Summary
Of the doctoral dissertation:

Moniring, diagnisis an control algorithms for complex mechatronics systems

The present study, Moniring, diagnisis an control algorithms for complex mechatronics systems, is the result of sustained study and research.

The achievement of research and objectives, involving knowledge and deepen of concepts and analysis methods for specialized disciplines of mechanics, systems and signal theory, mechatronics and mathematics, and using specific algorithms and programs of software and automatic tuning theory (Toolbox package Simulink - Matlab).

Results obtained in this paper would not have been possible without solid theoretical approach that intimacy into the dynamic process and without carrying out finesse experimental researches that allowing investigation of phenomena with high level complexity and feature specific of author's theme.

Chapter 1: INTRODUCTION

It defines the concept of telerobotics and teleoperation (1.1. Definition of telerobotics), in particular: Internet-based telerobotics (1.1.1. Telerobotics based Internet (Web)). Consultation of literature revealed some aspects of how the methods and criteria for classification and control architectures of robot teleoperation via the Internet (1.1.2. Classification of control methods for robot teleoperation via the Internet 1.1.3. Classification control architectures).

Also, in this chapter were presented basic principles of remote control (1.2. Remote control of mechatronic systems, 1.2.1. Fundamentals of remote control systems) entering the period of delay and ways in which this can occures in remote control systems (1.2.3. Delay in remote control systems, 1.2.3. Types of delays) and its compensation (1.2.4. Compensation of delays).

Another element introduced in this chapter was that of detection and location of defects in mechatronic systems (1.3. Fault detection in mechatronic systems), emphasizing the importance of the issue in management systems (1.3.1. Importance of fault detection and location) and while presenting some basic concept led remote fault diagnosis system (1.3.2. Concepts of failure diagnosis process, 1.3.3. Classification of fault diagnosis methods, 1.3.4. Aspects of timing packets according protocol 1.3.5. Detection and identification of defects in the joints of a robot).

Chapter 2: MONITORING AND DIAGNOSIS SYSTEM USED IN TELECONTROL OF MECHATRONICS SYSTEMS

In this chapter the author's efforts have focused on the comparative study of analytical methods for detection and fault location (2.1. Analytical detection and fault location) and selection from literature of relevant and complex engineering interest solutions helpful for experimental studies carried out in the paper.

Also in this chapter are presented and some aspects of data fusion for monitoring and diagnosis process (2.3. Using data fusion process for monitoring and diagnosis).

Original contributions claimed by the author is to determine:

- a diagnosis system for data fusion using the coherence function and correlation.

Chapter 3: MECHATRONICS CONTROL SYSTEM IN DEFAULT MODE

Mechatronic systems, either: stationary or mobile, joint or tentacular arm, single-wheeled transport platform or type multipozi complex structures are currently used in various fields, particularly in environments harmful or dangerous for humans, such as : handling of toxic substances, etc. Under these conditions the problem detection and localization of defects in its operation and management system of robots is a basic problem.

Defects in robotic structures can be caused by external environmental conditions (operating environment) or internal conditions (structure, sensors, actuators or driving schedule).

All the situations described above can be controlled through a system of monitoring (diagnostics), to detect any change and will review and monitor the robot as an appropriate algorithm.

Monitoring system, depending on its complexity, may adopt the following management strategies (from simple to complex) only detect and locate faults and suggest possible actions for containment and/or avoiding defective components, further ensuring the robot motion conditions stability and safety for minor defects; continue to bring in the robot's movement in a safe condition in a neighborhood of the end point if major defects, stopping the robot in a safe condition for maintaining stability in catastrophic defects.

General techniques for detection and identification of existing defects and the recovery after failure, can be applied to robot manipulator systems, thus causing their operating area in default mode (3.2. Determination space operating under fault conditions). In case of a manufacturing line that contains multiple robots with the same kinematic configuration, operating overcome these spaces allowed for each robot lead to interference problems. To avoid this, it eliminated a priori all areas which could be overcome, so that each robot has its own separate region. Thus, each robot has been defined for each operating region (called operating cell) rectangular. Then it was analyzed in terms of cinematic event of a failure due to blocked joint robot (3.2.1 Failure due to block a manipulator joint). It was assumed also that blocked the angle joint is unknown. Even if the lock position would not be available from each sensor attached joints, the terminal position can be calculated by solving the manipulator inverse kinematics.

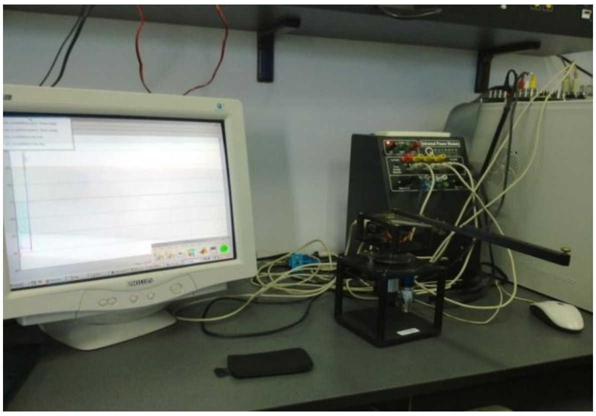
Original contributions claimed by the author consists in determining:

- kinematic restrictions of the operating space of the robot in case of failure;
- testing using Matlab and Simulink multiple filter method to detect and locate faults in this type of manipulator, considering three filters in one of them contains the correct mathematical model and the other two containing the corresponding mathematical models of failure due to blockade one of the two joints. By comparing the three filters in turn to each other could detect and locate the fault occurred (3.3. Fault detection using multiple filters for a robot manipulator);
- achieve position control robot manipulator by conventional driving laws in normal and damaged due to blockade of one joint (3.4. manipulator robot control in normal conditions for a joint lock);
- achieving management process in normal and damaged using conventional rules and methods of protection from damage transducers, performed a series of simulations

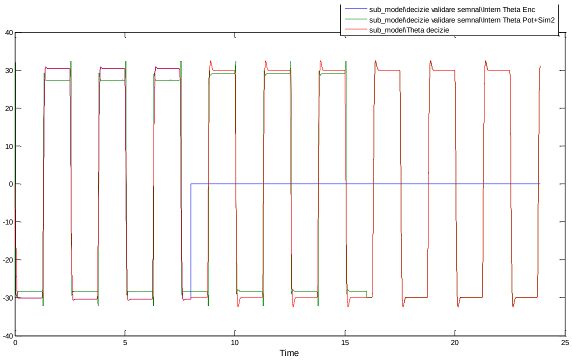
using Matlab and Simulink. The algorithm was tested using the SRV-02 Quanser equipment. In this experiment was considered a block "alarm" that has highlighted the proper functioning of the first transducer (encoder) until the second 8 and second transducer (potentiometer position) up to 16 seconds, the signal having value 0 and the occurrence of fault by switching it to 1. (3.5. SRV-02 Quanser actuator management in normal and defective by using conventional rules);

- driving a flexible-arm robot in normal and defective, the actuators using LQR - Linear quadratic regulator (3.6. Rotflex Quanser management system in normal and fault using LQR). In this experiment suggested a control scheme by which have been simulated (in the Simulink environment) the following cases:
    - proper functioning without flalt;
    - defective functioning is affected in turn two angles: θ (angle actuator) and α (angle of deflection of the arm).

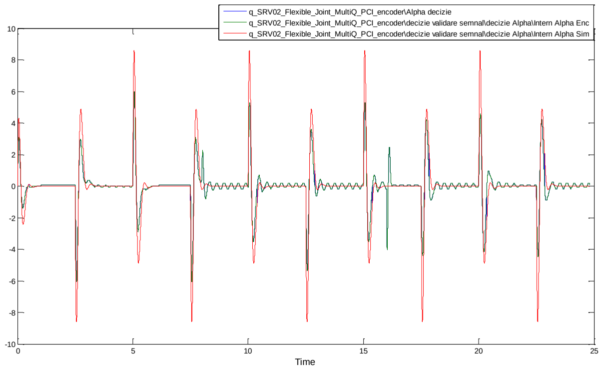
After these studies emerges as a major requirement for the need for mechatronics equipment remotely operating a high degree of robustness. This requirement may be satisfied by providing both a hardware redundancy and by introducing analytical redundancy. Was used in laboratory experiments both hardware and analytical redundancy. The latter allows using software means, fault detection and reconfiguration process.



Quanser SRV-02 system with equipment attached Rotflex



Angle θ (for SRV-02) measured the position encoder and potentiometer. Observe the second encoder fault occurred in second 8 and the potentiometer in second 16. The system is driven only by the simulated signal



Angle α (for arm ROTFLEX) is functioning properly, even if the potentiometer and tachometer are faulty and it is noted that the second 8:16 disturbances appear on the chart when it passes a new combined command signals

Chapter 4: REMOTE CONTROL OF MECHATRONICS SYSTEMS WITH DELAY

This chapter deals with the study of delay compensation in remote control using Smith predictors. At begining are some general notions of time delay compensation (4.1. Compensation of delay in the remote control) and modeling of human operator (4.2. Modeling human operators in control systems). If the delay due to propagation are greater than the sampling period they are attached form a dead time process driven. We obtained satisfactory results using both theorems to validate the conditions for stability of numerical systems with dead-time and specific control algorithms for this situation. Control structure is proposed using a modified variant Smith predictors. Model simulations resulted in good behavior, the algorithm developed with the following advantages: simple structure, easy to implement, and robustness against modeling errors. I think that Smith predictors can be implemented in autotunning regime if it is determined automatically the network delay times. (4.4. Predictors Smith in remote control systems).

Also in this chapter has studied the diagnosis of a network control system (4.5. Diagnosis of a controlled network), focusing on its damage due to:

- network-induced delays (4.5.1. Affecting the diagnosis process by network-induced delays);
- packet loss network (4.5.2. impairment loss diagnosis process network packets).

After these studies is showed that remote management structures can be equated with the direction of a process with dead time.

This equivalence is possible as long as the sampling period is greater than the delays introduced by network communications. This condition leads to the steps following when implementing such a system.

- P1. It examines the communication network to be used and determine experimentally the average spread of a data packet in full duplex mode.
- P2. Is studying the process and its dynamics is determined by the frequency (period) sampling. It is recommended that fixed value to be higher but close to the threshold value below which the control process would be impossible.
- P3. Control law is synthesized using standard specifies algorithms appropriate numerical control systems.

CHAPTER 5: CASE STUDIES FOR REMOTELY CONTROL WITH DELAY

This chapter focuses on testing and experimenting with a remote control system using modified Smith predictors (5.1. Case studies using modified Smith predictors).

In this study, it is considered that the equipment is located away from the driving process. Actuators receiving control signals through communication network while the process data acquired by sensors are targeted to all via the network controller. Because of this topology further delays occur due to data transfer.

These network delays can be classified in terms of direction of data transfers as: sensor - controller delays τ_{sc} and controller - processdelays τ_{ca}, these delays are present both direct and feedback path. Delay times can be grouped, for ease of analysis as a single time constant τ_c, called "control delay".

Both delays introduced by the network may be lower or higher than the sampling period T. In the first case the process can be conducted under optimal conditions (assuming no lost packets). In the second case of major problems of discontinuity of the management process which can lead to poor development and loss of process stability.

Following experiments to propose the following steps:

- Estimating the dynamic characteristics of process-driven, including execution elements and transducers (the fixed adjustment factors)
- Choice of the sampling period with the conditions of stability and performance
- Testing network to be used in the management and / or monitoring, considering the average delay times and the probability of error (packet loss).

If this time delay is much smaller than the sampling period required, the process can be driven by inclusion in the fixed part of a block of late.

If the delay times are comparable with the sampling period when a structure is recommended to use a Smith predictor.

Delays τ_{sc} and τ_{ca} include the following parts:

- waiting time τ_W - is a delay, in that a source (controller) must await the availability of the network before sending data packets.
- Time τ_F - is a delay due to the packet data network.
- propagation time τ_P - is a packet data transmission delay due to the physical network. Propagation time depends on the signal transmission speed and distance between source and destination.

These three basic types are delays that occur in a local network. If the packets are transmitted on the network, there may be additional delays such as waiting time at a switch or a router, and propagation time between nodes of the network. τ_{sc} and τ_{ca} delays, also, depend on other factors such as the maximum length of the band and packet sizes.

As a result of experiments have been grouped into three distinct situations remote management processes.

Case 1: Predictive control for systems with delay.

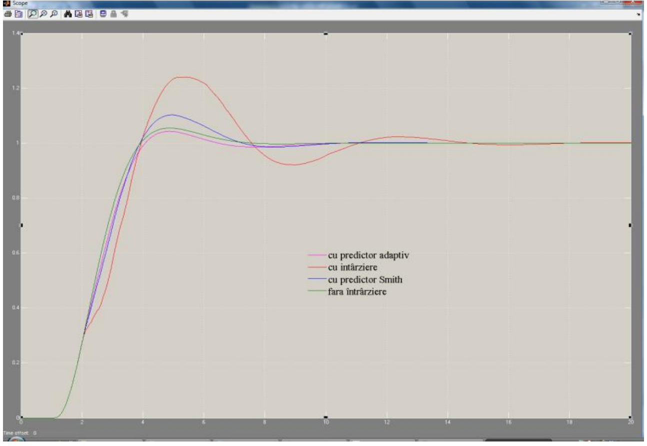
Case 2: Adaptive predictive control using a delay calculated aposterior: based on the experimental values to calculate an average delay which is used in the management algorithm.

Case 3: Adaptive predictive control using a variable delay apriori estimated: based on our experimental values of estimated time delays to delay the next sampling period.

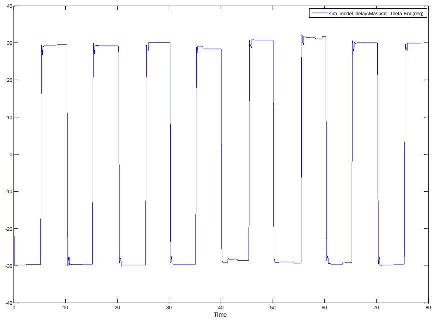
Original contributions claimed by the author consists in determining:

- remote control testing process using modified Smith predictors for late occurrence of two types: fixed and variable. From simulations performed using MATLAB and Simulink environment was found that when using a fixed delay, there is a greater gap response to the use of a variable delay (5.5.1. Remote control DC motor using Smith predictors modified);

- remote control testing process using an adaptive predictor, realizing a series of experiments in which responses were compared in four cases (5.5.2. Remote control of a DC motor using an adaptive predictor):
    - without delay;
    - variable delay;
    - with Smith predictor;
    - with predictor -adaptive structure.
- testing remote control actuator position Quanser SRV-02, using modified Smith predictors can be done in a series of experiments in real time (5.2. remote control actuator position Quanser SRV-02 using modified Smith predictors).



Response process in the four cases: a) immediately, b) with variable delay, c) with Smith predictor, d) with adaptive predictor 4T



Encoder measuring the angle θ to the introduction of Smith predictor structure with frequency control signal generation is 0.1Hz