Learning and Retrieval of Memory Elements in a Navigation Task

Thierry Hoinville[1,2], Rüdiger Wehner[3], and Holk Cruse[1,2]

[1] Center of Excellence Cognitive Interaction Technology (CITEC)
[2] Department of Biological Cybernetics, University of Bielefeld, Germany
[3] Brain Research Institute, University of Zürich, Switzerland

Abstract. Desert ants when foraging for food, navigate by performing path integration and exploiting landmarks. In an earlier paper, we proposed a decentralized neurocontroller that describes this navigation behavior. As by real ants, landmarks are recognized depending on the context, i.e. only when landmarks belong to the path towards the current goal (food source, home). In this earlier version, neither position nor quality of the food sources can be learnt, the memory is preset. In this article, we present a new version, whose memory elements allow for learning food place vectors and quality. When the agent meets a food source, it updates the quality value, if this source is already known, or stores position and quality, if the source is new. Quality values are used to select food sources to be visited. When one source has a too low quality, the agent also finds a shortcut to another known food source.

Keywords: Ant, Navigation, Learning, Decentralized Memory, Navinet.

1 Introduction

The capability to navigate, i.e., the faculty to find distant (not directly receivable) locations as food places or some home site, and the ability to exploit learned landmarks is an excellent paradigm to study the architecture of biological memories, in this case procedural memory [5]. Crucial questions concern how, in an autonomous agent, the memory content is learnt, in which way it is stored and how it can be retrieved in a context-dependent manner.

Intensively studied examples are various insects, in particular honey bees and desert ants. These animals are able to navigate using path integration and landmarks. Although a huge amount of experimental data is available [3,6,10,2], the neural and computational mechanisms underlying how food sites and landmarks are learnt, stored and retrieved are still unknown. A quantitative and therefore testable hypothesis on how this information may be represented in long term memory and how retrieval is possible has been proposed by [4]. However, the way learning and storing of this information may be performed has not been considered in this study. Here we extend and specify the earlier hypothesis by proposing a neuronal architecture that with respect to the general structure called Navinet I, follows the basic ideas of the earlier model, but now shows how both learning and retrieval may be realized using this neural architecture.

T.J. Prescott et al. (Eds.): Living Machines 2012, LNAI 7375, pp. 120–131, 2012.

In this earlier version, a food source memory simply consisted of two numbers, the vector describing the position of the goal. Neither position nor quality of the food source can be learnt. In this article we present a new version of Navinet, called Navinet II, whose memory elements are much more complex to allow the agent to learn food place memory vectors and food quality. During foraging, when the agent meets a food source, it updates the quality value, if this source is already known, or stores position and quality, if the source is a new one. Quality values are used to select food sources to be visited. When one source has a too low quality, the agent also finds a shortcut to another known food source.

2 Navinet I: Navigation through Predefined Places

The earlier model [4] consists of four parts (see Fig. 1) as does the new version.

2.1 Path Integrator and Area Concentrated Search

The first part is composed of two control modules, one being a Path Integrator (PI) and the other implementing an Area Concentrated Search (ACS). The PI continuously integrates displacements to maintain the so-called “current vector” pointing from the nest (null vector) to the actual position of the ant, and used to guide it back home. ACS consists in a randomized spiral-like exploration walk (see [4]) and is performed whenever the ant should have reached the nest according to the PI output, but arrives elsewhere in the neighborhood, due to the inherent PI error accumulation. Note that PI and ACS, combined together, repeatedly lead the agent back to the assumed nest position as shown in real ants [11]. Both PI and ACS capabilities are plausibly assumed to be innate since those are already observed when ants leave the nest for the first time [11].

2.2 Motivation Units

The second part of Navinet I (and II) is a motivation network consisting of so-called motivation units that represent and control different internal states, like “stay-in-nest” or “forage”. Motivation units are self-exciting, nonlinear summation units (saturing activation function) connected in such a way that related states excite each other, whereas conflicting states inhibit reciprocally in a winner-take-all fashion. Thus, “forage” state involves activating either “outbound” state, for walking from the nest to a food site, or “inbound” state, for walking back to the nest when satiated. One motivation unit is also associated with each food source, in order to decide which one should be visited. Here again, the whole motivation network is assumed to be an innate structure.

2.3 Predefined Food Places

Navinet I and Navinet II differ with respect to the organization of food place memories and landmark memories. In Navinet I, three types of memories have