Short summary overview of results, conclusions and the impact of the robotICs project.

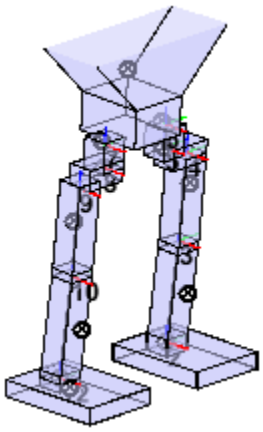
robotICs: do autonomous robots benefit from an Intermittent Control (IC) implementation?

Project No: 627959
Project Acronym: robotICs

Through the EU funded MC Fellowship, a multidisciplinary research project was created in which expertise in the fields of Human Movement Science, Control Engineering and Robotics was combined to extend and diversify the fellow's knowledge and skills required to start developing a robotics component to the Intermittent Control (IC) in Man and Machine paradigm.

The main objective of the MC fellowship was to validate the proposed IC implementation in autonomous (humanoid) robots. Results with respect to the work packages detailed in the proposed description of work are summarized below.

WP1: Model Development and Mathematical Simulation



In accordance with the hypothesis proposed, it was found that also in a robot context, IC can be a natural and effective control paradigm. That is to say, in the presence of actuators, sensors, systems and constrains; central refractoriness is an appropriate control mechanism especially when the plant model or sensor readings are unreliable and/or delayed (which for 'soft' robots is most often the case). At the Delft BioRobotics Lab we, using Matlab/Simulink, implemented an IC module to i) run simulations and ii) to validate the architecture on a physical system running the IC module on a real-time the target embedded within TUlip, a 1.1 m tall 18 kg humanoid robot with two legs that have 6 actuated degrees of freedom; 3 in the hip 1 in the knee and 2 in the ankle. To allow learning and adaptation the possibility of 'online redesign' has been supplemented.

WP2: Implementation and experimentation
Implementation of an Intermittently Controlled sensorimotor apparatus (e.g. the perception-action coupling in a robot) requires a good understanding of the perceptual motor, and control components of the system. The IC paradigm (and its neurophysiological basis) was further explored supported by the analysis of human participant data. In this work we elaborated on the role of different sensory organs (e.g. joint position, muscle length, spatial orientation) in order to construct the required control weightings. In the context of robotics, all system states can be observed or otherwise inferred by measuring the system outputs. Part of the project objective was to collect data of human subject controlling a (perturbed) balance task. To measure the participant's state (and differentiate between the sensory modalities) we recorded data in a human-in-the-loop setup using the 'whole-body-mover' at the Manchester Metropolitan

University. Recent analysis of the data which required the development of a new, remnant based, method of development at Glasgow University, revealed that Intermittent Control provides a deterministic explanation of linear and remnant components of human stance control without injection of random noise.
This result will be presented at ISEK 2016 which is held in Chicago 5-8 July 2016.

WP3: Validation
The newly developed IC module has been successfully implemented on TUlip and the MC fellow has run the appropriate perturbation (push recovery) studies to validate the concept at the Delft Biorobotics Laboratory .Currently we are finalizing a manuscript that shows that by implementing Tulip's controller with an intermittent open-loop interval we not only replicate the modal frequency that we see in human motor control but we also demonstrate that, in contrast to conventional continuous control, this robot is more robust to system perturbations when (due to unreliable identification of the plant dynamics) the controller gains are either too low or too high. From this we conclude that because in soft robotics an exact model of the plant dynamics is often not available therefore; intermittent open-loop control is relevant and beneficial.

Impact and future perspective

Through soft robotics, researchers try to solve the impedance mismatch between state-of-the-art robots and their environment. Led by the insight that IC is most beneficial/relevant in the context of series elastic and/or soft actuators the MC fellow has invested a significant portion of his time into the conceptualization of a new type of compliant actuation (starting a new research lab within the TUD robotics institute). This work (not proposed) resulted in the formation of a large European consortium with 10 partners (covering the entire value chain) from 7 EU countries that submitted two (rejected) H2020 multimillion € project proposals to ICT-24-2015 and FET-OPEN. Application of this actuation concept has been demonstrated within a student project within the TUD's MINOR robotics. The team of students coached by the MC fellow was selected to demonstrate their robot concept at the international science festival that is organized by the TUD specifically reaching out to the general public.

In sum, the Fellowship provided a valuable contribution to the professional development of the applicant and the research portfolio of the research group. Given the originality and cross disciplinary nature of the MC work, the quantity of the intended peer reviewed publications within 24 month has been challenging. To secure project output and the further development of the new research line originating from the robotICs project (incl. acquisition), the MC fellow's contract at TUD has been extended.