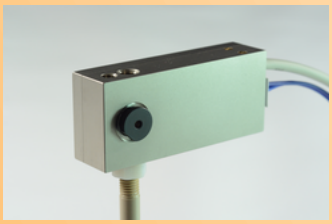
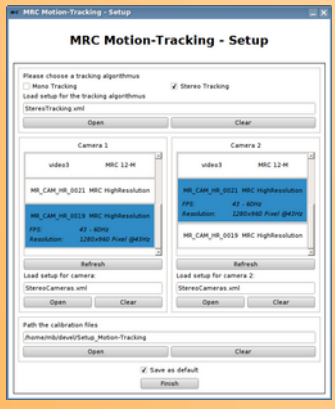
Motion Tracking in the MRI

MR compatible cameras



- Small size
- High resolution
- Interference-free use in the MRI bore
- Flexible lenses for different fields of view
- Modular configurations

Software



- Mono and stereo tracking algorithms
- Camera calibration
- Reliable marker identification
- Optimized for speed
- Variable outputs: Euler angles, Quaternions, translation vectors, rotation matrices, 3D coordinates
- Intelligent memory management
- Visualization

MR compatible LED light sources

- Single LED or LED array
- Adjustable brightness
- Small size
- Application-specific emission angles

Markers and other accessories

- Optimized markers (retroreflectors, user-defined patterns, printable 3D models)
- Camera/mirror mounts for head tracking
- Calibration tools

Hardware and software solutions

Since more than 15 years we offer MR compatible solutions for clinical and psychological applications. Our video cameras are widely used for patient monitoring, eye tracking, face recording, and also to detect desired and undesired motion [1].

Undesired motion can affect the image quality by strong artefacts. The most prominent are blurring and ghosting. Movements of subjects can also impede the interpretation of fMRI studies. In many cases the scans have to be repeated resulting in additional time and costs. According to a study of Andre et al. these costs can add up to $115,000 per scanner and year [2].

We offer a modular motion tracking system which can help to reduce these costs and problems.

Further applications are:

- Automatic monitoring of movements of hands, limbs or other parts of the body in neuro-scientific paradigms
- Monitoring of hand-held or robotic instruments in the scanner

In this brochure we give a brief overview on our hard- and software solutions for motion tracking. We hope to help you to decide which components can support your application or research.

We offer two tracking algorithms: stereo and mono. The stereo algorithm enables a higher accuracy, whereas the mono algorithm is faster and works with only one camera. This can help to find a free view onto the tracked object.

Special features

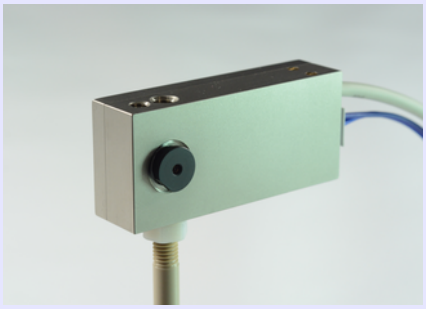
The main challenges of optical tracking in MR scanners are the limited space in the bore and the obstacles caused by coils covering the field of view. Our solution makes therefore use of flexible cameras and scalable markers which can be placed in arbitrary positions. In one scenario, a short distance to specific parts of the body (face, hand, knee, etc.) enables robust tracking with small and easy-to-use markers for high patient comfort. The short distance automatically leads to highest accuracy. In another scenario, the HighResolution camera with its excellent resolution can be used in a larger distance for whole body tracking.

Advantages:

- ✔ Arbitrary number of markers / Scalable and user-defined markers
- ✔ Fast and robust algorithms, modular software
- ✔ Mono and stereo tracking
- ✔ Flexible camera configurations: Adjustable distances and fields of view
- ✔ Different LED lights available
- ✔ Hardware can be used in the bore
- ✔ Easy setup and calibration
- ✔ Prospective image correction possible

We are looking forward to hearing from you!

MR-compatible video cameras

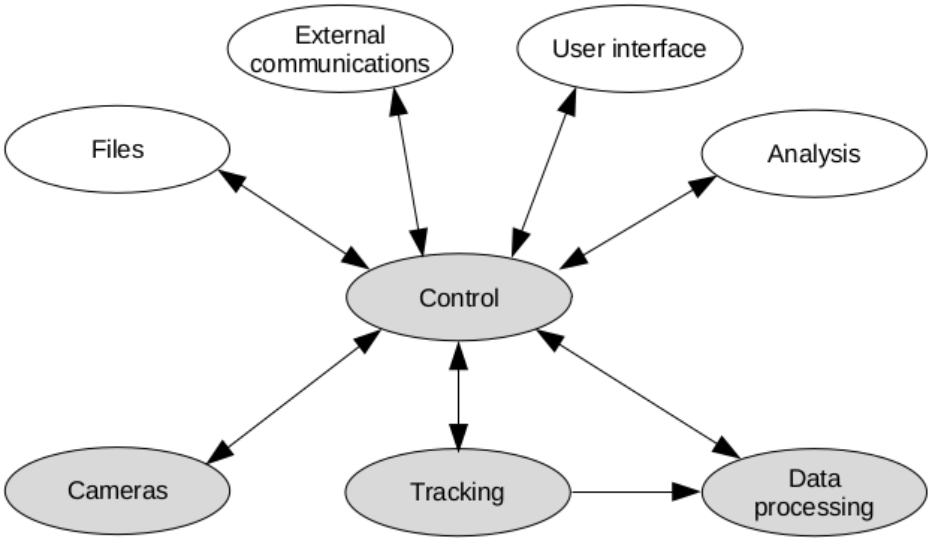
Model	Photo	Specification
Digital cameras		• Interference-free use in the MRI bore • HD resolution: e.g. 1280x960 pixel @43Hz • Hi speed: e.g. 1076Hz with 256x256 pixels • Global shutter • Different focal lengths • Interface: Gigabit Ethernet / GigE-Vision
Analog cameras		• Interference-free use in the MRI bore • 60 Hz, VGA resolution • Very small size, low weight • Different focal lengths • Available with integrated light source

MR-compatible LED light

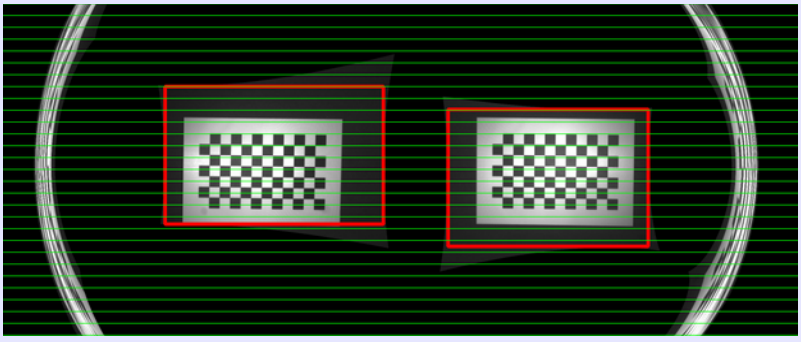
Model	Photo	Specification
Single LED		• Interference-free use in the bore • Eye-safe, 850 or 950 nm • Adjustable brightness • Working distance: 10 to 50 cm • Small and lightweight • Easy setup
Array with 18 LEDs		• Compact design • Up to 1080 mW, 850 nm • Adjustable brightness • Different emission angles, e.g. 10° spot light • Working distance: 50 cm – 3 m • Easy setup

Software

We offer a flexible and modular software package for motion tracking for different applications in different configurations.



Module	Features
Reading of camera streams	• Analog video, GigE Vision • Live recording of streams for post analysis
Calibration of cameras	• Chessboard calibration (based on calib3d library of OpenCV) • Rectification according to Hartley [4]
Image processing and Marker identification	• Pre-processing, conversion into binary images • Pattern recognition, marker identification • Determination of balance points • Smoothing



Tracking algorithms

Mono-algorithm for 1 camera

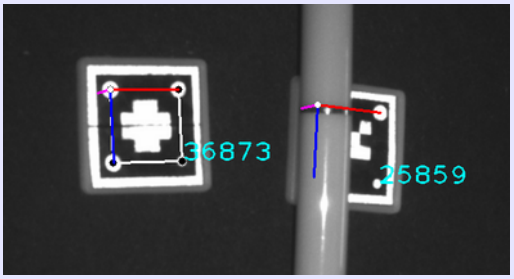
- Determination of marker position by solution of prospective n-point problem [5]
- Search areas / Regions of interest (ROIs) for markers
- Automatic movement of ROIs with markers in sequential images

Stereo-algorithm for 2 cameras in stereo setup

- Synchronisation
- Correspondence analysis
- Determination of position by triangulation

Both:

- Tracking of hidden markers by pattern estimates



Data management

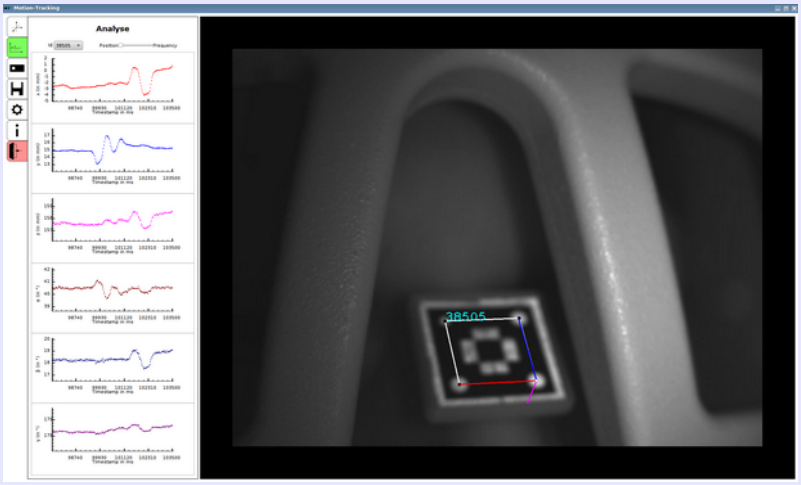
- Fast algorithms, optimized computing time, intelligent memory allocation
- Management of arbitrary number of markers

Outputs

- Communication module
- Data: Euler angles and quaternions, translation vectors and rotation matrices, 3D coordinates
- Frequency analysis

Visualization

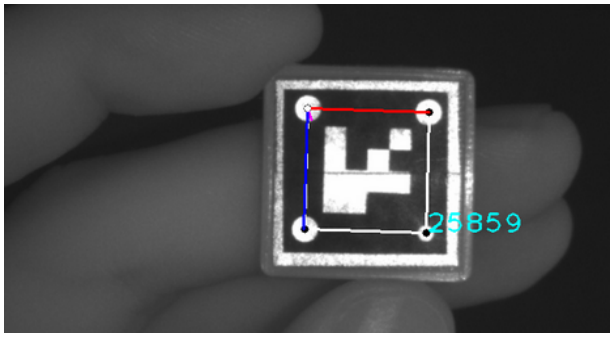
- Graphical user interface
- Live view with marker recognition
- Display of recorded videos



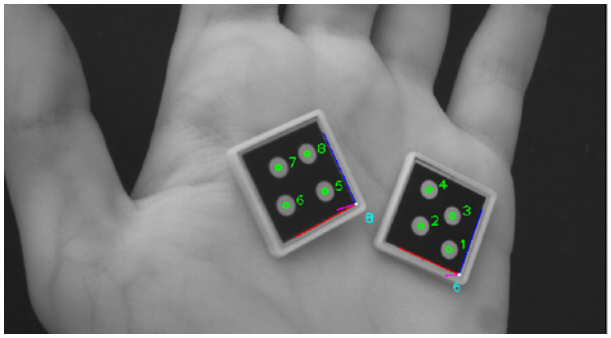
Markers & Accessories

Our software allows to define various marker dimensions and geometries. It is possible to differentiate an arbitrary number of markers by simple patterns. In that way you can e.g. identify each finger of a hand by a specific marker. It's also possible to sort the markers by a given priority.

Matrix coded markers [6]

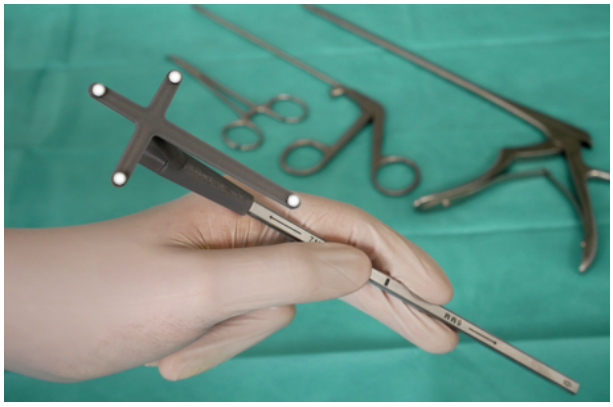


Patterned retroreflectors



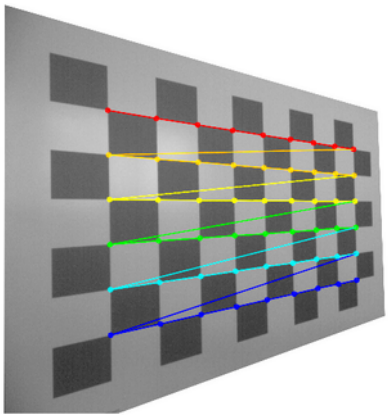
Movements of a hand

Spherical retroreflectors

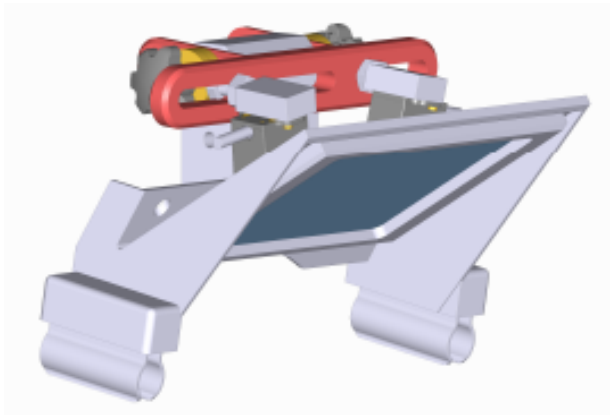


We also provide all required accessories to implement a fully working motion tracking system for your application:

Calibration tools



Mounts



Technical Specs

Cameras & LED lights	see detailed specs in user manuals [7]
12M, 12M-i models	• 60 Hz half frame rate, VGA resolution
MRC HighResolution	• 1,280x960 pixels with 43 Hz, 1,280x720 pixels with 60 Hz
MRC HiSpeed	• 250 Hz with VGA resolution, 1076 Hz with 256x256 pixel resolution
LED light	• single LED or array with 18 LEDs, wavelength 850 nm
Software	all data taken from [8] under ideal conditions in the lab
Modules	• Read-in, preprocessing, calibration, rectification, marker identification, correspondence analysis, triangulation, n-pattern solution, tracking (stereo, mono), data management & real-time analysis, communication & output, visualization
Used SDKs and libraries	• Qt version 5.9.2, OpenCV version 3.4,
Stability	• Stereo: RMS down to 3 µm in translation, 0.02° in rotation • Mono: RMS down to 41 µm in translation, 0,28° in rotation
Accuracy	• Stereo: RMS down to 1.7 µm in translation, 0.03° in rotation • Mono: RMS down to 3.2 µm in translation, 0.27° in rotation
Speed, latency	• HighResolution camera: 43 Hz, 12M/12Mi- cameras: 60 Hz; 4 markers simultaneously • HiSpeed camera: 250 Hz (depending on processing power) • Up to 5 ms latency between image and tracking result (1 marker)
Markers	
Matrix / pattern coded	• Reliable standard or user-defined coding, adjustable, scalable
Spherical retroreflectors	• Adjustable, scalable geometry

References

[1] https://www.mrc-systems.de/downloads/en/mri-compatible-cameras/publication-list_mrcam.pdf

[2] Andre, B. Bresnahan, M. Mossa-Basha, M. Hoff, C. Smith, Y. Anzai, and W. Cohen. Toward Quantifying the Prevalence, Severity, and Cost Associated With Patient Motion During Clinical MR Examinations. Journal of the American College of Radiology, 12(7):689– 695, 2015.

[3] F. Godenschweger, U. Kägebein, D. Stucht, U. Yarach, A. Sciarra, R. Yakupov, F. Lüsebrink, P. Schulze, and O. Speck. Motion correction in MRI of the brain. Physics in medicine and biology, 61(5):R32–56, 2016.

[4] R. Hartley. Theory and Practice of Projective Rectification. International Journal of Computer Vision, 25(2):115–127, 1999.

[5] T. Ke and T. Roumeliotis. An Efficient Algebraic Solution to the Perspective-Three-Point Problem. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2017.

[6] S. Garrido-Jurado, R. Muñoz-Salinas, F. Madrid-Cuevas, and M. Marín-Jiménez. Automatic generation and detection of highly reliable fiducial markers under occlusion. Pattern Recognition, 47:2280–2292, 2014.

[7] https://www.mrc-systems.de/en/products/mr-compatible-cameras

[8] M.D. Bechberger. Optisches Motion-Tracking in der funktionellen MRT, Master Thesis, HS Mannheim, 2020

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