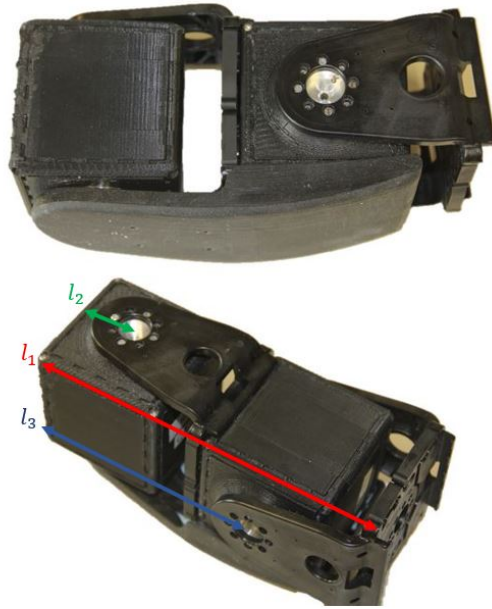


HOW TO REALIZE YOUR SNAKE-LIKE ROBOT

Typically, the structure of snake like robots consist of serially connected joint modules capable of bending in one or more planes. For the experiments in this work, we built our snake robot with 12 *Variable Stiffness Actuator (VSA) qbmove maker pro*, by *qbrobotics*.



Parameter	$l_1(mm)$	$l_2(mm)$	$l_3 (mm)$	$m (Kg)$
Value	163	39	127	0.78

Figure 1: Snake module

Using 2 cubes with horthogonal axis, we have created a module with 2 degrees of freedom, that is capable of bending in horizontal and vertical plane (Fig. 1). In order to increasing the friction properties, we produces a cover composed of 2 layers with different hardness. The first layer is composed of plastic and it have more hardness than the second. It is used to connect the cover to the module. The second layer, with a lower hardness, is made of rubber. It needs to have a uniform contact point during the snake movement. The picture of cover is depicted in the next figure (Fig. 2).

The whole snake is powered by three 12 volts battery.



Figure 2: Module cover

Set Up

We had to need the qbmove simulink libraries, in order to interface the cube with Matlab/Simulink. These libraries are available on qbrobotics website. Using the qbmove maker block, we have created a *simulink* model with 12 cubes, in order to control the snake robot.

Yaw and pitch joints are controlled with two wave on the form:

$$\theta_{hi}(t) = \alpha_h \sin(\omega_h t + (i - 1)\beta_h) + \gamma_h \quad (1)$$

$$\theta_{vi}(t) = \alpha_v \sin(\omega_v t + (i - 1)\beta_v + f) + \gamma_v \quad (2)$$

In the next figures are depicted the control scheme for the horizontal and vertical waves (Fig. 3 and 4).

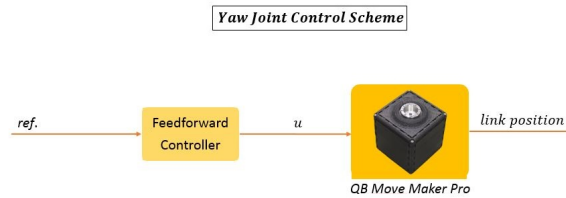


Figure 3: Yaw joint control scheme

As we know, the feedback is bad for VSA, because the control damps the spring effect. Hence, the most obvious choice is to control the cubes with a feedforward signal for both waves.

Since we would to allows the snake robot to avoid the obstacle automatically, we choose only the

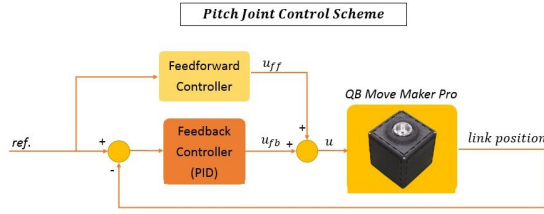


Figure 4: Pitch joint control scheme

feedforward command for yaw joint. In feedforward, using the spring of the cube, when the snake push up the obstacle, it can exploit the elastic energy of the spring of the cube to automatically avoid the obstacle.

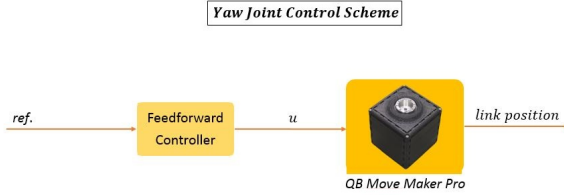


Figure 5: Yaw joint control scheme. Feedforward only with $k = 1$. Stiffness value is set to zero on the top, 10 on the bottom.

On vertical side with only feedforward command we have to increase the stiffness value, in order to allows the snake to moving forward. Usually this is done in a mechanical manner, with a more high stiffness value. However, this increasing produces more power consumption. As well as set the stiffness to an highest value, with the feedback we can add stiffness without increasing the value of the stiffness, and hence we allows to keep the current on the cube under the critical value. In our work, in practice, we have inserted a feedback command, keeping the stiffness value low.

In order to ensure that the current inside the cube remain under the critical value, we develop a safety circuit on our Simulink model.

To control the movement of the snake, we use a Logitech Joypad, that it allows us to change the parameters of the two waves on real-time during the simulation.

In the next picture (Fig. 6) there is the complete set up that we created for the experiment in this work.

With the control described previously (feedback and feedforward on pitch joints, only feedforward on yaw joints) it show that the snake is not be able to turn inside the pipe. It can only moving forward, but when find a curve it stop the run. In order to be able to turn autonomously we modify the control scheme: the pitch joints control is the same (Fig. 4), while the yaw joints are controlled with deflection control. This consist on unitary feedback of the link position, in order to guarantee



Figure 6: Final Set Up

that the joint follow the actual position of the link. With this modification, the snake is able to moving forward and turn autonomously inside the pipe. In the next figure (Fig. 7) is depicted the control deflection scheme.

Yaw Joint Deflection Control Scheme



Figure 7: Control Deflection scheme