University of Trento
Master in Mechatronics Engineering

Modelling and Simulation of Mechatronics Systems

Development, analysis and optimization of the performance of an innovative driving simulator

System requirements

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The objective of this project is to develop, analyze and optimize the performance of an innovative driving simulator. A simulator is a device that enables the operator to reproduce or represent under test conditions phenomena likely to occur in actual performance. Driving simulators are in general used both for research purposes and in the development process of a vehicle.

The simulator has to emulate the behaviour of a car like the one shown in Figure 1. In the first phase of the project it is relevant to impose a correct set of objectives (system requirements), in form of engineering specifications and performance indexes. To make the correct choice literature have been consulted and physical tests have been carried out.

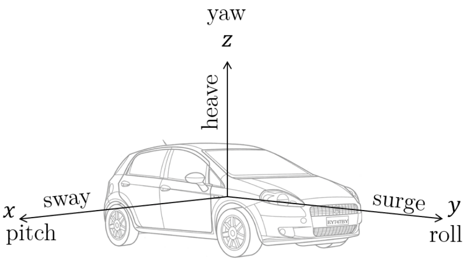

Figure 1: Reference system used.

1 Project Parameters

In order to choose the right parameters to be implemented in the driving simulator it was decided to start from two different models of already developed structures for driving simulators.

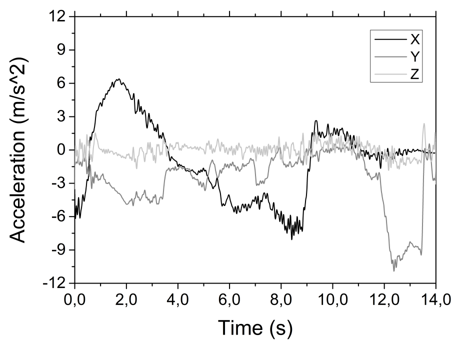

Figure 2: Experimental acceleration data obtained from a car.

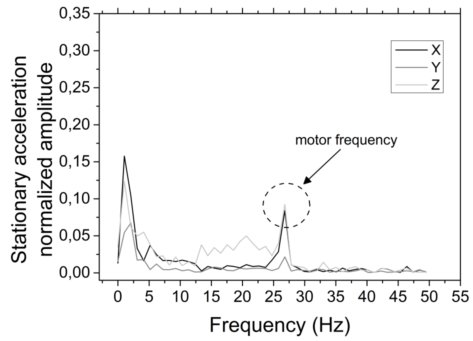

Figure 3: Fast Fourier transform of a window of the acceleration data.

The first one is the Advanced Vehicle Driving Simulator (aVDS) developed by ABDynamics (that is the structure on which this project is mainly based) [1]. Moreover, in order to obtain more data and to make a comparison with other systems usually exploited in this field, the parameters of the 6DOF Motion System designed by CKAS Mechatronics [2] were analyzed.

After that, focusing on the decision of checking if the design parameters given by the catalogues were actually correlated to a real behaviour of a car, it was decided to take some experimental data. In order to do this, it was taken a common car and exploiting the functionalities of the MATLAB application available for smartphones, some data were collected: linear acceleration (along the three Cartesian axes), orientation (Roll, Pitch and Yaw) and angular velocity (around the three Cartesian axes). Furthermore, data were collected making some specific maneuvers such as narrow curves, rapid acceleration and strong breaking performed both separated and together in order to see different results.

At the end, these experimental data were elaborated in MATLAB, as shown in the two examples of Figure 2 and Figure 3. Then, merging both the parameters from the catalogues and the experimental ones, the parameters that will be used for the development of this project were collected in Table 1 and 2.

	Yaw	**Pitch**	**Roll**
P	±30	±15	±30
V	±23	±23	±23
A	±150	±150	±150
B	35	50	35

Table 1: Angular system requirements. **P** = limitations [°], **V** = velocity [$°/s$], **A** = acceleration [$°/s^2$] and **B** = bandwidth [Hz].

	Surge	**Sway**	**Heave**
P	±65	±65	±65
V	±100	±100	±100
A	±13.2	±9.5	±13.4
B	15	35	35

Table 2: Dimensional system requirements. **P** = limitations [mm], **V** = velocity [mm/s], **A** = acceleration [m/s^2] and **B** = bandwidth [Hz].

2 Performance Indexes

Starting from the above mentioned parameters, performance indexes have been identified and divided into three main groups: kinematics, dynamics and control. Moreover, a priority coefficient (P) has been assigned to each index.

The main idea behind the definition of the kinematics indexes is based on the hypothesis that a good and uniform behaviour of the correlation between engineering parameters has a bigger impact on the performance of the system than the parameters alone. The kinematics objectives are:

- optimization of Sway - Yaw, Sway - Roll, and Surge - Pitch workspaces | P = 10;
- small error between desired and actual parameters regarding pose of the platform and its velocity | P = 7;
- small changes of output variables (platform) after big changes in the input ones (actuator) | P = 5;
- small ratio between lateral 1D envelope and workspace | P = 4.

The most important dynamics indexes correlate kinematics variables (angles) of the platform with their second derivative. The aim is to obtain:

- uniform dynamic behaviour in each zone of the workspace, for each plane. This means optimization of the workspaces between Roll and Pitch angles and their second derivatives | P = 10;
- small error between desired and actual values of maximum angular and linear acceleration | P = 7.

Cross planes dynamics requirements have not been assigned in this early stage.

The identification of the control indexes is based on the hypothesis that low frequency dynamics - with high amplitude - requires absence of overshoot, accepting a loss in the rapidity to converge to the desired state, so that the user's feel is realistic. On the other side, high frequency dynamics - with low amplitude - should involve rapid convergence to the desired state, accepting a certain value of overshoot. Under first hypothesis, this approach is expected not to compromise the user experience.

References

[1] "*Advanced Vehicle Driving Simulator*", ABDYNAMICS.

[2] "*6DOF Motion System*", CKAS.