

VALIDATION AND EVALUATION OF IGPS CONFIGURATIONS - DESCRIPTION OF A TOOL SIMULATING THE LINES OF SIGHT -

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Abstract:

This paper describes a tool for simulating the lines of sight of a dedicated measurement system (indoor global positioning system, iGPS) during the use within a cooperating multi-robotic assembly.

The tool evaluates the iGPS configuration of such a dedicated measurement system and therefore the declaration of the process capability of a complex assembly system can be estimated.

The papers result is a tool which evaluates the iGPS transmitter configuration during the robot movement. The iGPS-signals are monitored and controlled throughout all stages of assembly. The complex challenge to select a valuable transmitter configuration, due to the assembly task, can be solved in an early planning phase by simulating the real cell. This allows a fast reconfiguration of a robotic assembly process with an integrated and dedicated measurement system.

The simulation is evaluated by a real assembly cell equipped with cooperating robots and an iGPS measurement system.

Keywords: iGPS, simulation tool, line of sight, reconfiguration, validation

1. INTRODUCTION

Advanced production systems must cater for increasing product variety in response to market conditions, a high demand on quality in the context of high wage countries. Robotic assembly can potentially meet this challenge, but the iGPS metrology infrastructure for multi-robotic cooperative assembly is not yet sufficiently developed to cope with reconfigurable assembly systems. However, the introduction of such a dedicated measuring system brings additional complexity since the overall system consists of the cooperating robots and the measuring system as well as the application.

The dedicated measurement system (iGPS) depends on guaranteed lines of sight between a sufficient number of iGPS transmitters and the receivers, the latter positioned at the robots tool center point (TCP), to deliver the required measurement information [1-3].

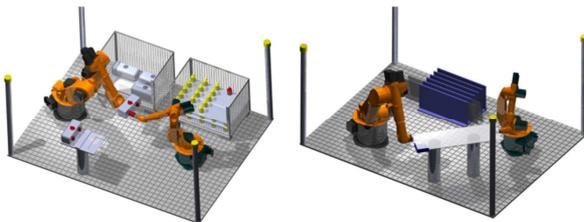


Figure 1: Cooperating Robots

The use of cooperating robots enables novel assembly processes and flexibility through robot-based work piece motion (Figure 1). Exemplary processes are the handling of large components and the jig-less assembly. Cooperating robots fulfill these requirements like load-balancing for reducing stresses inside components. Using these performances enables the handling of heavy, awkwardly shaped and refractory components, such as glass panels [4].

Figure 1 shows exemplary configurations of cooperating robots. This robot cell is equipped with an iGPS system which is implied by the four columns carrying iGPS satellites which transmit the sensor signal into the measuring area of interest.

These examples identify the need for optimized absolute positioning and path accuracy by the use of iGPS. But not only in robotic applications the iGPS improves the process capability of assembly systems.

An optimization of the positioning accuracy and the evaluation of the process capability of complex assembly systems during an early planning phase is a big industrial challenge. Additionally the introduction of a dedicated measurement system, such the iGPS, enables the efficient commissioning and reconfiguration of assembly systems.

But today's simulation tools are not able to reflect the special characteristics of the overall system incl. metrology. Therefore it is not possible to exploit the system's full potential and develop and evaluate new alternatives for system optimization. This simulation tools are developed rudimental and the performance evaluation will be described in this paper.

2. SPECIFICS OF A DEDICATED MEASUREMENT SYSTEM

The indoor Global Positioning System (iGPS) is a dedicated measurement system for use in large-scale metrology and tracking applications [1, 5, 6]. The system is able to measure both static and dynamic performances of the target objects with six degrees of freedom (DoF).

The iGPS system operates on the same general principle as traditional GPS and determines the position of sensors within a measurement volume encompassed by a network of transmitters (Figure 2).

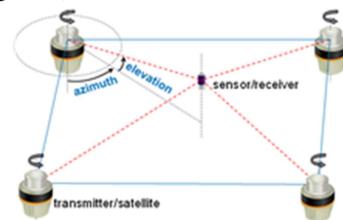


Figure 2: Network of transmitters surrounding a single receiver

The transmitters send one-way signals to the sensors. Similar to a spherical coordinate system, the ray between a sensor and a transmitter can be defined uniquely by the combination of azimuth and elevation angles (Figure 2). Under the assumption of known relative position and orientation of the transmitters, the intersecting rays from multiple transmitters at a sensor enable the triangulation for position calculation (Figure 2).

Two or more sensors are internally connected in a fixed configuration, which forms a receiver and allows the determination of orientation. Please find a detailed description of the iGPS in literature [1-7].

The iGPS is suitable for the control of cooperating robots, because it allows the usability of many measuring points, a large measurement volume and the system is scalable. But the measurement uncertainty is strongly dependent of the transmitter – receiver configuration [8, 9]. Therefore the transmitter alignment and the system setup directly affect the process quality.

However, the advantages of the measuring system can only be used, if a good signal quality is already predicted during the CAD-planning-phase for the setup of cooperating robots.

Using such a simulation to predict the process capability demands an answer for validation to proof the simulation.

3. SIMULATION OF PROCESSES INCLUSIVE THE IPGS

The Task of a metrology infrastructure (which is an integrated tool) is to cope all combined factors of influence and the domination of complex assembly systems. The tool estimates the assembly- and process capability during an early planning phase for new systems and processes. It is a strategic decision guide for the design and proving of complex systems. Additionally it is possible to compare between the benefits of alternative systems.

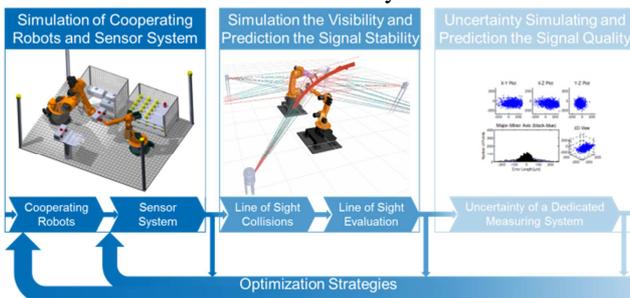


Figure 3: Metrology Infrastructure

Figure 3 shows the concept of the metrology infrastructure to meet the new challenges using iGPS in a multi-robotic assembly [7]. To perform an effective commissioning and reconfiguration of an assembly system strong and integrated simulation strategies are necessary:

Optimizing the position accuracy, evaluating the process capability and performing an effective reconfiguration of an assembly system by using the iGPS, three simulation strategies are required:

1. Simulation of cooperating robots
2. Simulation and evaluation of sensor visibility
3. Simulation of measurement uncertainty

These simulations are integrated into a single planning tool facing today's challenges.

It is possible to monitor the overall system performance of the cooperating robots, the system's setup and the quality of the iGPS measurement. Therefore the process capability of new processes and equipment can be evaluated in an early planning phase.

Each step for simulation is detailing the challenges using iGPS in a multi-robotic assembly. Each result can be evaluated and used as a starting point feeding information into optimization strategies in a quality backward loop.

The next chapter describes the simulation strategies. The validation of such a metrology infrastructure is described in chapter 5. The evaluation of the process capability is detailed in chapter 6. Chapter 7 presents optimization strategies and the evaluation of an iGPS configuration.

4. LINE OF SIGHT SIMULATION

The sensor visibility between the targets (receivers) and the corresponding measuring stations (transmitters) are simulated as prismatic robots connecting receivers and transmitters [4]. Figure 4 shows the comparison between reality (right side) and the simulation (left side) where the prismatic robots constitute the lines of sight.

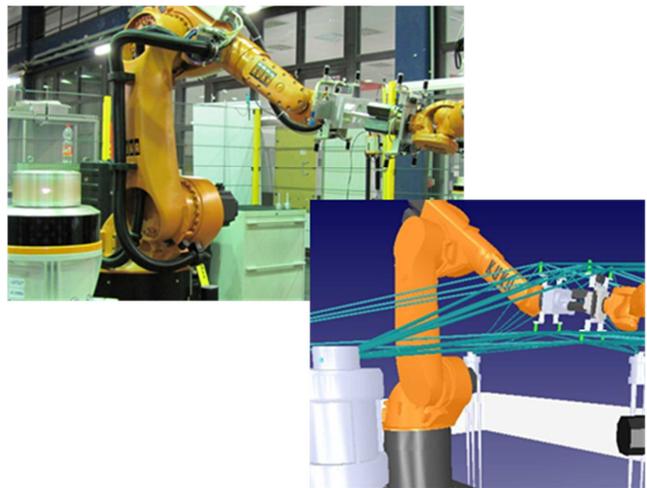


Figure 4: Cooperating Robots in iGPS environment - reality vs. simulation

A "collision detection" algorithm, which is implemented in the simulation software, allows to detect each collision between the prismatic robots and other obstacles in the overall assembly system. [4, 7] That means, that the disruption of each line of sight between the transmitter and receivers is recorded.

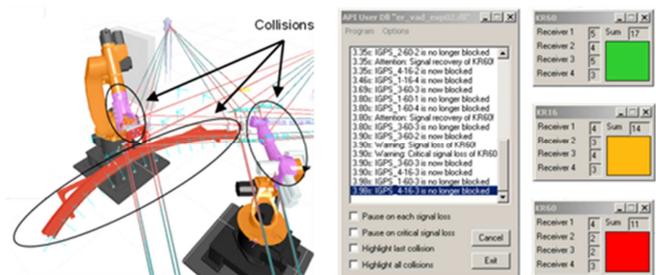


Figure 5: Disturbed line of sight and assignment of the signal stability

Figure 5 shows cooperating robots performing an assembly task. In the left side the collisions between the industrial robots and the prismatic robots as “line of sight” are highlighted. In the middle all events regarding the “line of sight-evaluation” are recorded. An algorithm distinguishes between collisions which influence the line of sights and rates the actual signal stability of the iGPS system in every robot pose of the system. The assignment of the signal stability for each industrial robot is indicated by traffic light symbols (Figure 5, right side). If the signal stability is insufficient, the arrangement of the robot cell, iGPS system or process components must be changed or the path of the robot movements must be adapted. [4, 7]

5. EVALUATION OF THE LINE OF SIGHT SIMULATION

The line of sight simulation is used to evaluate the process capability of complex assembly systems. But therefore the simulation itself must be evaluated and compared to the real system behavior. As described, our test scenario is an assembly cell with cooperating robots.

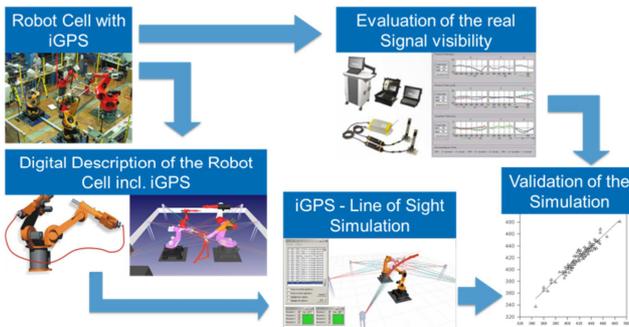


Figure 6: Technical requirements for doing the evaluation

Figure 6 shows the technical requirements for the execution of the evaluation. First of all the real **robot cell with iGPS** must be commissioned and calibrated e.g. by Laser-Tracker. The cell components are digitalized in 3D (e.g. SolidWorks) and transferred into the robot simulation tool EasyRob based on the calibration data. Additionally the **digital description of the robot cell incl. iGPS** is considered.

For an optimum use of the iGPS, fixed monuments are used to calculate the transmitters positions. The iGPS can be referenced according to these monuments.

The transmitter-position of the dedicated measurement system will be reconfigured during the optimization processes (chapter 7). After every reconfiguration the real transmitter-position must be again integrated into the simulation tool. Therefore the monuments are needed. The monument’s setup is calibrated to the robot’s coordinate system. This information is necessary to import the real transmitter-position into the simulation. The iGPS measurements software calculates the position of each transmitter relative to the monuments and send this information to the simulation tool. The simulation tool receives these information and position the transmitters automatically into the virtual environment.

The complete digital description is needed for doing the **iGPS line of sight simulation**. The result of this simulation

evaluate the process capability of the complex assembly system and is explained in the following chapter 6.

But the line of sight simulation must be evaluated at first to ensure the simulations ability. The simulated results for the transmitter – receiver visibility must be compared to the **evaluation of the real signal visibility** provided by the measurement software.

The **validation of the simulation** is performed by comparing the results for the sensor visibility of the simulation and the real signal visibility which is given by the real system.

The evaluation of the simulation line of sight simulation includes the following range of service (among others):

- Import the real transmitter position into the simulation by xml protocol
- Alignment between reality and simulation
- Referencing the transmitter position to the world coordinate system by iGPS monuments
- Verification of the line of sight simulation (iGPS) to the real robot cell
- Evaluation of the transmitter configuration by simple indicators
- Automated creation and evaluation of different transmitter configurations

6. EVALUATION THE PROCESS CAPABILITY OF COMPLEX SYSTEMS

To evaluate the improvements of the signal stability Figure 7 shows two different configurations of the iGPS sender setup. In both configurations the same process is performed by the robots. The graph shows the number of valid measuring signals (means visible sensor signals) of the robot (KR 16) during the simulation time. The green columns in the chart shows, that there are in average a higher number of valid signals for configuration 1 compared to configuration 2.

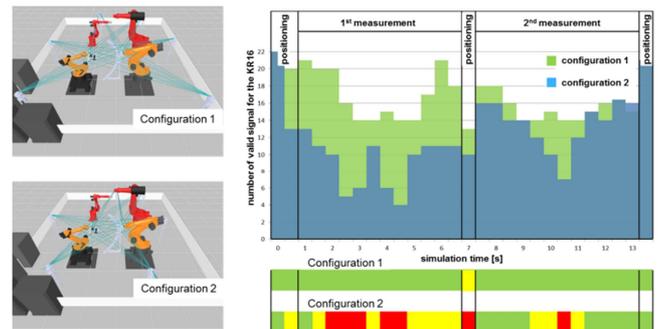


Figure 7: Evaluating the process capability

The assessment of the number of valid signals shows, that for configuration 1 there is a sufficient (green) signal quality during the complete simulation. For configuration 2, there are several spots with minimum (yellow) and insufficient (red) signal quality. The optimization strategy reaching improvement is described in chapter 7 [7].

It is approved that already slight movements in the transmitter-setup produce a big impact into the signal stability of the overall iGPS.

7. EVALUATION OF IGPS CONFIGURATION AND OPTIMIZATION STRATEGIES

As mention in chapters 4, 5 and 6 the accuracy and performance of the cooperating robot is evaluated and focused. Already small changes in the transmitter-setup produce a big impact to the quality of the measurement signal (chapter 6).

There are three options to deal with if there is an insufficient visibility:

1. Changing the receiver-frame for every robot
2. Changing the path-planning
3. Changing the transmitter position

This paper focus on changing the transmitter position.

At first critical situations during processes (joining, welding, testing, etc...) must be identified. Uncritical situations, like usual robot-movements can be neglected. For these critical situation the iGPS transmitter-configuration must be evaluated by specific criteria before doing an optimization. Each transmitter could be evaluated by the following criteria:

1. Summation of all visible receivers per transmitter
2. Summation of all visible receivers per robot per transmitter
3. Summation of min 3 visible receivers per robot per transmitter
4. Evaluation of single line-of-sight by weighting the resulting cutting angle
5. Evaluation of single line-of-sight by weighting the distance to the receivers
6. Additional criteria are topics of research ...

Specifying the criteria and performing the evaluation, on basis of the simulation tool, are actual topics of research.

An optimization strategy can be used to rearrange the transmitter setup in consequence of the transmitter evaluation.

A heuristic approach is moving lowest-rated transmitter into $\pm 1m$ in the X-Y plane and recalculating the evaluation of each transmitter position. Comparing the rating of each position shows the next best transmitter setup (Figure 8).

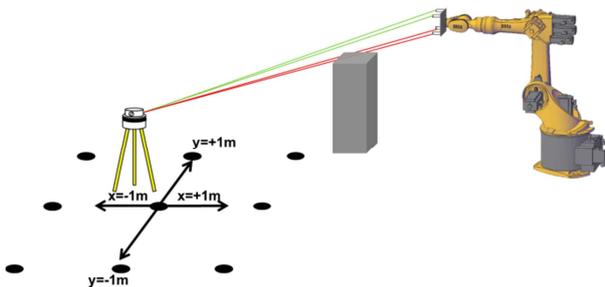


Figure 8: Heuristic optimization strategy

8. RESULTS AND OUTLOOK

Previous results are a combination of three integrated simulations to build a metrology infrastructure for multi robotic cooperative assembly that predicts the iGPS measurements signal quantity and quality during the robot movement. The number of iGPS-signals and the associated

uncertainties can be monitored and controlled throughout all stages of assembly.

But the validation and evaluation of the iGPS configuration was neglected. The papers results close this gap and present a tool which evaluates the iGPS transmitter configuration during the robot movement. The iPGS-signals are monitored and controlled throughout all stages of assembly. The complex task, selecting a good transmitter configuration, due to the assembly task, can be performed in an early planning phase by simulating the real cell.

The objectives like fast and effective reconfiguration of a robotic assembly process using the dedicated measurement system can be reached. And the mutual trust to the simulation evaluating the process capability is raised.

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