Mechatronic Design for Autonomous Mobile Systems

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Abstract: *Essential industry requirements involved a rapid development of autonomous mobile systems equipped with sensorial components. The paper examines the principles of designing an autonomous mobile robot. The authors describe the way they conceived the structure of the system. The mobile system is equipped by an own power supply and can be controlled either manually or automatically, from a PC, through a wireless communication channel.*

Keywords: *Mechatronic design, mobile system, sensor, modelling*

I INTRODUCTION

Exploring remote, isolated or hard to be reached environments, from within which information is imperiously necessary is facilitated by the sensors equipped- autonomous mobile systems. These systems can be used in real time data transmitting from dangerous, toxic, dark, far-off or narrow locations too. Autonomous mobile systems are helpful in:

- Nuclear industry - to supervise enclosed spaces, or to manipulate radioactive materials,
- Chemical industry - to monitor technological processes or to manipulate toxic materials,
- Military industry - to watch over and patrol, to investigate mined territories, to neutralize terrorist actions,
- Mining industry - in emergency assistance,
- Agriculture, education, preventing outbreaks of fire, humanitarian scopes, etc., are other domains where they can be useful.

The known bibliographical references mention more realizations varying in the constructive principles and functional applications [2, 5, 6].

The paper presents the authors' considerations about the autonomous mobile systems design, formulated as a result of their studies developed in the national excellence grant N. 21 CEEX I 03, "Studies regarding the possibilities of implementing the flexible intelligent systems in zonal companies".

II CONSIDERATIONS ABOUT THE MECHATRONIC DESIGN

The mechatronic design process begins by a macro design stage. In the case of a mobile robot, this is represented by Fig. 1. At the domains levels, a strong interaction takes place to complete the robot variants. The requirements regarding the system behaviour and functional parameters were firstly identified, in accordance to the mechatronic philosophy of developing the products.

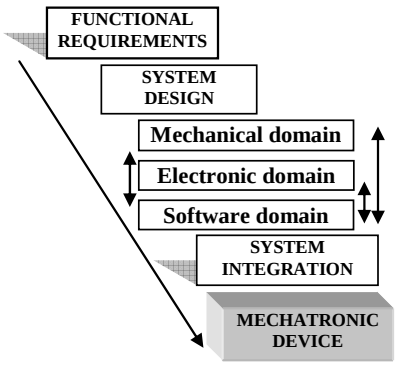

Figure 1
The mechatronic design process

These were:
- A selective directional mobility,
- A remote control, without any physical connection with the control centre (wireless control),
- A bidirectional communication between the operator and the robot,
- A power autonomy (limited).

The structural development of the autonomous mobile system was completed from "abstract" to "complex", following the mechatronic design principle. For the same reason, an integration of the hardware and software components was aimed together with an appropriate system-human operator interface.

Fig. 2 shows a sequence of the systemic improvement of the described autonomous mobile system (P - power, I - information) [7].

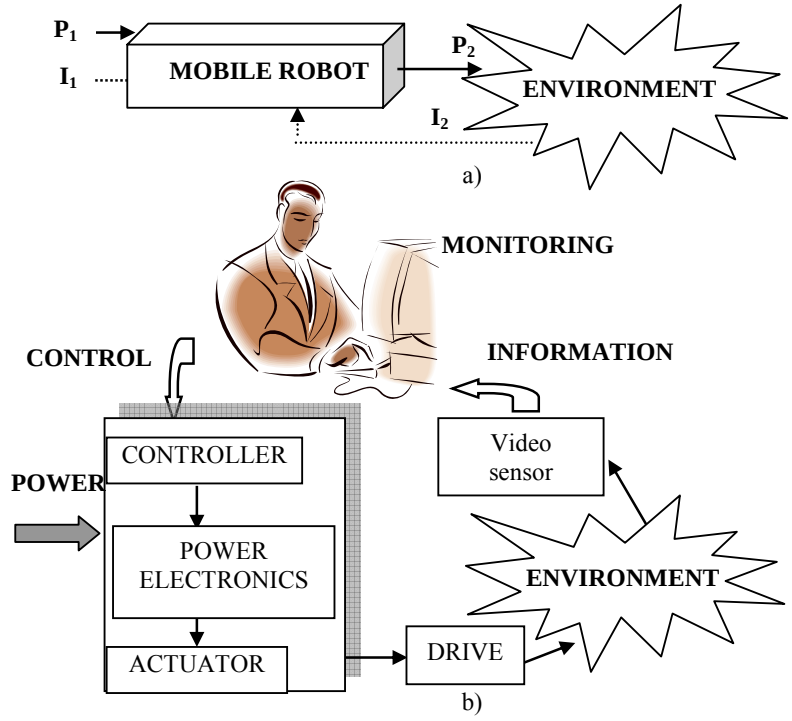

Figure 2
The systemic development of the autonomous mobile system described in the paper

The decision approach during the design process can be essentially simplified by using the decomposition methodology. In accordance to this methodology, the analyzed system can be structured on several levels by a hierarchical decomposition (Fig. 3). The applied decomposition took into account the system functions [8]. The established structure uses two principles from the machine theory:

- The vertical causality principle: cause – effect,
- The secondary functions principle, in accordance to which around each principal function a set of secondary functions exists.

The known references mention a set of criteria that could be considered in classifying and designing autonomous mobile systems. After an equivalency of the autonomous mobile system with a mechatronic system and the conformance to the required performance, the support functions of the inferior level subsystems were established. How a component is materialized to mach a certain function, was decided after a multi-criteria analyze. Table 1 shows the morphological chart for the systemic examination of the subject, including both the expected functions and the achievable solutions. The morphological chart corresponds to the systemic examination methodology applied on several different entities that could be considered as possible solutions for the product design.

The realized autonomous mobile system is shown in Fig. 4 [1].

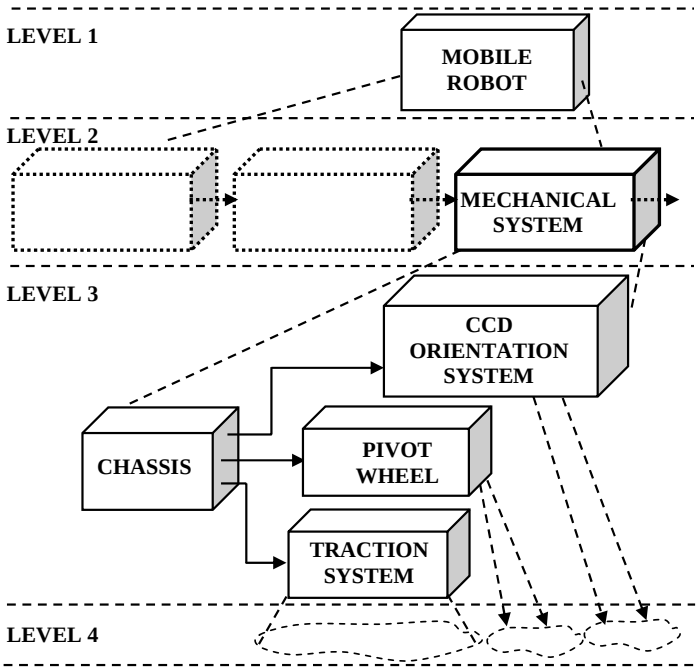

Figure 3
The hierarchical decomposition of the analysed system

Table 1

FUNCTIONS	SUB-SOLUTIONS		
	1	2	3
Directional mobility	Two motive wheels and a pivot wheel	Caterpillars	Stepping structure
Energetic autonomy	Electrical power accumulator	Electrical network, cable	
Guiding	Optical guiding	CCD Video sensors	Laser guide
Decision autonomy	Permanently remote controlled	Autonomous	Mixed - Autonomous and remotely controlled
Actuating system	C.C. motor	Step by step motor	

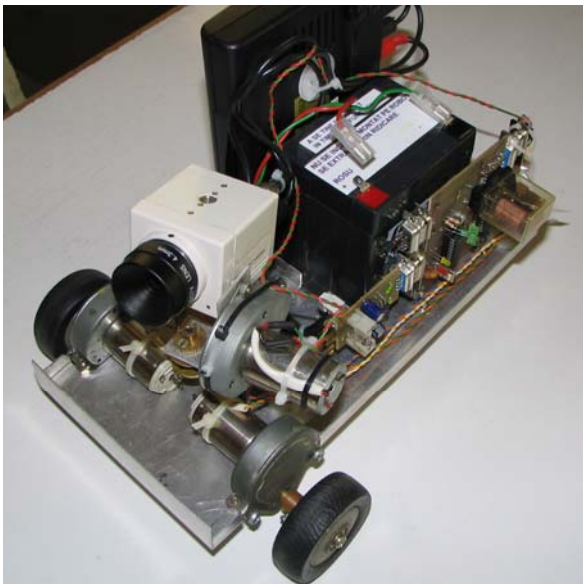

Figure 4
The picture of the autonomous mobile system built in the Sensors and Actuators Laboratory

The benefices for the designed product can be obtained by balancing the modelling (see Fig. 5) and the analysis, with respect to the validation of the experiments and the product construction. The concept of physical mechanism is extremely large and general. This concept is correlated with the notion of physical system and outlines the conceptual interaction of the system elements. One of the main methods in modelling and simulating physical systems in mechatronics is the bond-graph method (Fig. 6). The method can be implemented in suitable software environments [8].

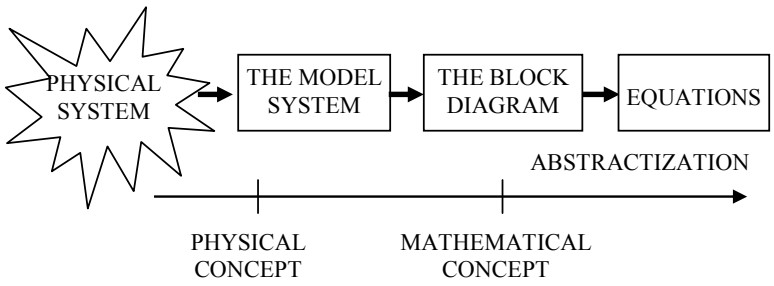

Figure 5
The modelling principle

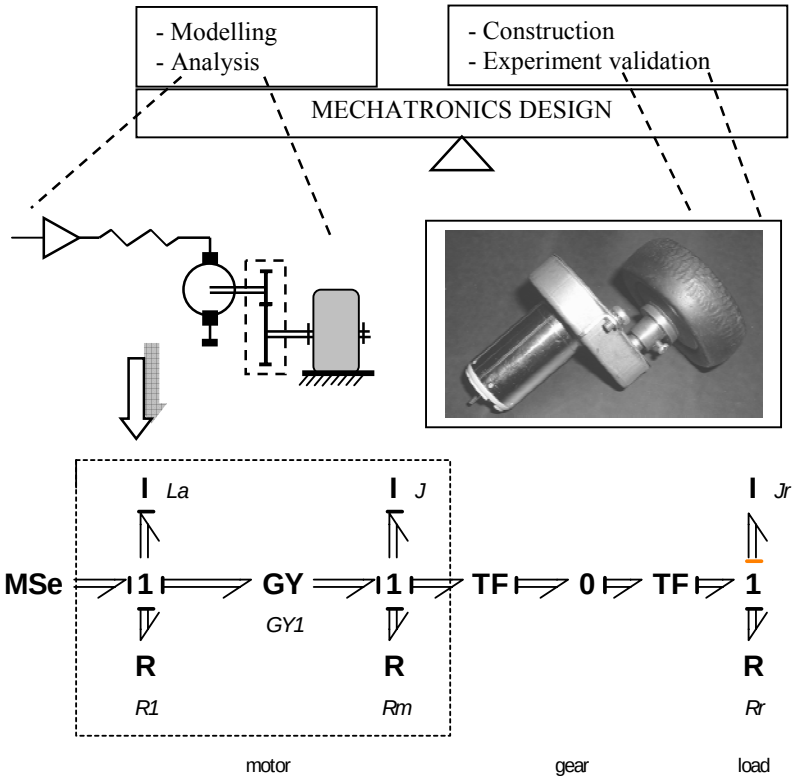

Figure 6
The authors' proposal of balancing the modelling and the analysis, with respect to the validation of the experiments and the product construction

Conclusions

Experiments were made on the model of the autonomous mobile system and they will be continued by other tests regarding the spatial displacement way and the capacity to keep an imposed prescribed trajectory. The built model is robust and responses conveniently to different manual- and remote controlled tasks. Solutions how to improve the model were revealed during the experiments.

References

[1] Băcican, C.: Sensor equipped mobile platform, Licence diploma project, Dep. of Mechatronics, "Politehnica" University of Timisoara, Romania, 2004 (in Romanian)

[2] Nițulescu, M.: Sisteme robotice cu capacitate de navigație, Editura Universitaria, Craiova, Romania (in Romanian)

[3] Xialin, F., Wenhai, L.: Robot Autonomous Navigation, California Institute of technology (USA)

[4] Pissard-Gibollet, R., Rives, P.: Asservissment visuel Applique a un robot mobile; Etat de l'art et modelisation cinematique, INRIA-1577, 1991

[5] Borenstein, J., Feng, L.: UMBark – A method for measuring, comparing and correcting dead-reckoning errors in mobile robots, Technical report UM-MEAM-94-22, University of Michigan (USA)

[6] *****, Robotics Projects, www.technologyindex.com/education/store/robotics

[7] Dolga, V., The Mechatronic Systems Design, Taught subjects, Dep. of Mechatronics, Timisoara, Romania, 2005

[8] Dolga, V., Dolga, L., Modelling and simulation of mechatronic systems, Mecatronica, Nr. 1, pp. 34-39, 2004