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Object-oriented modelling and control of vehicles with omni-directional wheels

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The scope of the project presented in this paper was to create a multibody model of a heavy-weight vehicle with so-called omni-directional wheels. The vehicle suspension was realised simply with linear guides and pneumatic shock absorbers. The next objective was to enable modelling of different vehicle variants.

The omni-directional wheels are wheels which can rotate about their axis as well as move in their longitudinal and – contrary to the conventional wheels – also in lateral direction, see e.g. [1]. Using such omni-directional wheels for vehicles operating on flat ground enables its excellent manoeuvrability. The vehicle can perform longitudinal, lateral or diagonal movement or it can yaw i.e. rotate about its vertical axis. Any simultaneous combination of these base movements is possible as well. By virtue of the omni-directional wheels the prescribed motion of the vehicle is accomplished solely by applying different driving torques on each of the wheels – hence no equipment to steer the wheel is necessary.

The movement variability of the omni-directional wheels is reached due to multiple rollers mounted along their circumference, see figure 1. The orientation of the roller rotation axes relative to the wheel rotation axis is fixed whereby the angle of common omni-directional wheels is 45° (also called Mecanum wheels) or even 90°. Consequently, the driving torque applied on the wheel results in both longitudinal and lateral forces at the contact point between roller and ground. The driving torques can be uniquely controlled in such a way that the resulting contact forces yield the desired vehicle motion.

To enable simulation of different variants of such vehicles in a most convenient way, a modular modelling concept was utilised. Consequently, the various design and parametrisation of wheels and vehicles as well as variable number of vehicle wheels can be applied. To realise the modular concept the two main assemblies of the vehicle were referred: Vehicle frame and wheel modules. The vehicle frame can be either rigid or flexible independently of the design of

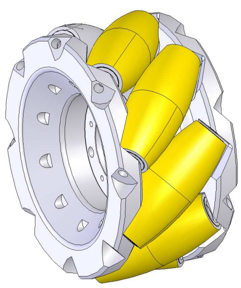

Fig. 1. Omni-directional wheel.

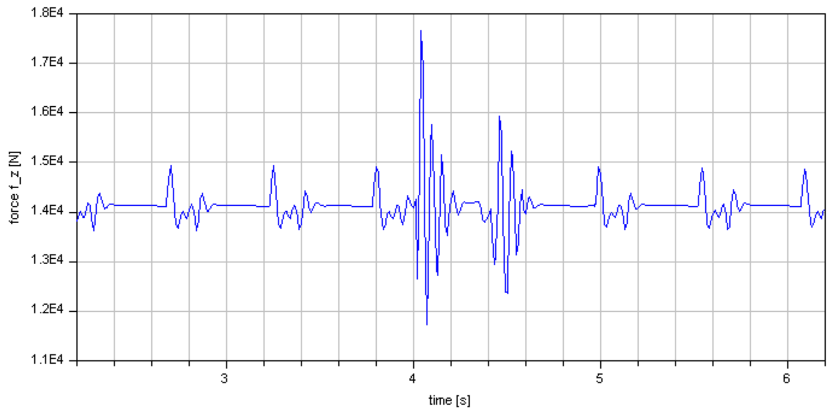

Fig. 2. Vertical force acting on frame of four-wheeled vehicle when passing over an obstacle.

the used wheel modules. Next, the wheel module was divided into following sub-assemblies: Omni-directional wheels, drives and suspension.

The drives were modelled as one dimensional rotational models. The drive torque is generated according to the controller signal and applied on the drive output flange. More sophisticated models of electric drives can be employed as well.

For vehicles with omni-directional wheels the simple linear suspension is used since the vehicle generally moves at low speeds. The prismatic guides in the suspension model are accomplished with either conventional spring and damper or alternatively with pneumatic shock absorbers. Using pneumatic suspension, the single wheel modules can be coupled together with pipes, thus enabling smooth vehicle load distribution over more wheels.

The essential item of the modelling was the generation of contact forces between rollers and ground. Within the modelling, the contact of each roller was regarded individually under consideration of roller and ground geometry. To generate the contact forces the slip velocity v_{slip} at the contact point of non-deformed rollers was introduced according to [3]. Based on the Coulomb's law for dry friction the slippage yields contact forces of the roller.

The control strategy for the vehicle movement was realised separate from the vehicle model. This complies with the selected modular concept and enables to investigate different control strategies in straightforward way.

The modular modelling concept was realised with the object-oriented modelling language Modelica. This free modelling language is designed to allow convenient, component-oriented modelling of complex physical systems, e.g., systems containing mechanical, electrical, hydraulic or control subcomponents (see [2]).

As a result of modelling effort, a Modelica library was created which reflects the abovementioned modular concept. Additionally, it includes different variants of the vehicle within various scenarios. As an example, a four-wheeled vehicle of 6000 kg mass passing over an obstacle of 15 mm height at a speed of 0.27 m/s was chosen. Figure 2 shows the vertical force acting on the vehicle frame at the place of front left wheel.

References

[1] Blackwell M., The URANUS Mobile Robot, Tech. report CMU-RI-TR-91-06, Robotics Institute, Carnegie Mellon University, 1990.

[2] Modelica. http://www.Modelica.org.

[3] Zimmer D. und Otter M., Real-Time Models for Wheels and Tires in an Object-Oriented Modelling Framework, Vehicle System Dynamics, to appear.