

## Introduction

The MEDARPA system [Med] is designed to support minimal invasive interventions. A semi-transparent display (Figure 1) has been developed to provide the surgeon with information about the patient's anatomy as well as to display the instruments at their positions relative to the patient. The optical tracking system – providing the doctor's and the display's poses – has been developed during the project, and the magnetic one – for tracking the instrument – comes from *Ascension* ('PCIBird'). See Figure 2 for a system overview.

The following three steps are necessary for setting up the system:

- calibration of the optical tracking system,
- alignment of optical and magnetic tracking,
- patient registration.

For the patient registration externally attached markers are used, which are visible in the imaging modality used. Their segmentation is performed in a pre-processing step using the software 'InViVo' which has been developed over several years at the FhG-IGD. Besides the possibility of segmenting the markers automatically it is desirable to do this task using algorithms working (semi-)automatically.



Figure 1: The MEDARPA display in a clinical environment

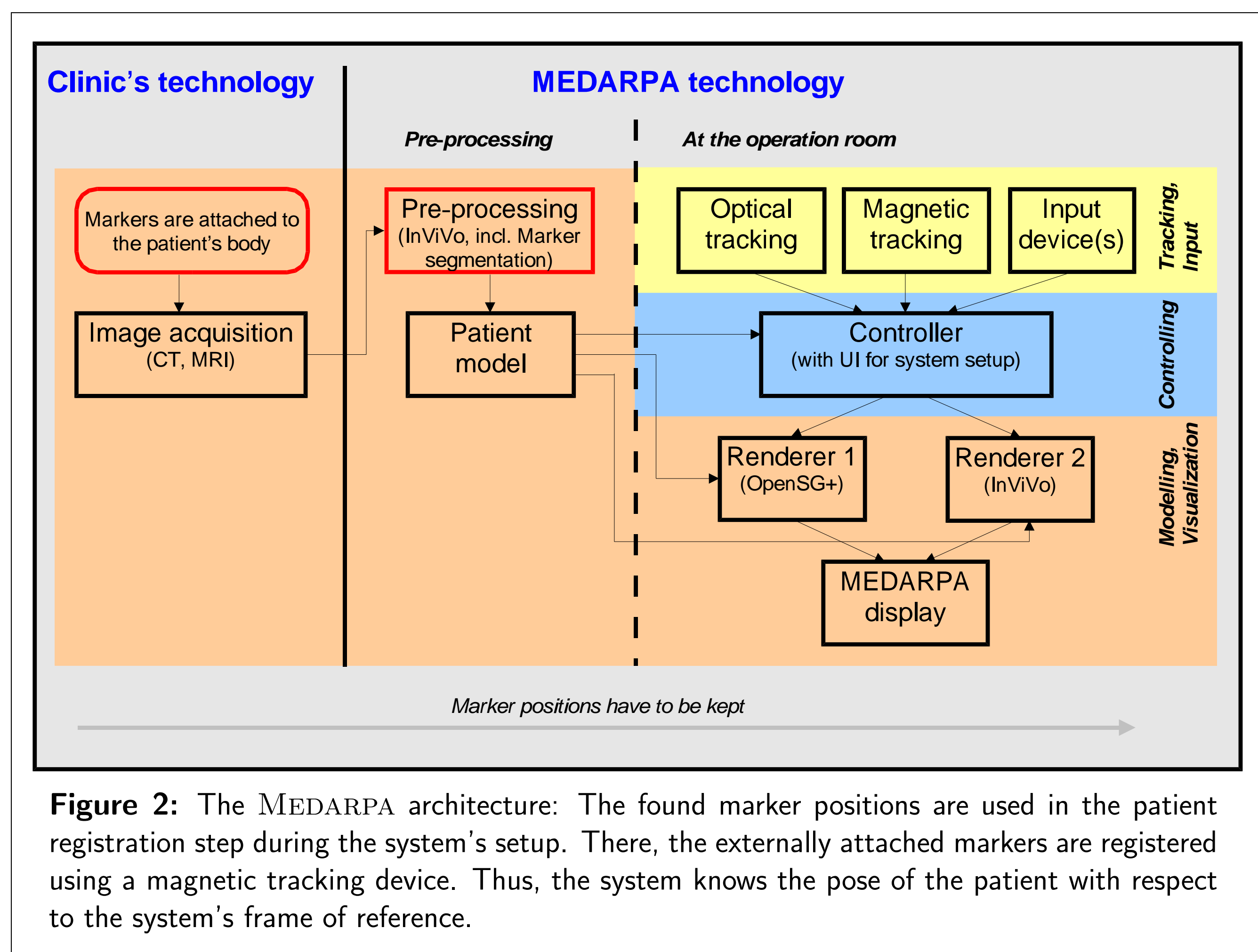


Figure 2: The MEDARPA architecture: The found marker positions are used in the patient registration step during the system's setup. There, the externally attached markers are registered using a magnetic tracking device. Thus, the system knows the pose of the patient with respect to the system's frame of reference.

## Segmentation methods and used data sets

Three (semi-)automatic segmentation methods are compared focusing on accuracy, speed and reliability. They are

- **A1**: a two-step algorithm, finding candidate markers in a first step and classifying them afterwards into probable and non-probable markers [Wan],
- **A2**: an algorithm presuming that the markers are the brightest objects in the data set [Cap] and
- **A3**: a combination of these both methods, detecting the markers only by their geometrical shape and size.

The basis of all these algorithms is the automatic setting of a global threshold ([Ots], [Kit]).

Table 1: The used data sets containing different types of markers

Data set	S1	R1	R2	R3
Type	synthetic	real	real	real
Resolution	$256^3$	$512^2 \times 50$	$512^2 \times 49$	$512^2 \times 38$
Voxel size	$0.5 \times 0.5 \times 0.5 \text{ mm}^3$	$0.7 \times 0.7 \times 3 \text{ mm}^3$	$0.5 \times 0.5 \times 3 \text{ mm}^3$	$0.7 \times 0.7 \times 3 \text{ mm}^3$
# of markers	5	5	8	5
Diameter [mm]	2	1.5	10	5
Remarks	Two markers connected to other objects	X-Spot, Beekley Corp.	Markers are not the brightest objects	ECG markers

## Results

Table 2: Accuracy test using data set **S1**: The distances in *mm* for each marker between the real positions and those calculated by the algorithms are shown in comparison with the accuracy achieved by a manual segmentation. There are always the markers' centers considered. (**A3** is not capable to detect markers which are connected to other objects.)

Marker	A1	A2	A3	Manual
1	0.15	0.27	-	0.02
2	0.03	0.02	0.00	0.02
3	0.04	0.03	0.00	0.05
4	0.12	0.27	-	0.05
5	0.03	0.03	0.00	0.05
Mean error	0.07	0.12	0.00	0.04
$\sigma$	0.05	0.12	0.00	0.02
Time needed [s]	15	8	8	(90)

Table 3: Reliability tests using data sets **R1**, **R2** and **R3**: The *X-Spots* in data set **R1** have been detected only by algorithm **A2** which failed with data set **R2**. There the other two algorithms worked better, but without being able to detect all of the markers. The press-stud shaped ECG markers in data set **R3** are a special case since they have been considered to be spherical for testing the algorithms. The segmentation with algorithm **A1** resulted in 12 false detections, algorithm **A2** separated 3 of the 5 segmented objects into two markers. (Algorithm **A1** could be sped up by implementing a subsampling as suggested by Wang et al. [Wan].)

	Data set R1			Data set R2			Data set R3		
	A1	A2	A3	A1	A2	A3	A1	A2	A3
Found markers	-	5/5	-	7/8	-	6/8	2/5 (+12)	5/5 (3sep.)	-
Time needed [s]	-	6	-	501	-	11	65	5	-

## References

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