# Capturing Human Motion inside a Moving Vehicle, that Obstructs the Camera Field of View

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**Abstract:** Human motion capture with optoelectronic systems is used effectively for the kinematics analysis of volunteers in the field of occupant safety and ergonomics. The acceptance of this tool in the field is due to its technical capabilities, 3d measurement, high accuracy, fast configuration but also intuitive, visual manner of presentation of the results. Its major disadvantages are the marker occlusion and misidentification. When these types of problems occur time consuming, dull, manual work should be performed for the correction of the errors. A new method to overcome these problems is presented in this paper. An algorithm was developed for the identification that is not based on tracking, but grouping the markers according to their position relative to a reference marker placed on the moving platform, in this case representing the vehicle, or on the volunteer. Later, a spline smoothing and interpolation algorithm GCVSPL, commonly used in biomechanics for signal treatment, was applied to filter and complement the marker tracks, when the markers were not visible. An experiment were the kinematics of the volunteers were reconstructed with this method is given as an example.

**Keywords:** motion capture; kinematics; motorcycle

## 1. Introduction

Research has been performed, the last sixty years, to enhance the safety of vehicles and study the occupant's injury limits. Experiments with volunteers, cadavers and dummies were performed. In many of these experiments the kinematics was of major interest, so they were captured with the use of various systems. In the recent years, more often, optoelectronic motion capture systems are used for this purpose.

## 2. Method

The optoelectronic motion capture systems are using the procedure presented in fig. 1 for the calculation of the kinematics parameters of interest. The system is calibrated at the beginning of the measurement so the intrinsic and extrinsic parameters of all the cameras are calculated. Markers are placed on the points of interest on the subjects. Then the motion capture session follows with the performance of the experiment. The calculation of the 3D coordinates of the markers is performed with a variation of the DLT algorithm [1,2]. Then with the marker identification algorithm the reconstructed 3D points are assigned names from the markers placed on the subjects. Then the rigid body motion of the subject can be calculated and the kinematics' parameters of interest can be extracted.

The most time consuming step in this process, is usually the marker identification. In the software of the systems available this identification is done based on marker tracking and additionally an enhancement of tracking, when markers are lost, by fitting a kinematic model of the markers to facilitate the automatic identification. But this method stops to be effective when markers are hidden for several frames which is a usual case when measurements with additional structures are performed.

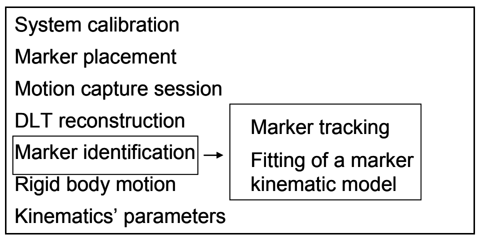


**Figure 1. Motion capture procedure**

A new algorithm was developed in MATLAB (The Mathworks, Natick, MA) for the marker identification problem. This identification method is independent of tracking during time and it is based on grouping of the markers according to their position, relative to a reference marker. The reference marker should be placed in a remote place from the rest of the markers to be identified. In the experiment that is presented below the reference marker was placed on the moving sled. The algorithm is presented in the table 1. The algorithm was implemented in a program with a graphical user interface (fig. 5).

## 3. Experiment

The context of this experiment was to analyze the motorcyclist's kinematics during braking, with the use of an optoelectronic motion capture system [3,4]. Braking is a common maneuver performed from motorcyclists before an accident. The deceleration involved is at maximum -

1Gx a value that allows the rider to control the motorcycle and stabilize his body according to different strategies. To study these kinematics strategies the environment of a motorcyclist during breaking was reproduced inside the laboratory. A moving sled and additional structures placed on the sled were used to reproduce the geometry of the motorcycle and to protect the volunteers from accidents; additionally a black fabric was placed at the front side of the sled to cover the field of view of the volunteers (fig. 2). These structures were hindering the optoelectronic system used for the kinematics analysis since the function of these systems is based on the direct view of markers on the studied subject from at least two cameras. A Motion Analysis (Santa Rosa, CA) optoelectronic system with 8 high speed (1000 fps) cameras with integrated red light stroboscopes was used to capture 16 reflective camera placed on the volunteer and 4 markers placed on the moving sled.

The sled was moving on rails performing a linear motion with stable acceleration. The 8 cameras were placed 4 at each side of the rails so at every point of the sled motion at least two cameras were able to capture all the markers (fig 2). This is the minimal requirement for this and similar optoelectronic systems to function. The problem when only two cameras are able to capture one marker is that measurement error is higher in comparison with more cameras and when the marker is lost from the field of view of one camera the sample of this marker is missing from the measurement.

The system's software (EVaRT v5.0) was used to reconstruct the markers' 3D coordinates (fig. 3) based on a variant of the Direct Linear Transformation algorithm [1,2].

**Table 1. Marker Identification Algorithm**

| Steps | Action |
|---|---|
| 1 | The front 2D projection of the 3D coordinates of all the reconstructed markers for all the frames of the experiment is plotted. |
| 2 | The points that correspond to the reference marker are manually selected in the 2D projection. |
| 3 | The relative position of all the markers to the reference marker is calculated for each frame. |
| 4 | The front and the side 2D projection of all the markers for all frames are plotted. (fig. 4). |
| 5 | Each marker is identified with the use of a selection box on the two projections. |
| 6 | The GCVSPL [5] algorithm is used for the interpolation of the hidden markers, two methods are possible linear and spline interpolation (fig. 5). |

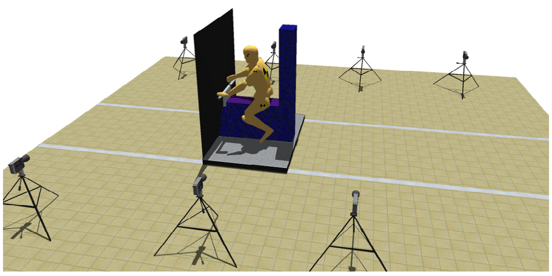

**Figure 2. Experiment setup**

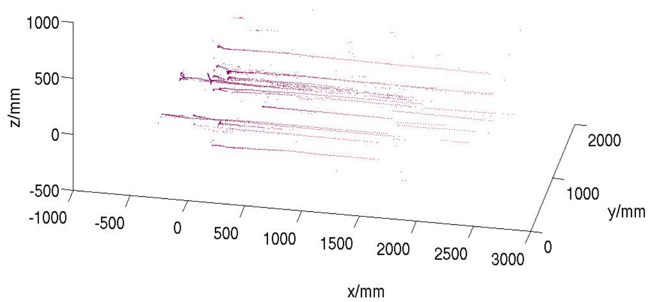


**Figure 3. Marker coordinates reconstructed from motion capture software**

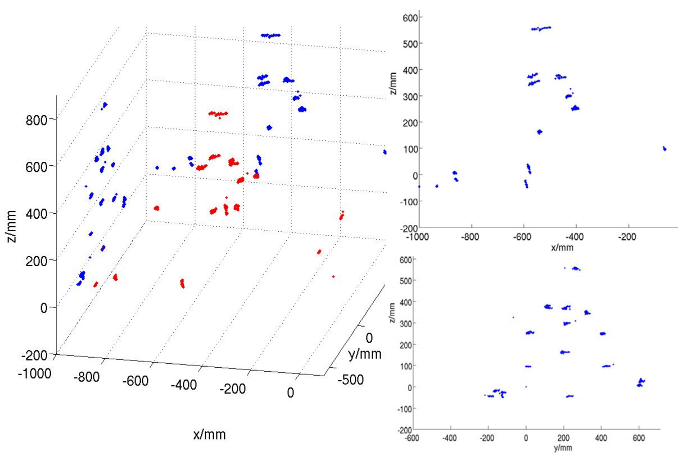


**Figure 4. (a) Relative motion of the markers to the sled (red), (b) side x-z and (c) front y-z orthographic projections**

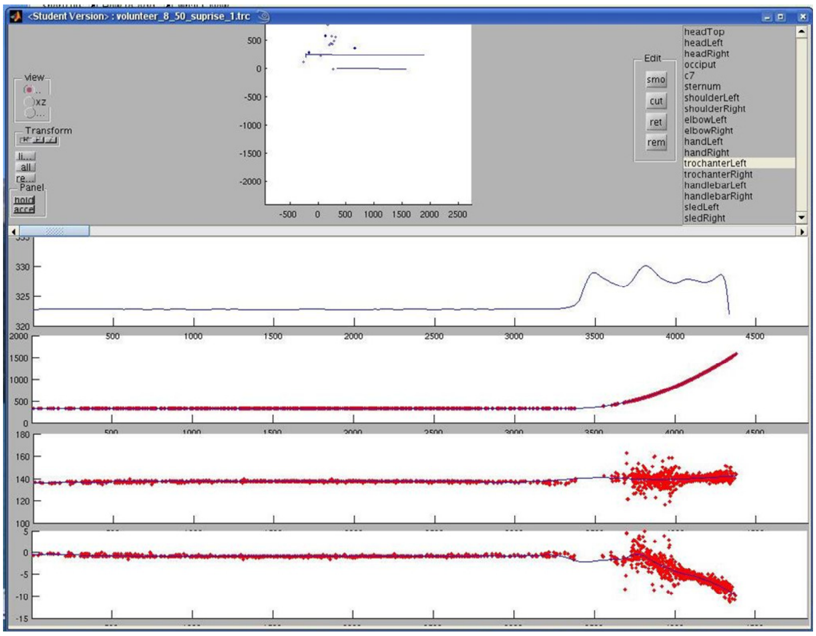


**Figure 5. The GUI of the program, Interpolation (thin blue line) of the kinematics curves when markers (red points) were hidden**

## 4. Discussion

The time needed, for the manual marker identification, performed by the authors, for all the marker of each test, was found to be less than 5 minutes for a measurement of 4500 frames. This algorithm is not based on tracking the markers during time but on the relative position of the markers of interest to a reference marker, with the advantage that there is no marker tracking performed but only a one time, manual identification of the markers at the end of the measurement. The application of the algorithm to a general motion instead of linear one is possible but it would require three reference markers to be selected at the first step of the algorithm to describe the rigid body motion of the reference frame.

## 5. Conclusion

The procedure followed for motion capture systems for the 3D reconstruction was presented and a new method for fast, manual, open to the user, marker identification was introduced. The main advantages of this method for marker identification over the traditional methods, in experiments where the markers on the volunteer are obstructed due to structures of the vehicle or its motion, are the fast identification time, the method is not influenced when markers are hidden for several frames and the researcher can monitor closely the whole procedure of marker identification with raw and processed track data representation.

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