Agile Justin: An Upgraded Member of DLR's Family of Lightweight and Torque Controlled Humanoids

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I. Abstract

This video presents the recent upgrades of the mobile humanoid Agile Justin, bringing it closer to an ideal platform for research in autonomous manipulation. Significant upgrades have been made in the fields of mechatronics, 3D sensors, tactile skin, massive GPGPU based computing power, and software communication framework. In addition, first algorithms and two experimental scenarios are presented that take advantage of these new capabilities.

Compared to other humanoid or two-armed robots like iCub [1] or PR2 [2], Agile Justin provides a unique combination of features: mechatronically it can perform highly dynamic as well as dextrous tasks, it is equipped with a multi-sensorial head for 3D modelling, a tactile skin with high spatial and temporal resolution on its hands, a wireless connection to a high performance GPGPU cluster, and a new software framework for performant realtime communication as well as higher level functional programming.

1) Mechatronics: Mechatronically the arms and mobile platform are about 1.5 times faster and system can perform well coordinated motions from the wheels to the fingertips with a time precision of 1ms over all 53 DOF. This allows Agile Justin not only to catch a ball, as has been previously shown [3], but even to throw it back again.

2) 3D perception: For advanced 3D perception an RGB-D sensors has been integrated in the head and a wirelessly coupled GPGPU cluster with 24000 cores runs a mapping algorithm [4]. This allows the realtime generation of dense 3D models of the whole workspace with a resolution of 2mm. Without ever transferring the models out of the GPGPU it is used for optimization-based planning over all 22 DOF of Justin's torso and mobile platform [5]. The high-quality models are also used as the basis for object recognition and pose estimation. Thus, multiple hypotheses on the objects' identity and pose are generated from the modeled scene surfaces through pose clustering [6]. This hypothesis set is evaluated and pruned by its match to occupied and free model space.

3) Tactile Skin: The articulated hands have been equipped with a sensitive tactile skin with a high spatial and temporal resolution allowing, e.g., to precisely sense and control the slippage of grasped objects. By processing the spatio-temporal signal of the skin it is possible to discriminate objects by their material – a skill which is esp. important when the objects would be indistinguishable from their 3D shape alone. To do so, the robot compares the data obtained by gently sweeping its fingers over the object with previously learned classes of spectral features.

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Fig. 1. Agile Justin, an upgraded variant of its older sibling Rollin'Justin [8].

4) Auto-Calibration: The multi-sensorial upper body is calibrated completely automatically and without any external tool in 5 min, resulting in intrinsic and extrinsic parameters for the stereo cameras, RGB-D camera, IMU, joint elasticities, and offsets [7].

5) Software Framework: The software architecture of Agile Justin is based on our new robotic framework aRDx (agile robot development next generation) [9] we developed for research in mobile manipulation and robot learning on complex and performant robotic systems.

The low level communication layer of aRDx is highly performant and hard realtime capable. It outperforms other robotics frameworks (e.g., ROS, see [9] for benchmarks) and allows for detailed control of the quality-of-service and optimally transports data packets for intra-process, inter-process (zero-copy) as well as networked (copy once) communication. This allows Agile Justin's fast and deep sensor-perception-planning-action loop to span multiple computers, even including a GPGPU server cloud in a remote building, with a timing precision in the millisecond range.

In aRDx, all higher level functionalities and abstractions needed in a robotic framework as well as a more flexible but less performant communication layer are implemented in a modern higher level language of the Scheme/Lisp family, i.e., Racket [10]. Racket's modern "programmable programming language" paradigm ideally fits the need of implementing various domain specific languages (DSLs) for efficiently coping with the multiple domains in a complex robotics application [11].

6) Experimental Scenarios: Two experimental scenarios have been set up. The building of a scaffold structure demands for dextrous as well as whole body manipulation. The longterm vision is to enable the robot to not only autonomously execute the task but to acquire the necessary skills by autonomous learning. The ball playing benchmark [3] demands for fast 3D perception and dynamical whole body motion planning.

II. SUMMARY

In summary, the upgrades make Agile Justin an almost ideal platform for research in autonomous mobile manipulation.

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