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SIMULATION OF MOVEMENT AND NAVIGATION OF LEGO NXT 2.0 MOBILE ROBOT IN UNKNOWN ENVIRONMENT INCLUDING INVERSE PENDULUM MODELING AND CONTROL

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ABSTACT: The mobile robot can be controlled by the moving direction with Inverse Pendulum control. In this paper, we estimate the one step forward of mobile robot position by using mobile inverse pendulum which represents a system, including a series of problems in control, such as instability, influence of dry friction, contact problems, sensor information processing and based on those estimation results, it can be controlled the one step forward of mobile robot direction. Here, we established simulation model of mobile robot and modeling environment. We build an abrasive trajectory path. This paper discusses also the use of simulation modeling to analyze the costs, benefits, and performance tradeoffs related to the installation and use of mobile robot with inverse pendulum to support moving robot inside an abrasive environment. Additionally, we think about possibilities to expand this moving with some intelligent systems, like fuzzy logic and neuro network.
Keywords: estimation, control, position, mobile robot, inverse pendulum

1. INTRODUCTION

Autonomous mobile robots controlled without human intervention we needed in many applications. When mobile robot moves from one point to another, it is obligatory to plan the best route. [1][2]

Careful planning and time management is essential for autonomous mobile robots. We are using two types of algorithms for planning of time, one planning a general time (off-line) and second is local path planning (on-line). We must have all the information about the location of fixed obstacles and the path for the obstacle's universal way. The robot calculates the best route once followed this path to the target point. If robot haven`t enough information on the environment, the mobile robot is using sensors to understand the environment, and this is called a local path planning (on-line) [4] [5]. In addition, the desired path must avoid obstacles [8].

Many engineers have tried to make mobile robots that have the ability to self-balance. The simulation of robotic systems is an essential tool in such papers [9], [10], [11], [12], [13], [14]. Without simulation tools like SolidWorks, CATIA, Virca it is impossible to design complex systems such as closed kinematic chain robots [11] or a mobile robot [13]. It is necessary to develop virtual environments for operator training [10]. Simulation is also a very important tool for teaching basic concepts of robot-like systems, without the actual experimentation [9]. Figure 1 shows the function diagram for a mobile robot.

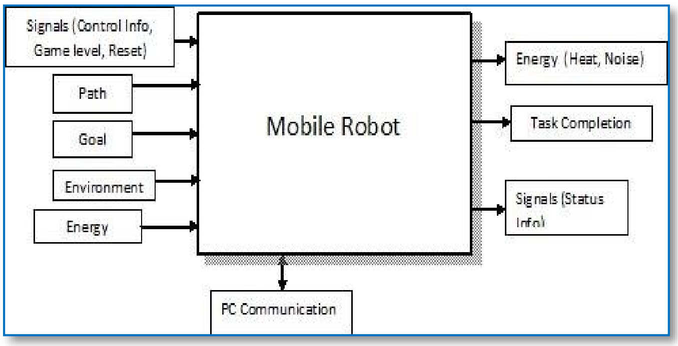

Figure 1. Picture of block scheme of Mobile Robot

2. MOBILE INVERSE PENDULUM MODELING

There are a many papers dealing with the mobile inverse pendulum. The model of the pendulum here is derived using Lagrange equations of the 1st kind like in [15, 16], but here, the constraint forces which are considered on base of Lagrange's multiplier components are also presented. The simulation and experiment here shows at least the same or, in some situations, a better conformity (which is hard to assess due to different pendulum parameters). Compared to the friction compensator in [19], the one presented here fuzzyfies the control logic, what is reflected in smoother added control torques. In the presented pendulum, the sensor fusion of the gyroscope and the inclinometer is done based on a detailed inclinometer model observer, which is reflected in accurate and dynamic body angle estimation. The system geometry is fully described using three coordinate systems as shown in Figure 2: Ca absolute coordinate system, Cb in the middle of the axis between two wheels with z-axis parallel to the Ca z-axis and rotated by angle Θ, and Cc in the C-OG of the pendulum body rotated by angle φ.

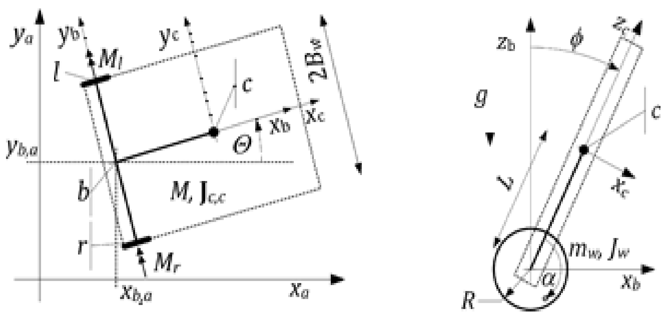

Figure 2. Top view (left) and side view (right) sketch of the mobile inverse pendulum

The mechanical system elements are: the pendulum body with mass $M = 20.9$ kg, inertia tensor $J_{c,c} = diag(J_x,J_y,J_z) = diag(1.18,0.95,0.27)$ kg m^2, and length $L = 0.39$ m from body's COG to rotating axis; left and right wheels with mass $m_W = 0.55$ kg and radius $R = 75$ mm, inertia torque in rotating direction $J_W = 0.008$ kg m^2, and wheel track $2B_W = 0.44$ m.

Actuators acting with torque M_l and torque M_r, respectively, are located between the pendulum body and the left and right wheels. The system is underlying the gravitation with acceleration $g = 9.81$ m/s^2.

3. SegWay TRANSPORTATION

Dean Kamen discovered the Segway individual transporter in the show "Good Morning America" on ABC TV network, described it as "the first self-balancing individual transporter in the world". When you look at the Segway ride, it becomes clear what he was saying.

To Segway move forward or back, it is sufficient that the driver leans slightly forward or backward. To turn left or right, the driver simply moves lean steer controller left or right.

To maintain balance, when bending forward, the wheels are turning right speed and to move forward. Segway using this extremely complex process called dynamic stabilization that allows the Segway transporter balance on just two wheels.

Segway Personal Transporter (PT) (Figure 3) is the World's first self-balancing transportation device with two wheels. The mechanism is based on the principle of the inverted pendulum with advanced control to maintain balance at all times.

Figure 3. SegWay

To move, rider leans forward or backward and the transporter accelerates in the proper direction to balance the system. Similarly, to take turns the rider leans sideways and the transporter adjusts the speed of both wells. Handling feels natural because the amount of lean, measured by gyroscope, controls the acceleration and the curvature of turns. Segway Personal Transporter (PT) is the World's first self-

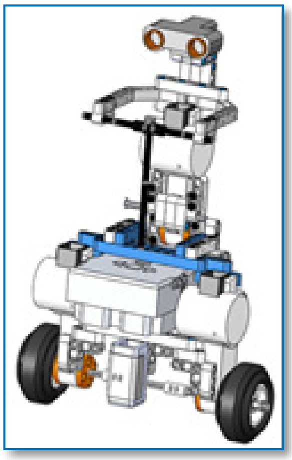

Figure 4. Lego Segway Robots

balancing transportation device with two wheels. The mechanism is based on the principle of the inverted pendulum with advanced control to maintain balance at all times. To move, rider leans forward or backward and the transporter accelerates in the proper direction to balance the system. Similarly, to take turns the rider leans sideways and the transporter adjusts the speed of both wells. Handling feels natural because the amount of lean, measured by gyroscope, controls the acceleration and the curvature of turns.

In this paper, the goal is to building the Segway robots (Figure 4) in the software Packet SolidWorks using ready-made components “Lego Mind storms NXT 2.0 kit” and then making simulations of the same in the specified software package. In this paper point of interest is simulation, while the assembly will be described in brief. More details can be found on the website whose link is given in the introduction. In order to reconstruct this project again, implies a knowledge of the software package SolidWorks. Robot assembly is done by known parts from internet and built a final robot model.

The real Segway transporter uses input from gyroscope to control the stability and balance. Because gyroscope is not part of the Lego kit, Segway robot makes use of the light sensor. The sensor registers the light intensity when the robot is started. As the robot tilts, the light intensity changes and the robot reacts by adjusting power to motors #1 and #2. As a consequence, the robot cannot maintain vertical position; it tries to maintain the position at which it is started. It is therefore necessary to start the robot at near vertical orientation. Simulation with Solid Works

Once you get familiar with the robot behavior when controlled using both simpler (Segway) and more advanced (Segway BT) programs, go ahead and build Segway robot in SolidWorks. When your model is complete, you will simulate both control scenarios in SolidWorks Motion.

Follow the instructions below to build your Segway robot assembly. Because all SolidWorks part files are supplied as part of this project, you only need to mate them to create a final assembly. Because the basic assembly building skill is a prerequisite to this lesson, the steps below do not detail how to mate parts.

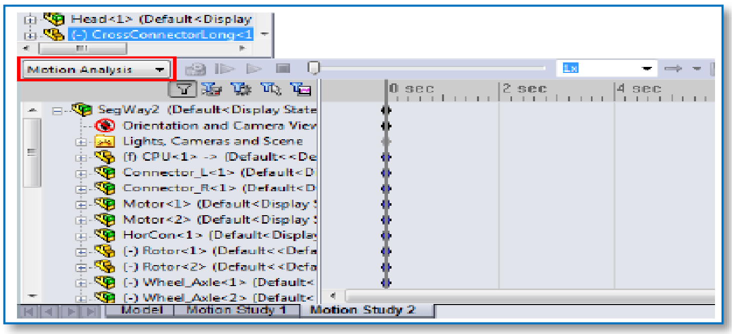

Figure 5. Type of Study in Motion Analysis

4. SOLIDWORKS SIMULATION

The New Motion Study is necessary to change the Type of Study in Motion Analysis as shown in Figure 5.

Assembled Robot necessary divided into three “solid group” (rigid groups) as shown in the Figure 6.

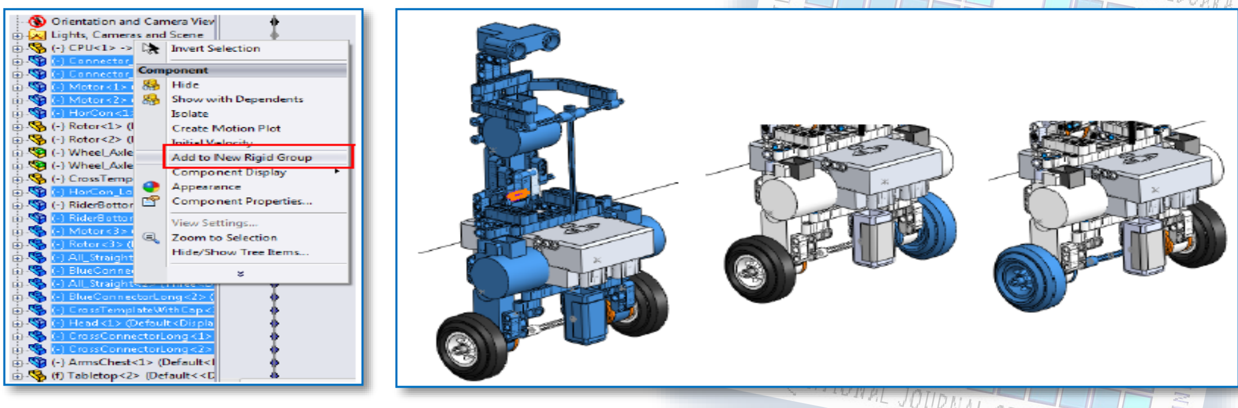

Figure 6. Rigid Group

Note: in “Rigid Groups” are not admitted CPU, as can be seen in the figure, because it will be used for measuring angular velocity and angular acceleration.

In other step, it is necessary to define contact surfaces and between one point and the plate and then repeat all of the other wheel and board. The following Figure 7 give as define of contact surfaces.

Maximum torque at the point that gives the engine Tmax can be expressed starting from the standpoint that the wheels do not skid to obtain the following equation.

$$T_{max} = F_n * \mu * 27.94 = 29.57 \text{ Nm}$$

$$T_{max} = 29 \text{ Nm}$$

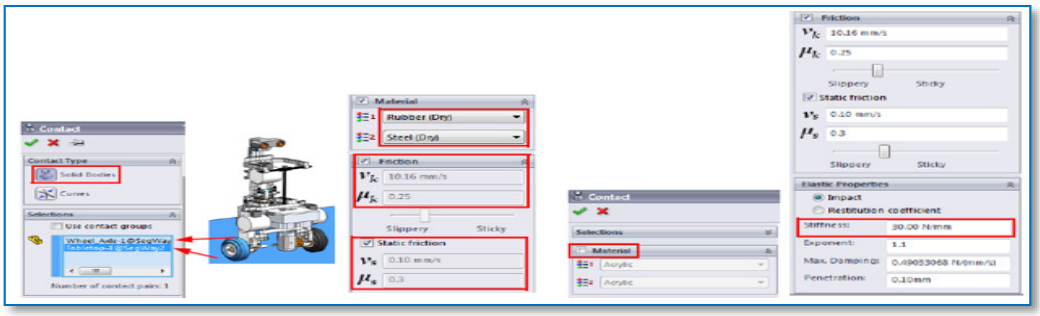

Figure 7. Define contact surfaces

Plotting diagrams of certain size is very important because that procedure specified these value are used to simulate the movement of the robot.

On Figure 8 will be shown the way to draw a diagram of one size is a function of time while the other identical diagrams drawn.

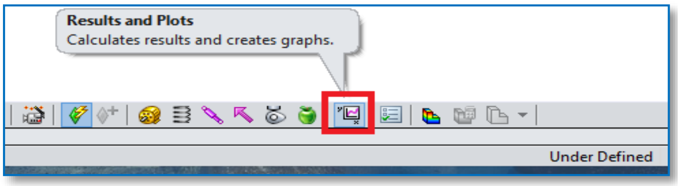

Figure 8. Diagram drawing Step 1

Note: drawing diagrams is very important, without those SolidWorks does not see the size of his essential for simulation, such as rotation angle, angular velocity and angular acceleration (Pitch / Yaw / roll, angular velocity, angular acceleration) (Figure 9)

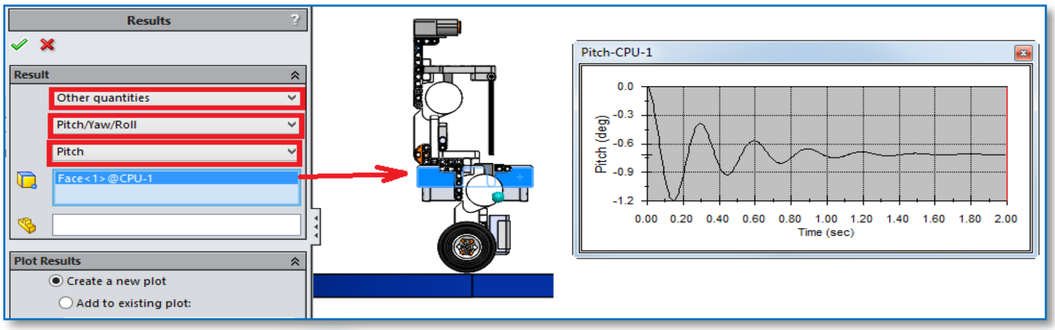

Figure 9. Diagram drawing Step 2

PID controller is one of the oldest and most widely used management strategy and its implementation can be successfully resolved about 90% of all management tasks. The PID controller has three constant action: proportional (P), integral (I) and differential (D). Law Management analogue PID controller is:

$$u = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(t)}{dt},$$

where is the control variable, Kp, Ki and Kd were all in proportion, integral and differential backup, an error signal equal to the difference between the reference signal and controlled variable y (e = Ref - y). Equation PID controller is also required to enter into the simulation in order to see its effect on the robot control. Determination parameters of the PID controller is a demanding process that can request a lot of time, because in this seminar used parameters are specified below. Reinforcements proportional, integration and derivation components are given respectively k1 = 10, k2 = 0.1, k3 = 0.01. After you set all the parameters, you can run simulations. After processing is complete movement, which takes some time, depending on the set number of frames per second, can let the simulation by pressing play.

Note: running a simulation computer performs the calculation of the movement of the robot. In doing so, your computer may take some time to process the data.(Figure 10)

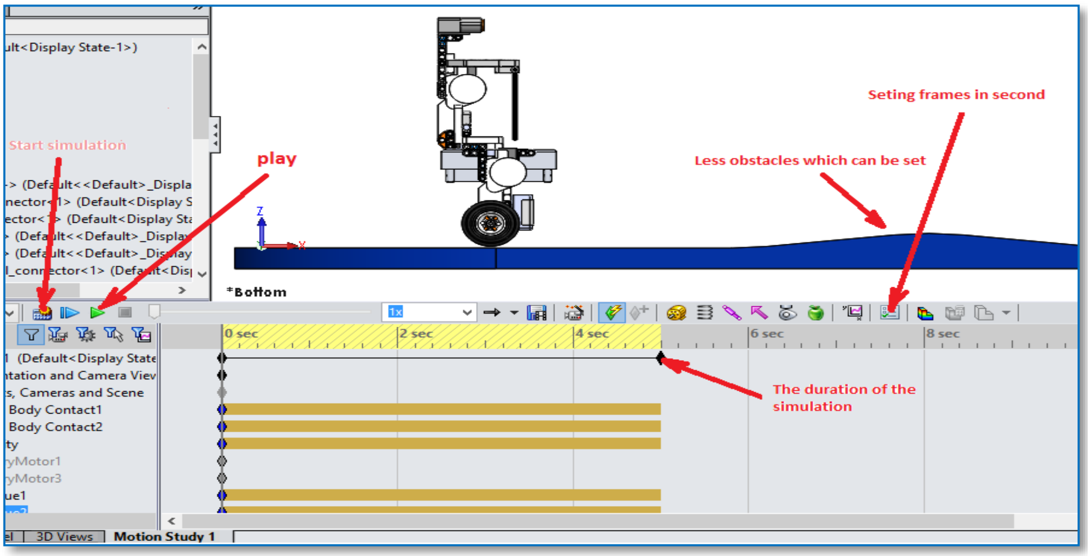

Figure 10. Final Simulation

5. CONCLUSIONS

This paper presented a review of the existing software tools for mobile robot simulation. We also discussed about introductory background aspects and about simulation processes and simulator architectures. This information can be important to researchers and developers interested in the simulation of mobile robotic systems.

In this paper it was possible to see a single physical model NXT Segway robots, and setting the parameters required to simulate movement in application Solid Works. According to these results it is possible to make a real Segway NXT Robot and compare the results of the same movement.

This paper is given simulation Segway robot only in a situation where it is trying to keep his balance. With this simulation it can go a step further where we can simulate the behavior of the action of external forces which tend to be out of balance.

Since this paper was made as an introduction to simulation Segway robot, for those who want to devote themselves to more detailed simulation of the above Segway Robot, in the references are listed links and sources that have been used for the production of this research paper.

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