GERMANY/HONG KONG JOINT RESEARCH SCHEME
THE PROJECT REPORT
(for Project Completion)

Project Number: G_HK025/10

Title

Joint emergence of disparity tuning and vergence eye movements 視差調諧與聚散眼球運動的聯合出現

Particulars

	Hong Kong team	German team
Name of Project Co-ordinator (with title)	English: Prof. Bertram Emil SHI Chinese: 施毅明	Prof. Jochen Triesch
Name of Co-Investigator (if any)		
Institution or Institutional affiliation	[ ] CityU [ ] HKU [ ] CUHK [x] HKUST [ ] HKBU [ ] LU [ ] HKIEd [ ] PolyU	[x] J.W. Goethe University [x] Others: Frankfurt Institute for Advanced Studies (FIAS)
Other project team members (if any)		

Funding Period

	1st year	2nd year (if applicable)
Start Date	01/01/2011	01/01/2012
Completion Date	31/12/2011	31/12/2012

Objective(s) as per original application

1. To integrate into a real-time robotic stereo vision system a reinforcement learning algorithm for binocular vergence control that leads to the emergence of disparity-tuned neurons.
2. To extend this learning algorithm so that the rewards used by the reinforcement learning algorithm are more intrinsically motivated, and to evaluate the performance of this algorithm using the real-time robotic stereo vision system.

Details of Report [Please attach relevant document(s)]

i) Outline of proposed research and results obtained

Through the collaboration supported by this proposal, the Hong Kong and German team have proposed a model of the co-development of behaviour and perception, which extends the efficient encoding hypothesis to include the effect of behaviour. The efficient encoding hypothesis posits that neurons respond so that they best represent sensory data while requiring as few neurons to respond as possible. Our model posits that behaviour also develops simultaneously to shape the statistics of the input so that it easier to encode. Thus, both perception and behaviour develop so as to maximize the faithfulness of the sensory representation, or equivalently, minimize reconstruction error. This developmental model is intrinsically motivated, since the reconstruction error is generated within the agent, and is determined by the fidelity of the agents internal representation of the environment. We demonstrated that this unified model can account for the joint development of stereo disparity perception and vergence eye movements in simulation [1], as well as on real active robotic vision platforms (the iCub robot) [2].

ii) Significance of research results

To our knowledge, this is one of the first models of unified joint development. Past work has either studied the development of perception in isolation, behaviour in isolation, or the development of perception and behaviour through processes decoupled both in time and objective, i.e. where the development of behaviour started only after the development of perception had concluded, and the two developmental processes sought to optimize different objective functions. As recognition of this contribution, our paper describing this model was awarded a "Paper of Excellence" award at the 2012 International Conference on Development and Learning – Epigentic Robotics [1].

This model may lay the groundwork for algorithms for self-calibrating robotic systems that have no need for manual calibration, which is costly and must be performed every time the robot's physical configuration changes. The general framework we have proposed seems widely applicable to other visual-motor tasks. For example, we have recently begun to extend this framework to model the joint development of motion perception and smooth pursuit.

iii) Research output

[1] Y. Zhao, C. Rothkopf, J. Triesch and B. E. Shi, "A Unified Model of the Joint Development of Disparity Selectivity and Vergence Control," presented at the *IEEE Joint International Conference on Development and Learning – Epigenetics and Robotics*, San Diego, CA, USA, Nov. 2012. (winner of a Paper of Excellence award)
[2] L. Lonini, Y. Zhao, P. Chandrashekhariah, B. Shi and J. Triesch, "Autonomous learning of active multi-scale binocular vision," to be presented at the *IEEE Joint International Conference on Development and Learning – Epigenetics and Robotics*, Osaka, Japan, Aug. 2013.

iv) Potential for or impact on further research collaboration

This work considered only one degree of freedom, vergence, between the two eyes. In fact, the eyes have six degrees of freedom, three for each eye. Each eye can rotate around horizontal, vertical and torsional axes. We hypothesize that if applied to a more realistic binocular eye model that includes all six degrees of freedom, the joint perceptual-behavioral development framework that we developed during this project to a will lead to emergence of these torsional control policies that are consistent with those observed in humans, e.g. Donder's and Listing's laws. In order to investigate this hypothesis, we are submitting a grant to the 2013/14 Germany/Hong Kong Joint Research Scheme to support our continued collaboration.