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Analysis of the Hexapod Work Space using integration of a CAD/CAE system and the LabVIEW software

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Abstract. The paper presents the problems related to the integration of a CAD/CAE system with the LabVIEW software. The purpose of the integration is to determine the workspace of a hexapod model basing on a mathematical model describing it motion. In the first stage of the work concerning the integration task the 3D model to simulate movements of a hexapod was elaborated. This phase of the work was done in the "Motion Simulation" module of the CAD/CAE/CAM Siemens NX system. The first step was to define the components of the 3D model in the form of "links". Individual links were defined according to the nature of the hexapod elements action. In the model prepared for movement simulation were created links corresponding to such elements as: electric actuator, top plate, bottom plate, ball-and-socket joint, toggle joint Phillips. Then were defined the constraints of the "joint" type (e.g.: revolute joint, slider joint, spherical joint) between the created component of the "link" type, so that the computer simulation corresponds to the operation of a real hexapod. The next stage of work included implementing the mathematical model describing the functioning of a hexapod in the LabVIEW software. At this stage, particular attention was paid to determining procedures for integrating the virtual 3D hexapod model with the results of calculations performed in the LabVIEW. The results relate to specific values of the jump of electric actuators depending on the position of the car on the hexapod. The use of integration made it possible to determine the safe operating space of a stationary hexapod taking into consideration the security of a person in the driving simulator designed for the disabled.

1. Introduction

The subject of conducted studies isthe stationary hexapod. It is the main executive system of a driving simulator for people with lower limb disabilities, (figure 1). The presented simulator was considered as the result of the research projectand was the subjectof many investigations conducted by theresearch team [5,8].On the hexapod is mounted the fiat panda car that has been mechanically modified. Modifications included the moving of mechanical systems, which are not required for correct functioning of a driving simulator (e.g.: transmission gearbox, suspension). The described system is connected to the control cabinet, which is responsible for the correct functioning of the hexapod and for cooperation with a virtual environment in which the car avatar is moving. Information from the virtual environment and from control elements of the modified car (gas pedal, brake one, clutch one, lights controls and speed indicator) are forwarded as inputs to the control cabinet. In this cabinet, basing on acquired information obtained from stored mathematical model, decisions are made concerning the mode of “behave” of the hexapod. It should be noted that the method of driving the modified vehicle does not differ from that of driving a car moving in the real traffic. This is due to the fact that all control elements (gas pedal, brake one, clutch one, lights controls and speed indicator) from the point of view of the driver look and function identically as in an unmodified car.

Figure 1. Virtual model and the real system of the simulator for car driving learning for disabled persons.

The whole simulator completes the virtual world image projection system, which consists of four multimedia projectors and four large screens. Three of them are connected to each other and allow realizing the projection of the driver's front and sides view, and rear screen allows to ride “over the shoulder” and control traffic by rear mirror mounted inside the cabin of the car.

The aim of investigations was to determine the maximal values of movement for each axis that could be performed by the frame with attached car body using the approach basing on the integration of the model prepared for driving simulation, created in the system Siemens NX program, and the control application created in the Lab VIEW program. In connection with realizing works leading to the best possible tuning of work of the real hexapod system, in the adopted environment of the simulator designed for driving lessons for people with movement dysfunctions, the important problem is determining the movement “margin” which could be realized by the hexapod without danger of collision of the car with the elements of the work environment of the simulator. The elements of the work environment of the simulator, with which may collided the car body, mounted on a hexapod, are predominantly components of the projection system of virtual environment. In contrast, the hexapod itself is exposed to the possibility of a collision between its drives and the pocket cavity of a foundation that has been made due to insufficient height of the room in which is installed the simulator system.

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2. Preparation of the hexapod model for motion simulation

The issues related to the designing and modeling are the basis for the creation of virtual models of technical systems [1,2,3,4,6,7,9,10,11,12,13,14]. Preparation of the presented 3D model of the hexapodwas realized on the basis of the 3D model in the "Motion Simulation" module in the software Siemens NX 8.5 of the CAD class (figure 2). In the first stage of works the components of the"link" typewere defined, among which it could be distinguished: platform_base_link (1), cross_link (2), motor_link (3), actuator_link (4), and body_link (5).

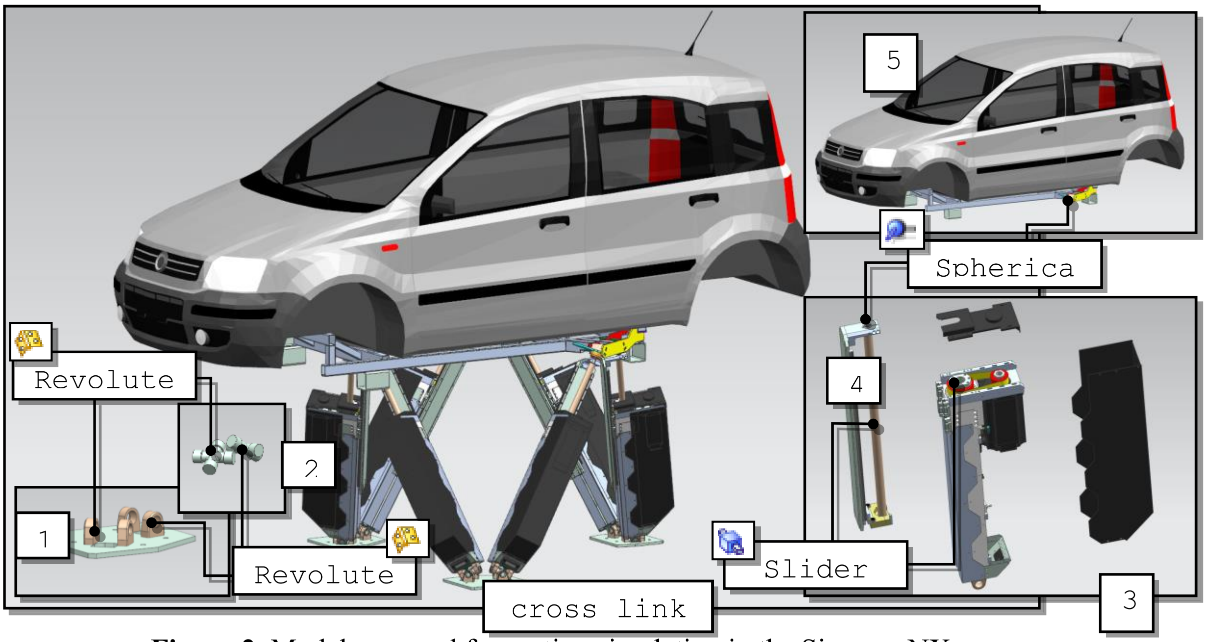

Figure 2. Model prepared for motion simulation in the Siemens NX program.

Due to the complex solid model of the analyzed system the particular components of the "link" type contains many elements of the "solid body" type. It should be noted that the elements being includedin the given component of the "link" type do not change their relative position during the motion simulation. Accordingly, the component of the "link" type is treated, by the simulation environment, as a single object, but its properties depend on the properties of its elements (e.g.: the weight of a component of the "link" type depends on the material properties assigned to particular elements of the "solid body"type). For mapping the hexapodoperation in a virtual environment between the components of the "link" type was established the components of the"joint" type.Among them it could be distinguished: revoluta joint -between the platform_base_link and the cross_link; revoluta joint - between the cross_link and the motor_link; slider joint - between the motor_link and the actuator_link and spherical joint - between the actuator_link and the body_link.

3. Control application created in the LabVIEW program

The developed control application was created in the LabVIEW program. The input parameters for the described application are the characteristic points ofthehexapod,with which is described the initial position (neutral) of the hexapod (figure 3). By neutral position of the hexapod is understood such position in which its all drives reach the displacement value equal to half of the maximal extension of the drive screw. On the basis of the neutral position is determined the length between the corresponding characteristic points representing the linear dimensions of the hexapod legs in the given position. In order to verify the correctness of work of the adopted mathematical model, describing the relationship between the position of the frame with a car and lengths of particular leg of thehexapod, it was used the virtual measurement tool, in relation to the 3D model of the hexapod in the Siemens NX software.

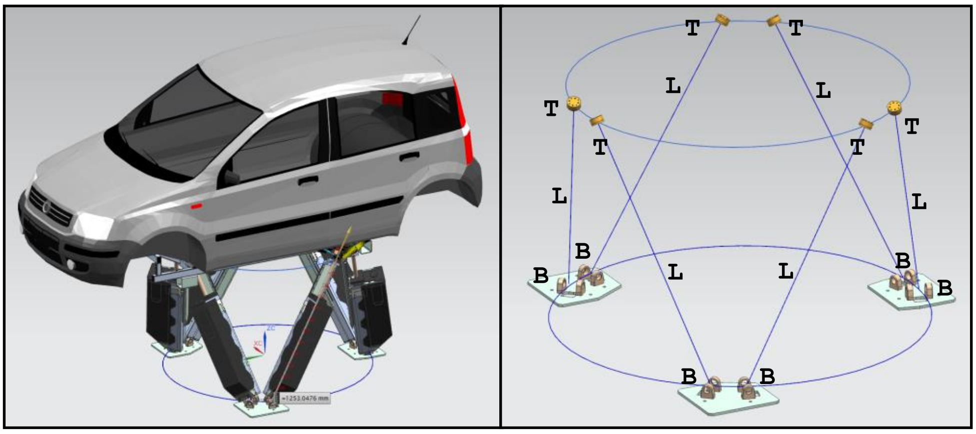

Figure 3. Adopted, simplified model used for determining the length of hexapod legs.

The leg length L_i (i = 1,…,6) of the hexapod, in the neutral position,are determinedon the basis of coordinates valuesof points T_i (i = 1,…,6) and B_i (i = 1,…,6) (table 1).

Table 1. Values of coordinates of pointsin the neutral position of the hexapod.

Coordinates of points of the hexapod located in the upper and lowerring					
T1; B1 [mm]	**T2; B2 [mm]**	**T3; B3 [mm]**	**T4; B4 [mm]**	**T5; B5 [mm]**	**T6; B6 [mm]**
X = 582; 77	X = 697; 756	X = 114; 679	X = -114; -679	X = -697; -756	X = -582; -77
Y = -469; -829	Y = -271; 347	Y = 739; 481	Y = 739; 481	Y = -271; 347	Y = -496; -829
Z = 1125; 37	Z = 1125; 37	Z = 1125; 37	Z = 1125; 37	Z = 1125; 37	Z = 1125; 37

In figure 4 is presented the view of the application using which it is possible to determine the values of the lengths of all hexapod legs depending on the position of the coordinate system.

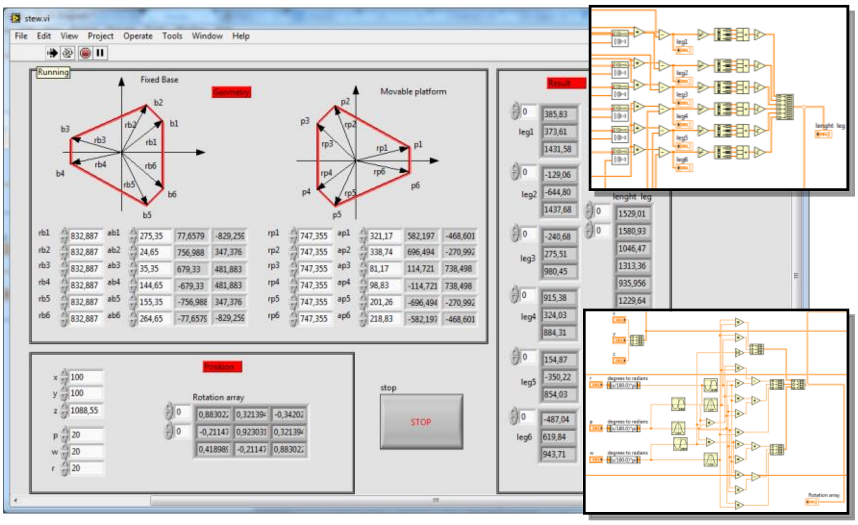

Figure 4. Application allowing determining the values of the lengths of all hexapod legs created in the LabVIEW program.

4. Analysis of hexapod displacements using an integrative approach

The process of movements analyzing of the hexapod, in the adopted simulator environment,consists of: changing the position and orientation of the coordinate system, closely connected with thehexapod frame; determining the length of the legs of the hexapod in thegiven position using the matrix of moving system transformation, associated with the frame, to the stationary system, connected to the hexapod base; determining the difference between the length of the legs in the position *i* and *i-1*, which is the value of displacement of the drive screw in the CAD model; storing the values to the integrator in the form of an Excel file; analyzing the positions of the car in the adopted CAD environment of Siemens NX basing on data from the integrator.

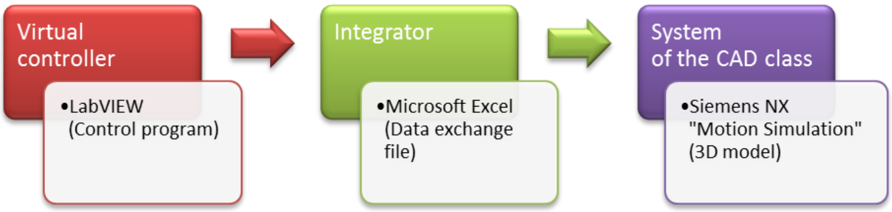

Figure 5. Scheme of the integration of the control application with the virtual 3D model.

The obtained values of displacement of the frame, with the mounted car body,in the particular axis of the system are shown in figure 6.

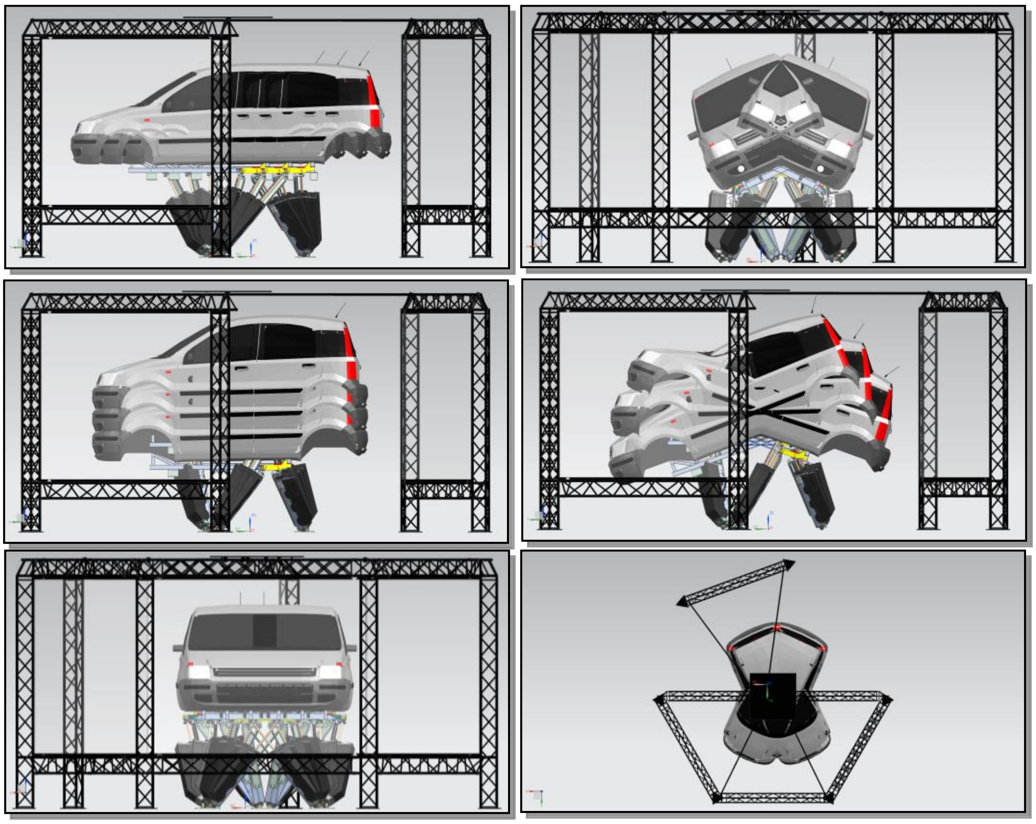

Figure 6. Locations of the hexapod, with the mounted car body, in the simulator work environment.

5. Conclusions

An important problem, related to the integration process of the control system model with the control application, is correct representation of operation of the analyzed system, whatis possible usingthe Siemens NXsoftware of the CAD class.The carried out works allowed the integration of the virtual model of the control system of thehexapodwith the control application created in the LabVIEW program, what allowedfor determination the displacements of the hexapod in the particular axes of the coordinate system.

Virtual analysesof systems, basing on the integration of the 3D model with the control application, allow determiningthe“margin” of movement concerning the analyzed hexapod.

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