PROCEEDINGS

55. IWK

Internationales Wissenschaftliches Kolloquium
International Scientific Colloquium

13 - 17 September 2010

Crossing Borders within the ABC

Automation,

Biomedical Engineering and

Computer Science

Faculty of
Computer Science and Automation

www.tu-ilmenau.de

TECHNISCHE UNIVERSITÄT
ILMENAU

Home / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=16739

Impressum
Published by

Publisher:	Rector of the Ilmenau University of Technology Univ.-Prof. Dr. rer. nat. habil. Dr. h. c. Prof. h. c. Peter Scharff
Editor:	Marketing Department (Phone: +49 3677 69-2520) Andrea Schneider (conferences@tu-ilmenau.de) Faculty of Computer Science and Automation (Phone: +49 3677 69-2860) Univ.-Prof. Dr.-Ing. habil. Jens Haueisen
Editorial Deadline:	20. August 2010
Implementation:	Ilmenau University of Technology Felix Böckelmann Philipp Schmidt

USB-Flash-Version.

Publishing House:	Verlag ISLE, Betriebsstätte des ISLE e.V. Werner-von-Siemens-Str. 16 98693 Ilmenau
Production:	CDA Datenträger Albrechts GmbH, 98529 Suhl/Albrechts
Order trough:	Marketing Department (+49 3677 69-2520) Andrea Schneider (conferences@tu-ilmenau.de)

ISBN: 978-3-938843-53-6 (USB-Flash Version)

Online-Version:

Publisher:	Universitätsbibliothek Ilmenau ilmedia Postfach 10 05 65 98684 Ilmenau

Home / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=16739

INDOOR POSITIONING ON INDUSTRIAL FACILITIES WITH AN ACCURACY OF MEASUREMENT OF ± 50MM

D. JOPP, M. C. LEMMEL

ABSTRACT

Within the joint project 'Indoor Positioning on industrial facilities with an accuracy of measurement of ± 50mm', the partners BIMAQ and IAT on behalf of BCM and the engineering consultant Obergfell + Partner (IPO.Plan) developed an automatic and wireless acquisition of conveyor-technical factory layouts to be transferred into a CAD model. The project is funded by the German Federation of Industrial Research Associations (AiF) from the 01.07.2008 to the 31.12.2009.

A system is developed to automatically capture the actual 3D-movements in conveyor-technical arrangements. An electronically or optically pursuable module, which follows the course of a conveyor, acquires defined parameters such as the conveyor height, role distances or inclinations using a new sensor system. The project aims at an exact and reliable detection within a covered facility.

After studying the market of upcoming tracking solutions a system which uses ultra-wideband (UWB) radio was installed into a tentative production facility of about 900 m². This technique is intrinsically more accurate than other radio technologies because of its resistance to signal distortions caused by the reflections that always occur in real-world deployments. The sensors detect Angle-of-Arrival (AoA) and Time-Difference-of-Arrival technology (TDoA) in combination. In addition a Camera System combined with a 3D-Sensor was built up at IAT to support hidden areas. This system was built-on a variable Skid which was designed by the engineering consultant IPO.Plan. Though, accuracies of approximately 10 - 15 cm could be reached overall.

1. INTRODUCTION

Conveyor systems play a substantial role in the industrial environment for transportation of components-in-processing between different production steps. To accomplish an efficient optimisation of this variable logistic, capture of the actual movement and velocity, which in most cases represent deviations from the planned process, is required.

The aim of the project is the development of a short-term and temporary installable system for the automated capture of actual 3D-movements in conveyor-technical arrangements. An electronically or optically traceable module, which follows the course of a conveyor, acquires defined parameters such as the conveyor height, role distances or inclinations. The challenge for such a system is the exact and reliable detection, even in covered spaces.

The development of a suitable interface to a CAD-system allows a direct conversion of the captured parameters into attributed 3D-objects. Through the capturing system, the current position within the conveyor facility is identified and processed for localisation of the captured objects in space.

Here, two technical principals have to be distinguished:

1. Wireless capturing system, integrated into the infrastructure
2. Independent, optical image processing system for environment recognition - as a fall-back solution

The focus lies on the wireless capturing system and on its localisation accuracy, to keep the deployment of additional sensors at a minimum. A camera system is to ensure data redundancy in case of communication loss of the primary system through electromagnetic shadowing due to production furnaces, for example.

2. PRINCIPAL SELECTION OF THE CAPTURING SYSTEM

In the context of a market analysis commercially available systems were examined regarding there classification and categorized regarding operating principal, workspace, accuracy and installation requirements. [JOP08]

For the selection of suitable basic technologies for the realisation of indoor capturing systems, various criterions have to be considered. Organisational goals are equally significant to the selections as is the constructional environment. It has to be distinguished between a triangular and a distance (trilateral) measurement when determining a position. Moreover, the accuracy of the position to be measured depends not only on the chosen method, but also on the location of the reference points [POS08].

Capturing systems based on GPS or telecommunication networks are ineligible for indoor use due to their principle and accuracy. To be able to determine the position with the requested precision, a solution employing RFID-radar is conceivable. However, the transponders have to be built into the surrounding architectural structure and have to be calibrated exactly. To avoid this, determination of the position with WLAN, utilising signal strength measurement or UWB is conceivable. A combination of the different technologies, which some manufacturers have already started to do, is most promising for the project, but because of the high expenditure and the existing infrastructure not possible [GRE03].

Under consideration of all boundary conditions, together with weighing of all disadvantages and advantages of existing systems, a solution based on a UWB-radio system seemed promising, since other systems lack accuracy or require an unreasonably high installation expenditure for this application. Figure 1 gives an overview over existing or upcoming technologies.

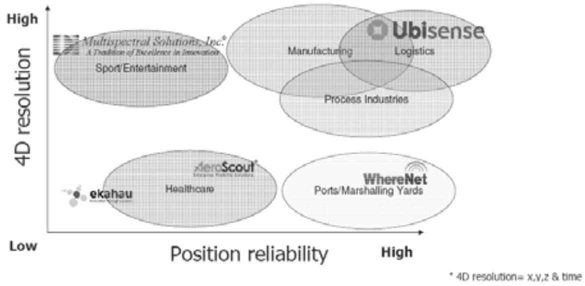

Figure 1 - Market positioning of relevant systems for localization [YIN09]

The manufacturer of the UWB-System ‘Ubisense’ claims, with their technology it is possible to dynamically locate and display persons and objects in 3D, with an accuracy of 15cm. Reasonable application areas of that system include logistics, retail, manufacturing, office, entertainment, military, health care and hazardous materials. The system is also suitable for detecting the access of a danger zone or for tool release at the assembly line in automotive manufacturing, for example.

The system is composed of three components: active, battery-powered tags for the generation of UWB-impulses (localisation signals), the installed sensors for receiving and evaluating the signals and a software platform, which records, conditions, visualises information and relays it to the user and IT-systems.

3. TECHNOLOGY UND FUNCTIONALITY

Especially within buildings, the differentiation between directly and indirectly received signals is difficult. Indirect signals originate from multidirectional reflection, for example on ceilings, floors, walls or pillars. The UBW-technology is affected to a lesser degree compared with other radio systems, because calculations are carried out utilizing time difference and not signal strength (Fig. 2). Very short-pulsed signals allow the required accuracy and can be displayed in real time [POS09].

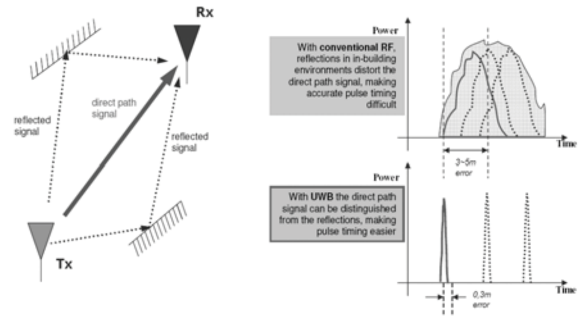

Figure 2 - Functionality of UWB-Technology [POS09]

For this purpose, a network comprised of sensors, which are fitted with antenna arrays, computes the position of the tags by evaluating the incoming direct UWB-signals. Every second, the sensors determine the position of the transponders multiple times. The calculation is carried out not only utilizing the response difference between the signal inputs of two sensors, but additionally utilizing the horizontal and the vertical angle of incidence of the UWB-signal, thereby reducing the required sensor density of the input range. Through this combination of measurement methods a high accuracy of location determination is supposed to be ensured.

The sensors are organised as cells, with one sensor per cell being defined as ‘master’ and one sensor out of the complete network being defined as ‘timing source’. This sensor is usually a master-sensor at the same time, to minimize the depth of the timing tree. Typically four to eight sensors are combined into a cell and cover an area of approximately 400 to $1000m^2$, depending on the shadowing of the covered area. Depending on the demand, a certain number of sensors is installed in the area, or integrated into an existing sensor network, which is extendable at any time. Thus, an unlimited number of cells can be integrated into an existing sensor network.

The calculated position data of the tags is transferred by the master sensor over the network to the central server, which provides data for several applications through the software included. The user interface can be generated with the graphical modelling tool of the software and creates a detailed real time representation of the area, among other features. Additionally, the position data is made available for external programs via APIs to be called upon for report generation or rendering of process data for evaluation purposes.

4. ADAPTION AND ACTIVATION

Through site prospecting to evaluate the characteristics of the facility, the spatial arrangement of the sensor network for optimal performance was devised. Subsequently the sensors were wired and the sensor network was set up, including establishing a connection to the server, on which the software platform is installed. To activate the system the sensors had to be measured in and calibrated by tachymeter after installation.

4.1. Location description

The test arrangement of the capturing system is deliberately installed in an exceptional building, which has the shape of a semicircle with a radius of approximately 30m and an integration of seminar rooms at the centre. The area to be covered amounts to 900m². On account of the structural conditions, like floor size and shape and the on-site shadowing, a requirement for a cell with 10 sensors for the application was identified to achieve best possible results [FOC08]. The sensors were placed and wired as follows (Fig. 3).

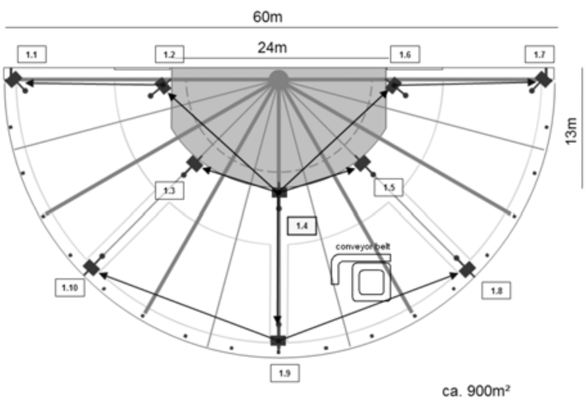

Figure 3 - Tentative environment of test scenario [FOC08])

4.2. Test set-up

To verify the accuracy of the wireless capturing system, a conveyor belt (Fig. 3) was set up in the building previously described. In the process the system can be tested over two different routs. To be able to indentify cornering or also rotations around the centre point during slow motion, an inclusion for a transponder was provided at the front and the back end of the carrier platform. This allows angle recognition by the means of two object points.

In a second step four light barriers were installed at the conveyor belt and measured in precisely, to have a time signal recorded by the Programmable Logic Controller upon skid passing. The main focus lay on synchronising the time signals of the PLC with the output signals of the localising system, to measure deviations between the detection time and the real arrival at the position.

4.3. Implementation of the test environment

To integrate the test environment into the software it is initially necessary to measure the whole building, including the conveyor belt, and reproduce it in a CAD-system. Afterwards, this data has to be exported in XML- (.xml) or DirectX-format (.x) to be compatible to the data formats supported by Ubisense. Then, the generated models are to be transferred into the platform and the assembly of the conveyor belt is to be positioned precisely in the building.

5. DEVELOPMENT OF ALGORITHMS AND FILTER PARAMETERS

To improve the localisation accuracy it is necessary to embed special algorithms and adjust them through variation of their filter parameters. In the process, accuracy depends on for example the adjustment of the parameters subsequently described in part.

'tag power class'

The filter is able to evaluate the transponder position, based on the power of the radio signals received by each sensor. To achieve this, the identity of the tag has to be known, to that the distance of the expected received power can be calculated.

'static distance'

The distance to the previously calculated position of a tag assumed stationary, to which *'static smoothing'* is applied – see also *'static alpha'*.

'static alpha'

The proportion (Alpha ranges form 0.0 to 1.0) of the current measurement, which is utilised in the low pass filter when the tag is assumed to be stationary. The position of the tag is calculated using the formula: *'(Alpha) * (current calculated position) + (1.0 - Alpha) * (previously calculated position)'*. If the motion of the tag is strongly damped, Alpha tends towards zero.

'max position variance'

The parameter sets the maximal deviance of the position estimation, with should be included according to the filter status. If several measurements are performed at one transponder position during a given time interval, the inaccuracy of the position estimation decreases. On the other hand inaccuracy increases, if only few measurements are performed, or if the measurements do not limit the transponder position in all directions.

'max valid position variance'

The parameter defines the maximum deviance of the position estimation, which is to be output as a valid target. This should be less or equal to *'max position variance'*. The difference between these two parameters is that if uncertainty is greater than *'max position variance'*, the prediction for the following target will not change, whereat filter settings are kept if uncertainty is greater than *'max valid position variance'*, but the position is set as not valid.

'max velocity'

The parameter sets the maximum velocity with which the tracked target can move.

'tag height above cell floor'

The z-direction is always given as altitude above the cell floor, which is an integral part of the *'location engine cell'*, which is set in *'Sensors and Cells'*.

6. DATA OUTPUT AND ADDITIONAL SETTINGS

With an additionally developed program the recorded data can be viewed and saved. The format is flexile and easily adoptable for further applications. Table 1 shows an overview of the outputted values via API.

	tag					x-coord.	y-coord.	z-coord.				slot
position:	020-000-021-082	in	cell	1	at	-2.664582	-13.228466	1.224414	valid	in	time slot	3277879
position:	020-000-021-082	in	cell	1	at	-2.666535	-13.225979	1.222925	valid	in	time slot	3277883
position:	020-000-021-082	in	cell	1	at	-2.666451	-13.227559	1.224177	valid	in	time slot	3277887
position:	020-000-021-082	in	cell	1	at	-2.671693	-13.230253	1.223543	valid	in	time slot	3277891

Table 1 - Data output of x-, y- and z-coordinates

Column 2 of Table 1 contains the MAC-address of the calculated tag. In column 5, the target cell is displayed, in which the tag was localised. In our case this is always 1, since the test setup consists of only one cell with 10 sensors. The columns 7-9 display the three coordinates in relation to a fixed origin. The last column contains the time slot in which the data set was generated. One timeslot is exactly 27,023 ms long. The highest actualisation rate occurs at maximum every fourth timeslot, so that every 108,092 ms a new data set can be made available, which equals a frequency of about 10 Hz.

7. VERIFICATION OF THE OVERALL SYSTEM

According to the developer the specification on the advertised 15cm accuracy means in detail:

"A tag which is placed in the middle of a simple 4 sensor cell, in a manner so that it is well visible to all sensors, will be measured with a probability of 95% within a 15 cm perimeter of the actual position."

These specifications will be verified in the following paragraph. For this, the relative and absolute position is calculated. Principally, for verification the parameters *'max position variance'* and *'max valid position variance'* have to be set to 100. In the process the values of *'std err'* have to be logged and the parameters are to be set thereafter in a way that at least 90% of all *'std err'* values are smaller than the variance. The parameters *'static distance'* and *'static alpha'* exist exclusively for smoothing of measured data. These falsify the measurement, since they cause an averaging in accordance with the calculations listed in the filter parameters. For deactivation, these parameters have to be set to zero.

7.1. Relative accuracy

Firstly, the relative deviation within one test series with 1134 measured values was regarded, evaluating the minimum and maximum of the variation of the individual coordinates. With this method it is assumed that the variance of the previous measurement range from 0,8m (x-coordinate) to ca. 1,15m (y-coordinate) with respect to the reference point, since the variance on average disperses relatively uniformly circular.

Utilizing an additionally programmed smoothing parameter (radius), the variance of all 1134 measured values can be reduced or increased individually. When restricting the variance from 50 cm to 5 cm, only very small deviations of the relative location in the millimetre rage are observable, which affirms the circular dispersion of the measured values. However, reduction of the radius to 5 cm reduces the number of valid values from 1127 at radius 50cm to 268. Taking into account the z-coordinate reduces the number of values to 71. Here, a circular dispersion can be observed also, but with a significantly higher variance in horizontal direction. In the sample measurement, the deviance averages 11 cm with respect to the x-axis, 4cm with respect to the y-axis and 26cm with respect to the z-axis.

Furthermore, the frequency of the distribution with respect to all three axes in detail, as well as the number of the deviations of all measured data and the accumulated probability of a measurement in relation to the weighted average have to be evaluated.

Thereby the distribution of the sample measurement revealed, that 1098 of 1134 measured values, with respect to the x-axis, with a probability of 97% lie within 30 cm (Fig. 4). The probability of measuring values within a range of 5 cm is 28%. Regarding the y-axis, only 4 measured values did not lie within the 30 cm radius, with equals to a probability of 99,64%. The probability of measured values in the 5 cm range is 71%. Regarding the z-axis of this measurement the probability of a deviation within a 30am range is 96%. The probability of measured values in the 5 cm range is 20%.

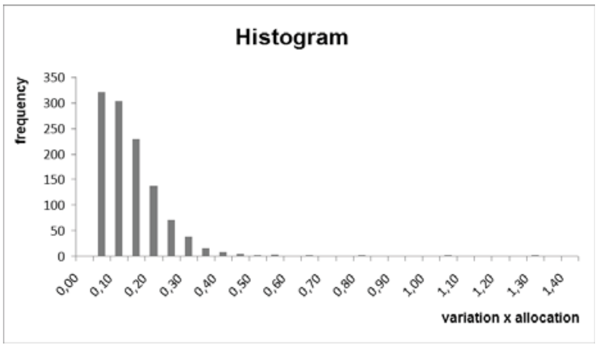

Figure 4 - Histogram of x-variation

7.2. Absolute accuracy

To verify absolute accuracy, at various positions tags were measured in precisely using a tachymeter. Subsequently several series of measurements with different filter settings were to be conducted. The corresponding parameters are to be varied in a way that allows testing in the limit range of the adjustment possibilities. Consequently the measurement results could be influenced most significantly by variation of the parameters *'static distance'*, *'static alpha'*, *'max position variance'* and *'max valid position variance'*

(Table 2). In the process it was detected that the largest deviances in the x- and y-range appeared in the measurements with static altitude specification.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
static distance	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	1	1	1	1	1	1	1	1
static alpha	0,1	0,1	0,1	0,1	1	1	1	1	0,1	0,1	0,1	0,1	1	1	1	1
max pos variance	4	4	100	100	4	4	100	100	4	4	100	100	4	4	100	100
max valid pos variance	4	100	4	100	4	100	4	100	4	100	4	100	4	100	4	100

Table 2 - Example of parameter setting

The chosen filter parameters with variable height achieved the best measurement results in the x-, y- and z-range. However, the two-dimensional coordinates influenced the z-axis significantly. The more precise results in x-and y-axis were achieved, the less precise became the z-axis. The average results had a measuring accuracy of 9 - 12 cm in the two-dimensional range and a deviation of 25 - 26 cm in the vertical direction.

8. CONCLUSION AND OUTLOOK

To date, no suitable method exists to perform a location with an accuracy of ± 5 cm. However, with the implemented technology a practicable basis could be found, that could be adapted to the desired accuracy through the development of special filters. [JOP09]

With the wireless technologies, the occurring disturbances on obstacle encounter in non-shaded areas can be smoothed on the one hand by the use of various plausibility checks on the software side, on the other hand the use of a Kalman-filter is to be considered. The Kalman-filter removes the disturbances caused by the measurement devices. The mathematical structure of the underlying dynamic system must be known, as well as the structure of the measurement falsifications. In contrast to the classical Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters of signal and time series analysis, the Kalman-filter is based upon a state space model, in which it is explicitly distinguished between the dynamics of the system's states and the process of its measurement. Generally, with the implementation of this filter it is estimated based on the mass of the skid if the measured value can have the deviation to the previous measurement. The use of this filter would have exceeded the time and budget limits of this project considerably, but it can be an option for further industrial activities.

In the case of radio shadowing image recognition offers a sensible supplement possibility. The "MVBlueFox"-camera, which was used during the performed test of the optical technology, was able to achieve the desired accuracy at a distance of 2m from the marker. With a larger distance between camera and marker a camera system with a higher resolution has to be chosen. The additionally implemented 3D-sensor was able to improve accuracy significantly under daylight or artificial lighting. For an industrial environment other 3D-Sensors should be considered, since the implemented sensor was inclined to error-proneness.

9. REFERENCES

[FOC08] Focke, Marco, "Ubisense Installationsplan", Ubisense AG, Dortmund, 17.09.2008.

[GRE03] Greisle, Alexander and Haner, Udo-Ernst, "Positionierungssysteme", http://www.cosy.informatik.uni-bremen.de/staff/seifert/UC-Seminar/GreisleHaner_Informatik2003_final.pdf, accessed on: 17.12.2009.

[JOP08] Jopp, Dirk and Dr. Lemmel, Marc, "Marktstudie zu drahtlosen Positionierungssystemen", BIMAQ, Bremen, 16.07.2008.

[JOP09] Jopp, Dirk and Dr. Lemmel, Marc, "Abschlussbericht - Drahtloses Indoor-Ortungssystem in industriellen Anlagen mit einer Messgenauigkeit von ± 50 mm", BCM, Bremen, 18.12.2009.

[POS08] Dr. Poswig, Jörg, Ubisense AG, http://www.ubisense.net, accessed on: 17.12.2009.

[POS09] Dr. Poswig, Jörg: Ubisense AG, http://www.ubisenseconsulting.de/media/pdfs/at-a-glance%20A4-GER-mail.pdf, accessed on: 17.12.2009.

[YIN09] Yin Mon (Yupar) Myint and Dr. Shailendra Vyakarnam, "*Path - Dependency Analysis on New Emerging Technology: Ubisense*", http://www.cfel.jbs.cam.ac.uk/resources/documents/UbisenseCaseStudyforwebsite.pdf, accessed on: 14.12.2009.