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Negotiating Complex Terrain: Insect Brains and Behavior and their impact on Robot Design

Abstract

In order to be useful in many dangerous missions, robots should be able to negotiate very complex terrain. Insects move seamlessly through complex environments in a manner that is the envy of any robotic device and, if we can understand how the accomplish this, would provide rich templates for advanced autonomous robot designs. In order to deal with large objects in their path, insects or legged robots must alter leg movements in a precise manner. We employ a range of behavioral and neurobiological techniques to examine how cockroaches perform these tasks. Our behavioral analysis shows how the cockroach evaluates the height and distance of plastic blocks then uses information, mostly from antennal contact, to guide rearing movements that initiate a climb. A shelf creates a choice between climbing over and tunneling. This is again dictated by antennal inputs. If the antennae contact the shelf from above, the cockroach climbs, but contact from below generates tunneling. Ambient light also affects the decision, with more tunneling occurring in the light than under dim light conditions. Likewise, in a T maze, the cockroach typically turns away from the antenna that touches the back wall first, but this "touch-and-turn" rule can be countermanded by stripes moving in the opposite direction. These interactions and others suggest that movements through complex terrain involve multi-sensory interactions that consider many factors in order to change direction of movement in a context dependent fashion. Where in the insect's central nervous system could these interactions merge? We have been examining a group of midline neuropils in the cockroach brain, collectively called the central complex (CC). Electrolytic lesions in specific regions of the CC have precise effects on various locomotory behaviors. Using multi-channel recording, we demonstrated that neurons in CC neuropils respond to antennal and visual stimulation with complex interactions occurring in a decidedly non-linear fashion. More recently, we have been injecting a local anesthetic into the CC to generate reversible changes in the insect's ability to negotiate barriers. In tethered preparations, we find neurons that increase activity in tandem with, and often before, changes in step rate, while stimulation through the same electrodes increase step frequency. Asymmetric activity in the CC precedes turning movement while stimulation in the lateral accessory lobe (a CC output region) regularly evokes turning movement. We are now trying to exam insect behavior in a more realistic environment. Placed in a well-lit arena, cockroaches have a strong tendency to seek out a darkened shelter. Faced with a transparent barrier, the cockroach appears to see the shelter, but its path is blocked. It then must use a combination of visual and tactile cues to get around the barrier and to the shelter. The algorithm that begins to explain how the cockroach solves these problems has been implemented in a wheeled robot that performs remarkably similarly to the insect. We believe that these interdisciplinary studies will lead to greater understanding of how insects negotiate complex terrain as well as robot designs that capture these behaviors.

Research interest

My laboratory examines how insects deal with barriers. We consider behavioral and neurobiological properties of insects facing barriers of various sizes and shape and then work with engineers in Roger Quinn's laboratory to incorporate our findings into robotic designs both for improved control and as hardware models of behavior.