2009 IEEE International Conference on Robotics and Automation
Kobe International Conference Center
Kobe, Japan, May 12-17, 2009

Rollin' Justin - Mobile Platform with Variable Base

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Abstract— **Research on humanoid robots for use in servicing tasks, e.g. fetching and delivery, attracts steadily more interest. With "Rollin' Justin" a mobile robotic system and research platform is presented that allows sophisticated control algorithms and dexterous manipulation. This video gives an overview of the mobile humanoid robotic system "Rollin' Justin" with special emphasis on mechanical design features, control issues and high-level system capabilities such as human robot interaction.**

I. System Design and Control

In figure 1 our mobile humanoid two-arm system *Rollin' Justin* is presented that combines the upper-body system "Justin" [1] and a newly developed mobile platform [2]. It is designed for research on sophisticated control algorithms for complex kinematic chains as well as mobile two-handed manipulation and navigation in typical human environments.

Fig. 1. DLR's *Rollin' Justin*.

A. The Upper Body

For the mechanical design of the upper body the following requirements have been taken into account: The system should be able to reach objects on the floor as well as objects on a shelf up to a height of about 2 m. It should have an anthropomorphic kinematic configuration for research on bi-manual grasping. The integration of link-side torque sensors in the joints has already proved very useful for the arm and the hand, and therefore was maintained throughout the system. Finally, a sensor head mounted on a 2-DoF[1] pan-tilt unit was integrated in order to allow for scene analysis based on stereo vision [3], [4].
It was designed to be slim enough to pass standard doorways of about 90 cm width. The overall weight results in 45 kg. Table I gives an overview of the 43 actuated DoF [1].

B. The mobile platform

The mobile platform [2] enables the system to interact with humans e.g. in carrying objects and pushes the system towards a universal service robotic platform.
An extendable robot base is required in order to take advantage of the large workspace and the dynamics of the upper body, while providing the stability of the overall system. Contrary, for a reliable and easy navigation compact dimensions are necessary. The mobile platform has four individually extendable and turnable wheels. Each leg incorporates a passive spring-damper system. This enables the whole system to move over small obstacles or to cope with the unevenness of the floor. By itself the mobile platform weighs 150 kg.
Mounted on the mobile platform the *Rollin' Justin* has a shoulder height of up to 1.6 m. The whole system is powered by a Lithium-Polymer battery block and has an operating time of about 3 h.

C. Control design

For the upper body various control algorithms have been implemented that realize impedance behaviors on joint level, on end-effector level, and on object level [5]. Furthermore, passivity-based state feedback controllers are available that provide small tracking errors while adding active joint damping using the joint torque measurements [6].

Subsystem	Torso	Arms	Hands	Head & Neck	$\sum$
DoF	3	2 x 7	2 x 12	2	43

TABLE I
Upper body overview.

[1]DoF - degrees of freedom.

Justin's mobile platform possesses the ability to vary its footprint over time by extending/retracting the wheel legs during motion. Therefore, we designed a control algorithm aimed at tracking an arbitrary linear/angular planar motion while, *at the same time*, imposing a decoupled and independent motion to each leg. The control law is based on dynamic feedback linearization of the system equations, so that exponential convergence of the tracking error can be easily obtained. Full details can be found in [7].

The upper body mounted on the mobile platform with a total of 51 DoF represents a highly complex kinematic structure. In the video a complex coordinated motion is presented. While holding a tray with two hands the mobile base is driving a circle. The upper body compensates for the motion of the platform and keeps the tray at a constant pose [8].

II. Human robot interaction

A. Visual Tracking/Servoing

The video shows Justin's capabilities to track (and grasp) freely moving objects in 6 degrees of freedom (DoF) with its hand and its head. These capabilities allow for the immediate reaction to changes in the environment and eventually for the interaction with a human. A fundamental challenge of the task consists in extending the universality of objects covered by the pose estimation algorithm while containing the (respective) requirements on the computational resources. This problem is approached here by estimating the object pose not at once in all 6-DoF but consecutively in a cascade of localization stages for increasing degrees of freedom with appropriate object models and exploration strategies [9].

B. Commands via speech recognition

Direct commanding of the robot is enabled through the use of CMU's open source large vocabulary, speaker-independent continuous speech recognition engine Sphinx [10]. For cross-checking and feedback, recognized commands are repeated by the robot using speech synthesis [11].

III. Service robotic Applications

A. Preparing Tea

During our tea serving demo model-based object recognition is used to determine the current position of a number of predefined objects. With our task-oriented programming (TOP), the successor of the MARCO framework [12], the robot is commanded on a high level of abstraction by combining a number of skills to form complex tasks. Pick and Place operations as well as simple manipulation tasks such as unscrewing a can are intuitively represented and commanded and is then executed using the estimated object positions.

B. Dual Arm Path Planning

In realistic setups the robot should act in more complex or changing scenes with a variable number of obstacles and an unconstrained arrangement of the objects w.r.t. each other. For these situations the use of a path planner [13] connected to the task-oriented programming software is demonstrated. Target configurations for the redundant system including the robotic arms and the torso are computed by the inverse kinematics algorithms presented in [14].

C. Dancing

The video is concluded by Justin dancing like in *Pulp Fiction*. It demonstrates its dynamic capabilities and was among the most popular attractions on the Automatica 2008 trade fair in Munich where *Rollin' Justin* was presented to the public for the first time.

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