Design of an open-robotics low-level framework for the control of complex mechatronics devices

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This paper presents the challenges met in the development of a new framework for multi-axis and multi-robot control. The increasing demand for multi-robot collaboration and robotic assistance, both in industry and service applications, has raised the level of interactions between robots and humans in a shared environment with real-time constraints. Some scientific and technological issues need to be unlocked to ensure safe human-robot interactions: to guarantee the response time during the robot perception-action process, to cope with dynamic interactions with the robot environment, to secure the collaborations between several machines and humans, and to improve the integration of the robots at home and in open zones of production lines. The specifications of a new hardware and software framework are set with respect to these observations. The framework will meet complex research and industrial issues for the future of multi-axis and multi-robot control, for example in the fields of humanoid robotics and dexterous manipulation.

The design concepts respect the following requirements: the framework must be run under real-time constraints, it must be transferable to industrial applications, scalable and manufacturer-independent. The framework design has also to guarantee the robustness of the machine interactions in a dynamic and collaborative environment. To evaluate the feasibility of our design strategy and assess its performance, we have developed mechatronic devices with a high level of human-machine collaboration. This paper outlines two robotic applications which require multi-robot real-time synchronization and are based on the proposed framework. The first one is an arm-hand system that combines an industrial robotic arm and a 16 degrees of freedom anthropomorphic dexterous hand. The second application is a human-sized biped. Both robotic cells require a high level of coordination for fine manipulation or walking tasks.

This paper presents the foundations of the framework (compatibility with industrial hardware, PLC-style determinism and respect of PLCopen compliant library writing recommendations). Next, the strategy used to merge IEC61131 PLC programming and object-oriented programming is detailed. Then we explain the interface mechanism with the main existing motion technologies and the method for designing the low-level controller for multi-axis machines.

This paper was motivated by the problem of proposing a transferable framework dedicated to real time multi-axis and multi-robot control. Most of existing middleware solutions do not unify accesses to the axis level and to the robot control level with a common programming approach and with real time capability. This is a key problem for achieving multi-robot synchronization and reaction times compatible with dynamic collaboration. Our framework is based on open robotics and object-oriented programming and implements the industrial standards for motion control.

Keywords — Multi-axis Control, Multi-robot Control, Collaborative Robotics, Industrial Ethernet, Real-time, Open Robotics.