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Acroban the Humanoid:

Compliance for Stabilization and Human Interaction

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Abstact. *This video presents the humanoid robot 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) at the same time move and walk dynamically while keeping its equilibrium even if unpredicted physical interactions are initiated by humans.*

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 (see in particular [1,2,3] for physical interations). 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:

Compliance. The robot is “soft” or compliant: instead of controlling motors in a stiff manner, their rigidity and simulated elasticity is dynamically changed based on forces that are sensed with proprioception. This is essential for compliance to external forces due to interactions, as well as for 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 with 5 degrees of freedom as well as complex hip and ankle systems (each leg including 7 degrees of freedom). 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 walking or 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 movement which creates 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 a physical 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 sort of command, and is the result of the dynamical properties of its motor primitives and morphological properties. Another example is when the robot is not walking and 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 if it changes its centre of gravity.

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.

Control. The control software environment of acroban allows to define robot motor behaviours on the basis of :
- Spline trajectories, designed point by point by the user via a graphical interface.
- (Closed) reaction loops, implementing the reactions of the robot relatively to its environment (inertial sensors, force applied to joins, but also control interfaces). Reaction loops are designed as PID control systems integrating proportional, integral and derivative reaction.
Let us note that closed control loops are used at two different levels. At low level the joins are controlled by a PID loop in position mode. At a higher level, PID loops are used to design the stabilizing moves of the robot (e.g. stabilizing torso or pelvis moves).
A crucial point is the interaction between this two kinds of components of moves :

- Trajectories can be used to define time variations of the closed loop parameters

- conversely (and even recursively), reaction loops can be used to regulate some parameters of the trajectories (amplitude, shift, etc.)

This interactions are used for instance to regulate the length of steps during the stabilizing process.

This system is used to design moves of Acroban, including soft compliant moves. So, the balancing system and the walking moves include programmed fixed trajectories, but also reactions to the environment of several natures: 1) reactions in joint positions (such as the pelvis position for balancing), 2) compliance level reactions (such as the feet compliance during the walk) 3) and finally direct reactions of the mechanical structure itself (being possible thanks to compliance and softness control).

To other extends, moves are embedded and executed in the electronic board of the robot (including an ARM microcontroler). This makes the robot completely autonomous (i.e. without wires).

Videos of Acroban platform are available at http://flowers.inria.fr/AcrobanIJHR.htm

References

[1] Samuel Agus Setiawan, Sang Ho Hyon, Jin'ichi Yamaguchi, Atsuo Takanishi. Physical Interaction between Human And a Bipedal Humanoid Robot. Proc. of IEEE Int. Conf. on Robotics & Automation. Detroit. 1999.

[2] Tiffany L. Chen, Charles C. Kemp. Lead Me by the Hand: Evaluation of a Direct Physical Interface for Nursing Assistant Robots. Proceeding of the 5th ACM/IEEE Int. Conf. on Human-Robot Interaction. Osaka 2010.

[3] Aaron Edsinger, Charles C. Kemp. Human-Robot Interaction for Cooperative Manipulation: Handing Objects to One Another. Proc. of the IEEE Int. Workshop on Robot and Human Interactive Communication (ROMAN), 2007.