Software and hardware specification for area segmentation with laser scanner SICK LMS 400

Pavel Neckar, Milan Adamek

***Abstract*—**The laser scanner SICK LMS 400 with software for area segmentation gives an opportunity to create dual system, which increases the safety and development of production processes. The setting of correct values supported full utilizable system, which is helpful in decision-making whether the person is located in the area of production or not. The developed software uses the distance values from laser scanner and data conditions which depends on operator decision. For correcting possible errors is recommended the trial operation of production line.

***Keywords*—**human safety, laser, production line, scanner, security areas, segmentation.

I. Introduction

In 1960, Theodore Maiman invented the ruby laser considered to be the first successful light laser. Maiman's laser was a "pink" ruby rod with its ends silvered placed inside a spring-shaped flash lamp. Maiman's laser, however, was only capable of pulsed operation due to its 3 energy level transitions. Soon afterwards, in 1960, Peter Sorokin and Mirek Stevenson developed the first 4 level laser (uranium doped calcium fluoride) which was capable in theory of continuous output although in solid state, a continuous output could not be achieved. The development of laser technology had begun [1].

The principle of laser technology supported creation of laser scanners technology. The laser scanner in combination with measuring instruments introduced separate segment of acquiring distance information. The laser scanners can be used in many parts of industry for supporting the production line like a feedback systems. The scanners provide only the information about the how far object is. For production process is this information very usable but means nothing without software solution which can give all information together and decide.

II. Laser principle

Laser principle is based on physical phenomena which are absorption, spontaneous emission and stimulated emission. Absorption and spontaneous emission are natural processes. For the generation of laser, stimulated emission is essential. Stimulated emission has to be induced or stimulated and is generated under special conditions as stated by Einstein in his famous paper of 1917. i.e. when the population inversion exists between upper and lower levels among atomic systems, it is possible to realize amplified stimulated emission and the stimulated emission has the same frequency and phase as the incident radiation. Einstein combined Plank law with Boltzmann´s statistics in formulating the concept of stimulated emission. In electronic, atomic, molecular or ionic systems the upper energy levels are less populated than the lower energy levels under equilibrium conditions. Pumping mechanism can put atoms to a higher energy level by absorption (Fig.1) [3].

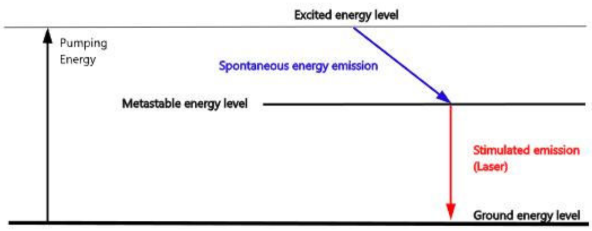

Fig. 1 Energy States of Three - level active medium [3]

The atom stays at the higher level for a certain duration and decays to the lower stable ground level spontaneously, emitting a photon, with a wavelength decided by the difference between the upper and the lower energy levels. This is referred to as natural or spontaneous emission and the photon is called spontaneous photon. The spontaneous emission or fluorescence has no preferred direction and the photons emitted have no phase relations with each other, thus generating an incoherent light output (Fig.2) [3].

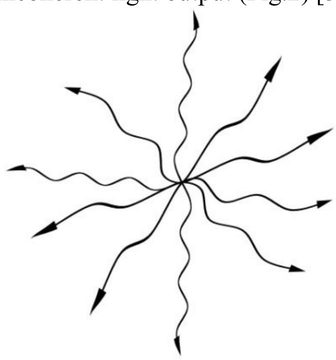

Fig. 2. Incoherent light [3]

But it is not necessary that the atom is always de-excited to ground state. It can go to an intermediate state, called metastable state with a radiation less transition, where it stays for a much longer period than the upper level and comes down to lower level or to the ground state. Since period of stay of atoms in the metastable state is large, it is possible to have a much larger number of atoms in metastable level in comparison to the lower level so that the population of metastable state and the lower or ground state is reversed. i.e. there are more atoms in the upper metastable level than the lower level. This condition is referred to as population inversion. Once this is achieved, laser action is initiated in the following fashion. The atom in the metastable state comes down to the ground state emitting a photon. This photon can stimulate an atom in the metastable state to release its photon in phase with it. The photon thus released is called stimulated photon. It moves in the same direction as the initiating photon, has the same wavelength and polarization and is in phase with it, thus producing amplification. Since there are a large number of initiating photons, it forms an initiating electromagnetic radiation field. An avalanche of stimulated photons is generated, as the photons traveling along the length of the active medium stimulates a number of excited atoms in the metastable state to release their photons. This is referred to as the stimulated emission. These photons are fully reflected by the rear reflector (100% reflective) and the number and consequently the intensity of stimulated photons increases as they traverse through the active medium, thus increasing the intensity of radiation field of stimulated emission. At the output coupler, a part of these photons are reflected and the rest is transmitted as the laser output. This action is repeated and the reflected photons after striking the rear mirror, reach the output coupler in the return path. The intensity of the laser output increases as the pumping continues. When the input pumping energy reduces, the available initiating and subsequently the stimulated photons decrease considerably and the gain of the system is not able to overcome the losses, thus laser output ceases. Since the stimulation process was started by the initiating photons, the emitted photons can combine coherently, as all of them are in phase with each other, unlike in the case of spontaneous emission and coherent laser light is emitted (Fig.2). Though the laser action will continue as long as the energy is given to the active medium, it may be stated that pulsed laser is obtained if the population inversion is available in a transient fashion and continuous wave laser is possible if the population inversion is maintained in a steady-state basis. If the input energy is given by say a flash lamp, the output will be a pulsed output and the laser is called a pulsed laser. If equilibrium can be achieved between the number of photons emitted and the number of atoms in the metastable level by pumping with a continuous arc lamp instead of a flash lamp, then it is possible to achieve a continuous laser output, which is called continuous wave laser [3].

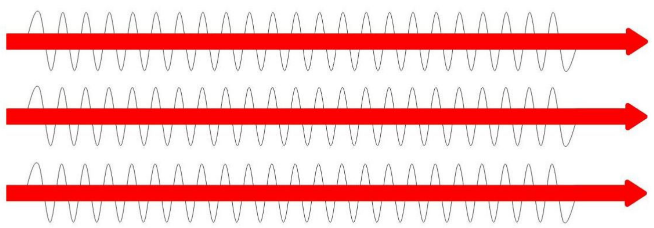

Fig. 3 Coherent light [3]

Laser action is preceded by three processes, namely, absorption, spontaneous emission and stimulated emission - absorption of energy to populate upper levels, spontaneous emission to produce the initial photons for stimulation and finally, stimulated emission for generation of coherent output or laser [3].

III. Laser construction

Laser is assembled from 3 main parts which are:

- Gain medium (containing a substance for excitation energy on the emission levels).
- Energy source (is used for induce excitation).
- Highly reflective optical cavity (is needed for reflecting photons and for resulting laser beam).

Description of laser parts [2]:

1. Gain medium
2. Laser pumping energy
3. Reflecting mirror
4. Half-reflecting mirror
5. Laser beam

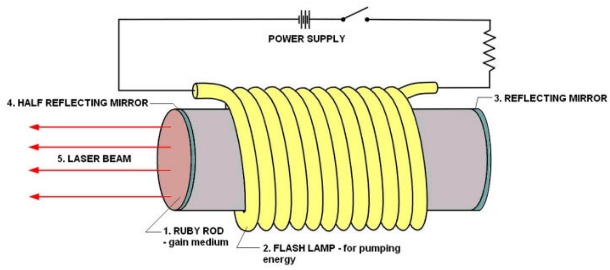

Fig. 4 Laser diagram [2][3]

IV. The measure distance methods with laser technology

A. *Triangulation method*

Triangulation method was introduced by National Research Council (NRC) in 1978. The name triangulation was created from location of various elements, which triangulation method need for determination of distance. The various elements are: source of laser beam, sensor and dot which is emitted by laser. Principle of triangulation method is finding distance between laser source and laser dot. Function is based on:

- Known distance between laser source and sensor
- Angles - which are created by the position of component (laser, sensor). The angle of laser is known and angle of sensor is determined by the dot on sensor surface [3].

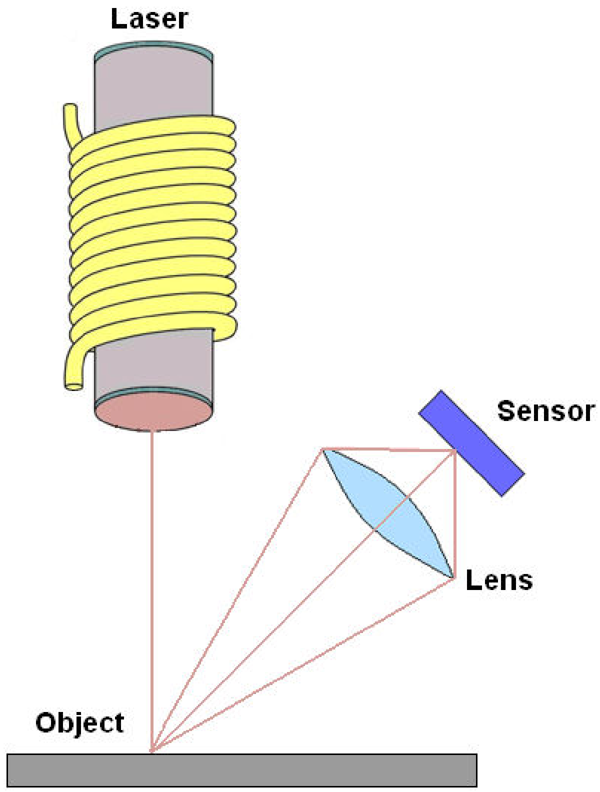

Fig. 5 Triangulation method [3], [11]

B. *Phase shift method*

Phase shift method using time of flight and wavelength of the laser ray for determining distance of laser dot. Technology is based on phase difference between beam send and the beam received (Fig. 6).

In the phase shift technology is used the sinus wave which is transmitted on measured object. After reflection from the object of interest the system evaluated the phase shift and time of flight between waves (send wave, received wave). Time value is multiplied by the light speed for distance value, but the distance value from the time value is doubled that is depend on the time of flight from source of laser beam to object and the time of flight from object back to the sensor. For correct distance is required dividing by two [4][5].

V. Laser scanner principle

Laser scanners using for determining distance the phase shift principle and decoder technology for rotating mirror. The principle of a 2D scanner is in the Fig. 8. The laser ray visualization by an arrow is a deflected rotating mirror. In this way, the 2D scanner can provide points lying in the plane of the semicircular ray deflection. The outline of the target object is obtained as a sequence of received pulses. The 3D scan of the surroundings is obtained when the scanner plane rotates at regular intervals around the axis passing through the centre of gravity of the scanner. [6]

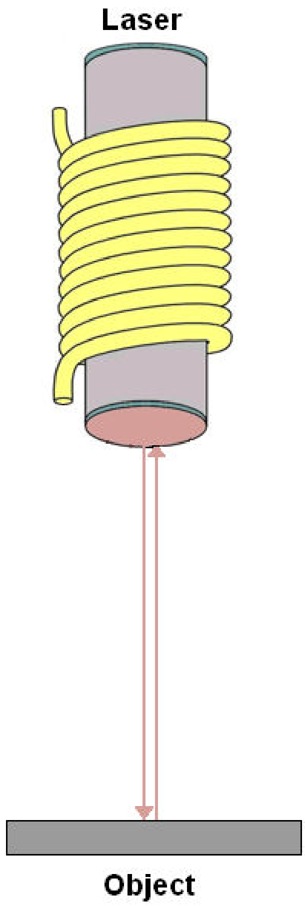

Fig. 6 Phase shift method [3]

VI. Description of laser scanner SICK LMS 400

Laser scanners use a measuring of a phase shift. The propagation time of the used light and the wavelength results in the phase shift between the ray sent and the ray received. This phase difference is converted to a frequency. The system determines the distance of the object from the zero point based on this frequency. This type of measuring method and decoder for a rotation mirror measurement creates wobbled laser ray. Scanners with the phase shift are used for shorter distance. Minimal and maximal measured range starts from 0.7 m to 3 m, but between 0 m and 0,7 m is a problematic range with distance anomaly. Measurement of the maximum angle is set in the range of 70° but the construction have a stable range angle between 55° - 125°.

The LMS 400 uses the 650 nm wavelength (visible ray). [7][8]

The system sending distance data throw the interface like answer on requirement which is created by PC. SICK LMS 400 can use two types of measured data:

- Distance values
- Remission values

Fig. 7 Laser scanner SICK LMS 400 [8]

The scanner has a wide range of configuration in frequency but data quality depended on resolution and scanning speed. If laser scanner working in problematic environment the changing values of frequency improved the output values. When the scanner is prepared for superior system on position input device is required modifying sensing properties.

The “Measured Value Quality” information expresses how much computation time is available to the system for the calculation of the measured distance value. The quality factor has range starts at 1 (worst quality) to 10 (best quality). Producer company SICK recommends measure setting on minimal quality factor 7, no less.

VII. Measurement accuracy SICK LMS 400

The SICK LMS 400 is a distance measurement system, and like every distance measurement system has a problem with distortion information, which shows us the quality of the measured value or the scan. Measuring distance with this system is influenced by 3 typically measurement errors.

- systematic measuring error
- remission
- filtering of measured values

A. Systematic measuring error

Typical systematic measuring error is based on same source of error. Finding this errors depend on multi repeat measurement. Measurement values are most of time higher or lower than real values. The errors could be eliminated only by better measuring procedure and by independent measurement methods. [8]

Types of systematic errors:

- method errors
- evaluation of method errors
- errors of determination measurement conditions
- errors of measuring instrument

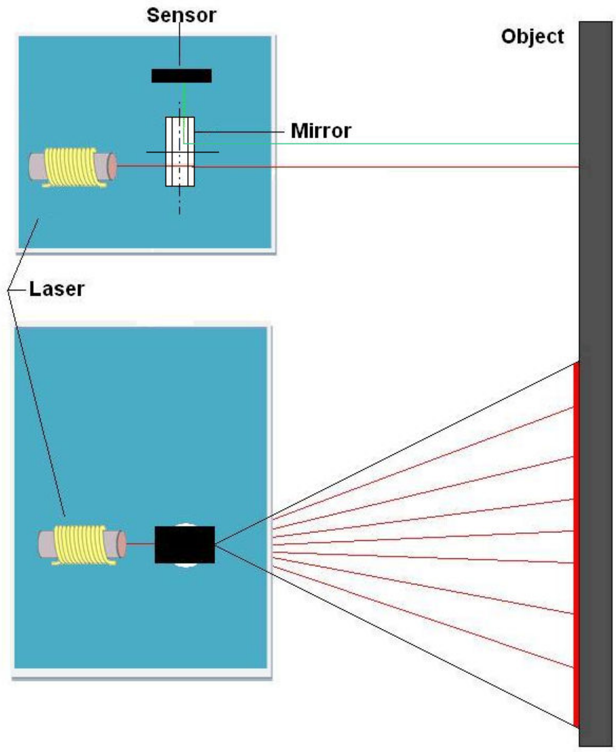

Fig. 8 Diagram of laser scanner SICK LMS 400

Laser scanner LMS 400 has a systematic measuring error with ± 4 mm. The error definition is for every measured dot with remission between 10 – 100% and with room temperature.

Table 1 shows typical and maximum measuring errors for measured value quality 7. The values were measured in room temperature and maximum external light of 2000 Lux.

Table 1 Statistical measuring error LMS400

Remission [%]	Distance [mm]	Statistical error (1 sigma)	
		Typical [mm]	Maximum [mm]
100/200	700 to 3000	3	
78	700 to 3000	3	
	1000 to 2500		5
	<1000 or > 2500		7
40	700 to 3000	4	
	1000 to 2500		8
	<1000 or > 2500		9
10	700 to 3000	9	
	1000 to 2500		12
	<1000 or > 2500		15
6.5	700 to 3000	10	

B. Remission

Every material has possibility to reflect light back. The name for this ability is remission. The remission values for each material and types of surfaces are different. Table 2 shows a few typical remission values.

Glossy objects have different remission values at the same distance with varying angle of incidence. The maximum remission of glossy objects is achieved on perpendicular incidence of the beam [7], [8].

Matt and dull surfaces have a diffuse remission and therefore have relatively similar remission values independent of the distance from the zero point with a constant angle of incidence [7].

Table 2 Materials remission [8]

Material	Remission value [%]
Photo cardboard (black, matt) 10%	10
Cardboard (grey) 20%	20
Wood (rough pine, dirty) 40%	40
PVC (grey) 50%	50
Paper (white, matt) 80%	80
Aluminium (black anodised) 110…150%	110 - 150
Steel (stainless, glossy) 120…150%	120 - 150
Steel (very glossy)	140 - 200

C. Filtering of measured values

The laser scanner SICK LMS 400 has four digital filters for processing optimal values which are obtained from distance measurement. With combination of all digital filters becomes possibility to eliminate errors of every measuring. If several filters are active, then the filters act one after the other on the result of the previous filter. The processing in this case follows the following sequence [7], [8]:

- edge filter
- median filter
- range filter
- mean filter.

The filters are applied and used inside the laser scanner on the distance values. After processing distance values through the filters becomes the correct distance value which appears on output of laser scanner. Every time when the filter function is active there is a change of measured values. It is not possible to convert filtered output values back to the original measured values.

1) Edge filter

The edge filter prevents extreme distance values at edges that result from it and it is not possible to determine a distance value for the previous or next point. It means that the next measured point is too dark or is outside of the 3 meters measuring range. With the edge filter enabled, the LMS400 also sets a distance value to 0 at each edge [8], [12].

2) Mean filter

The mean filter smoothes distance value. Evaluation scans from the mean filter are calculated by the arithmetic average. It is necessary to pre-set the number of scans [8].

3) Median filter

The median filter reduces individual extreme values over the entire measurement line by outputting the median for each measurement point from a 3 × 3 matrix (Chart 1). The matrix comprises nine measured values: distance values for the point and its neighbouring points, as well as distance values determined for points in the previous and subsequent scan [8], [13].

Table 3 Filtering the measured values with the Median filter (Non-filtered scans values) [8]

	Angular(distance from 1 to n)									
	1	2	3	4	5	6	7	8	9	…
Scan 1	0	0	850	1100	1150	1030	1050	1100	0	0
Scan 2	0	0	950	1200	1250	1130	1150	1200	0	0
Scan 3	0	0	850	1150	1200	1080	1100	1150	0	0

Table 4 Distance values from median filter [8]

These nine measured values are sorted in ascending order, the fifth highest measured value is output as the measured value [8].

	Angular(distance from 1 to n)									
	1	2	3	4	5	6	7	8	9	…
1 - lowest value	immeasurable	0	0	850	1030	1030	1030	0	0	0
2		0	0	850	1080	1050	1050	0	0	0
3		0	0	950	1100	1080	1080	0	0	0
4		0	850	1100	1130	1100	1100	1050	0	0
5 - median		0	850	1150	1150	1130	1100	1100	0	0
6		0	950	1200	1200	1150	1130	1100	0	0
7		850	1100	1200	1200	1150	1150	1150	1100	..
8		850	1150	1200	1200	1200	1150	1150	1200	..
9 – highest value		950	1200	1250	1250	1250	1200	1200	1150	..

Median filter usage terms:

- The edges of objects are, however, kept.
- It is not possible to determine a median for the first and last angular step in a scan. The distance value 0 is always output.
- It is not possible to send any measured values for the first scan after confirmation of the measured value message (scan counter = 1).
- Completion of the third scan follows; the median for the second scan is calculated and sent. Therefore an offset in time of one scan is obvious. However, the correct value for the scan (= 2) is always output in the scan counter such that e.g. the I/O status can be assigned to the scan.

If median and mean filters are used together, it is not necessary to take any additional offset time for the median filter into account. This is due to the formation of the mean filter, which takes longer time than determination of the median, and the median filter, which can be formed while the mean is determined.

4) Range filter

The range filter reduces the number of valid measured values only by outputting distance values that are within a specific distance range. For other measured values, the filter delivers the distance value 0 and the remission value 0 as the result.

Table 5 Measured values with a range filter from 1000 to 2000 mm [8]

	Angular(distance from 1 to n)									
Angular	1	2	3	4	5	6	7	8	9	...
Unfiltered Scan 1	890	950	1500	1450	1330	1450	1600	1800	2050	2150
Filtered scan 1	0	0	1500	1450	1330	1450	1600	1800	0	0

VIII. COMMUNICATION

Data transmission is provided only under the conditions that the device is connected to the computer and the communication software is running. The main control software creates a data stream between the LMS 400, and the function of this main software is supervising. The transmission is linked to the "Asking protocol" about the preparation for the connection and data exchange [8].

The communication has three steps:

- First step – enquiry from the PC to the SICK LMS 400 about the readiness to make the data exchange.
- Second step – the main control software is waiting for receipt of the confirmation from the LMS 400, or receipt of the error message.
- Third step – without error message from the second step, the program receives distance values in the continuous stream.

The error messages from the laser scanner show only the number of problems, but those are necessary to be found in the "Errors table" to find the solution. Every message has a framework and data. Different types of messages are used as data.

IX. THE MAIN CONTROL SOFTWARE

The system SICK LMS 400 is mostly used as a feedback in the production line. The range of the laser scanner system is mostly unfulfilled, because the laser scanner from the production of the SICK Company has the 3 m measurement distance and the 70° angle range. In the production line application, this type of device is more than normal production need, but with full cover only for production areas in places where is not necessary creating relevant measurement (Fig. 11) [10].

The typical measuring is related to the complete filling of boxes or crates. LMS 400 provide checking the area with condition: "full or empty places" (Fig. 8). For example is used the crate with bottles. The crates are transported through the scan line of the LMS400 for this check. When the crates move through the measurement area, among other aspects the tops on the bottles are scanned. If one or more bottles are missing, the setting border is not reached; the crate is detected as not full and system returning the box on other way of production line for filling [8]. But other parts of active area are still not used at all. Segmentation of area on parts production and secure create the active area full utilizable and safer like Fig. 12 shows.

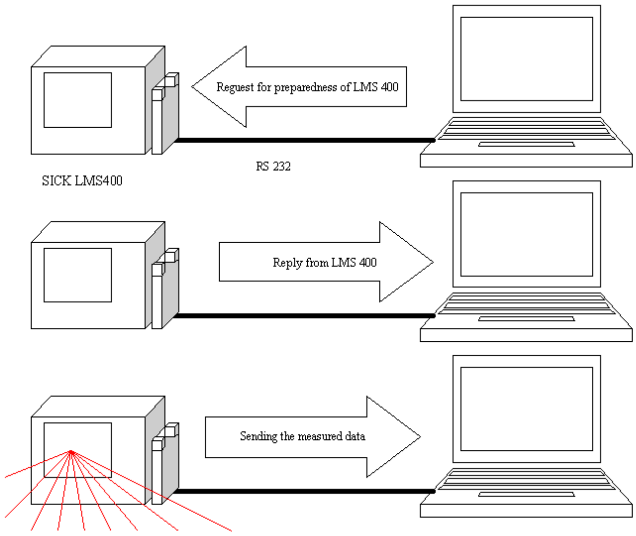

Fig. 9 Communication between LMS 400 and PC [7][8]

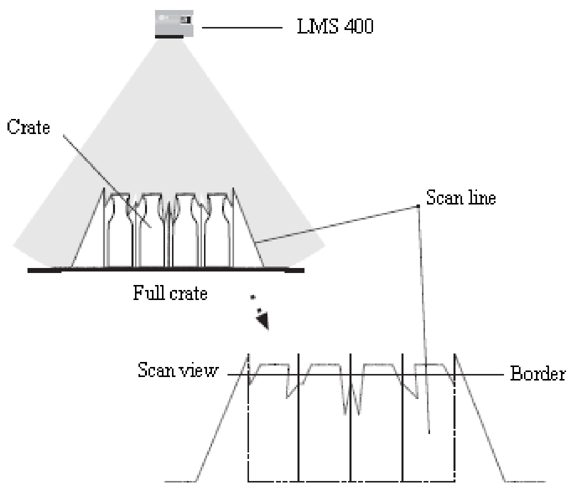

Fig. 10 Example for the evaluation of the columns [8]

The software for the SICK LMS 400 is made in the C# and the entire communication is incorporated to the software solution. In the start-up menu, by selecting the RS232 port a link between the computer and the laser scanner with a handshake is created. Received values from the SICK LMS 400 are displayed in the text box. Values are stored in hexadecimal distance values, followed by the computational algorithms processing. Filtered values are converted into the middle part of the software solution environment. After that, a graph of the measured distance values is created [10]. (Fig. 13)

Values from the graph support only visual orientation for operators. The main advantage of this software is input values (borders) setup (Fig. 12).

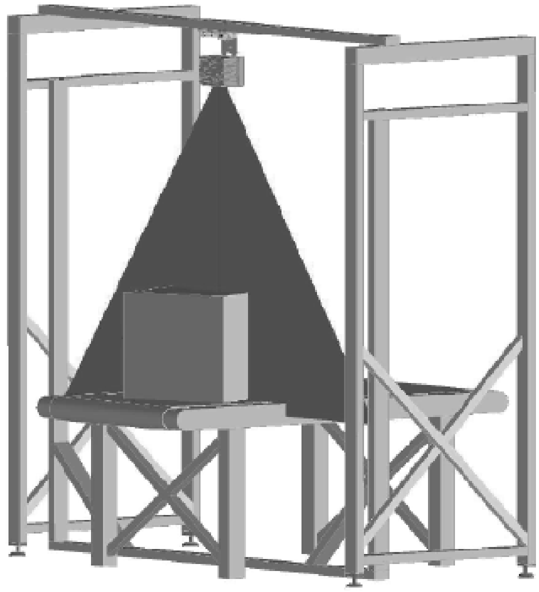

Fig. 11 Product line application without segmentation of production and safety area [8]

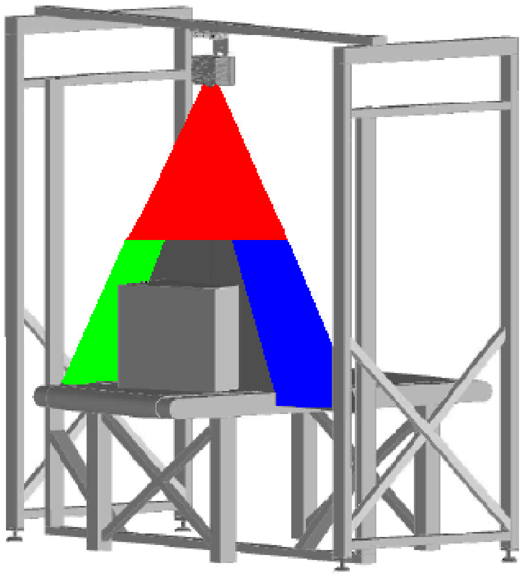

Fig. 12Product line application with segmentation of production and safety area [8]

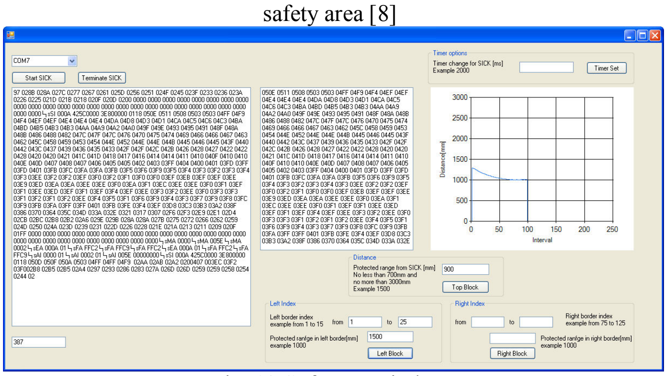

Fig. 13 Software window

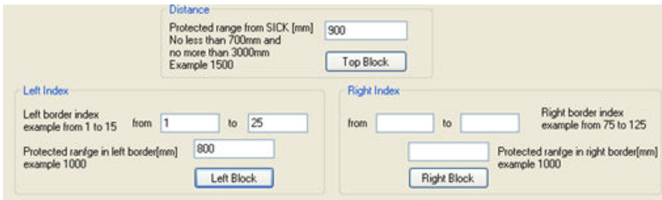

Fig. 14 Part of the window used for segmentation

Defining border inputs the software is able to decide on the relevance of the measurement, so that it designates which places are safety and which are the production place. The system calibration has to be made in the place where the system SICK LMS 400 is located. The main decision is to specify the products place, because this "active range" derives other safety places from this part of active range is derivative the other safety places. When the values of the safety place are out of the set range, the software creates an exception condition with possibility of dangerous on the production line. The human monitoring is not necessary in case of this application until the exception condition appears [10].

X. Conclusion

The main purpose for creation of this specific segmentation software with security elements is to define distance of the object in the active environment. The relevant aspects of measuring with the systematic calculations create a new combination of an industrial production and safety procedures supported by a single device. As a result, the intelligent measurement system for the production with safety features against the endangering of life and health of the work force is proposed.

Acknowledgment

This paper is supported by the Internal Grant Agency at Tomas Bata University in Zlin, project No. IGA/47/FAI/10/D and by the European Regional Development Fund under the project CEBIA-Tech No. CZ.1.05/2.1.00/03.0089.

References

[1] Essortment : Your source for knowledge [online]. 2010 [cit. 2011-06 13]. A Technical History Of The Laser. Dostupné z WWW: <www.essortment.com>.
[2] NIEMZ, Markolf H.. Laser-tissue interactions : fundamentals and applications. Berlin : Springer-Verlag, 2004. 305 s. ISBN 3-540-40553-4.
[3] PREMASUNDARAN, Dr. M. ; DAWAR, Dr. A.L. WORLD OF LASERS [online]. 2000 [cit. 2011-06-13]. Principles of laser action. Dostupné z WWW: <www.worldoflasers.com>.
[4] EMMON, Tim; BIDDISCOMBE, Paul. Adjustment of laser scanning for surveyors: the special needs for increased productivity. News from Surveying library.2006, 5, s. 13 - 15. ISSN 1566-9076.
[5] Brian Curless (November 2000). "From Range Scans to 3D Models". ACM SIGGRAPH Computer Graphics 33 (4): 38–41. doi:10.1145/345370.345399NIEMZ, Markolf H.. Laser-tissue interactions : fundamentals and applications. Berlín : Springer-Verlag,
[6] S. Poujouly and B. Journet. Laser range-finding by phase-shift measurement: moving toward smart systems. In K. G. Harding, J. W. V. Miller, and B. G. Batchelor, editors, Machine Vision and Three-Dimensional Imaging Systems for Inspection and

Metrology, volume 4189 of Proc. SPIE, pages 152–160. SPIE, 2001.

[7] LMS200/211/221/291 Laser Measurement Systems : Measurably more cost-effective [online]. Waldkirch : [s.n.], 2006 [cit. 2010-05-04]. Dostupné z WWW: <www.sick.com>. ISBN 8008970/QI72/2006-12.

[8] LMS400 Laser Measurement System : Pole position for robotics and material handling. Waldkirch : [s.n.], 2005. 116 s. from WWW: <www.sick.com>. 8010421/QB85/2006-10-31.

[9] LMS400 Laser Measurement System : Level Control. Waldkirch : [s.n.], 2005. 34 s. from WWW: <www.sick.com>. 8011813/QB85/2006-10-31.

[10] NECKAR, Pavel; ADAMEK, Milan; NECESAL, Lubos. Segmentation of Production and Security Areas with SICK LMS 400 . WSEAS/Europment International Conferences. 2011, 13, s. 145 - 147. ISBN 978-1-61804-004-6.

[11] Boehnke, K.: Fast object localization with real time 3d laser range sensor simula-tion. WSEAS Transactions on Electronics: Real time applications with 3D sensors 5(3) (2008) 83-92

[12] NOMURA, Atsushi, et al. Edge Detection Algorithm Inspired by Pattern Formation Processes of Reaction-Diffusion Systems. Naun : INTERNATIONAL JOURNAL OF CIRCUITS, SYSTEMS AND SIGNAL PROCESSING. 2011, 5, p. 105-115. online <www.naun.org>. ISSN 998-4464.

[13] JIMENEZ-FERNANDEZ, Victor, et al. Digital Circuit Architecture for a Median Filter of Grayscale Images Based on Sorting Network. Naun : INTERNATIONAL JOURNAL OF CIRCUITS, SYSTEMS AND SIGNAL PROCESSING. 2011, 5, p. 297 - 304. online: <www.naun.org>. ISSN 998-4464.