ROBUST MARKER TRACKING BY THE USE OF A PATTERN RECOGNITION METHOD

RALF LICHTENBERGER, HERBERT WEBER,
Universität Karlsruhe, Institut für Mechanische Verfahrenstechnik und Mechanik,
Bereich Angewandte Mechanik, D-76128 Karlsruhe

1 Introduction

Optical measurement techniques combined with image analysis, enable the extraction of detailed information from crash experiments or component tests in automotive industry. With this information modern security systems can be developed and the quality of the end-products can be controlled. Comparing the experimental results with simulated data further allows the improvement of the theoretical models and therefore leads to better accuracy in future simulations.

The marker tracking technique is a method to obtain information about the 2D-coordinates of marked points in a time sequence of images. This position information is the base for the calculation of e.g. track length, distances to other markers, velocities and accelerations of the marked points. For the classical marker tracking technique special markers (e.g. 5 point markers) must be attached to the object. Problems arise if the marker quality in the image sequence varies, e.g. if a part of the marker is covered by other objects, the marker gets distorted or the normal vector of the marker turns out of the camera direction.

This new approach of using a pattern recognition method can be applied to any pattern, e.g. holes or edges in a car body or attached letters.

2 Experimental procedure

2.1 Measuring setup

The marker tracking is an image analysis method and therefore requires the usage of a camera to record the experiments. To increase the time resolution of the measurements high speed cameras are required in the field of crash analysis and for automotive security systems. Typical cameras have frame rates from 1000 to more than 4.500 full frame images per second.

2.2 Pattern Recognition Method

The pattern recognition method was used in [Lichtenberger] to measure the in-plane deformation vector field of an airbag cover and is based on a digital correlation method [VanderLugt]. In the deformation analysis the images have been divided into small subsets in which the displacement vectors of the local image pattern have been calculated.

In contrast to this global application of the pattern recognition method, in the case of marker tracking we are only interested in the determination of the displacement vector of one or a few interesting image points. The surrounding of such an interesting point is defined as reference pattern and can have any size. The image data in this surrounding is copied in a reference subset (usually 16x16 pixels or 32x32 pixels size).

The surrounding of the same pixel position in the next image of the sequence is copied in the search subset. The pattern in the reference subset is then searched in the search subset according to the following method:

If the grey level of the reference subset at pixel position m,n is given by $f(m,n)$ and the grey level of the search subset by $g(m,n)$ then the Fourier transform of f and g are

$$F(u,v) = \mathcal{F}\{f(m,n)\} \tag{1}$$

$$G(u,v) = \mathcal{F}\{g(m,n)\}. \tag{2}$$

The correlation function follows from

$$K_{gf}(m,n) = \mathcal{F}^{-1}[F(u,v) \cdot G^*(u,v)] \tag{3}$$

with G^* being the conjugate complex of the function G. In pattern recognition G^* is called a matched filter. It is known that for patterns which have nearly uniform distribution of amplitudes in the frequency space the relevant information is contained in the phase φ of the Fourier transform of the pattern. Therefore filters which primarily are sensitive to phase information seem to be of great benefit for solving pattern recognition problems. One of these filters is the phase-only filter (POF) [Horner]. It is defined by

$$G^*_{POF}(u,v) = e^{-i\varphi(u,v)} = \frac{G^*(u,v)}{|G(u,v)|}. \tag{4}$$

With this filter the correlation function follows from

$$K_{POF}(m,n) = \mathcal{F}^{-1}\left\{\frac{G^*(u,v)}{|G(u,v)|}\cdot F(u,v)\right\}. \tag{5}$$

This filter we used sucessfully for the evaluation of speckle patterns [Gutmann]. Therefore we also applied it in this investigation.

To enhance the image contrast locally special marker stickers can be glued at interesting positions of the objects. This is also necessary for homogenous object surfaces without structures.

2.3 Analysis improvements

There exist numerous approaches for the improvement of the analysis procedure. An extract of these are:

- Usage of a subpixel algorithm to measure the position more precisely.
- Automatic adaption of the search pattern for every image.
- Automatic locking to markers with a central white peak during initialisation.

3 Results

A body block test demonstrates the applicability of the pattern recognition method. This test is used to measure the impact force of a body and to validate that the steering wheel keeps the regulations of the ECE-R-12.

Figure 1 shows the principal setup of such a body block test stand from top view. The body (mass $35kg$) hits horizontally on the steering wheel with a velocity of $v_0 = 24km/h$.

Using the marker tracking in this field of application additionally allows the accurate determination of the position, velocity and acceleration vectors, e.g. of the steering wheel and of the body.

Figure 2 shows an extract (every 207. image) of a sequence which was originally recorded with a frame rate of $4500/s$ [TRW]. On the body and on the steering wheel two 5 point markers are attached. In this case the markers are used to locally improve the contrast of the image. In a well illuminated environment these markers are redundant.

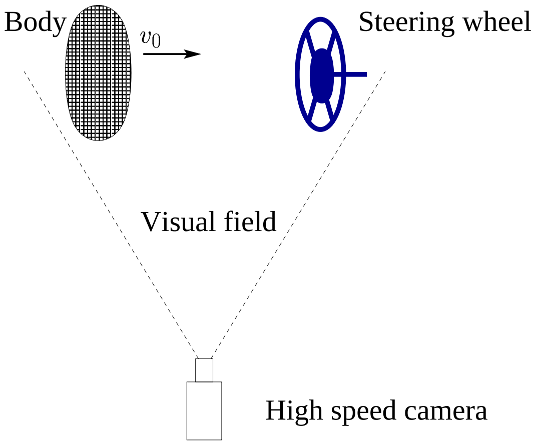

Figure 1: Top view from a body block test setup.

Figure 3 shows the first and the last image of the sequence with visualized tracks. Due to non uniform illumination the marker contrast is very poor on the left side in the image and the marker is nearly invisible. Because the search pattern is updated for every image small variations of the pattern (e.g. rotations, reflections, overlapping by other objects) are allowed from image to image. Although small pattern variations from image to image can lead to big differences between the pattern in the first and last image of a sequence the pattern will be sucessfully tracked.

From the sequence of images the track length and velocity of the pattern on the body as well as the distance between the pattern on the body and the pattern on the steering column can be calculated. Figure 4 shows the resulting diagram. The data was filtered with a CFC 1000 filter. The values are consistent with the light barrier measurement during the free flight of the body. The scatter of the velocity results from the fact, that the velocity is calculated from the slightly noisy position data via differentiation. Using other data format for the raw image (less noise and compressor artefacts) the position determination will be improved.

4 Conclusion

In this paper we presented a new approach for a marker tracking technique based on pattern recognition.

First tests with images of a body block experiment show that this technique can be used intuitivly without explicit pattern type definition and that it yields reliable results.

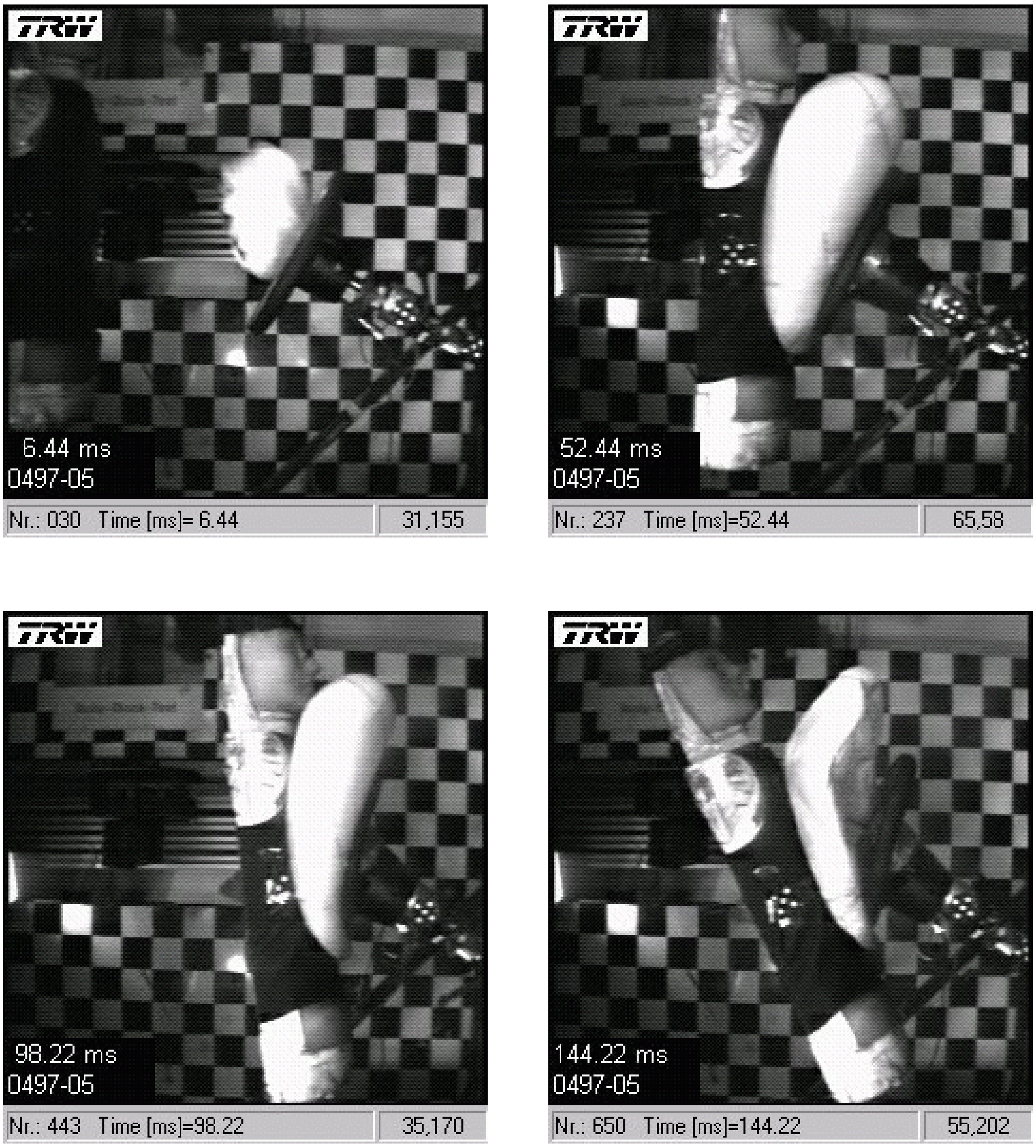

Figure 2: Extract of original sequence of images with time interval of 46*ms*.

The position determination is performed with subpixel accuracy.

Because the method works on the base of patterns and not on predefined markers it can be used flexibly on any small image region consisting of a certain pattern. The usage of markers enables the tracking of regions with low contrast. Due to the search pattern adaption in every image the pattern can be tracked automatically even when the pattern varies during the sequence.

Future experiments with other measurement techniques, e.g. acceleration sensors in

Figure 3: First and last image of the sequence with visualized tracking lines. In the 3. image the positions of the pattern are visualized.

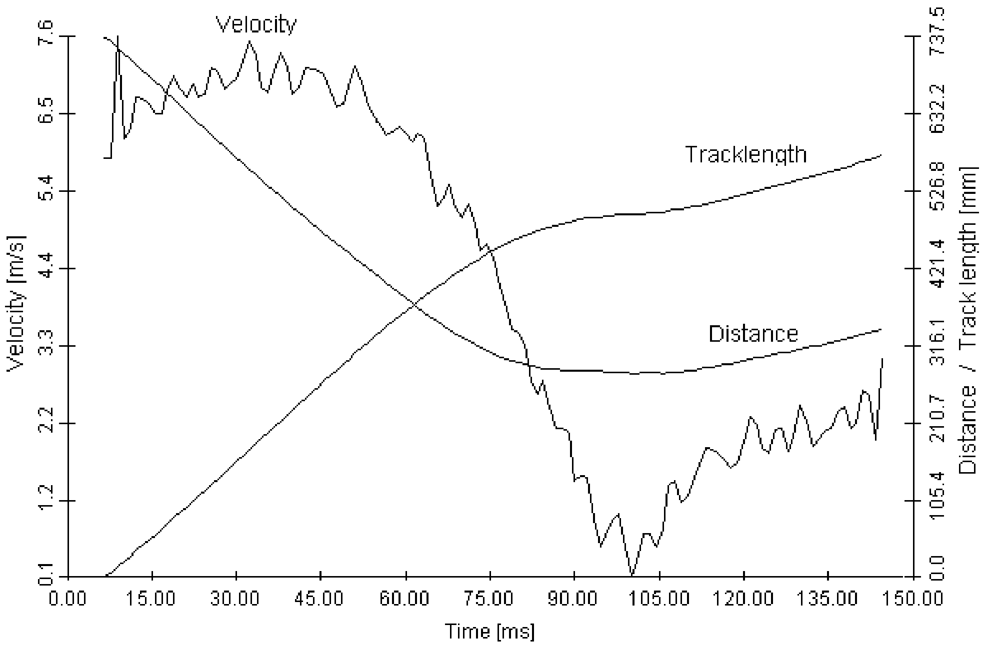

Figure 4: Track length and velocity of the body and distance between marker on the body and on the steering column the as a function of time.

sledge experiments, will give more detailed data for quantitative comparison.

Many thanks to TRW Automotive Safety Systems GmbH & Co. KG for placing the image sequences at our disposal.

References

[VanderLugt] A.B. VanderLugt: *Signal Detection by Complex Spatial Filtering*, IEEE Trans. Inf. Theory IT-10, 1964, 139-145

[Horner] J.L. Horner: Gianino, P.D.: *Phase-only matched filtering*, Appl. Opt. 23, pp. 812-816, 1984

[Wolf] T. Wolf:*Entwicklung eines optischen 3D-Verformungsanalyseverfahrens für geschäumte Polymere,* Ph.D. Thesis, Multimedia Verlag, Karlsruhe, 1996

[Lichtenberger] R. Lichtenberger, H. Weber, U. Bieber, T. Wolf: *The combination of speckle correlation and fringe projection for the measurement of dynamic 3-D deformations of airbag covers*, in: Airbag 2000, 4th International Symposium and Exhibition on Sophisticated Car Occupant Safety Systems, Karlsruhe/Germany, Nov. 30.-Dec. 2., DWS Werbeagentur und Verlag GmbH, Karlsruhe, 1998, pp 32-1 to 32-9

[Horner] J.L. Horner, P.D. Gianino: *Phase-only matched filtering*, Appl. Opt. 23, pp. 812-816, 1984

[Gutmann] B. Gutmann: *Deformationsmessungen an Schaumstoffproben mit Methoden der digitalen Bildverarbeitung,* Diploma Thesis, Institut für Mechanische Verfahrenstechnik und Mechanik (AM), Universität Karlsruhe, 1994

[TRW] TRW Automotive Syfety Systems GmbH & Co. KG: Image sequences of body block experiments.