Cognitive Challenges in Snake Robotics

Aksel A. Transeth[1], Pål Liljebäck[1,2],
Sigurd A. Fjerdingen[1], and Erik Kyrkjebø[1]

[1] SINTEF ICT, Dept. Applied Cybernetics, NO-7465 Trondheim, Norway
[2] NTNU, Dept. Applied Cybernetics, O.S. Bragstads plass 2D, NO-7034 Trondheim, Norway

Snake robots have the potential of contributing vastly in areas such as rescue missions, fire-fighting and maintenance where it may be too dangerous or cramped for personnel to operate. A key to achieve such motion capabilities is to enable snake robots to push against objects in order to obtain forward motion. Recently, the cybernetics group at NTNU/SINTEF coined the term "obstacle-aided locomotion" for such a principle of snake robot motion [1].

A number of cognitive challenges must be solved for a snake robot to perform obstacle-aided locomotion:

1) **Sense and *feel* the environment.** Methods for intelligent sensor fusion is crucial for obstacle-aided locomotion. These methods need to combine data from vision sensors and inertial sensors together with a large number of contact force sensors [2] and joint torque/position/velocity sensors.

2) **Motion control based on sensor input.** A snake robot must recognize suitable push-points that can be used for locomotion and perform appropriate winding motions. This is a considerable challenge mainly since snake robots have a large number of joints to control and coordinate.

3) **Do not get stuck.** A snake robot must be able to recognize if it is stuck in a network of obstacles and resolve the situation by coordinated control of its joints [3]. This is a challenge due to the high number of joints and possibly limited information from sensors which makes it hard to interpret the environment correctly.

Model-based control, reinforcement learning for optimizing snake robot motions based on experiments in its environment and model-based learning are techniques that could possibly prove advantageous in order to perform efficient and robust obstacle-aided locomotion. However, snake robots have a large number of joints. This constitutes a considerable challenge for robot control since the state-action space becomes high-dimensional.

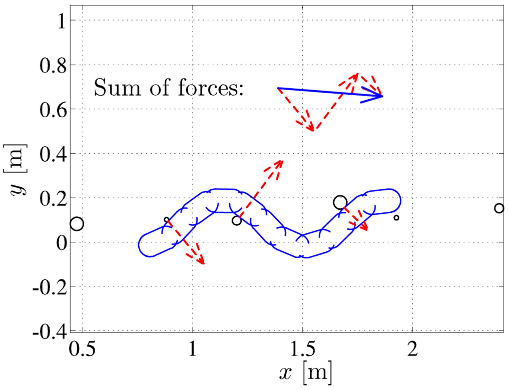

Fig. 1. Sum of forces on a snake robot during obstacle-aided locomotion (ground friction forces are omitted) [1].

Fig. 2. Application examples: Snake robots aiding in a search & rescue operation (left) and in a fire-fighting operation (right).

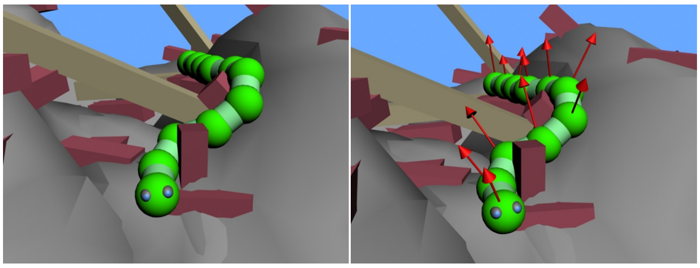

Fig. 3. Obstacle-aided locomotion: A snake robot pushing against obstacles in order to move forward.

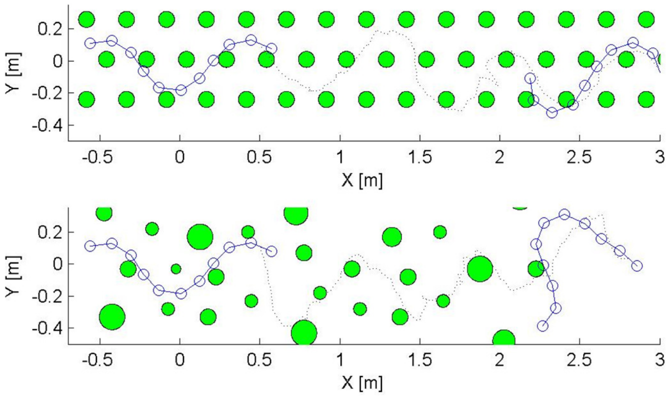

Fig. 4. Simulation of obstacle-aided locomotion with a model and a control strategy recently developed at NTNU/SINTEF [2], [3].

[1] A.A. Transeth, R.I. Leine, Ch. Glocker, K.Y. Pettersen and P. Liljebäck. "Snake robot obstacle aided locomotion: Modeling, simulations, and experiments," *IEEE Trans. Robot.*, vol. 24, no. 1, pp. 88-104, 2008.

[2] P. Liljebäck, S. Fjerdingen, K. Y. Pettersen, and Ø. Stavdahl. "A snake robot joint mechanism with a contact force measurement system," in *Proc. IEEE Int. Conf. Robotics and Automation*, 2009, pp. 3815-3820.

[3] P. Liljebäck, K. Y. Pettersen, and Ø. Stavdahl. "Modelling and control of obstacle-aided snake robot locomotion based on jam resolution," in *Proc. IEEE Int. Conf. Robotics and Automation*, 2009, pp. 3807–3814.