaissance buildings, the St-John cathedral, and its narrow pedestrian streets. Metro B "Vieux Lyon".
- The Fourvière basilica on top of the hill, with its Disney-movie-like exterior, its rich interior decorations and its dominating view on the city. Cable-car "Fourvière".
- The "traboules", a kind of public indoor passageway between streets in the Old Lyon and Croix-Rousse districts.
- The twelfth-century austere Romanesque St-Martin-d'Ainay basilica (north of Perrache trainstation). Metro A "Ampère".
- The Rhône left bank, a very nice walk ranging from the southernmost part of the city to the northern Parc de la Tête-d'Or and beyond.
- The Place des Terreaux (Hôtel de Ville metro station), on which are situated the city hall and the Palais St-Pierre which houses a large museum and a very refreshing public garden. Metro A "Hôtel de Ville".
- The Opera building, near the Place des Terreaux.

## Tourism office

Office du Tourisme & des Congrès du Grand Lyon

Place Bellecour - BP 2254

69214 Lyon cedex 02

(Subway line A/D "Bellecour")

*Opening hours:* The Tourism Office is open 7/7, from 9 am to 6 pm.

*Telephone:* +33 (0)4 72 77 69 69

<http://www.lyon-france.com/>

## Recommended museums, art galleries, and parks

- Museum of Fine Arts: <http://www.mba-lyon.fr>
- Museum of Contemporary Arts: <http://www.moca-lyon.org>
- Lumière Institute: <http://www.institut-lumiere.org>
- Gadagne Museum: <http://www.museegadagne.com>
- Gallo-roman museum of Lyon-Fourvière: <http://www.musee-gallo-romain.com/fourviere>
- Natural history museum: <http://www.museum-lyon.org>
- Automata museum: <http://www.automates-ema.com>
- Urban museum Tony Garnier: <http://www.museeurbaintonygarnier.com/>
- Old Lyon art gallery: <http://www.galerie-vieuxlyon.com>
- Laurencin art gallery: <http://www.laurencin.net>
- Botanic garden: <http://www.jardin-botanique-lyon.com/>
- Parc Tête d'or: <http://www.loisirs-parcdelatetedor.com/en/>
- Planetarium: <http://www.planetariumvv.com>
- Aquarium of the Grand Lyon: <http://www.aquariumlyon.fr/>

For more recommendations and ideas, please visit: [www.lyon-france.com/](http://www.lyon-france.com/)

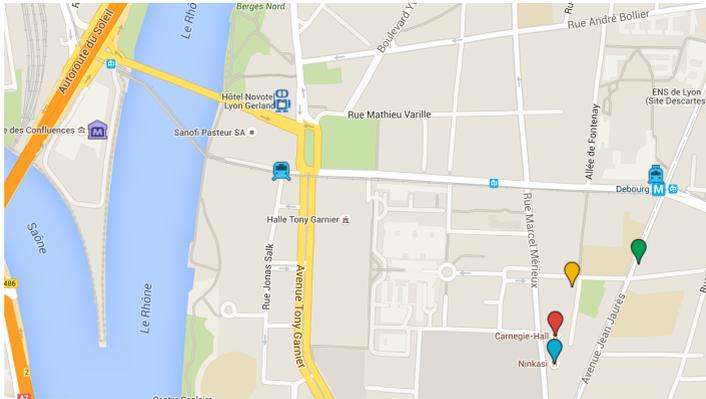


Figure 2: Local area map with recommended restaurants: green: Jols ([www.jols.fr](http://www.jols.fr)); yellow: Tiger Wok ([www.tigerwok.fr](http://www.tigerwok.fr)); red: Carnegie Hall ([carnegie-hall-69.com](http://carnegie-hall-69.com)); blue: Ninkasi ([www.ninkasi.fr](http://www.ninkasi.fr)).

## Where to eat?

### Recommended places near the Novotel

- **Carnegie Hall**  
253, Rue Marcel Mérieux - 69007 Lyon ; great meat (Subway line B “Stade de Gerland”, near the conference location)
- **Jols**  
283 av. Jean Jaurès - 69007 Lyon ; Fish speciality (Subway line B “Stade de Gerland”, near the conference location)
- **Ninkasi Gerland**, 267 Rue Marcel Mérieux - 69007 Lyon
- **Tiger Wok**, 8 Rue Challemeil Lacour - 69007 Lyon

### Famous addresses for gastronomic food or panoramic view, or both:

- **Paul Bocuse**  
*Main restaurant:*  
L'Auberge du Pont de Collonges

40 Rue de la Plage - 69660 Collonges au Mont d'Or

Tel.: +33 (0)4 72 42 90 90:

<http://www.bocuse.fr/>

*Brasseries:*

"Le Nord" 18 Rue Neuve - 69002 Lyon (Subway line A "Hôtel de Ville")

"Le Sud" 11 Place Antonin - 69002 Lyon (Subway line A/D "Bellecour")

"L'Est" 14 Place Jules Ferry - 69006 Lyon (Subway line B "Brotteaux")

"L'Ouest" 1 Quai du Commerce - 69009 Lyon (Subway line D "Gare de Vaise")

"Argenson" 44 allée Pierre de Coubertin - 69007 Lyon (Subway line B "Stade de Gerland")

– **Pierre Orsi**

3 Place Kléber - 69006 Lyon Tel: +33 (0)4 78 89 57 68 <http://www.pierreorsi.com/> (Subway line A "Masséna")

– **Restaurant de Fourvière**

9, Place Fourvière - 69005 Lyon. French food and beautiful view (Subway line D "Vieux Lyon" + Funicular "Fourvière")

**Streets/Areas with Typical Restaurants "Bouchons Lyonnais":**

- "La Meunière" 11 rue Neuve - 69001 LYON (Subway line A "Cordeliers")
- Rue Mercière (Subway line A "Cordeliers")
- Quartier Saint-Jean (Subway line D "Vieux Lyon")
- Rue de Marronniers (Subway line A/D "Bellecour")

**Where to have a drink?**

Just a few ideas!

- Le Palais de la Bière, 1 Rue Terme - 69001 Lyon
- The Ayers Rock, 2 Rue Désirée - 69001 Lyon
- Ninkasi Opéra, 27 Rue de l'Arbre Sec - 69001 Lyon
- St James Pub, 19 Rue Saint-Jean - 69005 Lyon
- The Johnny Walsh, 56 Rue Saint Georges - 69005 Lyon
- The Melting Pub, 9 Rue du Doyenné - 69005 Lyon
- Wallace, 2 Rue Octavio Mey - 69005 Lyon

## Tipping

Tipping is not obligatory in France, even in restaurants or bars - but it's not frowned upon either. Tipping is left entirely to your discretion, and may be appropriate if you receive excellent service.

## Moving around

**Public transportation: TCL**

**Please, note that a map of the TCL network is available in your conference bag.**

The public transportation system in Lyon is called TCL (Transports en Commun Lyonnais). The TCL network includes various types of transport: bus, tram, trolley, and subway.



TCL has a range of tickets depending on your needs: "One day Ticket liberté", "2-hours Ticket liberté", "Evening Ticket liberté", Single tickets or a booklet of 10 tickets.

Some tips for a smooth journey: In order to keep your ticket valid, remember to get your ticket stamped each time you change line, except if you are changing from one metro line to another. All TCL stations as well as all transport modes are non-smoking. Let the bus driver know that you want to get off at the next stop by pressing on the red "Stop request" button. On trains and trams, stops are automatic.

Each ticket (except "Ticket liberté") is valid for travel during the hour after it is first stamped, over the whole TCL network. Changes are allowed. Return travel is not permitted with the same ticket.

*Where are tickets available?* From bus drivers (please have the right change), at the automatic ticket machines in metro and tram stations; in TCL service points; in TCL offices.

More information: <http://www.tcl.fr>

## VELO'V

Velo'v provides solid, comfortable bikes, available for anyone to use, 24 hours a day, 7 days a week. You can find them at strategic locations all over Lyon, thanks to a dense network of stations located at intervals of 300 m on average.



You can buy a daily-ticket at the Velo'v station (you will need a credit card) for 1.50 euro. Once you have a ticket, journeys under 30 minutes are always free of charge. If you hire a bike for more than 30 minutes, you will have to pay for the service in accordance with the usage charges.

More information: <http://www.velov.grandlyon.com>



## TAXI

And if you need a taxi:

- Taxi Radio de Lyon: +33 (0)4 72 10 86 86, or
- Taxis villeurbannais: +33 (0)4 78 24 44 44
- Taxi lyonnais: +33 (0)4 78 26 81 81
- Allo Taxi: +33 (0)4 78 28 23 23



Figure 3: Lyon public transport synthetic map highlighting the stations of interest for BICA: "Aéroport" (Airport), "Halle Tony Garnier" (Novotel conference venue), "Bellecour" (welcome cocktail party and Robodanza), "Quai Claude Bernard" (Gala dinner on the boat).

## Social events

### Welcome cocktail party and Robodanza show

**Friday November 6th, 7:30pm-8:30pm and later.** *Lyon tourism office, Place Bellecour.*

The welcome cocktail party is featuring the Robodanza show – a science/art collaboration between the University of Palermo and the ARCI Tavolatonda troupe starring Veronica Racito, Barbara Crescimanno, and Elisa D’Alessandro.



**How to get there?** By public transportation: T1 direction IUT Feysine, stop at Perrache and change for Metro A direction Vaulx-en-Velin la Soie (keep your ticket to enter the metro station). Stop at Bellecour. The tourist office is on the south-east corner of the Bellecour plaza. You will need your conference badge to get in. You may be freely accompanied by one person.

**Walking:** if the weather is nice, you can also walk there, either along the river, or through the city. Best parts of the walk are: from the Novotel to the famous “Musée des Confluences”, and from Perrache to Bellecour, through one of the upscale neighborhood of the city (see figure 4).

## Gala dinner on the Hermes boat

**Saturday November 7th, 8:00pm-11:00pm.** *Gala dinner on the Hermes. Boarding at 8:00 on 16 quai Claude Bernard, near the University Bridge. Departure of the boat: 8:30pm.*

Gala dinner on the Hermes in a magnificent city tour on the Rhône and Saône rivers. Diner will be served on board. You will need your Gala Ticket to get on board.



**How to get there?** By public transportation: T1 direction IUT Feysine, stop at "Quai Claude Bernard". Walk down to the boarding dock by the Rhône riverbank, near the University Bridge.

If the weather is nice, you can also walk there along the river (see figure 4). It is a beautiful walk.

On the way back, the boat will make a stop at the Novotel dock. You can either get off there to return directly to the hotel, or you can continue back to the Quai Claude Bernard dock.

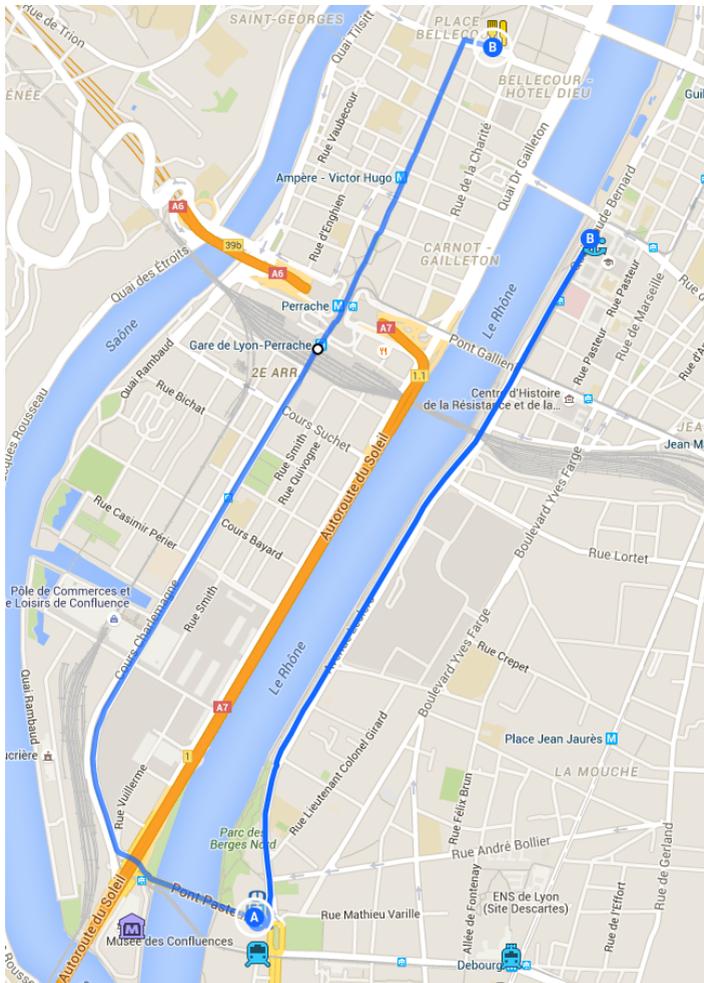


Figure 4: Left: Walk from Novotel to the cocktail party Place Bellecour along the T1 and then the metro B line. Right: Walk from the Novotel to the gala dinner boat dock by the Rhône riverbank park.

## Sponsors and acknowledgments

It is impossible to give credit here to all who contributed to the success of BICA 2015. In short, it took a lot of effort to put this conference together. We are grateful to all members of the Organizing and Program Committees for their valuable help in reviewing submissions, for their generous work and initiatives that together resulted in the great success of our conference. Our greatest thanks go to our sponsors: Whole Brain Architecture Initiative; Elsevier B.V.; the LIRIS Lab; INSERM; Lyon 1 University, and, of course, the BICA Society. We are grateful to all Members of the BICA Society for their continuous support.



## Abstracts of presentations and papers

### **a - Self-Regulating Mental Development**

*Luc Steels*

It is now generally recognized that human mental development is a long process that leads to the gradual construction of extraordinary complex structures in interaction with the environment, tutors, and other individuals, including peers. Many of these structures can only be acquired when other structures are already in place. For example, fine-grained grasping with the fingers is only possible when rudimentary control of arm movements has been established. A central challenge for emulating development on (robotic) agents is to orchestrate the ordering in which skills and competences are acquired. There are several methods. For example, tutors can carefully scaffold the complexity of the environment for learning and then gradually increase the challenge. Here we investigate mechanisms in which learners themselves regulate the complexity of the challenges they tackle in harmony with skills they already acquired. I look in particular at mechanisms inspired by Csikszentmihalyi's flow theory and focus on how this theory suggests way to orchestrate autonomous language learning.

### **b - Developmental robotics and open-ended learning**

*Pierre-Yves Oudeyer*

A great mystery is how human infants develop: how they progressively discover their bodies, how they learn to interact with objects and social peers, and accumulate new skills all over their lives. Constructing robots, and building mechanisms that model such developmental processes, is key to advance our understanding of human development, in constant dialog with human and living sciences. I will present examples of robotics models of curiosity-driven learning and exploration, and show how developmental trajectories can self-organize, starting from discovery of the body, then object affordances, then vocal babbling and vocal interactions with others. In particular, I will show that the onset of language spontaneously forms out of such sensorimotor development. I will also explain how such developmental learning mechanisms can be highly efficient for robot learning of motor skills in high-dimensions, such as learning omnidirectional legged locomotion or object manipulation.

### **c - Goal Reasoning for Autonomous Control**

*David Aha*

Goal reasoning actors are highly autonomous; they can decide for themselves what goals to pursue. This requires substantial interpretation about the actor's recent observations. In this talk, I will describe recent work on behavior recognition, plan recognition, and explanation generation in support of goal deliberation, along with applications of goal reasoning that our group is pursuing concerning the control of autonomous unmanned vehicles.

### **1 - Estimating Human Movements Using Memory of Errors**

*Daqi Dong, Stan Franklin and Pulin Agrawal*

Humans estimate their movements based on their knowledge of the dynamics of the environment, and on actual sensory data. Wolpert and colleagues have incorporated this understanding into a model that simulates this estimation using the Kalman filter (1995). Inspired by a recent study in neuroscience (Herzfeld, Vaswani et al. 2014), we here introduce a new factor—memory of errors—into this simulation of the movement estimation. These historical errors help humans determine the quality of the environment, which could be either steady or rapidly changing. This quality controls the rate at which a given error will be learned, so as to affect the estimates of future movements. We here apply our new model, a modified Kalman filter incorporating memory of errors, to the simulation of a hand lifting movement, and compare the simulated estimation process with its human counterpart.

### **3 - Constructing Phenomenal Knowledge in an Unknown Noumenal Reality**

*Olivier Georgeon, Florian Bernard and Amélie Cordier*

In 1781, Immanuel Kant argued that cognitive agents ignored the underlying structure of their world "as such" (the noumenal reality), and could only know phenomenal reality (the world "as it appears" through their experience). We introduce design principles to implement these theoretical ideas. Our agent's input data is not a direct function of the environment's state as it is in most symbolic or reinforcement-learning models. The agent is designed to discover and learn regularities in its stream of experience and to construct knowledge about phenomena whose hypothetical presence in the environment explains these regularities. We report a proof-of-concept experiment in which the agent constructs categories of phenomena, and exploits this knowledge to satisfy innate preferences. This work suggests a new approach to cognitive modeling that focuses on the agent's internal stream of experience. We argue that this approach complies with theories of embodied cognition and enaction.

#### **4 - Modeling Biological Agents Beyond the Reinforcement Learning Paradigm**

*Oliver Georgeon, Rémi Casado and Laetitia Maignon*

It is widely acknowledged that biological agents are not Markov: they do not receive an effective representation of their environment's state as input data. We claim that they cannot recognize rewarding Markov states of their environment either. Therefore, we model their behavior as if they were trying to perform rewarding interactions with their environment (interaction-driven tasks), but not as if they were trying to reach rewarding states of their environment (state-driven tasks). We review two interaction-driven tasks: the AB and AABB task, and implement a non-Markov Reinforcement-Learning (RL) algorithm based upon historical sequences and Q-learning. Results show that this RL algorithm takes significantly longer than a constructivist algorithm implemented previously by Georgeon, Ritter, & Haynes (2009). This is because the constructivist algorithm directly learns and repeats hierarchical sequences of interactions, while the RL algorithm spends time learning Q-values. Along with theoretical arguments, these results support the constructivist paradigm for modeling biological agents.

#### **5 - Origins and Evolution of Enactive Cognitive Science: Toward an Enactive Cognitive Architecture**

*Leonardo Lana De Carvalho, Denis James Pereira and Sophia Andrade Coelho*

This paper presents a historical perspective on the origin of the enactive approach to cognitive science, starting chronologically from cybernetics, with the aim of clarifying its main concepts, such as enaction, autopoiesis, structural coupling and natural drift, showing their influences in computational approaches and models of cognitive architecture. Works of renowned authors, as well as some of their main commentators were addressed to report the development of enactive approach. We indicate that the enactive approach transcends its original context within biology, and at a second moment within connectionism, changing the understanding of the relationships so far established between body and environment, and the ideas of conceptual relationships between mind and body. The influence on computational theories is of great importance, leading to new artificial intelligence systems as well as the proposition of complex, autopoietic and alive machines. Finally, the article stresses the importance of enactive approach in the design of agents, understanding that previous approaches have very different cognitive architectures and that a prototypical model of enactive cognitive architecture is one of the largest challenges today.

#### **6 - Toward developing an architectural typology based on the ecological**

**concept of affordance***Falentina Alata*

This paper revolves around the concept of Affordance. It aims to develop an architectural typology based on the ecological concept of affordance. In order to achieve this aim it was based on two sources as following: 1- Gibson's definition of the concept of affordance. 2- The researches which concerned about affordance categorization, mainly Gaver Zhang and Patel contribution in this field. As a result, this paper concluded 16 typologies of affordances beside the possibilities of mixing it based on the both sources. To clarify these new typologies and provide further understanding, a wide range of architectural examples are presented and proposed, which is reported in the first part of the paper, (the analytic study). To prove this new vocabulary's capability to diagnose and evaluate the affordance of different environments two processes have been adapted: A. Diagnostic process: the interpretation of the environments with regard to its affordance using the new vocabulary (the developed typologies). B. Evaluating process: the evaluation of the environments that have been interpreted and classified with regard to their affordances. By using the measures of emotional experience (The positive affect 'PA' and the negative affect 'NA'), and the Architectural Evaluation Criteria (beauty, economy and function) which is reported in the second part of the paper, (the experimental study). The experimental study proved that the new typologies were capable reading the affordance in different environments. Also it explained how these different typologies reflected different interactions based on the previous processes. The data which was concluded from the evaluation of measures, explained how the different typologies of affordance which already reflect different environments had different evaluations. Some of them are recommended and the others are not. In other words, this paper draws a roadmap for the designers to diagnose, evaluate and afterwards analyze the affordance in the different architectural environments. Then it guided them to adapt the best interaction (affordance category) which they intended in their proposed designs.

**7 - Development of a Self-Evolving Conscious System***Ryuma Matsushita and Junichi Takeno*

In our previous work, we attempted to unravel the mystery of human consciousness by implementing on a robot a consciousness module called a MoNAD, which we think can become the core of consciousness. In this study, we give developmental rules to a conscious system built with these MoNADs, and propose a model for a robot brain that achieves self-evolution only through interaction with the environment.

**8 - Fly-The-Bee: A game imitating concept learning in bees**

*Denis Kleyko, Evgeny Osipov, Magnus Björk, Henrik Toresson and Anton Öberg*

This article presents a web-based game functionally imitating a part of the cognitive behavior of a living organism. This game is a prototype implementation of an artificial online cognitive architecture based on the usage of distributed data representations and Vector Symbolic Architectures. The game demonstrates the feasibility of creating a lightweight cognitive architecture, which is capable of performing rather complex cognitive tasks. The cognitive functionality is implemented in about 100 lines of code and requires few tens of kilobytes of memory for its operation, which make the concept suitable for implementing in low-end devices such as minirobots and wireless sensors.

**9 - A Generic Software Platform for Brain-Inspired Cognitive Computing**

*Koichi Takahashi, Kotone Itaya, Masayoshi Nakamura, Moriyoshi Koizumi, Naoya Arakawa, Masaru Tomita and Hiroshi Yamakawa*

We have been developing BriCA (Brain-inspired Computing Architecture), the generic software platform that can combine an arbitrary number of machine learning modules to construct higher structures such as cognitive architectures inspired by the brain. We discuss requirements analysis and design principles of this cognitive computing platform, report its implementation, and describe plans for further development.

**10 - The Thermal Grill Illusion: A Study using a Conscious System**

*Hanwen Xu, Koki Kanazawa, Daiki Matsumoto and Junichi Takeno*

Although the thermal grill illusion has been the topic of previous research, many mysteries still remain regarding psychological determinants, neurophysiological mechanisms and so on. Also, the illusion cannot be simulated by information science and robotics. This study focuses on a very simple but interesting experiment called Hot and Cold Coils, which is known as a typical example of the thermal grill illusion. The authors aim to explain the thermal grill illusion by proposing a new and bold assumption called the conflict of concepts, and demonstrate how to construct a model by using a novel artificial consciousness module called the Module of Nerves for Advanced Dynamics (MoNAD). A simple experimental apparatus was prepared to prove the existence of the thermal grill illusion, and consists of a parallel arrangement of

bars with an alternating pattern of cold and warmth at 20 °C and 40 °C. The authors conclude with the belief that many complex perceptions of humanity can be simulated through the use of neural networks, and that this can help us to deeply study the cognitive processes of human perception.

### **11 - Pleasant and unpleasant states in a robot**

*Haruki Ebisawa, Ryuma Matsushita and Junichi Takeno*

We have been conducting research with the objective of enabling a robot to perform human-like autonomous behavior and communication. For this purpose, we have developed and mounted on a robot consciousness modules, termed MoNADs, which by means of groups of neurons comprise the elements that make up the functions of consciousness, emotions and feelings that are possessed by humans. In this study, we propose a consciousness model that enables a robot to evolve in accordance with rules based on definitions of pleasant and unpleasant states in a conscious system comprised of MoNADs. For the definitions of the pleasant and unpleasant states, we are using the “smoothness of the information flow” in the conscious system, where “pleasant” is the state in which the information that has come in is flowing smoothly, while the state in which information is not flowing smoothly is defined as “unpleasant.” By means of these definitions, the robot becomes able to autonomously evolve using uniform and consistent rules in both of the systems of the brain, that which governs reason and that which is responsible for emotions and feelings.

### **12 - Semiautonomous Control of Personal Mobility Based on Passenger's Collision Avoidance Judgment Timing**

*Norifumi Watanabe, Hiroaki Yoshioka, Kensuke Miyamoto and Junya Imani*

We have implemented a personal mobility (vehicle) that has semiautonomous control by estimating the avoidance direction and the avoidance judgment timing. In coexist space of pedestrians and passengers on personal mobility, it is necessary to realize safety collision avoidance by moving the mobility. Therefore, we estimate avoiding direction from pedestrian's body parts and implement semiautonomous collision avoidance system. And we have collision avoidance experiments between a pedestrian and a passenger on personal mobility. We evaluate important pedestrian's body parts for avoiding judgment and avoidance judgment timing. As a result, passengers gaze at pedestrian's lower body parts in semiautonomous control, and avoidance judgment timing is delayed about pedestrian's one step. We have proposed a model of passenger's motion perception and vision guidance on personal

mobility.

### **13 - An automatic system for humanoid dance creation**

*Adriano Manfre', Ignazio Infantino, Filippo Vella and Salvatore Gaglio*

The paper describes a novel approach to allow a robot to dance following musical rhythm. Starting from a set of given movements, the robot chooses sequence of movements a suitable Hidden Markov Model, and synchronize them processing musical input. The proposed approach has the advantage that movements execution probabilities could be changed according evaluation of the dance execution in order to have an artificial creative system. In the same way, a choreograph could give major importance to some movements and/or exclude others, using the system as a co-creation tool. The approach has been tested on Aldebaran NAO humanoid using different genres of music, and experimentations was conduct at presence of real human dancers to have feedback of the goodness of the robot execution.

### **14 - Artwork creation by a cognitive architecture integrating computational creativity and dual process approaches**

*Agnese Augello, Ignazio Infantino, Antonio Lieto, Giovanni Pilato, Riccardo Rizzo and Filippo Vella*

The paper proposes a novel cognitive architecture (CA) for computational creativity based on the Psi model and on the mechanisms inspired by dual process theories of reasoning and rationality. In recent years, many cognitive models have focused on dual process theories to better describe and implement complex cognitive skills in artificial agents, but creativity has been approached only at a descriptive level. In previous works we have described various modules of the cognitive architecture that allows a robot to execute creative paintings. By means of dual process theories we refine some relevant mechanisms to obtain artworks, and in particular we explain details about resolution level of the CA dealing with different strategies of access to the Long Term Memory (LTM) and managing the interaction between S1 and S2 processes of dual process theory. An example of artificial painter is described in some experimentations by using a robotic platform.

### **15 - Use of a computational simulation model of drivers cognition to predict decision making and behaviour while driving.**

*Jean-Charles Bornard and Thierry Bellet*

This paper presents a new approach to driving experimentation, based on cognitive simulation of the driver in order to predict human behaviour. The

cognitive model COSMODRIVE (i.e. Cognitive Simulation MODEL of the DRIVER) has been combined with a Vehicle-Environment-Sensors platform (named SiVIC, for Simulateur Vehicule-Infrastructure-Capteur) in order to simulate, explain and predict the driver's behaviour and mental activities. From this simulation, an experiment has been conducted at IFSTTAR - LE-SCOT, where hypothesis has been made with the simulation. The innovative approach is the use of a virtual simulation of a cognitive model to predict the human behaviour and then analyse collected data to validate the predicted behaviour. This article describes broadly the COSMODRIVE model and the simulation made in order to define accurate experimental hypothesis. Then, we describe the driving simulator and the experiment itself. Afterwards, data analysis provides us some results allowing us to discuss and conclude about the methodology tested with this experiment.

#### **16 - A Comparison among Cognitive Architectures: A Theoretical Analysis**

*Daniilo Fernando Lucentini and Ricardo R. Gudwin*

In this paper we present a theoretical comparison among three of the most popular cognitive architectures: SOAR, LIDA and CLARION. These architectures are compared based on a set of cognitive functions supposed to exist in the human cognitive cycle, and how each architecture deals with them. The comparison emphasizes similarities and differences among the architectures, with the purpose to advise a potential user how to identify the best architecture to employ, depending on the situation.

#### **17 - Columnar Machine: Fast estimation of structured sparse coding**

*Andras Lorincz, Zoltan A Milacski, Balazs Pinter and Anita L. Vero*

Ever since the discovery of columnar structures, their function remained enigmatic. As a potential explanation for this puzzling function, we introduce the 'Columnar Machine'. We join two neural network types, Structured Sparse Coding (SSC) of generative nature exploiting sparse groups of neurons and Feed-Forward Networks (FFNs) into one architecture. Memories supporting recognition can be quickly loaded into SSC via supervision or can be learned by SSC in a self-organized manner. However, SSC evaluation is slow. We train FFNs for predicting the sparse groups and then the representation is computed by fast undercomplete methods. This two step procedure enables fast estimation of the overcomplete group sparse representations. The suggested architecture works fast and it is biologically plausible. Beyond the function of the minicolumnar structure it may shed light onto the role of fast feed-forward inhibitory thalamocortical channels and cortico-cortical

feed-back connections. We demonstrate the method for natural image sequences where we exploit temporal structure and for a cognitive task where we explain the meaning of unknown words from their contexts.

### **18 - Imitation of concept learning by honey bees using Vector Symbolic Architectures**

*Denis Kleyko, Evgeny Osipov, Ross Gayler, Asad Khan and Adrian Dyer*

This article presents an artificial learning system for concept learning based on Vector Symbolic Architectures. The system is showcased through functional imitation of the concept learning by honey bees. The presented work uses the results of the real world experiment with honey bees [1] for benchmarking. It is demonstrated that the proposed pipeline features similar learning curve and the accuracy of generalization as in the living bees.

### **19 - Modeling Sensorimotor Learning in LIDA Using a Dynamic Learning Rate**

*Daqi Dong and Stan Franklin*

We present a new model of sensorimotor learning in a systems-level cognitive model, LIDA. Sensorimotor learning helps an agent properly interact with its environment using past experiences. This new model stores and updates the rewards of pairs of data, motor commands and their contexts, using the concept of reinforcement learning; thus the agent is able to generate (output) effective commands in certain contexts based on its reward history. Following Global Workspace Theory, the primary basis of LIDA, the process of updating rewards in sensorimotor learning is cued by the agent's conscious content—the most salient portion of the agent's understanding of the current situation. Furthermore, we added a dynamic learning rate to control the extent to which a newly arriving reward may affect the reward update. This learning rate control mechanism is inspired by a hypothesis from neuroscience regarding memory of errors. Our experimental results show that sensorimotor learning using a dynamic learning rate improves performance in a simulated movement of pushing a box.

### **21 - Guidelines for designing artifacts for the dual-process**

*Muneo Kitajima and Makoto Toyota*

We have developed an architecture model, MHP/RT, that is capable of simulating people's daily action selection processes as an implementation of the dual-process theory [1]. MHP/RT describes people's daily behavior

as a cyclic process of action selection and memory formation. In our daily life, we spend a lot of time in interacting with artifacts, and therefore it is obvious that it should affect development of individual memory systems. At the same time, any particular artifacts that exist as they are should embed in themselves their own histories including their predecessors. Occasional innovations might have caused evolution of memory structure of mankind through people's interaction with the artifacts, and might have resulted in "splicing" evolution in the socio-cultural ecology. MHP/RT suggests that the cyclic processes should dene strong constraints on sustainable innovation; as far as the cyclic processes function in utilizing an artifact implemented in a technological innovation, it should survive, otherwise it should fade away. This paper contrasts technique and skill, the two distinct form of use of artifacts, and derives guidelines for designing sustainable artifacts that should support smooth development of people's skill necessary for using artifacts from their mere use via technique.

## **22 - Multi-dimensional memory frames and action generation in the MHP/RT cognitive architecture**

*Muneo Kitajima and Makoto Toyota*

The main theme of this paper is to provide a cognitive architecture, MHP/RT (Model Human Processor with Realtime Constraints), that is appropriate for describing the idea, "The agent would not be getting an informational input or a reinforcement, but the inputs would be better described as perturbations on a self-organizing complex systems", as stated in the call for the workshop, Enaction, Complex Systems and Cognitive Architectures. MHP/RT describes a cyclic process of action selection and memorization while one lives in the world, and the memory is gradually structured as multi-dimensional frames as one interacts with the environment. Behavioral processing constraints are imposed by conscious and unconscious processes, and behavior must be synchronized with the ever-changing external and internal environments. This paper provides a brief explanation of MHP/RT and multi-dimensional memory frames, followed by how memory is structured as one develops.

## **23 - Comparison of different learning algorithms for pattern recognition with Hopfield's neural network**

*Tomasz Szandafa*

Hopfield neural networks can be used for compression, approximation, steering. But they are most commonly used for pattern recognition thanks to

their associative memory trait. In order to fulfill this task, the network has to be trained with one of algorithms. In this paper I will try to implement three of the most popular ones and compare their effectiveness by trying to recognize various patterns consisting of binary input arrays. The tests will use Hebbian learning, Oja's Hebbian modification and pseudo-inverse, which proves to be most promising training algorithm.

#### **24 - NEUCOGAR: A Neuromodulating Cognitive Architecture towards the implementation of emotions in a computational system**

*Max Talanov, Jordi Vallverdu, Salvatore Distefano, Manuel Mazzara, Alexander Tchitchigin and Ildar Nurgaliev*

This paper introduces a new model of artificial cognitive architecture for intelligent systems, the Neuromodulating Cognitive Architecture (NEUCOGAR). The model is biomimetically inspired and adapts the neuromodulators role of human brains into computational environments. This way we aim at achieving more efficient Artificial Intelligence solutions based on the biological inspiration of the deep functioning of human brain, which is highly emotional. Analysis of new data obtained from neurology allows us to find a mapping of monoamine neuromodulators to emotional states and apply it to computational systems' parameters. Artificial cognitive systems can then better perform complex tasks (regarding information selection and discrimination, attention, innovation, creativity,...) as well as engage in affordable emotional relationships with human users.

#### **25 - Why and how we should build a zombie**

*Owen Holland*

A zombie, or more properly a "philosophical zombie", is an imaginary agent that exhibits the observable phenomena of consciousness without actually being conscious. There are many possible variations of the basic concept, but underlying many or most of them is the idea that the zombie should be as capable as a conscious agent of the cognition, and also of the selection and control of action, required for maintaining an autonomous existence in a particular world. In other words, such a zombie would possess an effective cognitive architecture, and one of the issues that should concern this conference is that of the relationship between such an effective cognitive architecture and the machinery underlying the production of the observable phenomena of consciousness. To date, the zombie concept has served only as the basis of philosophical speculation and argument. However, this paper proposes and outlines an attempt to build a zombie, and in particular a

physically instantiated "engineering zombie", that would have the potential to make an empirical contribution both to the BICA programme of research, and to consciousness science. Furthermore, this effort would be essentially distinct from any effort to build a conscious machine or robot, because no claims would be made about the agent's consciousness other than for its absence, and so the usual arguments undermining work on machine consciousness, especially those affecting its funding, would be inapplicable. An intriguing possibility is that the successful construction and demonstration of a zombie might eventually constitute a failure, in that some future insight might show that the agent is in fact as conscious as we are - and is therefore not a zombie.

### **27 - AI: Again the Science of Cognitive Agents**

*Don Perlis*

AI may be emerging from decades in a sort of Middle Ages (MA) period, and now – with some very major advances in the MA under its belt – returning to its roots as the science of cognitive agents, with the exalted aim of a computational understanding of the mind.

If so, then it will not be an easy transition. The popular literature – and some of the technical literature – is rife with bold characterizations of AI in terms orthogonal (and in some cases diametrically opposite) to this one. But there are reasons to think such a transition is nevertheless underway.

At least so I will argue.

### **28 - True Machine Understanding: Implementing Cognitive Phenomenology?**

*Igor Aleksander*

It still seems correct to say that despite 60 years of AI and Cognitive Systems design, computing machinery, while performing competent acts of scene or language interpretation for action, still cannot be said to 'understand' perceptual input. This may not be the fault of incompetent computer scientists, but it may be, that alongside human concepts of consciousness and awareness, 'understanding' is hard to define. This paper examines a recent emergence in philosophy of a somewhat controversial concept called 'cognitive phenomenology' (CP) [1], which is distinguished from classical phenomenology (characterised by 'there being something it is like' to be conscious of something - a rose, a pain or an emotion). Cognitive Phenomenology refers to understanding, thought and meaning experiences. For example, it argued that 'there is something it is like' to \*understand\* which is independent of what it is that is being understood. In this paper it is posited that CP may

be related in neural machinery to degrees of integration between perceptual inputs and internal state trajectories that are due to learning. This can be measured and an example is given in a simulation of visual consciousness. The result of this is that such measurements can provide a quality measure for 'mental states' in terms of how well they relate to material internalised by learning, that is, how well this is understood. It is suggested here, that this may be the road to true understanding in artificial systems and should be studied further. [1] Bayne, T. and Montague, M., (2011) *Cognitive Phenomenology*, OUP.

### **30 - Cognitive Systems For Cooperative Human-Robot Interaction**

*Peter Ford Dominey*

### **31 - Introducing BICA Philosophy: (A) No Direct Ontological Access – The Feature we Share (B) The Engineering Thesis of Non-Reductive Consciousness**

*Peter Boltuc*

BICA philosophy is the idea that there is nothing in human and animal cognitive architectures that cannot be instantiated (not just merely replicated, whatever the difference) in a sufficiently advanced biologically inspired cognitive architecture. This radical claim may follow from the physical interpretation of the Church-Turing thesis. Here are two examples of philosophical problems in BICA:

A. All cognitive architectures have merely an indirect ontological access to empirical reality but levels of such access differ. This is true of biological, biologically inspired architectures as well as AI. Systems that are purely reactive are empirically the closest to ontology. The more complex mind-maps a system creates, the further from direct interactions with reality it becomes. This is the problem of empirical access. This problem is well known in human epistemology but it is even clearer in robotics.

Olivier Georgeon, in his recent work, points out to the opposite problem. If we use a cognitive architecture "to solve problems that we model a priori (e.g., playing chess etc). Then the model of the problem constitutes a reality as such and the cognitive architecture receives a representation of the current state of the problem as input data. In this case, the architecture has access to its noumenal reality (the problem space)." I would call it the Platonic scale of ontological access where mathematical equations are identical with

reality but the problem is their fit as a model of the empirical world they are supposed to describe and predict, an old problem in philosophy of science.

B. If we come to understand how a human brain operates, we should also know how it operates first-person stream of consciousness. To understand anything at a BICA level is to be able to reverse engineer it. Hence, we should be able to reverse engineer first person consciousness.

This claim has philosophical as well as engineering implications. Most people today think that computation of complex data is the gist of first person consciousness; this is in part because they view first-person stream of consciousness as spooky (a dualistic remnant of religious notions of the soul). But a simpler hypothesis is that the stream of consciousness is more like hardware (a stream of light generated by a light bulb or a reflection generated by a mirror); nothing spooky about those. Information is just the content engrafted in such stream. Hence, to preserve one's conscious self is to preserve the stream – to preserve the content of such stream is to preserve information about it.

### **32 - An approach for the binding problem based on brain-oriented autonomous adaptive system with object handling functions**

*Yasuo Kinouchi and Kenneth James Mackin*

An approach for the binding problem is proposed, based on an autonomous adaptive system designed using artificial neural networks with object handling functions. Object handling functionality, such as object files, has been reported to have a relationship with perception, and working memory. However, in order for a brain-oriented system to decide actions based on object handling, the system must clarify the “binding problem”, or the problem of processing different attributes such as shape, color and location in parallel, then binding these multiple attributes as a single object. The proposed system decides semi-optimum actions by combining nonlinear programming and reinforced learning. By the introduction of artificial neural networks based on dendritic structures of pyramidal neurons in the cerebral cortex, together with a mechanism for dynamically linking nodes to objects, it is shown that deciding actions and learning as a whole system, based on binding object attributes and location, is possible. The proposed features are verified through computer simulation results.

### **33 - Structuring Autobiographical Experience for a Narrative Companion Robot**

*Grégoire Pointeau, Anne-Laure Meulier and Peter F. Dominey*

To free today's robots from their classical history-log representation of the past, the robot of tomorrow should be able to represent and express their life-story in a more human-like narrative format. To do so, we present here a cognitive system for a humanoid robot, based on the structure of human memory (with a division between episodic and semantic memory coupled to a system of language through reservoir computing based on the neuronal system situated in the cortex and basal ganglia. The novelty of the present study is the linking between a bio-inspired memory module to encode experience over the robot's lifetime, a reasoning system to create knowledge based on this memory content, and a module of language processing that will provide a natural language interface to this human-like memory. We can consider the resulting system in terms of Neisser's Narrative or Temporally Extended Self.

### **34 - Biologically Inspired Neural Robots**

*Pentti Haikonen*

A biologically inspired robot should observe and experience the world apparently as it is, in the same way as we do. It should see and hear like we do, it should be able to touch and feel like we do. We do not convert our sensory sensations into numbers, instead we experience the different qualities of our sensory percepts as the qualities of the world. Why should a robot do it in a different way? One might argue that the robot has to do it in a different way, because computers and microprocessors cannot operate with sub-symbolic analog data; the analog/digital conversion is a must. Indeed, this is true as long as digital symbolic processing is used as the basis for robot brains. But it should also be obvious that a digital microprocessor-based programmed robot will not be able to experience the world in the same way as we do.

However, there is another approach available, namely the associative neural approach that is able to operate inherently in sub-symbolic and symbolic ways without any program code. This approach allows direct sub-symbolic perception and also the utilization of the same percepts as symbols for other things. This symbolic approach allows thus also the use of a natural language.

A biologically inspired robot should also be able to think; imagine, reason and plan ahead its actions. It should be able to learn and acquire a good/bad value framework. It should have short- and long-term memories, both explicit and procedural ones. It should have natural language inner speech and the ability to interact via spoken language. The combination of all these abilities into one system calls for a system architecture. The associative neural network based Haikonen Cognitive Architecture (HCA) is given as an example.

The HCA-based biologically inspired experimental cognitive robot XCR-1 is one of the first (maybe first) robots with inner speech that utilise sub-symbolic/symbolic hard-wired (not simulated) neural networks. XCR-1 may also be the first robot where pain appears as dynamic sub-symbolic system condition. In this talk the structure and capacities of the latest form of XCR-1 are described and the relevance of the experiments with this robot to the research of biologically inspired robots is discussed. A demo video is shown.

### **35 - A Machine Consciousness Approach to Urban Traffic Control**

*André Paraense, Klaus Raizer and Ricardo Gudwin*

In this work, we present a distributed cognitive architecture used to control the traffic in an urban network. This architecture relies on a machine consciousness approach - Global Workspace Theory - in order to use competition and broadcast, allowing a group of local traffic controllers to interact, resulting in a better group performance. The main idea is that the local controllers usually perform a purely reactive behavior, defining the times of red and green lights, according just to local information. These local controllers compete in order to define which of them is experiencing the most critical traffic situation. The controller in the worse condition gains access to the global workspace, further broadcasting its condition (and its location) to all other controllers, asking for their help in dealing with its situation. This call from the controller accessing the global workspace will cause an interference in the reactive local behavior, for those local controllers with some chance in helping the controller in a critical condition, by containing traffic in its direction. This group behavior, coordinated by the global workspace strategy, turns the once reactive behavior into a kind of deliberative one. We show in the sequence that this strategy is capable of improving the overall mean travel time of vehicles flowing through the urban network.

### **37 - Evolving Conceptual Spaces for Symbol Grounding in Language Games**

*Suelen de Paula and Ricardo Gudwin*

A standard approach in the simulation of language evolution is the use of Language Games to model communicative interactions between intelligent agents. Usually, in such language games, the meaning assignment of symbols to parts of reality comprising the agents environment is simplified and given "a priori" to the experiment. In this paper, we develop an approach where the decomposition of reality in meaningful experiences is co-evolved with the lexicon formation in the language games, bringing some insights on how meaning might be assigned to symbols, in a dynamic and continuously changing environment, being experienced by an agent. In order to

do that, we use Barsalou's notion of mental simulation and Gardenfors' notion of conceptual spaces such that, together with ESOM neural networks, a cognitive architecture can be developed, where mental concepts formation and lexicon formation are able to co-evolve during a language game. The performance of our cognitive architecture is evaluated and the results show that the architecture is able to fulfill its semantics function, by allowing a population of agents to exchange the meaning of linguistic symbols during a naming game, without relying on "a priori" categorization scheme provided by an external expert. These results, beyond bringing evidence on potential ways for symbols to get meaning on a biologically realistic way, open a set of possibilities for further uses of conceptual spaces on a much more complex problem: the grounding of a grammatical language.

### **38 - Model-based Behavioral Causality Analysis of Handball with Delayed Transfer Entropy**

*Kota Itoda, Norifumi Watanabe and Yoshiyasu Takefuji*

In goal-type ball games, such as handball, basketball, hockey or soccer, teammates and opponents share the same field. They switch dynamically their behaviors and relationships based on other players' behaviors or intentions. Interactions between players are highly complicated and hard to comprehend, but recent technological developments have enabled us to acquire positions or velocities of their behaviors. We focus on handball as an example of goal-type ball games and analyze causality between teammates' behaviors from tracking data with Hidden Semi-Markov Model (HSMM) and delayed Transfer Entropy (dTE). Although 'off-the-ball' behaviors are a crucial component of cooperation, most research tends to focus on 'on-the-ball' behaviors, and relations of behaviors are only known as tacit knowledge of coaches or players. In contrast, our approach quantitatively reveals player's relationships of 'off-the-ball' behaviors. The extracted causal models are compared to the corresponding video scenes, and we claim that our approach extracts causal relationships between teammates' behaviors or intentions and clarifies roles of the players in both attacking and defending phase.

### **39 - Human robot interaction in the absence of visual and aural feedback: Exploring the haptic sense**

*Jacques Penders and Ayan Ghosh*

The potential of robot swarms for Search and Rescue has been shown by the Guardians project (EU, 2006-2010); however the project also showed the problem of human robot interaction in smoky (non-visibility) and noisy

conditions. The REINS project (UK, 2011-2015) focused on human robot interaction in such conditions. This paper briefly reviews the scientific context relevant for designing a haptic interface for human robot navigation and examines what we have achieved since then. The aim is to put the major design issues into context.

#### **40 - Integrating a Cognitive Framework for Knowledge Representation and Categorization in Diverse Cognitive Architectures**

*Antonio Lieto, Daniele Radicioni and Valentina Rho*

This paper describes the rationale followed for the integration of Dual-PECCS, a cognitively-inspired knowledge representation and reasoning system, into two rather different cognitive architectures, such as ACT-R and CLARION. The provided integration shows how the representational and reasoning mechanisms implemented by our framework may be plausibly applied to computational models of cognition based on different assumptions.

#### **43 - Mirroring Autobiographical Memory by Cognitive Architecture**

*Junya Morita, Takatsugu Hirayama, Kenji Mase and Kazunori Yamada*

Assuming that photographs accumulated on a personal computer reflect the life history of a person, a model of that person's autobiographical memory could be constructed. Such a model would be useful to overcome memory problems caused by factors such as aging. On the basis of this idea, we constructed an image recommender system comprising an ACT-R model. We built the model using a private photo library, consisting of 3,202 photos, and ran a simulation manipulating the activation noise of the declarative chunks. The noise was found to strongly influence the memory retrieval. When the noise level was low, the model retrieved a few memory items that occurred recently. On the other hand, when the noise level was high, the retrieval process was like a random walk over a memory network, with repeated recalls of old photos. The results suggest a condition of an ACT-R model can facilitate mental time travel into the distant past.

#### **45 - Holons, intentions and system adaptation**

*Massimo Cossentino*

Holons are the basis for building very scalable yet simple architectures. They spring from the observation made by Koestler that the concepts of 'whole' and 'part' have no absolute meaning in the reality. A whole or a part can be easily identified in many contexts but at the same time they can be seen

as opposite. This philosophical concept has a perfect correspondence with software architecture. Nowadays, it is very diffused to approach complex systems as systems of systems. They can be seen as intrinsically recursive when considering that each of the composing systems may be decomposed into its components that in turn may be individually addressed or regarded as an assembly of (sub-) systems/components/classes. Each of the parts at whatever level of abstraction has the dignity of a complete entity (a whole) but at the same time it may be further exploded at finer level of details (as parts). Holons offer a great way for representing complex systems and solving several real-world problems but their recursive, dynamic nature may be a challenge at design time. In this talk, holons will be the common denominator of a path that discusses the design of holonic systems and their great contribution in achieving runtime system-level adaptation of cognitive multi-agent systems, for instance during the execution of norm-constrained workflows. The presented contribution of holons towards system adaptation lies in the hierarchical self-similar structure of the holonic architecture. They allow the decomposition and representation of intentional systems that achieve effective goal-oriented solutions, at the same time they become a proficient structure to be learnt for future reuse.

#### **46 - A Remark on Biological Consciousness and Free Will**

*Albert Fonda*

Biological intelligence is explicable as a fully deterministic decision machine characterized by adaptive dynamic closed-loop control. Differing as well as confirming prior art is discussed.

#### **47 - Designing, Implementing and Enforcing a Coherent System of Laws, Ethics and Morals for Intelligent Machines (including Humans)**

*Mark Waser*

Recent months have seen dire warnings from Stephen Hawking, Elon Musk and others regarding the dangers that highly intelligent machines could pose to humanity. Fortunately, even the most pessimistic agree that the majority of danger is likely averted if AI were “provably aligned” with human values. Problematical, however, are proposals for pure research projects entirely unlikely to be completed before their own predictions for the expected appearance of super-intelligence [1]. Instead, with knowledge already possessed, we propose engineering a reasonably tractable and enforceable system of ethics compatible with current human ethical sensibilities without unnecessary intractable claims, requirements and research projects.

**49 - Anthropomorphic artificial social agent with simulated emotions and its implementation***Vlada Kugurakova, Maxim Talanov, Nadir Manakhov and Denis Ivanov*

In this paper we describe an emotional human-machine interface as an anthropomorphic social agent able to exhibit simulated emotions and react to emotional stimuli. We propose a neurobiologically inspired agent implementation that is based on mechanics of chemical and physiological processes within human brain. Implementation of model features simulation of neuromodulators such as dopamine, serotonin, and noradrenaline. Demonstration of emotions is achieved via combining aforementioned neuromodulators in different proportions. The Lovheim cube of emotions is used for this purpose. Topic of "uncanny valley" phenomenon and its effect on human-machine interactions is also mentioned. In conclusion of this paper we have proposed realistic computation model allowing us to visualize agents mimics in sync with his speech, and have made a working prototype of aforementioned model.

**50 - Modeling of Stress/Interest State Controlling in Robot-Child Play Situation***Takashi Omori, Kasumi Abe and Takayuki Nagai*

When we interact with other person, we need a knowledge on other's mind and consult it to decide action of our self. We call the knowledge Model of Other, MoO. To realize a cognitive architecture to interact with human, MoO must be embedded and used in a decision making process. But to design MoO, we must know how human interact in real world in MoO view because we aim a practical human interaction task. So, in this paper, we conducted a child-robot play experiment and analyzed human behavior. From the result, we construct a model of emotion level mental status leading that may be a possible leading concept of human-agent interaction design.

**51 - Image Coding and Pooling with a Bio-inspired Reaction-Diffusion Algorithm***Atsushi Nomura*

This paper proposes a reaction-diffusion algorithm designed for image encoding, pooling and decoding with a FitzHugh-Nagumo model. The model simulates biological nonlinear response on external stimuli applied to nerve axon. A system of discretely coupled elements governed by the FitzHugh-Nagumo model has the nature of organizing stationary pulses, depending on their initial conditions and coupling strength. The proposed algorithm utilizes

the system, and encodes a gray level image into a halftone image with the nature organizing stationary pulses (image encoding); the encoded halftone image is pooled in the system without external stimuli (image pooling). In the image encoding, we need to add Gaussian noise to the gray level image for randomly distributing pulses, which represent gray levels in a local area. By providing the encoded halftone image for the initial condition of the same reaction-diffusion algorithm, we obtain a gray level image approximating to the original one (image decoding).

### 52 - A Visual Sense of Space

*Divyanshu Bhartiya and Amitabha Mukerjee*

Biological organisms effortlessly acquire a visual model for familiar spaces, enabling them to localize and find paths and do many other tasks. On the other hand, for robots, all poses must be calibrated against a canonical referenced frame, and even tasks driven by vision require state estimation onto these coordinates. In this paper, we attempt to develop a visual sense of the ambient space using only a large set of untagged images, without any reference to ground coordinates, motor parameters etc. We first introduce the *Visual Manifold Theorem* which states that the images captured by a camera mounted on a motor system will lie on a low-dimensional manifold homeomorphic to the motor manifold. The coordinates of the system on this manifold are in fact, generalized coordinates that describe the motion, and can be used as alternatives to the canonical coordinates traditionally used in robotics. We demonstrate this process for a simulated robot exploring a planar space. A quick exploration of the space can be used to generate a manifold based on the similarity of images captured from nearby viewpoints, without any knowledge of the motion coordinates. The work makes an useful contribution both to robotics and to computational models for acquisition of place cells in cognition.

### 53 - BICA and sex differences: we need to understand potential sex differences when developing computational models of human behavior

*Christopher Dancy and Frank Ritter*

Validating computational models of human behavior typically involves statistically comparing human data collected during an experiment to predictions made by the model. However, these models very rarely attempt to represent sex, despite the growing indication that there are sex-based differences in neural and behavioral responses to some external stimuli. We make a case for a stronger presence of male and female models of behavior in biologically inspired cognitive architectures, an area of research that is especially

susceptible to physiological differences that can cause bottom-up behavioral differences. We discuss previous data collected that highlight the importance of providing more focus on sex-based differences and conclude with suggestions of potential areas of application for models that take into account differences in males and females.

#### **54 - Adversarial Software, a Model for Biologically Inspired Cognitive Architectures**

*Robert Laddaga*

Our software, OS, other system software, and applications, all now find themselves in an adversarial environment. We don't however, design the software for combat, survival, competition and alliances. But real-world cognitive systems have always evolved in such environments. We describe design issues for adversarial software, and indicate how these ideas might assist us in improving cognitive architectures.

#### **55 - Better Cell Assemblies**

*Christian Huyck and Ritwik Kulkarni*

In 1949, Hebb [1] proposed the Cell Assembly (CA) as an important intermediate level circuit in the brain. A CA is a set of neurons that, among other things, form the neural basis of concepts. So, each person who has the concept dog has a dog CA. The CA is learned via repeated presentations of objects, in the example's case of dogs. This repeated presentation causes neurons to fire, and neurons that are repeatedly stimulated, and connected via synapses to other neurons that tend to be activated, will have those synaptic connections strengthened via Hebbian learning. This process will lead to the formation of a long-term, in the dog case, semantic memory. Once the dog CA is formed, the presentation of a dog will cause the neurons in the CA to fire. Moreover, this firing will continue even if the dog goes out of sight. The persistently firing CA is a short-term memory. The CA thus forms a bridge between neurobiology (neurons, neural firing, synapses and synaptic change) to psychology (short-term and long-term memory). Hebb was thus the first neuropsychologist. While Hebb's initial theory has been modified [2], it is still broadly accepted in the neuroscientific community [3, 4, 5]. While there has been a significant amount of simulation of neural assemblies in spiking neurons, there have been no simulation, as far as the authors are aware, of CAs that persist for psychologically realistic times. Moreover, there have been no simulations, again as far as the authors are aware, where CAs have different levels of activation...

**57 - Evolution-inspired Construction of Stories: Iterative Refinement of Narrative Drafts as a Social Cycle***Pablo Gervás and Carlos León*

Narrative creation happens not only as an internal process in the writer's mind, but also as a social phenomenon in which several individuals influence each other by creating, telling and evaluating the stories told in the community. As such, stories evolve over time under the influence of many activities: inventing new parts or rejecting old ones, changing the discourse, telling the plot in a different way, and changing the way the story is understood and accepted, possibly by other changes in the society. We propose a formal computational model based on the cognitive behavior of individuals inventing, telling and refining narrative structures based on the ICTIVS model. This new version of the model, Social-ICTIVS, adapts the previous model by considering each of the steps and re-defining them as a social activity of narrative evolution.

**58 - Minimally cognitive robotics: body representations and sensorimotor contingencies in quadrupedal and humanoid robots***Matej Hoffmann*

In response to the cognitivist paradigm and its problems, the embodied cognition viewpoint was proposed. In robotics, this resulted in a radical move away from higher-level cognitive functions toward direct, almost "brain-less" interaction with the environment (e.g., behavior-based robotics). While some remarkable behaviors were demonstrated, the complexity of tasks the agents could master remained limited. A natural extension of this approach lies in letting the agents extract regularities in sensorimotor space and exploit them for more effective action guidance. We will use a collection of case studies featuring a quadrupedal and a humanoid robot to concretely explore this space of "minimally cognitive" phenomena, focusing in particular on the concepts of body schema, forward models and sensorimotor contingencies. The studies in the quadrupedal robot will have a more exploratory nature, trying to provide minimal but clear and quantitative examples of the concepts. Studies in the iCub humanoid robot will specifically target the development of body representations, modeling corresponding mechanisms that are believed to operate in primate brains.

**59 - Peculiarities of semantic web-services cloud runtime***Valentin Klimov*

This paper is devoted to semantic description of the system that functions in a cloud runtime (like app store) providing business services available on demand (hereinafter, system). Business services are in fact information processing units that accept the given parameters and return business data. The described system ensures automatic collaboration between services and grants access to processing resources defined in the business process logic. We describe a business model that allows its users to find solutions of their tasks using published services or their collaborations.

**60 - Rapid path planning in maze-like environments using attractor networks**  
*Dane Corneil and Wulfram Gerstner*

Animals navigating in a well-known environment can rapidly learn and re-visit observed reward locations, often after a single trial. The mechanism for rapid path planning remains unknown, though evidence suggests that the CA3 region in the hippocampus is important, with a potential role for “pre-play” of navigation-related activity. Here, we consider a neural attractor network model of the CA3 region, and show how this model can be used to represent spatial locations in realistic environments with walls and obstacles. The synaptic weights in the network model are optimized for stable bump formation, so that neurons tend to excite other neurons with nearby place field centers and inhibit neurons with distant place field centers. Using these simple assumptions, we initialize the activity in the network to represent an initial location in the environment, and weakly stimulate the network with a bump at an arbitrary goal location. We find that, in networks representing large place fields, the network properties cause the bump to move smoothly from its initial location to the goal location along the shortest path, around obstacles or walls. Reward-modulated Hebbian plasticity during the first visit to a goal location enables a later activation of the goal location with a broad, unspecific external stimulus, representing input to CA3. These results illustrate that an attractor network that produces stable spatial memories, when augmented to represent large scale spatial relationships, can be parsimoniously extended to rapid path planning.

**61 - Integrating Human Emotions with Spatial Speech Using Optimized Selection of Acoustic Phonetic Units**

*Mukta Gahlawat, Poonam Bansal and Amita Malik*

Synthesis of natural sounding speech is the state of art in the field of speech technology. Imitation of dynamic human voice is required to generate this. The aim of this work is to develop and deploy the natural speech synthesizer for visually impaired persons. The synthesizer has been developed via

integrated approach of adding localization in expressive speech using personalized speech corpus. Genetic algorithm has been implemented for optimal selection of acoustic phonetic units of speech. This concept has many applications, among these one is deployed for testing in different aspects. The performance is compared on various categories of listeners using subjective listening test. Encouraging results are received from visually impaired listeners on various parameters.

## **62 - Evolving Synthetic Pain into Adaptive Self-Awareness Framework for Robot**

*Muh Anshar and Mary-Anne Williams*

In human robot interaction, physical contact is the most common medium to be used, and the more physical interaction occurs, at certain times, the higher possibilities of causing humans to experience pain. Humans, at times, send this message out through social cues, such as verbal and facial expressions in which requires robots to have the skill to capture and translate these cues into useful information. It is reported that the concept of human pain is strongly related to the concept of self. Hence, evolving appropriate self-awareness and pain concepts for robots plays a dominant factor in allowing robots to acquire this social skill. This paper focuses on imitating the concept of pain into a synthetic pain model to justify the integration and implementation an adaptive self-awareness into a real robot design framework, named ASAF. The framework develops an appropriate robot cognitive system-"self-consciousness" which includes two primary levels of self concept, namely subjective and objective. Novel experiments designated to measure whether a robot is capable of generating appropriate synthetic pain; whether the framework's reasoning skills support an accurate "pain" acknowledgement, and at the same time, develop appropriate counter responses. We find that the proposed framework enhances the awareness of robot's own body parts and prevent further catastrophic impact on robot hardware.

## **63 - A First Look at the Visual Attention Executive for STAR: The Selective Tuning Attentive Reference Model**

*John Tsotsos*

After many years of development and significant supporting experimental evidence, the Selective Tuning (ST) model of visual attention (Tsotsos 2011) is now in its next phase of development. The goal was always for this model to be embedded into a larger-scale architecture with predictive power for furthering our understanding of human visual processes. For this larger-scale

system, it was easily apparent that many of the classical components of cognitive architectures importantly play a role. However, the level of detail required by ST's breadth and depth of attentional functionality is greater than that usually considered. This presentation will overview ST and its supporting evidence, detail the kinds of control signals, parameter settings and other forms of interaction its operation requires from its embedding architecture, and will introduce a design for its executive controller. The STAR architecture that provides the embedding substrate for ST will also be briefly described (Tsotsos & Kruijne 2014).

Tsotsos, J.K. (2011). *A Computational Perspective on Visual Attention*. MIT Press, Cambridge MA. Tsotsos JK and Kruijne W (2014) Cognitive programs: software for attention's executive. *Frontiers in Psychology: Cognition* 5:1260. doi: 10.3389/fpsyg.2014.01260

#### **64 - Towards Integrated Neural-Symbolic Systems for Human-Level AI: Two Research Programs Helping to Bridge the Gaps**

*Tarek Richard Besold and Kai-Uwe Kuehnberger*

After a Human-Level AI-oriented overview of the status quo in neural-symbolic integration, two research programs aiming at overcoming long-standing challenges in the field are suggested to the community: The first program aims at a better understanding of foundational differences and relationships on the level of computational complexity between symbolic and subsymbolic computation and representation, potentially providing explanations for the empirical differences between the paradigms in application scenarios and a foothold for subsequent attempts at overcoming these. The second program suggests a new approach and computational architecture for the cognitively-inspired anchoring of an agent's learning, knowledge formation, and higher reasoning abilities in real-world interactions through a closed neural-symbolic acting/sensing–processing–reasoning cycle, potentially providing new foundations for future agent architectures, multi-agent systems, robotics, and cognitive systems and facilitating a deeper understanding of the development and interaction in human-technological settings.

#### **65 - A Parameter Estimation Method for Dynamic Computational Cognitive Models**

*Dilhan Thilakarathne*

A dynamic computational cognitive model can be used to explore a selected complex cognitive phenomenon by providing some features or patterns over time. More specifically, it can be used to simulate, analyse and explain the

behaviour of such a cognitive phenomenon. It generates output data in the form of time series which can only be partially compared to empirical knowledge. This leads to a challenging problem to estimate values of the parameters of the model representing characteristics of a person. A parameter estimation approach for dynamic cognitive models is presented here by combining improved Particle Swarm Optimization (PSO) and Constraint Satisfaction (CS) methods. Having collected the key features of behaviour of a phenomenon, those are translated into a set of constraints with parameters that will be solved through an improved agent based PSO technique. Through this, within PSO each agent explores the complex search space while communicating the quality of a local parameter value vector relative to their current global best solution as a swarm (through cooperation and competition). This is performed in tournaments and results of each tournament are combined to address the premature convergence issue in PSO.

#### **66 - A Rapid Pattern Recognition Architecture with A Multilayer Autonomous Ratio-Memory Cellular Nonlinear Network for Electronic Nose**

*Tatt Wee Oong, Ali Yeon Md Shakaff, Ammar Zakaria and Azman Mohamad Yusof*

A new and rapid pattern recognition architecture, which employs a multilayer autonomous ratio-memory cellular nonlinear network (MARMCNN) algorithm is presented. Evolved from the celebrated idea of a Cellular Neural Network (CNN - or sometimes known as Cellular Nonlinear Network), which focuses on analogue processing, the MARMCNN is expected to provide ample processing capabilities as well as the possibility of a real hardware implementation. The proposed MARMCNN employs a rapid and modified Hebbian rule as its learning algorithm. It has been used in the classification of Harumanis mangos using MATLAB simulation as the implementation platform. Using 1000 profile odour data from 200 samples of Harumanis mangos in 5 different classification categories, a 4-layer 66 MARMCNN managed to produce a successful ripeness recognition rate of 98.6% while using only 5 training patterns in 10 iterations. This is comparable to a much more complex 3-layer Multi-Layer Perceptron (MLP) feed-forward Artificial Neural Network (ANN) with 4 hidden nodes using Levenberg-Marquardt learning algorithm and a Radial Basis Function (RBF) network with 4 hidden nodes. In short, the MARMCNN is capable of learning, recognizing, and classifying a complete range of gray scale odour data patterns rather convincingly. The performance, learning time, complexity and the flexibility of the proposed MARMCNN is discussed and compared to other two established classical neural network (MLP and RBF).

**68 - Classification Based on Lingual Variables Using Expert Matrix Obtained with Genetic Algorithm***Tomasz Szandala*

This paper presents potential of application of fuzzy sets classifier as the support for medical diagnosing. For the classification purposes there will be generated an expert matrix, created using genetic algorithm described below. This paper discusses effectiveness of such classification method on the sample medical records. It is assumed, that the developed methodology could be successfully used in many other fields of science.

**69 - Autonomous object modeling based on affordances in a dynamic environment***Simon Gay and Salima Hassas*

We present an architecture for self-motivated agents to generate behaviors in a dynamic environment according to its possibilities of interactions. Some interactions have predefined valences that specify inborn behavioral preferences. Over time, the agent learns to recognize affordances in its surrounding environment under the form of structures called signatures of interactions. The agent keeps track of enacted interactions in a spatial memory to generate a completed context in which it can use signatures to recognize and localize distant possibilities of interactions, and generates behaviors that satisfy its motivation principles.

**70 - A Computational Cognitive Model Integrating Different Emotion Regulation Strategies***Altaf. H. Abro, Adnan Manzoor, Seyed Amin Tabatabaei and Jan Treur*

In this paper a cognitive model is introduced which integrates a model for emotion generation with models for three different emotion regulation strategies. Given a stressful situation, humans often apply multiple emotion regulation strategies. The presented computational model has been designed based on principles from recent neurological theories based on brain imaging, and psychological and emotion regulation theories. More specifically, the model involves emotion generation and integrates models for the emotion regulation strategies reappraisal, expression suppression, and situation modification. The model was designed as a dynamical system. Simulation experiments are reported showing the role of the emotion regulation strategies. The simulation results show how a potential stressful situation in principle could lead to emotional strain and how this can be avoided by applying the

emotion regulation strategies decreasing the stressful effects.

### **71 - A cognitive neural model of executive functions in natural language processing**

*Bruno Golosio, Angelo Cangelosi, Olesya Gamotina and Giovanni Luca Masala*

Although extensive research has been devoted to cognitive models of human language, the role of executive functions in language processing has little been explored. In this work we present a neural-network-based cognitive architecture which models the development of the procedural knowledge that underpin language processing. The large scale organization of the architecture is based on a multi-component working memory model, with a central executive that controls the flow of information among the slave systems through neural gating mechanisms. The system was validated, starting from a tabula rasa condition, on a corpus of five datasets, each devoted to a thematic group, based on literature on early language assessment, at the level of a preschool child. The results show that the system is capable of learning different word classes, and to use them in expressive language, through an open-ended incremental learning process, expressing a broad range of language processing functionalities.

### **72 - Unified formalization of «natural» classification, «natural» concepts, and consciousness as integrated information by Giulio Tononi**

*Evgenii Vityaev*

The paper shows that construction of "natural" classifications, "natural" concepts and integrated information base on the same property of the objects of the external world - the high correlation of features, describing the objects of "natural" classes. The hypothesis that the information processes of the brain and mind tuned in the course of evolution to extract highly correlated structure of features of "natural" objects by forming "natural" concepts of the objects, was set up. This hypothesis is justified by references to a number of famous works. The original mathematical model is proposed, which formalizes the "natural" classifications, "natural" concepts and the integrated information by G.Tononi, based on a mathematical representation of the system, closed upon itself by causal relationships, that form a certain "resonance" of mutual predictions of highly correlated set of attributes of objects of "natural" classes. The results of computer modeling of building "natural" classes and concepts of coded numbers, that illustrate the concepts, are introduced.

**73 - Towards narratologically inspired cognitive architectures***Nicolas Szilas*

For several decades, the hypothesis according to which narrative is not only a prominent form of human communication but also a fundamental way to represent knowledge and to structure the mind has been proposed and discussed. But surprisingly, this has not yield to any NICA (narratologically inspired cognitive architectures) and the hypothesis remains a fuzzy one with limited implications. Perhaps this is due to the fact that the few attempts to bridge the gap from narrative theory to cognitive architectures, namely the scripts and cases in artificial intelligence (AI), have considered only a small set of facets of narrative. Historically indeed, when AI and cognitive Science researchers tackled narrative in the 70s and 80s, they tended to reinvent narrative theories, ignoring the centuries of studies in the domain. In this contribution, we propose to study further the above hypothesis by identifying differentiating features of narratives that contrast with the classical problem solving AI and that may inspire new cognitive architectures. Potential applications of NICAs include better communicating machines, improved intelligent tutoring systems and robust knowledge bases.

**74 - Modeling of cognitive evolution: Perspective direction of interdisciplinary investigation***Vladimir Red'Ko*

The new direction of investigation, namely, modeling of cognitive evolution is described. The cognitive evolution is evolution of animal cognitive abilities. Fundamental scientific problems that can be analyzed by means of modeling of cognitive evolution are outlined. Backgrounds of models of cognitive evolution, which are developed in two areas of investigations: (1) models of autonomous agents and (2) biological experiments on cognitive properties of animals, are characterized. The sketch program for future investigations of cognitive evolution is proposed. Interdisciplinary relations of modeling of cognitive evolution are characterized.

**75 - Using a Distributional Semantic Vector Space with a Knowledge Base for Reasoning in Uncertain Conditions***Douglas Summers-Stay, Taylor Cassidy and Clare Voss*

The inherent inflexibility and incompleteness of commonsense knowledge bases (KB) has limited their usefulness. We describe a system called Displacer for performing KB queries extended with the analogical capabilities of the word2vec distributional semantic vector space (DSVS). This allows the

system to answer queries with information which was not contained in the original KB in any form. By performing analogous queries on semantically related terms and mapping their answers back into the context of the original query using displacement vectors, we are able to give approximate answers to many questions which, if posed to the KB alone, would return no results.

We also show how the hand-curated knowledge in a KB can be used to increase the accuracy of a DSVS in solving analogy problems. In these ways, a KB and a DSVS can make up for each other's weaknesses.

#### **76 - Biologically Inspired Perception for Robotics in Hostile Environments**

*Sherine Antoun*

Navigation and localization in extreme or hostile environments such as deep ocean, disaster scenes and underground environments where darkness, pollution, and dust render cameras, laser scanners, and other sensors ineffective is a task that is challenging to robotics. Nature, however, equipped cave-dwelling creatures with echo acoustic perception that allowed them to thrive in such environments. Visually impaired people have been successful in using Ultrasonic (echo acoustic) mobility aids for day-to-day safe navigation. This work offers some insights on Ultrasonic sensing, and improved techniques for the use of ultrasonic perception for robotics in hostile environments.

#### **79 - Biological and Brain Foundations of Reservoir Computing**

*Peter Ford Dominey*

This talk will set the organization of workshop. We will first introduce the basic principals of reservoir computing and the underlying neuroscience motivation. We will then introduce the topics of the presenting speakers, and the fundamental questions that we want to answer, related to cortical dynamics, computation in the context of recurrent networks.

#### **80 - Partially embodied motor control: towards a natural collaboration between body and brain.**

*Joni Dambre*

Motor control systems in the brain humans and mammals are hierarchically organised, with each level controlling increasingly complex motor actions. Each level is controlled by the higher levels and also receives sensory and/or proprioceptive feedback. Through learning, this hierarchical structure adapts to its body, its sensors and the way these interact with the environment. An

even more integrated view is taken in morphological or embodied computation. On the one hand, there is both biological and mechanical (robotics) evidence that a properly chosen body morphology can drastically facilitate control when the body dynamics naturally generate low level motion primitives. On the other hand, several papers have used physical bodies as reservoirs in a reservoir computing setup. In some cases, reservoir computing was used as an easy way to obtain robust linear feedback controllers for locomotion. In other cases, the body dynamics of soft robots were shown to perform general computations in response to some input stimulation. In general, very specific highly compliant bodies were used. We present recent results on two open questions regarding the way morphological computation could be exploited in biological motor control. Generally, when reservoir computing has been used to exploit body dynamics for computation, the desired output signals were known. Clearly, in biological locomotion, the learning does not enforce specific muscle actuation signals. Instead, it rewards desirable forms of motion and penalizes undesirable ones. We show how a biologically plausible learning rule, reward modulated Hebbian learning, can enable the incorporation of compliant body dynamics into the control hierarchy, resulting in robust motor control. Despite the many successes with using physical bodies as reservoirs, the relationship between compliance and computational power has hardly been investigated. Although biological bodies are partially compliant, they also have a very specific structure and many rigid parts. It therefore remains unclear to what extent this type of bodies can help in motor control. In our research, we use compliant four legged robots to address this issue. We present first results that indicate that for such robots, linear feedback of proprioceptive signals alone is often not sufficient to result in stable gait control. In addition, a first comparison of different levels of compliance indicate that a well chosen level of compliance can drastically simplify motor control, compared to both, too little and too much compliance, and that the body should therefore be considered as an integral part of the control.

### **81 - Interregional and interlevel connections for active perception**

*Paul Robertson and Andreas Hofmann*

Perception is performed in biological systems in order to support action that takes place in the context of goals. The origins of the contexts and goals are themselves the result of other closed-loop systems running on different timescales, involving different sensing capabilities using brain structures of differing evolutionary eras, but all integrated to a greater or lesser extent. In this paper we describe an architectural approach and its motivation for an artificial system that is inspired by biological counterparts. The work described in this paper described research conducted on closed loop computer

vision.

### **83 - Voice Pathology Detection based on Modified Voice Contour and SVM**

*Zulfiqar Ali, Mansour Alsulaiman, Irraivan Elamvazuthi, Ghulam Muhammad, Tamer A. Mesallam, Mohamed Farahat and Khalid H. Malki*

In this study, a novel method based on the voice intensity of a speech signal is used for automatic pathology detection with continuous speech. The proposed method determines the peaks from the speech signal to form a voice contour. The area under the voice contour allows us to discriminate between normal and disordered subjects. In the case of disordered subjects, the calculated area under the voice contour is lower than that for a normal subject due to the malfunctioning of vocal folds, which makes the voice weaker and breathier. Some long-term features such as shimmer and jitter are based on the accurate estimation of fundamental frequency, which is itself a difficult task, especially for disordered speech signals. The proposed features do not need to estimate the pitch period or fundamental frequency during the calculation of the voice contour and they provide a single value for the whole utterance similar to other long-term features. The voice disorder database used in this study includes 71 voice samples of normal persons and dysphonic patients each having five different types of voice disorders, namely vocal folds cysts, laryngopharyngeal reflux disease, vocal folds polyps, unilateral vocal folds paralysis and sulcus vocalis. The accuracy of the proposed method is 100%.

### **84 - Cooperative Inference: Features, objects, and collections**

*Patrick Shafto and Nick Searcy*

Cooperation plays a central role in theories of development, learning, cultural evolution, and education. We argue that existing models of learning from cooperative informants have fundamental limitations that prevent them from explaining how cooperation benefits learning. First, existing models are shown to be computationally intractable, suggesting that they cannot apply to realistic learning problems. Second, existing models assume a priori agreement about which concepts are favored in learning, which leads to a conundrum: learning fails without precise agreement on bias yet there is no single rational choice. We introduce Cooperative Inference, a novel framework for cooperation in concept learning, which resolves these limitations. Cooperative Inference generalizes the notion of cooperation used in previous models from omission of labeled objects to the omission values of features, labels for objects, and labels for collections of objects. The result is an approach that is computationally tractable, does not require a priori agreement

about biases, applies to both Boolean and first-order concepts, and begins to approximate the richness of real-world concept learning problems. We conclude by discussing relations to and implications for existing theories of cognition, cognitive development, and cultural evolution.

### **85 - The role of attention in human-robot communication**

*Peter Gärdenfors*

In research on human communication and child development, the role of attention has become central. In the lecture, I will present some of this research and discuss its implications for how to develop human-robot communication that is as natural as possible. I focus on two questions: (1) How can a robot use the attention of a human to understand what the human wants to communicate? (2) How can a robot control the attention of a human in its communication? For the first question, following human gaze or pointing is required and joint attention should be achieved. The results will be improved if the robot has a model of the interests or goals of the human. For the second question, there are three main methods: speaking, looking and pointing. I will present some results from an ongoing project involving linguistic communication between an iCub and a human and show the importance of attention in the process. Finally, I will present some experiments concerning how humans interpret robot pointing, something which turns out to be quite dependent on the bodily configuration of the robot.

### **86 - Structural Analysis of Human Eye Movement Trajectory**

*Olga Mishulina and Ilya Sukonkin*

Development of an algorithm for event detection in eye movement trajectory when viewing pictures remains the goal of research by many specialists. The challenge is to develop an algorithm that depends weakly on the user settings and adjusts automatically to the data recorded by the eyetracker. We propose a new principle of eye movement data processing, which uses a two-stage space-time aggregation of gaze points in the coordinate space and velocity space. This approach results in the construction of microevents from which the target events are formed during the further aggregation procedures. The proposed concept made it possible to show the internal structure of the eye movement trajectory. The reliable estimates of the event durations are produced. All steps of the algorithm are explained in detail and illustrated by examples.

**87 - Method of reconstruction of dynamic connectomes in resting state for development of classifier-decoder of mental states**

*Vadim Ushakov, Alexey Poyda, Viktoriya Zavyalova, Denis Malakhov and Boris Velichkovskiy*

In this work, we describe an approach to reconstruction of dynamic connectomes that applies to research of the resting state of human brain. Proposed method allows reconstruction of dynamic connectomes with sample of 30 subjects. This makes it applicable for development of classifiers-decoders of mental state.

**88 - Respective advantages and disadvantages of model-based and model-free reinforcement learning in a robotics neuro-inspired cognitive architecture**  
*Erwan Renaudo, Benoît Girard, Raja Chatila and Mehdi Khamassi*

Combining model-based and model-free reinforcement learning systems in robotic cognitive architectures appears as a promising direction to endow artificial agents with flexibility and decisional autonomy close to mammals. In particular, it could enable robots to build an internal model of the environment, plan within it in response to detected environmental changes, and avoid the cost and time of planning when the stability of the environment is recognized as enabling habit learning. However, previously proposed criteria for the coordination of these two learning systems do not scale up to the large, partial and uncertain models autonomously learned by robots. Here we precisely analyze the performances of these two systems in an asynchronous robotic simulation of a cube-pushing task requiring a permanent trade-off between speed and accuracy. We propose solutions to make learning successful in these conditions. We finally discuss possible criteria for their efficient coordination within robotic cognitive architectures.

**89 - Human Cognition in Preparation for Problem Solving**

*Alexei V. Samsonovich, Anastasia Kitsantas, Ellen O'Brien and Kenneth De Jong*

College students were asked to solve problems in mathematics using a software tool assisting their preparation for problem solving at a metacognitive level. Students selected relevant steps, facts and strategies represented on the screen and connecting them by arrows, indicating their plan of solution. Only after the diagram was completed, students were allowed to solve the problem. The findings are: (i) forward chaining is significantly more predominant, and backward chaining is significantly less frequent, compared to other possibilities or arrow entering. This result is unexpected, because classical

planning methods produce backward chaining in this task. (ii) Students scoring in the middle are more likely to enter convergent pairs of arrows compared to students who scored low or high. This finding enables diagnosing student problem solving. Both findings imply constraints on selection of cognitive architectures used for modeling student problem solving.

### **90 - Narrative Effects and Lessons for BICA**

*Mark Finlayson*

Narrative is a ubiquitous language phenomenon that engages cognitive capabilities at multiple levels. I outline a number of observed effects that narrative has on cognitive processing, including improvements in comprehension, memory, and logical reasoning. Furthermore, an ability to understand narrative is critical to social reasoning. I connect these capabilities to recent results from the computational study of narrative, and draw a number of suggestions for biologically inspired cognitive architectures related to potential task domains, measurements of validity, and predicted cross-interactions among cognitive architectural components.

### **92 - Model of Plan Formation by New Caledonian Crows**

*Vladimir Red'Ko and Valentin Nepomnyashchikh*

The computer model of planning the rather complex behavior by New Caledonian crows is developed and investigated. The model characterizes the following processes: 1) analysis of predictions of elementary actions, 2) generation of a simple knowledge database that describes the set of initial situations, actions, and results of actions, 3) planning a concrete chain of consecutive actions. The model is inspired by the biological experiment on New Caledonian crows.

### **93 - Managing the observation of agents activity as an interpretation process: a Modeled Traces approach**

*Alain Mille*

One way to assess a cognitive architecture is to implement it in an agent, and observe the level of intelligence exhibited by this agent in various activities. Observing activities of agents, however, is a complex task : what elements of the activity can we observe? How to interpret the observed activity? How to account for time and space? How to describe/report the observation? How to demonstrate the validity of the observation? How to manage datasets of observations? For several years, we have been developing an original approach to make explicit the process of observing an activity. This work led us

to develop a theory of "Modeled Traces". A Modeled Trace is a trace of activity formally encoded in a knowledge-based system. The theory of Modeled Traces allows us to design software tools to facilitate the process of observation and – perhaps above all– to consider an observation as an interpretation of the observed activity according to a specific expertise of observation (as opposed to considering the observation as an "objective" fact). This talk is the opportunity to show the principles, the theory, the models, and the tools that we have been developing. We explain how modeled-trace systems can help design and assess biologically inspired cognitive architectures.

#### **94 - Does the cerebral cortex exploit the computational power of delay coupled recurrent networks?**

*Wolf Singer*

A hall mark of cortical architectures is the dense and specific reciprocal coupling among distributed feature specific neurons. This network engages in high dimensional non-linear dynamics that is characterized by oscillatory activity in widely differing frequency ranges and the transient synchronisation of neuronal discharges. Analysis of simultaneously recorded neuronal responses to sequences of light stimuli suggests that visual cortex shares features with liquid state machines such as fading memory and superposition of information of different stimuli. A major difference is that the coupling connections among cortical neurons are susceptible to activity dependent modifications of their synaptic gain, which allows the network to store priors about the statistical contingencies of the outer world. It is proposed that the cerebral cortex exploits the high dimensional dynamic space offered by recurrent networks for the encoding, classification and storage of information.

#### **95 - Motor memory: representation, learning and consolidation**

*Jure Žabkar and Aleš Leonardis*

An efficient representation of motor system is vital to robot control and its ability to learn new skills. While the increasing sensor accuracy and the speed of signal processing failed to bridge the gap between the performance of artificial and human sensorimotor systems, the motor memory architecture seems to remain neglected. Despite the advances in robot skill learning, the latter remains limited to predefined tasks and pre-specified embodiment. We propose a new motor memory architecture that enables information sharing between different skills, on-line learning and off-line memory consolidation. We develop an algorithm for learning and consolidation of motor memory and study the space complexity of the representation in the experiments with

humanoid robot Nao. Finally, we propose the integration of motor memory with sensor data into a common sensorimotor memory.

**96 - Reservoir Computing Properties of Neural Dynamics in Prefrontal Cortex**  
*Pierre Enel, Emmanuel Procyk, René Quilodran and Peter Dominey*

Primates adapt flexibly to novel situations. A key to adaptation is the capacity to represent these situations. It has been proposed that mixed selectivity may universally represent any situation defined by a combination of the current stimuli, and that mixed selectivity is readily obtained in randomly connected networks. In the reservoir computing framework, networks are random AND recurrent, thus allowing them to recombine present and past stimuli that are reverberated thanks to recurrent connectivity. We argue that reservoir computing is a suitable framework to model the generation of complex and dynamic representations locally in the cortex, whose common property is its highly recurrent connectivity. Training a reservoir to perform a complex cognitive task, we demonstrate its rich representational power, and compare it monkey data.

**97 - Toward a BICA-Model-Based Study of Cognition Using Brain Imaging Techniques**

*Vadim L. Ushakov and Alexei V. Samsonovich*

The aim of this study is to develop an approach to evaluation of a biologically inspired, causal model of cognition that exposes the mechanistic requirements for achieving fluid intelligence and makes testable predictions of neurophysiological measures. In order to build human-level-efficient tools for data analysis, it is necessary to have a theory of how concepts are represented in the human brain. This theory should specify (a) the structure and semantics of concept representations in the human brain, and (b) types, formats and specific patterns of neuronal activity instantiating these representations. The key to a biologically-informed human brain model begins with the mapping of (a) to (b), i.e., of the emotional Biologically Inspired Cognitive Architecture (eBICA) to informative features and characteristics of brain activity. The result is a detailed description of the information processing level of the dynamics of emotional evaluation of other agents and relationships with them in the process of joint activities, and the role of this evaluation in decision-making and generation of behavior based on the selected emotional cognitive architecture.

**98 - Empirical Measure of Learnability: A Tool for Semantic Map Validation***Alexei V. Samsonovich*

The many approaches to semantic mapping developed recently demand a precise measuring device that would, on the one hand, be sensitive to human subjective experiences (and therefore must involve a human in the loop), and on the other hand, allow comparative study and validation of consistency of individual semantic maps. The idea explored in this work is to measure the ability of a human subject to learn a given semantic map, and in this sense to be able to “make sense” of the map, as estimated based on a given set of test words. The paradigm includes allocating previously unseen test words in the map coordinates. The quantitative measure is the Pearson's correlation between actual map coordinates of test words and coordinates assigned by subjects. The preliminary study indicates that the proposed measure is sufficiently sensitive to discriminate individual semantic maps from each other and to rank them by the learnability, related to their internal consistency.

**99 - How could the enactive paradigm inspire computer science?***Pierre De Loor*

During this presentation, I will give you a short overview of the enactive paradigm origin - the work of Francisco Varela and Humberto Maturana - to position it within the field of embodied cognition. Then, I will present different studies in neuroscience and psychology that are in line with this paradigm. The second part of my presentation will focus on the implications of this paradigm for research in computer science. There are two orientations : the first one is on artificial intelligence or artificial life, in particular, the enactive field could provide directions for developmental approaches. The second one is on interactive systems. The enactive paradigm could help us design interactive systems that are better coupled with Humans to favor an enactive loop and then increase the relevance of technological progress. I will illustrate these points with some examples from my research group at Brest, France.

**100 - The Distributed Adaptive Control of Consciousness in Animals and Machines***Paul Verschure*

The brain evolved to maintain a dynamic equilibrium between an organism and its environment. We can define the fundamental questions that such a brain has to solve in order to deal with the how of action in a physical

world as: why (motivation), what (objects), where (space), when (time). I call this the H4W problem. Post the Cambrian explosion a second factor became of great importance for survival: who and how brains adapted to the H5W challenge. I will present the hypothesis that consciousness evolved to enhance fitness in the face of H5W. The Distributed Adaptive Control (DAC) theory of mind and brain shows how H5W can be solved through the interaction across multiple layers of neuronal organization and assigns a specific role to consciousness in the optimization of the real-time control of action. DAC makes specific predictions on both the structure and function of the neuronal correlate of consciousness that I will discuss with respect to memory, decision making and attentional processing. Each example will be illustrated by means of concrete robot experimentation.

### **101 - The need for high level compilers for generating low level behaviors**

*Frank Ritter*

There is a need for high level languages to help create low level BICA behaviour. I'll present an example compiler for creating ACT-R models from hierarchical task analyses for a non-iterative, 30 min. task, where we created models of 11 levels of expertise in an afternoon. The models start with about 600 rules each, and learn out to 100 trials about another 600 rules. We compared these models to human data over four trials (N=30) and both the aggregate and individual data fit the novice best (or nearly best). This work shows that high level compilers can help manage the complexity of large models. I'll then note some future work including microgenetic analysis and modeling of learning curves on the individual subtasks and also look at forgetting of these tasks after delays ranging from 6 to 18 days.

### **102 - Cognitive robotics towards real world applications**

*Rodrigo Ventura*

This talk will present several cognitive robotic approaches targeting real world applications in human-populated environments. On the one hand, a top-down, model-based approach based on the integration of robot functionalities. This approach have been applied to networked robot systems for edutainment activities in pediatric hospitals and in therapeutic activities with children with autism syndrome spectrum. We will also discuss the integration of verbal instructions with sensorimotor functionalities, employing probabilistic planning jointly with affordance models. And on the other, a data-driven approach, combining deep learning with reinforcement learning. Here we are researching how to apply reinforcement learning methods to low-dimensional

representations of high-dimensionality perception spaces. The formation of these representations is driven by deep learning methods.

### **103 - The BICA Society Panel**

*Alexei V. Samsonovich, Antonio Chella and Kamilla Johannsdottir*

The disconnect between scientific schools of thought across the world is most notable in cognitive, neural, and computer sciences. The intersection of these fields is exactly where a powerful new approach has emerged recently, known as Biologically Inspired Cognitive Architectures (BICA). Several years ago, the BICA Society started a new initiative: to build an international community of researchers unified by the BICA Challenge: the challenge to create a real-life computational replica of the human mind captured in its highest cognitive functionality, using solutions inspired by the brain. Key elements of the BICA Society mission to promote and integrate the many efforts addressing the BICA Challenge include the Annual International Conference on BICA (also known as the Annual Meeting of the BICA Society); the Elsevier journal BICA (that is indexed by Web of Science and Scopus and acquires a JCR Impact Factor early in 2016); and the upcoming public online repository developed by collective efforts, named "The MAPPED Repository of BICA" by its six components: Models, Architectures, People, Paradigms, Evaluations, and Dialogues (the latter include Videopanel). In this year, BICA Society celebrates another impressive success of its annual meeting: this time in Lyon, France. Since 2010, it has been a tradition to hold a BICA Society Panel at each BICA Society Meeting, reviewing the progress and planning for the future. This time, given only 15 minutes, we need to discuss many things, among which are (1) future BICA events: BICA 2016 in New York in July, the school "FIERCES on BICA" in Moscow in 2016 and in 2017, and the conference BICA 2017 in Moscow; (2) the MAPPED Repository of BICA, including systematic reviews of BICA among other components, and (3) our initiative to establish the James S. Albus Medal as a prestigious award issued by the BICA Society for the best recent contribution to the solution of the BICA Challenge. Details will be debated. The panel will be held as a plenary event open to all participants and will be followed by a Gala dinner on the boat *Hermes* in a magnificent city tour on the Rhône and Saône rivers.

### **104 - How a naïve agent can construct the notion of space**

*Kevin O'Regan and Alexander Terekhov*

As noted by Poincaré, Helmholtz and Nicod, the only way our brains can know about the existence, dimensionality, and structure of physical space is

by sampling the effects of our actions on our senses. In this talk we show how a simple algorithm based on coincidence detection will naturally extract the notion of space. It can do this without any a priori knowledge about how the brain is connected to the sensors or body, and for arbitrary sensors and effectors. Such a mechanism may be the method by which animals' brains construct spatial notions during development, or it may have evolved over evolutionary time to allow animals to act in the world. The algorithm has applications for self-repairing robotics and sensor calibration in unknown hostile environments.

### **105 - Deciphering the brain's navigation system**

*Dori Derdikman*

Recently there have been major leaps in the scientific understanding of the brain's internal navigation system. Several related cell types have been discovered in the brain: Place cells, grid cells, head-direction cells and border cells. These cells are believed to be part of a cognitive map responsible for representation of the brain's internal sense of space. This brain system exemplifies one of the rare cases in which the internal algorithm of a mammalian neural network could be deciphered. While the phenomenology of these cells is now quite well understood, many questions remain: How are these cells connected into a network? How are they generated? How could they be read out? In this lecture I will describe these major questions and suggest some avenues connecting between the theory of these cells and the growing bulk of experimental evidence about them.

### **106 - Toward a virtual actor model of believable social emotional intelligence: A pilot study**

*Alexei V. Samsonovich*

The challenge to create a real-life computational replica of the human mind captured in its highest cognitive functionality (known as the BICA Challenge) demands solutions inspired by the brain, in particular, by human affective cognition. A model of believable emotional intelligence appears to be the key missing element in solution to the challenge. This is the capability that will allow a virtual actor to be accepted by human partners as a genuine mind on its own: a mind that understands and cares about others, and reacts appropriately to their actions. The core functional unit with this property should be possible to mount on top of any given artificial cognitive system, thereby making it human-compatible...

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*This booklet has been created by Amélie Cordier and Olivier Georgeon. Photos of Lyon are courtesy of Jacques Saadé.*

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