B/P/4 : Production robotics and bio-inspired robotics in the factory of the future

The basic concepts of commercially available production robots have remained very stable during the last 20 years. They rely on proven mechanical architectures and classical control strategies. R&D efforts have been limited to a slow and continuous improvement of known technologies. It is worth noting that all robotic companies offer more or less the same solutions with similar performances. The international competition pushes European and North-American companies to increase productivity; moreover, new production fields need to robotize tasks that are currently done manually [B/P/4-E1]. Research conducted on production robotics is not very well developed in France: outside IRCCyN, the only active laboratories are the LIRMM (Montpellier), the LAMI & LASMEA (IFMA Clermont-Ferrand) and the LCFC (Metz). In Europe, the Fraunhofer IPA is very active. Outside Europe, China has been recently devoted much research effort on production robotics, especially in Tsinghua (Beijing) and Jiaotong (Shanghai) Universities. In most cases, important scientific issues such as mechanisms design and control are treated separately. Designing in a concurrent way mechanisms and controls, while taking into account the interactions between the robot and its environment, is a key factor to reach very high performances. To meet this requirement, multidisciplinary research skills must be gathered, including robot modeling and design, control, sensing, mechanism theory and manufacturing process [B/P/4-E2], [B/P/4-E3].

The main objective of this research project is to develop innovative robots with very high performances. Such a new generation of robots will have to improve drastically the productivity of production factories. The project will be conducted along three main research lines:

1. New production robots
2. Human-robot interactions
3. Bio-inspired robotics

New production robots

In this section, two main research fields emerge:

1. <u>high-speed robotics</u>: High-speed robotics is a key technology in many industrial sectors. Nowadays, only few industrial robots achieve high velocities and high accelerations (up to 10*g*). The most recent researches on this topic have lead to the creation of robots that can accelerate up to 100*g*. Despite these excellent properties in terms of acceleration or velocities, their accuracy is very poor (more to 1 mm). The challenge is to improve the robot’s speed and acceleration while keeping a very good accuracy [B/P/4-E4], [B/P/4-E5]. Many process tasks are intrinsically difficult to robotize, especially when working on composite material (filament winding, machining of composite parts, assembly of multi-material parts, …). More generally, the coupling between the robot mechanical architecture, the controller, and the process is often very high and needs to be tackled precisely [B/P/4-1]. Taking into account deflections of the robot (when it must apply high forces) or of the parts (e.g. when handling large or flexible parts) is of primary importance to guaranty accuracy and quality, and requires efficient deflection models as well as advanced sensor-based control strategies [B/P/4-3].
2. <u>robots for working on large structures</u>: Existing robots are not suited to work on very large structures (in aeronautics, foundries, large dimension simulators, etc.). To enhance robots’ performances in such situations, radically new robot architectures and controllers must be invented (e.g. for climbing, crawling or walking). Several laboratories have begun to design new robotic structures for specific tasks (NIED in Japan, Shangai University, …). But these research works are at their beginning.

Several research directions are envisaged:

- design of new high-speed robots with improved accuracy; the lack of accuracy of high-speed robots can be explained by several factors: (i) when designing the robot, the preliminary design step (when only the number and types of joints is known) is not enough explored; but it is highly necessary to analyze and compared the different architectures of robots in order to see their advantages and drawbacks; (ii) the robot is only designed by taking into account the mechanical aspects, without any discussion with the control researchers/engineers; for high-speed applications, the influence of the controller is of utmost importance for the accuracy and performance criteria that allow improving the controller capacities should be taken into account at the earliest design stage;

- design of innovating robots well fitted for working on large structures: wire robots, mobile robots (with wheels, legs, climbing, etc.) and hybrid robots (parallel/serial, industrial robots mounted on mobile base, etc). Efficient design strategies will be carried out, such as conceptual design and multi-objective design;
- creation of models characterizing the global behavior of the robot that are able to run in real time in the control loop. Taking into account deflections of the robot (when it must apply high forces) or of the parts (e.g. when handling large or flexible parts) is of primary importance to guaranty accuracy and quality, and requires efficient deflection models;
- advanced control of robots; once the robots are designed, it is necessary to find the most adapted controller for obtaining the best performance (in terms of accuracy and velocity, vibration reduction, deformation reduction, quality, etc.). Some control scheme should be tested (computed torque control, input shaping, predictive control, sliding modes, vision, etc.) and modified in order to fit as best as possible.

Human-robot interactions

Coping with interactions between the robot and human workers is another key issue: in many situations it is desirable that the robot shares its workspace with a human worker or even collaborates with him. Human-robot interaction must be addressed both from the architecture design and control/sensing point of view.

This field is so promising that in USA President Obama recently launched the Advanced Manufacturing Partnership, a $500 million program to focus on robots that can work closely with humans-helping factory workers, healthcare providers, soldiers, surgeons, and astronauts to carry out tasks.

We envisage several research directions:

- Design of new architectures best fitted for working with human being (wire robots, ‘intelligent’ mechanisms with mechanical securities, climbing robots) and hybrid robots (parallel/serial, industrial robots mounted on mobile base, etc)
- Modeling of physical phenomenon appearing when the robot is working with human, analysis of the coupling human-robot
- Developing new controllers best fitted for the management of robots with human near or in their workspace (computed torque control, effort detection, human interaction,

Bio-inspired robotics for dextrous handling and enhanced locomotion

One of the big differences between animals and robots is that the formers are soft and the latters are hard and rigid. Soft robots would offer many advantages such as safe interactions with objects and human workers. Furthermore they would allow enhancing dexterity or manoeuvrability due to their infinite number degrees of freedom like in an elephant trunk or in a fish body. To reach this goal, a first step is to design hyper-redundant robot structures with controlled deformations. In this case, new materials and actuators or new combinations of available technologies should have to be developed. Another related perspective consists in exploiting the advantages of passive deformations rather than to try to remove them. This idea, if it is mastered, should have strong impact on our future robots. In particular, passive deformations can be exploited in order: 1°) to enhance the dexterity or manoeuvrability by adding degrees of freedom without adding actuators; 2°) to improve efficiency by implementing passive mechanisms of energy recovering as those developed by animals to reduce their energetic consumption. Devices with an infinite number of sensors are another promising perspective for robotics. This second idea is the counterpart of the previous one on the side of perception. One of the challenges in this field consists in designing artificial skins. In Nantes, we are today exploring a very interesting feature of some animals that sense their surroundings with electric fields (electro-location in some fishes). Remarkably, electric sense is a kind of touch without contact that can be implemented on cheap and robust technologies. Hence, it could be developed further, in particular in air, in order to develop high redundant sensing surfaces able to emulate the haptic sensing modality of our skin. These electric skins could be very useful for robots working in dark, cluttered environments and in close interaction with human beings.

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