Acroban the humanoid: Playful and compliant physical child-robot interaction

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Personal robotics is predicted to arrive massively in our homes in the 21st century, as well as impact importantly our society. Yet, before this vision can be realized, a number of very hard challenges need to be addressed. Among them are challenges related to human-robot interaction. Most personal robots, from entertainment to assistive robots, will need to interact with humans in a day-to-day basis: this implies that robot should afford intuitive, safe and pleasant interactions, as well as be able to adapt robustly to all unpredicted human behaviours. Many studies and technologies have elaborated in the field of human-robot interaction. In spite of this, physical human-robot interactions, which is central and unavoidable in real-world scenarios, have been only very little studied, in particular because existing hardware, humanoids in particular, did not allow easily for both safe and compliant interactions.

In this work, we present a lightweight humanoid robot, called **Acroban**, which is to our knowledge the first humanoid robot which is able to: 1) demonstrate **playful, compliant and intuitive physical interaction with children**; 2) move and walk dynamically while **keeping its equilibrium even if unpredicted physical interactions are initiated by humans**.

The robot combines uniquely several crucial features which make these advances possible:

Softness. The robot is "soft": instead of controlling motors in a stiff manner, their rigidity and simulated elasticity is dynamically changed based on forces that are sensed with proprioception. The mechanical structure includes itself natural softness by using elastics and springs. All of this provides compliance to external forces due to interactions, as well as leveraging the energy of gravity: the robot applies principles of powered passive dynamic walkers to a wide range of movements involving its torso and its arms.

Morphology. The robot has 32 degrees of freedom, and in particular is equipped with a complex semi-passive vertebral column as well as complex hip and ankle systems. The morphological design of these systems allows the robot an extreme robustness for keeping its balance dynamically. Coupled with the softness property, this allows fluid and robust physical interaction with humans while the robot is performing its own movements.

Motor and interaction primitives. Softness and morphology are leveraged in an advanced system of combinable motor and interaction primitives built as dynamical systems with a stable and drivable attractor dynamics, as well as with a particular design of movements which create a strong illusion of life.

We present a demonstration of the system in an entertainment human-robot interaction context, in particular allowing children to engage in the interaction. In this demonstration, the robot has a range of behaviors that it can combine and which all react intuitively, naturally and creatively to uncontrolled external human intervention. For example, when the robot is walking anyone can take its arms, like we take the arms of babies learning to walk, and drive in a fluid and transparent manner the robot in any direction. This is realized automatically without the need to provide the robot with any command, and is the result of the dynamical properties of its motor primitives and morphological properties. Another example is when the robot is showing a complex movement of its torso: anyone can interrupt physically the robot and take its arm, which will cause the robot's arm to follow the movements imposed by the human without falling.

This is the first time the Acroban humanoid is formally presented, and it was only showed once so far in a robotic public exhibition of the Science Museum of Napoli, Italy, in 2009. This allowed us to show that it efficiently affords a new kind of physical human-robot interaction, with children in particular, which is at the same time playful, intuitive, compliant, fluid and robust, as shown in the accompanying video.

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