Kraken: a Modifiable Compliant Robot

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Summary. Previous research has shown that compliant robot bodies can effectively perform computations which led to the term morphological computation. Kraken is a new compliant robot platform of which the dynamics can be changed easily. This allows, similarly to simulated systems, a quantitative measurement of the computational abilities for different configurations and corresponding dynamics, and of the impact on the central controller.

Traditional (stiff) robots are made to be fast, precise and controllable [1]. Their range in degrees of freedom depends only on the amount and type of actuators used, often resulting in complex control requirements. This implies they have difficulties performing tasks in unpredictable environments were they should adapt themselves to become more efficient [2]. In order to overcome these difficulties, compliant robots are gaining success. The use of compliant materials is advantageous for delicate tasks in cluttered and/or unstructured environments. Furthermore, it has been shown that this allows to offload parts of certain control problems to the (physical) body which frees computational resources. This is also known as morphological computation [3]. Examples are locomotion control of quadruped robots [4] and locomotion control of tensegrity robots [4], sensing in quadruped robots [5] and information processing via a soft silicone arm [7].

The previous robot examples have in common that they are all systems with complex and rich dynamics which can be perturbed externally and that a simple readout mechanism can be applied in order to perform a desired task. This is similar to reservoir computing systems [8]. However, in standard cases of reservoir computing systems, the reservoir is implemented as a recurrent neural network and simulated in software rather than being implemented physically. The key properties that a mechanical reservoir should have are input separability and fading memory [7].

The question is how can robot morphologies and thus body dynamics be improved by using the physical reservoir computing framework in order to facilitate control, balance ease of control and increase the power efficiency? In order to find an answer for this question, one should be able to explore the full dynamical capabilities. Unfortunately while some robots and tensegrity structures can exploit their highly compliant body to achieve computation, they lack the ability to change their dynamical properties. For example, the springs within the tensegrity robot ReCTeR [4] are not easy to replace. Consequently, there is a need for a new compliant robot platform of which the body is designed such that its dynamics can be changed easily and in a consistent way. This allows, similarly to the simulated systems, a quantitative measurement of the computational abilities for different configurations and corresponding dynamics, and of the impact on the central controller.

Figure 1: Final prototype of the compliant spherical robot, called Kraken. The (blue) pods can be switched in order to change the dynamic properties of its body. A video can be seen on https://youtu.be/7rH7FcR31L0.
Kraken (see Figure 1) is a robust, low-cost, lightweight and untethered robot of which the dynamics can be changed easily. Inspired by the Mine Kafon of Massoud Hassani and the robot Wild & Tame [9], Kraken was designed with a spherical morphology which is well suited for locomotion and path planning. Its movement can be performed with a low-dimensional control signal and it is statically stable in any position. Furthermore, the robot is designed to be a modular system, which allows the pods to be easily changed to pods with other compliant properties. This makes it possible to change the dynamics of the robot in a precise and consistent way. Each pod is connected to the body through a high-dimensional pressure sensor which make it possible to monitor the interaction of the robot with its environment and thus, observe the state of the reservoir. Consequently, it is possible to test the computational abilities of Kraken for different conditions on the stiffness. By experimentation with Kraken we want to get insights into how both the morphology of compliant robots and controlling systems can be changed in order to create the optimal body dynamics for motor control, balance, ease of control and power efficiency.

References


