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Some adaptive movements of animats with single symmetrical sensors

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Abstract

This paper shows that animats with a single symmetrical sensor, and using only simple two-instant locomotion mechanisms, can move reliably and efficiently towards a point source of stimulation, even in the presence of considerable noise. Some directional sensitivity in the sensor improves performance. Introducing some asymmetry into the algorithms can increase the reliability of finding the source. For environments differing in noise levels, competitive pressures, and availability of resources, different minimal algorithms are required to achieve the best adaptation to each environment.

1 Introduction

Motile organisms adapt to their environment primarily through the appropriateness of their movements. For simple creatures, there are relatively few different situations of interest, and the movements required for good adaptation are easily specified: for example, some local sources of sensory stimulation should be approached, some should be avoided, and some should be kept at a certain optimal distance. Although one might expect that the minimum requirements for the sensory, computational, and motor apparatus necessary for producing movements of these types would be known, this is not the case. Individual species of bacteria, protozoa, and other single celled organisms have been studied, and the functional and physiological basis of the control of movement is in some cases fairly well understood. Some multicellular organisms (e.g. maggots, flatworms, shrimps) sometimes appear to be operating at a very simple level similar to that of the unicellular organisms, and again there is some understanding of the underlying processes. There is a substantial body of classical work devoted to the classification of different types of movement in relation to various types of stimuli; the key original sources are Loeb (1913), Kühn (1919), and Fraenkel and Gunn (1940, 1961), and an excellent modern summary accessible to non-biologists like ourselves is given by Schöne (1984). However, there appears to be no systematic comparison of the abilities, efficiency, and effectiveness of various general mechanisms under different conditions of environmental stimulation and noise, and under various constraints on the available sensory, computational, and motor resources. This paper is an attempt to make such a comparison for a limited subset of agents, in order to enable the theoretical basis of adaptation through movement to be better understood.

The animats examined will operate in a planar environment containing a single fixed source of stimulation. They will have a longitudinal axis, and will be capable of movement forwards in the direction of this axis, and also of rotating the axis in either direction. For simplicity, a given segment of movement will consist of a turn followed by a forward movement; all trajectories will therefore consist of concatenated linear segments. Most importantly, each animat will be limited to a single sensor element, with a single field of view which is continuous and symmetrical about the longitudinal axis. The instantaneous output of the sensor will be equal to the instantaneous strength of the stimulation due to the source, subject to some allowance for noise. This model is easy to simulate, and will also be relatively easy to implement on a wheeled robot, which is one planned outcome from the study.

It might be objected that such a model is too simple to be really interesting. After all, Braitenberg (1984) disposed of the single sensor Vehicle 1 in less than three pages, moving on to the two sensor vehicles which seem to have been adopted by the SAB community as the minimal interesting robot designs. Vehicle 1 is only capable of active movement forwards; any lateral variation comes from physical interactions with the environment such as friction (and presumably collision). In biological terms, Vehicle 1 exhibits direct orthokinesis (Schöne, 1984), the increase of linear speed with increasing intensity of stimulation, a phenomenon observed in creatures such as fruit flies, mosquitoes, and flatworms. Although there are wheel arrangements where the kinematics can produce different trajectories from different values of a single signal (for example, separate steering and driving motors) these vehicles are only marginally more interesting than the basic Vehicle 1. A simple enhancement of Vehicle 1 is the provision of separate turn and move outputs, one being controlled by the sensor, and the other being controlled by some fixed or random output. This allows the vehicle to cover the plane in a way which does not depend on friction