Control, locomotion and geometry



Fig. 1



The science of control engineering involves modeling and 'control' of dynamical systems, or in simple words, understanding and manipulating systems that evolve with time. There is a wide gamut of areas that fall under this broad umbrella: economics, biology, environment and engineering to name a few. Our group studies the control of mechanical systems (mobile robots), aerospace systems (spacecrafts), locomotion of microrobotic mechanisms, and the underlying mathematical framework to model, analyse and synthesise control laws for these systems, ie., differential geometry.

Attitude control of spacecraft

Spacecraft are rigid bodies that are actuated by one of the following two principles. The first is that of action and reaction. In this category are gas jet thrusters; when gases are ignited and ejected at a high velocity from the spacecraft, the reaction forces actuate the spacecraft. The second category of actuators work on the principle of conservation of angular momentum. In this category are reaction wheels (wheels with a fixed axis and spinning at a high velocity; a change in their speed causes a change in the momentum of the spacecraft) and control moment gyros (CMGs) (in this case, the axis of rotation of the spinning wheel could be changed as well). We model these systems and devise algorithms to orient the spacecraft as we desire.

Locomotion in low Reynolds number (microorganisms and microrobotics)

Imagine swimming in honey or a thick viscous fluid; the experience would be quite different from that in a conventional swimming pool. Moving one's limbs in a manner as one does in a pool of water is no longer a feasible option due to the high viscosity of the surrounding fluid. Similarly, organisms whose dimensions are at the micrometer level or lower, like bacteria (Escherichi coli) and paramecia, locomote in fluid environments where viscous forces dominate inertial forces, a condition termed as locomotion in low Reynolds number. There is considerable



Fig. 3 (source: http://science.howstuffworks.com/life/ evolution/evolution4.htm)



interest in understanding the locomotion mechanisms of these organisms, partly spurred by the interest to develop mechanisms that use similar locomotion strategies at the micro and nano level - particularly in bioengineering and bio robotics. Mobile cilia in paramecia, body shape changes in amoeba, beating flagella in bacteria (Fig. 3) are a few examples of such mechanisms in the biological world. We model, build and study controllability and feedback control issues in these mechanisms.

Geometry and robotics

A simple pendulum is a commonly encountered mechanism in engineering. A mathematical description of this system, in a very matter of fact way, assumes that the angle of the bob of the pendulum varies between 0 - 360°, and this angle is represented as an interval of the real line (0 to 2). In reality, this open interval of the real line far from describes the position that the bob of the pendulum can assume. For instance, 0 and 2π represent the same configuration of the bob, but these two points are not identical on the real line, nor are points close to 2π reasonably close to 0. This seemingly simple example brings forth the need to study the configuration of a simple pendulum on a circle and not on the real line. The next task is to study the dynamics of the pendulum on the circle which brings in the need to study calculus on the circle. This elementary example extends itself to many more mechanical systems and justifies the study of differential geometry, which helps us to study and control the dynamical behaviour of systems that evolve on non-Euclidean settings. One such example is a spherical robot with internal rotors (Fig. 4) performing manoeuvres on the plane to change its orientation. We model, analyse and synthesise controls of mechanical systems in non-Euclidean spaces.