Adaptive predictive vibration control in vehicular rear view mirrors

Antoine Larchez
University of Wollongong

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Adaptive Predictive Vibration Control in Vehicular Rear View Mirrors

A thesis submitted in fulfilment of the requirements for the award of the degree PhD from University of Wollongong

By

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Diplôme d'ingénieur (Equ. M.EE), E.S.I.E.E. Paris, France, 2002 DEA, Paris VI University, France, 2002

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August 2007
DECLARATION

This is to certify that the work presented in this thesis was carried out by the author in the School of Electrical, Computer and Telecommunications Engineering at the University of Wollongong, and has not been submitted to any other university or institute.

Antoine Larchez
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Abstract

Reduction in rear view mirror vibration has been identified as a research and development priority by large automotive mirror manufacturers, such as Schefenacker Vision Systems Australia Pty Ltd (SVS), the industrial partner of this project. Mirror vibration, particularly in luxury and heavy vehicles, has proved to be a major source of complaints received from the customers. Such vibration may result in image blurring and the loss of rear vision. This can adversely affect the driver, the control of the car, and the safety of the driver and the passengers. The vehicle mirror vibration is also generally perceived to indicate the poor quality of a vehicle.

Mirror glass vibration is primarily caused by wind as the result of the motion of the vehicle. The structure-borne vibrations also contribute to vibration by affecting the mirror’s housing. The vibration intensity will depend on parameters, such as the roughness of the road, the engine speed, and wind intensity. Under some circumstances, the image provided by the mirror is not indicative of the true conditions behind the car, which can lead to incorrect perception and to driver misjudgement, resulting in the increased risk of an accident.

The main focus of this thesis is to investigate the feasibility of developing an intelligent active vibration controller capable of maintaining a sharp reflected image under all driving conditions. An adaptive predictive controller is proposed. As an adaptive method, the proposed system can generate a control signal, according to the driving conditions, to cancel the vibration. The predictive characteristics of the approach can minimise the effect of delay between the measurement of the vibration signal and the generated control signal.

An extensive review of the literature relevant to rear view mirrors, measurement techniques and active control of noise and vibration is carried out. The nature of the mirror vibration based on the road data is obtained empirically and statistically characterised. In order to develop and validate the vibration compensator, a number of experimental rigs are designed and developed.
In a rigorous and systematic approach, a number of active vibration techniques are
developed and validated through computer simulation and experimental work.
The structure of nearly all of these algorithms is based on internal model control,
where the actual disturbance signal is reconstructed analytically. The control
structures include at least one variant of the FxLMS adaptive filter in different
configurations. The results of modelling and validation are systematically
recorded in the thesis.

The results obtained show that the methodologies proposed in this study,
outperform the conventional controllers in reducing vibration levels in rear view
mirror.
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<tbody>
<tr>
<td>ADC</td>
<td>Analogue-to-Digital Converter</td>
</tr>
<tr>
<td>ANVC</td>
<td>Active Noise and Vibration Control</td>
</tr>
<tr>
<td>ARMAX</td>
<td>Auto-Regressive Moving Average with eXogenous input</td>
</tr>
<tr>
<td>ARX</td>
<td>Auto-Regressive with eXogenous input</td>
</tr>
<tr>
<td>AVC</td>
<td>Active Vibration Compensation/Control</td>
</tr>
<tr>
<td>AVI</td>
<td>Active Vibration Isolation</td>
</tr>
<tr>
<td>BOM</td>
<td>Bill of Materials</td>
</tr>
<tr>
<td>CVA</td>
<td>Canonical Variable Algorithm</td>
</tr>
<tr>
<td>DAC</td>
<td>Digital-to-Analogue Converter</td>
</tr>
<tr>
<td>EMI</td>
<td>Electromagnetic Interferences</td>
</tr>
<tr>
<td>ER</td>
<td>Electro-Rheological</td>
</tr>
<tr>
<td>FIR</td>
<td>Finite Impulse Response</td>
</tr>
<tr>
<td>FxLMS</td>
<td>Filtered-x Least Mean Square</td>
</tr>
<tr>
<td>FxRLS</td>
<td>Filtered-x Recursive Least Square</td>
</tr>
<tr>
<td>IIR</td>
<td>Infinite Impulse Response</td>
</tr>
<tr>
<td>IMU</td>
<td>Inertial Measurement Unit</td>
</tr>
<tr>
<td>IV</td>
<td>Instrumental Variable</td>
</tr>
<tr>
<td>LIVM</td>
<td>Low Impedance Voltage Mode</td>
</tr>
<tr>
<td>LS</td>
<td>Least Square</td>
</tr>
<tr>
<td>LVDT</td>
<td>Linear Variable Differential Transformer</td>
</tr>
<tr>
<td>MOSFET</td>
<td>Metal-Oxide Semiconductor Field Effect Transistor</td>
</tr>
<tr>
<td>MR</td>
<td>Magneto-Rheological</td>
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<tr>
<td>NVH</td>
<td>Noise, Vibration and Harshness</td>
</tr>
<tr>
<td>OE</td>
<td>Output-Error</td>
</tr>
<tr>
<td>PEM</td>
<td>Prediction Error Method</td>
</tr>
<tr>
<td>PWM</td>
<td>Pulse Width Modulation</td>
</tr>
<tr>
<td>PZT</td>
<td>Lead Zirconate Titanate</td>
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<tr>
<td>RBS</td>
<td>Random Binary Signal</td>
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<tr>
<td>RGS</td>
<td>Random Gaussian Signal</td>
</tr>
<tr>
<td>RMS</td>
<td>Root Mean Square</td>
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<tr>
<td>Acronym</td>
<td>Definition</td>
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<tr>
<td>RPM</td>
<td>Rotation-per-Minute</td>
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<tr>
<td>RTW</td>
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<tr>
<td>SM</td>
<td>Subspace Method</td>
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<td>Sport-Utility Vehicle</td>
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<tr>
<td>UOV</td>
<td>Unexplained Output Variance</td>
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