IEEE CIS

AMD Newsletter

Robotics
Psychology
Neuroscience
Machine Intelligence

The Newsletter of the Autonomous Mental Development Technical Committee

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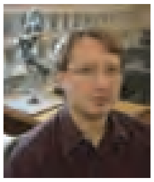
Message from the Past Chair of the AMD Committee



It is my pleasure to welcome Zhengyou Zhang as our new AMD Technical Committee chair. I had the pleasure of working with Zhengyou as a co-editor on the AMD special issue for the International Journal of Humanoid Robotics last year and I am certain that he will be an asset to our community. I hope that he will continue to receive the support and encouragement of the community that I have been privileged to enjoy.

The last few years have seen remarkable growth and strengthening in ICDL, with a host of authors and attendees becoming involved in our group for the first time. Our strength has come primarily from our interdisciplinary ties; our growth has been through the inclusion of developmental psychologists, neuroscientists, and cognitive scientists. I hope that we continue to focus on building bridges with these communities. While I do have doubts about the ability of IEEE to support the range of interests within our community, I hope that Zhengyou will continue to act as a strong advocate for the broad range of our membership.

I want to thank everyone involved in the AMD community for their support and invite you to continue to send papers to ICDL! Best of luck to the new chair!

-Brian Scassellati, Past Chair of the AMD TC

Message from the Chair of the AMD Committee

The AMD Community has seen a phenomenal growth since the establishment of AMD TC in 2004, as evidenced by the active participation in our annual ICDL conferences and by the publication of five special issues in 2006 and 2007. I want to thank Juyang (John) Weng and Brian Scassellati for their leadership and for their years' services to the AMD Community. I am honored and thrilled to serve this wonderful community as a TC chair. There are still a lot for me to learn, but with your help I will do my best to grow our community further.

My goal is to strengthen our community so researchers who are interested in advancing our knowledge of human brain functions and their development through computational modeling and in possible engineering applications of autonomous mental development find home in the AMD community. First, the AMD Newsletter has been a powerful tool for building our community identity. The Dialog Column is especially magnetic. I want to thank Yilu Zhang, Founding Editor, and Shuqing Zeng, current Editor, for their superb job. I encourage every community member to send us suggestions and contribute contents to this Newsletter. Second, because of the interdisciplinary nature of our community, AMDTC Task Forces are extremely important, and I will solicit your help to reinvigorate the activities of our Task Forces. Third, we continue our effort in raising the AMD community profile in the IEEE community by establishing an IEEE Transactions on AMD. Again, because of the interdisciplinary nature, our community and the computational intelligence community in general need a centralized IEEE publication on AMD. I am pleased to report that the Publication Committee of the IEEE Computational Intelligence Society has approved our proposal to move forward. There remains substantial work ahead before IEEE approves such a publication.

-Zhengyou Zhang, Current Chair of the AMD TC

Committee News

- The 2008 IEEE World Congress on Computational Intelligence (WCCI 2008) is to be held at the Hong Kong Convention and Exhibition Centre during June 1-6 (Sunday - Friday). All papers are to be submitted electronically through the Congress website by December 1, 2007. Detailed information is available at http://www.wcci2008.org/
- The 7th International Conference on Development and Learning (ICDL 2008) is to be held in Monterey, California, Aug. 9-12, 2008. General Chairs: Jay McClelland and Juyang Weng. Program Chairs: Gedeon Deak and Brain Scassellati.
- The IEEE CIS Publication Committee on October 17, 2007 approved our Proposal for IEEE Transactions on Autonomous Mental Development to move forward.
- Risto Miikkulainen, Professor at the University of Texas at Austin, is appointed by the AMDTC Chair to be the liaison of AMDTC in the Senior Members Subcommittee of the IEEE CIS society.
- Incenzo Piuri, President of the IEEE CIS, is organizing the Symposium Series on Computational Intelligence (SSCI 2009) in the east coast of the USA about in March 2009. Anyone who is interested in organizing a symposium or a workshop under the SSCI 2009 umbrella please contact Vincenzo at piuri@dti.unimi.it and copy to Zhengyou at zhang@microsoft.com.

Committee News

Recently, 5 special issues closely related to Autonomous Mental Development have been published:
1. Gedeon Deak, Marnie S. Bartlett, and Tony Jebara (eds): Neurocomputing, Vol. 70, No. 13-15, 2007.
2. Jay McClelland, Kim Plunkett, and Juyang Weng (eds): IEEE Transactions on Evolutionary Computing, Vol. 11, No. 2, 2007.
3. Koh Hosoda (ed.): Advanced Robotics, Vol. 20, No. 10, 2006.
4. Olaf Sprons (ed.): Adaptive Behavior, selected papers from ICDL 2006, Vol. 15, No. 2, June 2007.
5. Juyang Weng, Brian Scassellati, and Zhengyou Zhang (eds.): International Journal of Humanoid Robotics, Vol. 4, No. 2, June 2007.

Dialog Column

Should Robots Develop as Human Infants Do?

Minoru Asada
JST ERATO Asada Synergistic Intelligence Project (www.jeap.org)
Graduate School of Engineering, Osaka University

The question is intended not including physical development but focusing on mental development although there could be a tight connection between them. Most people may answer "NO" because of so much difference between robots and human infants in many aspects. But, actually, to what extent do we understand the human infant developmental process? Paterson et al. [1] says "Recent advances in cognitive neuroscience have allowed us to begin investigating the development of both structure and function in the infant brain. However, despite the rapid evolution of technology, surprisingly few studies have examined the intersection between brain and behaviour over the first years of life."

"Cognitive Developmental Robotics" (hereafter, CDR) [2] aims at providing new understanding of human development by building cognitive developmental robots. CDR consists of the design of self-developing structures inside the robot's brain, and the environmental design: how to set up the environment so that the robots embedded therein can gradually adapt themselves to more complex tasks in more dynamic situations. Therefore, the development of perception, behavior, motivation and their relationships are important issues in CDR (see [3] for more recent one).

The recent review of the human infant development of structure and function by Paterson et al. [1] reveals the followings:
1) The state of the infant brain, both in terms of structure and function, cannot and should not be derived from the adult brain. Areas involved in the development of a function are not the same as those required for its maintenance.
2) In face processing subcortical areas are recruited early in development but later a wider network is involved.
3) The developmental progression of joint attention, from responding to initiating is paralleled by the shift in the localisation of attentional mechanisms from the posterior to the anterior of the brain. As control of attention moves to more frontal areas, the infant is able to begin to modulate their own attention as well as engaging the attention of others more effectively and thus becomes a more effective social partner.

As long as we concentrate on the development of a single cognitive function assuming that other functions have already matured, we do not think that the change of the functions in physical modules is needed as the learning proceeds. However, if we challenge to simultaneously develop multiple cognitive functions of robots that actually happen in the human infant brain, we may have different aspects of the development: the development of one cognitive function may trigger the development of the other or the development of all functions affect each other. Since the brain areas are limited (the resource bounded condition), sharing, change or shift of cognitive functions among physical areas can be considered for their efficient use during the developmental process. Rather, it might be necessary for mutual development. Therefore, we may need a more structure in CDR so that these processes can be autonomous if we consider the development of multiple cognitive functions together as human infants do.

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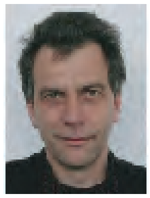
Dialog Column

Reply to Dialog: “Should Robots Develop as Human Infants Do?”

Robots Should Learn by Communication as Infants Do



Britta Wrede
Katharina J. Rohlfing
Yuki Nagai
Gehard Sagerer

Bielefeld University

Human infants’ learning is not only a mental but also a social and discursive process. They not only gain competences by perceiving the world and acting in it. They also learn from communication with adults and peers who transfer skills to them [8].

In natural tutoring situation, recent developmental research has revealed that the way knowledge is transferred differs from the implicit traditional assumption of robotics within learning by demonstrating scenarios. While learning by watching implied analyses of the ongoing situation, a modified situation is presented to infants. For example, when talking to infants, adults modify their speech, known as Motherese. Regarding other modalities, Gogate [5] suggested that modified speech is synchronized with action such as holding up an object. When introducing novel words for objects and their functions, parents moved the new objects in temporal synchrony to the novel label. Brand et al. [2] investigated that when mothers demonstrated novel actions to their children, they moved the objects differently than when addressing an adult. Analyzing these behavior modifications using objective measurement techniques [7], we showed that behavior in parents (fathers and mothers) is modified multimodally also for familiar actions.

What advantages does this behavior bring for the children and in what way could this behavior bring advantages for robots? We know so far that external real-world situations are rich and complex. Maybe far too rich to be captured accurately by a robot's internal models. Infants do not have to cope with the complexity by their own. Instead, the way adults present the world to them seems to facilitate both information registration and encoding. Gogate [4] showed that when moving objects synchronously to the label provided, infants’ memory for the label was enhanced. Brand [3] reports that infants preferred modified actions over non modified actions where their attention is guided to crucial parts of the performed actions. Simulating child’s attention [6], we noticed that modified action can help infants to detect the initial and goal states of actions. Thus, infants do not have to discover a meaning of a movement by themselves. Instead, adults seem to provide some structure. These examples make the point that cognition extends beyond a single agent’s brain [1] over an interaction between people. In designing cognitive functions of robots, robotic research must therefore take advantage of structures, regularities and affordances of the external situation as highlighted by multimodal modifications in parent-infant communication. Within such an approach, learning complexity in the programming by demonstration paradigm [7] is likely to be reduced.

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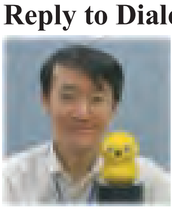
Reply to Dialog: “Should Robots Develop as Human Infants Do?”



Piaget in the Brain

Hideki Kozima (NICT)

By building bodies, we learn how our brains and the environment co-signify each other: how the environment "shapes" the brain (Kuniyoshi), and what "Umwelt" the brain would experience (Uexkull). This has motivated a number of researchers to take the open-ended development of human/animal/machine intelligence.

Dialog Column

As Asada suggested, such a co-signifying aspect can also be found in the brain development. One brain function stands on other brain functions as a background environment. There could be a clear topology where function A triggers another function B; however, such a clear sequential relation would be rare, and rather tangled (and yet continuous) unfolding under spatio-temporal constraints seems more powerful. As an organism adapts to the environment by open-ended development (Oudeyer and Kaplan), one brain function adapts to the whole brain so as to best-utilize its functions, and as a result, this changes the functions of the

This argument reminds me of Piaget's idea of "equilibrium", though it is quite classic. But I believe we should pay more attention to possible core mechanisms of autonomous mental development, which would govern the dynamics of mutual adaption in the microscopic world (intra-brain adaptation), mesoscopic world (physical adaptation of an individual), and macroscopic world (social/collective adaptation).

Reply to Dialog: "Should Robots Develop as Human Infants Do?"

Information from Neuroscience Will Likely Trigger Breakthroughs in Developmental Robotics

Juyang Weng, Department of Computer Science and Engineering,
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Asada has a raised an important point that multiple cognitive functions need to be simultaneously developed while these functions interact with one another. However, currently, developmental robotics faces a great challenge in terms of how to enable robots to develop multiple cognitive functions simultaneously: Many hand-designed modules are too rigid, not able to autonomously develop to handle increasingly more other tasks. Much of the developmental robotics work concentrates on task-specific behavior generation using *ad hoc* methods, but the system is *perception-weak*. These methods are superficially inspired by studies in developmental psychology, but they are not backed by the neuronal computational models of the biological brain. They do not translate to other tasks without a need of reprogramming.

Although we should allow different approaches to developmental robotics, brain inspired or totally artificial, I think that we will miss big if we are not informed by neuroscience. In fact, advances in neuroscience have provided rich information that is of great importance to developmental robotics. Such information ranges from the brain wring anatomy, to how the brain wires itself and refines its circuits according to neuronal activities, to cell mechanisms that enables grand-scale wiring and refinement to take place without an extra-cellular, central "government." Much of such information from neuroscience is not sufficiently complete to enable precise, biologically fully provable modeling. Nevertheless, we need to know that science about nature is always a process of improving approximation, as indicated, e.g., from Newtonian physics to relativity. The approximation nature of the information from neuroscience should not prevent us from using the information in our modeling. By piecing together such incomplete but rich information, this field is likely to make not only major breakthroughs in intelligent robotics, but also enable developmental robotics to contribute to understanding of the human brain.

For example, neural anatomy revealed that connections between many pairs of brain areas are two-way [1]. It is known in engineering that three-layer artificial feed-forward networks are sufficient to approximate any complex function to a given (finite) precision, if as many neurons as needed are available. However, practical feed-forward networks with error back-propagation learning (including the more recent version the Cascade Correlation Learning Architecture) suffer from a series of problems (e.g., lack of invariant representation critical for abstraction and effective generalization). A good news that that if top-down connections are modeled through multi-layer networks (see, e.g., [2]), the internal representation generated becomes increasingly "abstract" from earlier to later layers, allowing later learned tasks to take advantage of mental skills learned in earlier tasks. Thus, inspired by the biological brain, functions are not necessarily represented by separate modules and a single module is not sufficient for any conventionally understood brain function. In the brain, a multi-layer network (sensorimotor pathways) may carry out many functions which interact seamlessly based neuronal computation and adaptation.

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From "Cognitive Developmental Robotics" to "Developmental Cybernetics"

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In our modern worlds, there are many types of new intelligent machines that we need to communicate, such as new electric wave with vocalized manual, computer, TV and so on. Robots will be the one of those intelligent machines in daily life in the near future. Prof. Asada and his colleague try to realize the human development in a robot. That is very exciting and challenging

Dialog Column

attempt. Their main purpose is not only constructing a robot, but also appreciate the mechanisms of human development. Once they construct a robot, however, they need to evaluate it in some ways. I think that one of the best way to evaluate the agents by human infants or children without verbal behavior. This is something like a natural Turing machine.

I will introduce a new exciting research field based on the "Cognitive Developmental Robotics", called '*Developmental cybernetics*.'[1] Robots will not only perform household chores but also serve as caregivers and educators to children. To date, there is no scientific evidence to ascertain whether children, particularly younger ones, will be amenable to receive care, let alone learn, from robots as readily as they do from humans. Despite recent rapid growth in research on developmental cybernetics, it is entirely unknown as to what essential human characteristics must be built into a robot to facilitate such learning.

I proposed "*Developmental Cybernetics*", a brandly new field to investigate the development of mentalization in children. We used nonhuman agent, such as a robot, as a tool to clarify under what condition children can attribute goal-directedness, intention, and mental states to others. We found that subtle actions added to the robot, such as eye contact and gazing, are very effective to change the infants' re-enactment behavior [2]. Developmental cybernetics should be useful in both investigating the development of social cognition in children and in designing robots for human life.

Reply and Summary: Rethinking "Robots Develop as Human Infants Do"

Minoru Asada: JST ERATO Asada Synergistic Intelligence Project (www.jeap.org) Graduate School of Engineering, Osaka University asada@jeap.org

First of all, I appreciate four commentators who responded to my statement. I intended to raise the issue how we should reconsider the approach of "Cognitive Developmental Robotics" (hereafter, CDR) [1] that aims at providing new understanding of human development by building cognitive developmental robots. As a matter of course, four comments focus on different aspect of CDR.

Rohlfing, Wrede, Nagai and Sagerer at Bielefeld University claimed that robots should learn by communication as infants do. They pointed out the importance of the motionese that are a sequence of actions exaggerated by the caregivers, and therefore enable the infants to segment it into meaningful units which they may succeed in realizing. This claim seems a social aspect of my original statement "Should robots develop as human infants do?" while it seemed focusing on the internal developing structure. However, there is a close relationship between them. I mentioned that the development of one cognitive function may trigger another one. Rohlfing, Wrede, Nagai and Sagerer claimed that such a trigger may come from the social interactions. This is very persuadable, and both social and internal triggers enrich the aspects of developments. This relates to the Kozima's claim that I will mention later.

Itakura claimed a different viewpoint of the issue. A systematic evaluation is needed to verify the computational model of the CDR, and he proposed a new exciting research field based on the CDR called 'Developmental cybernetics.' where the cognitively developed robots are used as tools to clarify under what condition children can attribute goal-directedness, intention, and mental states to others. At the same time, we can check how CDR can contribute to the developmental cybernetics as tools. If the contribution is not so much, it would suggest that CDR may be missing something. Mutual feedback seems productive in both sides.

Kozima claimed three points closely related to each other. First, body shapes brain. It seems to me that body is open to the environment, and therefore physical constraints between the environment and the body shapes the brain that generates adaptive behaviors to the environment. Second, unfolding under spatio-temporal constraints seems more powerful than a fixed order of the cognitive development. The reason why I claimed the sequence is that in developmental psychology the order of the emergence of the cognitive functions seems almost fixed in general while the exact period of the emergence may change person by person. However, both do not seem different if we apply the universality of the environment on the earth. CDR may contribute to showing clear difference due to the difference in the environments. Third, possible core mechanisms of autonomous mental development should be focused on more, which would govern the dynamics of mutual adaption in the microscopic world (intra-brain adaptation), mesoscopic world (physical adaptation of an individual), and macroscopic world (social/collective adaptation). This is what we are now looking for exactly (visit our project web page: http://www.jeap.org/web/). We like to find a principle of the human cognitive development that can explain the development itself regardless of the scale. Piaget is still alive changing its shape and appearance.

Weng claims the importance of the information from neuroscience. Actually, my statement was much inspired by a paper from "Neuroscience & Biobehavioral Reviews" journal [2]. However, we should notice that neuroscience is a sort of science that seeks for the principle of explanation. But, we are looking for the principle of design that differentiates itself from the existing scientific disciplines. We should build a new principle for both explanation and design.

Dialog Column

Again, four comments were very suggestive and productive for CDR. If we ask ourselves "should robots develop as human infants do?," we have to carefully consider this question from a viewpoints of different issues like the comments I've got on my statement. Neuroscience always provides the interesting arguments and suggestions. Developmental psychology provides us new observation data. Both stimulate the CDR researchers, but at the same time, we should contribute to both disciplines by CDR.

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Dialog Initiation

How the Mind Works and How the Brain Develops

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Studies on how the mind works can be categorized in different ways. For the purpose of this dialog, the following is a particular sequence of account:

1. *Observation of behavior*. Studying human and animals behaviors under varying task and stimulus conditions.
2. *Modeling behavior*. Computational modeling of behaviors under varying task and stimulus conditions and verification of the modeling from studies in category 1. This level of modeling does not necessarily take into account how the mind develops from experiences or how the brain works.
3. *Modeling the brain basis of behavior*. Computational modeling of how the brain works -- i.e., how it's activity gives rise to behavior, at many different scales, including the cortex, specific circuits and individual neurons. This level of modeling does not necessarily take into account how the brain develops from experiences.
4. *Modeling brain development*. Computational modeling of how the brain develops from conception to adulthood, across different scales. This level of modeling takes into account how the brain works and how the brain develops, and considers how experience and context structure brain development and produce the functional consequences of this development.

Three major dimensions are involved in the above order: from observation to modeling; from the mind to the brain; and from brain to the experience-dependent developmental processes that shape both brain and behavior. Of course, one could proceed through these dimensions in a different order; for example, one could develop models of how experience shapes behavior, without regard the brain basis of this process; and surely, experimental investigation of the brain (and of its development) must complement computational studies at levels three and four.

The questions that we would like to raise for discussion are these:

a. First, can a particular level of investigation benefit from the other levels of investigation?
b. Second, do we see a light in the tunnel? In other words, does computational modeling at level 4 potentially unify major studies across all four categories? For example, will Bayesian modeling at a behavioral level be explained or modified by studies in neuronal computation and development?
c. Are cell-based computations within the networks in the brain too basic to give rise to rich accounts about how the mind works?
d. Can there be a computational theory (in the sense of Marr, 1982) that encompasses investigations at all four levels? Marr himself considered perception and its neural basis but did not give much attention to experience or development.

Responses should be sent to weng@cse.msu.edu and jlm@psych.stanford.edu by March 15, 2008.

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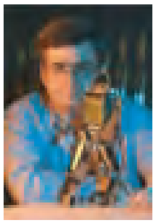
Conference Reports



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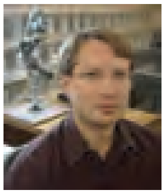


Scassellati

Mareschal

The 6th IEEE International Conference on Development and Learning (ICDL-2007) took place at Imperial College London between the 11th and 13th of July 2007. This year the conference benefited from support from the IEEE Computational Intelligence Society and the euCognition European Network of Excellence in Cognitive Systems. ICDL continued to be an exceptionally interdisciplinary conference, with many submissions that spanned the gaps between computer science, robotics, developmental psychology, anthropology, and cognitive science and attempted to shed light on the complex phenomena of natural and artificial development.

The review process for ICDL was similarly interdisciplinary and rigorous. Each submission was assigned to two program committee members, one from the biological sciences and one from the computational sciences. The program committee members ensured that each submission had at least three (and at times as many as six!) reviews, at least one of which came from each side of the computational/biological spectrum.

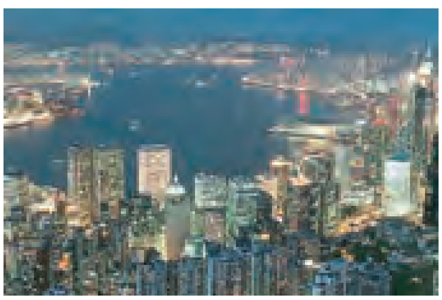
ICDL 2007 received more than 105 submissions to both the regular and special sessions. The review process was highly selective and the quality of the submissions exceeded our expectations. The program committee selected 31 papers for oral presentation and 28 papers for poster presentation. Regardless of the presentation format, all accepted submissions were published as full papers, and are archived by the IEEE Press (through IEEExplore).

We were also fortunate to have four world-renowned invited speakers. Professor Mark Johnson offered insight into how to build a social brain while Professor Kerstin Dautenhahn described her work on the use of robots as social mediators for children with autism. Professor Thomas R. Shultz presented a model of constructive learning targeted at both artificial and biological learning systems while Professor Atsushi Iriki described complex humanistic behaviors (such as tool use) in non-human primates.

-Yiannis Demiris
ICDL 2007 General Chair

-Brian Scassellati and Denis Mareschal
ICDL 2007 Program Co-Chairs

Call for Papers



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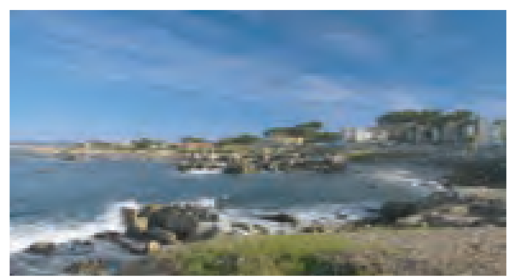

Glossary

Neuroevolution: A learning method for artificial neural networks in which evolutionary computing techniques are used to optimize the network architecture and/or weights for a given task. Unlike gradient-descent methods such as backpropagation, neuroevolution is effective on a wide range of architectures, including recurrent networks and threshold activation functions. It also works in domains where supervised information is not available, such as sequential decision tasks with sparse reinforcement. Compared to standard reinforcement learning with value function approximation, it is particularly effective in continuous domains and partially observable reinforcement learning problems. As such, neuroevolution is a good way to develop controllers for robotics and processes, as well as behaviors for agents in artificial life environments and multi-agent systems.

-Supplied by Risto Miikkulainen

Editor: Shuqing Zeng Editorial Assistant: Ashley Towner