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Multi-link Model Method for Dynamic Motion Estimation of Crash Dummies

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According to the global road accident analysis, the decrease in the number of fatalities in 2020 was slower than the decrease in traffic volume at the beginning of the Covid-19 outbreak, and further countermeasures are required. The design and development of automobile crash safety performance requires analysis of the mechanism of human injury occurrence, and for this purpose it is important to measure and analyze occupant behavior.

Occupant behavior during a collision has been estimated by video tracking using cameras and sensor output analysis.However, it is known that the video analysis of the camera may intercept the tracked object, and the output of the sensor contains cumulative errors in integrating the results of the calculation.

This study attempted to apply a multi-link system to a collision dummy to estimate its behavior. Figure 1 shows the system configuration. The behavior of a collision dummy is estimated by treating the parts from the head to the feet as a series of links. Gyroscopes are placed on each part of the collision dummy, and the orientation of the links is calculated using an extended Kalman filter. Next, we devised a method to estimate the behavior of the continuous links by calculating the motion of the link system from the head to the feet. The dummy was represented as a multi-link model, link **1** is foot , link **2** is leg , link **3** is thigh , link **4** pelvis , link **5** is spine , and link **6** is head.

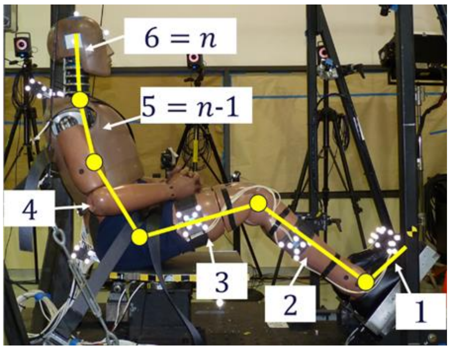

Fig.1 Crash dummy and a multi-link model

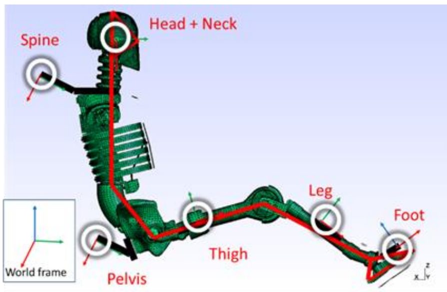

Fig.2 Dummy skeleton model

A SLED Test equivalent to a frontal collision of 40 km/h was conducted with this system. From the measurement data obtained in this test, the dummy's skeletal motion during the collision was visualized as the behavior of a three-dimensional dynamic link model. For comparative verification, motion capture analysis using multiple cameras was also performed. Accelerometer and gyroscope sensors were attached to the dummy surface and to an extension jig so that they were in the same position as the motion capture markers. Figure 2 shows the dummy link model and the measurement positions of the sensors and markers.

As a validation and discussion of the estimation results, we compared and verified the foot trajectories calculated from the link model and the motion-capture marker trajectories for the dummy right foot part, because the further away from the starting point the link is in a multi-link system, the larger the error becomes.

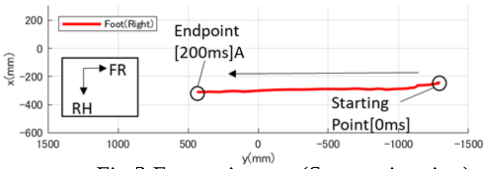

Fig.3 Foot trajectory (State estimation)

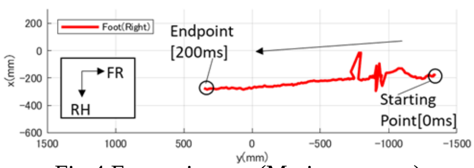

Fig.4 Foot trajectory (Motion capture)

Figure 3 shows the marker trajectory of the dummy right foot motion capture and Figure 4 shows the trajectory of the dummy foot calculated from the link model. The motion capture trajectory swings left and right, creating a discontinuity. The trajectory of the multi-link model moves straight ahead and backward and is continuous. This indicates that the multi-link model might be less affected by external factors than motion capture.

However, in this study only a gyroscope was used to calculate the link angles, and errors were included due to one-time integration. Therefore, the error may increase at sites with more links than the starting point, and further verification of the error and the need to add new sensors is required.