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E. Andrada / H. Witte

How many neuronal activity does need the body stem during normal locomotion?

Intelligent Mechanics in Robotics

Since Weber & Weber (1836) biomechanical observations and models were mostly restricted to the extremities' behavior. But our quadrupedal phylogenetical ancestors produce up to 50% of their locomotion by movements of the trunk [1]. These movements are coordinated with those of the extremities to optimize the behavior and adaptability of the whole system [2]. In humans, the ubiquitous characteristic of the body stem morphology was inherited from our phylogenetic ancestors and adapted to the exigencies of bipedal walking by changing the principal body axis (pronograde to orthograde) by 90°. In addition, the human lower limbs still retain an ancestral three-segment construction, with proportions adapted to the needs of self-stabilization [3]. Under this point of view, it is plausible that bipedal walking has to involve also interaction and task sharing between the rhythmic oscillations in the body stem and the cyclic motion of the lower limbs. The locomotion process starts in the head, and will be generated in the trunk. Under this constellation, the head is used as an inertial guidance platform to provide a stable reference frame. Thus, to achieve stable locomotion (and to have a global reference parameter), head and trunk have to be stabilized with respect to the environment. Three main mechanisms have been identified to play an important role in postural stability during walking: 1) the coordination between head and trunk segments (phase shift angle between body stem segments), 2) the existence of a gradual damping mechanism (dm) from lumbar level to head, and 3) compensatory movements (cm) of the head and the trunk during straight walking. The questions arising at the moment are: how are these mechanisms coupled? Are the changes in the amplitudes and phase of the body stem with the speed only related to a very sophisticated neuronal control? A recently published study [4] showed that the variations of the 6 DOF kinematical parameters of trunk motion during walking are not simply correlated with anthropometry. The missing link between all those observations may be the individual dynamics of the trunk, determined by elastic and damping properties

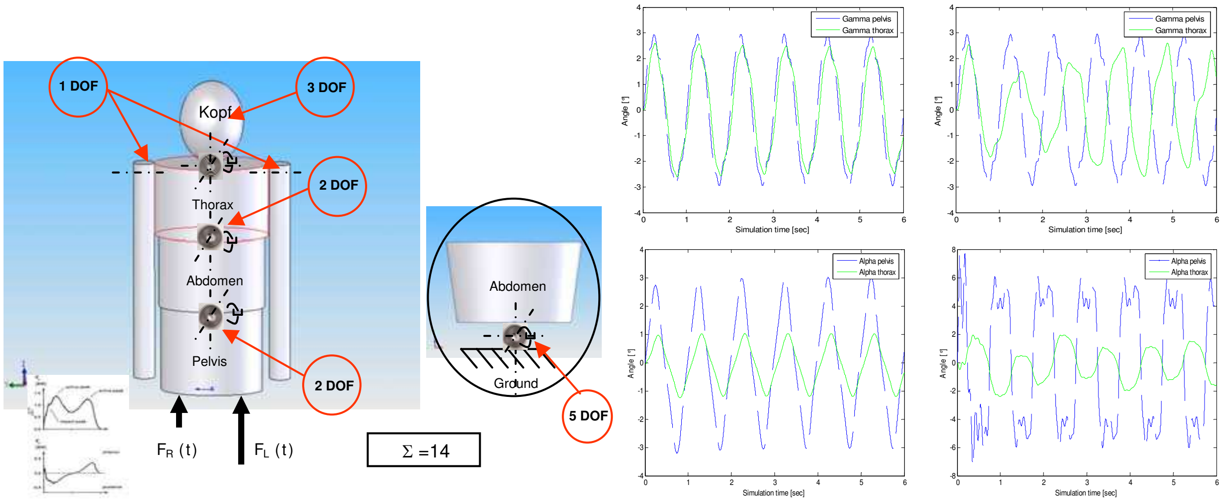

Figure 1: Left: Anthropo-functional model of the body stem based on Hanavan's model (14 DOF). Right: Change from in-phase to out-of-phase in the relative motions between pelvis and thorax. Upper: transversal plane, bottom: frontal plane. Changes were produced only by changing visco-elastic parameters in the joints and keeping ground reaction forces constant

of muscles and soft-tissues. We propose a 14 DOF morpho-functional model of the trunk based on Hanavan's model [5] (fig. 1-left) to make accessible that information via experiments. The results of the simulations show that the visco-elastic parameters (spring stiffness and damper constants), which are obtained by the simulations, control individual variations in amplitudes and phases of the different body segments in normal walking. These changes can be made keeping the ground reaction forces constant (fig. 1-right). Spring stiffness is the main cause in changing absolute amplitudes, while damping parameters produce the variation of the phases between segmental body stem parts. Finally, our simulations display the so called 'cm' without acting in any way the thorax or the head. This fact together with our kinematical results [4] convinced us that they are a result of the motion's dynamics (intelligent mechanics) and not due to a neuronal control, which was the accepted hypothesis up to now.

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