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A Brief Historical Review

Lund, Henrik Hautop

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Modular Playware Technology – A Brief Historical Review

Henrik Hautop Lund

Centre for Playware, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

hhl@playware.dtu.dk
www.playware.dk

Abstract

In this paper, we present a shortened historical review of the building blocks concept. With the concept we show that three B's can lead to three A's: Building Bodies and Brains leads to applications for Anybody, Anywhere, Anytime. Hence, we outline how the inspiration from artificial life, especially regarding the relationship between the body and brain, leads to a building block concept based upon interactive, distributed parallel processing. The historical outline shows how biomimetic robotics and behavior-based robotics has inspired the development of modular playware. Application examples based upon the concept include LEGO I-Blocks, playgrounds, multi-sensory rooms, robomusic, etc. In the paper, we attempt to explore the theoretical characteristics of the concept and the lessons learned for playware application fields.

Introduction

Research into artificial life and robotics over the last few decades has provided background and insight for developing new kinds of interaction between human beings and physical electronic systems. The artificial life focus on living material provides a direction for the development of the physical systems (e.g. robotic systems) towards systems with "living" characteristics (growing systems, adaptive systems, flexible systems, social systems, etc.). We may speculate that such a focus may possibly allow for more natural interaction with such systems, since we as human beings are familiar with interaction with natural systems, hence we use the term 'natural' interaction. It is interesting to study if and how the artificial life inspiration to the creation of robotic system may lead to natural interaction for the users of such systems, and thereby expand the use of the technological systems to diverse users and diverse application fields.

Body and Brain

One of the main inspirations from artificial life to the field of robotics has been the understanding of the interplay between the body and the brain. Artificial life experiments in the form of biomimetic robotics [1, 2] have shown us how the brain structure and complexity to obtain certain behaviors is dependent on the physical body. For instance, by designing robotic ears and a robot mimicking female crickets, we [2] showed how cricket phonotaxis behavior could be obtained with a much simpler neural system than often hypothesized by biologists based on their behavioral experiments with crickets. Later, many other animal species have been mimicked in similar biomimetic robotic experiments. Such studies have enlightened both biological studies to enhance our fundamental scientific knowledge about nature, and they have enlightened robotics for the creation of intelligent robotic systems putting emphasis on creation of the right interplay between the body and the brain to achieve intelligent robotic systems.

Using artificial life as a means to understand and facilitate user interaction was initially performed as studies of simulation environments. For instance, we developed interactive evolutionary computation for users to express facial expressions and artistic design [3]. In this case, users were presented with a population of potential solutions (e.g. facial expressions or artistic design) on the computer screen, and the users would select a few of the most appealing to the user for reproduction. These selected examples would then reproduce with mutation (and possibly cross-over) to form the next generation presented on the computer screen, and the user would again select the most appealing ones. In this fashion, the user would select for generation after generation towards creating appealing solutions (e.g. facial expressions or artistic designs).

A similar approach of interactive evolutionary computation was used to allow users to develop their own controllers for simulated Khepera robots and LEGO robots. Indeed, in 1996-97 we developed interactive evolutionary robotics as a children's game for young children to make LEGO robots out of the Edinburgh LEGO robot platform [4]. With this approach, young children were able to simply select robot behaviors of their preference on the screen and make an evolutionary process to develop robot controllers that were afterwards downloaded to the physical LEGO robots. It demanded no technical knowledge to perform the selection for the development of robot controllers. Anybody would be able to express their preferences of the robot behaviors visualized on the computer screen and after an interactive evolutionary process download the developed controller to the physical LEGO robot.

This inspired us to engage in further collaboration with the LEGO company on the development of LEGO Mindstorms, e.g. with the development of the first public demonstration of LEGO Mindstorms during RoboCup 1998 [5], the pilot projects for the FIRST LEGO League, and the RoboCup Junior in 1999 [6]. Indeed, our invention of the RoboCup Junior in 1999 used the interactive evolutionary robotics approach and also a user-friendly behavior-based approach to allow even young children to develop LEGO robots for the soccer tournaments.

The behavior-based system allowed users to make the coordination of behaviors. A number of primitive behaviors (at a fairly high abstraction level) were shown on the computer screen, and the user could select among these and combine these to make up the overall soccer playing behavior and download this to the LEGO robots that would then play the robot soccer games [6].

This use of behavior-based robotics to allow non-expert users to develop fairly complex robot behaviors was the inspiration to make a physical version of the behavior-based approach. Indeed, in our LEGO Lab an approach to resistors in LEGO bricks was developed to allow the children to combine different bricks to make up behaviors for the robot. Here, the children would combine physical resistor bricks on top of a LEGO Mindstorms robot to make the overall behavior of the robot instead of combining the primitive behaviors on the computer screen [7].

Building Bodies and Brains

We can describe these examples of artificial life inspired approaches to facilitate user interaction as approaches based on distributed, parallel processing (populations with individuals running in parallel in the evolutionary computation approaches, and behaviors running in parallel in the behavior-based robot approaches). In a physical form, such distributed, parallel processing can manifest itself in a modular approach. Even though the interactive behavior-based approaches developed in the past with users combining primitive behaviors on the computer screen or physically in the form of resistor bricks entailed a somewhat serial processing, a distributed parallel processing version is an interesting possibility.

Based upon the exploration of the body and brain relationship and our exploration of this relationship in robotics, we developed a concept of physical and functional building blocks in order to explore interactive, distributed parallel processing in a physical form. We have explored this general concept since the mid-1990s and developed several physical platforms in order to test the concept in different use contexts.

Generally, the concept can be used to create self-reconfigurable modular robots [8], which autonomously change their physical shape, which we did later in the 2000's, but here we will focus on how the concept can be used to create *user-configurable modular interactive systems*. Here, the user constructs with the technological building blocks to create a physical entity and the functionality of this entity. By making changes to the physical shape of the entity, the user can change the functionality of the entity. This happens simply by attaching or detaching technological building blocks, and moving technological building blocks to different positions. Hence, in such a case, the user is making the physical configuration in a hands-on manner, and the user does not need to do traditional programming to change the functionality of the entity. Therefore, in some cases, it is believed that the building block approach may lead any user to develop solutions in a *simple* and very *flexible* manner. Further, the modularity and distributed processing of the building block approach means that the produced solutions are *robust to failure* of individual building blocks. If one building block fails then the rest will still be working, contrary to most traditional technological solutions with a central processing that makes everything fail if one component fails. Also, since there is no central processing and large infrastructure, but the system is composed of a set of individual building blocks (modules), these may potentially be easily transported around and set up anywhere.

Indeed, in 1995 we got the first idea on putting processing and communication capabilities into each individual LEGO brick. As one of the appealing research directions, at the time, together with Orazio Miglino we envisioned the possibilities for exploring neural networks in a physical form with this new building block concept. Even though the exact implementation was not done until the early 2000's, we explored the concept in several variations on the LEGO robot platforms in the 1995-2000, e.g. as the resistor bricks with LEGO Mindstorms mentioned above [7] and in co-evolution of bodies and brains experiments with the Edinburgh LEGO robot platform [9].

Finally in 2000, it became feasible from a technological point of view to start implementing processors, communication means, sensors, and actuators into the individual LEGO brick, though from a practical prototyping perspective we started making implementation in the LEGO DUPLO bricks [10]. The initial prototypes were based upon a PIC16 microprocessor and communication with two male connectors on the top and two female connectors on the bottom of each LEGO DUPLO brick.

Having processing and communication capabilities in the individual bricks allows both physical (body) and functional (brain) construction. Everything happens as soon as bricks are put together, contrary to e.g. the LEGO Mindstorms approach which imposes a certain sequential process and split of building, programming and testing in the real world. Hence, with LEGO Mindstorms there is a long way from conceiving ideas to actually testing in the real world, which may prevent the non-expert user from overcoming the abstract, cognitive challenge to develop his/her own robotic system. The building block approach is a response to the Mindstorms split processes, and it provides 'action in the interaction', where things happen as soon as the user puts two pieces together, and thereby get an *immediate feedback* (e.g. sound, light, motion) in the construction process.

Numerous tests showed that diverse child users were able to use the technological building block approach implemented in the LEGO bricks to physically confront abstract cognitive challenges e.g. in mathematics, language training, understanding emotions, etc. [11]. Later, cubic blocks – termed African I-Blocks and cubic I-Blocks - were developed as a response to some users' difficulty with building with the LEGO bricks.

Physical Interaction with Modules

The concept became the foundational technological concept when in 2001, Europe's largest producer of playgrounds, KOMPAN, engaged in the development of interactive electronic playgrounds [12]. Initially, sensors and actuators were distributed on traditional playground products, later wire-connected modular tiles were developed as the ground of playgrounds, and finally the ICONS product emerged on the market. The playground tiles became an implementation used for several studies of children's physical interactivity and of adaptation to the individual user.

Despite the relative success of the playground experiments, we wanted to push towards a more free use of modules. Some of the playground work was based on wired connection between modules, which essentially limited the reconfiguration of modules to be performed by the installation worker, and not to be performed by the user.

Therefore, we developed the modular interactive tiles. According to the concept, each tile is a self-contained module with processing power and communication to neighboring modules, and a number of these can be put together in any physical shape by the user within a minute. The tiles light up in different colors and can perceive the pressure when people press them with their hands or jump on them with their feet. Numerous games (exercises) are running on the tiles, and these games aim at providing high motivation for people to engage physically with the tiles. Therapists have used the tiles to provide treatment for a large number of patients who receive hospital, municipality or home care, although the tiles can as well be used for prevention with elderly or for fitness with normal people. The tiles have been tested extensively with cardiac patients, COLD patients and stroke patients in hospitals and in the private homes of patients and elderly, and it have been found that therapists are using the modular aspect of the tiles for personalized training of a vast variety of elderly patients modulating exercises and difficulty levels [13].

Modules and Applications – Some Lessons

In the mid 2000's, we started combining the different technological platforms to explore the building block concept for different user sensory modalities by combining heterogeneous building blocks. For instance, we combined the modular interactive tiles and cubic I-Blocks in the creation of a multi-sensory room in the HC Andersen children's hospital [14], we combined rolling pins and light&sound cylinders in the creation of a multi-sensory room for elderly with dementia [15], and we combined modular tiles, rolling pins, and light&sound cylinders for the first RoboMusic concert [16]. With the different kinds of technological building blocks, we were able to make applications and tests these in many different contexts. Some examples include:

- Neema Rehabilitation Unit, Iringa, Tanzania – therapy of handicapped children
- Orphanage Ilembula, Tanzania – play and education
- Pommern Secondary School, Tanzania – language and mathematics education
- Casa Protetta Albesani, Italy – elderly dementia patients therapy
- Ringe neurorehabilitation center, Denmark – stroke patient therapy
- OUH Hospital Svendborg, Denmark – cardiac and stroke patient physiotherapy
- Townships in South Africa – football competitions during FIFA World Cup 2010
- Winter Music Conference, Miami – RoboMusic performances

An important lesson learned from the many experiments with modular playware technology is that the building block concept facilitated users in engaging with modules with different sensory modalities, and that the concept made it easy to configure the technological systems to the users' preferred sensory modality or activity. Based on all these implementations of the concept, we can now summarize the types of modules and control used:

Modules:	Control:
arithmetic blocks, behavior blocks, language blocks, neural blocks, spiking neural blocks.	open loop, randomness based, rule based, user interaction based, AI and ALife based, morphology based.

Conclusion

We presented a shortened historical review of the building blocks concept. We believe that the concept has shown to be a general approach to facilitate user interaction. We can formulate this as with the building block concept three B's can possibly lead to three A's: **B**uilding **B**odies and **B**rains leads to applications for **A**nybody, **A**nywhere, **A**nytime.

References

[1] M. O. Franz and H. A. Mallot. Biomimetic robot navigation. *Robotics Auton Systems 30*, 133–153, 2000.

[2] H. H. Lund, B. Webb, and J. Hallam. Physical and temporal scaling considerations in a robot model of cricket calling song preference. *Artificial Life, 4(1)*:95-107, 1998.

[3] L. Pagliarini, H. H. Lund, O. Miglino, and D. Parisi. Artificial Life: A New Way to Build Educational and Therapeutic Games. In C. Langton and T. Shimohara (eds.) Proc. of Artificial Life V, MIT Press, MA, 1996.

[4] H. H. Lund, O. Miglino, L. Pagliarini, A. Billard, and A. Ijspeert. Evolutionary Robotics : A Children's Game In Proceedings of IEEE 5th International Conference on Evolutionary Computation. IEEE Press, NJ, 1998.

[5] H. H. Lund and L. Pagliarini. LEGO Mindstorms Robot Soccer. In Proceedings of RoboCup'98, LNAI 1604, Springer-Verlag, Heidelberg, 1999.

[6] H. H. Lund and L. Pagliarini. RoboCup Jr. with LEGO Mindstorms. In Proc. of Int. Conf. On Robotics and Automation (ICRA2000), IEEE Press, NJ, 2000.

[7] H. H. Lund. AI in Children's Play with LEGO Robots. In AAAI Spring Symposium Series 1999, AAAI Press, Menlo Park, 1999.

[8] E. H. Ostergaard, K. Kassow, R. Beck, and H. H. Lund. Design of the ATRON lattice-based self-reconfigurable robot. *Autonomous Robots 21(2)*, 165-183, 2006

[9] H. H. Lund, J. Hallam, and W.-P. Lee. Evolving robot morphology, in *Proc. 1997 IEEE Conf. Evolutionary Computat. (ICEC'97)*. NJ, IEEE, pp. 197–202, 1997.

[10] H. H. Lund. Intelligent Artefacts. In Sugisaka and Tanaka (Eds.), Proc. of 8th International Symposium on Artificial Life and Robotics. Oita: ISAROB, 2003.

[11] H. H. Lund, and P. Marti. Designing Manipulative Technologies for Children with Different Abilities. *Artificial Life and Robotics Journal, 9:4*, 175-187, 2005.

[12] H. H. Lund, T. Klitbo, and C. Jessen. Playware Technology for Physically Activating Play, *Artificial Life and Robotics Journal, 9:4*, 165-174, 2005.

[13] H. H. Lund and C. B. Nielsen. Modularity for Modulating Exercises and Levels – Observations from Cardiac, Stroke, and COLD Patients Therapy. Proc. of IEEE 8th Intl. Conf. on Ubiquitous Robots and Ambient Intelligence (URAI 2011), Korea, pp. 253-258, 2011.

[14] H. H. Lund, A. Henningsen, and R. Nielsen. Modular Robotic System as Multisensory Room in Children‟s Hospital. In Sugisaka and Takaga (eds.) Proc. of 14th International Symposium on Artificial Life and Robotics (AROB'14), ISAROB, Oita, 2009.

[15] P. Marti, L. Giusti, and H. H. Lund. The Role of Modular Robotics in Mediating Nonverbal Social Exchanges. *IEEE Trans Robot 25:3*, 602-613, 2009.

[16] H. H. Lund, and M. Ottesen. RoboMusic – A Behavior-Based Approach, *Artificial Life and Robotics, 12: 1-2*, 18-23, 2008.