

Indirect Tracking for On-The-Fly Elimination of Occlusion Problems. Evaluation in Industrial Setup.



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Integration
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Versuchsfahrzeugbau



München



Freude am Fahren

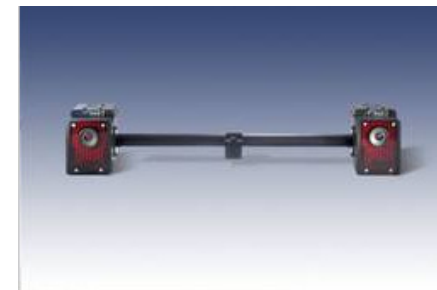
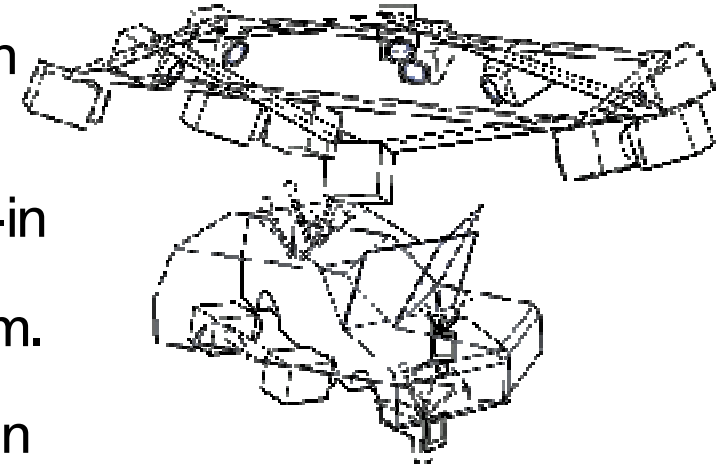
Motivation.

What is Indirect Tracking?



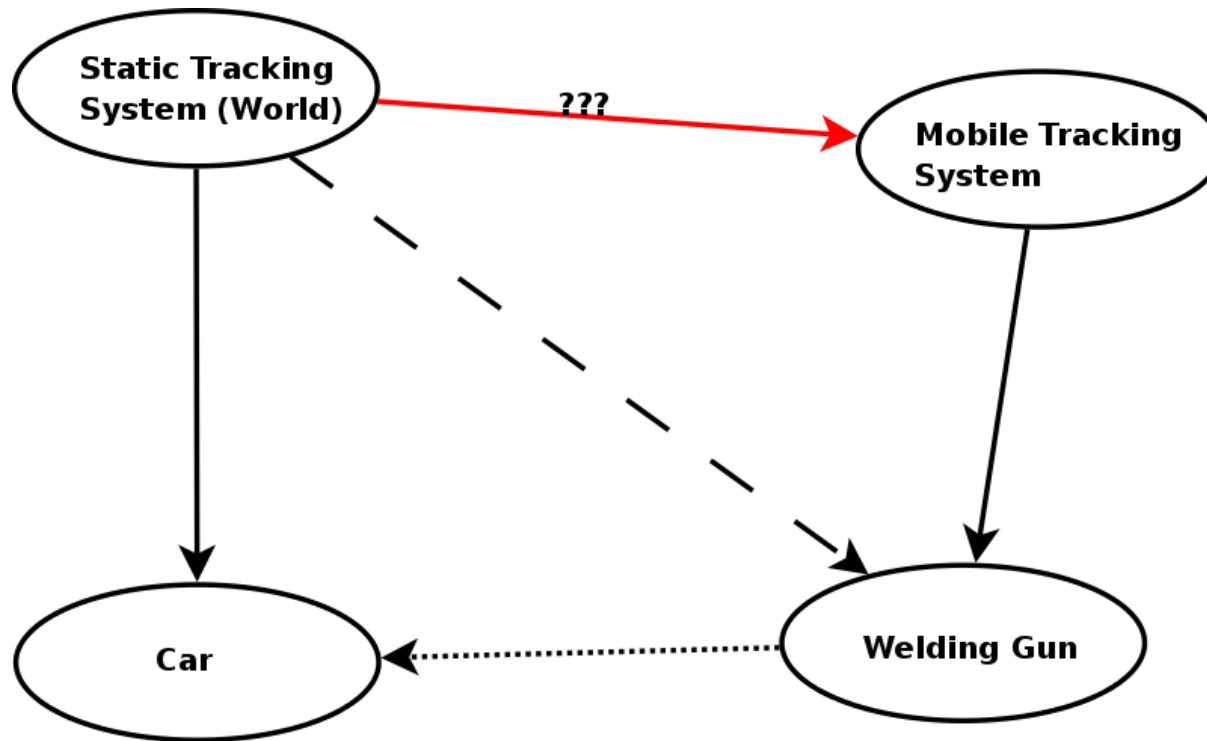
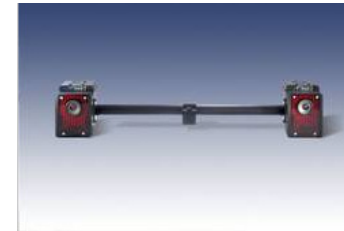
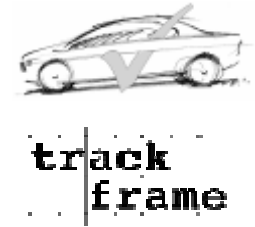
track
frame

- Exemplary scenario: Stud welding in experimental vehicle construction.
- Classical outside-in approach.
 - Static tracking system (outside-in tracking).
 - Defines world coordinate system.
 - Problem: Occlusion.
- Idea: Use additional, mobile inside-in tracking system.
 - Can be placed on-the-fly.
 - Establish relationship to world coordinate system (e.g. via marker).



Overview.

Spatial Relationship Graph.

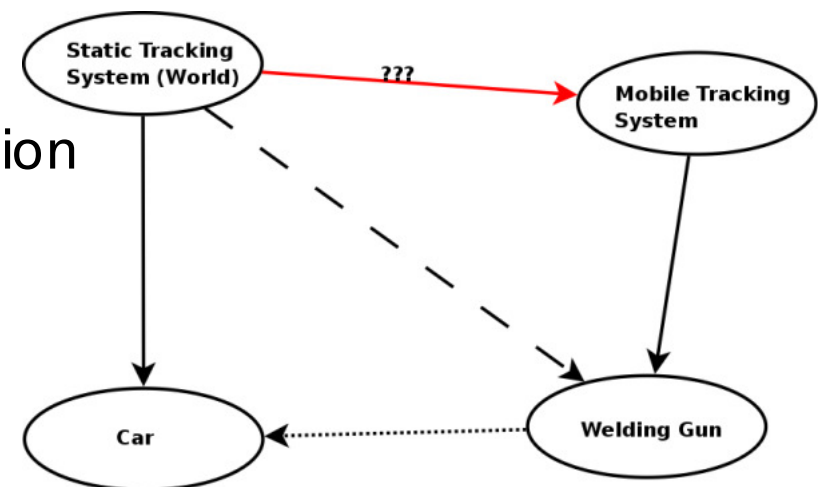
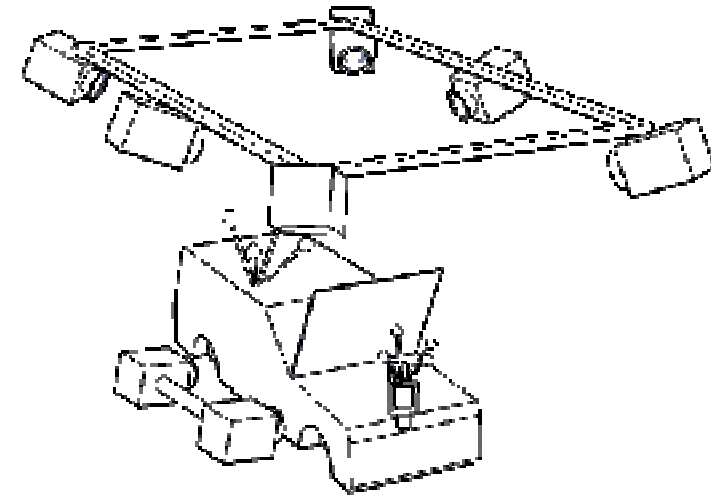


Registration of Coordinate Frames.

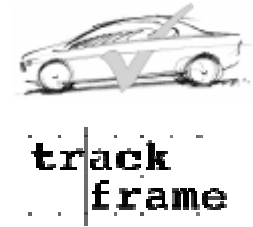


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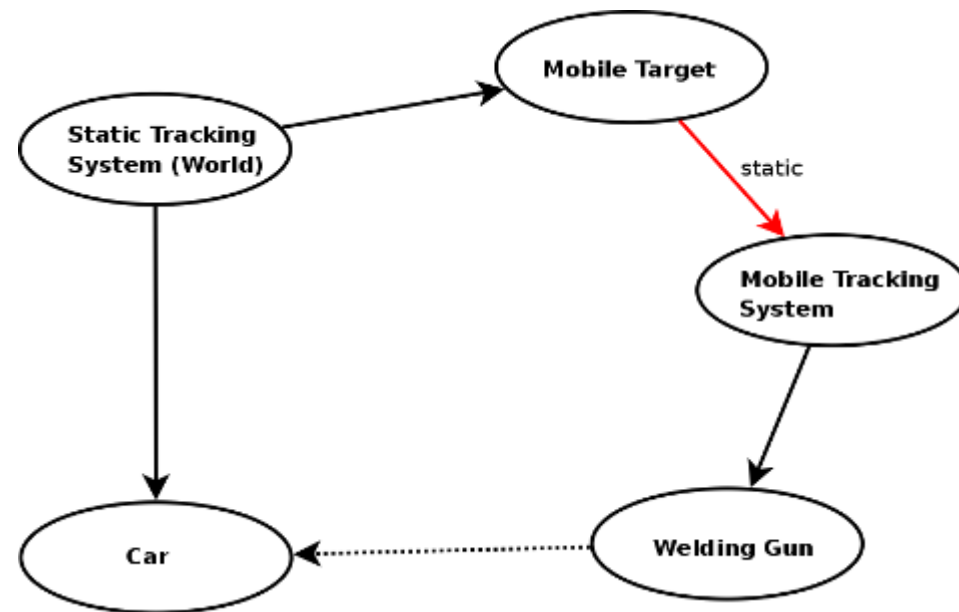
- Standard registration procedure.
 - Use tool to generate point correspondences in commonly visible area.
 - Use any absolute orientation algorithm [Horn86].
- Drawback: Requires explicit re-registration after movement of mobile tracking system.
- Direct tracking useful for evaluation (reference value).



Indirect Tracking. without Re-Registration.



- Basic Idea.
 - Track the mobile tracking system via a marker.
 - Infer desired spatial relationship by concatenating edges in the SRG.
- Accurate registration of Mobile Target with Mobile Tracking System is crucial!

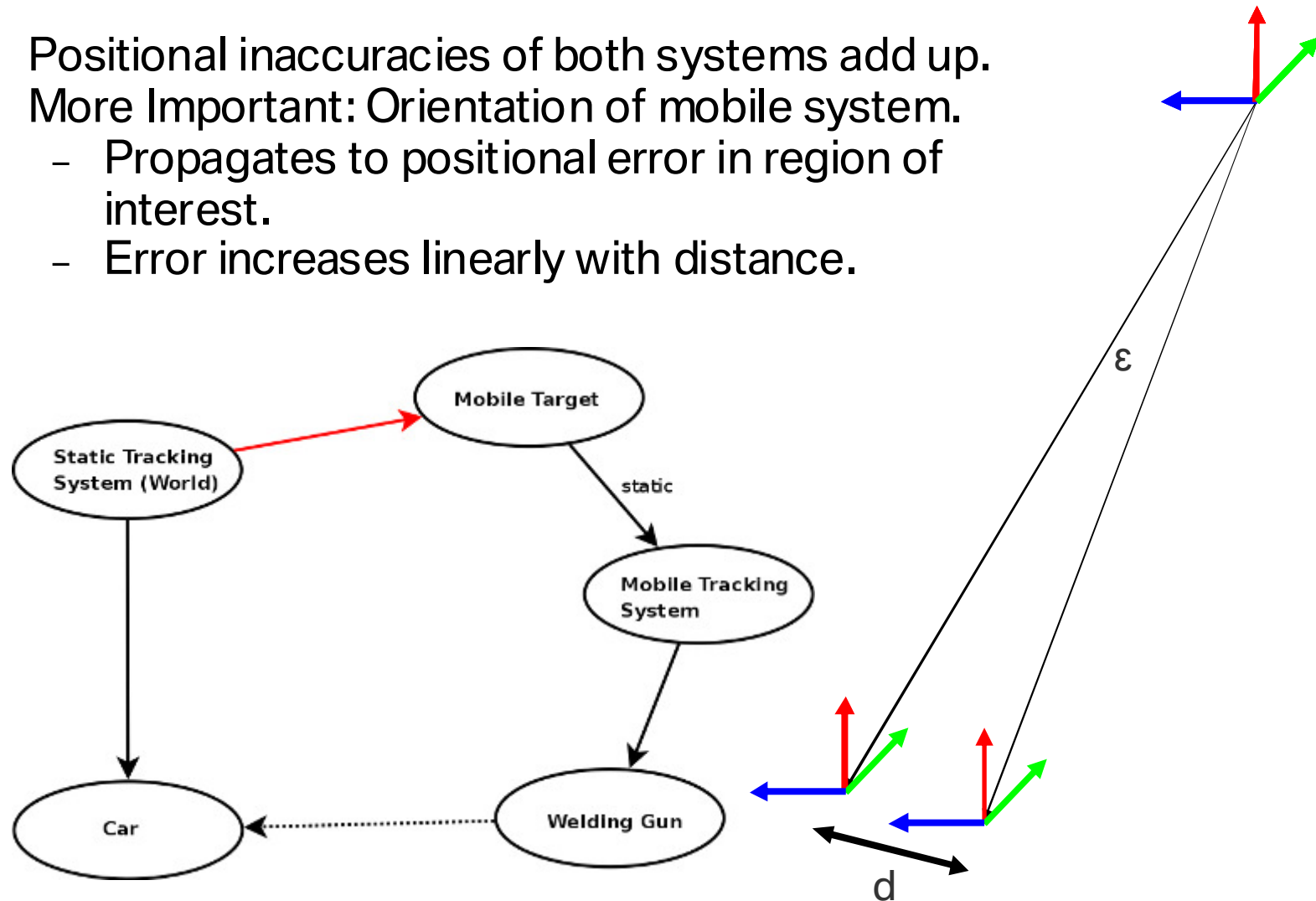


Problem Statement.

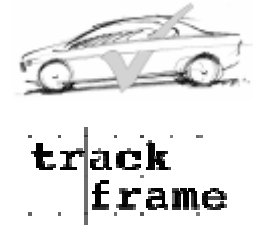
Rotational Errors.



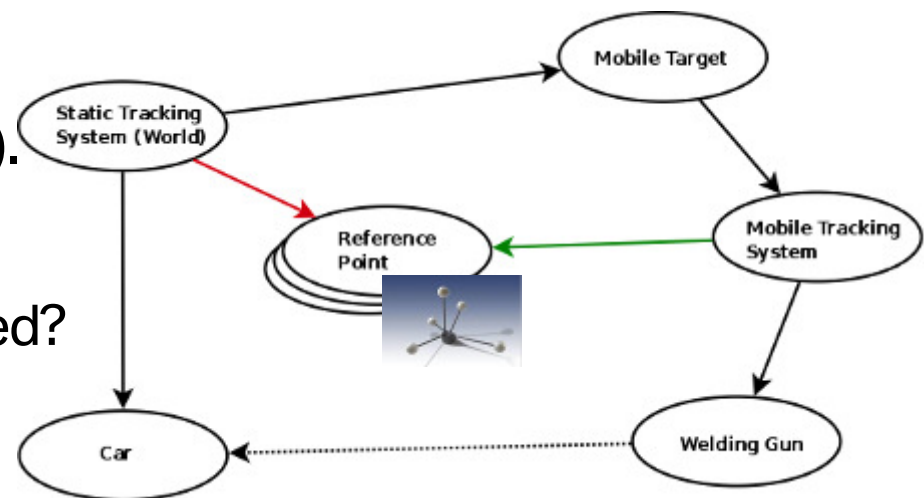
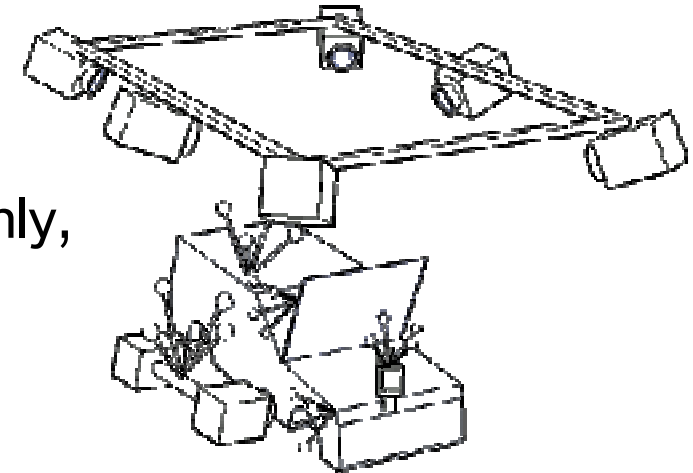
- Positional inaccuracies of both systems add up.
- More Important: Orientation of mobile system.
 - Propagates to positional error in region of interest.
 - Error increases linearly with distance.



Correction Approaches. Basic Ideas.



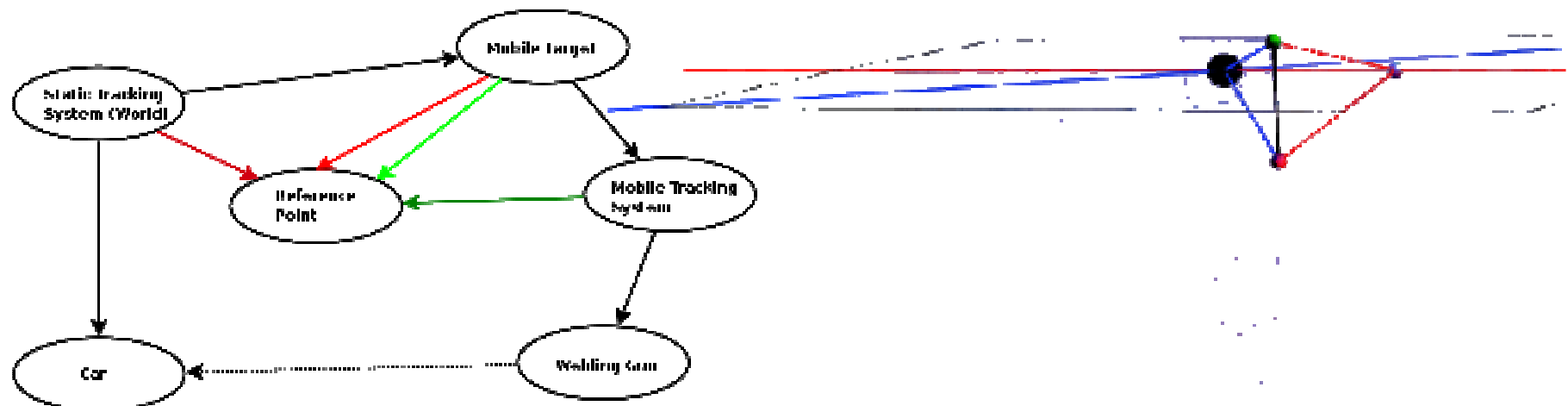
- Basic Idea: Use common reference points in the scene (3D position).
 - Reference targets (3D position only, discard orientation).
 - Simple fiducial.
- Placement of reference targets.
 - Inside-in.
 - Inside-out.
- Transfer reference points in mobile target coordinate system
 - Reference measurement(s) (green).
 - Erroneous measurement(s) (red).
- How many points are needed?



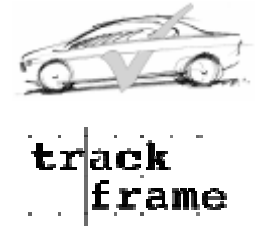
Correction Approach. One Reference Point.



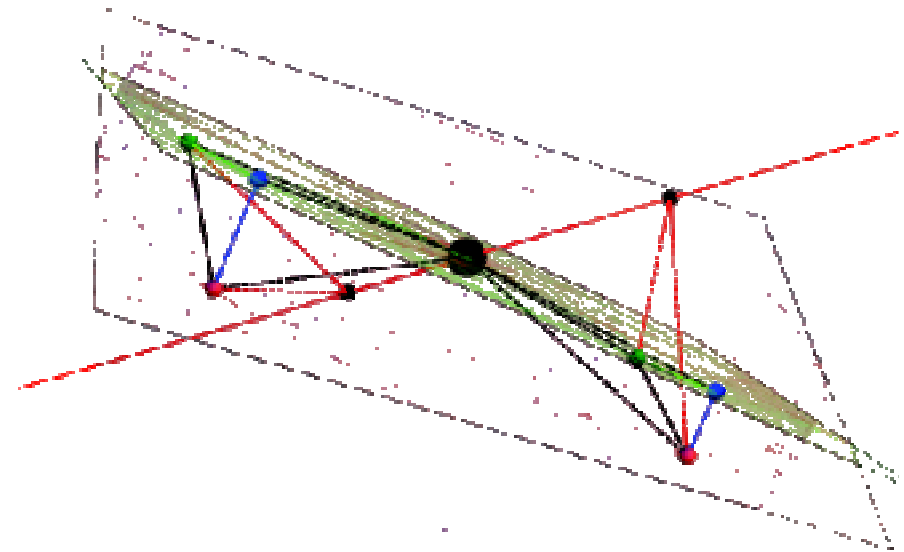
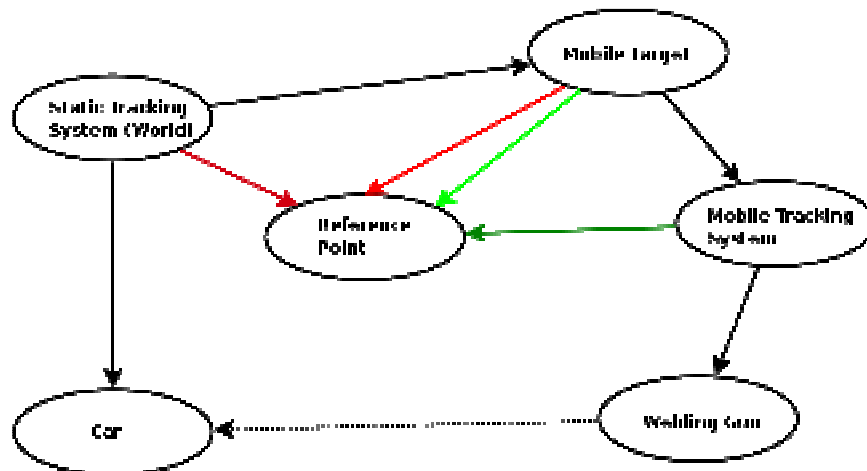
- Assume position of mobile target to be error-free
=> Common center of coordinate frames.
- Reference point.
 - Reference measurement (green).
 - Erroneous measurement (red).
- Only partial correction possible.



Correction Approach. Two Reference Points.

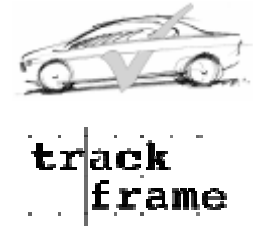


- Assume position of mobile target to be error-free.
=> Common center of coordinate frames.
- Two reference points.
 - Two reference measurements.
 - Two erroneous measurements.
- Full estimation of rotational correction (least-squares) [Horn86].

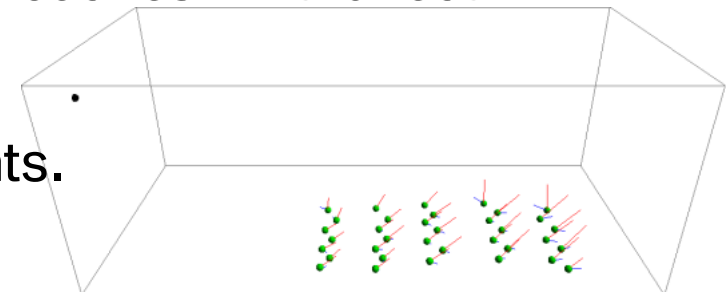


Laboratory Investigation.

Approach.



- Setup.
 - Static 3 IR camera setup (A.R.T. Track 1).
 - Mobile stereo IR setup (A.R.T. SmARtrack).
- Measurements.
 - 35 points on table surface using measurement tool.
 - Direct tracking.
 - Indirect tracking (w/o correction, one-point-correction, full-correction, absolute orientation).
 - Arbitrary (combination of) reference points (no explicit reference markers).
- Evaluation.
 - Distance of indirect tracking approaches w.r.t. direct tracking.
 - Separated for different (combinations of) reference points.

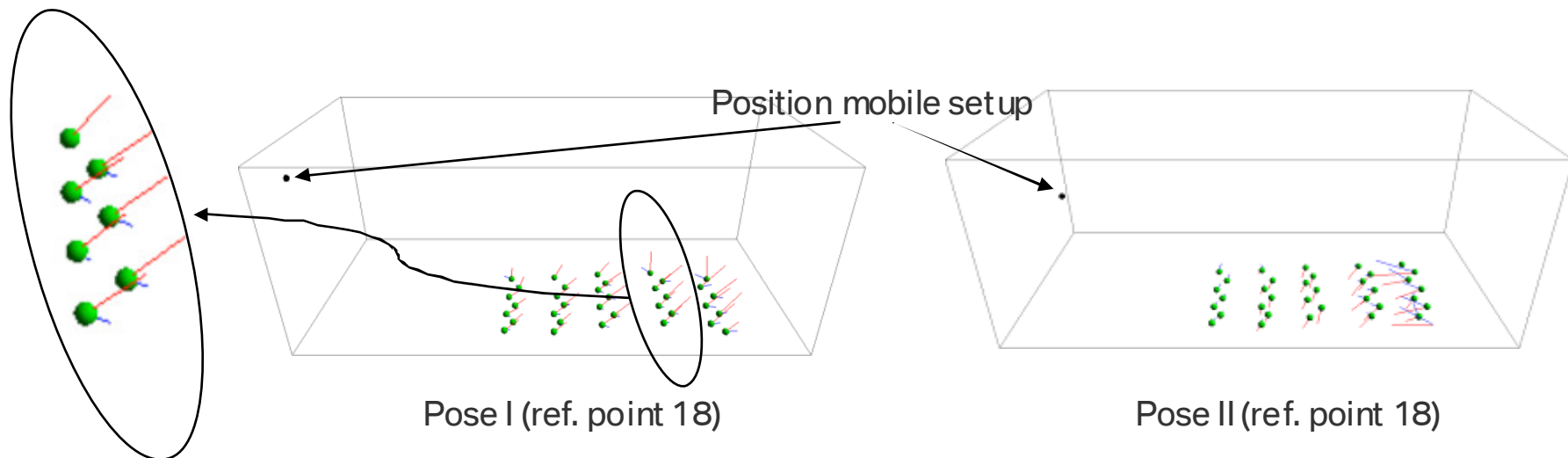


Laboratory Investigation. Results.



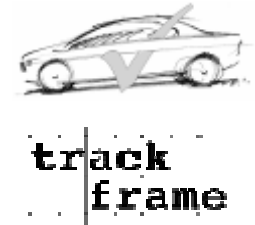
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<i>Pose of mobile tracking system</i>	I	II
Optimal pose (absolute orientation with all points)	1.0 mm	1.2 mm
No correction	3.1 mm	2.7 mm
Simple correction (one reference point)	1.1 mm	1.5 mm
Full correction (two reference points)	1.3 mm	1.9 mm
Absolute orientation of static and mobile (near points)	1.1 mm	1.4 mm



(Deviations w.r.t. direct tracking in mm RMS; red: uncorrected; blue: corrected)

Industrial Environment Investigation. Approach.



- Setup.
 - Static 5 IR camera setup (A.R.T. Track 1).
 - Mobile stereo IR setup (A.R.T. SmARtrack).
 - Faro arm.
- Measurements.
 - 15 points on part of car body.
 - Modalities.
 - Indirect tracking.
 - direct tracking.
 - Faro arm (reference).
 - 6 Different poses of mobile setup in scene.
- Evaluation.
 - Comparison of ind. tracking (w/o correction, one-point-correction, full-correction, absolute orientation) and direct tracking against reference (Faro).

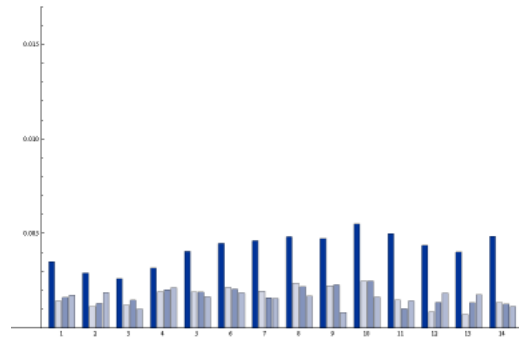


Industrial Environment Investigation. Results.

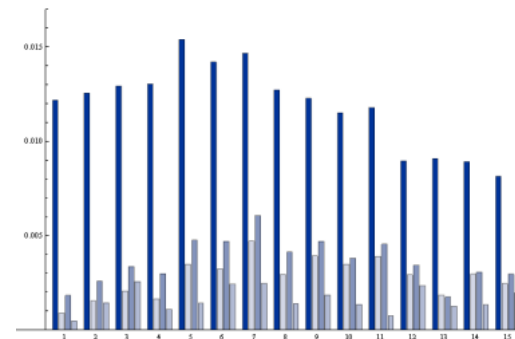


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- Trend: Errors incline with increased distance.
- In some cases indirect outperforms direct tracking.
- Plots for 2 exemplary poses of mobile setup (near and far).



Near distance



Far distance

- Results.

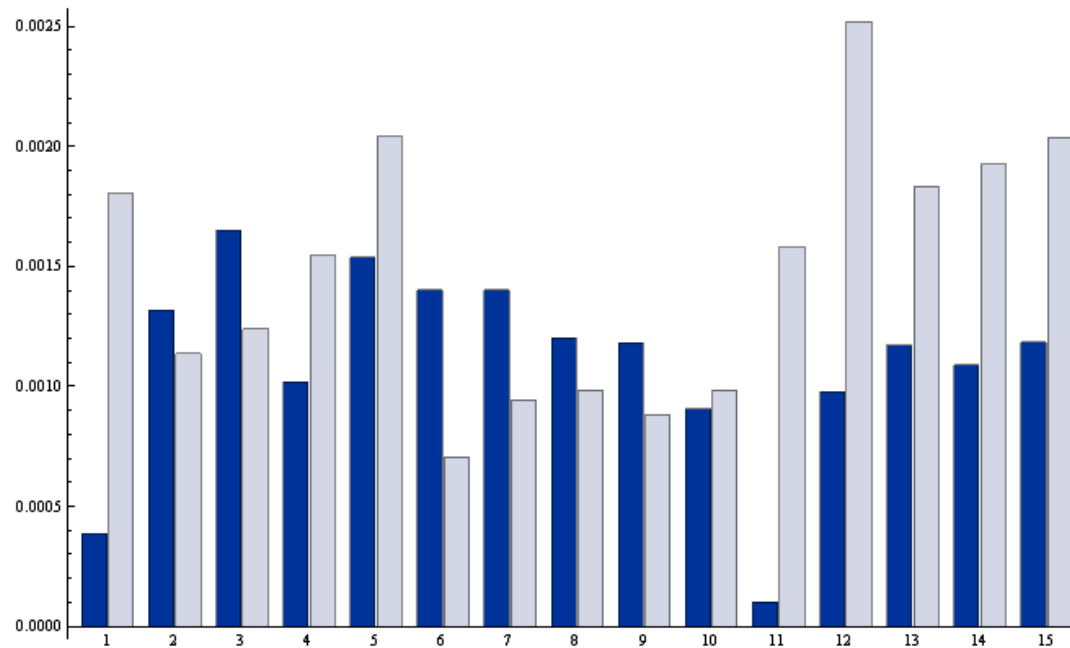
	<i>uncorrected</i>	<i>one point</i>	<i>full correction</i>	<i>direct (static)</i>
<i>near distance</i>	2.5 mm	1.9 mm	1.7 mm	1.4 mm
<i>far distance</i>	9.7 mm	2.6 mm	3.0 mm	1.6 mm

Industrial Environment Investigation. Results.

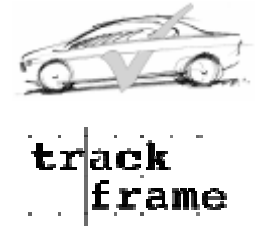


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- Results direct tracking.
 - 1.2 mm RMS static tracking system w.r.t. Faro.
 - 1.6 mm RMS mobile tracking system w.r.t. Faro.



Summary.



- Interpretation of results.
 - Indirect tracking is feasible.
 - Complex and error-prone calibration tasks.
 - In some cases simple correction outperforms full correction.
 - In some cases indirect corrected tracking outperforms direct tracking.

- Outlook.
 - Need for more intuitive calibrations.



track
frame

Thank you!

Questions?