DYNAMIC MODELLING AND SIMULATION OF A SIX WHEEL AUTOMATIC GUIDED VEHICLE

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Abstract. This work describes the construction of a dynamic model of the suspension and locomotion subsystems of an Automatic Guided Vehicle (AGV). The vehicle has six wheels, four are caster type in the corners and the other two in the center of the AGV are driven by electric motors with gearboxes. The vehicle has a straight displacement when the two wheels have the same speed and are used for differential steering of the vehicle when one of the wheels has a higher or lower speed than the other. All the six wheels joint to the vehicle chassis by a suspension, which is composed by a spring and a damper for each wheel. The model is made using the software Universal Mechanisms for the simulation of kinematics and dynamics of planar and spatial mechanical systems. The model is tested and adjusted to meet the real AGV constructed at the Mechanical and Mechatronics Department of the National University of Colombia, at Bogota. The future utility of the model is to be used for the design and test of the motor controllers to follow programmed paths.

Keywords: Dynamics, Car modeling, Automatic guided vehicle, Simulation.

1. INTRODUCTION

Automatic Guided Vehicles (AGV) are used as a transport subsystem in automated systems. Application areas of AGV are flexible manufacturing systems and cells, marine port terminals, automated storage and retrieval systems (AS/RS), vehicle assembly lines and others.

An AGV has capacity of self locomotion. It moves over defined paths using automatic control of traction and steering. The paths are established by electric wires buried under the floor, colored or reflective strips on the floor or virtual paths defined over the work area. It has communication devices to receive task jobs or path information from a central controller.

An AGV prototype was built at National University of Colombia and a first dynamic models of the AGV and the controller was developed with good results. New models are in development in order to improve the controller. This work is about the modeling of this AGV at LABROB, Robotics and Machine Design Laboratory at COPPE-UFRJ. This new model is based on the software tool Universal Mechanism.

2. THE AGV

The AGV is formed by a chassis, wheels, motors and electronics (Fig. 1). The chassis was made of square pipes and bars of carbon steel, the bars are for six arms to receive the wheels. Each arm has a suspension system formed by a spring and a damper. The suspension permits the AGV to pass over little obstacles or floor discontinuities, decreasing the impact effects on the load.

There are six wheels of polymer with steel cubes. Four are caster type for the corners of the AGV. The two central wheels are driven by a motor with gearbox. These wheels are responsible for the traction and steering of the AGV.

It is used the differential velocity steering mode. If the two wheels have the same velocity, then the AGV moves in a straight path. If one wheel has greater velocity than the other, then the AGV displaces in a curve near a circular path.

The motors are 24 volts DC type, with a maximum current consumption of 3 amperes. The gearbox is planetary type and the motor with gearbox gives a maximum velocity of 100 RPM. The power supply for the motors is a pack of two batteries in series connection. Each battery has a 56 A-h capacity.

The electronics are based in a Siemens PLC 400 series with PID and other control functions. A set of buttons and pilot lights are used to receive manual orders and for signaling. It has a specific sensor to measure errors on the trajectory and a set of proximity sensors for obstacles and for senses objects passing in front of the vehicle.
There is an electronic board to regulate the supply voltage, a second board for conditioning signals from the sensors and a third board with an H-bridge to control the voltage and to send current to the motors. All the electronics are supplied with a pack of four batteries with 6 volts and 1 A-h, each.

The signal of the path sensor is conditioned and sent to an analog voltage input of the PLC, this device is programmed with the control algorithm. The output of the PLC is a PWM signal; this signal is amplified with the H-bridge circuit and sends a variable voltage to the motors. Each motor gives torque to the gearboxes and traction wheels to control the movement of the AGV.

Initially was developed a model to simulate the AGV dynamics using a transfer function calculated from experimental results (Ramirez, 2005) and based on this model were designed some control algorithms. The best algorithm, obtained with the pole allocation method, was a PDPD controller. This means the use of two PID blocks in a serial connection, the integral gain for each block was set to zero.

3. EQUATION OF MOTION

The AGV is a typical multibody system. A multibody system consists of many components interconnected by joints and force elements such as springs, dampers, and actuators (Shabana, 2001). A body can have an unconstrained movement with six degrees-of-freedom. If the body is joined to other bodies, it becomes in a constrained movement. The number of degrees-of-freedom is reduced depending on the type of joints used.

Equations of motion of a multibody system have the following form of differential-algebraic equations (Pogorelov):

\[
M(q, t)\ddot{q} + k(q, \dot{q}, t) = Q(q, \dot{q}, t) + G^T(q)\lambda
\]

(1)

Where \(M\) is the mass matrix, \(k\) is the vector of generalized inertia, \(Q\) is the vector of applies forces, \(G\) is the Jacobian matrix of the constraint equations after elimination of auxiliary coordinates, \(\lambda\) is the vector of Lagrange multipliers corresponding to reactions in auxiliary coordinates.

The set of constrains of the system is represented by:

\[
h(q, p) = 0
\]

(2)

Where \(q\) is the vector of basic coordinates of the system and \(p\) is a vector of auxiliary coordinates.

The model presented in this paper uses the software tool Universal Mechanisms (UM). This software in an interactively form constructs the equations of motion (Eq. 1) under a set of constrains (Eq. 2) and solves them. The solution is showed by a simulation of the movements of the AGV.
4. NEW MODEL

The software UM has an interface to create or import CAD models of parts. Those parts are assembled with joints and contact models. It can be added models of dynamic elements like masses, inertia moments, springs and dampers.

The models are created with parts provided by the software, boxes, cylinders, springs and profiled parts. For each part are attributed values for the mass, inertia tensor and the coordinates of its center of mass. Based on known parameters of the real AGV like part dimensions, masses, spring and damper constants, was created the model shown in Fig. 2.

Joints were used to assembly the parts and simulate the rotation movements of the wheels and axis. It was not necessary to implement any specific type of joint other than translational and rotational joints. The suspension uses a model of bipolar linear spring with damper system.

For the contact between wheels and floor the model used was circle and plane contact force. The model of contact is defined by two forces, one is normal to the plane and the second is parallel to the axis of the circle, this is shown in Fig. 3. The model permits to make changes in the static and dynamic coefficients of friction between the parts, stiffness constant and damping coefficient. Were tested different models for the contact between the wheels and the floor, this parameter is determinant on the behavior of the model.

![Figure 2. Model of the AGV in UM](image)

![Figure 3. Contact forces on wheels](image)
The motors and actuators of the real systems are simulated by the software using forces and torques applied in the joints. In the AGV model was used a torque function in each junction of the central wheels. The torque function acts like a control algorithm. The solver calculates position or velocity components, the difference of these values to the desired positions or paths are the position or velocity errors. A torque in function of the errors acts on the vehicle to correct the errors and control it.

5. RESULTS

The results of movement are visualized in the screen, measured and stored. Then were compare experimental measures and videos taken on the real AGV. A sequence of pictures of the real and the modeled paths are shown in the fig. 4 and Fig 5.

Figure 4. Sequence in a curve trajectory

Figure 5. Sequence in UM simulation
6. CONCLUSIONS

The virtual model created is satisfactory and using the torque function permits to simulate quickly the effects of the control algorithms.

The software tool selected and the options for modeling vehicles and the phenomena of contact between wheels and floor is fully adequate for study and analysis de Automated Guided Vehicles.

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8. REFERENCES


9. RESPONSIBILITY NOTICE

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