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Motorcycles Dynamic Stability Monitoring During Standard Riding Conditions

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Abstract

The target of this work is to improve driver safety related to dynamic instability, often the cause of accidents involving powered two-wheeled vehicles as explained in the UNECE Transport Review of Road Safety [1].The paper explains the feasibility study of an advanced driver assistance system (ADAS) with regards to the real-time instability conditions identification of a generic motorcycle during typical use. As well known, these types of systems have been typically applied and relied on in the automotive sector, however have not yet broken through for two-wheeled vehicles. Recently there has been an increase of interest and awareness for the application of ADAS systems to motorcycles as can be deducted by the SAFERIDER project [2].The first step of the research consists in an investigation on the methodologies that can lead to a positive outcome in identifying the approaching instability of a vibration mode of the motorcycle, and choosing the most efficient algorithm considering the final application on a diagnostic real-time system. An initial study of the vibration modes of a motorcycle led to the isolation of the weave mode and the wobble mode as the most likely to occur during motorcycle use [3]. Normally these two vibration modes have isolated frequencies [Figure 1]; while the weave mode is typically a low frequency oscillating mode (1-4Hz) which consists of the front assembly and rear assembly oscillating with an opposite phase one to the other, the wobble mode is a oscillation of the front assembly around the steering axis with little movement of the rear assembly and occurs at a higher frequency (8-11Hz).

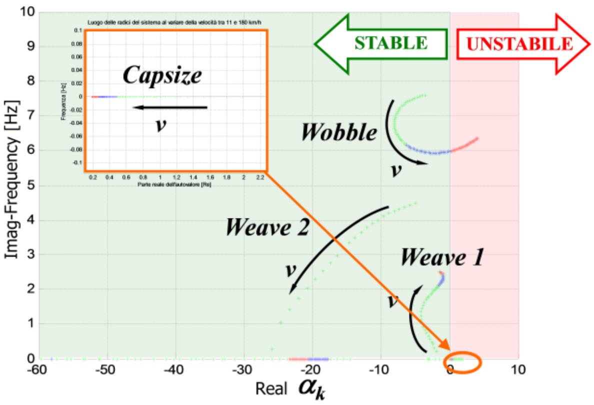

Figure 1. Root locus plot in straight running; speed varies from 3 to 50 m/s.

To determine when the weave mode and the wobble mode are moving towards a possibly critical situation, it is possible to estimate the respective damping coefficient of the considered modes. If the damping coefficient tends to a null value a dynamic instability is occurring. Thus the damping coefficient has been considered as the instability index.In the paper various methods will be proposed and discussed as possible candidates to estimate the frequency and damping coefficients of the two modes. The methods considered are based both on a one DOF system (fitting of a one degree of freedom frequency response function, peak picking method, phase differentiation method), acceptable because the frequencies of the vibration modes are distant one from the other, and a multi DOF system (Prony's method). The methods have been evaluated from both a numerical result and time complexity point of view, due to the fact that the chosen methodology must be sufficiently accurate and be able to run in real-time conditions.
In Figure 2 a flow chart containing the logical procedure with which a possible dynamic instability is identified and evaluated is shown. As can be seen, an averaged autocorrelation function of the extracted time signal is calculated in order to obtain a decay function and eliminate noise.

This function is passed into the frequency domain and the peak picking method is applied. Two damping coefficients are identified, relative to the weave and wobble modes. Should one of these damping coefficients be below a critical value, Prony's method is launched. Prony's method identifies critical frequencies and damping factors if present, and returns a visible warning message based on the results.

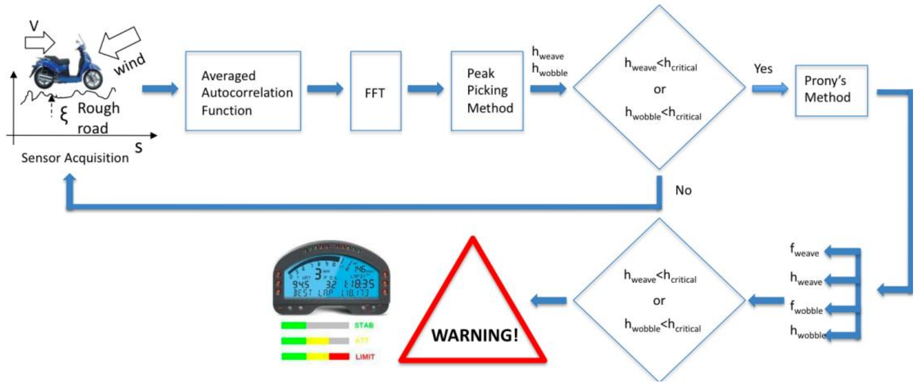

Figure 2. Flow chart explaining the logical procedure with which the time signal is analysed.

The proposed method must be successfully applicable to several motorbike typologies. Thus, to prove the efficiency of the methodology, in the first step of the research, several experimental tests have been carried out on different motorcycles. The developed intelligence has been adapted to offline post-process signals acquired by sensors while on road running tests. Figure 3 box A shows the acquired time history from sensor mounted on the steering assembly and the vehicle speed. In part B there is the spectrogram of the time history. Box C illustrates frequencies identified by Prony's Method, while in box D damping factors are shown. At time 53 seconds there is wobble oscillation. As can be seen the spectrogram gives a pick of amplitude (in red), while Prony's method identifies frequency and damping coefficient. By the analysis of achieved results, the same experiences allowed to define both the most sensitive sensors for the identification of vibration modes and the outer prefixed threshold.
Next actions are the integration of the intelligence on a real time on board system able to communicate with driver. Then, it will be possible to preview an active control device [4] able to reduce the occurred danger situation.

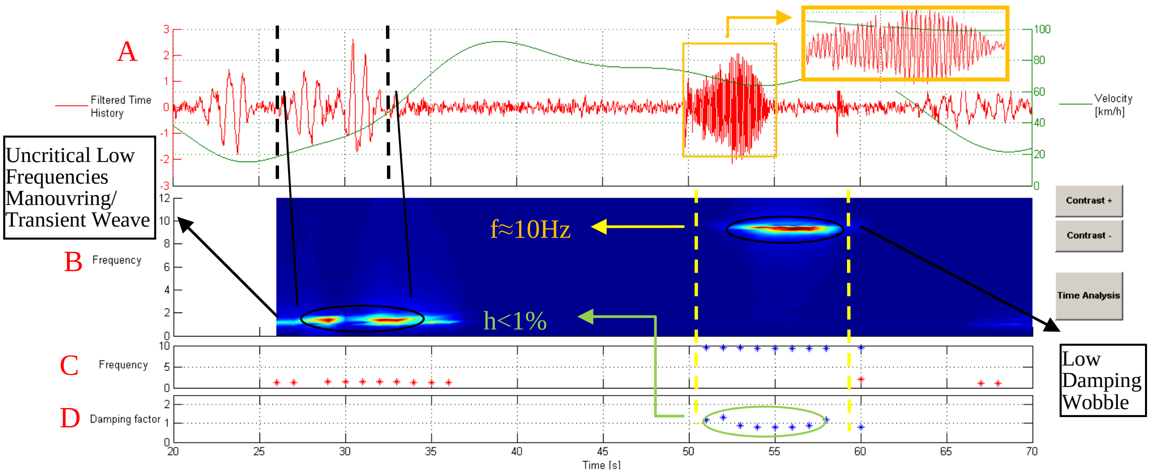

Figure 3. From top to bottom: (A) time history acquired by sensor and vehicle speed, (B) spectrogram, (C) identified frequencies, (D) identified damping coefficient.

References

[1] UNECE, *Transport Review: Road Safety*, United Nations, 2008
[2] SAFERIDER project, "Advanced telematics for enhancing the safety and comfort for motorcycle riders", *1st Joint Workshop on PTW Integrated Safety*, 2008
[3] V. Cossalter, *Motorcycle Dynamics*, LULU, 2006
[4] S.Evangelou, D.J.N.Limbeer, R.S.Sharp, M.C.Smith, "Control of motorcycle steering instabilities", *IEEE Control Systems magazine* 26 (5), pp. 78-88, 2006.