COMPONENTS AND INTERFACES FROM MECHATRONIC SYSTEMS

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ABSTRACT: Within the mechatronic systems, there are interfaces for both hardware and software components. In the construction of the mechatronic system by a team, these interfaces must be considered, in order to create a system as the client wishes. The delivered system must incorporate the proposed requirements, execute them correctly, without additional unwanted functions. These interfaces must be properly tested and, depending on the complexity of the system, an appropriate method must be selected to verify and validate the system. The mechatronic system consists of mechanical, electrical and electronic elements and these are controlled by software uploaded to the system, which executes the required commands. Due to these components, the hardware and software interfaces must communicate correctly in order to perform the proposed functions. The interface is tested and validated, as are the system components. The structure of these mechatronic systems is discussed, with its elements to be considered.
KEYWORDS: hardware and software components, interfaces, testing and validating, certification, mechatronic system

1. INTRODUCTION

The area of coverage of mechatronics combines mechanics and electronics, hence the term in the literature. [1]

The systems of this type became more complex, and then the definition of mechatronics was extended to include more technical fields. The direction of development is to create systems capable of performing the desired functions and to allow the control of rapidly evolving systems. [2]

The people involved in the design of mechatronic systems must be able to create circuits of analog type, but also digital, to be able to choose compatible components of the system based on microprocessors. The list also includes mechanical devices, sensors and actuators. These are controlled by a controller and the final product achieves the desired goal. [3]

To develop a mechatronic system, knowledge from several disciplines is used, such as mechanical engineering, electronic engineering and computer science. In making the desired system, each component was developed separately, and then all of these are integrated into a final system. In order to carry out a high-quality project, all these engineering disciplines must be taken at the same time. Therefore, mechatronics brings an intrinsic complexity in system design. More research is being developed to find out the best methods. [4]

The engineering of these systems requires the design at the same time and on several disciplines of some subsystems that contain:

- a part that can be called operative (mechanical and electromechanical part;
- a part of control (as electronic and real-time computers);
- a part referring to interfaces, which can be between machine and machine (in this case, data is exchanged between two separate systems) and interfaces between human and machine.

A general approach reduces costs. But reliability and modularity need to be considered. The way in which technical products integrate mechanically and electrically tends to integrate mechanics with digital electronics and information processing. [5]

Integration is done between hardware and software components, like information-based functions. Hence the integrated systems are called mechatronic systems.

An optimal balance must be found between the basic mechanical structure, as well as the implementation of the sensor and the actuator, information that is processed automatically, and the control in general to be performed without problems. [6]

Mechanical An advantage is that some mechanical functions are often replaced by functions that can be controlled in the electronic field. this leads to better system functionality, but also to simpler mechanical structures.

With the increasing complexity of mechatronic systems, new functions can be performed by such systems, possible only with mechanics or electronics.

Here is about technical progress, which has a great influence on several products from fields such as mechanical, electrical and electronic engineering.

This also changes the design of conventional electromechanical components. As an example, it would be the automotive field, with some other precise mechanical devices. [7]

2. ELEMENTS TAKEN INTO CONSIDERATION

As shown, a mechatronic system includes mechanical, electrical and electronic parts. All these components coexist, communicate with each other, to achieve a functional system. These components are hardware. [8]

Within mechatronic systems, there are mechanical elements that make up the mechanical structure, its mechanism, but also the thermo fluid elements for example. The hydraulic aspects are part of a mechatronic system.

Electromechanics exists as a combination of mechanical and electronic elements. This is a combination of electrical and mechanical elements, refers to sensors and actuators.

Electrical elements refer to electrical components, such as resistor, capacitor, transformer, inductor, etc., but also to analog circuits and signals.

Electronic elements refer to electronics, which is analog or digital, they also refer to power electronics and signal conditioning.

These are used for the interface of sensors and electromagnetic actuators with the hardware elements, for the realization of the control interface.

The hardware elements of the control or calculation interface refer to the types of analog and digital conversions, digital processing signals, etc.

In terms of computational control hardware, a control algorithm is implemented. It uses measurements from the sensors to calculate the options that can be applied to the actuator.

Computer elements used in mechatronic systems are the hardware and software used for operation and simulation and data processing.

Interfaces are compatible connections between the components of the mechatronic system.

These elements, including interfaces, must be tested during the development phase of the system. [9]

The testing of the mechatronic system is performed depending on the field (mechanical, electrical, information theory).

For the mechanical part, standard methods are defined for the three fields participating in the mechatronic integration.

For the mechanical field, is needed to have the specification of the problem, to define the functions and structures, to find the solutions and principles, to make the division of feasible modules (in sub-activities), modeling on components, and also modeling on the final product, plus the preparation of the execution plan and instructions for use.

For the electrical and electronic field, the specifications need to be clear, to have a description of the system with an overview also a description of the algorithms used, of the interfaces, the logical functioning and a plan of integration of those.

For information technology (software code) the problem needs to be defined, the problem analyzed, the analysis of the requirements needs to be done, the description, design, implementation and component needs to be tested, followed by the system testing and using of the product.

In the case of mechatronic systems, it is difficult to distinguish between them and an electronic system. An electronic circuit is part of the mechatronic system, but it is not a mechatronic product. As the mechatronic system encompasses these areas, it is easy to confuse the finished product. [10]

Apart from the fields of mechatronic integration, there is design. Design procedures consist of rules to follow, recommended sequences, which often provide acceptable solutions.

Acceptance testing is performed against all product requirements, thus each validating the specifications of the mechatronic system.

The verification has been performed since the implementation of the requirements, instead, the validation is performed before the product is delivered.

3. APPROACH IN PROJECT MANAGEMENT

This results in the realization of the mechatronic system according to the system requirements and two approaches are used, adapted from the software testing techniques. [11]

A combination between those testing techniques offers sometimes better results.

- Waterfall predictive approach (used in software testing and adapted for a mechatronic system).

This is done for deliverables in any field of activity where there are detailed, clear, measurable and demonstrable initial specifications. These are specified in the financing agreement (predictability in execution). This approach is one of the most common.

- ➢ The Agile approach (from the software testing) can be done for deliverables in areas where the initial specifications are very general, without the possibility of detailing (partial or total lack of predictability -> flexibility, adaptability in execution).
- ➢ The hybrid approach, which is form that combines the predictive with the adaptive approach.

In this case, the following are highlighted:
- some components of the deliverable that are clearly defined from the beginning and for them the Waterfall method is adopted (predictive);
- other components are finalized during the project and for them the Agile (adaptive) method is adopted.

4. TESTING OF AN ACTUATOR AND A SENSOR

The interface is like a "border" between two subsystems. The exchange of information between two components of the system is possible if there is a common concept and a common coding system. The interface refers to all the ways (buttons, graphic display, etc.) to supervise and assist the processes in a system.

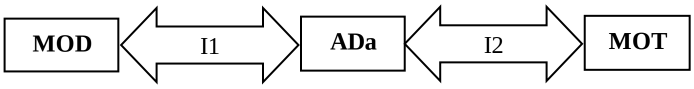
The mechatronic systems contain (at least) one actuator. The actuator is an actuating element (electric motor, electromagnet, etc.) used in automatic control systems.

There are interfaces between the mechanical - control - electrical system. In order to develop a test method for the actuator-type interface, all mechanical as well as control and electrical parts must be considered.

The actuator-type system could be found in a motion band, for example (an axis, a forward and backward motion is made to a certain point), as well as in the actuator of a robot (as another example) that lifts the object from tape and place it in a storage position.

Knowledge of the actuator system is very important, such as the axes on which the actuator moves. Depending on the axes of motion, we have interfaces with the control system (connection to the servo port) as well as with the electrical system (powering the actuator, which is often done through a separate voltage source).

A diagram of the tested actuator connections can be defined as in figure 1.



MOD	Module, where the software execution code is stored
I1	Software interface
I2	Hardware interface
ADa	Actuator adapter
MOT	Motor

Figure 1. Actuator connections that are tested in a system

As a testing procedure, testing is tailored to two case studies. These are performed for an actuator as well as for a sensor that detects the position of the object in the mechatronic system.

Testing was chosen for these two components because totally different test models are used. For the actuator (motor and adapter) most functions are clearly defined and cannot vary.

For the sensor (position detection and reporting so that the software code commands the actuator to stop for example) the functionality may vary, depending on how you want to report intermediate states, and this is done only in a more advanced state of construction of the mechatronic system, after the integration of several components.

Testing for the sensor interface must follow the same logic as for the actuator, but customized for the sensor: powering the sensor and transmitting the information to the control component.

The role of the sensor is only to identify and report a certain state of the object. Object detection is reported and the control system (a programmable logic controller) executes a programmed command. There are several sensors in the mechatronic system, but as a function, their role is the same: it determines the presence of an object at a certain point in the mechatronic system.

This case refers to the actuator connections in the mechatronic system. An actuator can be of several types, depending on the type of motor and the directions of movement. A DC motor, which can be moved on several axes, was used to test the actuator component interface.

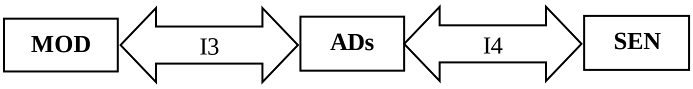
The actuator connections are:
- electric type: in this case we have the standard power supply of the motor, which can be of AC or DC type; for the mechatronic system, this power supply is included in the control cable

(which also contains the cables that control the actuator) and there are no problems in the power variation used;

- command, which is performed by executing the code, which depending on a certain state of the system (for example, object detection), the command to move object or stop tape is executed.

In real mechatronic systems, the motor supply must be supplied separately so that the required power is correctly distributed. This aspect is also considered in the tested interface.

In the second situation, shown in figure 2, testing the sensor interfaces is a much more complex activity, due to the lack of detailed information. Similar to the actuator, the diagram for the sensor was made.



MOD	Module, where the software execution code is stored
I3	Software interface
I4	Hardware interface
ADs	Sensor adapter
SEN	Sensor

Figure 2. Sensor connections that are tested in a system

This is where the "creation" part of the manager comes in, because the number of sensors it deems necessary is entered, and the code can vary greatly. For the sensor, an adaptive method is used, where the cascading model is combined with another type of software testing, such as the "V" model. This is very important for the software interface.

Inadequate presentation of information or lack of other information to the operator raises problems in understanding the processes and diagnosing them.

5. GENERAL TEST INTERFACE

The use of elements with sensors is extremely wide and has been specified in the definition of mechatronic systems. They can be briefly specified as areas of use: automated systems, security systems, quality control, environmental analysis, etc.

An extremely important application in this extreme field is the one related to the interface of electronic instruments (multimeter, signal generator, oscilloscope, etc.), computer systems, sensors, actuators, etc. with centralized computing system. Two main reasons require such an interface: the remote establishment, through the program, of the working characteristics of the system component, respectively the taking over of data related to the ongoing process. The implementation of the interface depends essentially on the application, although some common aspects can be specified.

An analysis of these uses allows us to state the existence of four stages in the exploitation of the sensor elements:

- the initial (rudimentary) system that still knows a wide spread. The error resulting from the processing of the control signal and the sensor signal will be processed by the control system;
- the system developed with the inclusion of conditioning and signal transmission elements.

The sensor is associated with signal conditioning and transmission elements so that it can be received and used remotely. In this situation, the systems based on intelligent sensors have become possible by associating a processor in the vicinity of the sensor element. It could be systems with dedicated processor, a developed form of intelligent sensors with dedicated signal processor.

The intelligent sensors are materialized by a primary sensor element and a computing capacity provided by a programmable circuit - microcontroller, microprocessor.

This type of sensor contains a microcontroller, an analog / digital converter, amplifier and sensor (the detection part itself).

The microcontroller part is based on multiplexers, analog to digital and digital to analog converters, microcontroller and required memory, analog and digital inputs and outputs, all included in a single integrated circuit.

The advantages of using these sensors are diverse and multiple: metrological (high accuracy), functional (self-testing, self-calibration, interoperability), economical (reductions in stocks and calibration and calibration time, increased reliability, etc.).

The use of intelligent sensing systems leads to the prioritization of surveillance, control and regulation functions. Basic operations, acting on a single system parameter, even the one measured by the smart sensor in question, can be transferred to it.

The central control system will thus be freed from simple operations, its tasks being those of complex level.

In addition to the classic variants, the information provided by the smart sensor must be credible.

Regarding sensors, their operation and performance can be affected by:

- own defects of the sensor: damages, modifications of the characteristics;
- defects due to the attached electrical and electronic circuits: changes in the characteristics of the components, damage, etc.;
- collateral defects due to the measurement operation: exceedances of the measuring range, disturbing factors, etc.;
- information transmission errors.

The sensor achievement is made by:

- validation of the transmitted information (figure 3);
- testing, diagnosis, history of the measurement operation, system and environment.

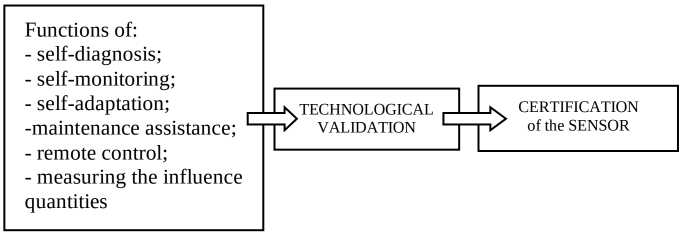


Figure 3. Validating the "sensor" component

The validation function, which cannot be separated from other functions specific to the intelligent sensor (being correlated even with the aspect of information credibility) refers to technological and metrological aspects.

The configuration function consists in adapting the sensor to the conditions imposed by the chosen operating mode. Included in this feature are:

- the technological configuration which is the result of the set of actions aimed at the integration of the intelligent sensor in the working environment;
- the functional configuration which is the result of some actions aiming at the operation of converting the primary information and the communication made by the sensor with the rest of the system;
- operational configuration that refers to the actions aimed at dedicating the sensor to a specific application;

The exchange of information via the interface of the sensor is possible due to three spacing codes:

- the name space is necessary to understand the meaning of the transmitted values;
- the time space serves to define the moment of existence of an event in communication;
- the value domain ensures the coding scheme of the values to be transmitted;
- communication between the two subsystems A and B is controlled either at the request of the sender (push style: control of flow and data flow, by request of the sender) or at the request of the receiver (pull style: control of flow and data flow, at the request of the receiver).

A communication model between two subsystems is based on the decoupling of data transfer control. This possibility is ensured by a configuration corresponding to the intelligent element with sensor (smart sensor: control of the flow and of the data flow, realized in a global time).

The real-time service interface performs real-time service for smart sensors during system operation. The diagnostic and management interface allow access to the internal communication channels of the smart sensor.

The diagnosis is followed, for setting parameters, for finding information, etc. The activity is carried out without disturbing the rest of the services in real time. The configuration and planning interface are required to access the configuration of a network node.

In mechatronic systems the flow of information is one of the three presents: energy, matter and information. The initial information that can be presented in various forms must finally be able to be processed by the attached computer systems.
In addition to the test operation, the system components are also certified. This is done using certain standards in force.

As a human-machine interface standard, there is ISO 9241-210: 2019, which refers to the ergonomics of human-system interaction, and in part 210, refers to human-centered design for interactive systems. [12]

This standard defines three components that describe the operator-machine interface:

- effectiveness - it is according to the user's requirements and ensures the correctness of the information;
- efficiency - can be understood quickly and can be exploited with minimal effort and errors;
- satisfaction - the user is satisfied with the existing product, and this reduces the stress from the operation.

Some requirements and recommendations regarding the design principles and activities in the life cycle of computerized interactive systems are provided.

The standard is used by people who manage the design process and want to improve both the software and the hardware, the human-system interaction. Inside is provided an overview of human-centered design activities. It does not provide detailed coverage of the methods and techniques required for human-centered design, nor does it address health or safety issues in detail. Although it addresses human-centered design planning and management, it does not address all aspects of project management.

Machine-to-machine interfaces are best characterized by standardization. The main goals for the current stage would be: plug & play through control elements, interface libraries, learning techniques, robust control architectures, control integration standards.

The technical products have the need to connect with other products through a standard interface.
A number of other standards consider aspects related to the design of the interface.

6. CONCLUSIONS

When a mechatronic system is built, the choose of the elements which will be included in the system need to take care of requirements, but also the standards. It is a focus on testing procedures, depending on the field, on generalized test interfaces for mechatronic systems.

An adaptive method can be used in the majority of complex mechatronic systems, but with mechanical as well as electrical / electronic parts, we cannot use a "pure" test method. Some "Waterfall-V" method can be used in product management, as in the product life cycle.

For a mechatronic system, a hybrid approach is the best solution, due to the constituent elements of such a product, which involves step-by-step or incremental development, depending on the component to be integrated.

Regarding the electrical / mechanical tests, the interface of the electronic instruments (multimeter, signal generator, oscilloscope, etc.), computer systems, sensors, actuators, etc. must be performed with centralized computing system.

As shown in figure 3, with the implementation and validation of functions for a component, the next step is to validate the technological point of view, and the final step is the certification.

Regarding the standards applicable to mechatronic systems, the human-machine interface and the machine-machine interfaces are considered.

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