



CONSTRAINTS OF LOCOMOTION  
CONTROL IN EVOLUTIONARY ROBOTICS  
AND NEUROSCIENCE  
ARNDT VON TWICKEL

---

Born in 1978 in Berlin; studied Biology and Neuroinformatics at the University Freiburg, at the École Normale Supérieure de Lyon, and at the University Bonn; Research Assistant at the Fraunhofer Institute IAIS, Sankt Augustin and the Group of Theoretical Biology, University Bonn; currently graduate student at the University Cologne with Professor Ansgar Büschges and Research Associate at the University Osnabrück with Professor Frank Pasemann. – Address: Institut für Kognitionswissenschaft, Universität Osnabrück, Albrechtstraße 28, 49076 Osnabrück. E-mail: arndt.von.twickel@uos.de

Being invited as a Short-Term Fellow of the Wiko, I was extremely excited to return to the city of my birth. A previous visit had shown me how productive and inspiring one week at the Wiko can be. I was determined not to miss a chance to return. But now that I had the chance I had two doubts: Firstly my wife was expecting to give birth to our first child just shortly after my planned return from the Wiko. Could I leave my wife during this exciting, yet burdensome period of time? What if birth started earlier than expected? Secondly I realized that I was going to be the least experienced and least renowned Fellow and asking myself if I could live up to the expectations of being a Fellow at the Wiko.

#### Field of Research

Seemingly “simple” motor behaviors like walking result from multiple non-linear interactions between local neural networks, muscles and sensors distributed across multiple

appendages, and more centralized “higher” neural systems and the environment. On the one hand, reductionist approaches fail to explain emergent behaviors, e.g. gait patterns cannot be explained by investigating just a single leg. On the other hand whole-system approaches pose non-trivial challenges, e.g. it is extremely difficult or even impossible to experimentally obtain sufficient data, due to the complexity of the systems under study. Therefore synthetic approaches, i.e., numerical simulations and robotic models, have become invaluable tools in motor control research. These approaches integrate data from neuroscientific, biomechanical, and behavioral experiments. Partly missing data are either given by the experimenter to test specific hypotheses or are systematically varied to derive new hypotheses.

In my research I focus on the neural control of walking in insects and humans. To this end, I employ physical simulations and robotic models driven by artificial neural networks. Neural networks are derived from biological data, designed by hand, or derived via artificial evolution. Artificial evolution repeatedly varies the structure and parameters of a neural system and on average selects those changes that improve the performance of the system with regard to a fitness function and a given context. A fitness function could reward high walking speeds in a rough environment, for example. Resulting controllers are analyzed and compared to learn about their mechanisms. In order to compare them with biological systems, it is crucial to recognize the functional constraints of body and environment, e.g. the role of muscles and how they differ in the natural and artificial system. The role of some of these constraints was the focus of my research at the Wiko.

#### Work at the Wiko

Without any institutional duties, I set myself ambitious goals for my three-month stay. Underestimating the dynamics at the Wiko, I only partly succeeded in reaching these goals. Since I was invited as a member of the focus group that had the goal of learning about structure-function relationships in motor control systems, I was enthusiastic about employing computational tools to contribute to the group’s project. First of all I had to learn that the group members’ views and backgrounds were so diverse that we could not quickly agree on specific questions that could be transferred to simulation experiments. But over time this mild disappointment turned into appreciation of the fact that less time was spent on technical details and more time on discussions, clarifying and broadening our viewpoints. To summarize our discussion, we are preparing a joint review article.

More specific ideas about meaningful simulation experiments emerged at the end of my stay and I am optimistic that at least some of us will tie in with some of these ideas in the future. I am greatly indebted to all group members, i.e., Harald Wolf, Binyamin Hochner, Frank Pasemann, Volker Dürri, and Sergiy Yakovenko, for sharing their expertise not only during group meetings but also during Grunewald walks, pub visits, and other joint activities. Especially valuable were the times that I spent with Sergiy Yakovenko, discussing until late at night about simulation techniques, the roles of central pattern generators, sensory feedback, and muscles in motor control. A jointly held Thursday colloquium taught me how to prepare presentations for an extremely mixed audience.

Apart from the interaction with the focus group, I worked mainly on two projects. First I took steps toward the integration of the approaches of two former Fellows, namely Ansgar Büschges and Holk Cruse, to shed light on the mechanisms of stick insect walking. Both of them visited the Wiko during my stay, allowing plenty of time for discussions and giving valuable advice. In a simulation study I was able to demonstrate the constraints of neural networks derived via a reductionist neurobiology approach when put into diverse behavioral contexts as used in a systems-oriented behavioral approach. The resulting paper was submitted during my stay and is currently under review. Second, I took advantage of the outstanding service of the library to review the literature about scaling constraints in locomotion control. In this context I built a detailed parameterized stick insect simulator in addition to a previously built, scaled-up robotic simulator to allow a comparison of different neural controllers in the two systems. A third project about the constraints of natural and artificial actuators in motor control I was not able to advance beyond a literature review due to time constraints.

### Life at the Wiko

Initially I planned to withdraw from social events as much as possible to concentrate on my own work. Once I arrived at the Wiko, I quickly realized that I would miss something valuable, namely the chance to broaden my view of my own research and related fields as well as of more distant fields, e.g. from the humanities. The Tuesday colloquia taught me not only how differently from the natural sciences the humanities approach research, but also how valuable a seemingly basic question can be: Asking e.g. “Why do you do this kind of research?” started heated discussions, often lasting much longer than the colloquium and the following lunch. Discussions during various meals and after

evening events (concerts, lectures ...) with Co-Fellows, former Fellows, and other guests allowed me to put my own work into different contexts and to learn about completely different research areas. Additionally, living so closely together with the other Fellows led to valuable friendships: Sharing a kitchen with Marie Farge had the consequence not only of sharing dinners, but also of frequent, hours-long discussions about science and almost anything else. On a frequent basis, Kiran Nagarkar got me out of the world of research, not only by means of his wonderful books but also with our conversations during meals. Finally, the outstanding atmosphere was not only due to the Fellows and the Grunewald environment, but also heavily supported by the fantastic Wiko staff and administration. Most wishes were almost fulfilled before I could ask.

Overall the three months that I spent at the Wiko were not only productive, but also gave me new ideas for years to come and strengthened my enthusiasm for science. I am deeply grateful to the Wiko for this extraordinary opportunity. I was sad to leave two weeks prior to my planned departure, but less sad than I would have been under different circumstances: I am greatly indebted to Kiran and Marie for convincing me to return home early – I did so just in time to attend the birth of my daughter Helene.