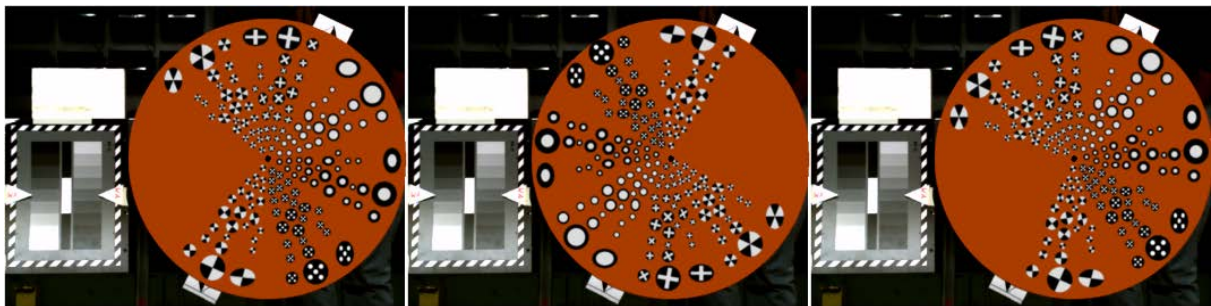


## FalCon MovXact – Tracking Accuracy + Robustness FAQ

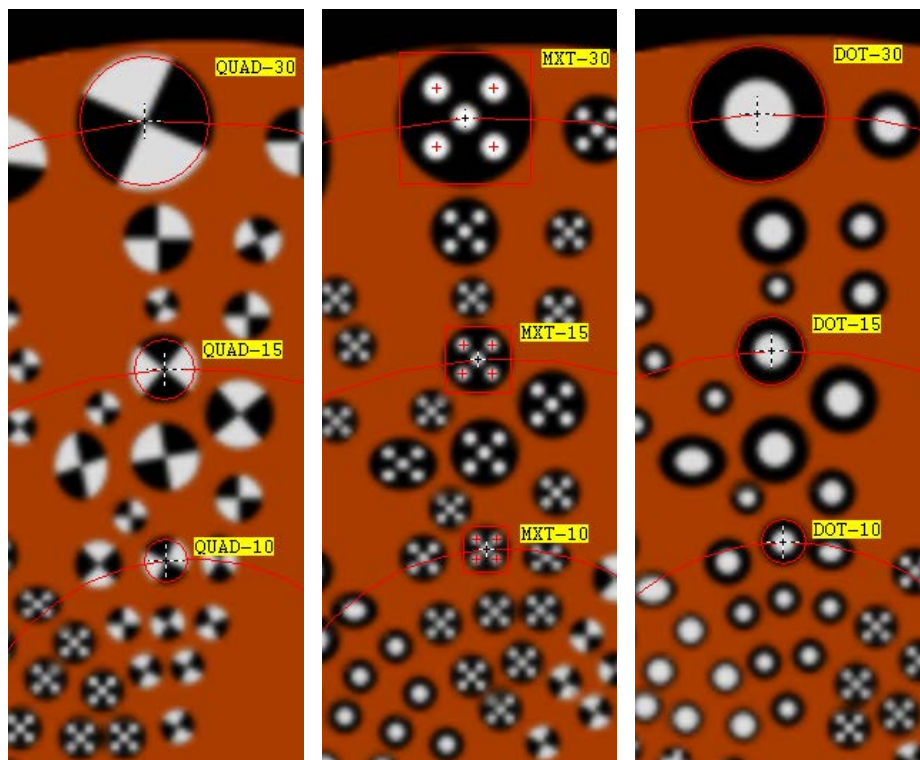
- *Which accuracy have image measurements?*
- *Which markers are suitable for crash tests?*

The working group "Image processing at impact tests" of German car manufacturers initiated in the year 1999 a comparison of different tracking algorithms with respect to accuracy and robustness.

The **absolute accuracy** can be evaluated by the means of a known motion between the images of a sequence. Input data was a "synthetically generated" AVI video. The targets (= markers) show an optimum contrast and no interference with the constant rotary motion in the scene, even if the markers do not "rotate" together with the disc, i. e. they keep always the same angle of rotation.



*MaCon2: 36 frames, 512x384 pixel, uncompressed*

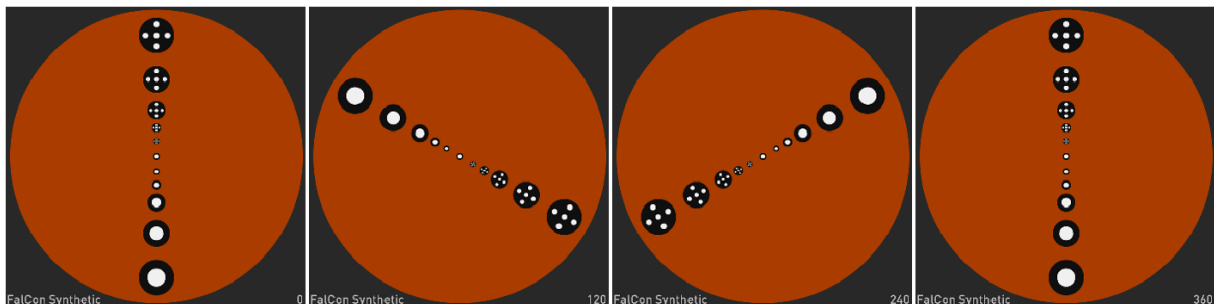


*Marker types at different sizes*

| Marker Type & Size | Mean Error |  | Standard Deviation |  |
|--------------------|------------|--|--------------------|--|
|                    | original   |  | original           |  |
| DOT-10             | 0.020      |  | 0.014              |  |
| DOT-15             | 0.010      |  | 0.006              |  |
| DOT-30             | 0.007      |  | 0.004              |  |
| MXT-10             | 0.030      |  | 0.011              |  |
| MXT-15             | 0.027      |  | 0.013              |  |
| MXT-30             | 0.047      |  | 0.020              |  |
| QUAD-10            | 0.145      |  | 0.112              |  |
| QUAD-15            | 0.222      |  | 0.094              |  |
| QUAD-30            | 0.133      |  | 0.059              |  |

(unit pixel)

An example from the year 2024 shows, which accuracy can be achieved in contemporary high-resolution images and using markers with larger diameters. The MXT markers have the same rotary motion as the disc.



*FcSynthetic: 361 frames, 1024x1024 pixel, rotation angle 1°/frame*

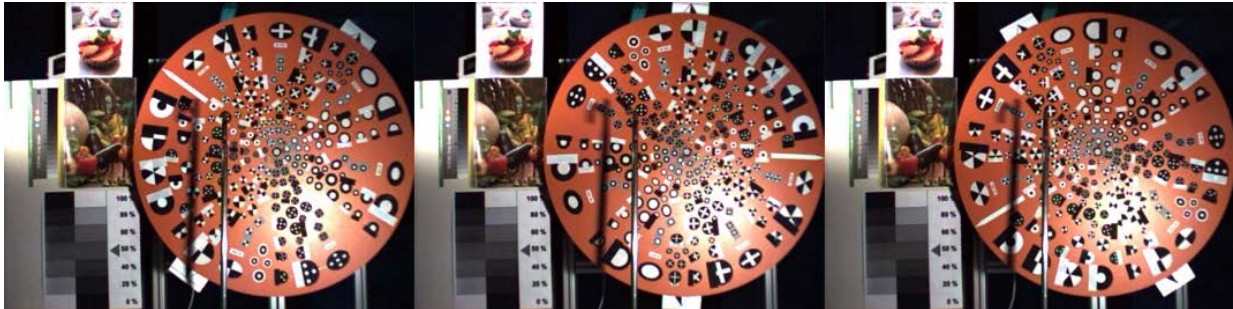
The MXT algorithm supports now also diameters above 70 pixel. The results show however, that the accuracy slightly decreases in case of very large markers.

The video with the synthetic motion is measured in the first instance uncompressed/original and then compressed by means of the **x264** codec (at recommended settings) to a data rate of 0.23 %. The mean errors as well as the standard deviations remain very low and almost identical.

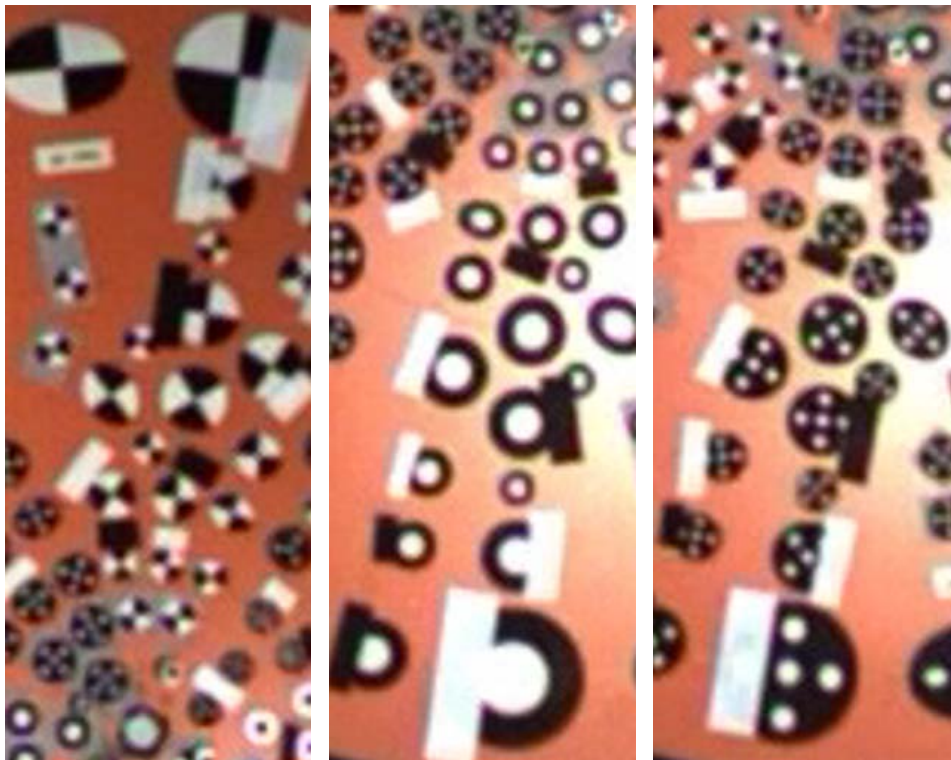
| Marker Type & Size | Mean Error |            | Standard Deviation |            |
|--------------------|------------|------------|--------------------|------------|
|                    | original   | compressed | original           | compressed |
| DOT-20             | 0.011      | 0.016      | 0.004              | 0.008      |
| DOT-30             | 0.009      | 0.012      | 0.003              | 0.006      |
| DOT-60             | 0.007      | 0.009      | 0.003              | 0.005      |
| DOT-90             | 0.005      | 0.008      | 0.002              | 0.004      |
| DOT-120            | 0.005      | 0.007      | 0.002              | 0.004      |
| MXT-20             | 0.033      | 0.032      | 0.017              | 0.017      |
| MXT-30             | 0.038      | 0.038      | 0.020              | 0.020      |
| MXT-60             | 0.071      | 0.073      | 0.043              | 0.041      |
| MXT-90             | 0.093      | 0.098      | 0.074              | 0.055      |
| MXT-120            | 0.140      | 0.139      | 0.075              | 0.073      |

(unit pixel)

The **robustness** of the marker types and their adapted algorithms was tested by a “real” video, which was taken by a high-speed camera. Markers of different types and sizes have been stuck on a rotating panel. Static and dynamic occlusions as well as spotted illumination should cover typical problems during crash tests.



*RoTest2: 300 frames, 512x384 pixel*



*Sections showing realistic marker samples*

## Conclusions

- The tracking algorithms measure point coordinates in the unit pixel. Comparisons of known synthetic and tracked trajectories show in not-disturbed environment show accuracy **below 0.1 pixel**. The standard deviations of the mean errors are within few percents of a pixel.
- The AVI compression by the **x264** codec has (in the example) no effect to the measuring quality.

- Depending on the marker type and its size the achievable **accuracy** is in practice (mostly) **better than 0.2 pixel**.
- **MXT** markers are best "**crash proven**"; they are extremely robust with regard to variations of illumination, geometrical changes (rotation, shearing) as well as blurring. Additionally to the position the internal orientation angle can be measured.  
Minimum size ca. 12 pixel
- **DOT** markers can be used in case of small physical space.  
Best ratio of black ring to white radius = 1:1.  
(also available DOT-I = inverse spots with black kernel.)  
In case of partial masking the determined marker position is shifted to the center of the visible remaining area (: warning of misinterpretation); in cases of low contrast between dot and encircling ring (: local overexposure) the tracking even stops. Thus, this marker type allows exact measurements but suffers from less robustness.  
Minimum size ca. 7 pixel
- **QUAD** markers show higher deviations and peak errors, which cannot be avoided also by manual tracking. They have been popular using celluloid films, but are no more recommended for digital high-speed videos.  
Minimum size ca. > 15 pixel

## Recommendations

- The markers should show a high contrast (attention using yellow-black markers!).
- The markers should be absolutely mat, i.e. not glossy.
- The optimum physical size of the markers depends on the photographic setting and the camera resolution.
- The images should not show strong post-processing artifacts from sharpening filter or video compression.

## Special Features of FalCon MovXact

- Fast setup of markers (auto-centering).
- Tracking combines all state-of-the-art methods within a sophisticated parallel procedure.
- Dropout handling with group model (= rigid body).
- The program interface combines typical work steps in clearly designed dialogs so that the user can evaluate both series tests and special tests **quickly, reproducibly and accurately**.