Laser Tracker and 6DoF measurement strategies in industrial robot applications

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Introduction

- Efficiency of industrial robot applications are dependent on multiple influences
- Components of the application have to be analyzed separately
- Adjustment of single influences result in evident accuracy increases

>> Even with adjusted components there is still a gap between theoretical (simulated) and practical world

Introduction

- Dedicated measurement strategies for identification or calibration of application components

- Improvement of resulting accuracy by integration of 3D and 6DoF measurement results for correction

- Various possibilities to use laser tracker systems to compensate static or dynamic influences

In this presentation

- How to identify system inaccuracies?
- What are influences on application accuracy?
- Which parts can be measured / calibrated / corrected using laser tracker?
- How can the influences be avoided / reduced to a minimum?
- Is it possible to get rid of all component influences ?

Analyzing industrial robots

- Robot accuracy depending on time-variant influences
- Every robot is different due to manufacturing tolerances
- Offline programmed robot movement positions never fit to reality
- Robot model selection for dedicated application tasks is depending on robot accuracy
- Identification of peripheral geometries help to increase the accuracy of the system

Analyzing industrial robots

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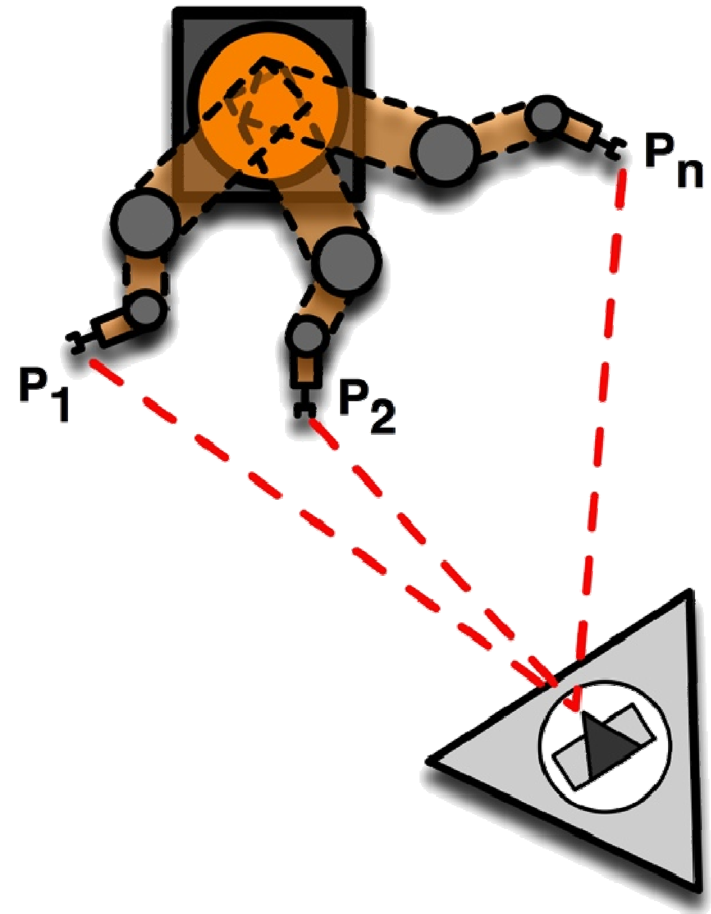
- Identification of robot base frame by laser tracker measurement
- 6-dimensional measurements for exact tool center point detection
- Check of robot static positional accuracy via residual vectors of best-fit transformation

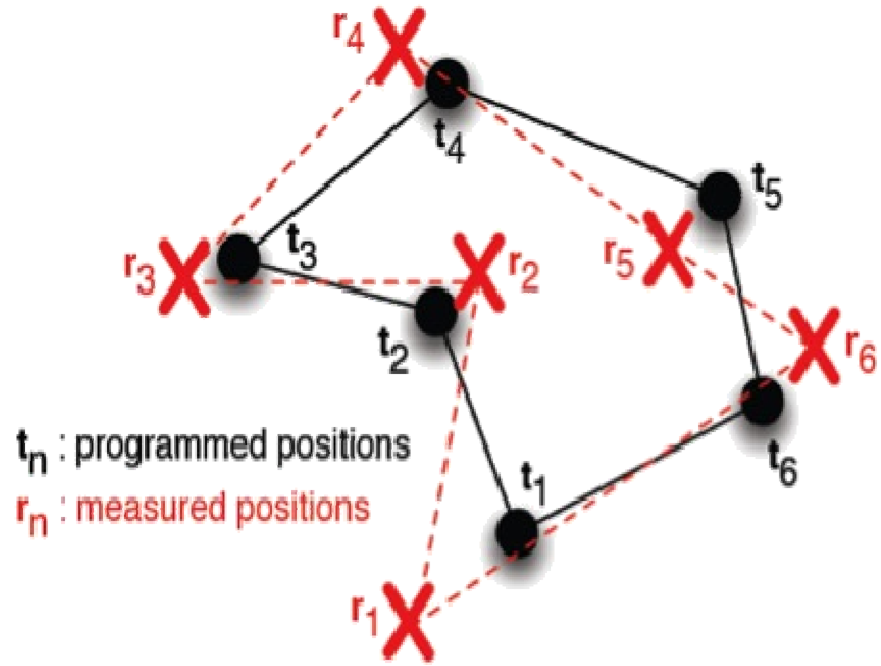


Analyzing industrial robots

- Determination of robot static & dynamic accuracy via DIN EN ISO 9283

- Evaluation process for customer

- Dynamic 6-dof measurements with a rate of up to 1 kHz



- Path motion behavior analysis even with high movement speed

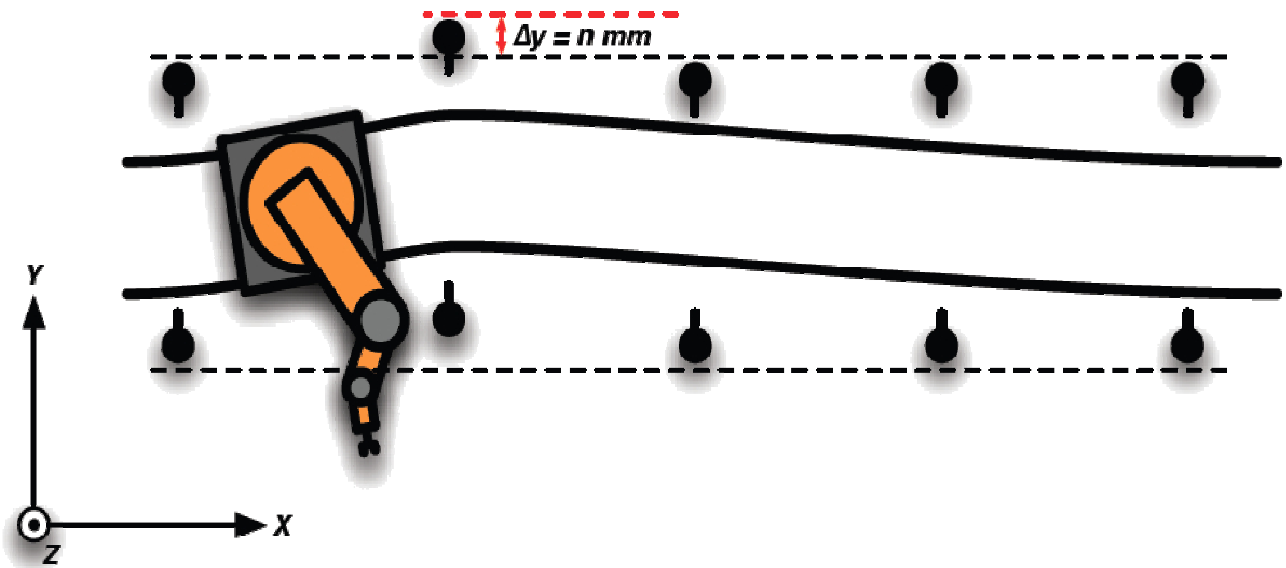
Linear Tracks

- Used for increasing the robots working range
- 2m to up to 30m for long range application e.g. in aircraft of windcraft industry
- Linear tracks are influencing application accuracy additional to the robot
- Adjusted during the mounting process, robot weight and movement influence is not considered
- Dynamic robot movement on skid causes forces and torques

Linear Tracks

Common techniques:

- Simple two-point measurements for gear factor identification

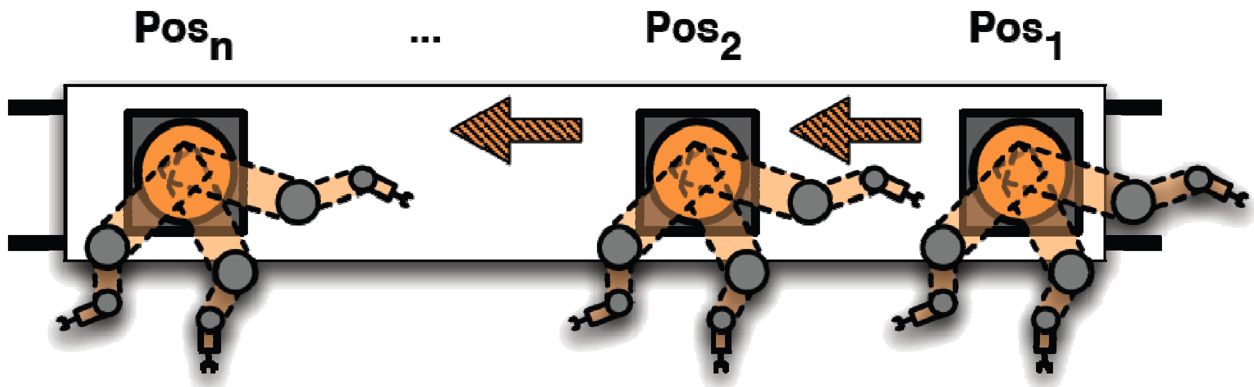


- Track direction identification in robot coordinate system (alignment)

Laser Tracker method:

- Non-linearity of the track identified by 6-dof measurement

Linear Tracks



Approach 1:

- Measurement of robot base frame for multiple skid positions on the track

- Robot works as „rigid body“ based on its repeatability of <0,2 mm

- Cubic spline interpolation of identified base frame along the track

>> Many measurements needed for an accurate description of the track

Linear Tracks

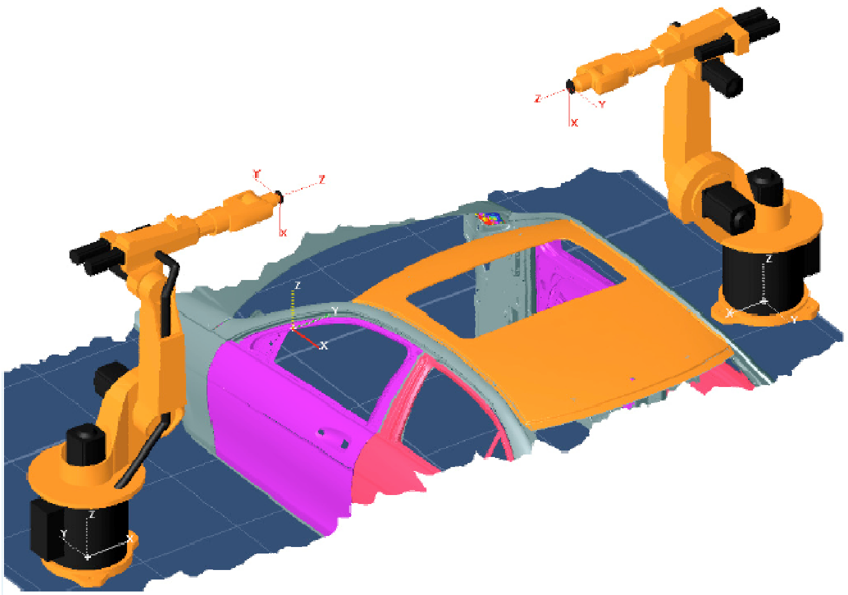
Approach 2:

- 6-dof continuous measurement scan of the linear track skid
- Exact geometrical description of track profile via fine scan
- Positional correction of robot in 6 dimensions for arbitrary skid positions

>> Easy measurement procedure

Copy & Mirror of robot programs

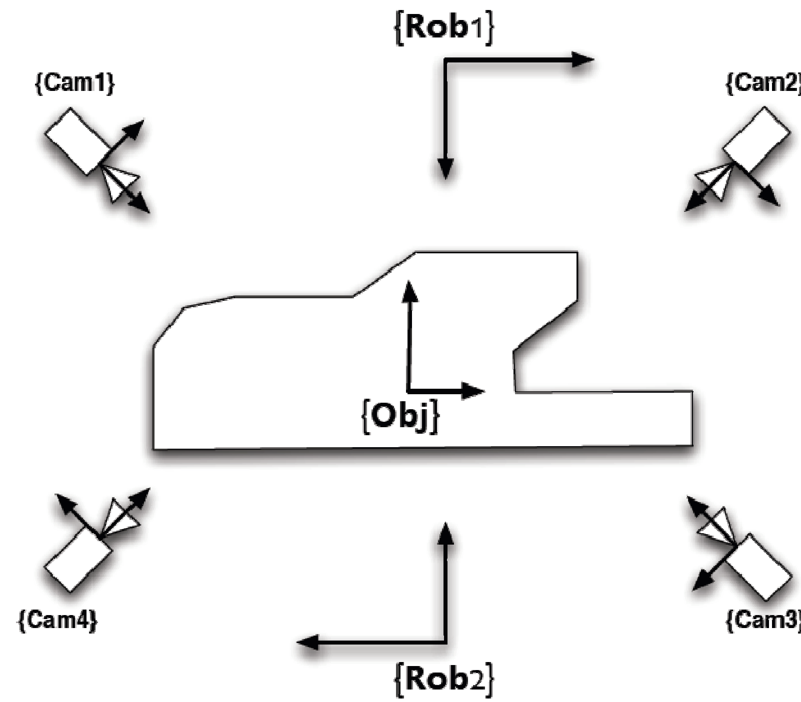
- Robot program construction off-line using CAD simulation tools
- Generation for one robot, mirroring on symmetrical work pieces
- Copying of programs to parallel working cells



>> Integration of acquired measurement results into copy & mirror process to keep the needed accuracy

Vision System calibration

- Object position identification via vision system
- Multi-camera, laser-line, light-stripe or other methods base on good calibration
- Determination of sensor positions or calibration using 6-dof measurement technology
- Even hidden points e.g. for sensor body reference measurement possible with special tip adapters



Laser tracker as inline measurement system

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- Optimal setup of components results in high accuracy for application
- But: Resulting accuracy is still depending on dynamic forces and non-avoidable influences

>> Always existing gap between theoretical world (CAD) and practical movement due to limited accuracy

>> Offline-generated programs always have practical deviations

Laser tracker as inline measurement system

- Laser tracker not only used for accuracy improvement or calibration
- Over-all pose correction via TCP movement identification

Static correction:

- Integration of laser tracker into working coordinate system
- Measurement of TCP-position in dedicated application positions
- Calculation of 6-dimensional correction offset for each position

Laser tracker as inline measurement system

- Offline correction of robot program with processing of movement results

>> Application of robot with repeating accuracy !

>> 10-times better than positional accuracy !

>> Laser tracker not needed all time in the cell !

>> Correction measurements repeated periodicaly !

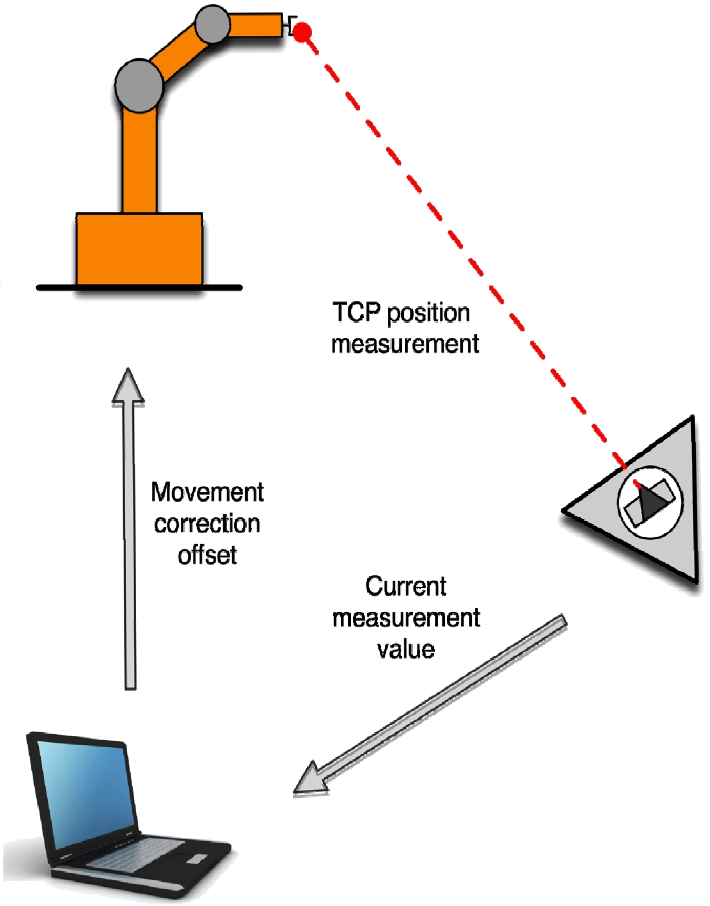
Laser tracker as inline measurement system

Dynamic correction:

- Continuous measurement of TCP-position by laser tracker
- Dynamic correction control loop via real time interface to robot
- 6D-online correction of robot movement
- Correction of dynamic effects caused by application forces

>> Complete path motion controlled !

>> Absolute accuracy increased significantly !



Measure Assisted Production

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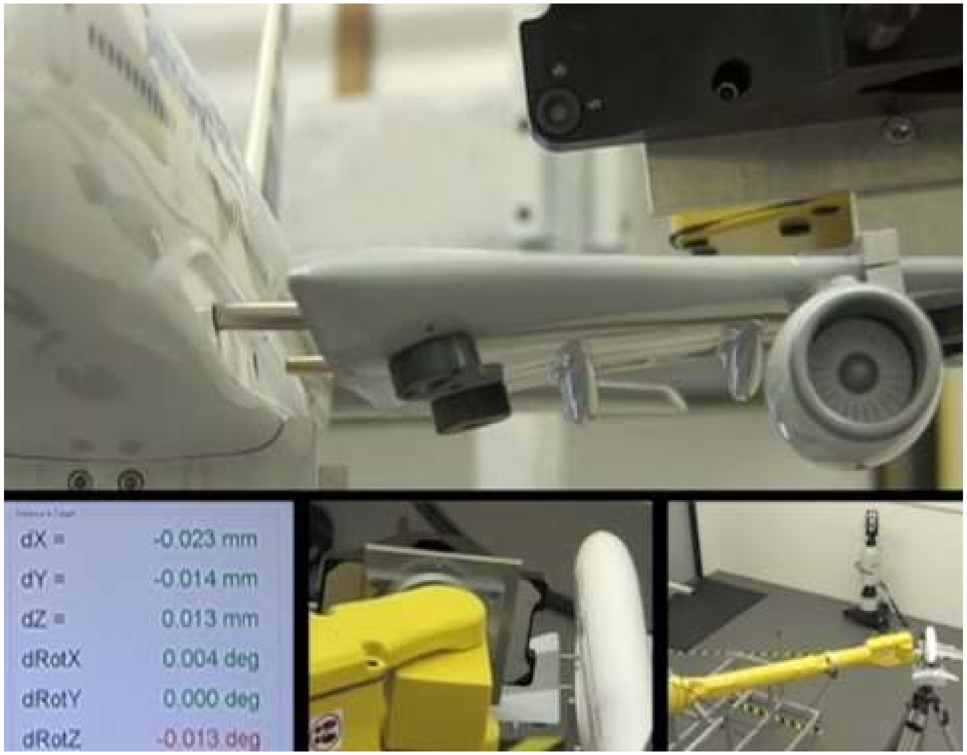
- Example implementation of correction control loop
- Mixture of static and dynamic correction via iterated movement correction
- „Blind“ movement steps between correction points
- System is easily adaptable to high-speed dynamic correction via real-time interface
- Assembling application as example for robot path guidance

Measure Assisted Production

- Airplane wing-to-body task
- 6-dimensional measurement of robot tool
- Fixed tool-to-wing transformation
- Calculation of correction values in multiple path positions
- Final blind step for assembling
- Not depending on robot absolute accuracy



--Link to video--

Results

- From optimization up to full movement control usage of laser tracker measurements
- With inline correction control loop all accuracy influences compensated
- Dynamic robot path motion control with up to 1kHz measurement rate
- Resulting accuracy ranges:
  Absolute static: <0,1 mm
  Dynamic: <0,3 mm (depending on speed)