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ABSTRACT

An approach to task coordination for hyperflexible robotic workcells

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The manufacturing industry is very diverse and covers a wide range of specific processes ranging from extracting minerals to assembly of very complex products such as planes or computers, with all intermediate processing steps in a long chain of industrial suppliers and customers. It is well know that the introduction of robots in manufacturing industries has many advantages. Basically, in relation to human labor, robots work to a constant level of quality. For example, waste, scrap and rework are minimized. Furthermore they can work in areas that are hazardous or unpleasant to humans. Robots are advantageous where strength is required, and in many applications they are also faster than humans. Also, in relation to special-purpose dedicated equipment, robots are more easily reprogrammed to cope with new products or changes in the design of existing ones.
In the last 30-40 years, large enterprises in high-volume markets have managed to remain competitive and maintain qualified jobs by increasing their productivity with the incremental adoption and use of advanced ICT and robotics technologies. In the 70s, robots have been introduced for the automation of a wide spectrum of tasks such as: assembly of cars, white goods, electronic devices, machining of metal and plastic parts, and handling of workpieces and objects of all kinds. Robotics has thus soon become a synonym for competitive manufacturing and a key contributing technology for strengthening the economic base of Europe . So far, the automotive and electronics industries and their supply chains are the main users of robot systems and are accounting for more than 60% of the total annual robot sales. Robotic technologies have thus mainly been driven by the needs of these high-volume market industries.
The degree of automation in the automotive industries is expected to increase in the future as robots will push the limits towards flexibility regarding faster change-over-times of different product types (through rapid programming generation schemes), capabilities to deal with tolerances (through an extensive use of sensors) and costs (by reducing customized work-cell installations and reuse of manufacturing equipment). There are numerous new fields of applications in which robot technology is not widespread today due to its lack of flexibility and high costs involved when dealing with varying lot sizes and variable product geometries. In such cases, *hyper-flexible robotic work cells* can help in providing flexibility to the system and making it adaptable to the different dynamic production requirements. Hyper-flexible robotic work cells, in fact, can be composed of sets of industrial robotic manipulators that cooperate to achieve the production step that characterize the work cell; they can be programmed and re-programmed to achieve a wide class of operations and they may result versatile to perform different kind of tasks
Related key technology challenges for pursuing successful long-term industrial robot automation are introduced at three levels: basic technologies, robot components and systems integration. On a systems integration level, the main challenges lie in the development of methods and tools for instructing and synchronising the operation of a group of cooperative robots at the shop-floor. Furthermore, the development of the concept of hyper flexible manufacturing systems implies soon the availability of: consistent middleware for automation modules to seamlessly connect robots, peripheral devices and industrial IT systems without reprogramming everything (”plug-and-play”) .
In this thesis both innovative and traditional industrial robot applications will be analyzed from the point of view of task coordination. In the modeling environment, contribution of this dissertation consists in presenting a new methodology to obtain a model oriented to the control the sequencing of the activities of a robotic hyperflexible cell. First a formal model using the Colored Modified Hybrid Petri Nets (CMHPN) is presented. An algorithm is provided to obtain an automatic synthesis of the CMHPN of a robotic cell with detail attention to aircraft industry. It is important to notice that the CMHPN is used to model the cell behaviour at a high level of abstraction. It models the activities of each cell component and its coordination by a supervisory system. As more, an object oriented approach and supervisory control are proposed to implement industrial automation control systems (based on Programmable Logic Controllers) to meet the new challenges of this field capability to implement applications involving widely distributed devices and high reuse of software components. Hence a method is proposed to implement both controllers and supervisors designed by Petri Nets on Programmable Logic Controllers (PLCs) using Object Oriented Programming (OOP). Finally preliminary results about a novel cyber-physical approach to the design of automated warehouse systems is presented.