論文 / 著書情報
Article / Book Information

題目(和文)	認知ロボティクスのための脳型知能情報処理機構
Title(English)	Cortically-Inspired Mechanisms of Computational Intelligence and Learning for Developmental Robotics
著者(和文)	TarekNAJJAR
Author(English)	Tarek Najjar
出典(和文)	学位:博士（工学）, 学位授与機関:東京工業大学, 報告番号:甲第10229号, 授与年月日:2016年3月26日, 学位の種別:課程博士, 審査員:長谷川 修,新田 克己,渡邊 澄夫,宮下 英三,小野 功
Citation(English)	Degree:, Conferring organization: Tokyo Institute of Technology, Report number:甲第10229号, Conferred date:2016/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	Computational Intelligent and Systems Science	専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	（Engineering）
学生氏名： Student's Name	Tarek NAJJAR		指導教員（主）： Academic Advisor(main)	Osamu HASEGAWA	
			指導教員（副）： Academic Advisor(sub)		

要旨（英文800語程度）
Thesis Summary（approx.800 English Words）

Both inspired by developmental psychology and cognitive neuroscience, a new field in robotics has emerged which is the field of Developmental Robotics. This multidisciplinary field combines developmental child psychology, cognitive neuroscience, artificial intelligence and robotics. The basic concern in this discipline is to formulate embodied artificial agents that are capable of semi-continues cognitive development; which is the ability of the agent to adapt and grow mentally in the way it perceive, represent and process its experiences and the way it acts in the world around . This development must take place through interaction with the environment using the agent's sensors and actuators in a semi-open-ended manner. One of the most essential and fundamental milestones of development of intelligence is the ability to use one's own body and to actuate in the environment. Teaching a robot to control its arm joints, in order to achieve coordinated reaching tasks, without explicit computation of forward and inverse kinematics, poses multiple challenges on the control system; One of which, is the problem of enabling a robot to, autonomously, generate an internal representation of the control system given the fact that neither explicit kinematic model nor a transformation mechanism is provided by the designer. The basic approach we follow in this study in order to achieve such motor competence is through Motor Babbling which is described as the exploratory learning process of generating sensory-motor associations through continues random motions with ballistic trajectories. These motions serve the purpose of sampling representative data points that bootstrap the learning system into incremental generation of internal model and implicit control policy for the system at hand. The mechanism we are proposing is based on the idea of autonomous, incremental generation of implicit system model and control policy using layers of self-organizing maps and joint-egocentric representation of reaching experiences. The robot is not provided with any control models or methods for calculating inverse and forward kinematics. Besides, the learning process does not involve separated training and testing phases, but rather the system starts off by exploratory motor babbling behavior then a gradual shifting toward coordinated goal-directed reaching trajectories is noticed to take place in a smooth manner that reflect the current level of maturity of the learned model. This babbling approach was tested on a robotic arm that is used to demonstrate the developmental sensory-motor learning process, starting by random motor-babbling actions and then shifting gradually toward performing more coordinated target-reaching trajectories. It is crucial to mention that the robot was not provided with any knowledge about how to control its joints, besides no action-consequence model was preprogrammed by the designer beforehand of learning. Recorded collected data showed that systems starts by babbling-like ballistic trajectories, then the robot shifts toward coordinated actions with continuously decreasing error. This Developmental approach toward robot

learning was demonstrated by the fact that no preprogrammed control policy was provided beforehand of learning. But rather the robot explored, on its own, the action-consequences contingencies of its joints and then, autonomously, generated an implicit control model through motor babbling actions.

After designing a robot control-architecture for learning through exploration the next natural move was to build the learning mechanism itself that would fits the developmental approach of learning adopted so far , so a novel neural network was designed which can be described as a Hebbian Network of Self-organizing Receptive Field Neurons. This neural network is an Incremental learning mechanism that can bootstrap from a state of complete ignorance of any representative sample associations. In order for the proposed network to learn the problem in hand, three sub-problems need to be learned: first of all the input-space of the underlying function need to be captured. Second, the corresponding output-space as well is modeled as a set of representative elements. Finally, associative relations between major components of these input and output spaces are captured and learned in order to make up the backbone of the governing associations implicit to the learned function.

The main approach is that each of input and output space is modeled by a set of self-organizing nodes that represent emergent major components of the corresponding space. After the major component nodes of each space have been learned, a Hebbian plasticity process is employed in order to correlate the major component nodes of each space with those of the other one. Any data point, within each space, is represented as a combination of locally activated space component nodes, where the activation of each node is influenced by the excitation level of its receptive field which in result would affect the contribution level of that space component node in the representation of the given data point. Multiple experiments where performed in order to validate the efficiency of the proposed mechanisms. Collected data were analyzed in order to reflect the performance of the suggested algorithms. As a conclusion we can claim that Learning through babbling makes a viable framework for incremental learning. Besides Babbling-based mechanisms have the ability to adapt to unanticipated changes to the system itself or the operational conditions. It has been found as well that Cortical Mechanisms of Learning can give us valuable insights in order to build better learning algorithms. Finally we believe that Learning is NOT purely developmental but rather build on seed-concepts and knowledge elements intrinsically embedded into the learner before actual interaction with the world around.

This work is NOT an attempt to reconstruct or to model the brain, actually we believe that such job is impossible to achieve neither now nor ever as the brain is the creation of Allah, but rather all we are trying to do is to benefit from what we understand about the way the brain works in order to get inspired for building computer algorithms that solve the proposed problems in better way than traditional algorithms do.