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AUTOMATION SYSTEM OF A SMART HOSPITAL BED

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Abstract: *This paper has as its main purpose the description of the concept underlying the architecture and the mode of operation for the automation system and functionalities of a hospital bed, intended for people unable to move or manage independently. The general objective involves the development of an automation system capable of managing the functional modules that interact with the autonomous driving system, the hospital bed control system and the brain control system by processing the information received from the sensors, from the medical staff or from the patient and managing the commands sent to the actuators so as to ensure an advanced and autonomous control to increase patient comfort and reduce the load on personnel medical.*

Key words: *List 5-8 keywords. (10 pt, italic).*

1. INTRODUCTION

Into the era of "smart" paradigm that we are experiencing nowadays, engineers and designers can grow highly sophisticated functionality by integrating mechanical and electrical systems that aims to improve the functions and operation of the hospital beds [1]. This developing range of the medical applications, on the other hand, leads to higher production costs, with a vast impact from the point of view of affordability, especially in the developing countries [2].

With the increasing of aging rate of the world population, the growing demand for medical equipment and the lack of experienced medical personnel represents a major problem in patient care; therefore, in the coming years the challenge will be to manage to sustain the medical staff by decreasing the amount of physical interaction with patients [3].

As specific objectives, they are briefly presented below:

- Mechanical and electrical system design and development for hospital bed
- Electro-mechanical integration and development of software functionalities for the control of autonomous driving systems and hospital bed control.
- Interfacing the brain control system attached to the patient, extracting and processing useful information for reconfiguring bed positions and increasing the comfort level.
- Implementation of autonomous travel mode using a virtual map and semi-autonomous using a medical staff tracking system.
- Development of the local and remote manual control mode.
- Identification of ways to integrate the access and safety system of the hospital bed with the central ITC system of the medical unit.

2. SYSTEM ARCHITECTURE

The mechanical and electrical structure of the smart bed (Fig. 1) was developed and presented in another paper and is not the subject of this study. The developed smart bed can currently perform eight medical positions according to specific requirements, and there is also the option to develop three more positions [2].

In the current paper, the conceptual architecture of the hospital bed automation system is presented, along with the essential actuation or monitoring systems and elements.

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The essential systems are interconnected with each other and represent:

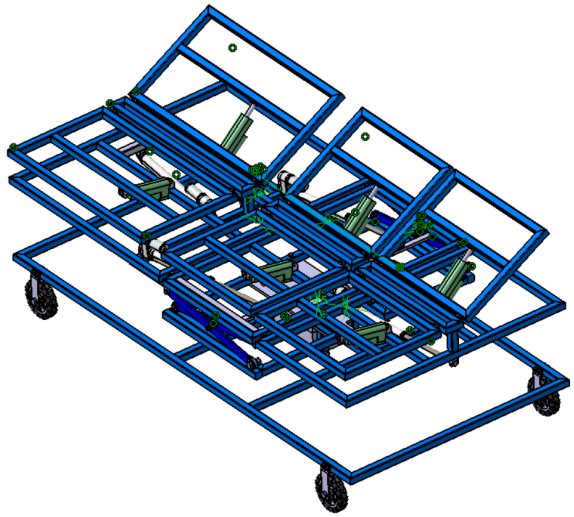

Fig. 1 Mechanical structure of the bed

1. hospital bed control system – with a role in modifying the positions of the hospital bed by means of actuators and sensors;
2. autonomous driving system – with a role in docking, connecting and powering to the hospital bed control system during medical procedures involving patient transport;
3. safety system – with the role of facilitating the patient's shutdown or securing of the mechanical component of the hospital bed control system;
4. brain control system – with the role of interpreting the brain waves generated by the patient's brain activity in the situation in which he wants to change the position in which he is and to transmit commands to the mechanical system.

2.1 Autonomous driving system

The main objective of the autonomous management system is to facilitate the safe transport of hospital beds where patients with locomotor disabilities are admitted for various medical investigations.

The implementation of the main objective is achieved through the key elements presented within the Autonomous Driving System functional block of the automation system architecture. The control element is a hybrid system consisting of a Programmable Logic Controller (PLC) and an industrial process computer with Windows 11 operating system.

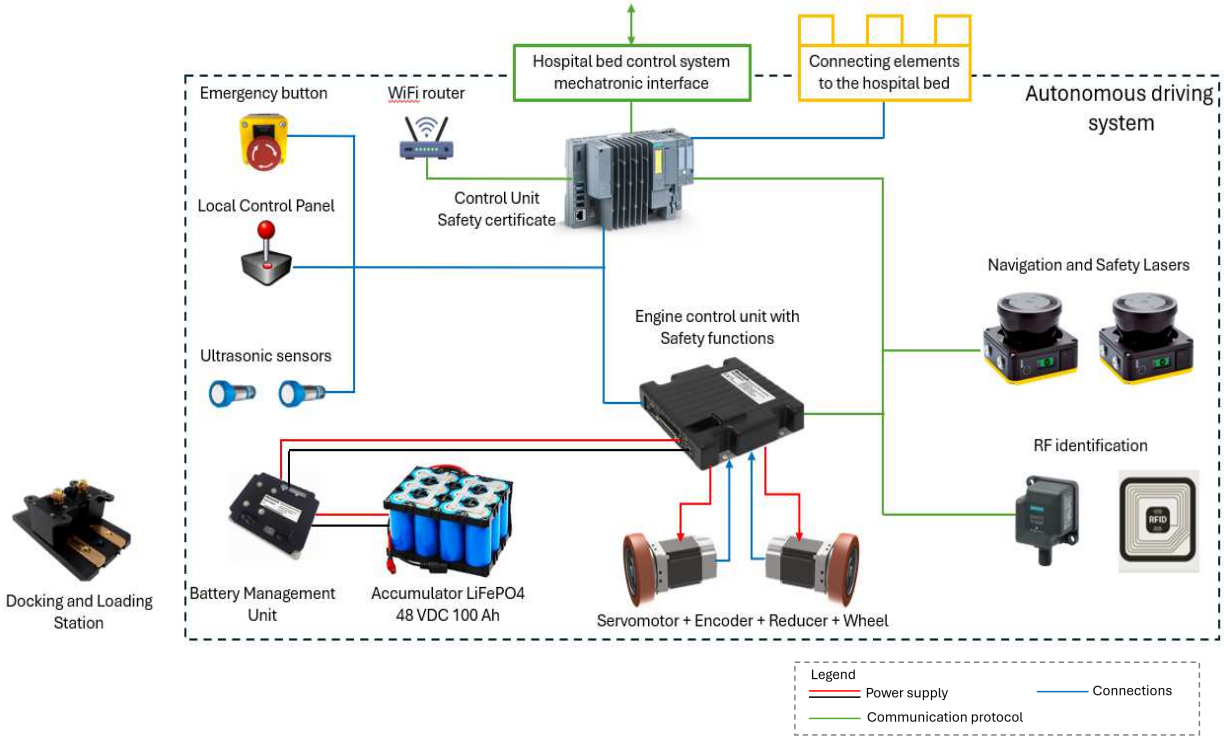

Fig. 2 Autonomous driving system

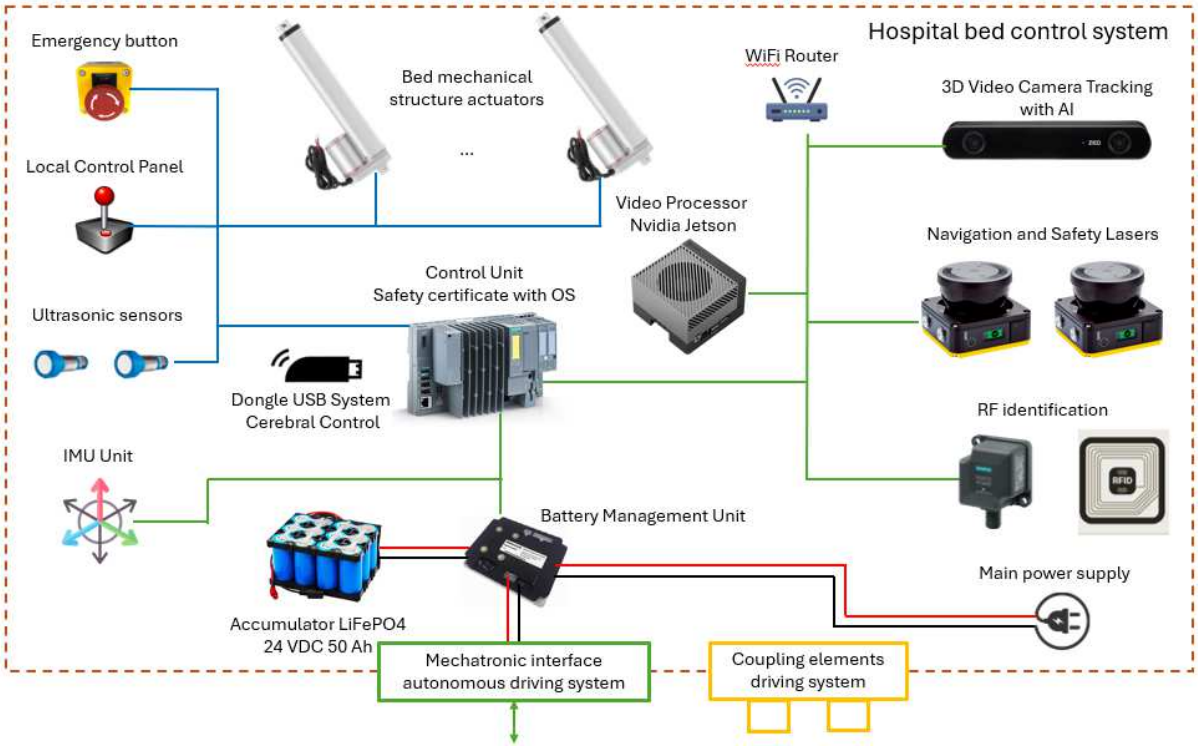

Fig. 3 Hospital bed control system

The Logic Programmable Logic Controller through the control algorithm, the input/output system and the communication protocols ensures real-time interaction with the actuators and sensors of the autonomous driving system:

- ✓ It communicates with the engine drive unit for movement in space by transmitting the parameters of speed, acceleration and distance.
- ✓ interact with the radiofrequency identification system to: operate the mechanical coupling elements to the control system of the bed to be taken over, facilitate the authentication process and access to the hospital infrastructure and allow the registration in RFID tags of important data for the traceability of the actions performed.
- ✓ ensures safe emergency shutdown when the emergency button is pressed.
- ✓ It processes data from ultrasonic sensors in order to assist the navigation and driving process in certain atypical cases or with a medium to high degree of uncertainty.
- ✓ It takes over the signals generated by the actions of a human operator on the local control panel and facilitates operation in fault mode or manually.
- ✓ facilitates through the mechatronic interface the transfer of data, information, signals and energy with the hospital bed control system during transport.
- ✓ allows the control and debugging of the program application executed by the PLC remotely through a router-type networking equipment.
- ✓ The industrial process computer allows the execution of complex programs and applications that require processing resources and that have been designed to run on the platform offered by Windows operating systems:
- ✓ facilitates the synergy between a process computer and a control unit intended for interaction with actuators and sensors.
- ✓ Allows storing a virtual model with the navigation space configuration.
- ✓ integrates and processes data from laser navigation and safety sys for real-time

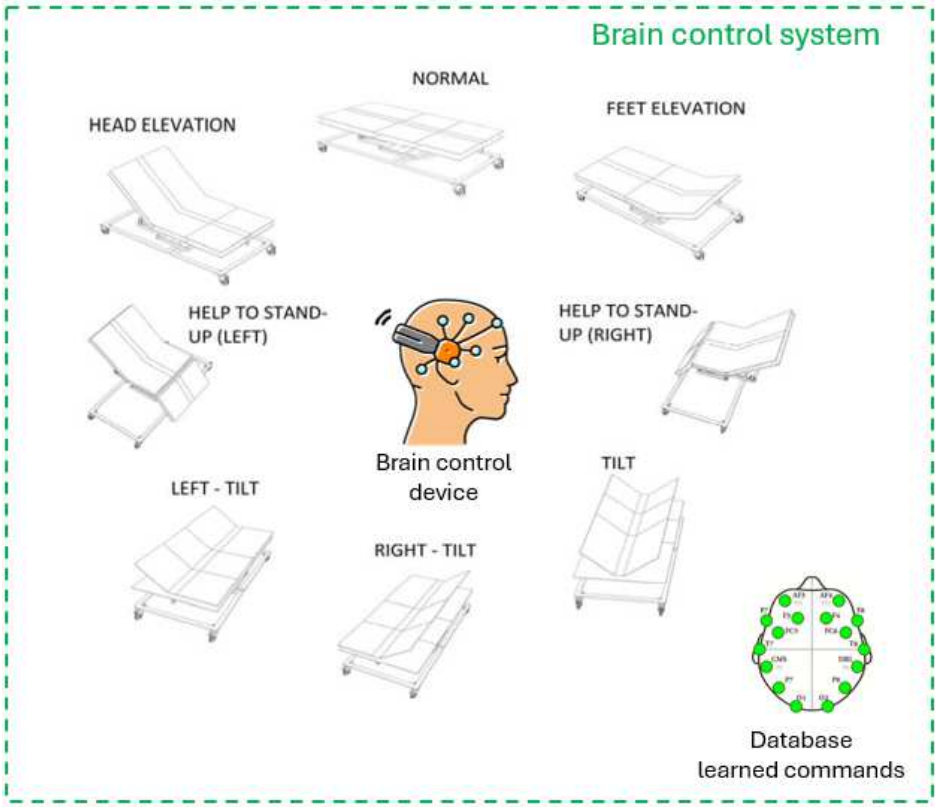

Fig. 4 Brain control system

navigation and transmits space movement parameters that PLC.

- ✓ provides a favorable environment for the installation of software programs such as: Matlab or other engineering programs necessary for the configuration of the components of this system.
- ✓ allows remote operation of the autonomous driving system.
- ✓ sends notifications to the medical staff and saves information in the hospital's IT system

2.2 Hospital bed control system

The main objective for the hospital bed control system is to control the actuators connected to the mechanical structure of the bed and change their configuration.

Changing the configuration of the actuators has the effect of reconfiguring the position of the bed according to the desired position. The desired position is transmitted to the hospital bed control unit in the form of a mental command triggered by the patient and identified, validated and transmitted by the brain control system.

The secondary objective is to switch between navigation and safety systems after coupling the autonomous driving system with the hospital bed control system to keep the autonomous navigation functionality working properly and safely.

The implementation of the objectives is achieved through the key elements presented within the functional block Hospital bed control system from the automation system architecture.

The control element is a hybrid system consisting of a Programmable Logic Controller (PLC) and an industrial process computer with Windows 11 operating system.

The Logic Programmable PLC through the control algorithm, the input/output system and the communication protocols ensures real-time interaction with the actuators and sensors of the hospital bed control system.

Actuators connected to the mechanical structure of the hospital bed are controlled by the management units to change the physical configuration of the hospital bed and facilitate the safe modification of the position of the patient in bed. The modification of the physical

configuration aims to ensure a higher degree of comfort but also to avoid the appearance of medical problems generated by the patient's lack of movement.

Each configuration of the hospital bed must be defined and stored in advance in the memory of the program application that is executed by the control unit. A configuration involves modifying one or more actuators. The achievement of a position is ensured by means of the feedback elements of the actuators.

Through the integrated functionalities, information about the degree of charge, battery voltage, voltages, currents and temperature of each battery cell as well as statistics and reports are transmitted to the control unit. Based on this information, the control unit can notify via the hospital's IT infrastructure if an automated hospital bed needs to be loaded.

The Video Processing equipment and the 3D Video Camera with Artificial Intelligence located on the structure of the hospital bed are used to implement a mode of movement that generates movement coordinates based on the tracking of a visual identifier placed on the medical staff.

RF Identification equipment uses radio wave technology to contactlessly read or write information from electronic devices with or without their own power source, called RFID tags.

2.3 Brain control system

The brain control system consists of a helmet with a control unit, Bluetooth transmitter-receiver and electrodes whose main objective is to perform an Electroencephalography (EEG). This is a non-invasive method of monitoring and recording the electrical activity of the brain by placement of electrodes on the scalp.

Electrodes from the scalp it collects signals from the brain, providing information about thoughts, emotions and mental health. The collected signals are amplified and digitized by the headset control unit. Then, through a wireless communication protocol, the information is sent to the process computer of the hospital bed control unit for storage and processing.

Through a software, developed by the manufacturer of the brain control headset, which runs on the process computer of the hospital bed control unit, a learning procedure specific to each patient is performed.

The learning procedure is a repetitive process lasting 2 hours through which the patient is motivated to think only about a certain configuration of the hospital bed, when significant brain activity is detected, it is memorized and confirmed as a pattern of brain activity for that configuration of the hospital bed. After a sufficient number of repetitions, a statistical pattern for brain activity specific to a certain configuration is generated. The learning procedure should be performed for all hospital bed configurations, shown in Figure 1.

After the brain control system has been learned and brain activity has been assigned to some hospital bed configurations, the information is saved in the database of learned commands.

When the patient thinks, the brain control system analyzes the brain activity and if it fits into an existing model or template in the database, a command is generated to the process computer of the hospital bed control unit. The command is taken over by an interface software module called node-Red and then transmitted to the programmable logic controller of the control unit that controls the management units so that the desired hospital bed configuration is achieved.

3. CONCLUSION

The analysis of the current state indicated an untapped research niche with a remarkable potential for applicability in the medical field.

The added value that the architecture of the automated hospital bed presented in this project has in the medical institutions intended for the care of partially or totally immobilized patients is significant.

The novelty element within the architecture of the hospital bed is represented by the integration of a brain control system with an autonomous hospital bed.

Motivating an immobilized patient to go through the learning steps necessary for the

brain control system to correctly recognize the commands generated brings an important contribution in terms of the patient's independence and facilitates the increase of motivation levels.

Thus, the lack of solutions to compensate for the precarious situation of the immobilized persons facilitates the implementation of the architecture presented above.

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SISTEM DE AUTOMATIZARE A UNUI PAT DE SPITAL INTELIGENT

Abstract: Lucrarea evidențiază descrierea conceptului care sta la baza arhitecturii si modul de functionare pentru sistemul de automatizare si functionalitatile unui pat de spital, destinat persoanelor afalte in incapacitate de a se deplasa sau gestiona independent. Obiectivul general implica dezvoltarea unui sistem de automatizare capabil sa administreze modulele functionale care interactioneaza cu sistemul autonom de conducere, sistemul de control pat spital si sistemul de control cerebral prin procesarea informatiilor primite de la senzori, de la personalul medical sau de la pacient si gestionarea comenzilor trimise actuatorilor astfel incat sa asigure un control avansat si autonom pentru a creste confortul pacientilor si a reduce incarcarea personalului medical.

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