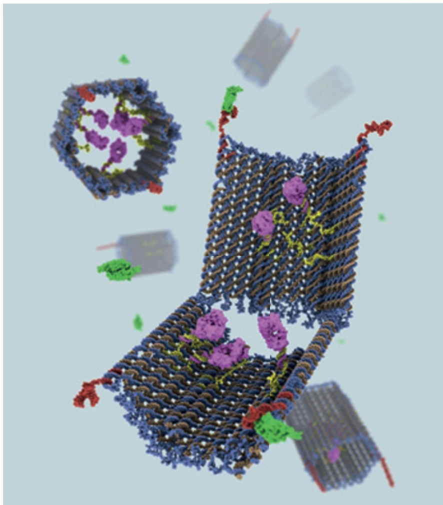
Put more 'nano' in robotics

DNA nanotechnology has proven to be a powerful approach for fabricating active nanostructures with biological functionality. Now, it is time to investigate more solutions from biology to downscale robotics, says **Christian Martin.**

Robots with nanometre dimensions or, in short, nanobots, are notorious icons of nanotechnology. Despite doubts regarding their practical feasibility, as well as fear of their potential to turn all life on Earth into grey goo, they continue to fare well with futurists. Just last year, artificial intelligence expert Ray Kurzweil reiterated the notion that nanoscale robots could one day populate our bodies to enhance our health as well as our cognitive performance[1,2]. This could easily be dismissed as science fiction if it was not for the fact that Kurzweil is currently a director of engineering at Google, the company that made headlines at the beginning of this year through the acquisition of several robotics companies as well as ventures into the healthcare field. And indeed, rumours of upcoming nanobot releases started to circulate ahead of the company's annual technology conference, Google I/O 2014.

Although (perhaps not surprisingly) no such announcement was made, nanobots seem to have remained vivid even in the minds of the more sober of robotics scientists. The European robotics association euRobotics, which together with the European Commission in June this year launched the €2.8 billion public–private partnership 'SPARC', includes 'nano robots' in its Strategic Research Agenda as well as its roadmap[3]. The National Robotics Initiative, which aims to accelerate robotics research in the US, even goes so far as to detail the development of "nano-robots for drug delivery, therapeutics, and diagnostics" within a 15-year timeframe[4]. But how would such machines work? Unfortunately, both industry roadmaps leave such details largely unaddressed.

Last year in this journal, Chris Toumey pointed out that the downscaling of macroscopic concepts will not be a viable route towards robots with nanometre-sized features[5]. Instead, he argued, tomorrow's nanobots could be molecular devices manufactured in bottom-up processes to fulfil specific functions in the body. And indeed, exciting proofs of principle have been reported in this area. Ido Bachelet and colleagues have, for example, recently implemented elementary logic gates using nanoscale DNA-based structures that were capable of interacting through the sensing and the triggered display of molecular keys[6]. The researchers used their nanostructures, which were fabricated using DNA origami, to perform a number of logical operations and also to control the release of a therapeutic molecule in living cockroaches. This method, they suggest, could be a first step towards the computational control of human therapeutics.



DNA-based nanobots are capable of releasing payloads on the sensing of molecular keys[9]. Image created by Campbell Strong, Shawn Douglas and Gaël McGill using Molecular Maya and cadnano, courtesy of the Wyss Institute, Harvard Univ.

In this and other studies, DNA origami has proven to be an incredibly successful approach to designing and manufacturing nanostructures with biological functionality, and it should be pushed forward for the sake of its potentially groundbreaking applications in healthcare. However, will this be the only viable route to nanorobotics? The performance of these nanostructures depends on their collision statistics, which makes them most suitable for closed systems in which their concentration can be controlled.

In many other environments, one would expect a robot to be capable of working independently and autonomously. Fundamental limitations to the amount of energy that can be stored in a small volume, to on-board computational power, and to mobility in liquid environments and on surfaces represent tremendous challenges to the designer of any autonomous nanoscale robot. Novel technologies for energy supply, data processing and propulsion will be key to further progress in this area. In human-sized robots, such as the ones manufactured by Google's recent acquisition Boston Dynamics, familiar technologies from the fields of mechanical engineering, electronics and digital controls can be adapted to ensure autonomy. Already on the centimetre scale, less common approaches are needed. For example, since the 1990s, the branch of 'biomorphic' robotics has sought to design small, survival-oriented machines that harvest energy and that control their movements using an artificial nervous system implemented by a simple network of sensors and analogue circuits[7]. In the micro- and nanometre range, autonomy will have to be achieved using even more exotic concepts.

The most promising approach could again rest on solutions familiar from biology — the combination of synthetic functional components with biological actuators. The first steps in designing such hybrid organic–inorganic systems have already been reported[8]. To proceed from these early demonstrations to fully autonomous robots will be a formidable challenge. Although sizes below a few micrometres may eventually prove impossible to achieve, events such as the IEEE's Mobile Microrobotics Challenge, whose entrants have so far largely relied on external actuation, should provide a great motivation to put more 'nano' in robotics. ❐

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