9

Wrapping Things Up...

If we will only allow that, as we progress, we remain unsure, we will leave opportunities for alternatives. We will not become enthusiastic for the fact, the knowledge, the absolute truth of the day, but remain always uncertain... In order to make progress, one must leave the door to the unknown ajar.

unsourced quote, credited to Richard Feynman

That man is prudent who neither hopes nor fears anything from the uncertain events of the future.

Mother of Pearl: The Procurator of Judea*, Anatole France (1892)*

9.1 Introduction

After introducing the reader to the set of tools encompassing probabilistic approaches for robotic perception, we are now in the position of coming full circle regarding our introductory consideration of Chapter 1.

In this chapter, we will evaluate the appropriateness of these approaches when applied to modelling cognition and therefore perception, examine the different levels at which this appropriateness might be accepted or challenged, and assess the relevance of these types of computational approaches when comparing to their competition.

We will close the chapter and this book by offering our outlook on the opportunities and challenges faced by those who embrace Bayesian approaches for robotic perception.

9.2 Why Go Bayesian?

9.2.1 The Bayesian Approach and Modelling Cognition

For many years and for several reasons (in most cases, of technical, computational, or even epistemological nature), probabilistic approaches remained outside of the focus of cognitive sciences [7]. However, in the past couple of decades, as confirmed, for example, by Chater, Tenenbaum, and Yuille [7], probabilistic approaches have become very much ubiquitous.

J.F. Ferreira and J. Dias: *Probabilistic Approaches for Robotic Perception*, Springer Tracts in Advanced Robotics 91,
DOI: 10.1007/978-3-319-02006-8_9,

This stems, according to these authors, from the fact that the restrictions on the use of such approaches having been substantially reduced, mainly due to the significant technical advancements in the development of supporting mathematical (theoretical) and computational (implementation) tools.

As a consequence, Bayesian approaches have had a substantial increase of authors advocating their use for modelling cognition – see, for example, Chater et al. [7], or more recently Tenenbaum et al. [3] – but also of sceptical authors criticising their popularity – see, for example, McClelland, Botvinick, Noelle, Plaut, Rogers, Seidenberg, and Smith [5].

Between the two extremes, many researchers have also suggested that probabilistic approaches might be very useful, but only at specific levels and even scales of explanation of cognitive processes. These levels will be introduced in the following section.

9.2.2 Marr's Levels of Probabilistic Explanation

Chater et al. [7], following the taxonomy adopted by many researchers when assessing the appropriateness of applying probabilistic approaches to modelling cognitive processes, suggest that they should be seen in the light of Marr's three levels of computational explanation [9]: the *computational level*, relating to the nature, logic and inputs and outputs of the cognitive problem being solved; the *algorithmic level*, specifying the details of the representations and processes used to solve such problems; and also the *implementational level*, which specifies how these representations and processes are to be realised in practice.

Most authors, including the defenders of probabilistic approaches (e.g., Jacobs and Kruschke [2]) but also their detractors (e.g., McClelland et al. [5]; Colombo and Seriès [1]), generally accept their usefulness in covering the computational level of explanation – this was the basis of our argumentation in the introductory section of Chapter 1 – but are generally either respectively very cautious or completely against accepting the explanatory capabilities of Bayesian modelling in the other two levels. This happens due to the fact that this particular level of analysis is focussed entirely on tackling the nature of the cognitive problem at hand, with no commitment to the actual representations and processes involved, and most of all to the practical realisation of such a cognitive solution [7].

Although the algorithmic and the implementation levels are obviously relevant for robotic perception modelling, affecting, for example, the acceptance of their biological plausibility, they are most certainly not a necessary condition to the development of effective modelling frameworks, as we have seen repeatedly throughout this book[1]. In fact, what Colombo and Seriès [1] refer

[1] Nonetheless, even the scepticism regarding the explanatory power of probabilistic approaches concerning these two levels is being challenged by exciting new research. More on this later on.