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# STUDIES REGARDING THE ACHIEVEMENT OF CONTROL STRATEGIES FOR MINI-ROBOTS

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## ABSTRACT

*The development of new robotized structures is heavily oriented in the mini and micro robots direction covering all the EU fields of interest like IT new devices, health, biotechnologies, new materials and production technologies & management, energy & automotive, security and environment monitoring & protection.*

*The mini robotics industry and mini robotics applications imply new technological meanings like adequate materials, manufacturing facilities, devices etc. and therefore a safety control system. The special characteristics of the mini-robots consist in: components dimensions, actuating systems; energy supply facilities, the components materials shape and functionality. The preoccupations presented in this paper are considering the PLM (product life management) approach for defining the control design based on the control strategies that are developed by using the PLM criteria.*

*The elements that are defining the PLM are the CAD -the computer aided systems design, CAM-computer aided manufacturing, CAE-computer aided engineering and the PDM –product data management. Briefly, from the development point of view it can be considered that PLM=CAD/CAM/CAE/PDM.*

**Keywords:** PDM, mini-robots, control

## 1. CORRELATED CONTROL

The control strategies design is considering all the data that can be received from the PLM and integrates all the provided mathematical solutions within the PLM system.

Generally, the main elements considered within the control design are regarding the actuating variables and restrictions, sensors characteristics and sensors system configuration, together with facilities related to the imposed accuracy and the imposed reaction speed. On second place are placed the elements that are defining the mechanical system dynamic behaviour, reliability & flexibility in repairing, upgrading and recycling the components. This second list of elements is considered (if ever) only on special demand and not in the initial design stage. Therefore any feedback between a first adopted solution and the alternatives is little correlated. At this stage the virtual prototyping is considering separate the system control as an added independent made system. Therefore a large effort is made to create open systems and distributed control as a panacea that is responding to a large variety of mechanical structures and mechanical behaviours.

The general behaviour of the system is to be modelled by using the facilities created by coupling the simulation methods and simulation techniques in respect to the available measuring and manufacturing devices intended to be used for the parts prototyping and in the same time to appreciate the characteristics and the quality of the design solution, indicating the possible improvement for the virtual (and the real) model improvement.

The use of the most advanced PDM, that exist within a PLM system, facilitate that the embedded mini-systems properties to be correlated with the external actuating characteristics.

In this case the control strategies derived from the PDM results and may give a valuable feed back for the CAD modeling by reshaping and remodeling the mechanical parts of the mini–robots. Another feedback is given for the CAM solutions that are defining and embedding the processing, manufacturing and costs strategies for different stages, different materials and different technologies (imposed by the parts material properties). The thirds feedback is given for the CAE systems used to redefine some planned (or achieved) properties, together with the parts interaction and parts replacement (within the manufacturing or repairing process). All together are collected within the PDM system intended to insure the interactive data transfer within the design process and manufacturing system useful for both, the controlled system design and for the system control in an continuous correlation with the signals received from the "most indicated" sensors used within the on line interaction

The strategies in creating mini and micro-robots are largely following the tendencies developed within projects funded under the FP6 IST priority. The tiny robots (that tend to reach the nano range) are designed to successful manipulates parts and tools in different fields of applications like electronics, pharmaceutics, medical minimal invasive research, scanning, surgery, micro-assembling and atomic power exploitation.

The control strategies are considering the process control ensuring the SF transfer (from science fiction to science fact). The applications generally consider independent self standing serial robots that may join together in order to react at a specific task and cooperate in achieving the specified goal.

In this case the control is divided into a local control separately for each and any robot and a strategic (a parallel) control designed to group all the individuals robots together. In some cases by having different type of actuators and different type of griping devices the "group" of serial robots is quite versatile and they can fulfil a lot of tasks.

In our last decade researches the focus was on the parallel robots structures where the process control implies a parallel control even if can be considered that the two systems may fusion in a single one. The evolution of the concept is slow because of the mechanical complexity and the strong tendency to have fixed parallel robots with actuating system mainly on the fixed platform where are concentrated all the power and control connections.

The evolution of the infrared and wireless control determine that the complex mechanical structure of any parallel robot to become "mobile" for a process and to accept an even stronger parallelization by coupling different parallel robots in a more complex tasks or to "connect" serial robots to form a parallel serial structure. If for the new remote controlled structures the data transfer gives smaller problems the power transfer remains a major problem until also wireless power transfer will be solved.

The traditional robots applications (machine-tools loading and unloading or welding, assembling etc. to new applications like measurements, soldering, sealing and insulating (i.e. seam sealing, underbody sealing, soundproofing etc.) requires new ides on control strategies concepts.

The mentioned applications not only considers six axes robots, that may replace intensive manual labour, but also robots groups and robots tasks that are requiring correlated control concepts. The correlated control may consider 4 or 8 six axes robots that are working together on the manufacturing (processing) lines ensuring the simultaneous control and not the master slave stile. The technological operation is considered like a single task that must be processed by a single device, therefore it is used a single entry for all 24 (48) numerical controlled axis that must be correlated in time and space. In the meanwhile auxiliary equipments such gantry systems linear tracks and rotary indexers are controlled together with the robots axes.

The correlated control results in no cross-talk between robot controllers and hence no time-lag between relative movements adding the advantage to eliminate the expensive jigs and the hysteresis for the part positioning and manipulation. All together may increase the productivity with from 40% to over 350%. Using the windows based technologies can be created macro-applications that enables to switch the activity of the groups of robots i.e. from welding, to testing, paint spraying, machining or any other sort of application.

It is obviously that the correlated controls implies a series of special functions like collision forecasting, variable collision sensitivity, advanced motion control, optimized acceleration control, circular and corner edge speed control, inertial compensation for high velocity movements considered at specific functions but that must work together.

More like other control systems the correlated control is dealing with fully decentralized multi-sensor system for the path control or parts and devices tracking and surveillance. The multi-sensor configuration provides a larger display of measurements that can provide different combinations of data for keeping the entire process on tracks and in the same time increase the system capability to readapt itself (to survive) to sensors failure situations.

The correlated control is greatly based on decentralized multi-sensors system that may have a central (specialized or general) processor where all the data fusion take place or, a multiprocessor system that forms a central sensors communication system through which all the messages between sensor and the logic unit must pass. In both cases the central communication rise data bottleneck problems susceptible to a total failure when the accumulated data amount is too large or the central communication facility fails.

Combining different type of sensors like contact, proximity, CCD and optical barriers etc. both people and robots activities can be controlled by tracking the technological motion and the numerical controlled axes reactions. The decentralized sensing architecture forms a network with processing facilities nodes that together are “cooperating” without need of any centralized processing unit or synchronizing clock. The signal and data processing is made locally in each sensors network node, the communication may occur between any two nodes if required. The problem is to minimize the internodes communication and to eliminate any initial synchronized starting between nodes.

## 2. CONTROL STRATEGIES

For conceiving the strategies for the mini-robots is to be considered the type of the motion controller. There are high costs motion controllers indicated for very complex applications and the low cost motion controllers for the every day applications. In the same time must combine automatic control theory with related subjects (i.e. data communications devices and systems, signal acquisition and processing, sensors implementation and sensors fusion, hardware structures and connections), that together can be managed within a PLM system. In the same time is to be considered that the controller for the mini-robots has to deal with two different sort of actuating systems: by mini and micro-motors and the shape memory alloys (SMA) actuating elements and that must ensure a real time response for the imposed tasks and the environment changes.

If the mini and the micro-motors control implies similar problems like the medium scale ones for the SMA actuating systems the problem is totally different the controllers implies to obtain cinematic and dynamic behaviour of the mini-robot by imposing actuating parameters for different shape, dimensions and materials actuating elements, dealing with different physical descriptions and different configuration geometry.

Due to the particular type of actuation the SMA controllers are considering for the actuating elements not only the general elements like cost, shape change temperature, traction force and the chemical composition, but also “secondary elements” that leads to a more accurate control system like alloys ductility, recoverable motion, hysteresis, corrosion resistance, band with of the transformation temperature, electric resistance (80-90 ohm/cm) conductivity, thermal conductivity, ability to be heated (electrical – Joule effect, conductivity, radiation). In the same time the SMA controls deals with a reduced number of parts but with a larger number of physical parameters that must be monitored and commanded increasing the reliability and reducing the associated quality costs.

The first element that must be controlled is the existence of martensite transformation and the temperature of complete transformation Tm, that must be above the working environment temperature Te. $\Delta T = Tm - Te$ , must offer a safe value for the actuating control.

In the 44 year of existence, since the Ti SMA were discovered, a relative large variety of mathematical models that describe the SMA behaviour are developed, In spite of this fact is still difficult to select an adequate model in order to predict the exact behaviour and from here the most adequate control mode. Within the most used models is the Graesser and Cozzareli model, the Landau-Devonshire theory and the Stalman-Van Humbeeck and Delaey model.

The Graesser and Cozzareli model is numerically stable, uses for one dimension case two basic equations related to the stress rate and to the dimensional back stress. The model parameters are related to the elasticity module, the slope of inelastic region and the threshold stress. The others parameters are heuristic determined for controlling the type, size and forming of the hysteresis, the

transforming from the linear elastic to the inelastic region and return, etc. The model is not considering the difference between the martensite and austenite elasticity modulus.
The Landau-Devonshire theory is the well known being one of the early models considering the free energy as a function of temperature. The material reaction is varying in accordance with the strain $\varepsilon$, being proportional with the partial derivative equation with respect to $\varepsilon$. This model can not reproduce the isothermal constitutive behaviour or the constant-stress transformation.

## 3. CONCLUSIONS

As conclusion in mini-robotics the specific materials, specific tasks, the type of robots, the necessary auxiliary used materials, the structure of the manufacturing line and the end application determine to be considered one of the following four strategies:

- Master slave control of the robots activity, where a strict hierarchy is defined and implemented from the beginning. The master slave control (MSC) is adequate for mass production of simple parts on unparallel manufacturing lines. The time cycles are very strict and the production I totally predictable.
- The distributed control is conceived on a floating hierarchy where the technology is the leading elements that determine that one machine, robot or device to receive the main attention for the accurate technology implementation. The distributed control (DC) is adequate for large production of medium complex parts on parallel manufacturing lines. The time cycles could be little longer, not so strict defined but ensure a better implementation of an accurate technology with higher costs much complex control algorism
- The correlated control concept is used for special activities where several robots with different tasks are working in the same time on the same part. The correlated control (CC) is used on relative complex parts and tasks where the technology implies different activities to be performed in the same time. The influences of positioning error, actions delays, or technology deviation are diminished, the quality improvement being doubled by the reduction of the cycle times with minimum of 25%.
- Adapted control at the SMA physical characteristics correlated with the mechanical imposed structure.

## 4. REFERENCES


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