The Development of Gecko Robot Locomotion on Uneven Surface Using an Artificial Hormone Mechanism

INTRODUCTION

Geckos have shown us lots of interesting abilities such as climbing on steep slope and vertical wall. Many researchers are now interested in locomotive ability of geckos as well as they are trying to imitate those ability on the robot. A climbing robot can be applied for doing many tasks such as climbing up a building, video surveillance, maintenance and space exploration. Previously developed gecko robots have illustrated its climbing performance on both incline and vertical wall; however, none of them has shown an ability to perform locomotion on discontinuous surface.

Adaptation on uneven surface can be created. The robot should receive feed back and stretch its leg properly. As on-line adaptation and long term behavior regulation are in our concern, an artificial mechanism (AHM) is in our interest. An artificial hormone mechanism introduced in [1] consists of only a hormone and thus its may not suitable to solve the complex problem of the gecko robot. Adopting this concept, we perform another study on AHM consisting of more than one hormone interact with each other and central pattern generator-based neural control.

OBJECTIVES

1. Develop neural control for gecko robot consisting of 16 DOFs in total
2. Develop artificial hormone mechanism for gecko locomotion on uneven surface

METHODOLOGY

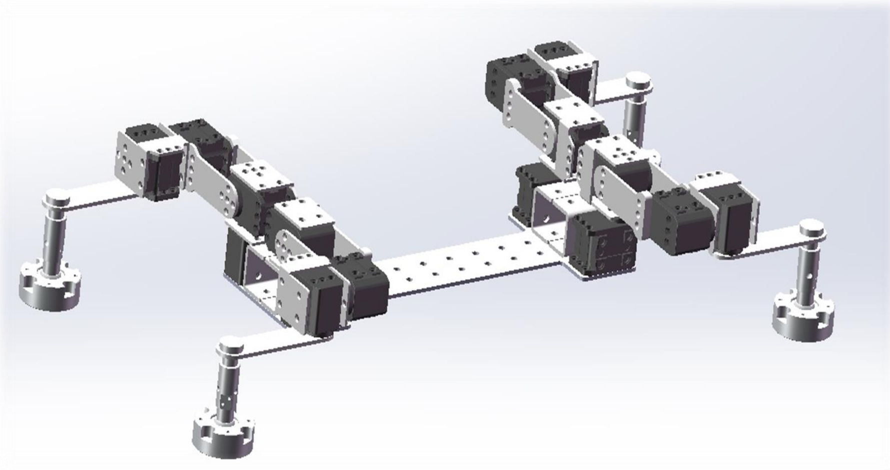

Figure 1 picture of the gecko robot

The gecko robot consist of four legs. Each leg has four joints. Pectoral/Pelvis joint provides swing motion. Humerus/Femur joint makes lift or lower its foot. While wrist/ankle and elbow/knee joint are activated those joints help maintain foot orientation around vertical and frontal direction, respectively.

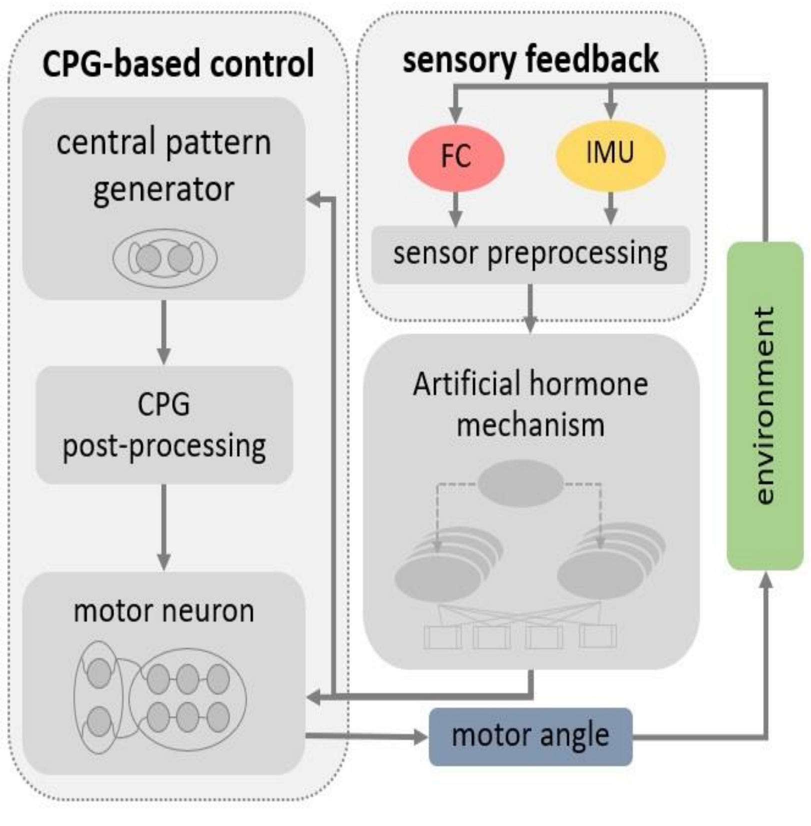

Figure 2 system overview

In this research, a bio-inspired approach including modular neural control (MNC) and artificial hormone mechanism are employed. The MNC creates locomotion without sensory feedback. Generating signals, shaping signals and passing them to corresponding motor, provide a open-loop locomotion with rapid computation. In addition, this method is prepared for integrating some sensory feedback that receives environmental signal for automatic altering the robot behavior such as gait, speed and amplitude transformation of the locomotion. The output signals form MNC are used as motors angle. To upgrade this system to an open-loop controlled system, sensory feedbacks are added. Receiving signal from environment, force signal from foot contact sensor and inclination from inertia measurement unit are preprocessed and used as input of artificial hormone mechanism. There are three hormone in the propose mechanism, they are named leg-stretching hormone, body balancing hormone and confidence-inspired hormone. Then, three hormones interact with each others to create adjusting signal, They affect three targets, the motor neuron, central pattern generator and hormone gland.

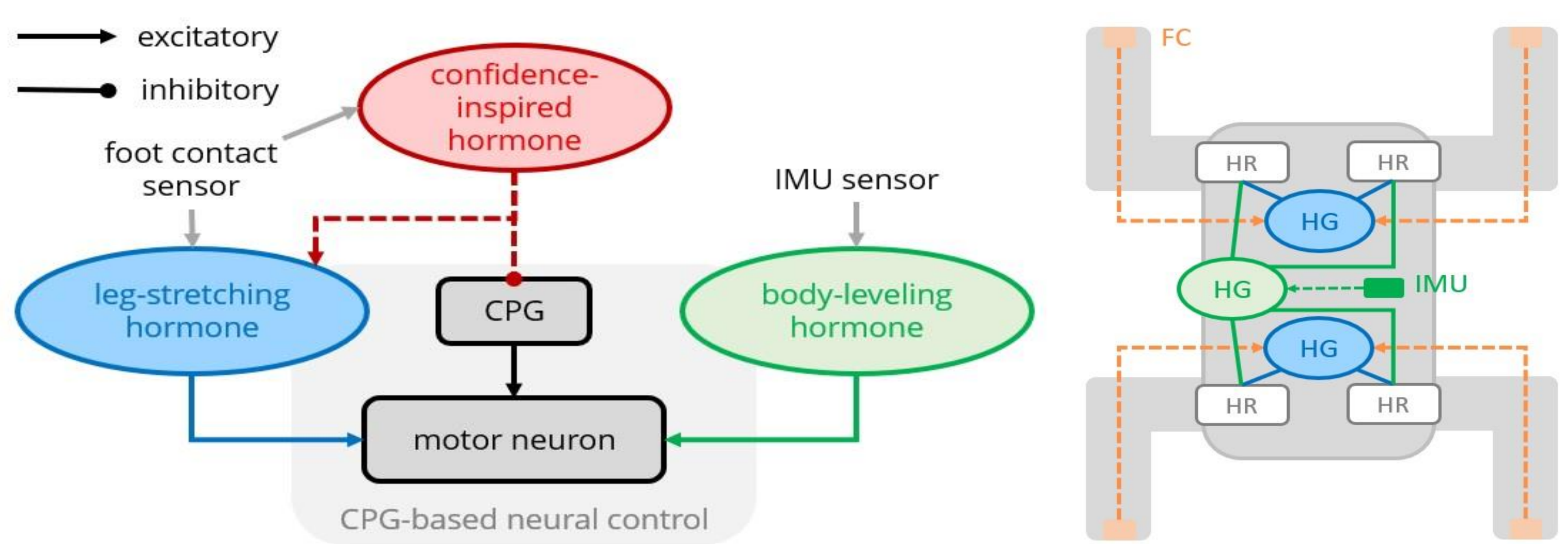

Figure 3 Artificial hormone mechanism proposed in this work

Three artificial hormones are employed in this thesis. (1) First hormone is call leg-stretching hormone, it is produced from the hormone gland indicated with blue in Figure 3. Force measured from foot contact sensor and the expected force signal are the stimulus to first hormone. Leg stretching hormone controls relative stretching length between left leg and right leg. (2) Second hormone named body balancing hormone. Its production depends on difference between surface inclination and the inclination of robot's body. Body balancing hormone concentration goes up and the front legs are stretched when front leg fall into a gap. (3) Confidence-inspired hormone produced by the hormone gland colored in red. This hormone has two effects. First, confidence-inspired hormone changes stimulation rate of leg-stretching hormone. Second, it slow movement of the robot down when the concentration reach threshold. These effects have the same goal which is helping the robot walk across different-depth-gap, and they are compared in the next chapter.

RESULTS

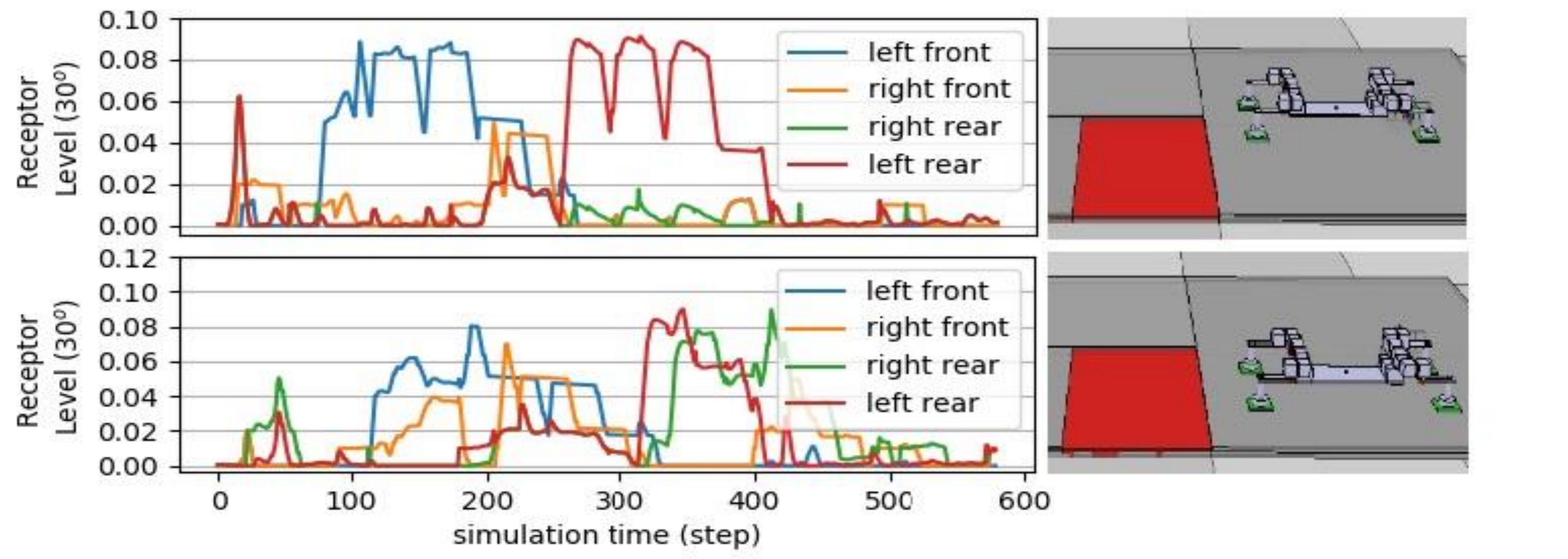

Figure 4 Stretching signals of the simulated robot walking on surface with the different between gray surface and red surface is 0.5 cm

Stretching signal corresponding to robot legs are presented in Figure 4. Consider the graph and picture on the top, when it fall in to lower level region, hormone concentration was increasing and left front leg is stretching. Hormone then stay in homeostasis and the left front leg remain at the stretching length that fit with 0.5 cm lower region. After the front leg got out of red region, stretching signals went to zero. This process occurred again when left rear leg fall in to red region. Effect of leg stretching hormone was presented in this experiment.

The second result corresponds to another experiment tested on body-balancing hormone. The robot will fall down of its body angle is different from the slope too much. The robot has two front leg falling in to red region that make robot body tilted. Left and right front leg is stretched by the effect of body-balancing hormone to maintain body angle of the robot. Then those legs were shrink back to its initial length before rear leg is stretched.

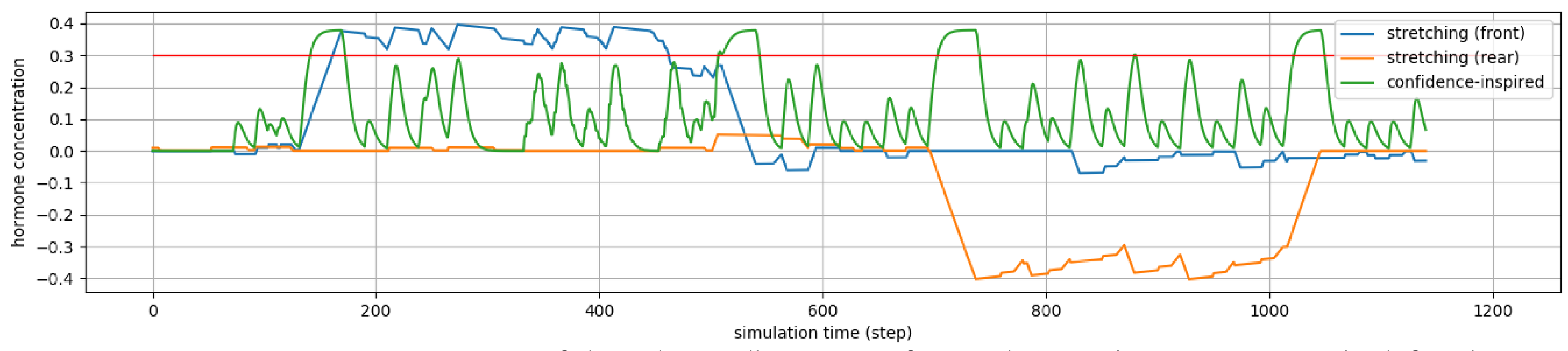

Figure 5 Hormone concentration of the robot walking on surface with 2 cm lower region on the left side

To let the robot freeze its locomotion and stretch its leg until its foot touch the surface, confidence-inspired hormone is added and this approach was verified on surface with 2 cm lower region on the left side. Threshold for the confidence-inspired hormone is set. When hormone concentration goes over this threshold, the modular neural network was freeze. In this case, the threshold is set to 0.3, at 170 simulation time step, the left front leg fall into the lower region, thus confidence-inspired hormone was increased. Then the locomotion was freeze when hormone concentration goes more than 0.3 to prevent it left another leg and make the locomotion fail. At this instance, left front leg was continuously stretching until the foot reached the surface and confidence-inspired hormone concentration decreased. After it went below the threshold, robot start to walk again. Note that the threshold can be set to be more than 0.3 when the slope is below 75 degree, since when it walking on the low slope, it won't fall down.

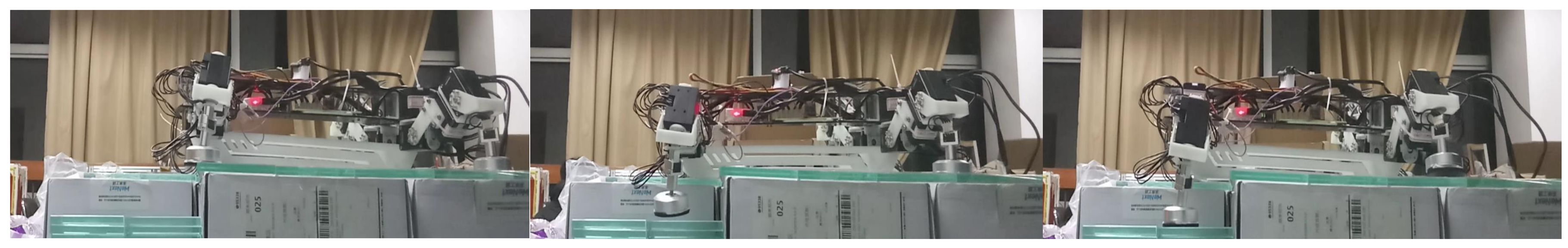

Figure 6 Experiment on real robot

This approach was also verified on the real robot. The real robot is able to stop walking and stretching its leg when its foot doesn't touch the surface after walking for a while. Then It continue its locomotion when it foot touch the surface. In addition, body-leveling hormone can achieved maintaining body angle. Without the adhesive material and with proposed artificial hormone mechanism, it achieved locomotion on 25 degree and surface with 1 cm lower region (on 20 degree) which the one without artificial hormone can't achieve. However, the maximum stretching length depends on robot structure and mechanism parameter for example the limitation of the real robot employed in this experiment is 6 cm.

CONCLUSION

In this thesis, the proposed mechanism can create online-adaptive behavior for walking on uneven terrain. Modular neural control perform like a central nervous system to create locomotive pattern. Leg-stretching and body-balancing hormone behave like hormone that has an effect on muscles and create reflex. Confidence-inspired hormone acted as hormone in another layer and affect modular neural network as well as another hormone gland. This hormone can be used to prevent falling but the locomotion is freeze, so it is suggest that on surface which has slope bellow 75, the threshold for this hormone can be set higher than normal. However, this approach also has limitation depending on set parameter and mechanism. It is suggest that using locomotion planning algorithm or high level control handle this limitation.

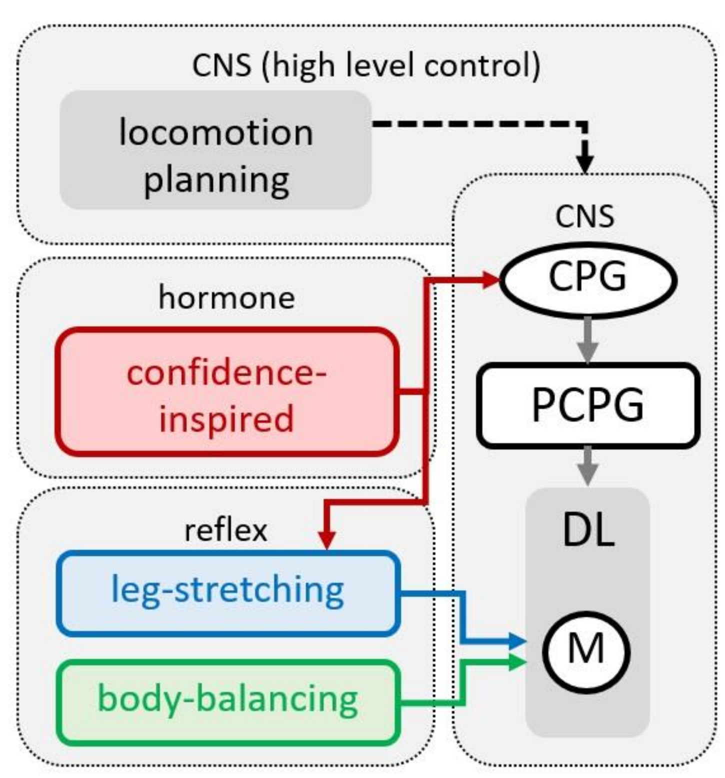

Figure 7 mechanism proposed in this work presented along with their analogy to biology

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SOURCE
[1] J. Homchanthanakul et. al., Using of artificial hormone to improve hexapod robot locomotion in changing environments, 2017

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