Dynamics and Control of a Robotic Lawn Mower

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Abstract

Wheeled mobile robots play an important role in the service area and are well accepted by both, industry and domestic scenarios, see e.g. [1]. Very successful service robots are private robotic lawn mowers which are available on the market for about twenty years. The Swedish company Husqvarna generated and also made-up the word Automower® which is now their trademark, too. Different designs of robotic lawn mowers are found in Ref. [2].

From a robotic point of view, differentially driven lawnmowers are nonholonomic mobile platforms carrying the cutting knives, the power unit with battery, as well as all the sensors and microelectronics. Due to its nonholonomic constraint, this kind of mobile platform has unique features such as vanishing direct lateral motions and control by two wheels inputs. Since it is designed for grass cutting, the cutting strategy or in the robotic view the motion planning is important. Motivated by above considerations, in this paper a model of the lawnmower is presented as a general differentially driven mobile robot and it will be validated by simulations and experiment, see also Ref. [3].

The model of a lawn robot is shown in Figure 1. The robot has two wheels mounted along one axis and one caster located at the front sensor location 'F'. In the literature other support and balance designs have been discussed, too, which are more or less consistent, see for examples in [4, 5].

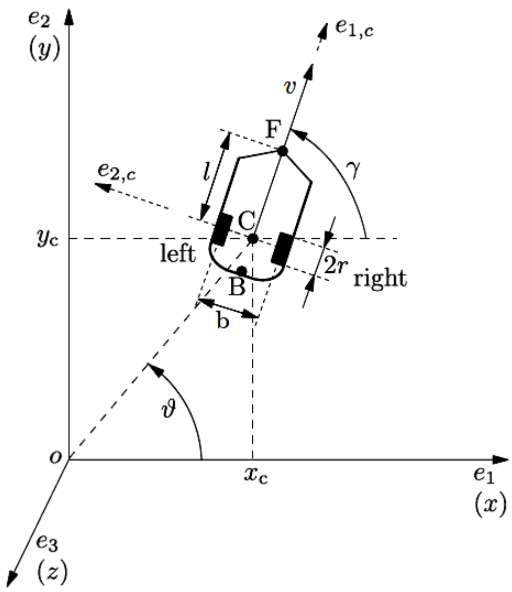

Figure 1. Model of a lawn robot design

Based on Figure 1 one can easily derive three kinematical equations for the global velocity of the robot body where *v* and *w* are the robot body translational velocity with respect to point 'C' and its rotational velocity, respectively. Here 'C' coincides with both, the center of mass and the wheels axial center. In addition one gets the rotational velocities of the right and left wheel from the body local velocity where *r* is the wheel radius and *b* represents the distance between the two wheel centers subject to the nonholonomic constraint.

In this paper the dynamics model of the robot is derived from a multibody point of view based on Newton-Euler equations and Jourdain's principle. For this robot, there are four generalized constraint forces: three normal forces from the left and right wheel, respectively, and from the front caster while the fourth reaction is generated along the wheels axis. The only applied force is due to the weight.
From the six Newton-Euler equations and Jourdain's principle there remain two equations of motion. Combined with the three kinematical equations one gets five state equations representing five first order ordinary differential equations (ODEs).
The cutting strategy used in simulation and experimental tests is quite trivial since we validate our model firstly. The robot is initially located in the grass area, and then begins to move meanwhile cutting grass by its equipped knives set. Once the robot detects any boundary or obstacle, it brakes and goes backward a little bit. Then, it rotates with a certain angle as its forward direction for the next step. If it is still in the range with conflict to the boundary or obstacle, it continues to rotate until it gets a free signal for its forwarding. After the process of avoiding collisions, it goes on for its task. At the moment, the rotation degree taken by the robot in each step of obstacle avoidance is randomly.
Simulation results and experiments on a green lawn are shown in Figure 2. Thus, the nonholonomic robot model is validated. More general cutting strategies are under investigation.

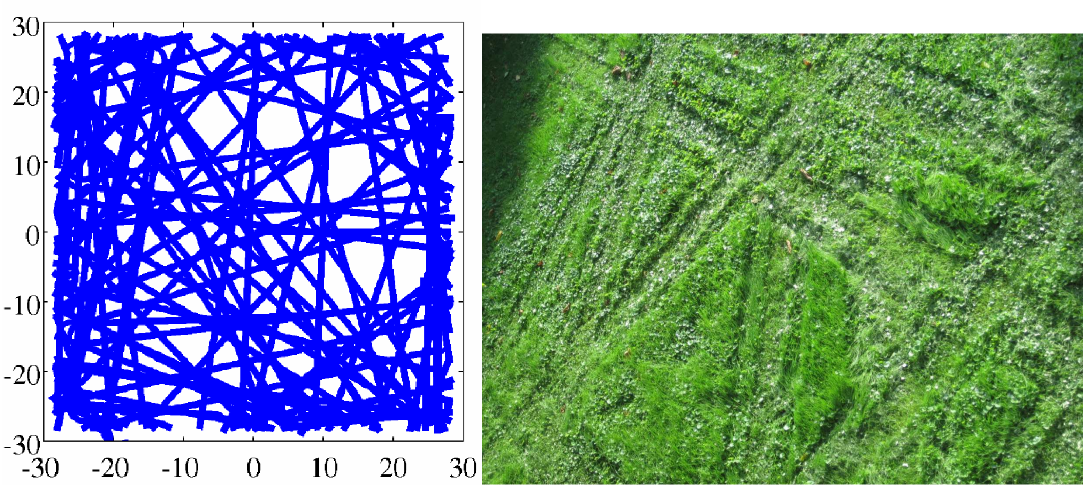

Figure 2. Simulation results and experiments

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