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Analysis of Elements of Mechatronic Systems

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Final Evidence 2

Description of the Mechatronic System that Solves the Problem Situation, Including a Simulation of the Said System

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Description of the Mechatronic System that Solves the Problem Situation, Including a Simulation of the Said System

- Second Final Course Evidence -

Specific requirements, instructions, and operational functionalities for the development of an automated Industrial Rolling-Up Door System (IRUDS) under operational logic, numerical boundaries, construction restrictions and safety parameters, within other additional task successful achievement indicators. The following written report will emphatically analyze the initially given design requirements for the system and the process through which it was given a simulated solution; this, to finally analyze the operational logic of the designed system with the merely purpose of identifying strengths and weaknesses in the resolution interface for the generation of an iterative improvement recommendations brief report.

Summarized Problem Situation (Process to Automate Trough Control Engineering)

A IRUDS system containing a 3-4 meters width for 3-7 meters electable heigh was asked to be build trough the usage of a mixed opaque-transparent plastic material with an average wight of nine hundred grams per square yard, plus de addition of a 17.5 kilogram per lineal meter metal bar in its end to generate additional tension [1]. Further than the mere construction of a physical IRUDS, the developing team composed by Mechatronical Engineers was asked to automate the recently described system under diverse regulatory parameters such as limit boundaries, optimal functional requirements, and operational safety parameters [1].

An ideal and deeply analyzed combination of sensors, actuators control programs and parameters shall be merged up into an automated IRUDS in which the sensorial subsystem shall be able to compilate and monitor environmental general system information such as the precise position of the rolling door, its movement direction and the presence of either animated or unanimated obstacles below the curtain to send instructions to actuators through a programmable set of control instructions that will allow the actuation system to respond to user-elected (trough an HMI dashboard) parameters such as a total opening/closing speed/velocity corresponding to a 3-5 seconds maximum, cancel any operation indication or movement while the STOP latch detent button is pressed up and going to the upper position, raising an alarm and recording when identifying obstacles below the curtain [1]. As an additional actuator system requirement, it must be mentioned that when not rolling, the curtain must be held in place through a break to avoid the exploitation of the motor system because of applying negative torque; the actuator system of the rolling door may also maintain a constant rolling speed to avoid any possible undesired incident [1].

Finally, in what respects to the main concerns of the present written report, a Human-Machine Interface (HMI) must be developed and simulated with the purpose of representing the operational management of the designed system [1]. This commented HMI is meant to differentiate between operators (allowing to move the curtain either manually or automatically to a desired permitted position and to access to the historic generated alarms register) and supervisors (allowing to set upper and lower limits, to introduce new velocity settings and to clear up the alarm historic register) [1]. The HMI shall allow either a manual (manipulated through up, down, and break activation buttons) or automatic (aided by a proximity sensor, including raise, lower, activation of IRUDS buttons and both automated velocity adjustment and brake systems) operation [1].

Mechatronic System Solving the Problem Situation

The following Block Diagram represents the complete system, in which the control, sensor and actuation subsystems coexist.

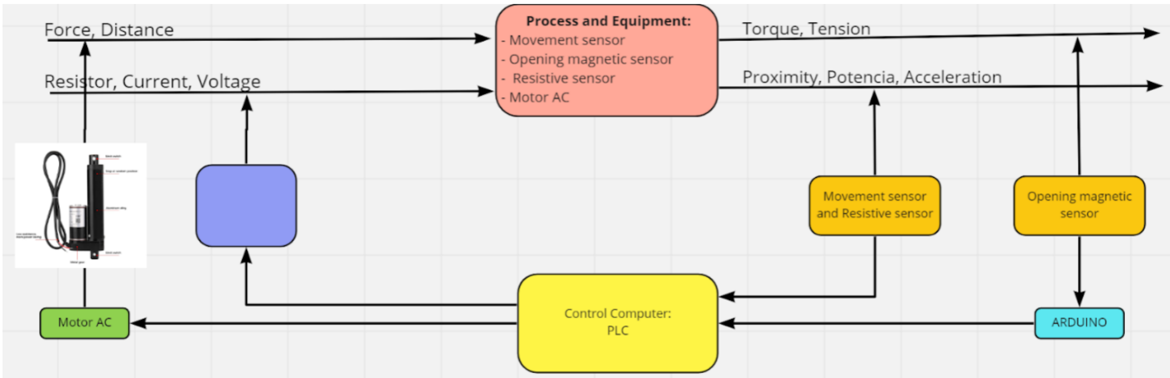

Figure 1. System Block Diagram.

Considered units for measurable variables considered in the designed Block Diagram:

- Force: Newtons [N].
- Distance and Proximity: Meters [m].
- Resistance: Ohms [Ω].
- Current: Amperes [A].
- Voltage: Volts [V].
- Power: Watts [W].
- Acceleration: Meters per square second [$^{m}/_{s^2}$].
- Torque: Newton-meter [Nm].
- Tension: Pascals [Pa].

Sensor System

The present subsystem shall be able to read two vital parameters that will enter as inputs to the system to transform them into an angular velocity output that will be sent to the motor engine actuator.

Rolling Door Position

This variable will determine de distance between the IRUDS and the floor to control the rolling door velocity parameters according to an HMI via elected movement direction.

Obstacle Detection

To allow the activation of the Upper State Emergency subsystem that will be explained on future subtopics of this written evidence ("Analysis of the Developed Simulation Process").

Actuation System

Shall be able to modify the movement direction and position of the IRUDS at any moment by using the position feedback given by the sensor system, the user HMI via introduced total opening/closing time, an obstacle detection system, and the HMI via elected movement direction.

This, trough modeling the rotatory/angular velocity and applied torque of the motor engine system as output actions.

Control System

Shall send indications to actuators according to the system feedback obtained through sensors, the specific functioning of this subsystem will be explained on detail for the given resolution on the following section "Analysis of the Developed Simulation Process".

Analysis of the Developed Simulation Process

The previously defined mechatronic system will be now represented taking as implicit the appliance of both actuator and sensor system; but emphasizing the control automation processes that could take place in the operational cyclical process. The mentioned simulation was designed aided on the usage of the MatLab Works software Simulink.

Representation of Variables: Implementation Logic, Inputs & Outputs

This section presents as an introduction to the developed operational manipulation HMI, the control engineering commands behind the designed dashboard, the operational logic of its functioning, the inputs, and the outputs of the generated code to use the perceived detections of the sensor system for the correct automated control of actuators whose action will lately feedback the sensor system in an interconnected subsystems loop represented on the jet presented block diagram.

Main Entrance Subsystem

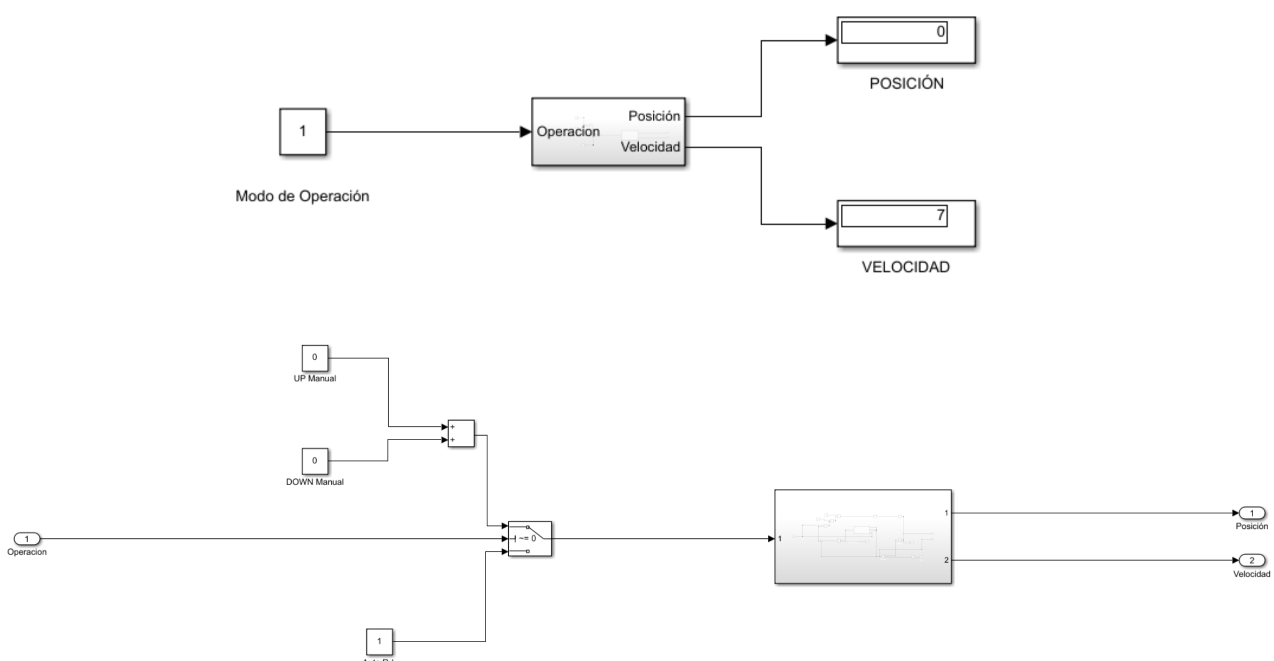

Figure 2. Main Entrance Subsystem.

The “Modo de Operación” variable is first given a binary (0,1) signal indicating the operational methodology required by the user either manual or automated. This given instruction will then enter into a switch; when being 0, operation will be automated and the “Auto R-L” variable will indicate the movement direction of the curtain (where 1 is opening and -1 is closing); on the given initial 0 case, the curtain will always be of a default BRAKE-ON state that will not allow any automated movement until the Up button (sending a 1 signal to the general subsystem) or Down (sending a -1 signal to the general subsystem) button are pressed. The outputs of this subsystem will be position and velocity; whose obtention will be lately defined.

General Subsystem

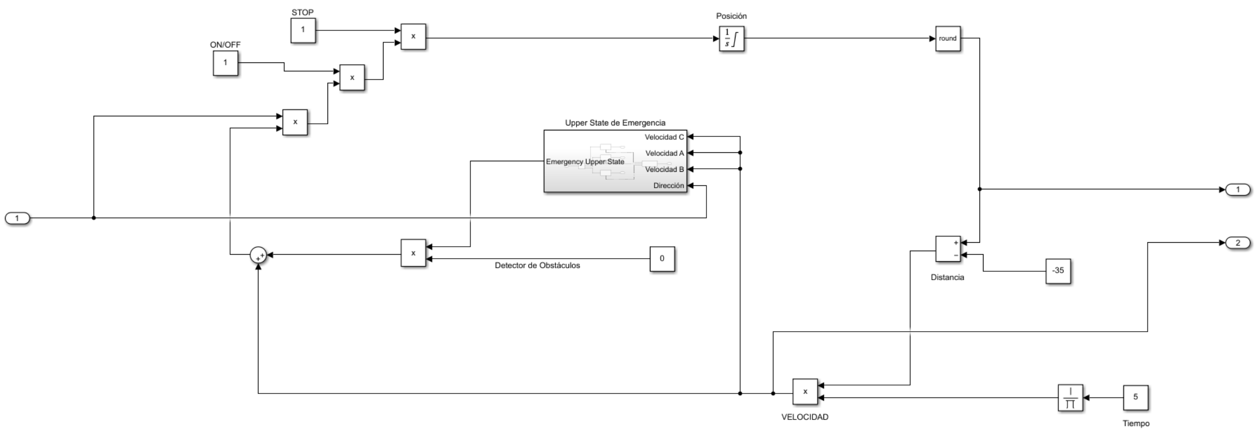

Figure 3. General Subsystem.

Once given the movement direction of the curtain, it will be multiplied on a product with the pre-iteration system speed, transforming it into a velocity value. To sequential products will now take place in the functioning; allowing the previously obtained value to pass through without any change or transforming it directly to zero and cancelling the movement of the curtain. Such products depend respectively on the “ON/OFF” variable (sending a 1 while ON and a 0 while OFF) and the “STOP” variable (sending a one while unpressed and a zero while pressed). Once done this, the final velocity will enter an integrator command and rounded up, transforming it to a discrete value for the position of the curtain and generating the previously mentioned output for position.

Once achieved this step, the difference between the actual position of the curtain and its upper state position will be obtained through the usage of a set point to identify the required lineal distance to roll-on the industrial door.

The “Tiempo” variable will then receive from the HMI a desired total opening/closing time and this information will enter a reciprocal block to then multiply it through a product with the necessary distance to cover, obtaining thus the necessary movement speed. This speed will be summed up to an arbitrary speed added trough the “Upper State de Emergencia” subsystem of normal value 0 that will only change if any obstacle is detected to be below the curtain trough a sensor. Then, the process will be repeated cyclically as required. The position must be detected trough a proximity sensor, the presence of obstacles trough an ultrasonic sensor and velocity must be manipulated trough the actuators brakes and motor engine.

Upper State de Emergencia Subsystem

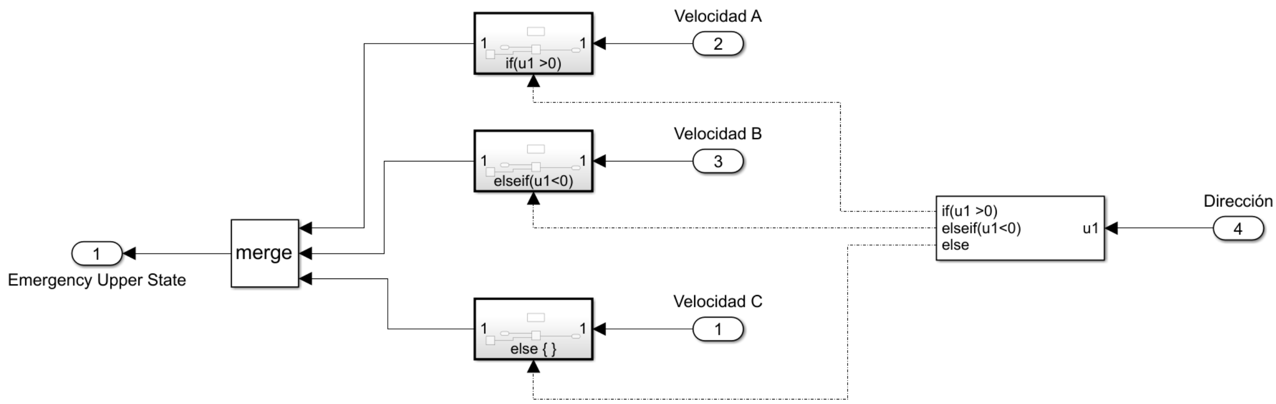

Figure 3. Upper State de Emergencia Subsystem.

The obtained velocity from the activation of the present subsystem will only be added to the common cycle velocity when any obstacle is detected under the curtain (marked trough the "Detector de Obstáculos" variable that will multiply the velocity of the block by zero if not any obstacle is detected or by one when detecting any obstacle). The inputs of this subsystem will be the common cycle speed and the movement direction of the IRUDS, obtaining an emergency sum-up velocity as output. About the functional logic of this process, it must be said that direction will be the determining action parameter; selecting how to transform the input common cycle velocity as follows and launching the respective result:

- 0 (no movement) will multiply the velocity to add-up by zero; the curtain will stay on its same position. A sonorous alarm will be raised, and the events will be recorded.
- x > 0 (opening) will multiply the velocity to add-up by 0; the curtain will continue its opening process. A sonorous alarm will be raised, and the events will be recorded.
- x < 0 (closing) will multiply the velocity to add-up by a -5 negative constant; the curtain will cancel its closing process and move into its upper position. A sonorous alarm will be raised, and the events will be recorded.

Human-Machine Interface: Satisfied Requirements and Implementation.

Once having explained the inputs, outputs, and specific operational logic of each subsystem in the design, the generated operational implementation dashboard will be presented remarking satisfied initial requirements covered by each element.

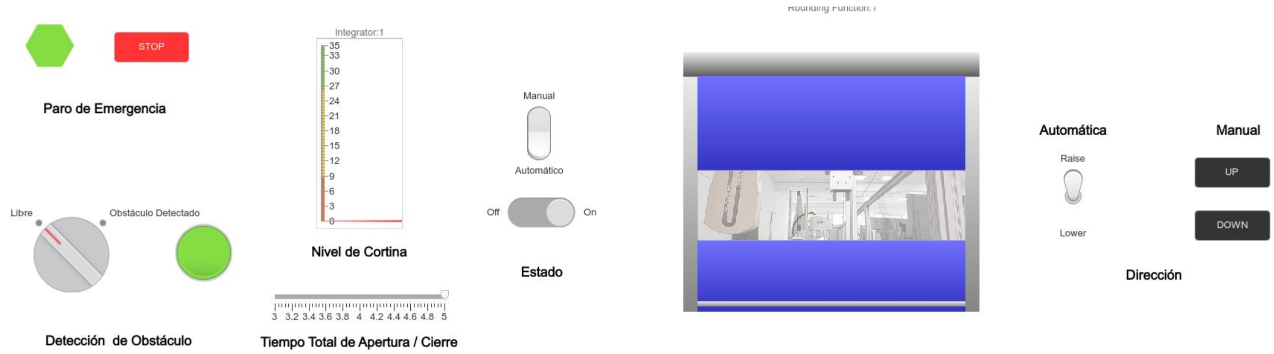

Figure 4. Operational Dashboard

The following chart resumes the functionality of each element in this presented system.

Table 1. Dashboard Elements Satisfaction of Requirements.

Dashboard Element	Type of Element	Satisfied Requirement
Paro de Emergencia	Security Element	Will not allow any further functional operation movement or introduced parameter lecture by part of the system until it is returned to its original unpressed state; will also raise up a sonorous alarm and record the happening event (represented by the colored lamp).
Detección de Obstáculo	Security Element	Will take the IRUDS into its upper state position if moving while any animal, object or human obstacle is detected. This element will also raise an alarm and record the events (represented by the colored lamp).
Nivel de Cortina	Control and Monitoring Element	Will allow the operator to visualize on real time the position of the rolling door at any moment to place it into any desired position.
Tiempo Total de Apertura / Cierre	Operation and Parameter Manipulation Element	Will allow the supervisor to indirectly edit velocity parameters to achieve a 3-5 second total opening/closing time through a sliding switch.
Estado Manual / Automático	Operation and Parameter Manipulation Element	Will allow the operator to choose an either automated or manual functional methodology according to situational given requirements.

Estado On / Off	Operation and Parameter Manipulation Element	Will function as a break when operating on an automated mood allowing the movement of the curtain when ON and cancelling it when OFF; this same switch can either allow or cancel the manual operation buttons, however it will not function as a brake for manual operation as the mentioned process is yet automated.
Dirección Automática	Operation and Parameter Manipulation Element	Will allow the operator to choose the rolling direction of the industrial door when operating on an automated mode.
Dirección Manual UP	Operation and Parameter Manipulation Element	Will allow the operator to roll upwards the industrial door when operating on a manual mode while pressing this button.
Dirección Manual DOWN	Operation and Parameter Manipulation Element	Will allow the operator to roll downwards the industrial door when operating on a manual mode while pressing this button.

Final Conclusive Comments, Reflections and Observations

The presented generated automation system shows yet a refined and effective, while simple in terms of required control operations, automation program that works through highly visual, logically predictable, specific and common understanding dashboard; however, as it is a constant on human-made designs, total perfection will never become an achievable parameter; for so, the following section will identify the strengths and weaknesses of the presented final development with the purpose of proposing viable improvements so that the system covers the given operational, functional and safety requirements given in the present problem situation.

As main strengths of the final presented system, it must be mentioned that is operational process is based on simple sequential operations that led to a total control of the programmable system through a highly ordered, signaled and in general terms easy to follow subsystem division. It must also be mentioned that the system fulfills most of the given specifications for the IRUDS and is represented to a highly generally logical and easily understandable interface with various kinds of switches to avoid confusion, security color codes and numerically identifiable control parameters such as the real time position of the IRUDS of the total opening/closing time election sliding switch.

The main weaknesses of the presented system reside on the velocity manager, brake, and obstacle detector emergency upper state systems. The first weakness consists of having an unclear understanding of the applied set point functioning to determine the distance required to cover, which does not consider movement direction and thus results on an unprecise closing and opening velocity calculus. About the second point, it must be identified that the automatic mode break results manual while it shall be automatic and that the manual mood break results of an automatic nature while it shall be activated trough the usage of a push-up button or switch.

Finally, on the third identified weakness, it must be added that it has been identified that the electrical circuit implementation of an if-else-elseif module could become complex and laborious if not counting with desired computer programming conditions; to this point, it must be added that the upper emergency state is achieved by multiplying the actual velocity by an arbitrary negative constant (not an optimal value based on the corresponding calculus and theoretical backgrounds).

As improvement recommendations for the presented system, the used position set point and distance cover algorithm shall contemplate the corresponding direction of the curtain and must be studied to greater detail in search of viable changes in the algorithm. The brake systems of both operational modes must be exchanged trough the corresponding code redevelopments, and the upper state emergency subsystem may be simplified trough the usage of a switch of logical parameters or the usage of an absolute value block; if not simplified, the emergency arbitrary negative multiplication constant must be calculated to its optimal value.

As a persona and extra addition to the previously presented conclusory comments, it must be said that once generated the block diagram of necessities for the system, function and operational dashboards simulations must be carried out before defining precise sensor and actuator systems; this, as the computational simulation of the process allows to the identification of the primary and non-essential variables that shall or could take place in the process to optimize its functional characteristics with out investing on material, human and time additional resources.

Bibliographical References

[1] ITESM. (s.f.). Automating a Rolling Door. Canvas Course.
https://experiencia21.tec.mx/courses/262212/pages/description-of-the-problem-situation