別紙２

Results report

１． Title of Research and Development： Autonomous Learning of Active Depth Perception: from Neural Models to Humanoid Robots

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４． Results of Research and Development:

During the first few months of their postnatal development, humans and other animals autonomously learn how to use such depth perception cues like disparity, motion parallax and optical flow. Thereafter, they continue to adapt and self-calibrate their vision to compensate for growth of the eye, head, and body, but the underlying neural mechanisms are still largely unknown. Providing robots with similar abilities to autonomously learn and self-calibrate sensori-motor loops for active perception would make them more autonomous and robust. Therefore, in this research period, we proposed a system for the autonomous self-calibration of active depth perception based on motion parallax using a single moving camera. Our system is based on active efficient coding (AEC) framework for the autonomous self-calibration of active perception which autonomously learns to represent image motion and perform compensatory eye rotations to keep the object fixated during lateral movement – thereby learning to actively estimate the object’s distance.

First, to validate our research, we implemented an active binocular vision hardware framework by using two dimensional linear actuators to realize human’s body movements and the two camera with pan-tilts unit for mimicking the eye’s rotation. Second, the new cost function was designed by considering the active efficient coding theory with intrinsic motivation concept to simultaneously train eye rotation (action) and sensory representation (perception) of the autonomous robot under the motion parallax phenomena. The intrinsically motivated visual system can generate a suitable eye movement to increase the redundancy between successive images for understanding of the motion parallax phenomena. Third, the generated eye movements was transferred to the input of the depth estimator as a goal-directed visual learning system to autonomously estimate the depth between the observer and an arbitrary object. An autonomous depth estimator was developed by two layer feed-forward artificial neural network to map between the eye movements and the object’s distance.

Finally, we had validated our proposed model by using computer simulation and real robot experiments. The motion parallax based self-calibrated visual framework achieved good results with less than 0.1 estimation error of eye rotation degree in the computer simulation and 0.05 estimation error in the real robot experiments. And also, it can estimate accurate depth information from eye movements with less than 7% depth estimation error in the computer simulation and less than 3% depth estimation error in the real robot experiments. Moreover, the proposed framework can successfully estimate depth and generate eye movements to keep the object at the center of gaze by autonomous self-calibration when we apply a perturbation to the system.