Bioinspired micro- and nanorobotics

Friedrich C. Simmel
TU Munich, Am Coulombwall 4a, D-85748 Garching, Germany

There are many similarities between biological and robotic systems. Robots are complex technical systems that typically integrate sensing and actuation with computation, control and decision making. With increasing capabilities in biomolecular design, bionanotechnology and synthetic biology, we can ask whether robotic functions can also be implemented at the molecular and cellular scale, using biochemical "wetware" rather than hardware.

At the molecular or nano scale, in particular DNA nanotechnology has already demonstrated systems that perform a variety of robotic functions - such as movement, sensing and simple information processing. Among the major challenges for the field is to integrate these capabilities into consistent systems, speed them up, power them and let them interact with realistic environments. A major application envisioned for such systems will be biomedical molecular robots that detect diseases, evaluate diagnostic rules, and produce or release drugs for therapy. An alternative line of research is the realization of molecular assembly systems that can transport molecules or materials, characterize and manipulate them, and control chemical reactions.

As the capabilities of single or a few molecules are limited, some functions can only be implemented in more complex integrated systems of sensors, actuators and information processing units, which are more likely to resemble cell-like structures. Similar as for the molecular systems, challenges that have to be addressed is the energy supply of such systems, their interface with the environment and the speed of the sensor/actuator/computer processes embedded - these capabilities will decide how, for how long and at which time-scale these systems will be able to interact with their surroundings.

Physics will play an important role in the development of such systems. Apart from providing characterization techniques and physical models for their dynamics, it will help to clarify the limits of such systems - how fast and how energy-efficient they are, how much information they can be process, etc. It can also offer novel approaches for driving small robotics systems with unconventional mechanisms that are outside of the realm of classical robotics and mechanical engineering.

In the talk, a brief introduction into the field will be given, with several examples from DNA nanotechnology and synthetic cell research. We will then briefly touch upon potential applications of such systems and challenges for their future development.