Jörg Bandura
Theoretical Biology, IZMB, University of Bonn, Germany
e-mail: bandura@chaos-engine.net
Prof. Wolfgang Alt
Theoretical Biology, IZMB, University of Bonn, Germany
e-mail: wolf.alt@uni-bonn.de

Cell migration inspired design of crawling robots

Animal tissue cells (as fibroblasts and keratinocytes) are utilising a unique principle of locomotion: the adhesive cell migration for crawling on a fixed substratum. It is a higly complex process involving the cytoskeleton and multiple regulation mechanisms [1]. The moving cell is polarised as a result of asymmetric cytoskeleton modifications by assembling and disassembling microfilaments [2]. Transmembrane glycoproteines such as integrins adhere to the substratum and are dynamically coupled to actin filaments inside the cell, which are cross-linked to myosin dimers. By exertion of contractile stress this actomyosin complex is able to transfer a traction force onto the substratum, enhancing cell polarisation: at the front, 'soft' centripetal forces pull the cell body forwards, whereas in the rear, 'stiff' centripetal forces mechanically disrupts the cell from the substratum [3].
This project is using the basic physical principles causing the propulsion during cell migration as a bio-inspired approach for designing a new form of crawling robot locomotion. The aim is not to copy the cell migration mechanism itself but rather its basic physical outline. This outline consists of an autonomously induced *gradient of stiffness* of the adhering cell cortex, increasing from front to rear, persisting during migration due to the successive assembly and strengthening of microfilaments at the adhesion sites. These physical properties are implemented into a computational model with corresponding simulations of an autonomous self-crawling and self-deforming robot. The two-dimensional model consists of double elastic chains, linked by radial elastic segments, which adapt their stiffness and elasticity to their adhesion or non-adhesion state over time: building up a gradient of stiffness during adhesion and decreasing it after disruption.
Simulation runs demonstrate that this model is able to move autonomously and that it is capable to move upwards inclinations and walls without losing stability. The model is designed simple enough for construction in reality. This leads to possibly new forms of crawling locomotion in robotics, advantageous in situations, where legged and wheeled propulsion is not usable or working.

References

[1] Lauffenburger DA, Horwitz AF (1996) *Cell migration: a physically integrated molecular process*, Cell, 84, pp. 359–369.
[2] Evans EA, Calderwood DA (2007) *Forces and bond dynamics in cell adhesion*, Science, 316, pp. 1148–1153.
[3] Alt W, Bock M, Möhl C (2010) *Coupling of cytoplasm and adhesion dynamics determines cell polarization and locomotion*, in: A. Chauvière, L. Preziosi, C. Verdier *Cell Mechanics: From Single Cell-Based Models to Multiscale Modeling*, Chapman & Hall CRC, London, pp. 89–131.