The methods of biorobotics

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Abstract

Biorobotics is a form of 'hard' Artificial Life research, as it involves experimentation on robotic models of living organisms. Rational justification of biorobotic experiments requires a careful analysis of their methodological structure. Philosophy of science has much to offer for this purpose. Here it is suggested that interactive branches of biorobotics adopt a methodology which radically departs from the "understanding by building" approach as traditionally conceived. It is also observed that some biorobotic studies aim neither at explaining nor at predicting phenomena, but at creating them in Hacking's sense. Finally, it is suggested that biorobotic studies vary in their scope, some of them being limited to the analysis of animal-robot interaction, others reaching conclusion on animal-animal interaction. These considerations are brought to bear on the complexities involved in the justification of biorobotics.

Biorobotics and philosophy of science

Artificial Life (ALife) has been defined by Bedau (2003) as an interdisciplinary study of life and life-like processes that adopts a synthetic approach, which involves the implementation (or synthesis) of computer-based, robotic, and biochemical models of living organisms (Aguilar et al., 2014). As such, so-called *biorobotics* – the use of robots to study the adaptive and social behavior of living systems (Romano et al., 2019; Webb, 2001; Datteri, 2017) – can be properly regarded as a 'hard' form of ALife research.

Biorobotics gives rise to methodological questions which arise in connection with 'soft' and 'wet' forms of ALife research too (Fahmy, 2014). In biorobotics, human-made systems are used as experimental tools to theorize about the behavior of living systems. One may legitimately doubt that the use of systems whose internal structure and material composition differs so much from that of living organisms can shed any light on the mechanisms of biological behavior. How can this epistemic use of machine be rationally justified? Under what auxiliary assumptions can one safely draw conclusions about the mechanisms of adaptive and social behavior in living organisms from the results of biorobotics experimentation (Datteri and Tamburrini, 2007; Tamburrini and Datteri, 2005)? These broad questions pertain to the philosophy of science, as they concern the logic and rational justification of particular scientific methodologies.

To address these questions, it is important to note that biorobotics is methodologically rich and diverse. Biorobotic studies differ from one another in methodologically important respects. This richness is reflected in the richness of philosophical (ontological, epistemological, methodological) problems that must be faced to justify the use of biorobots to study biological behavior.

The aim of this contribution is to emphasize this methodological richness by suggesting that biorobotic studies may differ from one another (a) in the system subjected to analysis and experimentation, (b) in the scientific purpose, (c) in the scope of the obtained results. Disentangling these dimensions by means of a rational reconstruction of biorobotics may enable one to understand and justify its logic.

Beyond the synthetic method

Biorobotic studies may differ from one another in the system subjected to analysis and experimentation. This distinction, more thoroughly discussed in (Datteri, 2020a, 2020b), reveals the methodological novelty of more recent "social" branches of biorobotics, that go in important ways beyond the classic "understanding by building" or "synthetic" approach (Pfeifer et al., 2008). In the synthetic approach, one builds a robot R and, by analyzing how it behaves in controlled settings, draws theoretical conclusions about living system S. This is essentially model-based science, characterized as follows: (1) the system subjected to analysis and experimentation is the robot R, (2) R is used as a surrogate for reasoning about living system S, and (3) S is not present in the experiments. Robotic system R can be regarded as a *robotic simulation* of S (Datteri and Schiaffonati, 2019). Many biorobotic studies (see Gravish and Lauder, 2018 for a review) adopt this approach.

Interactive branches of biorobotics adopt a radically different approach. In interactive biorobotics, robot R interacts with living system S in controlled settings. The analysis of how S reacts to R – and of how its behavior varies depending on the characteristics of R – is brought to bear on the mechanisms of social behavior and cognition; see (Romano et al., 2019) for a review. As argued in (Datteri, 2020a), interactive biorobotics marks a point of departure from the synthetic method as classically conceived. Indeed, interactive biorobotics differs from classical biorobotics in the following respects: (1) the system subjected to analysis and experimentation is not the robotic system, but the living system S which interacts with it; (2) R is not used as a surrogate for reasoning on S, but as a system which stimulates S; (3) S is present in the experiments. Unlike classical biorobotics and the "understanding by building" approach as typically conceived, in interactive biorobotics the robot is not used to *simulate* living organisms, but to *stimulate* them.

The justification problem takes different forms in classical and interactive biorobotics. In classical biorobotics, it amounts to justifying the legitimacy of using robots as surrogates for reasoning about living organism. In interactive biorobotics, it is the problem of justifying that the dynamics of animal-robot interaction are informative of the dynamics of animal-animal interaction (see, however, the ensuing "Scope" section).

Scientific purpose

Biorobotic studies may differ from one another in their scientific purpose. Some studies aim at the *explanation* of living system behavior. Other studies aim at the *prediction* of animal behavior (including the prediction of the behavior of extinct animals, as in Long, 2012). As argued in (Datteri, 2017), the justification of explanation-oriented and prediction-oriented studies rests on different auxiliary assumptions, as far as the relationship between the robot surrogate R, the target system S, and the theoretical model M which is implemented in R is concerned. Other biorobotic studies aim at what Ian Hacking (1983) calls "creation of phenomena". In many interactive biorobotic studies reviewed in (Romano et al., 2019), for example, robots are used to identify the determinants of certain social phenomena. As such, the goal is neither to explain nor to predict a phenomenon, but to *reveal* it (in Hacking's terms, to create it) by precisely circumscribing the conditions under which it manifests itself. Methodological justification, in these studies, crucially involves reflecting on whether robot-induced behavioral phenomena resemble to a sufficiently high degree social phenomena that would naturally occur in the animals' ecological niche: at least, this is required in so-called *distal* studies, as pointed out in the following section.

Scope: proximal and distal studies

Biorobotics differs from so-called biologically inspired robotics (Beer et al., 1997) because in the former, but not in the latter, experiments with robots are brought to bear on theories on animal behavior. This does not imply that all biorobotic results have a straightforward impact on some purely biological hypothesis. As argued by (Datteri, 2020a), in interactive biorobotics we may find so-called *proximal* and *distal* studies. In proximal studies (e.g., Ruberto et al., 2016), animal-robot experiments are taken to support theoretical conclusions that concern *how animals react to the presence of robots*. In distal studies (e.g., Butler and Fernández-Juricic, 2014), an additional inferential step is performed: theoretical conclusions on how animals react to robots are taken to support theoretical conclusions on *how animals react to other animals* – i.e., on social interaction among animals, properly. Justification of proximal and distal studies requires auxiliary assumptions that differ in their nature. In particular, justification of distal studies involves a reflection on the relationship between the robotic model and the modelled animal, a reflection which is not essential in proximal studies.

Concluding remark

The proliferation of approaches and methodologies characterizing contemporary biorobotics *qua* form of 'hard' ALife research requires intensive engagement of philosophers of science, whose task is to study the conditions under which biorobotics can be properly regarded as a *science*. Part of this task – only sketched here – involves operating a rational reconstruction of biorobotic methodologies and analyzing their epistemic justification.

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