

When biologists study the behaviour of animals they often need to manipulate the system being investigated. A textbook example is that the biologist Nicolas Tinbergen was trying to understand the begging behaviour of seagull chicks. He noticed a red spot on the beak of female seagulls and started manipulating it. For example, he covered the red spot and saw that the begging behaviour stopped and when he made it bigger the chicks pecked it even more. He discovered that the chicks would even peck on a piece of cardboard with a red dot painted on it.

Robots have been used in such manipulations for many years in species from insects and spiders to fish and mammals. I present a taxonomy that sorts all this research into ten categories. Further, I show that the ability to handle data fast enough to influence the process producing it is essential. I call this online operation and I point out how robotic systems with this ability can enable new research. However, we need computers to online detect what the animal is doing and react accordingly. Detecting what the animal does means that we must be able to represent behaviour in a computer system and doing it online means that we need very fast analysis.

I propose to represent behaviour with events consisting of a timestamp and a label. Events can be handled by an infrastructure called event processing developed for social media, e-commerce and stock trading. The advantage of event processing is that we can handle huge amounts of data very fast by distributing the load across many computers. However, it is not enough to be able to handle big data, we also need to analyse it very fast. In cloud solutions this is also solved by distributing the load over many computers in so called microservices. So in summary, I propose using microservice- and event processing infrastructure in online analysis of behaviour.

The idea was explored in three interdisciplinary projects conducted in collaboration between biologists and engineers. In the first project, we developed an architecture for online analysis of behaviour and tested it in long term sound recordings of bats and video recordings of mongoose. In the second project, we applied the architecture in a virtual reality setup for birds. We showed that the birds can communicate through the system and that we can drive their behaviour. In the third project, we demonstrated that the architecture can be used to make a brain simulation control a robot.

The main knowledge gained from the three research projects is that the ability to operate online is essential in biorobotics. The ability to analyse behaviour online while it is happening can enable otherwise impossible manipulative experimentation. We also learned that behaviour can be represented by events in a comprehensible way and that cloud infrastructure can support research in biology. In the process we also found new ways to experiment with birds using virtual reality and neuron models using robots.

There is still much to do especially in optimising the technical solutions but the work presented in my dissertation provides a proof of concept and comprises an initial investigation of online biorobotics.