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Design and Implementation of a Mobile Robot for the Mechatronic Survey

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***Abstract* – Mechatronic survey has becoming a topic of great interest because of the importance for the sustainability, management and preservation of heritage and historical assets. In fact, the main concerns refer to the accessibility of the sites to inspect and invasiveness of the investigation, which are very often time consuming and high-cost due to security issues. In this paper, we discuss a mechatronic solution for the survey based on a mobile robotic platform, on which equipment and sensors are installed to perform automatic or semi-automatic survey. In this regard, a suitable simulation of the operation is very useful for training and verification of the robot motion capabilities. Simulation tests are reported for the robot carrying equipment, together with experimental tests. The developed solution may be used for indoor or outdoor inspections.**

I. INTRODUCTION

The assessment and maintenance of existing structures and infrastructure, heritage and historical assets are of current great interest, including large-scale constructs such as plants, tunnels, bridges, roads and pipelines. Robots and automatic systems can perform a mechatronic survey with good results and high efficiency for those time consuming and repetitive tasks. Furthermore, safety can be also improved by performing robotic inspection instead of operators in dangerous or unsafe environments. Therefore, manual and (human) visual inspection can be replaced with objective methods using mechanical, electronic and robotic systems. In addition, data provided by suitable sensors such as images, thermal images, laser can be combined with wireless communication and sensor network to constitute a powerful tool for the survey of sites of interest. It is important to point out that this approach is broadly applicable to historical and cultural assets, as well as to inspection of infrastructures.

Conservation of historical assets requires scheduled or continuous monitoring involving a multidisciplinary approach to improve knowledge and prevention. In the above-mentioned process, the monitoring and data acquisition are the first step [1]. New technologies such as computers and digital tools have opened new opportunities in the process of conservation of cultural heritage. These emerging tools are becoming of great importance, a review of the literature is proposed in [2,3]. In this regard, mobile robots, traditionally used for search & rescue, and planetary exploration [4-7], are starting to be used as service robots for guided inspection tasks [8-10] and for the survey of historical sites [11-16]. Most of the time in indoor environment robots are tele operated because of the lack of wireless connection; an example of semiautonomous survey of historical sites is proposed in [17]. When referring to automatic and semi-automatic robotic solutions, it has to be designed and programmed to execute the survey. In this regard, the simulation plays an important role since allows understanding if the robot is suitable for the application, i.e. its main dimensions and motion capabilities compared to accessibility and ability of overpassing obstacles, but also it can be powerful to simulate an efficient trajectory for the motion. In this paper, we have developed a suitable mechanical multibody model of the robot, which has been verified replicating the simulation with an experimental test performed with a built system.

MAIN REQUIREMENTS AND SOLUTIONS FOR A MECHATRONIC SURVEY

The traditional procedure of data acquisition, processing and maintenance can be improved in terms of time saving, human security; this is because a large number of sites is difficult or dangerous to access. Furthermore, new tools allow the reuse of models and information. Main design issues to take into account for a mechatronic survey performed by robots can be summarized as follows: mobility, sensorization, communication, [15].

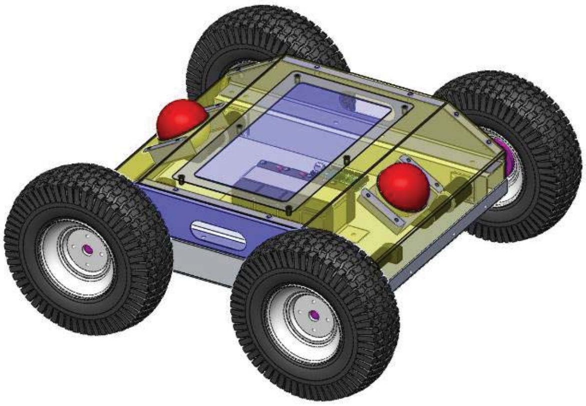
Referring to *Mobility* a large number of indoor and outdoor inspections requires small sized robot for *accessibility* issues. Referring to historical sites, most of the time *accessibility,* in terms of max high or width, can strongly limit the use of a mechanical device. *Mobility* also refers to the ability of overpassing obstacles, in most of the time the site to inspect presents obstacles, which may be ruins, debris, steps, ramps, and the robot has to deal with them.

Sensorization can be classified in two types, namely internal/navigation sensors and external/application sensors. The internal ones give the robot mobility control and navigation capabilities. They may include such devices that allow the robot to be commanded and controlled, i.e. activate and control the motors, and equipment for localization, obstacle detection, position estimation and goal tracking. External sensors are related to the task, if the inspection/surveillance/search and rescue task is the goal, then sensors such as cameras, thermal cameras, laser, light, temperature, gas, smoke, oxygen, humidity, listening and ultrasound are the most common used sensors to detect the environment in indoor and outdoor environment.

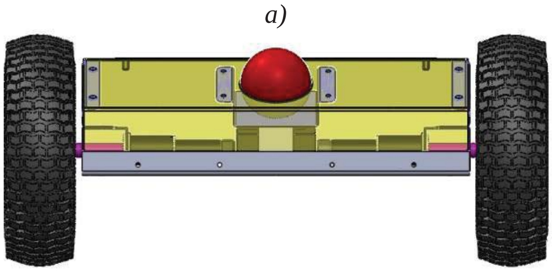
Communication. Either wireless or wired-based communication systems can be used for robot localization/navigation and data transmission, which are the main issues for the robotic application.

MOBILE ROBOT FOR THE MECHATRONIC SURVEY

The main objective of the development of wheeled robotic solution in Fig. 1 is to perform the inspection of infrastructures, such as bridges or pipelines, or historical assets, when it is possible to move on horizontal surfaces.



a)



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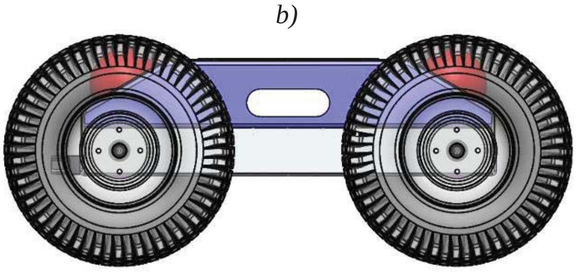

c)

Fig. 1. Mechanical design: a) 3D view; b) front view; c) side view.

Figure 2 shows the control scheme of the robot, consisting of an electronic board that commands the motors for the four independent wheels. The connection among sensors and HMI is wireless via WiFi.

Figure 3 shows the overall layout for the robot prototype. Figures 4 and 5 show the same operation of the robot, first simulated and then executed, in climbing a slope and surpassing a gap. Figures 6 to 8 show the results of the numerical simulation reported in Fig. 4.

The prototype is shown in Fig. 9.

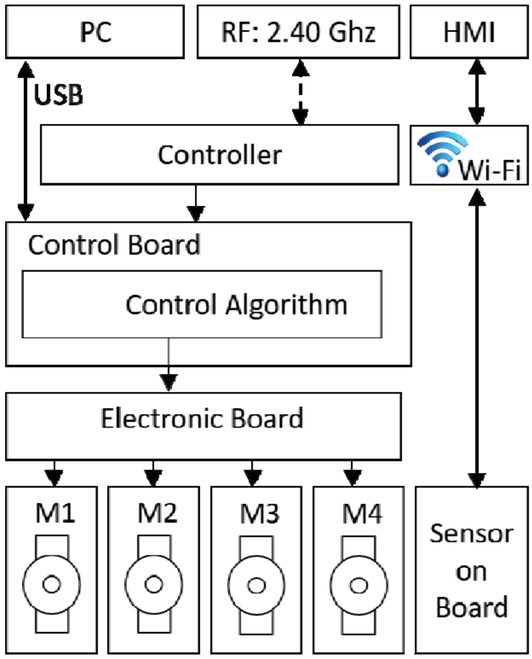

Fig. 2.Control scheme.

Fig. 3.Overall System: 1) robot 2) HMI 3) rear and front camera 4) RC controller 5) internal view of the robot-control boards 6) electronic board for motor control 7) Spektrum Receiver Mk610.

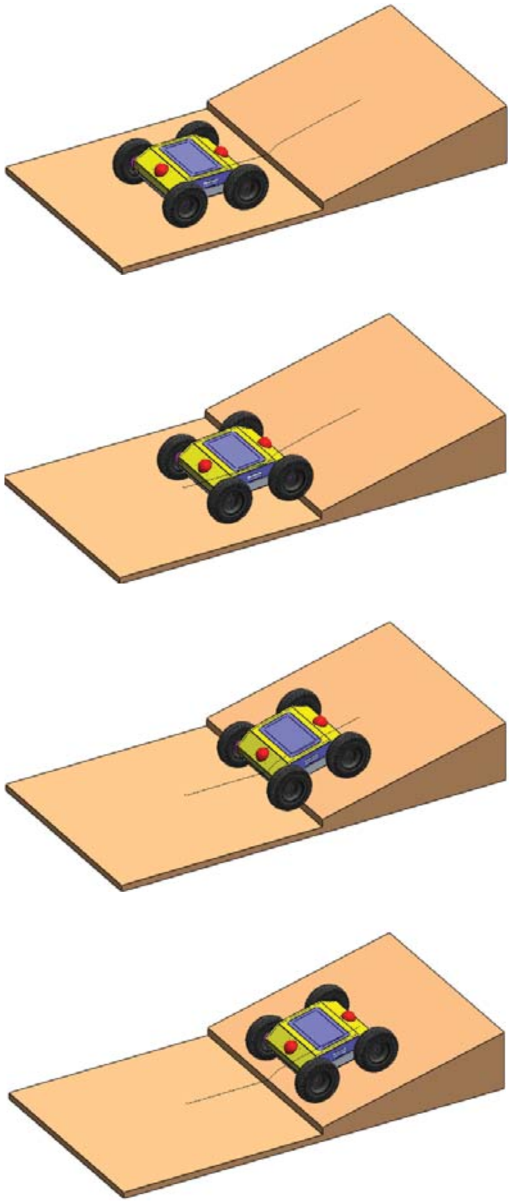

Fig. 4. Motion sequence (simulation).

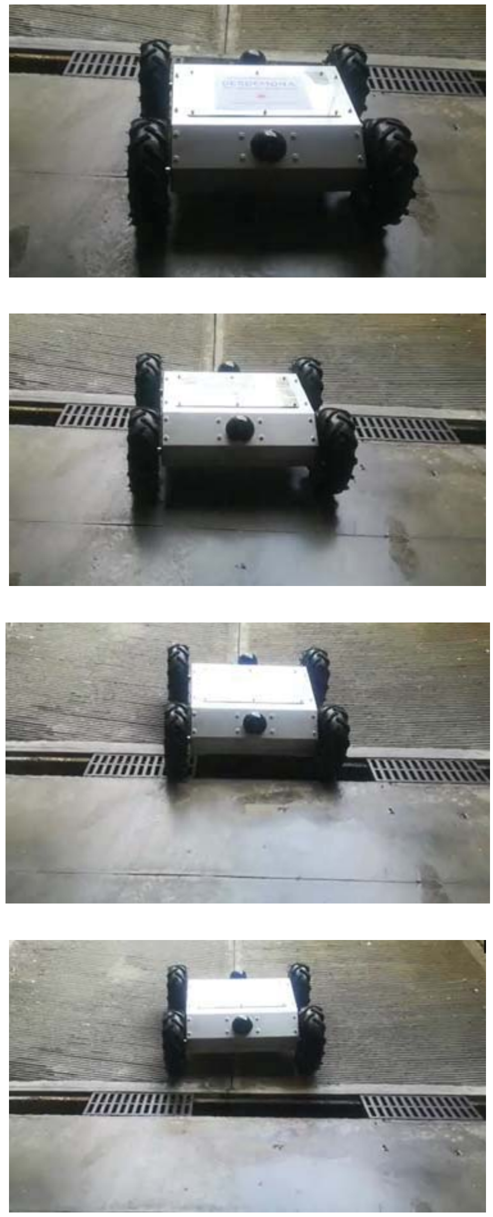

Fig. 5. Motion sequence (experiments).

Several solutions can be adopted for the inspection when moving on a flat surface [15,16]. If it is relatively smooth, with suitable dimensions of the obstacles, wheeled solution is the most efficient, in terms of power consumption, costs, complexity of operation and control, robustness, travelling speed [13]. Technical requirements can be summarized as: Ability to move in an open/close environment; Wheels or tracks for flat surfaces; Ability to overpass obstacles of high compared with the wheel radius; Teleoperation (wired) if wireless connection cannot be used; Max dimensions no more than the openings for access; Thermal and imaging analyses; Ability to carry loads. Suitable sensorization volume.

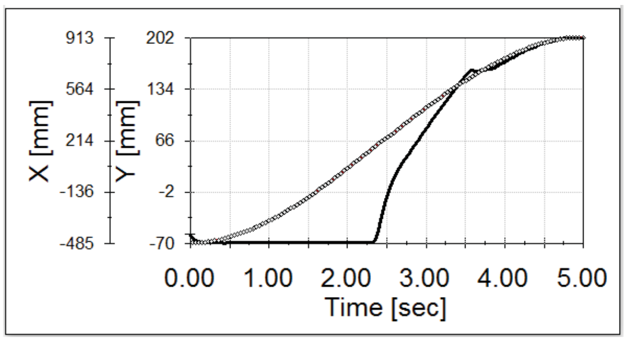

Fig. 6. Results for the simulation in Figure 4: position of the center of gravity.

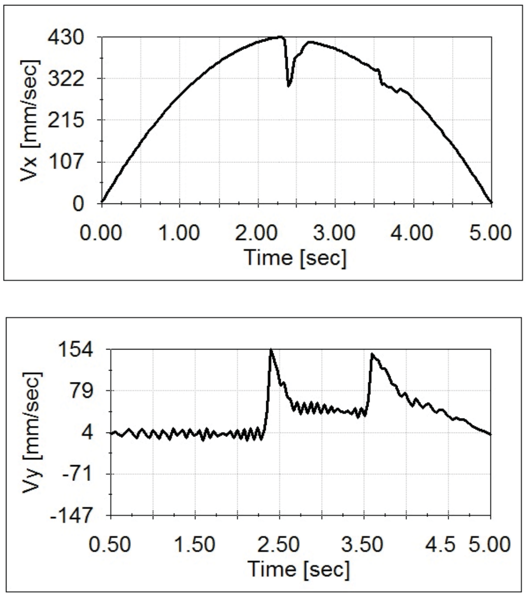

Fig.7. Results for the simulation in Figure 4: velocity of the center of gravity.

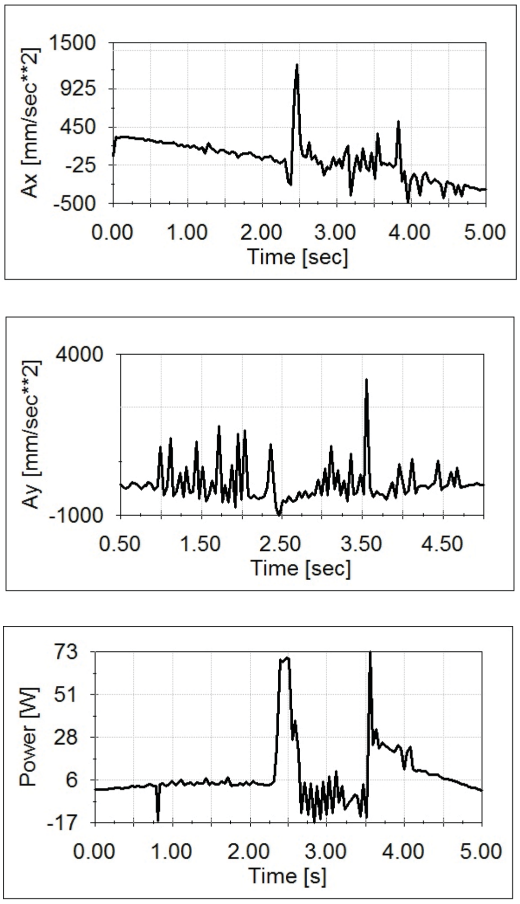

Fig. 8. Results for the simulation in Figure 4: acceleration of the center of gravity and required power.

The mechatronic control scheme is built according to design principles reported in [18, 19].

In particular, the overall system in Fig. 3 consists of the four wheeled robot, which is controlled and operated through a tablet for sensors control. At this stage rear and front cameras are mounted, having both pan, tilt and zoom, which can be controlled by a virtual joystick shown in Fig. 3 as the red point on the screen of the tablet, the used cameras allow infrared vision. The RC controller is a Spektrum DXe 6-Channel 2.4GHz coupled with a Spektrum Receiver Mk610 2.4GHz 6 Channel.

Possible use of the wheeled robot is the inspection of cultural and historical assets for which a compact and robust solution is preferable. The current sensor suit is going to be integrated with a thermal camera for such application, as described in [13, 15].

The simulation using 3D multibody model in Fig. 1 can be very efficient both for the mechanical design and for actuation sizing, but also for planning the operation in several scenarios before the survey.

The proposed model can be further implemented and simulated while interacting with a realistic scenario.

Fig. 9. Experimental set-up for tests.

CONCLUSION

In this paper, we have proposed the simulation and experimental tests of a four wheeled robot proposed for inspection and survey of sites. In particular, a suitable 3D multibody model permits the development of the simulation of realistic scenario and operation planning for a mechatronic survey. First simulations and experimental tests show a good match between simulated and real behavior of the robot allowing the planning of more complex operations of the system. Future developments of the proposed robot is the integration of the sensor suit with thermal cameras and experimental tests on indoor application.

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