Mobile robot for agriculture support in uneven terrain – design and simulation

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ABSTRACT

1 Introduction

Robotics and mobile platforms are becoming essential in agriculture automation [1, 2], as they support human labor in challenging tasks, with large equipment and potentially harmful substances, while also boosting productivity. In this work, the goal is to develop a robot that can assist with agricultural tasks such as harvesting premium tomatoes. The intention is to design a mobile platform, with a mounted manipulator, that will have great mobility and adaptability in irregular ground conditions (off-road).

2 Materials and methods

The predicted operating circumstances (Fig. 1a), which were then utilized to determine the kinematics and dimensions of the robot, were acquired thanks to the literature review and anticipated work environment for tomato picking. Therefore, the selected manipulator has a spatial linear structure with mobility of 6 and solely rotational joints.

In addition, the robot must be able to maneuver in unstructured areas, such as off-road terrain. For this purpose, reliable stability and mobility may be achieved with wheels, when paired with suitable control systems and suspension. Particularly, in order to achieve a light and compact design, an independent double wishbone suspension system with mobility of two is used. This mechanism allows for both the vertical wheel movement and the realization of wheel track changes. All these aspects will improve the vehicle's balance and implementation flexibility, enabling it to overcome ordinary obstacles and to evade big/vast obstructions. Moreover, to reduce the possible excessive vertical motions and vibrations of the platform, a semi-active suspension [3], with magnetorheological (MR) dampers, which can in real time adjust the level of damping force, is considered.

The manipulator and platform's (Fig. 1b) 3D dynamic numerical models are constructed in Adams software based on the selected kinematics and dimensions, likewise on their planned characteristics, anticipated operating circumstances and intended usage. Under predetermined scenarios and planned experimental modes, a selection of couple simulations is carried out. Several trajectories and objectives are defined for the manipulator to demonstrate its capabilities, particularly in terms of workspace (max. vertical/horizontal reach of 1.1 m/1.25 m), pose adaptability, and potential to make up for base orientation/position inaccuracies. Two different barriers (step, sinusoidal) and scenarios with fixed or variable damping coefficients are taken into account for the platform's simulations.

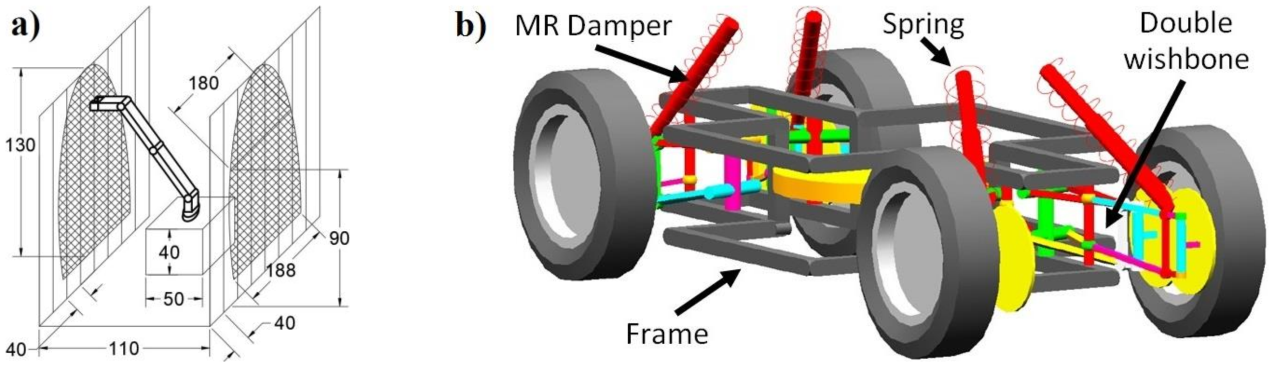

Figure 1: a) Expected operating environment for gathering tomatoes (values in cm) and crosshatched - "primary operating plane" of the manipulator [4], b) Platform's 3D numerical model constructed in Adams with key components designated by arrows [5]

3 Results

Some of the simulation findings are shown in the following figures. For instance, for the manipulator's maximum horizontal reach experiment, Fig. 2a shows that the motor at the bottom of the manipulator must deliver the maximum torque of 58.1 Nm in order to move almost the entire device. For the platform, generally, when the damping coefficient was adjusted, the degree of uncontrollably occurring vertical motions decreased. The maximum acceleration value decreased by 0.1 m/s^2 to 9.7 m/s^2 and its RMS value decreased by 0.04 m/s^2 to 1.77 m/s^2 for experiment with three step obstacles (height of 50 mm and length of 300 mm). Furthermore,

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the average wheel torque was around 3.75 Nm and the vertical acceleration was less than 0.4 m/s^2 in terrain with sinusoidal barriers (Fig. 2b). Additionally, the vertical ground reaction forces and the amount of time that the wheels were off the ground were measured.

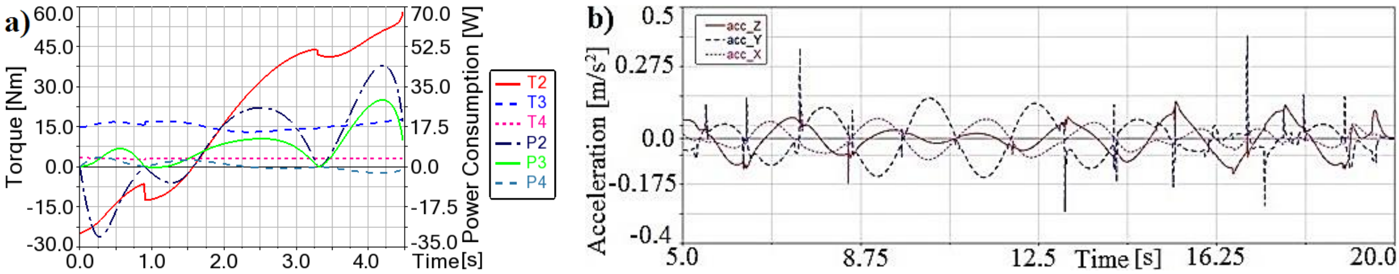

Figure 2: a) Torques and power consumption of manipulator's motors in simulation of max. horizontal reach [4], b) Accelerations of vehicle's chassis centre of mass, while riding on a road with sinusoidal obstacles, with variable damping coefficient [6]

Finally, using standardized parts and chosen motors, conceptual 3D CAD models are created in Inventor – the manipulator with gripper (Fig. 3a) and the platform (Fig. 3b). These models serve as a solid foundation for future fabrication of a research prototype.

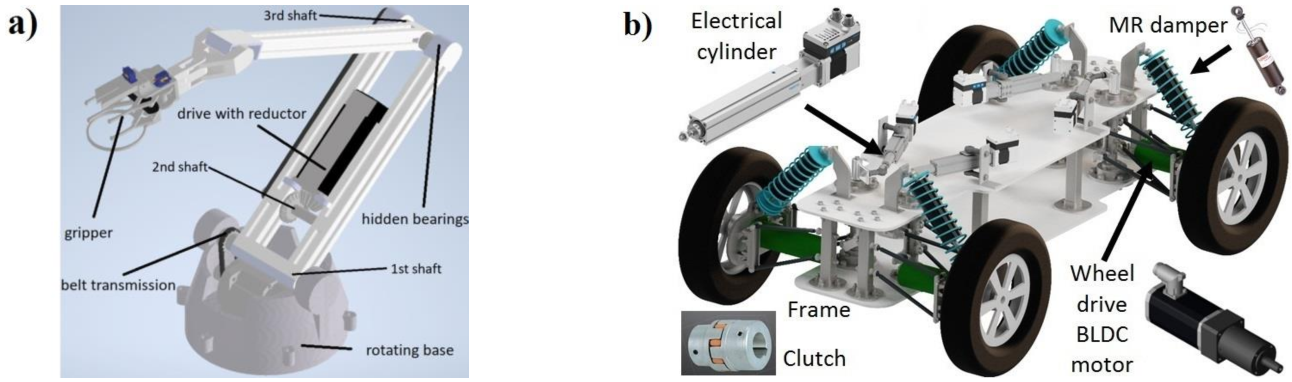

Figure 3: Designed 3D models created in Inventor (CAD software): a) manipulator with indicated main parts [4], b) mobile platform with suspension system and some of the selected items, motors, MR damper etc. [6]

4 Summary and conclusions

The goal of the project was to design a wheeled mobile robot that could negotiate rough terrain and assist with agricultural tasks, such as gathering tomatoes. The ultimate objective is to apply autonomous machinery to reach precise and smart farming.

In summary, the conducted simulation trials have validated the practical attributes of the manipulator's design, such as its broad applicability owing to its vast workspace and its exceptional flexibility (mobility of 6), which is significant in agriculture (convenient amid branches and creepers). Likewise, further findings demonstrated the viability of the platform and the ability of the semi-active suspension system, which included MR dampers, to reduce the unwanted vertical movement and acceleration of the vehicle's body. This, together with the possibility of changing the track of wheels, could potentially increase the vehicle's maneuverability and adaptability to different types of terrain, agricultural settings and specific situations in unstructured and uneven areas.

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