Modeling Maturational Constraints for Learning Biped Humanoid Locomotion

INVENTEURS DU MONDE NUMÉRIQUE

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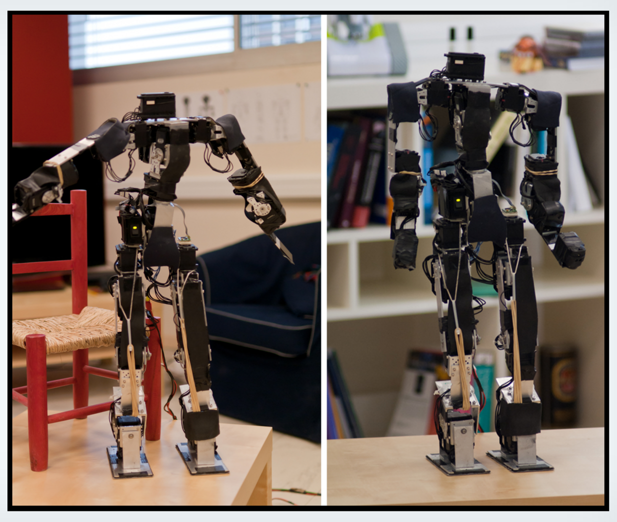
The challenge of **motor learning in high-dimensions** is typically associated with robots using a large number of degree of freedom. Such as the case of humanoid robot involving a lot of actuator and, above all, of the highly complex human anatomy. Mechanisms for **self-bounding the space for autonomous exploration** are necessary, but they should be as little ad hoc as possible. To reach this objective, we may take **inspiration from maturational mechanisms in biological organisms.**

This poster outlines a **new developmental approach to motor learning** in very high-dimensions. This approach relies on the modeling and coupling of several advanced **mechanisms for actively controlling the growth of complexity and harnessing the curse of dimensionality**: 1) Motor primitives; 2) Maturational constraints for the progressive release of new degrees of freedoms and progressive increase their explorable ranges; 3) Adaptive, multi-objective and staged fitness functions; 4) Social interaction.

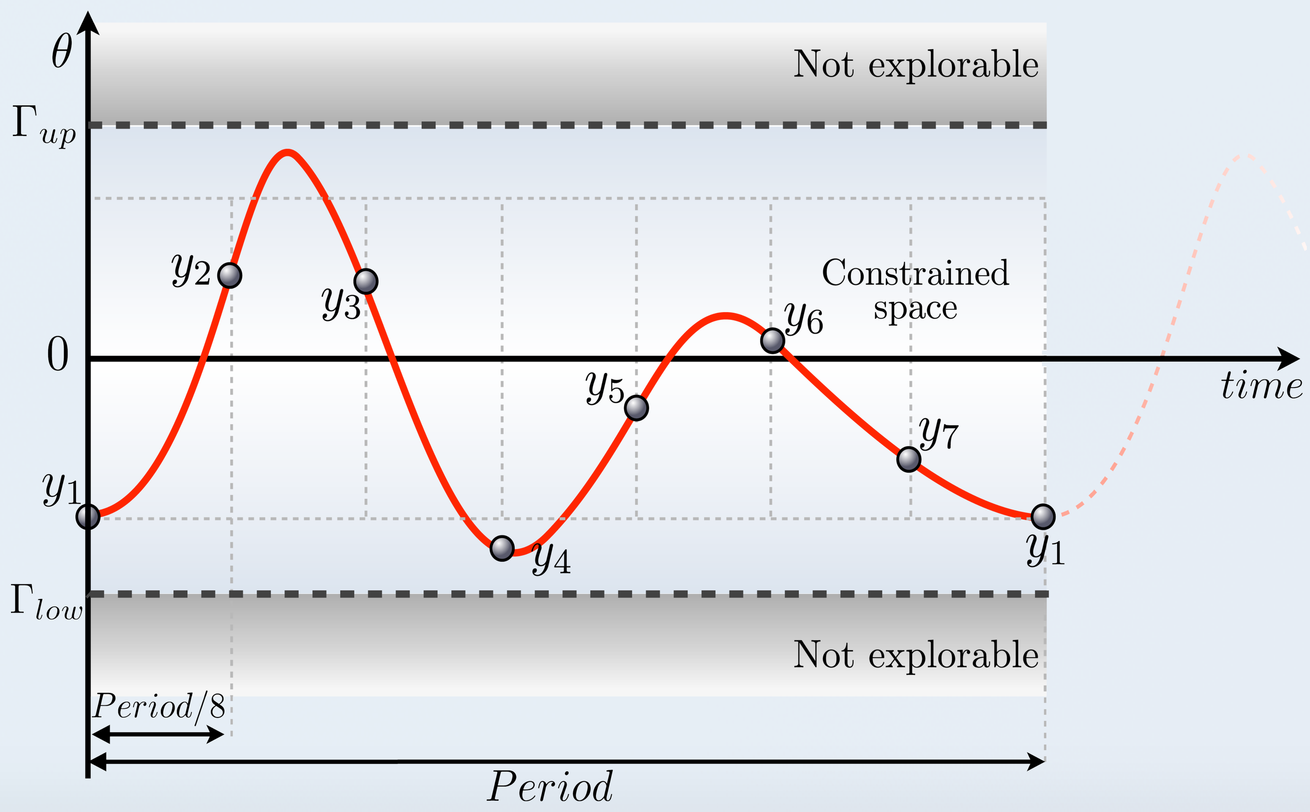
This model is based on the Acroban morphology and dynamic [1] (figure on the right).



MOTOR PRIMITIVES

Human babies are born with neurally embedded dynamical systems which allow them tuning motor and muscle sensorimotor primitives which generate parameterized coordinated movements ([2], [3], [4], [5], [6]). These sensorimotor primitives can considerably decrease the dimensionality, and thus the size of the explorable sensorimotor spaces and transform complex low-level action planning problems in simpler higher-level dynamical system tuning problems.

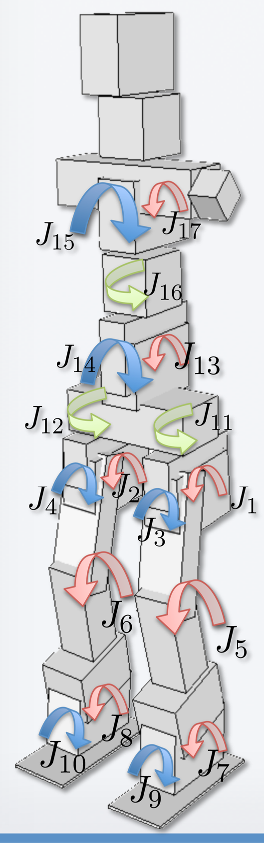
We model these motor primitives by Bezier curves that control angular joints positions over time and allow approximating a wide variety of motor control while reducing the dimensions thanks to high-level parameters. These curves are parameterized by 9 high-level parameters:

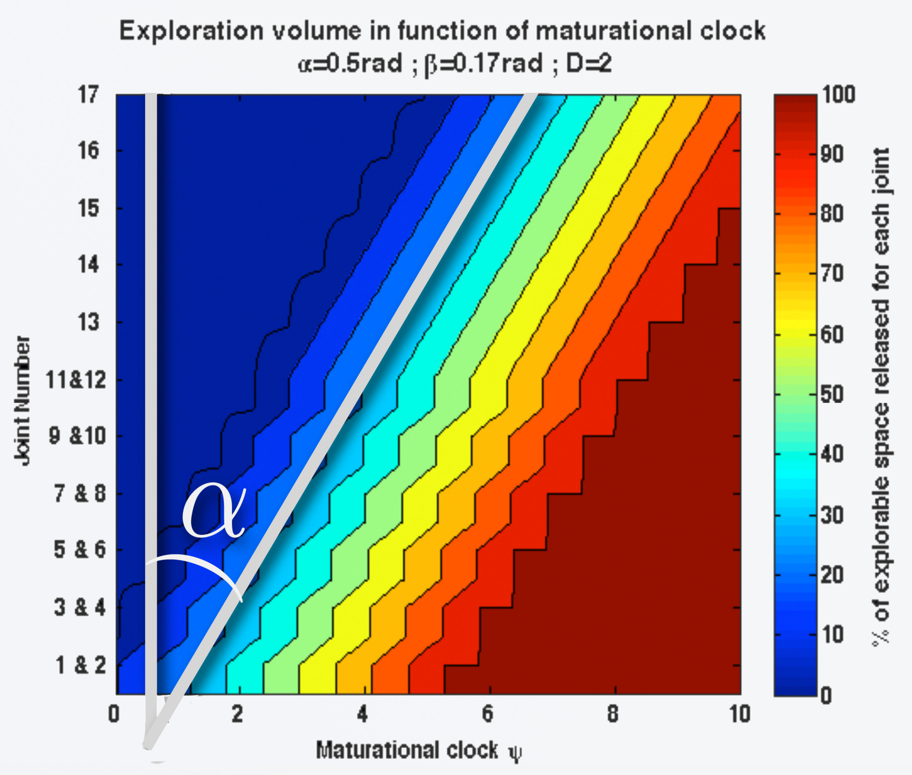


RELEASE CONSTRAINTS

The degree of freedom problem was suggested by Bernstein (1967). He proposed that steps existed in children and gradually release new degrees of freedom. First, when infants learn new skill (reaching, touching, walking), articulations that are farther from the trunk, such as ankle and wrist are reduced to a minimum i.e. freezed. Then, as the infant progress in his learning, restrictions at the periphery are gradually lifted (freeing), until all degrees of freedom are incorporated.

In our model, a joint completely constrained/freezed correspond to a joint with an amplitude null. We set the maturational clock ψ, which controls the evolution of each release of constraint, as depending on the learning activity, and more precisely on competence progress.



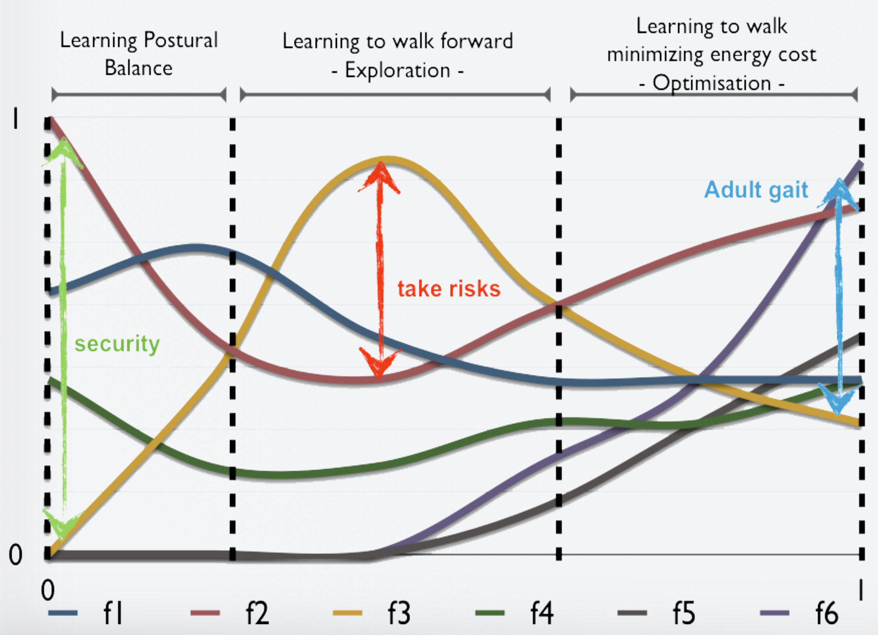


$$MaxAmpli_{Jointi} = (\psi + (D - i) \times \tan(\alpha)) \times \tan(\beta)$$

DEVELOPMENT STAGES

Before walking, children should learn to keep their postural balance then there are 2 stages in learning to walk. In the beginning, his biomechanical strategy is to minimize the risk of falls. He then makes small steps, spreads feet to keep lateral balance, spends few time on one foot and has a small step rate. Learning objectives change during grow up of the child. He will take more and more risks as its central nervous system (CNS) becomes mature [7]. Finally, acquiring its adult gait, its objective will be to minimize energy consumption during the walk.

We use weighted multi-objective functions to model stages and evolution of the optimisation strategy during the maturation. The figure below shows the evolution of weigths for each fitness function during maturation of the robot :

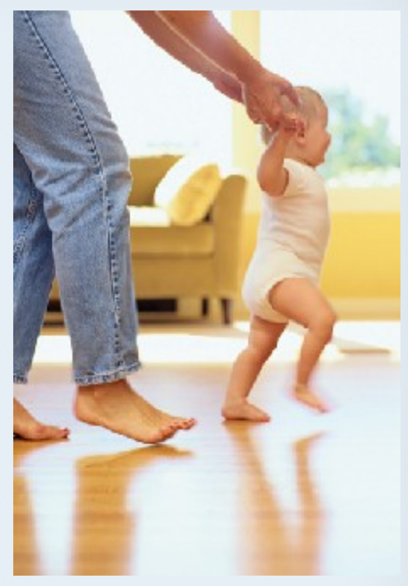


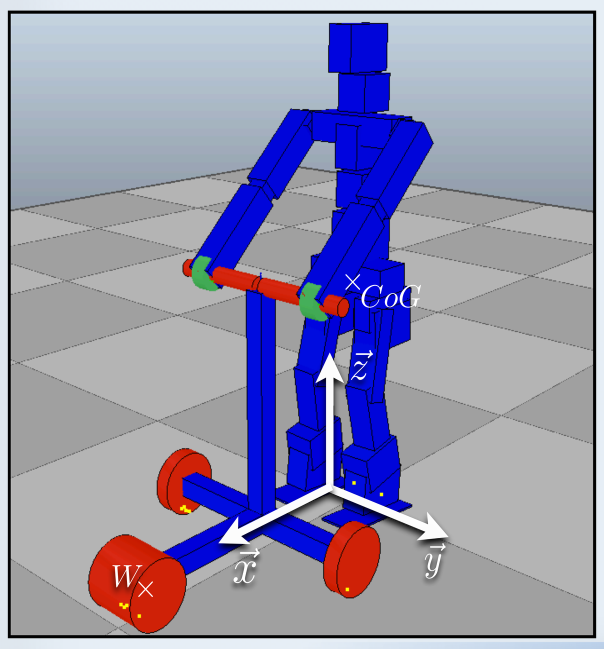
f1: Minimization of head movement,
f2: Maximize time of balance before falling,
f3: Maximize distance done by the center of gravity,
f4: Minimization of torso joints torques,
f5: Minimization of Forces between hands and trolley,
f6: Minimization of legs joints torque

SOCIAL GUIDANCE

In the weeks prior to independent walking, infants exhibit several transient upright skills that mitigate the requirements of single limb support. They hold furniture and pull up to a vertical position, stand while holding onto furniture and take forward steps while holding a caregivers hands[8]. Each of these skills involves manual support of upright posture. The furniture or caregiver compensates for the missing levels of leg strength and balance control.

For our model, we have added a baby trolley to our simulation. This trolley helps the robots to keep its balance. It models a parent helping his baby to keep his balance





This trolley is motorized and controlled with a proportional controller. This controller allows the trolley to go ahead if the robot goes ahead or goes backward if the robot goes backward.

Nevertheless, if motor primitive produce very unbalancing actuator commands, the robot could fall backward, forward or sideward.

References :

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