Autonomous Mobile Robots Using Machine Learning Methods to Recognise the Rapid Spread of the Ongoing COVID-19 Epidemic

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Abstract: The purpose of this article is to implement an algorithm that allows an autonomous ground robot to intervene for the rapid identification of patients with symptoms of COVID-19 in the absence of the medical staff needed to sort patients in hospitals. Based on this autonomous mobile robot-type UGV, it is possible to quickly detect people who show signs of infection with COVID-19. In order to address these problems, investigative equipment (for 3D perception, mapping, navigation, thermal scanning, thermal imaging, detection of facial expressions and of the presence or absence of masks, etc.), as well as behavioral control work were considered on complex scenarios, initially generated online and then by introducing random obstacles. The obtained results showed that the use of mobile robots for special purposes is thus an excellent solution, both for reducing the exposure of medical personnel to the virus, and for increasing the capacity to identify, analyse and warn about the observance of the protection protocols against COVID-19.

Keywords: Autonomous vehicle, Stability, Mobility, Engine, COVID-19, Unmanned ground vehicle.

1. Introduction

The SARS-CoV-2 virus (severe acute respiratory syndrome 2, coronavirus 2019-nCoV, or COVID-19) pandemic is considered by all the states, governments and non-governmental organizations to be one of the greatest extant threats to public health. Unpredictability is a determining factor of the current health crisis (Kaplan et al., 2021; Anderson et al., 2020). It has manifested itself in the evolution/involution graphs (so-called saw tooth graphs) of the endemic, which results in increases followed by successive decreases in the number of cases over short periods of time (Kapecki, 2020; Hariri-Ardebili, 2020). All these have been reflected in the medical field, in which blockages generated by the lack of medical staff, medical equipment and protective materials are continuing to cause problems (Eissa, 2020).

In this context, as humanity is faced with the COVID-19 pandemic, it may be fruitful to consider the use of unmanned ground vehicles (UGVs) (Jameel et al., 2019). Depending on the missions they must perform, UGVs can have wheeled or tracked propulsion systems (Ye & Borenstein, 2003). A mobile robot can be practically transformed from a computer on wheels, which is able only to detect certain characteristics of the environment through its own sensor system, into an intelligent agent, which is able to identify characteristics, to learn from experience, to self-locate and to surf. Thus, this area of study could support the fight against the spread of the new coronavirus.

The main requirements imposed on the simulation process for UGVs are: a high degree of generalization, a high degree of constructive detailing and increased flexibility (Militano et al., 2016; Yang et al., 2018). These requirements must allow the definition of terrain types, obstacles, environmental conditions, ease of operation and the ability to interact with dedicated data analysis programs. The characteristic situations for simulation (Palafox et al., 2019; Chu et al., 2015) are the following:

- Rolling speed on non-deformable terrain: horizontally or with longitudinal slopes of maximum 17% rectilinear direction of travel and wide turning radii; and horizontally with natural or artificial obstacles, with a direction of rectilinear movement for a short time and with small turning radii and gauge restrictions.

- Low-speed rolling on deformable terrain: horizontally with longitudinal and transverse slopes, with natural or artificial obstacles, with a rectilinear direction of travel and with variable radii.

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The functional parameters that determine the mobility of the autonomous robot are the following: acceleration, manoeuvrability, the ability to pass different types of obstacles and the ability to orientate in the field (video, acoustics, etc.).

Figure 1 shows the terrain modelling, which is based on information about tread geometry, robot speed and acceleration, terrain topography, shape and size of obstacles and tread changes (Shiller & Yu-Rwei, 1991; Ciobotaru et al., 2006).

The sensor systems communicate with each other and with the ground control station (GCS) via the Raspberry Pi III, IV and NVIDIA Jetson Nano (V3) controllers. The displacement and coordination algorithms take into account the fact that the working environment is an unstructured environment and the atmospheric variations (temperature, pressure, humidity, air flow) are random. In this pandemic period, the emergency interventions have become a reality that can no longer be ignored. Perception, knowledge, decision and communication algorithms aim to reduce planning and reloading time (Zhang et al., 2020).

The shortage of personal protective equipment (PPE) for critical situations has led to take into consideration the creation of a robot that can intervene in place of human personnel to perform measurements and to intervene in order to reduce or eliminate the effects of SARS-CoV-2. The robots can reduce the COVID-19 respiratory infections if they involve the development of a modular UGV, which can be equipped with different operational platforms, depending on the tasks they have to solve.

The present study proposes the simulation of a six-by-six vehicle model, for which experimental data capable of validating the simulation methods adopted are used. This simulation is based on identifying references in the medical field regarding the use of specialized programs and methodologies for evaluating unmanned ground vehicle (UGV)-type autonomous mobile robots. Particular attention was paid to the identification of operational requirements, namely, the volume of input data, as well as on the analytical functional quantities determined. Quantifying the efficiency of a UGV is in fact a balance between output load and energy consumption. In addition, the movement planning algorithms for this robot are based on different types of uncertainties.

In search of a universally available COVID-19 detector, the purpose of this article is to present a virtual model of an autonomous, all-terrain vehicle, in the six-by-six formula, that can be used as a mobile telemedicine platform and that can help in the triage of patients suspected of having COVID-19. Aspects related to the virtual model of the mobile platform, as well as the mobility and stability of the mobile platform are described in the present study which is conducted in order to design and implement the technology demonstrator. The obtained results showed that this model can be used in the recognition of some of the most common symptoms of patients with the SARS-CoV-2 virus. Furthermore, this

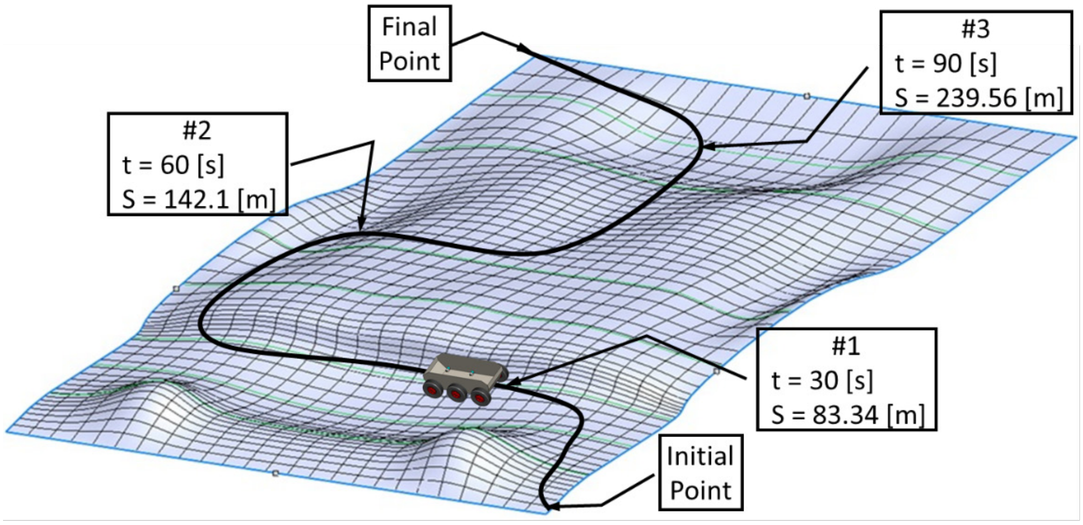

Figure 1. Model for optimizing the runway of an autonomous robot

paper also describes the analytical-numerical models that are used for navigation planning, depending on the tasks and obstacles that may arise. In order to address these problems, investigative equipment (for 3D perception, mapping, navigation, thermal scanning, thermal imaging, detection of facial expressions and of the presence or absence of masks, etc.), as well as behavioral control work were considered on complex scenarios, initially generated online and then by introducing random obstacles.

The remainder of the paper is organized as follows: in Section 2, previous research regarding kinematics model of analytical UGV is discussed. Section 3 analyses the dynamic model of analytical UGV. Section 4 focuses on the experimental results and discusses the findings. Section 5 draws the conclusions and proposes a future work in this area.

2. UGV Kinematics Analytical Model

The terrestrial mobile robot is a multibody system (MBS), in which the components fall into the category of rigid bodies (Peng et al., 2018). A multibody system is a finite set of rigid bodies, physically and geometrically interconnected with each other, working within a field that does not belong to the MBS. The construction of the MBS assembly is achieved by establishing and imposing kinematic and dynamic constraints, which describe the modes of geometric interconnection: degrees of freedom, forces and moments.

In order to be able to analyze a rigid body in a fixed coordinate system it is necessary to determine, from a kinematic point of view, the set of position vectors of the complete structure and/or its component elements. The kinematic model of the robot (Dénes & Gábor, 2013; Said et al., 2018) with six driving wheels, without any of them being directional, is made based on the following hypotheses: (1) the following phenomena are neglected: forces, moments and friction; (2) the description of the kinematic equations is based on a coordinate system in the plane $\{2D|Z=0\}$; (3) the lateral dimension of the vehicle is considered zero; and (4) the wheels are symmetrical.

The equations describing the kinematics of the terrestrial mobile robot analyse its direct stationary linear laminar stability. The system described in Figure 2 is a kinematic model of

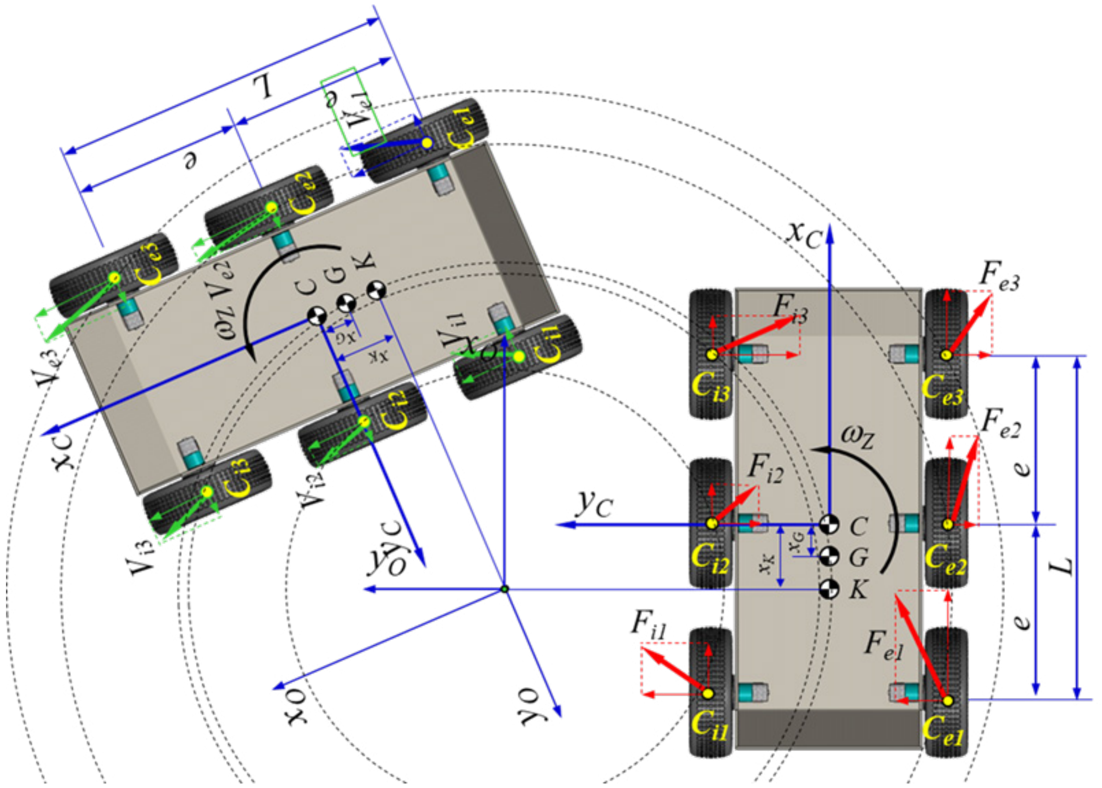

Figure 2. (a) Qualitative graph of lateral force Fy according to sliding angle α and normal force; (b) Sliding top view model with asymmetrical front and rear sliding angles

a terrestrial robot on wheels, established based on the assumptions described above. In reality, in order to be able to overlay the results of the analytical/numerical models with those obtained from the experiments, the models must be constructed taking into account as many degrees of freedom as possible. Thus, it follows that systems of equations with ordinary derivatives (ordinary differential equations (ODEs)) and/or with partial derivatives (partial differential equations (PDEs)) require analytical-numerical solving methods, or even the use of empirical, approximate methods. There are also analytical solutions that use delay differential equations (DDEs) which describe the initial dimensional structure and use fewer parameters and state variables than ODE or PDE systems.

The general equation describing the motion of our robot in the plane is given as follows

$$\dot{X}_{CG} \cdot \cos\psi + \dot{Y}_{CG} \cdot \sin\psi = v\left[{}^{m}\!/_{s}\right] \quad (1)$$

Equation (1) is used for a non-holonomic system, and it is based on the Appel–Gibbs equations. The vector orientation of the velocity v [m/s] is similar to the choice of a pseudo-velocity δ [m/s], which respects the kinematic constraints:

$$\begin{cases} \delta_f = -\dot{X}_{CG} \cdot \sin\psi + \dot{Y}_{CG} \cdot \cos\psi\,[\mathrm{m/s}] \\ \delta_f = \dot{\psi}\,[\mathrm{m/s}] \end{cases} \quad (2)$$

From equations (1) and (2), it results:

$$\begin{cases} \dot{X}_{CG} = -\delta_f \cdot \sin\psi + \dot{Y}_{CG} \cdot \cos\psi\,[\mathrm{m/s}] \\ \dot{Y}_{CG} = v \cdot \sin\psi + \beta_f \cdot \cos\psi\,[\mathrm{m/s}] \\ \dot{\psi} = \delta_s\,[\mathrm{m/s}] \end{cases} \quad (3)$$

The carrier platform, the terrestrial robot on six-by-six wheels (all wheels are motorized) designed in the present work is characterized by non-holonomic behavior, due to the effects of the interaction of the wheels with the tread, and also due to the hysteresis of the rubber. Differential equations with second-order partial derivatives (SOLPDEs) are used for the description of equations of motion. The flattening of the wheel during travel and the action of shearing during cornering produce tension in the wheel, and therefore, the contact spot has a variable size, as shown in Figure 3.

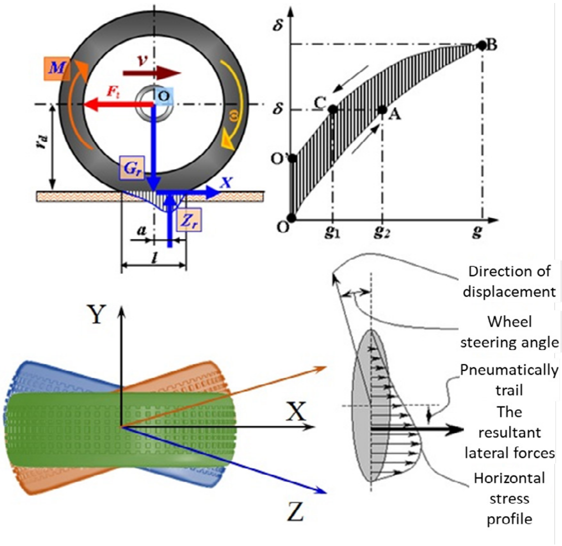

Figure 3. Representation of the interaction between the wheel and the running track

Therefore, the equations that describe the movement of the robot must also include the sensors of movement and the movement of the wheels, whose data induce the necessary corrections regarding the power supply of the electric motors as shown in Figure 4. There are three distinct types of cases for the analysis: free running, running with the wheel braked and rolling the driven wheel (Saafi et al., 2020; Tringali & Cocuzza, 2020).

$$\begin{cases} \dot{p}_f\left(X_f,t\right) = -\delta_s - \left(l+e+X_f\right)\cdot\delta_r - p'_f\left(X_f,t\right)\cdot\dot{X}_f\,[\mathrm{m/s}] \\ \dot{p}_r\left(X_r,t\right) = -\delta_s - \left(l+e+X_r\right)\cdot\delta_r - p'_r\left(X_r,t\right)\cdot\dot{X}_r\,[\mathrm{m/s}] \end{cases} \quad (4)$$

Figure 4 shows that the equations that describe the direction are differential equations, which enable the designed robot to have a high maneuverability, similar to that of a crawler robot. The 6x6 robot kinematics description refers to the following features: the drive wheels are not steering wheels; the robot turns only by changing the rotational speeds of the drive wheels; cornering radii are dependent on: the speed of rotation of the drive wheels, the coefficient of adhesion with the ground and the sliding coefficients. If there is a uniform rectilinear motion regime and the conditions of motion are considered ideal, kinematics is not influenced by any factor. In reality, even the pressure in the feathers influences the way in which the contact with the ground of the wheel balloon is made. Other elements that influence the robot's kinematics are the position of the center of gravity and the weight of the robot.

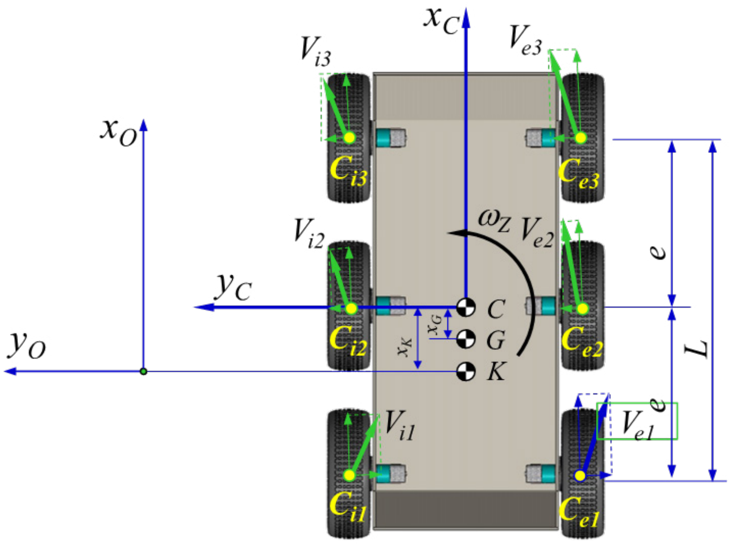

Figure 4. Representation of the result of the speed vectors of the 6 drive wheels

3. UGV Dynamic Analytical Model

This analytical model describing the dynamics of the six-by-six robot takes into account the angular speed of the wheels. This algorithm was chosen because the speed of the robot is given by the rotational speed of the wheels, which, in turn, are controlled by changing the supply voltage using a controller (Heshmati-Alamdari et al., 2020; El-Shafeiy et al., 2018). The dynamic model of the robot (Tavoosi et al., 2018; Zhang & Li, 2020) presented in this paper is given by the following system of equations regarding the action of forces and moments on the propeller:

$$\begin{cases} F_{x1E}+F_{x2E}+F_{x3E}+F_{x1I}+F_{x2I}+F_{x3I}-R_x-m\cdot\dfrac{v_{CG}^2}{R}\cdot\sin\beta=0\,[\mathrm{N}] \\ F_{y1E}+F_{y2E}+F_{y3E}+F_{y1I}+F_{y2I}+F_{y3I}=m\cdot\dfrac{v_{CG}^2}{R}\cdot\cos\beta\,[\mathrm{N}] \\ M_d-M_r=0\,[\mathrm{N}\times\mathrm{m}] \end{cases} \tag{5}$$

where $F_{x1E}, F_{x2E}, F_{x3E}, F_{x1I}, F_{x2I}, F_{x3I}\,[N]$ represent the longitudinal friction forces; $F_{y1E}, F_{y2E}, F_{y3E}, F_{y1I}, F_{y2I}, F_{y3I}\,[N]$ represent the lateral forces; $R_{x1E}, R_{x2E}, R_{x3E}, R_{x1I}, R_{x2I}, R_{x3I}\,[N]$ represent the forward/rolling resistances; $M_d\,[\mathrm{N}\times\mathrm{m}]$ is the engine torque and $M_r\,[\mathrm{N}\times\mathrm{m}]$ is the moment of resistance.

According to Tavoosi, Marzbanrad and Mirzaei (2018), depending on the deformation coefficient $j\,[-]$, the stress τ [N / m2], or the tangential unit effort, in the wheel is given by the following:

$$\tau=p\cdot\mu\cdot\left(1-e^{-\frac{j}{k_\gamma}}\right)\left[{N}/{m^2}\right] \tag{6}$$

where p [N / m2] is the normal ground pressure; $\mu\,[-]$ is the coefficient of friction and $k_\gamma\,[-]$ is the shear deformation modulus coefficient. For the robot designed and represented in Figure 4, the longitudinal sliding forces and the lateral forces are given by the following:

$$\begin{cases} F_{xfR}=\int_{-\frac{L}{2}}^{\frac{L}{2}}\int_{-\frac{b}{2}}^{\frac{b}{2}}p_R\cdot\mu_R\cdot\left(1-e^{-\frac{j_{fR}}{k_{\gamma R}}}\right)\cdot\sin\left(\pi+\omega_{\gamma R}\right)\cdot dx_R\cdot dy_R\,[\mathrm{N}] \\ F_{yfR}=\int_{-\frac{L}{2}}^{\frac{L}{2}}\int_{-\frac{b}{2}}^{\frac{b}{2}}p_R\cdot\mu_R\cdot\left(1-e^{-\frac{j_{fR}}{k_{\gamma R}}}\right)\cdot\cos\left(\pi+\omega_{\gamma R}\right)\cdot dx_R\cdot dy_R\,[\mathrm{N}] \end{cases} \tag{7}$$

$$\begin{cases} F_{x1E}=\int_{-\frac{L}{2}}^{-\frac{C}{2}}\int_{-\frac{b}{2}}^{\frac{b}{2}}p_{1E}\cdot\mu_{1E}\cdot\left(1-e^{-\frac{j_{1E}}{k_{\gamma 1E}}}\right)\cdot\sin\left(\pi+\omega_{\gamma 1E}\right)\cdot dx_{1E}\cdot dy_{1E}\,[\mathrm{N}] \\ F_{y2E}=\int_{-\frac{L}{2}}^{-\frac{C}{2}}\int_{-\frac{b}{2}}^{\frac{b}{2}}p_{2E}\cdot\mu_{2E}\cdot\left(1-e^{-\frac{j_{2E}}{k_{\gamma 2E}}}\right)\cdot\cos\left(\pi+\omega_{\gamma 2E}\right)\cdot dx_{2E}\cdot dy_{2E}\,[\mathrm{N}] \\ F_{y3E}=\int_{-\frac{L}{2}}^{-\frac{C}{2}}\int_{-\frac{b}{2}}^{\frac{b}{2}}p_{3E}\cdot\mu_{3E}\cdot\left(1-e^{-\frac{j_{3E}}{k_{\gamma 3E}}}\right)\cdot\cos\left(\pi+\omega_{\gamma 3E}\right)\cdot dx_{3E}\cdot dy_{3E}\,[\mathrm{N}] \end{cases} \tag{8}$$

$$\begin{cases} F_{x1I}=\int_{\frac{C}{2}}^{\frac{L}{2}}\int_{-\frac{b}{2}}^{\frac{b}{2}}p_{1I}\cdot\mu_{1I}\cdot\left(1-e^{-\frac{j_{1I}}{k_{\gamma 1I}}}\right)\cdot\sin\left(\pi+\omega_{\gamma 1I}\right)\cdot dx_{1I}\cdot dy_{1I}\,[\mathrm{N}] \\ F_{y2I}=\int_{\frac{C}{2}}^{\frac{L}{2}}\int_{-\frac{b}{2}}^{\frac{b}{2}}p_{2I}\cdot\mu_{2I}\cdot\left(1-e^{-\frac{j_{2I}}{k_{\gamma 2I}}}\right)\cdot\cos\left(\pi+\omega_{\gamma 2I}\right)\cdot dx_{2I}\cdot dy_{2I}\,[\mathrm{N}] \\ F_{y3I}=\int_{\frac{C}{2}}^{\frac{L}{2}}\int_{-\frac{b}{2}}^{\frac{b}{2}}p_{3I}\cdot\mu_{3I}\cdot\left(1-e^{-\frac{j_{3I}}{k_{\gamma 3I}}}\right)\cdot\cos\left(\pi+\omega_{\gamma 3I}\right)\cdot dx_{3I}\cdot dy_{3I}\,[\mathrm{N}] \end{cases} \tag{9}$$

where $j_{1E}, j_{2E}, j_{3E}, j_{1I}, j_{2I}, j_{3I}\ [-]$ represent the movements of each wheel and $\omega_{\gamma 1E}, \omega_{\gamma 2E}, \omega_{\gamma 3E}, \omega_{\gamma 1I}, \omega_{\gamma 2I}, \omega_{\gamma 3I}\ \left[{}^{rad}\!/_{s}\right]$ represent the angular velocities of the wheels.

This type of architecture facilitates the integration of new hardware and software with sensors, motors, motor control drivers and other equipment that are part of the hardware structure of a UGV.

4. Experimental Results and Discussion

For the development of the payload, hardware and software for the analyzed demonstrator, a certain generalization was tried, in the hope that it can be implemented on other mobile robotic platforms with application programming interfaces (APIs) and customized loading capacities. The robot is a robust solution that can be used in ad-hoc environments (medical tents, hospital parking lots, hospital halls, medical wards, etc.). Considering the constructive specifications presented above, the proposed UGV constructive architecture allows the following: active optimization of heterogeneous subsystems; temperature testing of people in the movement/action area of the robot; real-time transmission of data taken by sensors to the ground control station (GCS) for real-time evaluation; integration of algorithms specific to each subsystem; coordination and synchronization of the movement of the final effector, depending on the internal/external area, the running track and the different obstacles, distinguishing living obstacles from artificial ones; integration of inertial navigation systems (INSs) with inertial measurement units (IMUs) and global positioning system (GPS) and orientation sensors; open-source software. It should be noted that, in the presented model, the notions specific to autonomous collaborative robots were approached. The principle of operation refers to the design and implementation of specialized platforms. These platforms, which consist of hardware and software elements, are able to communicate with each other. The hardware of a six-by-six unmanned ground vehicle (UGV) is defined by all the components (Figure 5) necessary to perform all the following actions:

1. ***Perception*** – it is defined by technologies that include sensors. There are no metrics and procedures for benchmarking algorithms, so the solutions are almost unique and are based on individual measurements and calibration procedures;
2. ***Planning*** – it is the process of generating a trajectory of movement from a starting position to an objective position, while avoiding environmental obstacles. The planning algorithm considers the travel data as positive elements, and the obstacles that must be bypassed between the starting points and the objective points as negative elements;
3. ***Mission*** – it is the result of the autonomous planning, which goes far beyond route planning. The definition of the mission by the UGV is in fact an assumption (from the point

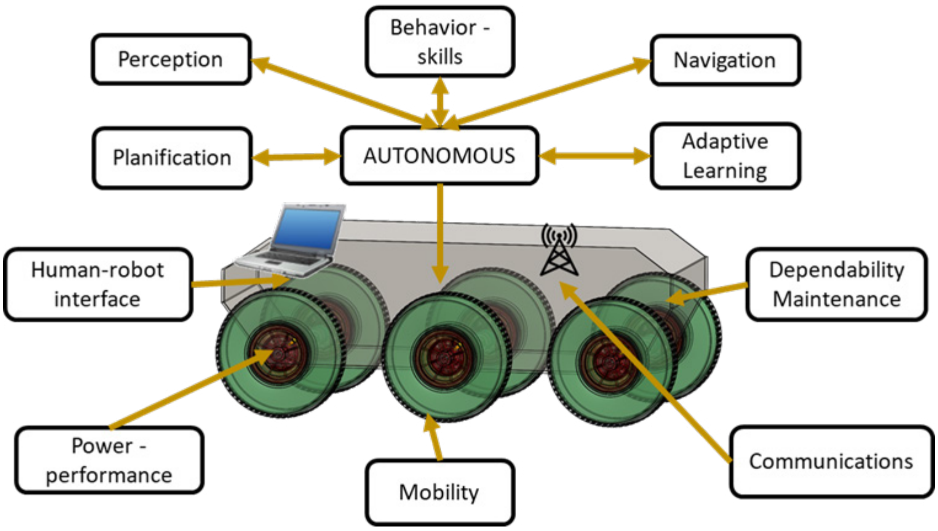

Figure 5. Representation of UGV hardware components

of view of AI) of the objective, conditions, and operating procedures (for example, travel legislation on public roads);

4. ***Communication*** – it depends on the autonomous mode of operation, the UGV needs a communication system with high bandwidth, low latency, and high reliability: - *in the case of teleoperation*, the communication channel is placed directly in the control loops between the vehicle and its associated systems (sensors, effectors). Teleoperation requires the operator to have a continuous line of communication with the vehicle being controlled (any "dead zone" in coverage could quickly become a black hole into which the vehicle is sent), and the robot must also operate over short distances; - *in the case of wireless solutions*, communication technology options need to reach Technology Readiness Level 6 (TRL 6). Wireless solutions may cause problems if the network connectivity is affected by the non-line-of-sight (NLOS) interference caused by terrain or obstacles (e.g., building walls);

5. ***Navigation*** – it is based on the integration of perception, planning, communications, various navigation techniques, and so on.

For local navigation, sensors to perceive the environment and to plan movement in real time are used. The robot can be controlled remotely by teleoperation, even if its functionalities due to sensors, Electro-Optical/Infra-Red (IR/EO) video cameras and any other attached devices allow data sampling, otherwise it will move autonomously. Because the working environment is unstructured, GPS equipment is necessary in order to implement learning techniques (machine learning and deep learning) used to perceive and plan movements.

The controllers that equip the proposed UGV are based on accessible commercial off-the-shelf (COTS) components (Tsolakis et al., 2019). The ability to solve various autonomous, task-oriented missions creates the necessary capabilities to identify and solve both predefined and random tasks (Wang et al. 2016; Palafox et al., 2019). The integration of systems, leading to the flow of information between the command-and-control station (the controller itself) and the GCS, is a feasible approach. The designed UGV has the following subsystems: locomotion, energy, positioning, sensors, navigation, movement control, communications, human–machine interaction (HMI) interface, mission control and payload control (Galimov et al., 2020; Ha & Hong, 2019). The operating diagram (Figure 6) shows the main components, including the remote control (RC) receiving station.

To identify, analyze and warn about the compliance with the protection protocols against COVID-19, the robot operates according to the following algorithm:

- Moves and makes a tour to detect and locate the land to be covered;
- With the help of sensors, it identifies the presence of people and directs the camera towards them;
- Starts the routines specific to identifying the wearing of a mask and social distancing;
- Continuously calculates runway data, indicating their position in relation to the reference system defined as the origin;
- Identifies possible obstacles.

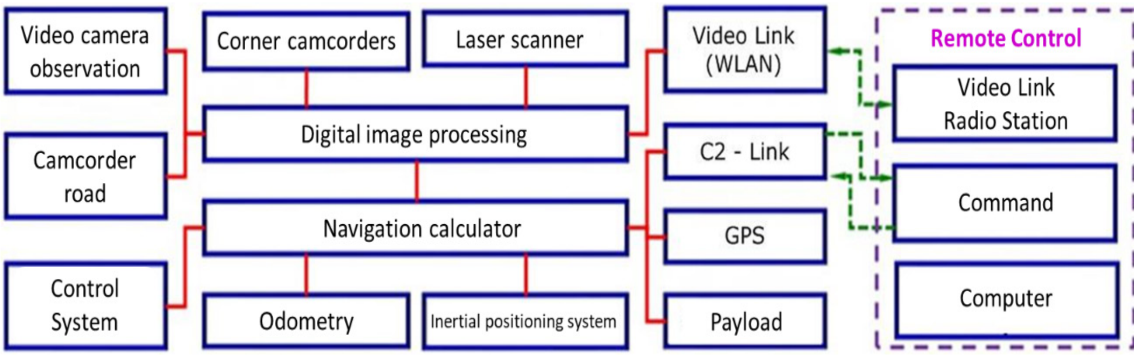

Figure 6. Logic diagram corresponding to the UGV's hardware architecture

Also, what is new in this current evolution of the model it that it is not just pure communication, as in the case of previous updates of professional regulations with newly developed technologies. What should be especially noted as being imperative is the fact that is operates as a human sensory perception which can be complemented and reinforced by information technology, without the spatial proximity between doctor and patient.

On top of that, the UGV designed by us thus allows structural innovation in the diagnosis of patients, and based on the information provided can comprehensively improve the quality of treatment and processes, as well as the efficiency of care for relevant groups of patients. Moreover, the model proposed in this study allows for the subsequent care of the patient who has been diagnosed with COVID 19 symptoms, supports efficient clinical trials and a safe environment for patients and healthcare workers. It can supplement the work of doctors and nurses so that personal contact can be minimized in the sections intended for infectious diseases. The proposed model also supports the procedures of individual and regular monitoring of patients detected with COVID 19 and social interaction with these patients. As this model reduces workload, the nurses and other caregivers can show patients more empathy and human interaction, which promotes long-term well-being. One of the future challenges is to scientifically and rigorously accompany the creation of new applications and to rigorously evaluate the existing applications for their effectiveness and safety. In the future, the evaluation must cover the same outcome parameters in order to be able to give a relevant status to the recognition of some of the most common symptoms of patients diagnosed with SARS-CoV-2 virus.

5. Conclusion

In terms of their performance, distribution and availability for special situations such as epidemics and pandemics, the use of robots is only at the beginning. The development of command-and-control technologies, in parallel with the costs reduction for mechatronic systems have allowed the creation of robots, not only for industrial and security applications, but also for applications in the medical field.

It is worth to note that the introduction of an autonomous all-terrain vehicle in the six-by-six formula designed to equip the medical system could significantly contribute to a considerable reduction of COVID 19 patient deaths by quickly identifying those infected and could help to reduce illnesses among hard-working medical staff in overcrowded hospitals.

The main contribution of this paper is the implementation an algorithm that allows an autonomous ground robot to intervene for the rapid identification of patients with symptoms of COVID-19 in the absence of the medical staff needed to sort patients in hospitals. Based on this autonomous mobile robot-type UGV, it is possible to quickly detect people who show signs of infection with COVID-19.

In the context of the current pandemic and in accordance with legislation, from a managerial point of view, this research may contribute to the implementation of optimal controls for identification, analysis and attention to the observance of protection protocols against COVID-19 in hospitals. Moreover, the verification of the functionality of the various subassemblies—the engine, displacement sensor system, battery status sensor system, EO/IR camera system and video camera, shows that the technology demonstration meets the requirements of the research topic. Thus, the use of mobile robots for special purposes is an excellent solution, both for reducing the exposure of medical personnel to the virus, and for increasing the capacity to identify, analyse and warn about the observance of the protection protocols against COVID-19.

Consequently, it is possible to find a drug treatment that is exactly adapted to the respective COVID 19 infected patient's immune reaction by determining his/her specific profile by means of a virtual model of an autonomous, all-terrain vehicle, in the six-by-six formula.

Because most of the robots presented in previous studies were moving as single systems with previously defined tasks, it is intended to develop this model in the future so that it can be incorporated into a network of robots. This approach could allow cooperation and collaboration not only between robots and humans, but also between robots. They would help each other fight this pandemic. For example, future studies will consider the development of subsystems for environmental sterilization and spraying of decontamination solutions against COVID-19. They could be part of the basic service and can be used if necessary. It seems that, as technology advances, the hardware of a six-by-six unmanned ground vehicle (UGV) will act more and more autonomously and eventually perform certain tasks completely by itself. This allows doctors, nurses and other healthcare professionals to focus on being more empathetic with patients.

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