Brain-Inspired Robotics: A Dynamical Systems Account For Cognitive Behavior

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While our understanding of the human brain is far from complete, novel neural mechanisms are being identified that may better inform efforts by robotics researchers confined by currently computational modeling approaches in designing machines. Such biological principles may open new routes to autonomous, learning robots. To illustrate, we know that patients with impairments in regions associated with higher visual processing cannot perceive objects consciously, yet they can grab or point to the object even if they are not consciously aware that the object there. It is known that this type of unattended behavior is generated in the dorsal path way of brains including the association cortex where the streams of the sensory perception and the motor generation are intermingled, thereby being inseparably processed. This contrasts with the conventional view that first the visual cortex recognizes target objects, then the motor cortex generates the corresponding action based on the information obtained.

Along with other emerging data, these findings indicate that the brain may not work through assemblies of localized functional modules (such as recognition, planning, action and learning) that regulate the entire system. Hence, current computational models may also be imprecise. We took a different brain-inspired approach and developed a system that assumes the presence of some type of global hermeneutic dynamics. These dynamics emerge from the sensory-motor coupling between the neuronal dynamics and physical movements of the body within an environment where each function appears distributed in its flow.

Our robotics research attempts to extract the hermeneutic dynamics of the brain and examine its essential mechanisms synthetically using a variety neuro-cognitive robotics experiments. These experiments include imitative interaction with human, learning object manipulation, and behavior-linguistic associative learning which are implemented in mobile robots as well as humanoids. Our robots successfully generated flexible and situated cognitive behaviors when hermeneutic dynamics were sufficiently self-organized following iterative learning in an environment. We also found that the robot behavior can be shaped more effectively if the learning proceeds in a co-development way between the robots and human tutors by having dense interactions. We would like to explore, here, the significant potential of such brain-inspired approaches to robotics to advance humanitarian robotics by providing a means to autonomy through a robot's intrinsic properties and thereby facilitate closer interactions with humans.