Whole-Body Imitation of Human Motions with a Nao Humanoid

[Video Abstract]

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ABSTRACT

We present a system that enables a humanoid robot to imitate complex whole-body motions of humans in real time. For recording the human motions, any sensor system capable of inferring the joint angle trajectories can be used. In our work, we capture the human data with an Xsens MVN motion capture system consisting of inertial sensors attached to the body. Our framework converts the human joint angles to the robot's joint angles in real time. Here, we use a mapping between the human's and the robot's joints to ensure feasibility of the motion. The focus of our system lies in ensuring static stability when the motions are executed which is a challenging task, depending on the complexity of the movements. To avoid falls of the robot that might occur when using direct imitation of the joint angle trajectories due to the different weight distribution, we developed an approach that actively balances the center of mass over the support polygon of the robot's feet. At every point in time, our approach ensures that the robot is in a statically stable configuration, i.e., that the ground projection of the center of mass lies within the convex hull of the foot contact points. To achieve this, we apply inverse kinematics given valid foot positions that satisfy the stability criterion and generate the corresponding leg joint angles. In more detail, our system first finds valid positions for the robot's feet by determining a target plane and its orientation, so that the feet can be placed planar and the robot's center of mass is over the support polygon. The new positions of the feet are chosen as the projection on the target plane. Afterwards, the corresponding leg joint angles are calculated via inverse kinematics. To determine whether the configuration is in the double support modus, and if not, which foot is the stance foot, we evaluate the position of the center of mass relative to the feet.

As can be seen in the experiments with a Nao humanoid, our approach leads to a highly stable imitation of challenging human movements (see also Fig. 1). In contrast to recent approaches that capture human data using a Kinect-like sensor and only imitate arm movements while keeping the body static, our system can deal with complex, whole-body motions. Note that our approach does not require a prior learning phase but computes stable configurations online and almost in real time as can be seen in the accompanying video.

Figure 1: Nao imitating complex whole-body motions. The robot actively balances its center of mass to achieve static stability.

We are currently working on imitating motions to learn complex navigation actions such as climbing up staircases or walking down ramps. Our system can also be used for teleoperated tasks that include whole-body movements where stability needs to be guaranteed in order to successfully fulfill the mission.

Categories and Subject Descriptors

J.m [**Computer Applications**]: Miscellaneous

General Terms

Experimentation

Keywords

Humanoid Robots, Imitation

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