Final Year Project

Master’s Degree

University of La Coruña and Technical University of Sofia

Computer-Aided Design of Platform and Cab for a Car Driving Simulator.

Author: Tsvetozar Yordanov
Supervisor: Miguel Ángel Naya
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Objective of the Project

• The design of several of the sub-systems of a mid-level driving simulator. This would include:
  - Problem identification and definition
  - Choice of hardware for the main sub-systems of the simulator;
  - Preparation of 3D models for these items;
  - Design of a supporting structure;
  - Analysis and optimization of the frame;
The Design Process

Conventional Design

1. Recognition of a need
2. Definition of the problem
3. Synthesis
4. Analysis and Optimization
5. Evaluation
6. Presentation

CAD

1. Geometric Modeling
2. Engineering Analysis
3. Design Review and Evaluation
4. Automated Drafting
Introduction to simulation

Definition of Simulation

Areas of Application of Simulation

- study of and experimentation with complex systems;
- verification of analytical solutions;
- training and evaluation of personnel;
- experimentation with new designs prior to implementation;
The Driving Simulator

- Complete control of environmental factors.
- Cost-effective for set-up and data collection.
- Safe environment for testing.
- Dynamic driving environment with workload and tasks similar to actual driving.
Classification of Driving Simulators

- High-level;
- Mid-level;
- Low-level;
Problem Identification and Definition

- Recognition of a need for a driving simulator
  - Explore the possibilities and the robustness of the developed by the Mechanical Engineering Laboratory multibody dynamics formulations.
  - Offer a competitive, efficient and low-cost tool to driving schools.
Problem Identification and Definition

- Definition of the problem.
  - Minimized overall dimensions and weight;
  - A six degree-of-freedom motion base, capable of accelerations between 0.5 and 2g;
  - A high quality visual system for full immersion in the simulation;
  - Sound system, control units and seat;
  - Supporting structure;
Problem Identification and Definition

Functional Analysis System Technique

Driving

- Provide sound stimuli
- Appropriate mounting
- Provide motion stimuli
- Provide visual stimuli
- User interface
- Provide support

- Use 6 DoF
- Apply accelerations
- Display simulation
- Input interface
- Ensure seating

Ease of maintenance
Allow unhindered access
Display information
Allow adjustability
Choice of a Motion Base

- Six Degree-of-Freedom Motion Bases
  - Serial Mechanisms;
  - Parallel Mechanisms – the Stewart Platform;
  - Hydraulic Actuators; Series 6DOF9000H
  - Electric Actuators; DSMP608 electric
  - Electromagnetic Actuators; Emag-400 series
Choice of Control Units

- **Force Feedback Wheel and Pedals**

  PC with Pentium® 166+ MHz (or compatible processor)
  
  Windows® 98, Me, 2000, XP
  
  Mac® OS X 10.2.3 or later
  
  32 MB RAM
  
  20 MB available hard drive space
  
  CD-ROM drive
  
  Available USB Port
Choice of a Visual System

- Primary Visual System
  - Projection Screens;
  - Display Systems;
  - The Head Mounted Display;
- Secondary Display
Choice of a Seat

- The Recaro Mobility LXF Seat
  - Ergonomics;
  - Dimensions;
  - Price;
Design of the supporting structure

• Determination of basic dimensions;
• Simulator model;
• Analyses – procedures followed and results;
• Optimization of the designed structure;
Design and Modeling of the Supporting Structure

- **Determination of the dimensions for the frame and platforms.**
  - Overall dimensions of the parts to be mounted;
  - Ergonomic requirements and anthropometric data for a standard population;

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Design Eye Point
Elbow Point
Poplitea Point

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Design Eye Point
Elbow Point
Poplitea Point
The Simulator Model

- The model of the frame
- The simulator assembly
Analysis: Model Meshing

- Type of Elements Used for the Finite Elements Model.
  - Thin Shell Elements – surface for meshing;
  - Lumped Mass Elements;
  - Rigid Bar Elements;
  - Surface Thickness Input;

- Material Properties

- Model Meshing.
Analysis: Boundary Conditions

- Application of restraints.
- Loading conditions – maneuvers performed.
  - Severe braking;
  - 180°-degree turn;

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Resultant accelerations

- Sum Linear Accel.
- Sum Ang. Accel.

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accelerations

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<th>time (s)</th>
<th>0.00</th>
<th>0.96</th>
<th>1.92</th>
<th>2.88</th>
<th>3.84</th>
<th>4.80</th>
<th>5.76</th>
<th>6.72</th>
<th>7.68</th>
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<th>10.56</th>
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<th>15.36</th>
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Analysis: Results

- The severe braking maneuver.
  - Stress values–criterion is
    \[ \sigma \leq \sigma_{\text{yield}}/2 (\sigma \leq 137.5 \text{N/mm}^2) \]
  - Displacement values
Analysis: Results

- The 180°-degree turn maneuver
  - Stress values-criterion is $\sigma \leq \sigma_{\text{yield}}/2 (\sigma \leq 137.5 \text{N/mm}^2)$
  - Displacement Values
Analysis: Modified Design

- Modifications applied.
- The 180°-degree turn maneuver.
  - stresses;
  - displacements;
Analysis: Further Modifications

- Modifications applied.
- The 180°-degree turn maneuver.
  - stresses;
  - displacements;
Optimization

- Geometry-based math programing redesign.
- Redesign parameters.
- Stress limit – 137.5 N/mm².
- Displacement limit
- Design goal – minimization of mass.

<table>
<thead>
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<th>Parameter</th>
<th>Initial value</th>
<th>Maximal value</th>
<th>Minimal value</th>
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<tr>
<td>Bar width</td>
<td>80mm</td>
<td>88mm</td>
<td>72mm</td>
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<tr>
<td>Rib width</td>
<td>100mm</td>
<td>110mm</td>
<td>90mm</td>
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<tr>
<td>Platform thickness</td>
<td>4mm</td>
<td>5mm</td>
<td>3mm</td>
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</table>
Optimization - Simplified

- **New boundary conditions.**
  - Removing the lumped mass elements;
  - Applying distributed forces in place of the weights of the parts;

- **Results.**
  - First iteration;
  - Last iteration;
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<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Price in Euro</th>
<th>Mass in kg</th>
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<tr>
<td>Motion base</td>
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<td>Wheel and pedals</td>
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<td>80</td>
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<td>Head Tracker</td>
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<tr>
<td>Display</td>
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<tr>
<td>Seat</td>
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<td>450</td>
<td>6</td>
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<tr>
<td>Steel channels (80mmx45mmx6mm)</td>
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<td>307</td>
<td>34</td>
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<td>Steel channels (60mmx30mmx3mm)</td>
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<td>Steel plate (4mm)</td>
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Conclusions

- The design of a driving simulator would offer a multitude of opportunities for investigation and research;
- A preliminary solution for an economical, yet effective driving simulator has been reached;
- The I-Deas 10 NX Series CAD software has been found to offer a wide range of modeling and simulation capabilities;
- The performed analysis showed that the loading conditions are much more demanding when angular accelerations are dominating.
- A feasible solution for the platform was obtained;
- The variation of the parameters during optimization was found to have negligible effect on performance;