Chapter 9
Modelling and Analysis of Agent Behaviour

Ulrich Nehmzow
University of Ulster, UK

ABSTRACT

Mobile robotics can be a useful tool for the life scientist in that they combine perception, computation and action, and are therefore comparable to living beings. They have, however, the distinct advantage that their behaviour can be manipulated by changing their programs and/or their hardware. In this chapter, quantitative measurements of mobile robot behaviour and a theory of robot-environment interaction that can easily be applied to the analysis of behaviour of mobile robots and animals is presented. Interestingly such an analysis is based on chaos theory.

1 INTRODUCTION

1.1 Life Sciences and Robotics

One major aspect of the life sciences, psychology and ethology is the description and analysis of behaviour, for instance the behaviour of a foraging mammal or insect, following a specific trajectory, the navigating behaviour of migrant birds, or the search behaviour of desert ants.

For principled experimentation it would be of great interest to describe the observed behaviour quantitatively, i.e. to measure it. Qualitative descriptions are only of limited use if the relationship between an independent variable, such as room temperature, is to be set in relation to a dependent variable, such as shape of trajectory taken. But how can behaviour be measured, how can it be described quantitatively?

It is also often of interest to predict behaviour, and to form and test hypotheses. If a set of experimental parameters is given, how is the agent going to respond to them? Faithful models of animal behaviour would give an answer to this question, but how could one obtain these models? Faithful models would not only answer this question, but due to their abstraction and reduction to relevant factors would also allow us to make

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further statements about the observed animal behaviour, perhaps to discover new factors that govern a particular behaviour.

Often it is interesting in ethology and related disciplines to compare the behaviours of individual animals. Is there a difference in the navigation behaviour between young and older, more experienced carrier pigeons? Is a particular observed behaviour typical for all animals of the same kind, or an individual deviation? Again, "measuring" behaviour could give an answer, but the "behaviour meter" has to be obtained first!

And finally, it is sometimes interesting to design behaviour, not only for machines like robots, but also in animals. If a certain animal behaviour is desired, which environmental parameters would lead to that behaviour? If a certain robot behaviour is the goal, which environmental parameters, as well as which sensors are required? Again, faithful modelling could provide an answer here.

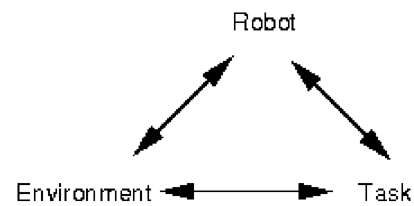
At this point mobile robotics can be a useful tool for the life scientist. Mobile robots combine perception, computation and action, and are therefore in some aspects comparable to living beings. They have, however, the distinct advantage that their behaviour can be manipulated not only by changing environmental parameters, as in animals, but also by changing their control code or their morphology (e.g. placement of sensors).

In experiments at the University of Essex and the University of Ulster we have developed quantitative descriptions of mobile robot behaviour that can easily be applied to the analysis of animal behaviour. The same can be said for the modelling methods we have developed to form testable hypotheses about mobile robot behaviour, and model analysis methods. This work is described in detail in (Nehmzow, 2009).

1.2 Objectives of the Work Described in this Chapter

The overall objective of the work described in this chapter is to develop a theory of robot-

Figure 1. The behaviour of a mobile robot emerges from the interaction between the robot's control program (task), the morphology of the robot and the environment



environment interaction, i.e. a description of all aspects that govern the behaviour of a mobile robot and their relationship to each other. Such a theory would allow to form testable hypotheses about a robot's behaviour, make predictions about the robot's behaviour and allow the principled design of robot behaviour, off-line and without using a real robot. This idea is discussed further in the following section 1.2.1.

A further objective of this chapter is to show in practical examples how such a theory and the tools it provides can be applied to the analysis of behaviour of mobile robots and animals. This is presented in section 2.

1.2.1 A Theory of Robot-Environment Interaction

The behaviour of a mobile robot is not only a result of the control program that is running on the robot, but emerges from the interaction between three components: the robot's morphology, i.e. placement and type of sensors, centre of gravity, aspects of the drive system *etc.*, the robot's control program, and the environment the robot is operating in. Figure 1 shows this relationship.

This fact can easily be visualised by the following thought experiment. Suppose a wall-following robot is not performing the wall-following action correctly. We can change the robot's behaviour by changing the control program – the

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