Characterisation of motorcyclist's upper body motion during braking manoeuvre

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ABSTRACT

Motorcycle braking experiments with volunteers were performed in lab, to study the body posture and reactions of the motorcyclists during braking with the aim of providing input for human modelling. Human motion capture methods were employed for the kinematics and the recorded data was further analyzed with clustering methods for time-series. The validity of the clustering results was also studied.

Eight volunteers in two different setups (aware-unaware) were analyzed. Two kinematics behaviours were identified.

Keywords: volunteers, sled tests, neck, kinematics, validation

MOTORCYCLE CASUALTIES REPRESENT 16% OF THE TOTAL ROAD FATALITIES [COST, 2001]. From the main two motorcycle accident epidemiology studies [Hurt, 1981] and [ACEM, 2004], we can conclude that braking is a common motorcycle pre-crash manoeuvre. Braking is resulting in an out-of-position posture of the rider, due to inertial loads to his unconstrained body on the motorcycle. With the following experimental campaign the influence of braking to the motorcyclist's posture is studied.

METHODOLOGY

A device was built that could reproduce the geometry of a motorcycle (MGD). The MGD included only the motorcycle - rider interface and was mounted on a sled. Reverse sled accelerations, relative to the forward facing volunteer, was used to simulate braking. The sled could be activated externally by a researcher (unaware setup), or internally by the braking action of the volunteer (braking setup). In order to provide valuable input for modelling these two very distinct setups were selected, from a larger campaign of measurements regarding braking scenarios e.g. autonomous braking. The acceleration employed had an average value of 0.35g and a similar shape compared to braking accelerations recorded on field tests [Hugemann, 1993]. An optoelectronic motion capture system was used to capture the motion of the volunteer.

A bicycle helmet with some additional weight was used instead of a motorcycle helmet not to cover relevant anatomical points on the head. A consistent initial head orientation was insured with positioning of the head' Frankfurt plane parallel to the ground plane. The volunteer was prevented from visually or aurally perceiving the initiation of the sled motion. The experiment setup is discussed in detail in [Symeonidis, 2008].

RESULTS

The kinematics of 8 volunteers 5 males 3 females were captured in two test-setups aware and unaware, the test was repeated two times per setup. The output data of the motion capture system was the 3d coordinates of the markers during the test. For the analysis of the kinematics' behaviour of the volunteers instead of using corridors to describe their motion, a variant of the clustering method presented in [Robert, 2006] was used. Two time-series parameters were selected for the analysis the head horizontal translation and the head rotation from the initial posture right before the initiation of the experiment as presented in Fig. 1.

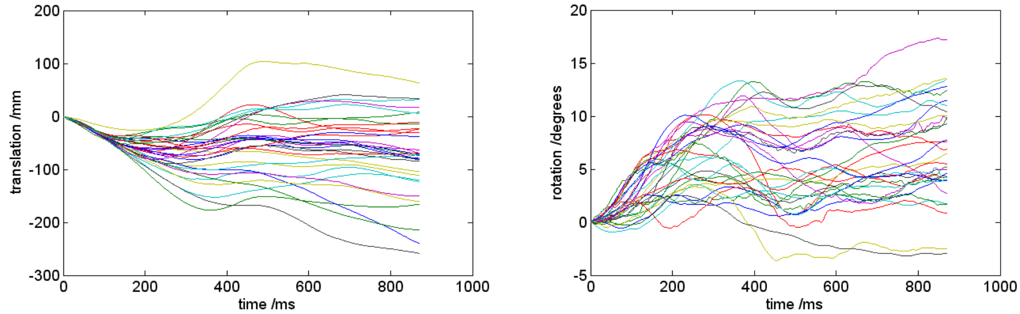

Fig. 1 Head horizontal forward translation and head horizontal forward rotation (flexion), respectively.

To normalize the parameters the z-score standardization method for time-series was used. For each time-series the z-score was calculated for all its samples with the following equation:

$Z(s) = \dfrac{X(s) - \mu}{\sigma}$, where *X(s)* is the value of the time-serie at sample s, μ is the mean value and σ the standard deviation of the complete time-serie.

The new form of the curves is presented in Fig. 2.

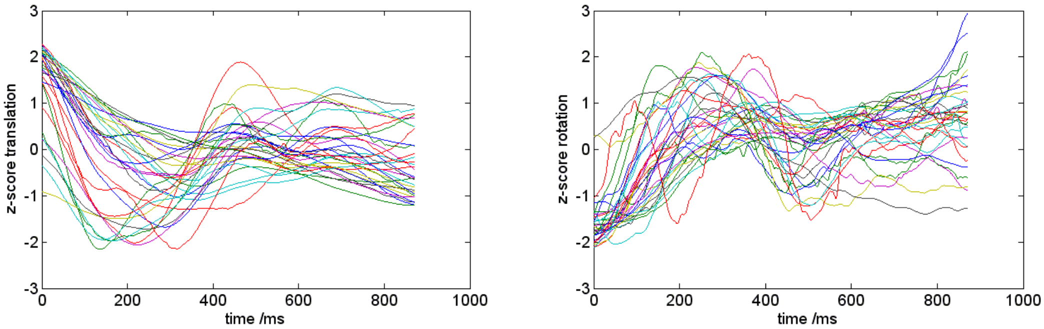

Fig. 2 Z-score normalized curves.

In the next step a clustering method was applied to separate the time-series in groups. Two clusters were selected as the number of groups. The Euclidean distance per each frame between all the time-series and the Ward cluster joining algorithm for the cluster analysis were the methods applied for the clustering.

The mean values of the identified clusters and one standard deviation are presented in Fig. 3.

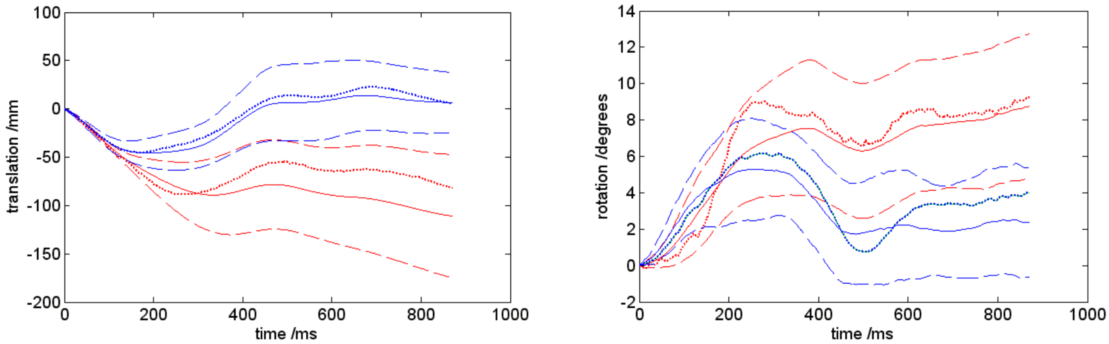

Fig. 3 Results from clustering, with mean, one standard deviation and the track with the closest total distance from the mean (doted line) per each cluster.

By plotting the distance matrix of the time-series the difference between the clusters is depicted in Fig. 4.

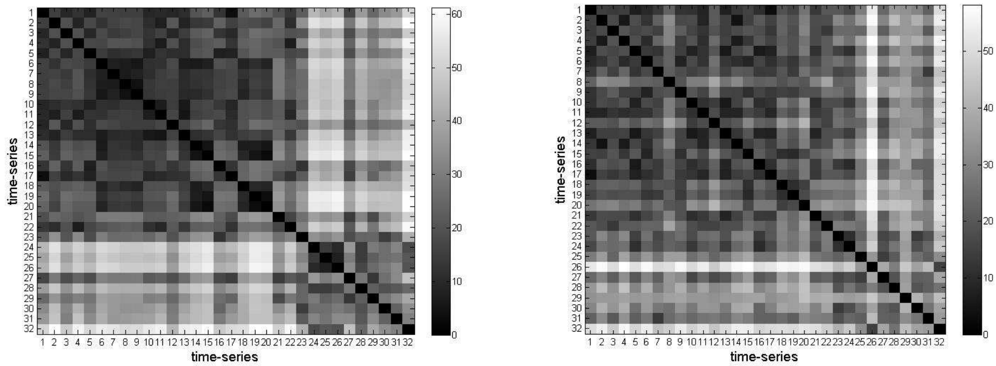

Fig. 4 Distance matrix of time-series; for simplicity all the time-series of the first cluster are enumerated from 1 to 22 and of the second from 23 to 32. Each time-serie is plotted per column and per line and their distance is presented in their cross-section. The lighter brightness areas represent higher difference.

To study the difference between the clusters during time a Mann-Whitney U-test as described in [Robert, 2006] was performed for the two clusters for all the time-series per sample. Significant difference was found between the clusters except for the initiation of motion; the results of the tests are presented in Fig. 5.

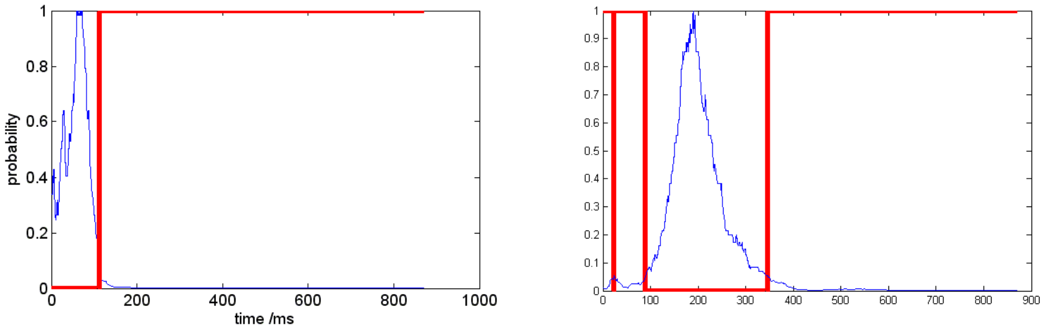

Fig. 5 Probability (blue) and rejection of the null Hypothesis of no significant difference for $p<0.05$ (red).

These two clusters represent different head stabilization strategies of the volunteers. Most of the volunteers consistently stayed in one of these clusters during all the repetitions and for both the test setups, as presented in Table 1.

Table 1. The clustering results per volunteer

volunteer \ cluster	1	2
1	3	1
2	1	3
3		4
4		4
5		4
6	2	2
7	4	
8		4

Finally, a Wilcoxon matched-pairs signed-ranks test was performed to determine a difference between the voluntary braking and the unaware setup (control group). The analyzed parameter was the maximum head horizontal translation. The calculated T was more than the critical $T=15>4$ for $p<0.05$, so no difference couldn't be established between the two setups at least from our restricted sample. Further, no difference was found for the two setups from the clustering algorithm, since as stated previously the volunteers showed a preference for one of the clusters for all the tests.

DISCUSSION

The two different groups identified represent different strategies of the volunteers for head stabilization (stiff and floppy) as reported also in the literature [Vibert, 2006]. The clustering method was found useful in analysing kinematics influenced from different behavioural strategies. For the braking setup, the head rotation was very consistent for the first 150ms amongst 60% of the volunteers while the head translation was consistent in both setups for the first 100ms of the experiment. After these times the different behavioural strategies of the volunteers took place. Instead of using relaxed and tensed muscle scenarios, a braking setup and an unaware setup was used achieving more realistic conditions for the experiment in the laboratory, closer to motorcycle riding.

CONCLUSIONS

In this paper a study of the motorcycle posture and braking kinematics is presented. An experimental setup that allows aware (active braking from the volunteers) and unaware (external trigger) was developed. For the analysis of the kinematics results a clustering method for time-series was used and its validity was studied. The outcome of this research is that braking influences the position of the motorcyclist's upper body and especially the forward displacement of the head. Two strategies for head stabilization were identified (stiff and floppy). The results from the experiment will be applied to an active human model that can predict the motorcyclist's kinematics during braking. Additionally, since the amplitudes of head motion in unaware and braking setups were not found to differ significantly, further analysis will be performed for the improvement of the braking process for motorcycles. Finally, these results will be studied also with respect to airbag implementations for motorcycles.

LIMITATIONS OF THIS STUDY

The MGD device mounted on the sled could not lean laterally and it was not equipped to allow pitch. Only one motorcycle geometry was used (motorcyclist with an upright upper-body riding posture). This was selected due to larger amplitude of upper-body motions relative to other types during pre tests. The acceleration used was similar to motorcycle braking in normal riding, not in emergency braking, but it was sufficient to produce out of position posture for the volunteers.

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