ISSN 1407-6160

TRANSPORT AND TELECOMMUNICATION

Volume 15. No 3

2014

Transporta un sakaru institūts
(Transport and Telecommunication Institute)

Transport and Telecommunication

Volume 15, No. 3 - 2014

ISSN 1407-6160
ISSN 1407-6179
(On-line: www.tsi.lv)

Riga – 2014

05
T82

All articles are reviewed.
Articles can be presented in the journal in English.

EDITORIAL CORRESPONDENCE

Transporta un sakaru institūts (Transport and Telecommunication Institute)
Lomonosova iela 1, LV-1019, Riga, Latvia.
Phone: (+371) 67100594. Fax: (+371) 67100535
E-mail: transport.journal@tsi.lv, http://www.tsi.lv

TRANSPORT and TELECOMMUNICATION, 2014, vol. 15, no. 3
ISSN 1407-6160
The journal of Transport and Telecommunication Institute (Riga, Latvia).
The journal is being published since 2000.

Abstracting & Indexing:
Celdes, CNKI Scholar (China National Knowledge Infrastructure), CNPIEC, DOAJ, EBSCO Discovery Service, Elsevier – SCOPUS, Google Scholar, Inspec, J-Gate, Journal TOCs, Naviga (Softweco), Primo Central (ExLibris), ProQuest – Advanced Technologies Database with Aerospace, ProQuest – Engineering Journals, ProQuest – Illustrata: Technology, ProQuest –SciTech Journals, ProQuest – Technology Journals, Referativnyi Zhurnal (VINITI), SCImago (SJR), Summon (Serials Solutions/ProQuest), TDOne (TDNet), TEMA Technik und Management, Transportation Research Board, Ulrich's Periodicals Directory/ulrichsweb, De Gruyter Open, WorldCat (OCLC), Cabell`s Directory

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Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/ttj-2014-0015

THE ANALYTICAL DESCRIPTION OF REGULAR LDPC CODES CORRECTING ABILITY

Leonid Uryvsky[1], Serhii Osypchuk[2]

Institute of Telecommunication Systems
National Technical University of Ukraine "Kyiv Polytechnic Institute"
Kyiv, Industrialny Street, 2, Ukraine, 03057
E-mails: [1]leonid_uic@ukr.net; [2]serhii.osypchuk@ieee.org

The analytical description of regular LDPC (Low-Density Parity Check) codes correcting ability has been investigated. The statistical dependencies for the maximum number of corrected bits per the code word as a function of LDPC code word length and code rate are given based on multiple experimental analyses of LDPC check matrices. The analytical expressions are proposed for the cases of linear, exponential and polynomial approximations of given results. The most exact analytical formula is proved by criterion of the minimum divergence between the experimental and theoretical results.

Keywords: LDPC code, correcting ability, analytical description

1. Introduction

The main task of telecommunication (TC) is the *information transmission* from a source (S) to a recipient (R). Withal it is implied that there is *significant distance* between S and R, and this means a necessity of message transformation to the appropriate form for transmission through a communication channel. As known, communication channel can be built based on copper wire, optical fibre, metal waveguide and wireless environment.

One of the most widely used environments for signal transmission in TC systems is *a wireless environment*. It is used for communication for both very big distances (satellite, tropospheric, radio relay communication) and small distances (mobile cellular communication, wireless local networks). At the same time, the *quality criterion* for wireless digital TC systems is *the bit error probability* (BER) of received bits p_{bit} on the receiver side, i.e. *information reliability*. The requirements for BER can stand in limits $10^{-5}\ldots10^{-9}$. Real BER value in practice depends on a number of TC system parameters and parameters of propagation medium.

One of the methods to *increase the reliability* for information transmission is an *anti noise coding* that allows improving the information transmission reliability at the expense of energy, frequency and time resources of a communication channel. This article is devoted to one of anti noise coding methods, namely LDPC (Low-Density Parity Check), which is one of the most effective anti noise codes on a number of parameters among other known anti noise coding methods.

LDPC codes are linear block codes with cyclic decoding procedures (Gallager, 1963). Due to specific coding and decoding procedures of LDPC codes, the exact analytical model does not exist for determination of their correcting ability t, bits, as function of code word length n, bits, and code rate, R. As known, code rate R is the ratio of information bits number k in a code word to a total number of all the bits n in a code word: information k and redundant $r = n - k$. Other known anti noise codes such as BCH (Bose–Chaudhuri–Hocquenguem) codes have the exact analytical model for determination their correcting ability t based on other known code parameters n, R (Uryvsky, Prokopenko and Pieshkin, 2011). Thus, the task exists for determination the correcting ability of t, bits as function of code word length n and code rate R based on the analysis of multiple experiments on the LDPC code check matrices and detection their properties. It's expected that obtained dependency $t = f(n, R)$ allows us to indicate the number of corrected bits per one LDPC code word without searching the check matrix H with some best parameters. Many works in the LDPC codes area (MacKay and Neal, 1996; Luby, Mitzenmacher, Shokrollahi and Spielman, 1998; Ping and Phamdo, 1999; Honary, Kou and Lin, 2004; Ohtsuki, 2007) are devoted to a study of LDPC codes correcting ability, but an attempt to generalize results into the analytical expression is not made. The results presented in this article are development of work (Osypchuk, 2014) and are devoted *to the search of analytical description* for regular LDPC codes correcting abilities: $t = f(n, R)$.

2. Task Statement

Generation of regular LDPC codes is defined by consecutive procedure.

Regular LDPC code with code word length n is formed based on check matrix H, which is characterized by constant number of one's W_r in every line and constant number of one's W_c in every column (Gallager, 1963). Check matrix H has low density of one's (the density of one's is considered as low if relative part of one's is less than 50% of all elements (ones and zeros) in check matrix).

Correcting ability t of LDPC code depends on check matrix parameters n, W_r, W_c. The position of ones in check matrix H is formed based on casual columns permutations in basic submatrix that contains only single one in each column. Thus, a regular LDPC code rate R is determined by a formula:

$$R = \frac{n - \left(n \cdot \frac{W_c}{W_r} - \left(W_c - 1 \right) \right)}{n} = 1 - \frac{W_c}{W_r} + \frac{W_c - 1}{n}. \tag{1}$$

At the same time, LDPC code check matrices H with identical dimensions and number of ones can generate codes with different code distance d and correcting ability t. Thereby, there is a problem of finding the best LDPC code check matrix with specific parameters set n, W_r, W_c by criterion of the maximum correcting ability $t_{\max} \le \left(d_{\max} - 2 \right) / 2$.

The LDPC code check matrix is presented as:

$$H = \begin{bmatrix} H_1 \\ \hline \pi_1 \left(H_1 \right) \\ \hline \cdots \\ \hline \pi_{W_C - 1} \left(H_1 \right) \end{bmatrix}, \tag{2}$$

where H_1 is a basic submatrix, $\pi_i(H_1)$ are submatrices given by casual columns permutation of basic submatrix H_1, $i = 1,2, \ldots, W_c - 1$.

LDPC code check matrix N can be led to the view (3) by method of Gaussian exclusion:

$$H = \left[A \mid I_{n-k} \right], \tag{3}$$

where A is fixed matrix with dimensions $\left(\left(n - k \right) \times k \right)$ that include zeros and ones and is not sparse; matrix I_{n-k} – identity matrix with dimensions $\left(n - k \right) \times \left(n - k \right)$.

The matrix G for generating the code words:

$$G = \left[I_k \mid -A^T \right], \tag{4}$$

where I_k – identity matrix with dimensions $k \times k$; A^T – transposed matrix from a matrix A.

If the check matrix H is presented in the form (3), then generation matrix G (4) can be deduced from check matrix N by transformations. G matrix also is called as generating matrix as far as code words are all possible linear combinations of rows in matrix G. Matrices N and G are connected by expression (MacWilliams and Sloane, 1977):

$$GH^T = 0, \; HG^T = 0. \tag{5}$$

Forming of a code word is performed based on multiplication and addition operations on information bits and lines of generation matrix G. Decoding a code word can be performed by numerous different iterative methods.

The task consists in search of the analytical dependence for LDPC code correcting ability t as a function of the code word length n and the code rate R based on carrying out multiple numerical experiments with analysis the LDPC code check matrices H.

Input information: randomly generated check matrices H with parameters: n, W_r, W_c.

Intermediate information: correcting ability t of each check matrix H.

Output information: the experimental and analytical dependencies of maximal LDPC code correcting ability t as a function of the code word length n and the code rate R:

$$t = f(n, R). \tag{6}$$

3. Research of the LPDC Code Analytical Description

Thousands of random check matrices H are generated with specific parameters sets: n, W_r, W_c. *The best characteristics* of generated LDPC code check matrices are presented in the coordinates (6), where d is LDPC code distance: $d = 2t + 2$ (Fig. 1). *The best characteristic* means a maximum number of corrected errors t in a code word with length n bits. In this work, the check matrices for code word length n are examined: 50, 100, 200, 500, 1000 bits. The gray solid line on Figure 1 designates the Plotkin limit that shows the border for existence of block codes in coordinates (6) (MacWilliams and Sloane, 1977). Anti-noise block code does not exist above the Plotkin limit, and if code is closer to this limit, then code is better by criteria of high code rate value and the maximum number of corrected bit errors per a code word. The Plotkin limit on Figure 1 is applicable for code word length with hundreds and thousands bits per a code word.

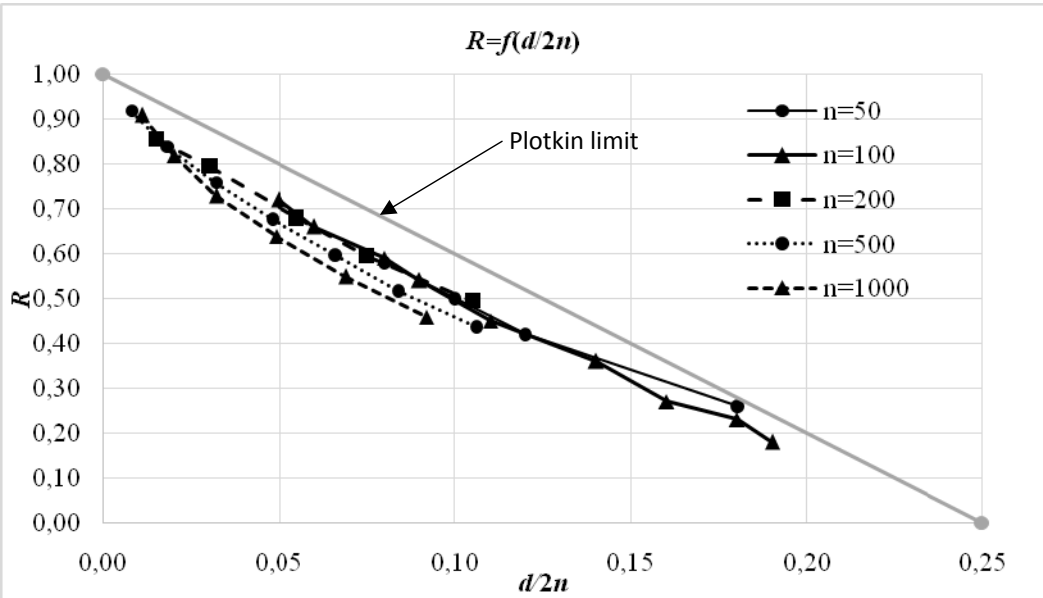


Figure 1. Experimentally given dependencies for LDPC codes: $R = f\left(\frac{d}{2n}\right)$

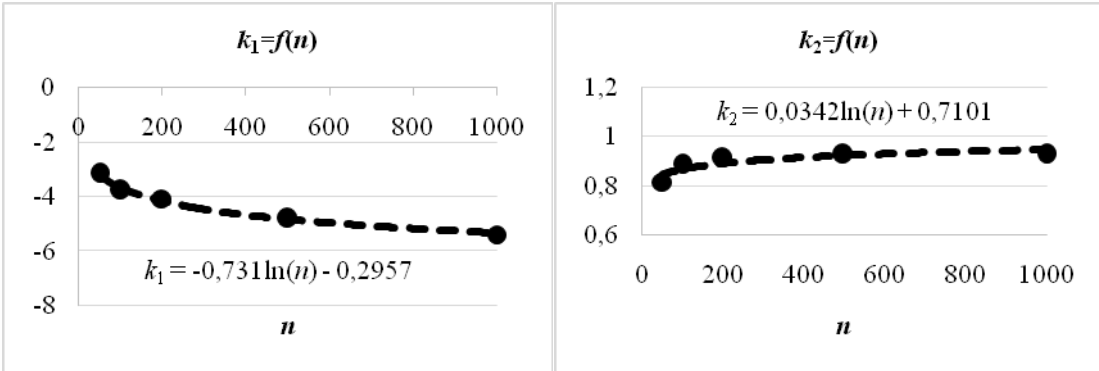
As it is shown above, the code distance for LDPC code is $d = 2t + 2$. If divide both parts on $2n$, then we receive: $\frac{d}{2n} = \frac{2t+2}{2n} = \frac{t+1}{n}$, from where $R = f\left((t+1)/n\right)$ and $t = f(n, R)$. The dependency $t = f(n, R)$ for regular LDPC codes with code word length n = 50…1000 bits is studied below.

3.1. Linear approximation

It is possible to match a linear approximation for every experimental line on the Figure 1 $R = f(d/2n)$ for different n values: $R = f\left((t+1)/n\right)$; $y = k_1 x + k_2$, where k_1, k_2 – factors of linear function, $x = (t+1)/n$ – argument. The factors of linear approximation are presented in Table 1 for every studied code length value n.

Table 1. Factors of linear approximation

n	k_1	k_2
50	-3.1429	0.8171
100	-3.7582	0.8871
200	-4.0713	0.912
500	-4.8146	0.927
1000	-5.3911	0.9293



a b

Figure 2. Approximation of factors k_1 (a) and k_2 (b) for linear function $R = k_1 \cdot \frac{t+1}{n} + k_2$

Thus,

$$R = f\left(\frac{t+1}{n}\right) = k_1 \cdot \frac{t+1}{n} + k_2,$$
$$t = \frac{n\left(R - k_2\right)}{k_1} - 1. \tag{7}$$

As it is shown on Figure 2,

$$k_1 = -0,731 \ln n - 0,2957,$$
$$k_2 = 0,0342 \ln n + 0,7101. \tag{8}$$

The expression for linear approximation $t = f\left(n, R\right)$ becomes as:

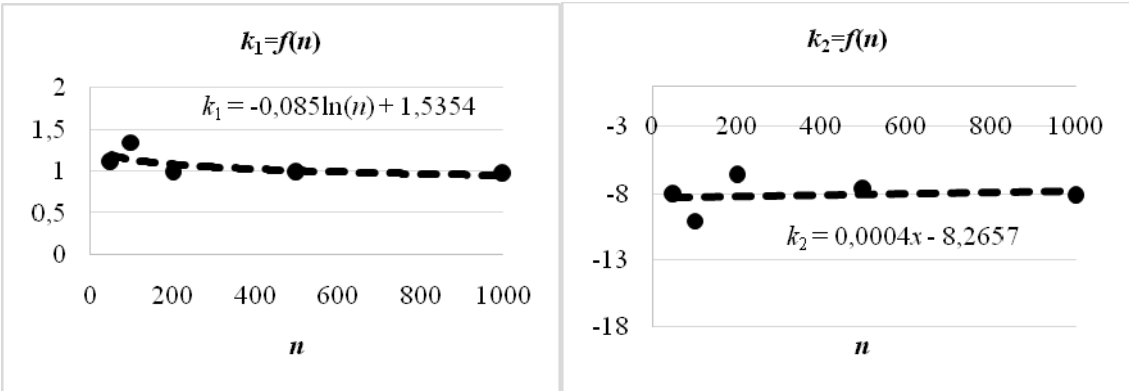
$$t = \left\lfloor \frac{n\left(R - 0,0342 \ln n - 0,7101\right)}{-0,731 \ln n - 0,2957} - 1 \right\rfloor. \tag{9}$$

3.2. Exponential approximation

Similarly, every line presented on Figure 1 $R = f\left(d / 2n\right)$ for different code word lengths n can be described by exponential approximation $R = f\left(\left(t+1\right)/n\right)$: $y = k_1 e^{k_2 x}$, where k_1, k_2 – factors of exponential approximation, $x = \left(t+1\right)/n$ – argument. The factors of exponential approximation are presented in Table 2 for every studied code length value n.

Table 2. Factors of functions of exponential approximation

n	k_1	k_2
50	1.1106	-8.066
100	1.3427	-10.05
200	0.9831	-6.583
500	0.9842	-7.647
1000	0.9676	-8.174



a b

Figure 3. Approximation of factors k_1 (a) and k_2 (b) for exponential function $R = k_1 \exp\left(k_2 \frac{t+1}{n}\right)$

Thus,

$$R = f\left(\frac{t+1}{n}\right) = k_1 e^{k_2 \frac{t+1}{n}},$$
$$t = \frac{n}{k_2} \ln \frac{R}{k_1} - 1. \tag{10}$$

As it is shown on Figure 3,

$$k_1 = -0,085 \ln n + 1,5354,$$
$$k_2 = 0,0004n - 8,2657. \tag{11}$$

The expression for exponential approximation $t = f(n, R)$ becomes as:

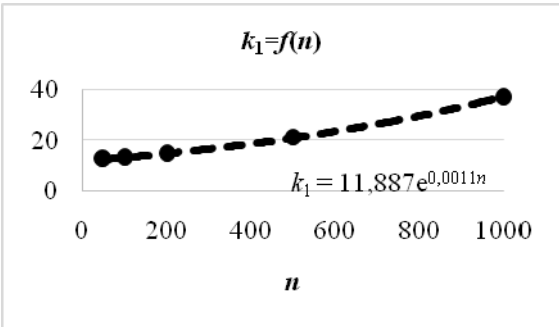
$$t = \left\lfloor \frac{n}{0,0004n - 8,2657} \ln \frac{R}{1,5354 - 0,085 \ln n} - 1 \right\rfloor. \tag{12}$$

3.3. Polynomial approximation

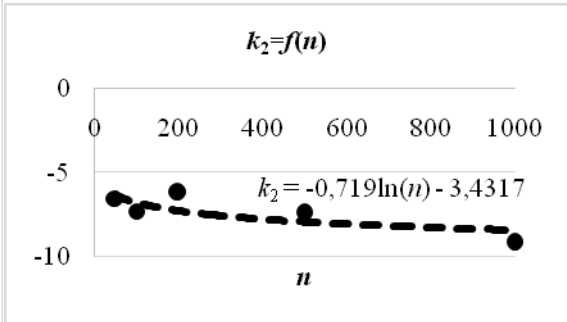
Every line $R = f(d / 2n)$ that is presented on Figure 1 for different code word lengths n can be described by polynomial approximation $R = f((t+1)/n)$: $y = k_1 x^2 + k_2 x + k_3$, where k_1, k_2, k_3 – factors of function, $x = (t+1)/n$ – argument. The factors of polynomial approximation are presented in the Table 3 for every studied code length value n.

Table 3. Factors of functions of polynomial approximation

n	k_1	k_2	k_3
50	12.707	-6.5193	1.0215
100	13.199	-7.2674	1.0983
200	14.746	-6.1859	0.98
500	21.377	-7.4009	0.9861
1000	36.906	-9.1433	0.9948



a



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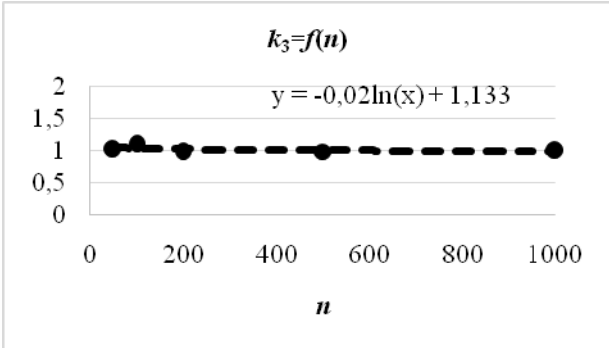

c

Figure 4. Approximation of factors k_1 (a), k_2 (b) and k_3 (c) for polynomial function $R = k_1\left(\frac{t+1}{n}\right)^2 + k_2\left(\frac{t+1}{n}\right) + k_3$

Thus,

$$R = k_1\left(\frac{t+1}{n}\right)^2 + k_2\left(\frac{t+1}{n}\right) + k_3; \tag{13}$$

$$t = \left\lfloor \frac{-\left(2k_1 + nk_2\right) - \sqrt{\left(2k_1 + nk_2\right)^2 - 4k_1\left(k_1 + nk_2 + n^2k_3 - n^2R\right)}}{2k_1} \right\rfloor, \tag{14}$$

where

$$\begin{aligned} k_1 &= 11{,}887e^{0{,}0011n}; \\ k_2 &= -0{,}719\ln n - 3{,}4317; \\ k_3 &= -0{,}022\ln n + 1{,}1336. \end{aligned} \tag{15}$$

The comparison of LDPC code correcting ability values t that is *calculated based on the deduced analytical expressions* (linear (9), exponential (12) and polynomial (14)) and *experimentally given values* of LDPC code correcting ability values t (Fig. 1) based on simulation modelling and check matrices analysis, shows the following results:

- The analytical expression $t = f(n, R)$ (12) for exponential approximation the most precisely describes the dependence $t = f(n, R)$ from the three deduced approximations (9), (12), (14). The deviation from experimental values of LDPC code correcting ability stands in bounds $\Delta t_{\text{dev}} = \left| t_{\text{experim}} - t_{\text{approx}} \right| = 0 \ldots 2$ bits, and just in small number of point it reaches $\Delta t_{\text{dev}} = 3$ bits;
- The analytical expression $t = f(n, R)$ (14) for polynomial approximation also enough precisely describes the dependence $t = f(n, R)$ and $\Delta t_{\text{dev}} = \left| t_{\text{experim}} - t_{\text{approx}} \right| = 0 \ldots 3$ bits, but in separate individual points the deviation of an analytically given value reaches $\Delta t_{\text{dev}} = 3 \ldots 6$ bits;
- The analytical expression $t = f(n, R)$ (9) for linear approximation the least precisely matches with experimental results by criterion of compliance the calculated values with expression (9) and experimentally given values (Fig. 1). In some cases the deviation $\Delta t_{\text{dev}} = \left| t_{\text{experim}} - t_{\text{approx}} \right|$ reaches up to 10 bits, mostly when code rate R tend closely to 1. This is an expected result because of obviously nonlinear experimental characteristic $R = f(d / 2n)$ (Fig. 1).

The most precise analytical expression $t = f(n, R)$ (12) is plotted on Figure 5 for code lengths 200, 500 and 1000 bits.

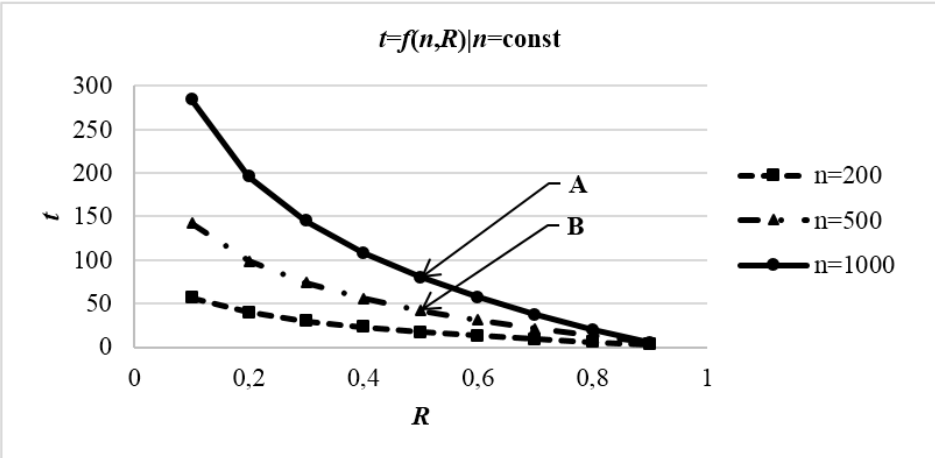

Figure 5. The exponential approximation $t = f(n, R)$ (12) for code lengths 200, 500 and 1000 bits

Two points are pointed out on Figure 5: A (n = 1000; R = 0,5; t = 80) and B (n = 500; R = 0,5; t = 42). These points show the exact number of maximal number of corrected errors t bits per a LDPC code word with length n bits and code rate R. The paper (Uryvsky, Prokopenko and Pieshkin, 2011) proposes the method for search the best anti-noise code to meet the required BER on the receiver side and keep maximal information efficiency. Following this method, if the next parameters are known: signal to noise rate in the receiver point, modulation technique, required BER on the receiver side, then the deduced formula (12) for LDPC code can be used for calculation the LDPC code parameters (n, R, t) that is able to correct specific number of errors and keep a maximal information efficiency.

4. Conclusion

Regular LDPC codes error correcting ability per a code word is explored based on the analysis of multiple randomly generated check matrices of LDPC code with code word length 50…1000 bits and code rates 0,15…0,92. The analytical expressions are investigated for regular LDPC code error correcting ability in this work based on the results given experimentally for LDPC codes error correcting ability *t*, bits.

Three analytical expressions for approximation the regular LDPC code error correcting ability are given: linear, exponential and polynomial.

The exponential approximation (12) is recommended as the most exact analytical expression for definition the LDPC codes error correcting ability following the results of comparison the experimental and analytically calculated number of bits that are corrected per a code word. The deviation of analytically calculated values and experimentally given values stands in bounds 0…2 bits for the exponential approximation, and only in rare cases, the deviation can be 3 bits.

The investigated exponential approximation can be used for a definition the exact LDPC code that is able to correct a specific set of bit errors per a code word, meet the required bit error rate on a receiver side, and reach maximal information efficiency.

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Transport and Telecommunication, 2014, volume 15, no. 3, 185–195
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/ttj-2014-0016

INTELLIGENT STORAGE SYSTEM BASED ON AUTOMATIC IDENTIFICATION

Peter Kolarovszki, Juraj Vaculík

University of Žilina, Faculty of Operation and Economics of Transport and Communications
Department of Communications
Univerzitná str. 1, 01026, Žilina, Slovakia
Phone: (+421) 908227492.
E-mail: peter.kolarovszki@fpedas.uniza.sk, juvac@fpedas.uniza.sk

This article describes RFID technology in conjunction with warehouse management systems. Article also deals with automatic identification and data capture technologies and each processes, which are used in warehouse management system. It describes processes from entering goods into production to identification of goods and also palletizing, storing, bin transferring and removing goods from warehouse. Article focuses on utilizing AMP middleware in WMS processes in Nowadays, the identification of goods in most warehouses is carried through barcodes. In this article we want to specify, how can be processes described above identified through RFID technology. All results are verified by measurement in our AIDC laboratory, which is located at the University of Žilina, and also in Laboratory of Automatic Identification Goods and Services located in GS1 Slovakia. The results of our research bring the new point of view and indicate the ways using of RFID technology in warehouse management system.

Keywords: RFID technology, warehouse, management, automatic identification, processes

Introduction

This article describes basic concepts of AIDC technologies related to radio frequency identification technology, its basic components and functions. Describe it in warehouses, storage options and their management through the Warehouse Management System. Further disclosed is a database management system MySQL database, middleware, programming language PHP and a text editor Notepad + +. The aim of this article is the design and partial realization of the warehouse management system using RFID technology, enabling recording arrival and departure of goods in the warehouse and premises and assigns each item. The paper describes the creation of configuration management warehouse in program AMP 2.

1. Automatic Identification and Data Capture Technologies

Identification (Thornton and Lanthem, 2006) processes that rely on AIDC technologies are significantly more reliable and less expensive than those that are not automated. The most common AIDC technology is bar code technology, which uses optical scanners to read labels. Most people have direct experience with bar codes because they have seen cashiers scan items at supermarkets and retail stores. Bar codes are an enormous improvement over ordinary text labels because personnel are no longer required to read numbers or letters on each label or manually enter data into an IT system, they just have to scan the label. The innovation of bar codes greatly improved the speed and accuracy of the identification process and facilitated better management of inventory and pricing when coupled with information systems. RFID represents a significant technological advancement in AIDC because it offers advantages that are not available in other AIDC systems such as barcodes. RFID offers these advantages because it relies on radio frequencies to transmit information rather than light, which is required for optical AIDC technologies. A type of AIDC technologies clearly describes Figure 1.

Like bar codes in an earlier time, RFID is the next revolution in AIDC technology. Most of the advantages of RFID are derived from the reliance on radio frequencies rather than light (as is required

in optical technology) to transmit information. This characteristic means that RFID communication can occur:

- Without optical line of sight, because radio waves can penetrate many opaque materials,
- At greater speeds, because many tags can be read quickly, whereas optical technology often requires time to manually reposition objects to make their bar codes visible, and
- Over greater distances, because many radio technologies can transmit and receive signals more effectively than optical technology under most operating conditions.

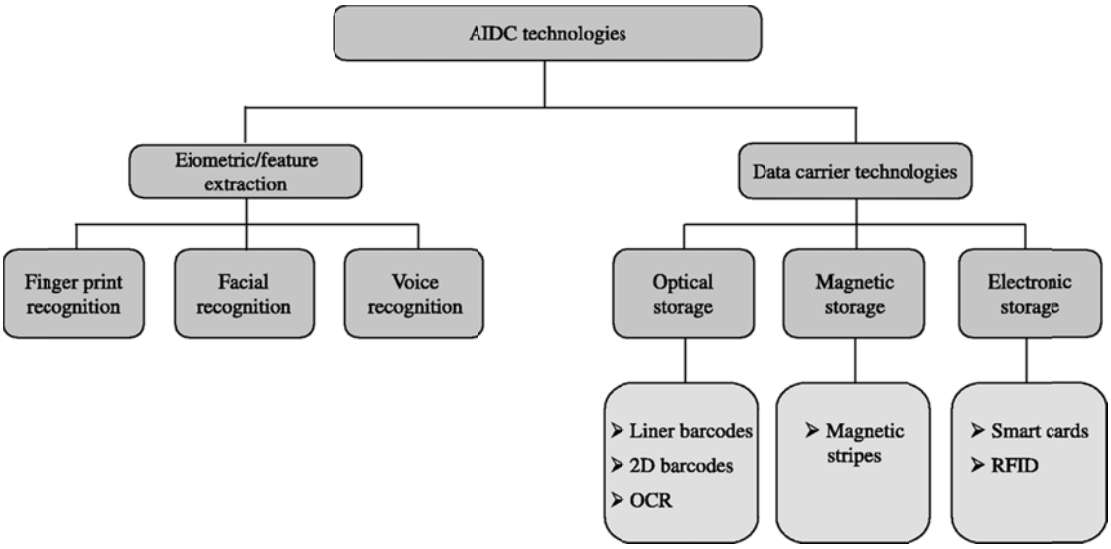

Figure 1. Type of AIDC technologies

1.1. Radio frequency identification

Radiofrequency identification (RFID) (Hunt, Puglia, 2007) is a form of automatic identification and data capture (AIDC) technology that uses electric or magnetic fields at radio frequencies to transmit information. An RFID system can be used to identify many types of objects, such as manufactured goods, animals, and people. Each object that needs to be identified has a small object known as an RFID tag affixed to it or embedded within it. The tag has a unique identifier and may optionally hold additional information about the object. Devices known as RFID interrogators (also called readers) wirelessly communicate with the tags to identify the item connected to each tag and possibly read or update additional information stored on the tag. This communication can occur without a line of sight and over greater distances than other AIDC technologies.

1.1.1. RFID system components

RFID systems can be very complex, and implementations vary greatly across industries and sectors. For purposes of discussion in this document, an RFID system is composed of up to three subsystems:

- An RF subsystem, which performs identification and related transactions using wireless communication,
- An enterprise subsystem, which contains computers running specialized software that can store, process, and analyze data acquired from RF subsystem transactions to make the data useful to a supported business process, and
- An inter-enterprise subsystem, which connects enterprise subsystems when information needs to be shared across geographic or organizational boundaries.

Every (Kebo, Staša, Beneš, Švub, 2013) RFID system contains an RF subsystem, and most RFID systems also contain an enterprise subsystem (Figure 2). An RFID systems supporting a supply chain is

a common example of an RFID system with an inter-enterprise. In a supply chain application, a tagged product is tracked throughout its life cycle, from manufacture to final purchase, and sometimes even afterwards (e.g., to support service agreements or specialized user applications).

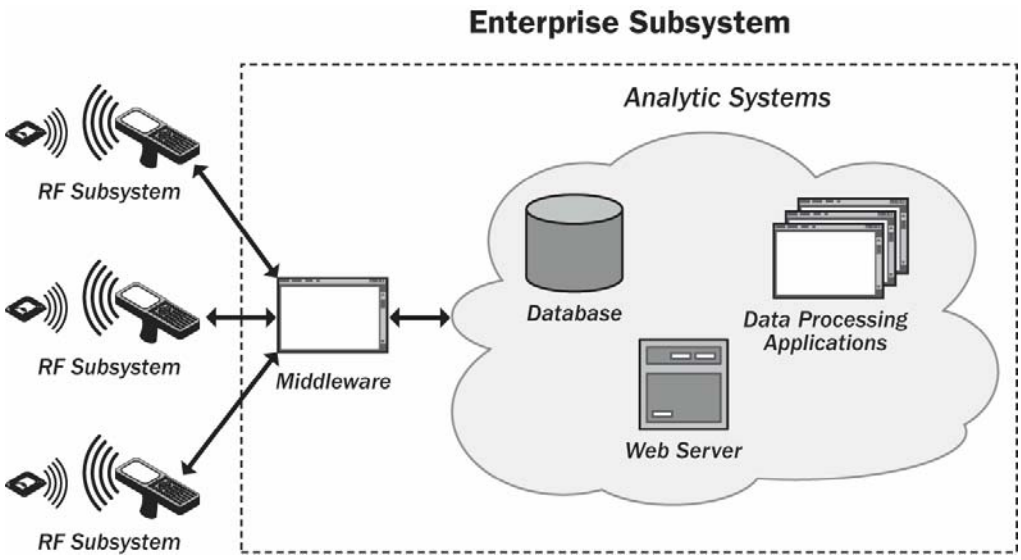

Figure 2. RFID system architecture

1.1.2. RF Subsystem

To enable wireless identification, the RF subsystem consists of two components:

- RFID tags (sometimes referred to as transponders), which are small electronic devices that are affixed to objects or embedded in them. Each tag has a unique identifier and may also have other features such as memory to store additional data, environmental sensors, and security mechanisms.
- RFID interrogators (often called readers), which are devices that wirelessly communicate with tags to identify the item connected to each tag and possibly associate the tagged item with related data.

Both the tag and interrogator are two-way radios. Each (Kocur, Machula, Kulda, Vojtěch, 2010) has an antenna and is capable of modulating and demodulating radio signals. Figure 3 shows a simple RF subsystem configuration.

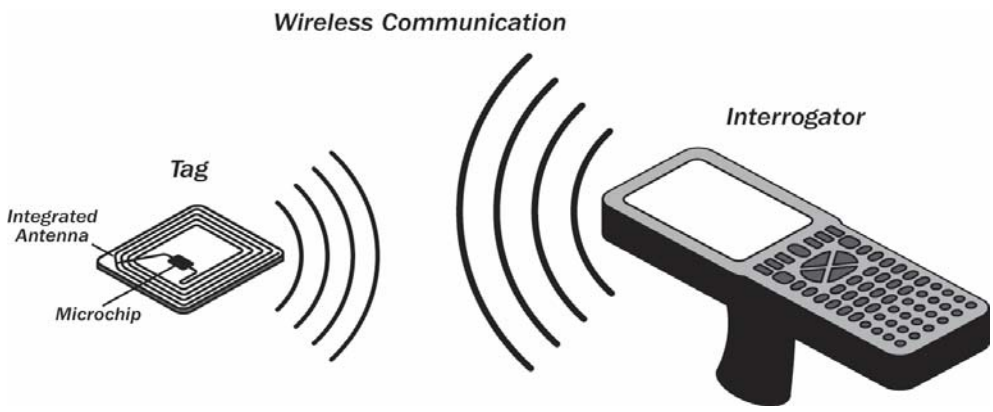

Figure 3. RF subsystem configuration

An RFID tag (Beneš, Kubáč, Staša, Kebo, 2013) is a small device that can be attached to an item, case, container, or pallet, so it can be identified and tracked. It is also called a transponder. The tag is composed of microchip and antenna. These elements are attached to a material called a substrate in order to create an inlay.

Tags are categorized into three types based on the power source for communication and other functionality:

- Active.
- Passive.
- Semi-passive.
- Semi-active.

1.1.3. RFID middleware

Middleware is software that controls the reader and the data coming from the tags and moves them to other database systems. In our cases we have used the Aton AMP middleware. It carries out basic functions, such as filtering, integration and control of the reader. RFID systems work, if the reader antenna transmits radio signals. These signals are captured tag, which corresponds to the corresponding radio signal.

This is a very special software device enabling mutual communication between two and more applications. This device is marked also as a mediator between various application components. The core activity of such devices covers the linking and switching of various different applications or hardware components for exchange, record and data modification purposes. There is a RFID middleware located between reader and server/database or other software device. This can have various functions depending on complexity of the system.

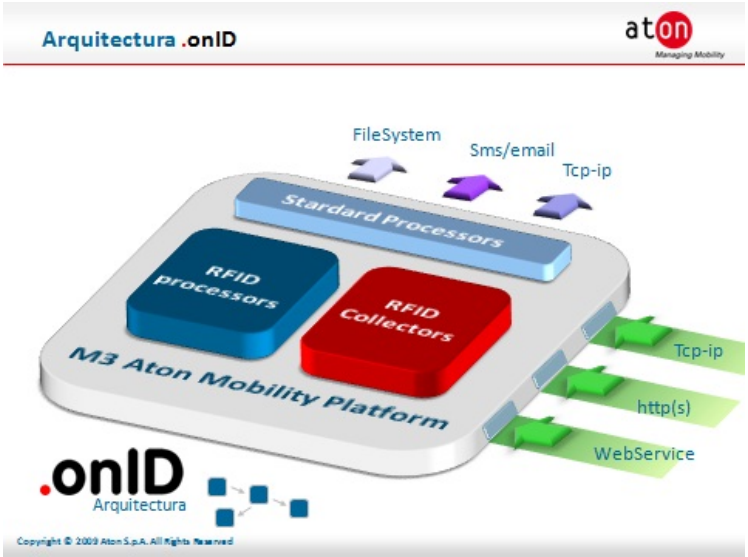

Figure 4. AMP platform

2. Warehouse Management System

2.1. Warehouse management

The management of a warehouse is the main function of a warehouse management system. On the one hand, these systems keep record of the storage capacity, i.e., the specification of the existing storage bins (location management), on the other hand, of the stored units (inventory management). In addition to this, it should also include several control functions to optimize the storage activities.

2.1.1. Warehouse type management

While the staffs in a manually operated warehouse system is able to independently choose the right conveyor and storage facility owing to their knowledge and experience, in an automatic warehouse management system single elements have to be assigned according to their compatibility. Furthermore, the manual operator fulfills certain tasks intuitively while an automatic system is not able to derive the sequence of work steps, like the loading or unloading of the storage channel according to the FIFO principle, from the instructions.

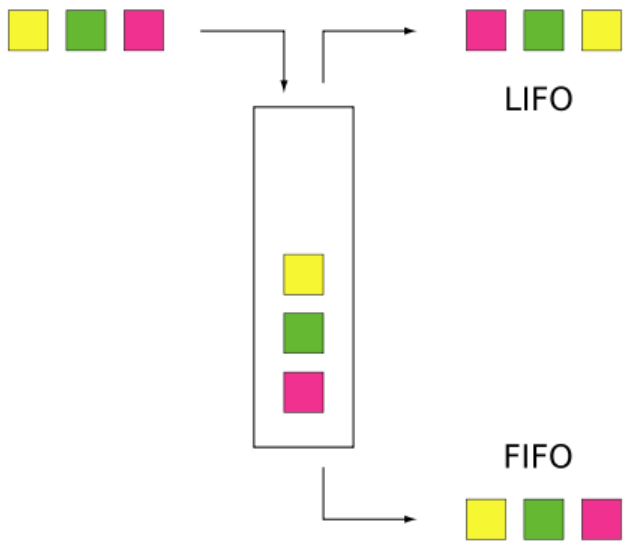

Figure 5. FIFO and LIFO strategy (Klapita and Mašek, 2012)

Some warehouse functions call for the independent generation of orders, e.g., to define restorage or to optimize the gripping time, and thus for the knowledge of the right storage and retrieval operations.

The basis for such optimizations, thus are the stringent classification of the storage and conveyor technology from the informational point of view. For this purpose the warehouse types listed in Table 1 should be defined.

Table 1. Warehouse types

Description	**Parameters**
Storage bin	Bins, shelves, channels,
Access to single locations	Random, stack, LIFO, FIFO
Execution	Automatically – manually
Storage operation	Definition of suitable storage facilities (loading capacity, range, rights)

2.1.2. Management of storage bins

At first (Klapita and Mašek, 2012), the management of storage bins represents the technical warehouse structure, i.e., the specification of the storage bin based on the storage technique (e.g., shelf racks) including the description of the dimensions, loading capacity and position (e.g., shelf coordinates). Some strategies for the assignment of storage bins require such a precise description of storage locations. More flexible storage methods (e.g., floor storage areas) may only need the specification of the areas and coordinates.

The management of storage bins also includes the management of units stored at a certain location. This includes the entry of goods specific data such as article specification (article number or number of the unit load) as well as the registration and update of the quantities stored in each location.

Status data are required for the control of storages and retrievals. When the storage bin is registered at the identification point, on the one hand, its availability has to be sure, and on the other hand, it is has to be ensured that this location is not assigned twice. For this purpose, different states are assigned with regard to the storage bin which is then blocked or reserved for certain articles or orders.

In case of retrieval, it has to be known if a certain unit is available. To make sure that the chosen unit is assigned to the current order the article status has to be linked to the order. In addition to the storage and retrieval the blocking of stocks or the setting of blocking indicators are an elementary management function used for various operations. These are above all:

- Blocking for storage and retrieval and
- Blocking for certain warehouse operations (e.g., avoid restorage of fragile goods).

The list of all occupied locations, i.e., the representation of the current warehouse status, is called bin status report. The bin status report may also include the type and quantity of articles stored in each bin.

2.1.3. Quantity management (Inventory management)

Quantity (Klapita and Mašek, 2012) and inventory management are another logical aspect, which focuses on the registration and update of the quantities of each stored article, sometimes under consideration of the relevant states. The management of goods according to different criteria (min/max. stocks) should to ensure the supply and avoid excess quantities. When fixed limits are exceeded or not achieved messages or actions (orders, restorage, etc.) have to be generated.

This function, however, requires a careful control of the stored goods including the allowed storage time and blocking of the article when a certain (expiration) date has been reached. Under certain conditions the respective goods have to be taken out of store to protect other goods.

The main difference to an enterprise resource planning system (ERP), which has similar functions, is the warehouse management, while an ERP system mainly focuses on customers and sales. For this reason, a warehouse management system generally does not contain customer data or prices. Nevertheless, a functioning overall system needs the continuous exchange between WMS and ERP.

3. WMS Based on RFID Technology

In our research, we aimed to create a configuration for warehouse management using RFID technology. We will not focus on the hardware but the software part of the essence of the whole application. We have based on the current status of the issue abroad, as illustrated on Figure 6.

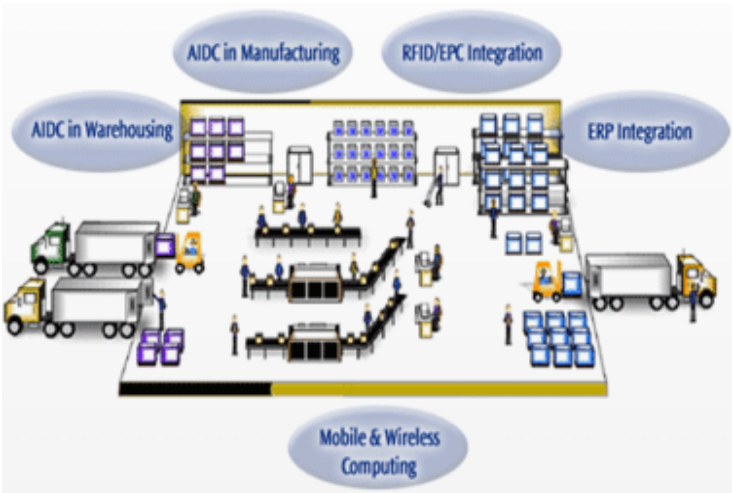

Figure 6. AIDC technologies in WMS

3.1. Configuration WMS in middleware AMP 2

As a software support for our WMS application we used middleware AMP2, which communicates with the tags and readers. The following sections of this chapter will introduce the configuration in this program.

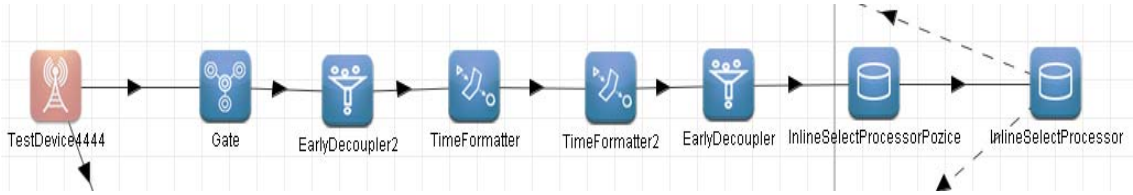

Figure 7. Configuration for tagId generating, filtering, registration time and date

Test Device is used to simulate the transition RFID identifier through the reading point, the configuration settings are assigned tag. Id value 763521473254102154474869. The number represents the EPC code, which clearly indicates that item. Processor Test Device sends this information to the processor GATE.

Gate processor further transmits this information only if the configuration is set to open (default is close). If the Gate is open tagId transmits information to another processor, which is Early Decoupler, his job is to filter out duplicate values.

Subsequently (Lúčan, 2013), the data are sent to the processor Time Formatter, which is used to assign a timestamp to the value tagId. Inline Processor Select Position provides assignment lowest available value of the position of the wireless, so to that number tagId assigned a position in the stock. It is only in this case that is the position of state = 0, so the position is free. Next in line is again Inline Select Processor, whose task is to compare the value with the value tagId is already registered in the database table, namely it is a table count_store. Depending on whether the value given in the table is or not will be based on the conditions set in the processor branching. In the event that the item is not in count_store branching occurs on Select Inline Processor 3.

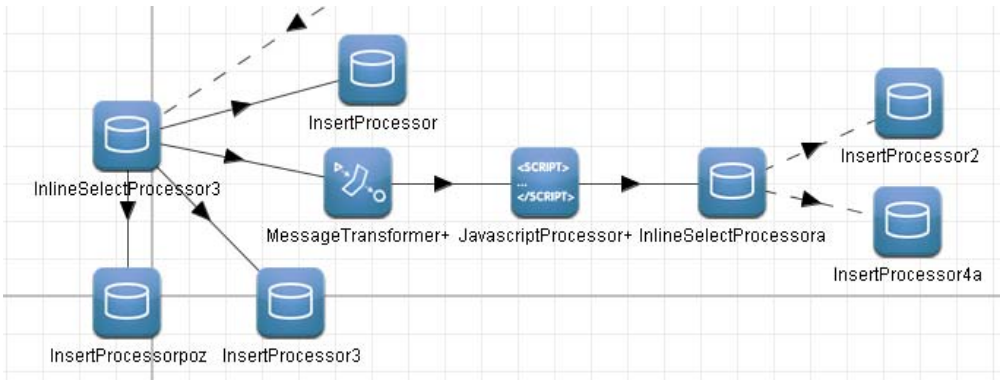

Figure 8. Configuration for writing date into the database (Lúčan, 2013)

Inline Select processor 3 (Lúčan, 2013) receives data, if the condition in Inline Select Processor is not true. Insert Processor insert data into a database table called count_store. Using SQL functions insert are data inserted into the table information about identifier that is tagId. Than assigned him the position, which represents the lowest available value in the table position. Based on this information it is possible to identify a particular product and also determine its specific location in the warehouse. Insert processor poz, updates the position of the table, where the position of the assigned status changes to 1, which means that the position is occupied.

Another processor, which is used to write data into table is Insert the Processor 3. The processor writes data into the table journal. To journal table are written tagId values, on which it is possible to accurately identify the product, further writes the date and time of receipt of items in storage. Then writes status, which determines whether the product is put away or removed and further down the number of positions at which the product is stored.

Message Transformer + processor ensure the removal of only certain parts of XPath. In a specific example, the part tagId that is required for the next processor, which is a Java Script. His role is of a specific character string extracted the required number of characters. In our example Java Script processor with Split method is set to remove the part tagId, which represents the EPC code that represents the type of product, thus sending a further modified value.

Inline Select processor selects from a table store the number of items in the column indicating type. Based on the conditions is divided into these processors. If the condition is true, therefore the type of product is already in stock, then increasing the number of pieces of the same type of products to 2. This operation performs the Insert Processor 2. If that condition is not satisfied, therefore, that type of product is not in stock yet. Insert Processor 4a ensures inclusion of this type to the table named as store. Than is entered the value of id, type, count, position that is the serial number of the product type, actual product type, number of units and assigned position.

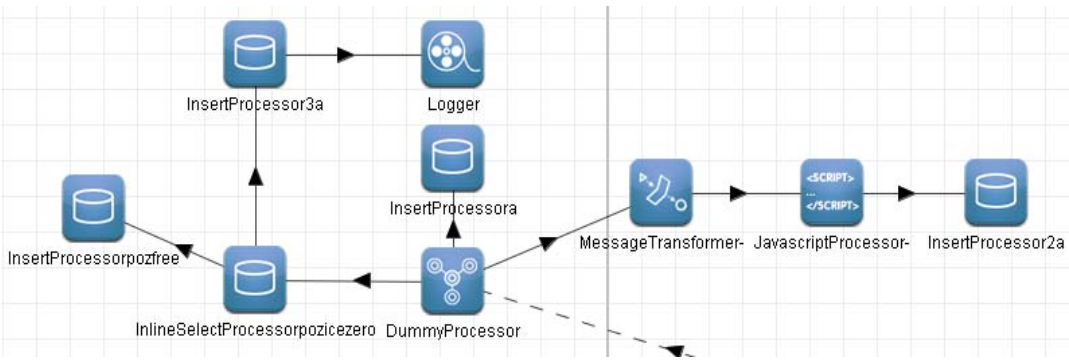

Figure 9. Configuration for removing data from database (Lúčan, 2013)

In (Lúčan, 2013), the event that the item is located in count_store branching occurs on Dummy Processor. The identifier with the value tagId gate passes a second time, which implies that it is the direction of the product out of the warehouse (removal of goods). Insert 2 Processor based on the extracted parts tagId update the store table, which will reduce the number of items 1.Insert Processor is used to delete data from a table count_store, removing of these data represents the removal process of goods from the warehouse. Select Inline Processor pozicezero selects a value position from the table count store. Insert Processor pozfree on the basis of information, which obtained from the previous processor, updates the data in the table position. In this case, set the value to 0, because if the item be removed from storage, frees up the position at which it was located.

The last processor in this tree is Insert Processor 3a, which added information concerning the removal items to the journal table. Write the serial number id, tagId, which represents a particular product, time and date of removal, status. In this case, the 0, because the item has left the warehouse, and finally the position at which the item is found itself. In this tree configuration is the processor Logger, which shows information about readable identifier to the consol.

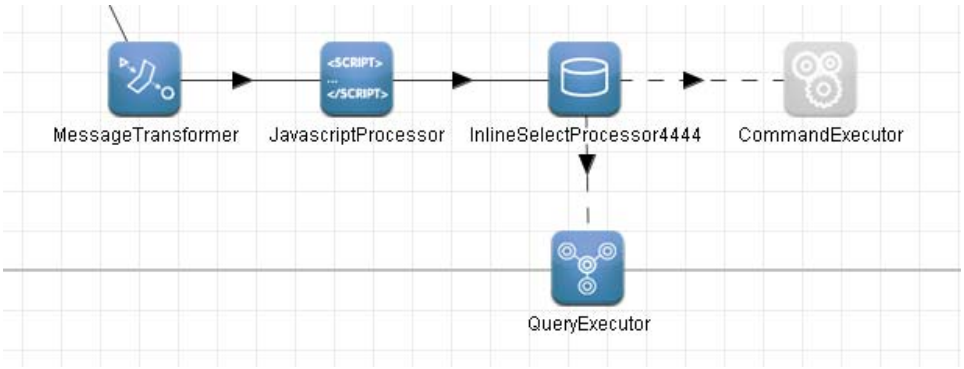

Figure 8. Configuration for the detection of supported items (Lúčan, 2013)

In this tree is tested whether the specified value tagId representing an item in the list of supported products for the store. Whole configuration is shown in next figure.

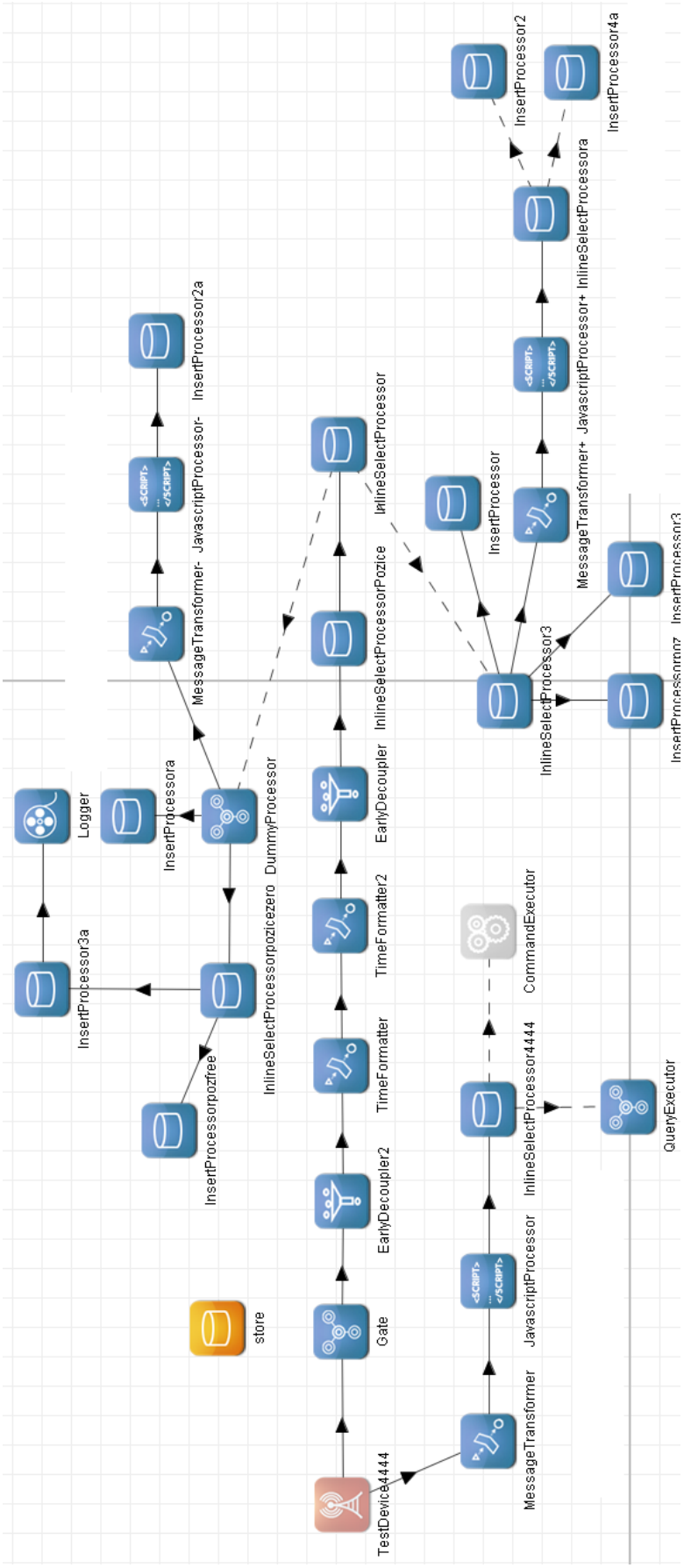

Figure 10. Final AMP configuration(Lúčan, 2013)

4. Conclusions

Technology of automatic identification plays a significant role nowadays in all the fields of economics. Regarding the optimisation of supply chains, the bar code technology is utilized for this purpose in a long term. Technology of radio frequency identification is getting more and more popular considering multitude of advantages and therefore it is highly expected, that its application will be extending further into all the fields of economics, including logistics sector. Managing inventory control is possible in several ways. We have chosen the path Coding RFID tags with subsequent creation of applications for warehouse management. The software named as AMP2 met our expectations and we can say that through it is possible to manage stock. In our case it was a model example but experience from abroad shows that more and more logistics companies tend to technologies such as RFID.

Acknowledgements

This article was created to support project named as:

- *Centre of Excellence for systems and intelligent transport II (048/2009/2.1/OPVaV, Aktivita 1.4) – ITMS 26220120050*

E!7592 AUTOEPCIS – RFID Technology in Logistic Networks of Automotive Industry (RFID technológie v logistických sieťach automobilového priemyslu)

This article was created in response to tackle a project co-funded by the EU titled "The Quality of Education and Human Resources Development as Pillars of the Knowledge Society" at the Faculty PEDAS at the University of Žilina, ITMS 26110230083"

Modern education for the knowledge society / project is co-financed by the EU

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Transport and Telecommunication, 2014, volume 1 no. 3, 196–208
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/ttj-2014-0017

RESEARCH OF READABILITY AND IDENTIFICATION OF THE ITEMS IN THE POSTAL AND LOGISTICS ENVIRONMENT

Peter Kolarovszki

University of Žilina, Faculty of Operation and Economics of Transport and Communications
Department of Communications
Univerzitná 1, 010 26, Žilina, Slovakia
Phone: +421 908227492. E-mail: peter.kolarovszki@fpedas.uniza.sk

This article deals with RFID technology, which is a part of automatic identification and data capture. Nowadays, the identification of parcels in postal sector is carried through barcodes. In this article we would like specify, how can be postal parcels located in postal container identified in the transmission process of postal main processing centre by UHF RFID technology. All results are verified by measurement in our AIDC laboratory, which is located at the University of Žilina. Our research contains 12 different types of orientation tags and antennas and more than 1000 tests. Our identification performance was close to 100%. All tested parcels were located in postal container. The results of our research bring the new point of view and indicate the ways using of UHF RFID technology in postal applications. At the end of this article the utilization of the RFID technology in postal logistics chain is characterized.

Keywords: RFID technology, logistics chain, parcels, identification, postal container

1. Introduction

Technology of automatic identification plays a significant role nowadays in all the fields of economics. Regarding the optimisation of supply chains, the bar code technology is utilized for this purpose in a long term. Technology of radio frequency identification is getting more and more popular considering multitude of advantages and therefore it is highly expected, that its application will be extending further into all the fields of economics, including postal sector. This article deals with an application of RFID technology in the field of postal network optimisation, in particular within processes of identification of parcel posts placed in postal container. The technology of RFID is specified in the article along with performed research of readability of RFID identifiers attached to parcel posts positioned in postal container. Considering the performed research, the layout of placing of particular RFID identifiers on parcel posts has been designed.

2. Objective and Methodology

Object of the research are the parcel posts transported in postal containers within postal network consisting of particular components. These shipments contained UHD RFID identifier that was read by use of 2 or 4 antennas of particular scanning device. In order to achieve the relevant results of the research, more than 1.500 measurements were performed by various types of testing. For testing purposes, we used cubicle postal container that is real utilized at transport of parcel posts. Within methodology or series of steps, we chose diagram of partial goals that is depicted in detail on Figure 1.

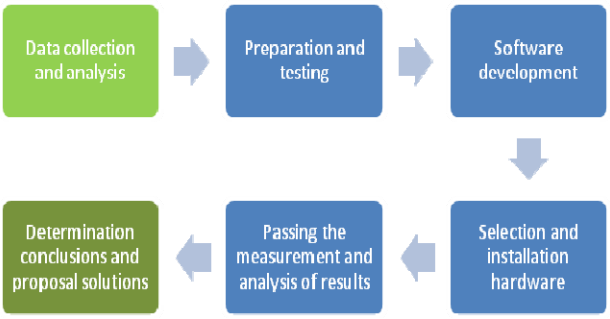


Figure 1. Diagram of partial goals

3. Postal Transport Network

Postal transport (Kolarovszká and Fabuš, 2011) is an important part of the process of filing a postal item to its delivery to the addressee in compliance with established quality standards for different types of mail under postal license requirements and the quality of universal postal service.

Postal transmission network consists of road transport courses and road itinerary. By the structures of postal transmission network there are used various tools and systems. Postal transport network is currently divided into three main levels:

- district transport network (OPS) – connects the establishment and other facilities on the territory of the district processing centre and regional units (OU) with the delivery points,
- regional transport network (RPS) – connects the main processing centres in regional processing centres with their own circuit, the main processing centres with appropriate regional nodes, where each regional processing centres,
- the main transport network (HPS) – connects each major processing centres, the main processing centres with regional processing centres from another circuit HSS, includes transport findings in international relations.

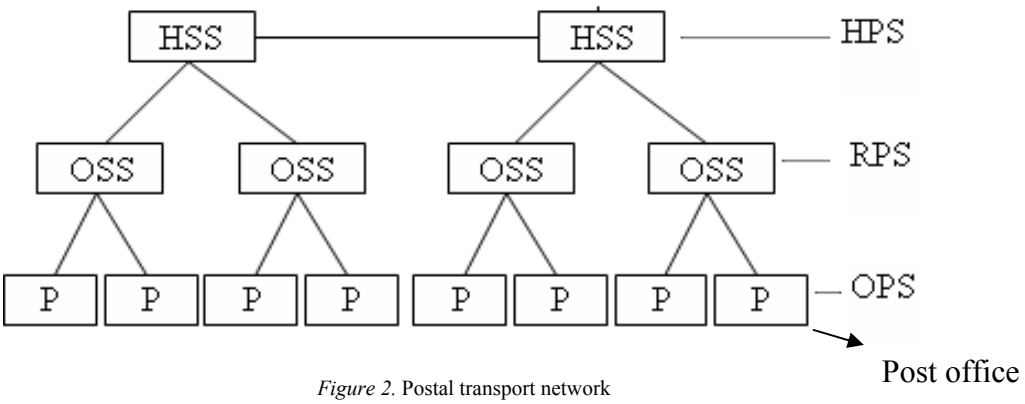


Figure 2. Postal transport network

In the carriage of postal items is necessary to decide what type of transport used for this purpose, what are the flows of items and what is their intensity. Way to connect and type of vehicle depends on the following factors:

- o density and organization of the postal network,
- o flows of different types of postal items and their size,
- o the carrying capacity of vehicles used,
- o transport time of each species of postal items,
- o safety and effectiveness of postal traffic.

Processing of items is implemented in the workplace of the Slovak Post:

- HSS – main processing centre – the facility providing treatment and quest items posting its area of perimeter, mail items addressed to your district and in transit in its dealings with OSS circuit, in contact with other HSS and OU,
- OSS – regional processing centre – post office responsible for preparing and quest items posted at post offices in his own constituency and in transit in contact with your postal district and interacted with the HSS, the facility responsible for receiving, processing and quest items express postal services,
- Selected post – post office responsible for preparing and quest items selected species within a specified range (usually as OSS),
- Exchange post – processing the shipment and ensure shipments to post offices exchange foreign postal administrations,
- Regional hub as department of express service – establishment is responsible for receiving, processing and quest items express postal service.

3.1. Technological Procedure of Parcel Mails Processing

The technological procedure of parcels processing consists of several following phases. Parcels assigned for delivery within delivery area of delivery post are left at this post. If the parcels are assigned for delivery out of this delivery area, dispatch is created so that the parcels could be transported from post without sorting procedure into respective OSS/OU. Dispatches are out = carded at OSS/OU with following sorting of parcels for own delivery area and the others. If the parcels are directed our of OSS/OU delivery area, the dispatch is created and parcels are shipped to HSS of mail register.

Parcels are sorted for own delivery area and other HSS manually or by use of auxiliary parcel posts sorting device after out-carding of dispatches into HSS. Out-sorted parcels are stored and later dispatched into respective postal course freely or in containers on the road or by railway. Once the parcels are delivered to respective HSS, the parcels are divided according to type (the 1st and 2nd class) and are placed into separate containers or freely. Prior to the sorting process, bar codes are scanned for the purposes of track-and-trace service. After unloading of shipping containers from postal course mails are sorted in place that is divided into parcel sorting room and trans-loading. There is a sorting of registered mails, express mails and parcels inappropriate for mechanical processing. All the parcels of the 1st and 2nd class appropriate for mechanical processing are sorted in parcels' sorting room. After that, the dispatches are created and parcels are shipped freely in containers to respective OSS/OU and subsequent to office of delivery.

4. RFID Technology

Radio frequency identification (Hunt, Puglia, 2007) is a wireless data collection technology that uses electronic tags, which store data, and tag readers, which remotely retrieve data. It is a method of identifying objects and transferring information about the object's status via radio frequency waves to a host database. RFID is not necessarily a direct replacement for bar codes, but as the costs of RFID systems continue to decrease, the functional utility of RFID will greatly surpass that of bar codes.

An RFID system is a set of components that work together to capture, integrate, and utilize data and information. This section describes some of them. The components are as follows:

- Sensors, Tags, Antennas, Readers.
- Connectors, Cables, Networks, Controllers.
- Data, Software, Information Services.

4.1. RFID Tags

An RFID tag (Kebo, Staša, Beneš, Švub, 2013) is a small device that can be attached to an item, case, container, or pallet, so it can be identified and tracked. It is also called a transponder. The tag (Beneš, Kubáč, Staša, Kebo, 2013) is composed of microchip and antenna. These elements are attached to a material called a substrate in order to create an inlay.

Tags are categorized into three types based on the power source for communication and other functionality.

- Active.
- Passive.
- Semi – passive.
- Semi – active.

4.2. RFID Reader

The second component (Thornton and Lanthem, 2006) in a basic RFID system is the *interrogator* or *reader* (Figure 3). Readers can have an integrated antenna, or the antenna can be separate. The antenna can be an integral part of the reader, or it can be a separate device. Handheld units are a combination reader/antenna, while larger systems usually separate the antennae from the readers. The reader retrieves the information from the RFID tag. The reader may be self-contained and record the information internally; however, it may also be a part of localized system such as a POS cash register, a large Local Area Network (LAN), or a Wide Area Network (WAN).

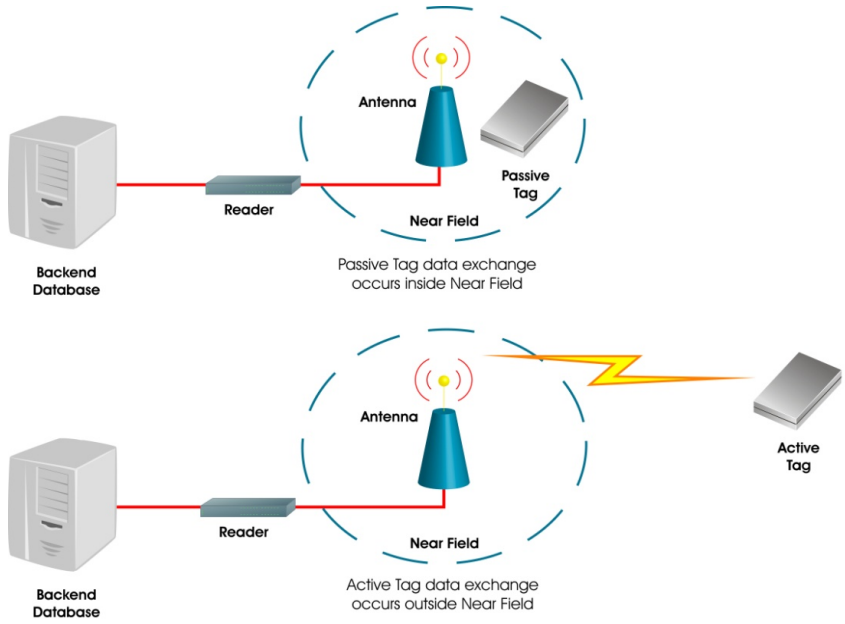


Figure 3. Passive and Active Tag Processes (Thornton and Lanthem, 2006)

4.3. RFID Middleware

Middleware is software (Kocur, Machula, Kulda, Vojtěch, 2010) that controls the reader and the data coming from the tags and moves them to other database systems. In our cases we have used the Aton AMP middleware. It carries out basic functions, such as filtering, integration and control of the reader. RFID systems work, if the reader antenna transmits radio signals. These signals are captured tag, which corresponds to the corresponding radio signal.

This is a very special (Michálek, Vaculík, 2008) software device enabling mutual communication between two and more applications. This device is marked also as a mediator between various application components. The core activity of such devices covers the linking and switching of various different applications or hardware components for exchange, record and data modification purposes. There is a RFID middleware located between reader and server/database or other software device. This can have various functions depending on complexity of the system.

We can say that middleware fulfils following functions:

- Masks the communication distribution of many cooperating parts of the system located in various physical places,
- Masks the heterogeneity of various hardware components, their different operational systems and communication protocols,
- Provides unified interface enabling easier system extension and its easier communication with world.

5. Description of Measurements and AMP Model Configuration

In order to achieve relevant outcomes, it was inevitable at first to design functional system enabling realization of single measurements under laboratory conditions. In order to comprehend single measurements, we have to define the principle they operate under and what is being detected by them.

5.1. Description of Measurements

At first (Koškár, 2013), we have to find out the readability of RFID tags of parcels placed in metal postal container at the moment of its passing through RFID gate with antennas. At second, we have to realise that we perform several types of measurements. These types differ in RFID tags orientation on parcels as well as by number of antennas; by their use tags are scanned. In order to ensure the credibility of measured results, each type of measurement is repeated 100 times and therefore each single of them is called partial measurement. We do have the type of measurement and 100 partial measurements within, from which we made statistical results. The relation between types of measurement and partial measurements:

- Type: Placing of identifiers on the top of the parcel post: four antennas:
  - Partial measurement No. 1
  - Partial measurement No. 2
  - Partial measurement No. 3

By accomplishment of single measurements, we obtained required data for deduction of results and recommendations. The accomplishment of measurements according to our requests needed certain preparation indeed. As for the preparation process, it was inevitable to select pasteboard boxes representing the parcels placed in postal container. In order to fill up the entire loading capacity, we needed 40 boxes of different size.

As each single parcel had to contain one RFID tag, we needed 40 passive UPM Raflatac DogBone RFID tags. The identification number (tagID) of each tag was re-programmed by use of hand RFID reader in order to get the other activities simplified. The structure of these IDs would be 3008 0000 0000 0000 0000 00xx. As we used 40 parcels overall, the last two digits would be 00 to 40, where the first value 00 would be assigned to launching RFID tag placed on container. At the same time, we were detecting the readability quality of particular RFID tags during the process of reprogramming. Thanks to that, we noticed, that one tag had much lower level of readability in comparison to other tags. This tag was assigned the value 01 of last two digits.

Following reprogramming process, we placed the tags to parcels. In order to prevent any damage of tags and at the same time, to ensure their fully functionality after realization of our measurements, we stick them by using of adhesive tape. We wrote the last two digits of tag's ID during the sticking of tag due to later identification and analyse. All the parcels were placed into container, whereby the parcel with lower readable tag (01) was placed on the very bottom of the container. Afterwards, ID´s of tags were filed into MySQL database and configuration's Whitelists, by which we set the RFID reader exclusively for scanning of 40 + 1 tags.

The very last step was the involvement of antennas. The upper two antennas were placed onto metal construction and the sides of antennas were attached to telescopic stands, by which we ensured RFID gate simulation.

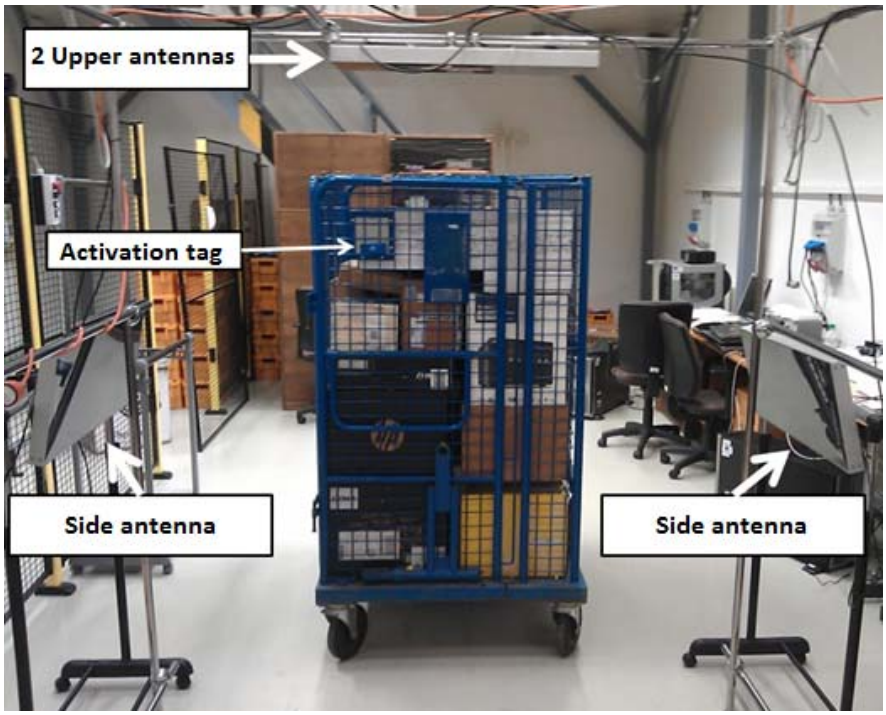


Figure 4. Preparing for measurements

5.1.1. Hardware Part

Hardware part consists of server, connecting cables, RFID gate (reader with antennas) and indeed with RFID tags placed on parcels and on plastic container. RFID reader Motorola was inevitable component of our hardware set. The reader consisted of four active antennas maximally in our configuration.

Figure 5. RFID reader Motorola FX7400 RFID reader Motorola FX7400

This RFID reader is characteristics by its compact processing, easy installation, high performance and besides, is able to be hooked up directly by use of data network cable (Power over Ethernet). Its use is applicable also in case of limited areas.

The very important part was to choose efficient and affordably priced RFID identifier. We used passive RFID tags UPM Raflatac DogBone applicable for such a laboratory tests. Their structure consists of antenna and integrated circuit. These components are with vapour on elastic sticky plastic paper, so the tags can be easily stuck directly to needed object.

Figure 6. RFID tag UPM Raflatac DogBone

5.1.2. Software Part

As for the software parts, we used operation system MySQL database, middleware and web application. The mutual relations of particular components (items) are depicted in the most proper way on figure 7. What needs to be said is that this is only a very simplified model and not every item can be marked as elementary, because each of them consists of other parts.

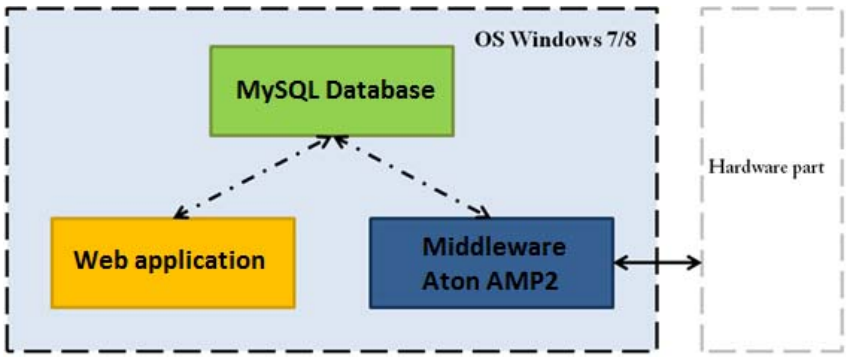


Figure 7. Software part

Operation system ensures the flow of overall model, particular software items run under the system. As can be seen, web application doesn't communicate with middleware directly, but data are exchanged between them through MySQL database. In order to get overall view, we will explain shortly the basic functions of particular items and system operation principle.

Middleware (Vaculík and Tengler, 2012) ensures communication between hardware and software part of our model. At the same time, it enables to set up the configuration itself, so by its use we define

practically what, how and when should the particular hardware and software components operate. Considering the close collaboration of our department with company ATON spa, we chose middleware OnID or AMP that actually made our work with collected date much easier.

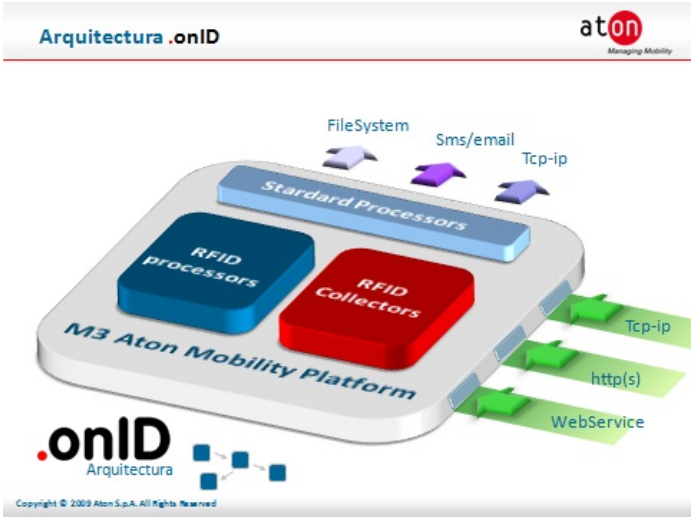
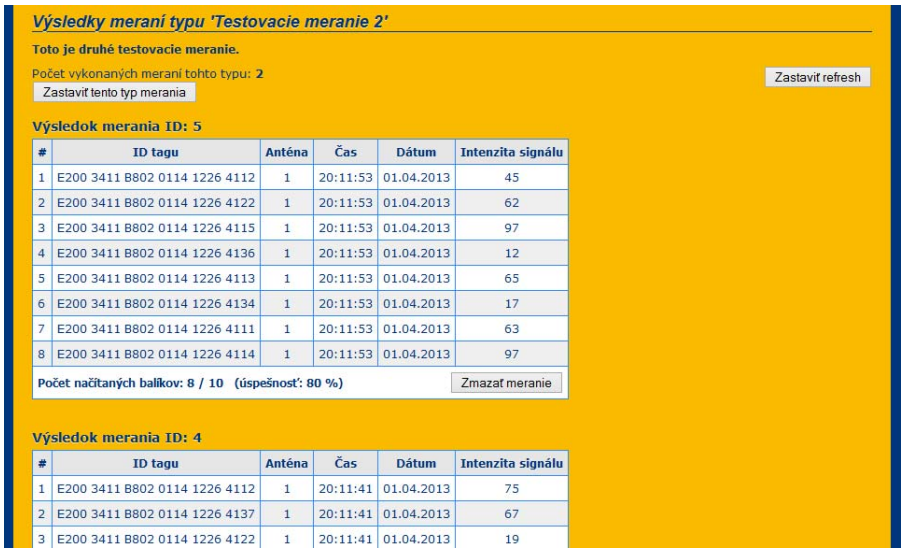


Figure 8. AMP platform

All the data obtained from RFID gate are stored into database as well as all the data sent by user through web application. These data are accumulated here and provided by request to web application and to middleware. MySQL database serves as a place for gathering of all the collected data waiting for further demand. Web application serves for presentation of all the data from database and its further processing due to need to accomplish analyse by user. In our case, the user also gives directions to start the single types of measurements through application.



Výsledky meraní typu 'Testovacie meranie 2'

Toto je druhé testovacie meranie.

Počet vykonaných meraní tohto typu: **2**

Zastaviť tento typ merania

Zastaviť refresh

Výsledok merania ID: 5

#	ID tagu	Anténa	Čas	Dátum	Intenzita signálu
1	E200 3411 B802 0114 1226 4112	1	20:11:53	01.04.2013	45
2	E200 3411 B802 0114 1226 4122	1	20:11:53	01.04.2013	62
3	E200 3411 B802 0114 1226 4115	1	20:11:53	01.04.2013	97
4	E200 3411 B802 0114 1226 4136	1	20:11:53	01.04.2013	12
5	E200 3411 B802 0114 1226 4113	1	20:11:53	01.04.2013	65
6	E200 3411 B802 0114 1226 4134	1	20:11:53	01.04.2013	17
7	E200 3411 B802 0114 1226 4111	1	20:11:53	01.04.2013	63
8	E200 3411 B802 0114 1226 4114	1	20:11:53	01.04.2013	97

Počet načítaných balíkov: 8 / 10 (úspešnosť: 80 %) Zmazať meranie

Výsledok merania ID: 4

#	ID tagu	Anténa	Čas	Dátum	Intenzita signálu
1	E200 3411 B802 0114 1226 4112	1	20:11:41	01.04.2013	75
2	E200 3411 B802 0114 1226 4137	1	20:11:41	01.04.2013	67
3	E200 3411 B802 0114 1226 4122	1	20:11:41	01.04.2013	19

Figure 9. Web application (Koškár, 2013)

5.2. AMP Model configuration

Configuration of the model for readability measurement of parcel posts was designed in environment of AMP middleware. It was split into three parts:

- Launch of measurements,
- Capacity control and sound signalisation,
- Time formatting and recording into database.

5.2.1. Launch of Measurements

The first module serves for initialisation of MySQL database, RFID reader as well as for detection, whether some type of measurement had been already launched. According to this finding, we define next procedure and following processes.

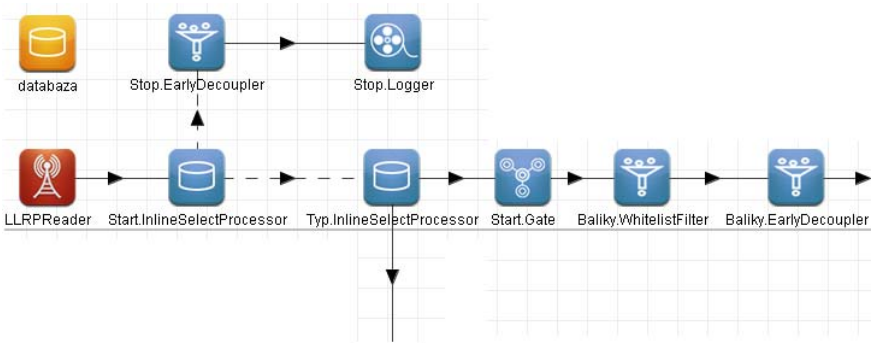


Figure 10. Launch of measurements (Koškár, 2013)

5.2.2. Capacity control and sound signalisation

The second (Koškár, 2013) module ensures us entering of records about new partial measurement of respective type of database. This section also defines when this partial measurement is finished and when the gate capacity closed again and what is being accomplished besides sound signalisation.

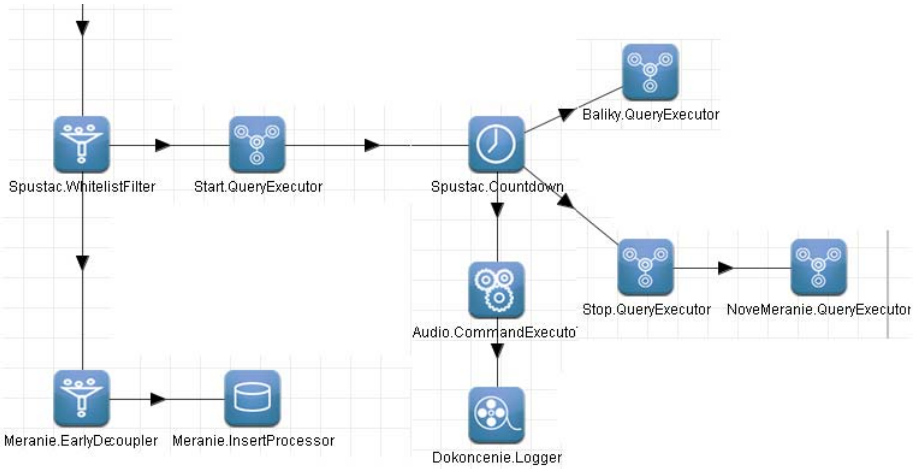


Figure 11. Capacity control and sound signalisation (Koškár, 2013)

5.2.3. Time Formatting and Recording into Database

The third module formats at first the date and time of scanning of each parcel and mainly ensures the entry of data about scanning of particular parcels in container into MySQL database.

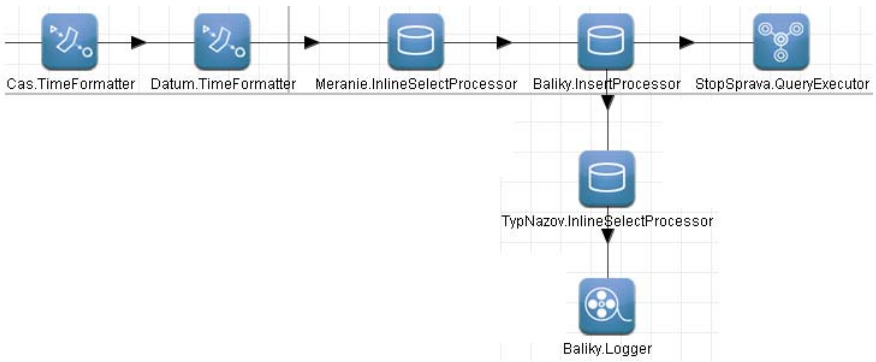


Figure 12. Time formatting and recording into database (Koškár, 2013)

6. Results from the Measurements

Prior to launching of measurements themselves, we had performed a line of several testing measurements in order to detect the functionality of overall system. At the same time, we found out by use of these tests that intensity of reader's scanning set in configuration has a minimal effect on scanning of particular tags in container. Therefore we set this intensity at each measurement for 100% level.

Concerning the readability research of parcels placed in postal container, we performed the measurement for dependency of RFID identifiers placing on parcels as well as their orientation in regard to position of reading antennas. We performed following types of measurements:

1. Tags placed on the top side of parcels,
2. Tags placed on the bottom side of parcels with regard to bottom of the container,
3. Tags placed with edges towards all antennas,
4. Tags placed at the walls of container.

6.1. Tags Placed on the Top Side of Parcels

The choice (Koškár, 2013) of the first type was the one with RFID tags placed on the top side of parcels. We assumed that the results should be theoretically the best of all the types as the position of antennas was most favourable, considering radio frequency waviness and its impact to RFID tags.

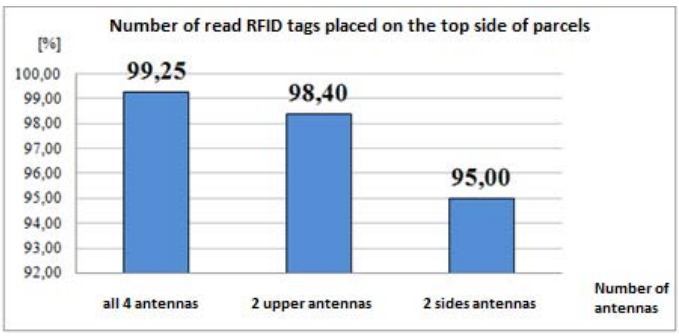


Figure 13. Results of measurements 1 (Koškár, 2013)

As we can see, the results of this type of measurement are indeed very positive. We measured the readability efficiency of 99,25% by scanning of the container with parcels with all four antennas. The only tag with weaker level readability was the one with tagID 01. This was successfully read only 76 times out of 100. Signal was not strong enough so that the antennas could successfully detect at each measurement the parcel with weaker readable tag placed on the very bottom of the container. If we ignored this one particular tag, we would have achieved overall average readability attacking level of almost straight 100%.

6.2. Tags Placed on the Bottom side of Parcels with Regard to Bottom of the Container

At this case (Koškár, 2013), we assumed moderate fall of readability. This assumption was not that much fulfilled at the very end.

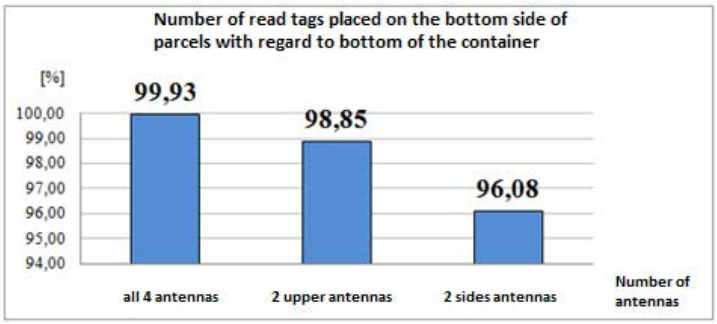


Figure 14. Results of measurements 2 (Koškár, 2013)

We can see, that the readability was not only reduced but even increased by scanning with all the antennas up to level 99,93%. The most relevant influence on this outcome has indeed the problematic tag 01 that was placed again at the very bottom of the container, but this time the tag was directly touching the bottom of container. The presence of the tag closer to floor and reflection of signals either from metal construction of container or from the ground very likely caused its 100% readability by scanning with all four antennas.

6.3. Tags Placed with Edges Towards All Antennas

At this variant, we made our decision to make the reading of the tags more difficult with their placing vertically to all the antennas. The tags were replaced on sides of parcels relating to back side of the container. Besides, the previous type of measurements proved that just by linking of side antennas had the orientation of tags moderate influence of readability. Therefore we stuck the tags also into horizontal position.

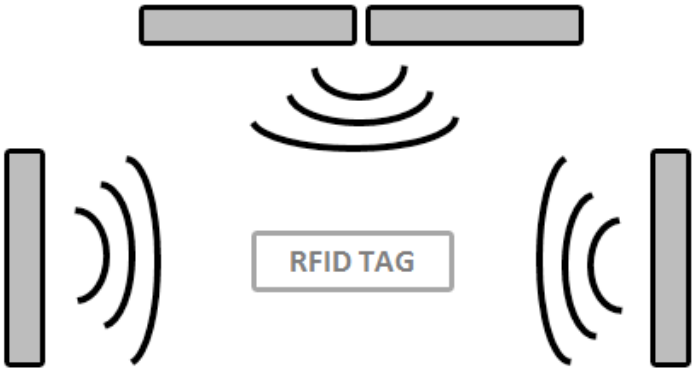


Figure 15. Configuration of measurements 3

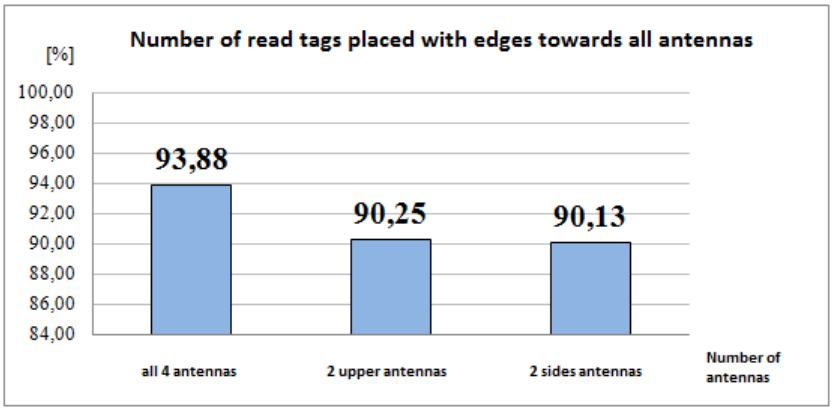


Figure 16. Results of measurements 3 (Koškár, 2013)

Not even at this cased dropped the readability under 90% what can still be considered for a very good result.

6.4. Tags Placed at the Walls of Container

We detected at previous types of measurements, that the barred metal wall of container from which the signal reflected had the major influence for scanning of parcels. Therefore we decided that at the last variant, the most of RFID tags of the parcels would be placed at the walls of container. We assumed that this setting of parcels would have the most significant influence with regard to readability.

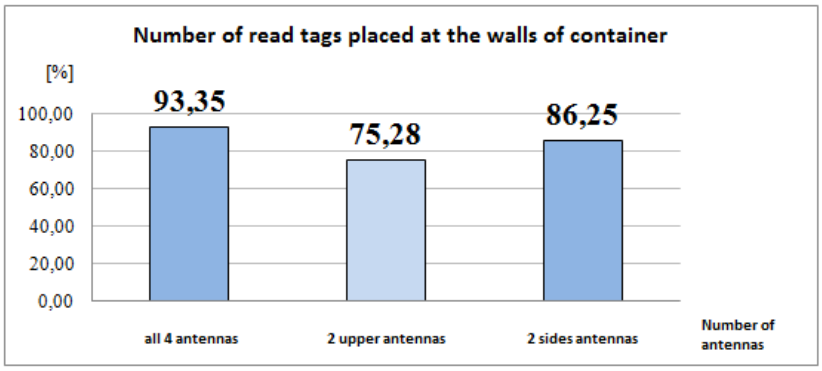


Figure 17. Results of measurements 4 (Koškár, 2013)

The readability of tags didn't drop significantly by scanning with all four antennas, it just dropped to still very satisfying level of 93,35%. Despite quite a good average outcome of readability, we have to state that the tags placed at metal parts behave unpredictable from readability point of view.

On the next table we can see the result from all measurements, which were made at the laboratory conditions.

Table 1. Results of measurements (value in %)

Type of measurements	Number of antennas		
	4 antennas	2 upper antennas	2 sides antennas
1	99,25	98,4	95
2	99,93	98,25	96,08
3	93,88	90,25	90,13
4	93,35	75,28	86,25

6.5. Proposed Placing of tags on Parcels and Lay-Out of Antennas of RFID Gate

Based (Koškár, 2013) on results of previous measurements, we could perform a measurement dealing with most convenient placement of RFID tags on parcels in container along with a placement on antennas. Tags were placed upon top side of parcels. So that the results of measurements were not deformed by any weaker readable tag (01), we made a decision at recommended configuration to change this tag for the other one. At first, we scanned exclusively just by use of two top antennas. After 100 repetitions, we recorded average detection of parcels at level 99,8%. Then, we placed another two antennas upon second end of top construction of RFID gate, by which we ensured vertical scanning by all four antennas at once. Two antennas were indeed placed at input and two at output of RFID gate, by which we achieved approximately the same long scanning interval of each tag in container. We performed the measurements 100 times. We achieved at such a configuration the average level of readability equal 100%. The very same results were achieved also in case, when the tags were turned so that they were placed on the bottom side of parcels – in direction to bottom of container.

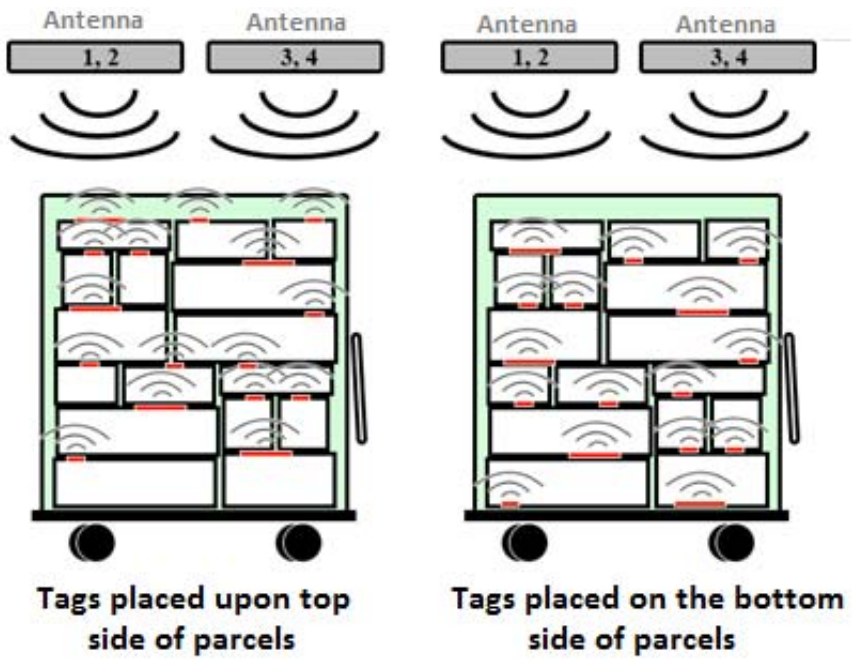


Figure 18. Proposed placing of tags on parcels

7. Conclusions

We can state that introduction of passive radio frequency identification of parcel posts in postal operation is technically feasible as a very high level of readability was achieved by scanning of particular parcels under laboratory conditions, reaching equal 100%. The results are very dependant indeed on specific placement of RFID tags on parcels in container where are they placed and at the same time on placement of antennas of RFID reader. Another significant gained knowledge is that optimal solution is with utilization of four RFID antennas placed on top side of RFID gate enabling scanning of tags in vertical direction. Two antennas were placed at input and two at output of RFID gate. Thereby we ensured equally long scanning internal of each parcel in container resulting in a very high overall level of readability. Such a solution wouldn't be technically demanding under real conditions in operation. Besides we found out that metal parts of container construction represent the prime problem of parcels´ scanning in container. Signal reflected in this case significantly that means the potential scanning/ un-scanning of parcels would be very tough to predict. On the contrary, the highest percent efficiency of scanning was recorded in case of RFID tags placed on top and bottom side of parcels. Under these conditions, the signal is not interfered by metal parts of container construction and the parcels are scanned without any serious problems even in case of only two top antennas utilization. At the end of this article I would like to thank my diploma student Ing. Lukáš Koškár for high-quality processing of the diploma thesis and the proposed solutions.

Acknowledgements

This article was created to support project named as:

E!7592 AUTOEPCIS – RFID Technology in Logistic Networks of Automotive Industry (RFID technológie v logistických sieťach automobilového priemyslu)

This article was created in response to tackle a project co-funded by the EU titled "The Quality of Education and Human Resources Development as Pillars of the Knowledge Society" at the Faculty PEDAS of the University of Žilina, ITMS 26110230083

Modern education for the knowledge society / project is co-financed by the EU

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Transport and Telecommunication, 2014, volume 15, no. 3, 209–214
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/ttj-2014-0018

AN APPLICATION OF COMPUTER VISION SYSTEMS TO SOLVE THE PROBLEM OF UNMANNED AERIAL VEHICLE CONTROL

Alexey Y. Aksenov[1], Sergey V. Kuleshov[2], Alexandra A. Zaytseva[3]

Saint-Petersburg Institute for Informatics and Automation of RAS
14th line V.O., 39, Saint-Petersburg, 199178, Russia
Phone: +7 812 3235139. E-mails: [1]a_aksenov@mail.iias.spb.su, [2]kuleshov@iias.spb.su, [3]cher@iias.spb.su

The paper considers an approach for application of computer vision systems to solve the problem of unmanned aerial vehicle control. The processing of images obtained through onboard camera is required for absolute positioning of aerial platform (automatic landing and take-off, hovering etc.) used image processing on-board camera. The proposed method combines the advantages of existing systems and gives the ability to perform hovering over a given point, the exact take-off and landing. The limitations of implemented methods are determined and the algorithm is proposed to combine them in order to improve the efficiency.

Keywords: computer vision, unmanned aerial vehicle control

1. Introduction

The rapid development of technology of autonomous robotic systems and the need of unmanned aircraft in various fields, including military purposes, led to the accelerated pace of development and deployment of small unmanned (UAVs) and remotely piloted (RPV) aircraft. The most actively developing are the multi motor flying platforms (tri-, quad-, hexa-copters).

The common features for all objects of given class are the design and the principle of flight. The central part of multicopter is intended to carry the equipment, cargo and battery. Radially from the centre the micro engines with rotors are mounted on beams, forming star-shaped layout of copter. Nevertheless such a symmetrical layout assumes presence of front and rear parts considering the direction of flight. During the flight the multicopter maintains relative to ground horizontal position, move sideways, change altitude and hover. In presence of additional equipment the automatic and half-automatic flights are possible. To compensate the twist due to momentum the rotors rotate in different directions. To perform a movement the quadrocopter is needed to be taken out of balance by throttling combinations of rotors. As a result quadrocopter tilts and starts to fly in needed direction. To rotate quadrocopter clockwise the front and rear rotors are spinning-up and left and right rotors are slowing down. The counter clockwise twist is done by analogy (Schmid, 2012).

Multi motor UAVs have several advantages compared to other unmanned and manned aircraft, especially the ability to survey small ground objects with high spatial resolution. Thus multi motor UAV unlike helicopter are more stable in air, less expensive to maintain and easier to control (Barbasov, 2012).

In general multi motor UAV is a universal, efficient and simple type of unmanned vehicle, which can take advantage over traditional helicopter design on the market and become useful instrument for mass media, photo and video industry etc. The greatest interest in UAVs show government agencies and services, which functions are related to the protection, control and monitoring of the facilities, including the liquidation of emergency situations, energy companies, and companies whose activities are related to obtain spatial data (Zinchenko, 2012).

Increasing the autonomy of UAVs and the transition to a fully autonomous UAV-robots working on the basis of the flight plan are made by improving the electronic autopilot and stabilization systems.

Among the existing stabilization systems for which information is not closed, the NAZA system (DJI Innovations, 2013) should be noted – a light, multi-axis control system designed specifically for small aircraft and including a flight controller, gyroscopes, accelerometers and barometer.

The other systems such as Wookong Multi-Rotor stabilization controller and FY-DoS GPS (flight control system for multi rotor LA for commercial and industrial autopilot applications) are belonging to the class of inertial stabilizing systems with hovering and auto-return functions.

All of the mentioned above stabilization systems unsatisfactorily solve a number of specific operations that are relevant for flying robots:

- auto take-off;
- auto landing at given site;
- automatic maintaining of absolute spatial position at low altitudes (hovering) for a long period of time.

The most urgent and difficult problem to solve is a problem of hovering over a given point, as it is most prolonged mode of stabilization which provokes a big deviation from the given spatial point caused by the wind conditions and the drift of the inertial navigation system parameters. Therefore hovering is an advisable check for the developed method of using video data from on-board cameras to stabilize aircraft.

At present the following methods to solve the problem of hovering over the given point are exist:

1. The usage of external markers. Advantages – accuracy and ease of implementation in a limited space (Figure 1). Disadvantages – requires preliminary preparation of area, which achievable only in limited areas.
2. The usage of barometric sensors and inertial navigation systems. Advantages – versatility. Disadvantages – parameters drift, poor resistance to the wind.
3. The usage of satellite navigation GPS / GLONASS. Advantages – simplicity and versatility of the method. Disadvantages – large error, the inability to solve the problem for small heights and areas.
4. The usage of cameras and video processing techniques (Computer Vision).

The second and third methods in its current form are fundamentally inapplicable to resolve problem at low altitudes. The first and fourth methods are potentially useful for implementing, but with certain limitations.

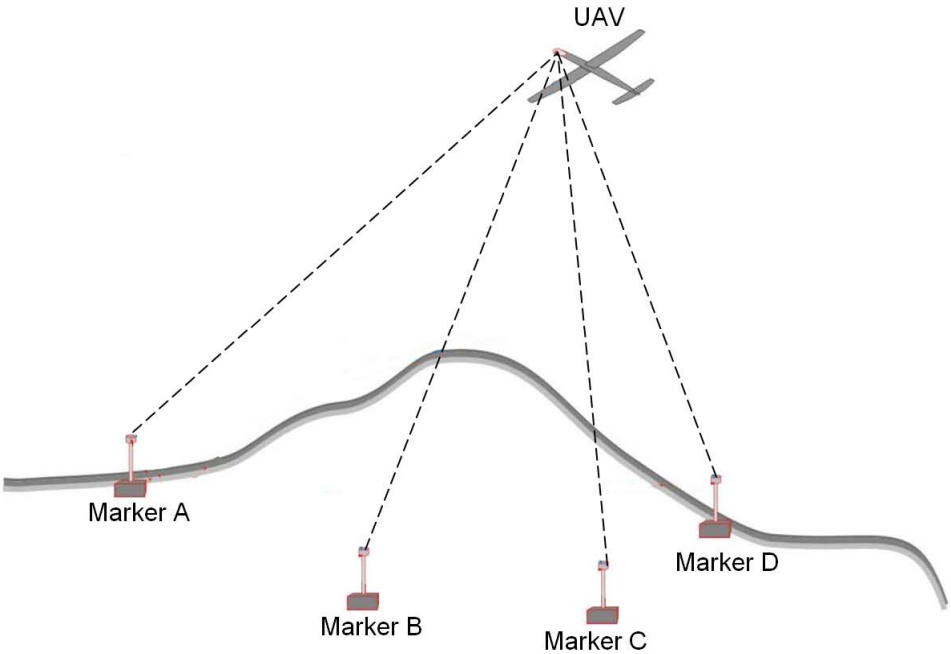

Figure 1. The usage of external markers

The typical accuracy of modern GPS receivers in horizontal plane reaches 6-8 meters given good satellite visibility and correction algorithms. Over the territory of USA, Canada and other countries it is possible to increase accuracy to 1-2 meters using the differential mode. Thus the use of GPS system over other territories for this issue appears to be not efficient.

As a variant of application that utilizes both markers and computer vision it is worth to mention a multicopter collective control project developed by Institute for Dynamic Systems and Control (IDSC) at ETH Zurich (ETH IDSC, 2014). The computer vision system with two or four cameras is used to automatically maintain the given direction of flight. This system achieves high accuracy but needs preliminary prepared workspace because the markers are located on UAV and the computer vision system is located stationary outside the UAV (Ritz, 2012).

In this paper an attempt is made on hardware and software solution for the problem of hovering over a given point at a low altitude for a long time by combining the existing methods without the use of external markers.

2. Algorithm of Motion Compensation Based on Computer Vision

To solve the problem hovering at a given point (the stabilization of the spatial position of the aircraft by the images from the cameras) the analysis of local motion vectors blocks is proposed (VirtualDubDeshaker filter, available in works by Vatolin, Soldatov, Strelnikov, 2011 and Thalin, 2011).

The proposed method tries to find the panning, rotation and zoom combination that, when applied to the current image, makes it similar the previous image. This procedure takes blocks of pixels in the two images and finds the shift that makes them match with least error. The first step determines the motion of the whole image. This is accomplished by reducing the scale of images. The next step is similar to first but it compares images in a scale twice as big and with four times as many blocks. This step is repeated until the motions for all blocks are determined (Figure 2). The last step finds the best values for panning, rotation and zoom based on these motion vectors which are then transmitted to aircraft autopilot control system (Figure 3).

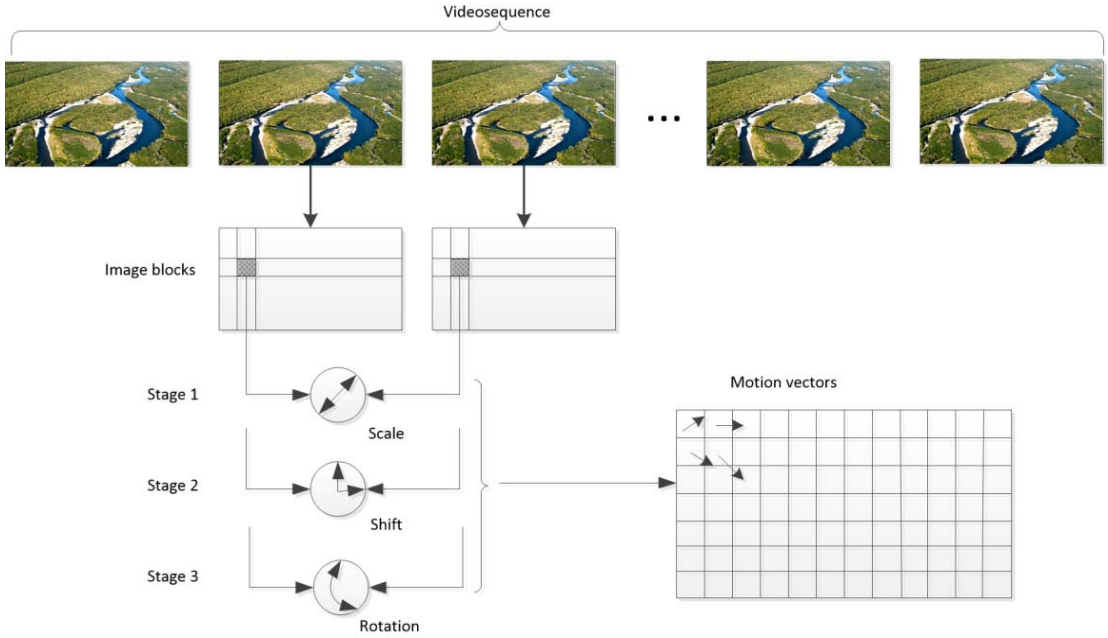

Figure 2. Algorithm of motion vector's determination

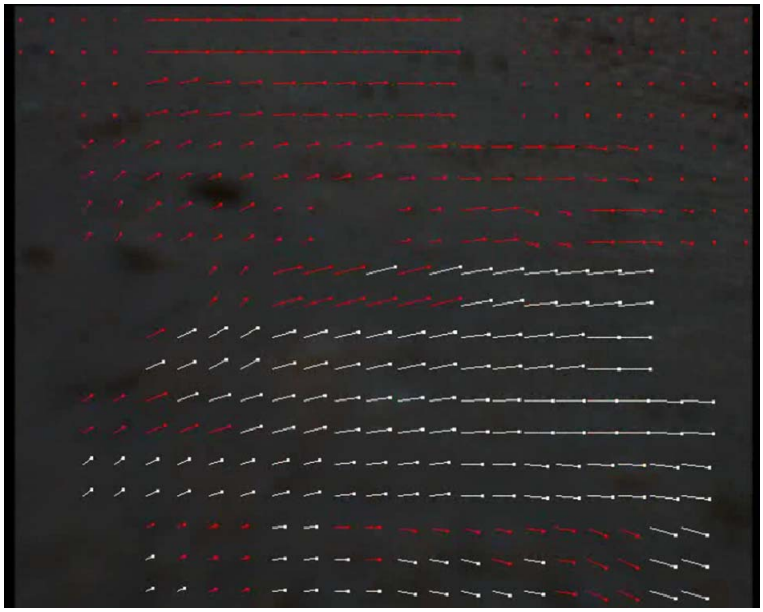

Figure 3. The result of motion estimation step

Using the results of onboard camera images analysis and computation of the camera motion relative to horizontal surface fragment, the control impulses for flying platform engines necessary to maintain given spatial position are forming. To eliminate the influence of tilt (roll and pitch values) in the processing the instantaneous values of the angle obtained from an inertial navigation system, in particular a gyroscope are used.

The proposed algorithm has a limited usage in conditions of low contrast low sharpness image of a horizontal surface, which may be due to the properties of the surface (i.e. water), limited visibility associated with weather conditions, as well as to the lack of surface lighting.

3. System Realization

The electronic control unit for an autonomous UAV is proposed to implement as a multiprocessor system, implemented in the form of a "system on a chip" (SoC). For reliability the automatic control system (ACS), which forms the controlling influences on the servo motors, is separated from the processor that analyzes images from onboard cameras and performing flight mission (Figure 4).

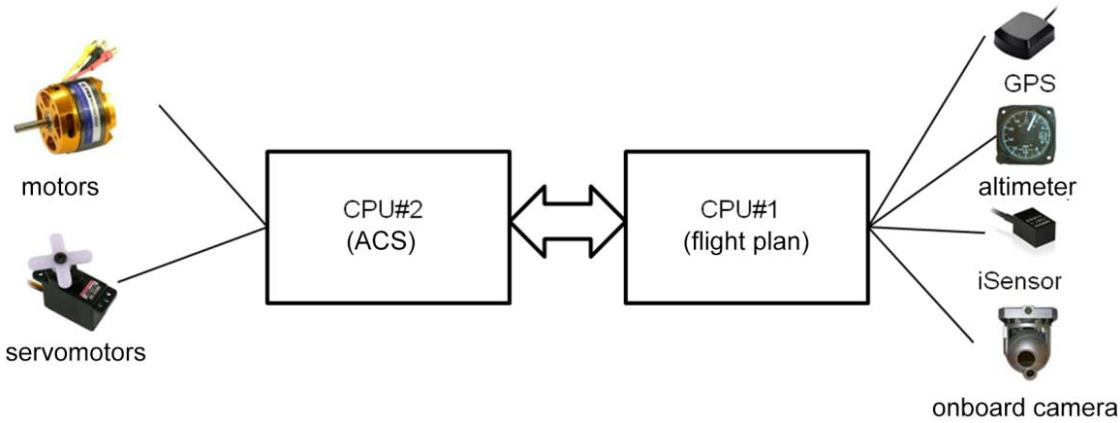

Figure 4. The structure of software-hardware components interaction

Physically, both processors are implemented on FPGA Altera, which also comprises peripheral memory controllers, interfaces for interfacing with the radio module and decoder (Figure 5).

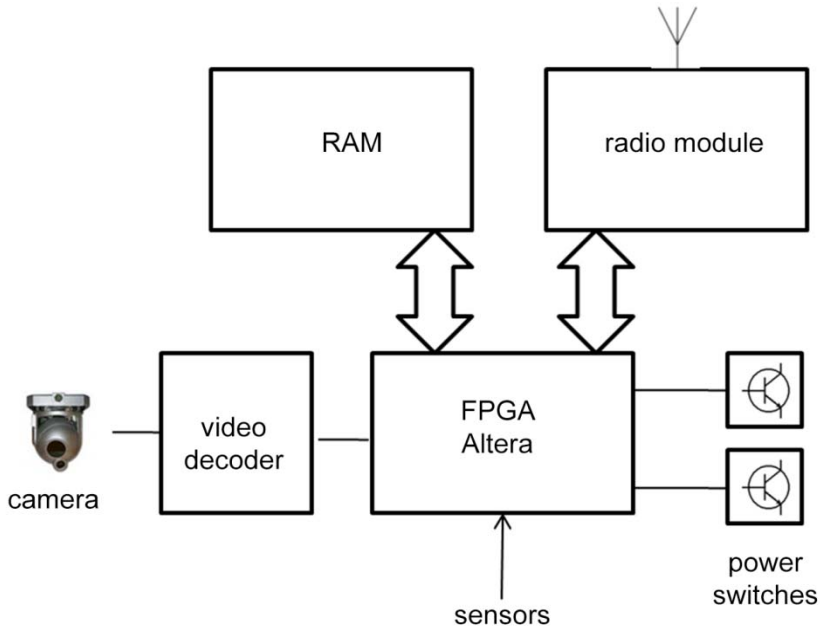

Figure 5. Structural schematics

The peculiarity of the use of GPS systems is the presence of errors, resulting in the emergence of coordinate errors and, consequently, the spontaneous movement of the UAV near the point of equilibrium in an attempt to compensate for the change of coordinates, caused by the error. The error value reaches tens of meters, which is unacceptable on ultra low altitudes. Therefore, the efficient usage of satellite navigation systems in the stabilization system (Figure 6a) is determined by topography and the mission and is only possible for altitudes greater than 2.5 m (Barbasov, 2012).

On the other hand, the efficiency of the optical stabilization system decreases with increasing altitude (Figure 6b), due to the limited spatial resolution of the final matrix of photosensitive cameras and limitations on focus range of optics used in it.

As a solution that combines the advantages of both systems and giving the ability to perform tasks of hovering over a given point, accurate take-off and landing, it is proposed to use a combined optical stabilization system based on the methods of motion compensation and stabilization system based on GPS (Figure 6c).

The decision on stabilization mode can be made on the following principles:

- on exceeding the altitude threshold on the barometric sensor (nominal change of stabilization mode),
- on ground command (forced change of stabilization mode),
- on flight plan,
- on inability of using onboard camera images due to weather conditions, lightning conditions or unsuitable horizontal surface (emergency change of stabilization mode).

4. Conclusions

This paper proposes a way to solve the problem of small sized UAV hovering over a given spatial point (maintaining of absolute spatial position) at a low altitude for a long time. The proposed method combines the advantages of existing systems and gives the ability to perform hovering over a given point, the exact take-off and landing. The main feature of method is the combination of optical stabilization system based on motion compensation methods using the computer vision, and stabilization system based on GPS. The limitations of implemented methods are determined and the algorithm is proposed to combine them in order to improve the efficiency.

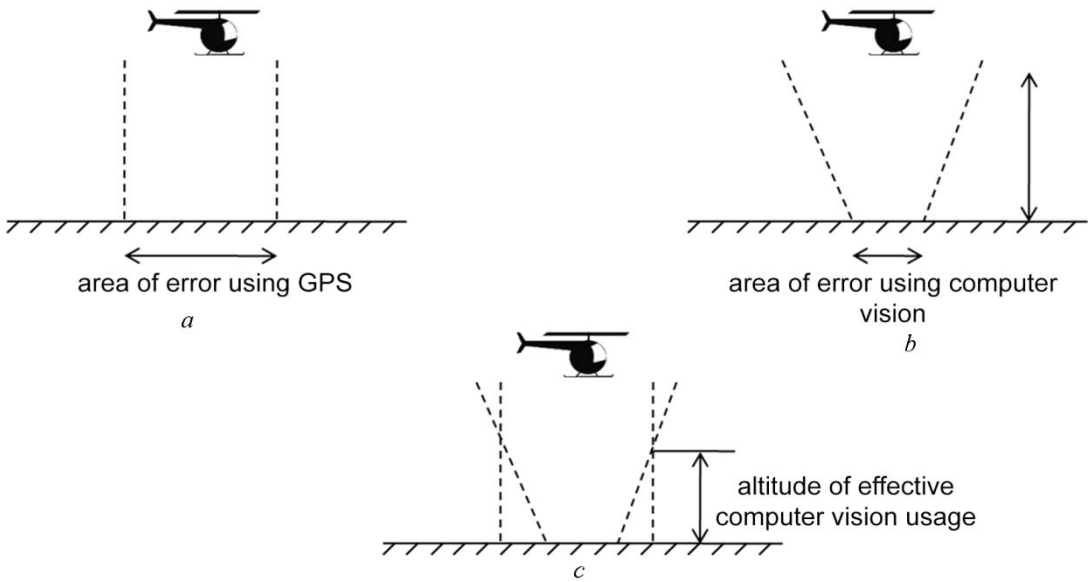

Figure 6. Usage of computer vision for UAV spatial positioning

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Transport and Telecommunication, 2014, volume 15, no. 3, 215–226
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/ttj-2014-0019

DIGITAL ADVERTISING SYSTEM IN URBAN TRANSPORT SYSTEM OF ŽILINA TOWN

Radovan Madleňák[1], Lucia Madleňáková[2]

The Faculty of Operation and Economics of Transport and Communications
University of Žilina
Univerzitná 1, 01026, Žilina, Slovakia
[1]Phone: ++421/41/5133124. E-mail: radovan.madlenak@fpedas.uniza.sk
[2]Phone: ++421/41/5133125. E-mail: lucia.madlenakova@fpedas.uniza.sk

The Internet and information and communication technologies (ICT) have changed everything: news, commerce, advertising, relating to others, getting information and transport too. It has changed how the people work, how they practice religion, how they date, how they spend the free time and how they travel. One of the technological innovations that are based on usage ICT in advertising space is digital signage. This article presents the results of research dedicated to investigate the relationships between customers-passengers and this new ICT technology in real environment. The results of the research stimulate the discussion about the future advertising practices in Žilina town. Based on the wide analysis of opportunities the digital signage technology in advertising practices, the presented marketing research investigates how passengers accept virtual advertising technology in urban transport system of Žilina town. Authors highlight the advantages of interactivity between digital signage technology and consumers. The conclusions of this article triggers further investigations in the area of the interactions between the digital advertising technology and passengers, and the passengers' perception and acceptation of shopping activities on the basis of advertising in digital signage medias.

Keywords: digital signage, marketing digital media, transport system, calculation, ROI

1. Introduction

Advertisement is all around us. We cannot avoid the contact. Products and services do need advertisement to increase their awareness. Marketers utilize all possible places and methods to catch customers' attention.

There is no guaranteed evidence of the first advertisement. Some specialists consider wall paintings in the caves as some sort of advertisement. We can certainly say that advertisement exists as long as the surplus production. When people started to produce more goods than they were able to consume they needed to barter them for something else. The easiest way how to capture the attention was shout the slogans loud. The Slovak word for advertisement ("reklama") has its origin in Latin. Re-clamo means shout repeatedly (Reklamu.cz, 2014). The voices of the sellers were used as the medium how to deliver the advertising content to the ears of buyers. In the noisy crowd of markets sellers needed specific vocal resonation, vocal registration and remarkable content to distinguish their offer from other sellers.

Advertisement on papyrus was used in Egypt to spread the commercial messages. Similar method was used in Pompeii and ancient Arabia especially to spread political messages. To capture wider audience, they even carved their messages on rocks and walls. In the Middle Ages the population lacked of education and there were only few scholars. Therefore sellers used signs to attract customers. Similar signs are still used nowadays although they are replaced with new types of advertisement (Mogel, 1993).

Advertisement experienced rapid development after the year 1447. It was the year when Johannes Gutenberg invented printing. Therefore sellers could spread their messages faster, easier and more efficient.

The remarkable name connected with advertisement is Théophraste Renaudot, the first French journalist. As a reaction to the poor situation with unemployment in Paris, he created message board for those who offer jobs as well as for those who were seeking for the free positions. To propagate this idea he established the first French newspaper La Gazette in 1631 (the title has its origin in Italian currency unit – gazetta) (Tungate, 2007).

Another French newspaper, La Presse, published first paid advertisement in June 1836. This lowered the price of the newspaper as part of the costs was covered with money made from advertisement. Seeing that this method appeared to be very efficient other newspaper adopted it as well (Burde, 2009).

First public radio broadcasting took place in United States of America in 1906. Even though started radio KDKA in Pittsburgh in 1920 regular broadcasting and British BBC in 1922 (Holakovsky and Rakovsky, 2014).

As the operation of radio requires money owners soon realized that sponsoring is very efficient way how to cover the costs. At the beginning each radio program has its own sponsor. This turned out to be less profitable. For that reason radio owners started to sell short time allocations during the broadcasting as commercial time. Radio started to lose influence after the Second World Word with the beginning of television broadcasting. However in the 1970s with introduction of FM broadcasting listening to the radio became fancy among young generation again. New radio stations appeared and covered niche market places offering different styles of music. This brought great opportunity to advertisers to apply target marketing.

Initially radio station BBC started with television broadcasting in previous century. First reporters spoke to the viewers from Alexandra Palace in London on November 2nd 1936. Although the Second World War interrupted television broadcasting for a while after the end of the conflict television influenced population even stronger. The very first television commercial was shown on WNBT station in New York. Bulova Company advertised its watches before the baseball game on July 1st 1941 with the slogan "America runs on Bulova time" [12]. Sponsoring widely used in radio broadcasting was employed in television as well. Movies and programs were interrupted with commercial breaks. Sponsoring of the whole program was used very rarely. Impact of television advertisement rose up with the introduction of cable television. Specialized stations with commercial content were introduced to the viewers. They could order the products via phone directly to their home any time a day. This was new method how to reach the customers.

In the late 1990s the Internet boom overloaded the advertising market. New types of shops started to emerge. Traditional "stone" shops were complemented with their online versions and even pure online shops succeeded on the markets. The so called dot-com bubble reached its climate on March 10th 2000. Stocks of companies that offered their product online increased their value rapidly during this period of time. Some real benefits arose from the Internet for the marketers. Target marketing achieved new dimension.

One-on-one marketing enable communication with potential customer more effectively. Geographic distances are no longer obstruction for purchase. Customers can order products online and receive them very next day via express delivery service e.g. DHL or UPS. In comparison with traditional "stone" shops, online shops are open twenty four hours per day and seven days per week. Customers can purchase online from the comfort of their homes. Internet offers new distribution channel as well. Products such as software can be delivered online what eliminates intermediaries and lowers the price.

One of the new and perspective marketing techniques is the digital signage. It is a type of out-of-home advertising. Some companies use different names for digital signage to differentiate from others. Therefore we can come across names like narrowcasting, screen media, place-based media, digital merchandising, digital media networks and digital out-of-home or captive audience networks. Disregarding various names it is still just one product of mass marketing (Tungate, 2007). There are many possibilities where to implement digital signage. The list is not completed and places depend on the company, which is installing this type of advertisement. However, there are certain places where we come across digital signage more often.

One of the common applications of digital signage is for public information. Municipalities install interactive touch screens on the places with high visit rate. Inhabitants and tourists can easily find shops, historic monuments, sport centres or even look for free job positions. This type of digital signage considerably complements info centre and increases amount of points of contact with citizens (Madleňák and Mitrev, 2006).

Digital signage is implementing as internal information channel in companies. Employees are informed about corporate news, goals, missions, visions and internal rules via digital screens placed on frequented areas in company buildings. We can come across this type of digital signage in banks for example. Companies are promoting their own products and direct customer's attention to special offers.

Huge stores can implement digital signage to help customers find different types of products instead of traditional cardboard signs. Screens also make waiting in the lines less unpleasant. They are also successfully utilized for enhancing the environment. Now we have continuously shifted to the main application of digital signage – advertisement. Although there are many opportunities for digital signage that have not been utilized yet, advertising campaigns are the most promising and most profitable application of this marketing tool.

"Flasma" is another innovative method of digital signage implementation. The idea arises from the walls overloaded with commercial messages. Customers therefore walk with their eyes stick to the floor. And floor has not been utilized for commercial purposes enough yet. This innovative approach can be successfully used in shopping malls and pedestrian zones.

2. Analysis of the Digital Advertising Systems – Global Entertainment Media

GEM is a shortcut for Global Entertainment Media. It is a software solution, which enables its users to display different type of digital content on the screens. It is most suitable for public locations, e.g. urban mass transportation, train or bus station, airport or even shopping malls. This concept has got its origin in Slovenia. Therefore the first testing took place in Ljubljana, capital of Slovenia. GEM comprise of three main parts: server, network transport, location player and displays.

- Server is running a standard Microsoft Windows Server Operation System. It is a central point for manipulation and communication. It provides the playlists, RSS feeds, real-time content, etc for the screens. SQL database is the foundation for the web-based GEM Interactive server software used for the management of the system.
- Network transport could be wireless or fixed line. It depends on the type of the location. Network transport enables communication between server and location player. It is not necessary to have wireless connection however when the advertisers want to deliver real-time content, this type of network transport is essential (Vaculík, Kolarovszki and Tengler, 2012).
- Location player is the binding point with customers. It displays the content according to the request from the server.
- Displays have to be very tolerant to temperature and humidity, especially in public transport.

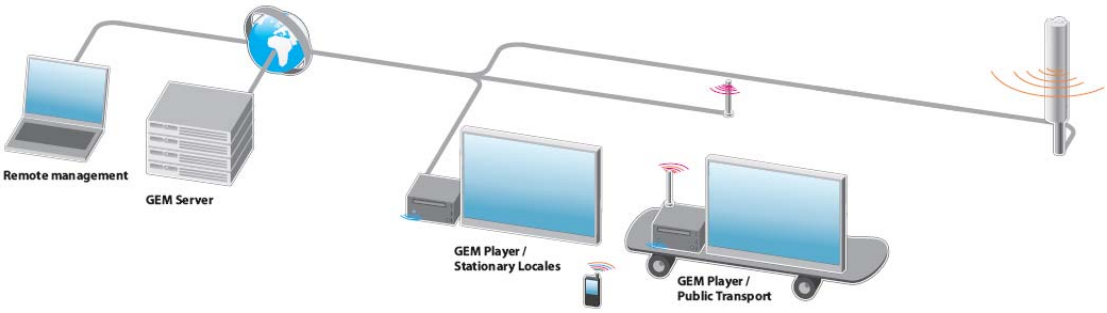

Figure 1. GEM Interactive communication

Generally GEM combines three technologies in one solution. Firstly, there is positioning, usually GPS. If you want to deliver up to date content according to the place, you need to know what your actual position is. Secondly, there is mobile telecommunication. As long as the concept is interactive, there has to be a possibility for back coupling from the users. And, finally, there is digital signage.

2.1. GEM Usage - Public transport

One of the most suitable places where to apply GEM Interactive is urban mass transportation. Anyhow all kinds of public transport are appropriate for digital signage. There are clearly several benefits for passengers. Travelling and especially commuting could be tiresome. In public transport there is no time and no place to start any kind of work. Passengers are therefore looking around for some entertainment. Advertising posters become boring very soon. Changing them every other day is very expensive and therefore impossible. Advertisers are searching for new ways of delivering the content to the customers more effectively. They discovered opportunity in using digital screens on frequented places, e.g. buses, trams or trains. They can capture broad masses of different segments of customers. It is much easier to deliver the right content to the right segment because it is predictable who is travelling on which bus line on which time.

GEM Interactive is based on two different triggers – time trigger and GPS trigger as you can see on Figure 2. GPS triggers initiate advertising content with regard to the location. As the bus enters the geographic cell of opera house for example, its computer gets information about it. As the result the commercial for new opera play appears on the digital screen. Passenger can even book the tickets via SMS.

Very efficient method how to attract customers is offering them bonuses. Shops in big malls can use GEM Interactive to offer discounts in the form of number code as a counter value for SMS. In the geographic cell of shopping mall the commercial for clothing store appears on the screen. It invites passengers to visit the store. If they send SMS with the key word on the given number they receive SMS with number code, which can be used for discount in the store (Hrudkay, 2011).
Second type of trigger is based on time. In some areas where no shopping malls, no theatres and no other amusement facilities are is no need for commercials. For that reason news or weather information can be shown. Time triggers initiate the content according to expected time in timetable. However this type of trigger is not that reliable because of traffic jams, for example (Kolarovszki and Dúbravka, 2010).

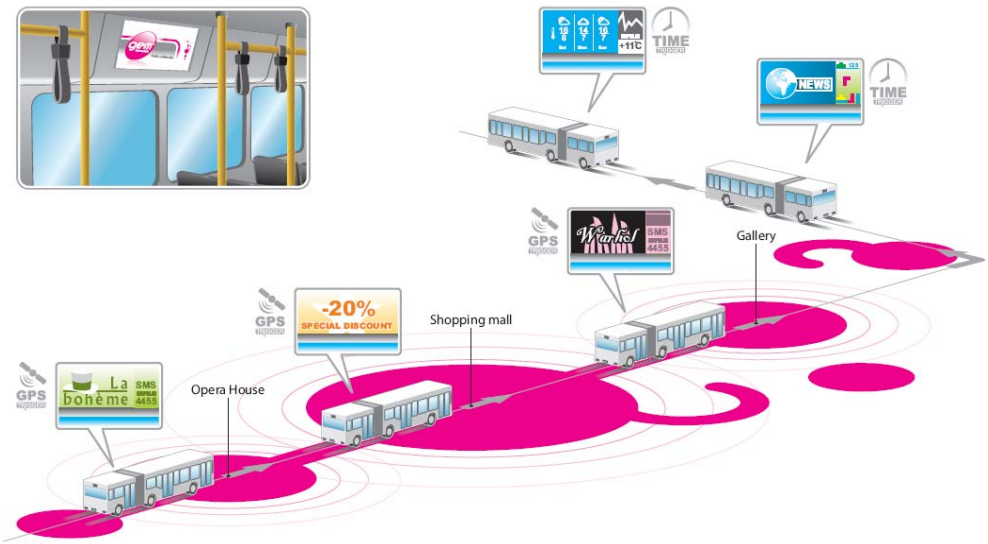

Figure 2. GEM Interactive triggers (Prumaro Interactive, 2012)

2.2. GEM usage - Stationary locations

Every frequented location or even a place where people are waiting in the line is a great opportunity where to capture customers. Digital screens are appearing on newsstands, in stores, in stations, on squares or in the airports. It is not enough to bring the content to the customers. However GEM Interactive brings new ideas. Accordingly to that it is more attractive for advertisers.

Figure 3. Examples of GEM Stationary kiosk in Ljubljana (Prumaro Interactive, 2012)

It is not necessary to bring the advertising content. Using GEM Interactive in stations and terminals can make the waiting less boring. Offering passengers pricing games, news, voting and content influence makes the travelling and commuting more interesting and it can create lifetime relationship. People tend less to switch to private transport when it is possible.

3. Methods and Methodology of Research

Nowadays companies, especially because of the complicated economic situation, consider their investment very carefully. Although marketing research cost money as well it can save much more than money when it is accomplished right (Madleňáková, 2005). Companies that do plan to implement digital media network as their marketing tool need to perform in-depth study. As digital signage is not wide spread in Slovakia and nor in Žilina we need to collect information about the awareness among residents and their interest in this advertising tool.

There are many types of marketing research process methods. They are basically the same and differ only in the number of steps. On Figure 4 we can see one of the possibilities of marketing research process.

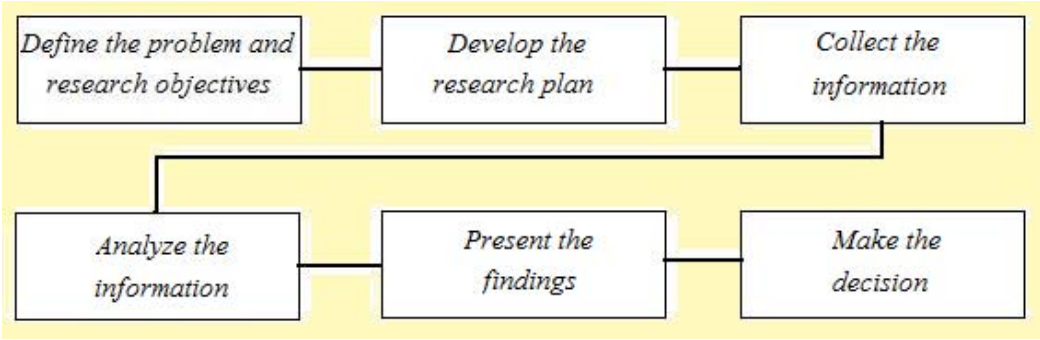

Figure 4. Marketing research process (Kotler and Armstrong, 2006)

This six steps method includes many subparts. We will go through the first five steps and will skip the last one. As this is marketing research focused on awareness of the digital signage it will not contain calculation of the digital network implementation. The last step will be skipped because it is not in our competency to make decision whether implement the system or not.

3.1. Defining the problem and researching objectives

To define the problem properly can help researchers to find the way how to solve it. Although it appears that this step is very easy, most of the failures of researches arise from bad definition of the problem. Sometimes managers set the problem too broadly and therefore get information they do not need. On the other hand problem defines too narrowly does not bring enough information to solve it (Kotler and Armstrong, 2006). As digital signage is not widely used in Slovakia and is only at the beginning of its era we will consider on *three problems*:

- Do customers use urban mass transportation lines in Žilina, which can be effectively involved in digital media network?
- Do customers know about digital signage and how do they perceive it in comparison with printed posters?
- Would passengers use the opportunities that are offered by digital signage?

We will consider on implementation of digital media network in urban mass transportation in Žilina, as GEM System is designed for public location and urban mass transportation. The testing period in Ljubljana was good success and brought a good start point for system expansion.

3.2. Developing the research plan

Researchers can utilize two types of information, primary data and secondary data. Secondary data represent information that was collected for other purposes. This type of data is available for free or for a fee. Researchers use this information usually at the beginning of the project. They try to find secondary data that will help to solve the problem at the lowest cost. However this type of data is often obsolete, incomplete and not too suitable as they were collected for other purpose. Researchers are therefore compelled to collect primary data. Primary data represent information that is collected for special reason for the first time. There exist several types how to gather primary data e.g. observation, focus groups, experiments and more (Čorejová and Imrišková, 2008).

In our research we will collect primary data. This sphere of marketing and advertising has not been investigated enough yet. Digital signage in urban mass transportation is sort of innovation in Slovakia. For the purposes of the research we will consider on two customer's segments. Segments will be divided on the basis of demographic – specifically on the age. Millenials is the so-called demographic group, which members were born between 1979 and 1994 (Strauss and Frost, 2008). This group is very promising for marketers. More than 90% members of this group use Internet and therefore we will conduct online survey. 80% members have mobile phones. These findings help us to solve two problems we have established in the first step of our research process. As Millenials is big group we will divide it in two subgroups. First subgroup Segment A – will include 18 to 24 years old people. Second group Segment B – will include 25 to 33 years old people. The questionnaire includes eleven questions. We can aggregate questions in four parts. Three parts help us to solve the problems we have determined; and the fourth part separates respondents into two subgroups according to their age.

3.3. Situation analysis

The first part of the questionnaire is oriented on the public transportation analysis. We need to know whether Millenials use urban mass transportation in Žilina and if so how often they travel. There is one question oriented on the lines, which serve areas with shopping malls as we can see on Figure 5.

Figure 5. Map of the urban mass transportation in Žilina (Valašková and Križanová, 2008)

In Žilina there are five existing shopping malls that can utilize digital media network in urban mass transportation and few shopping malls is under construction. Already existing shopping malls are OC Atrium Dubeň, ZOC MAX Žilina, TESCO Hypermarket, Aupark Žilina and OC Mirage. Aupark Žilina has a place for hundred and thirty shops. TESCO hypermarket does not include variety of different shops but it is a part of successful business chain. Line number 99 is serving the area of these shopping malls (Aupark and TESCO) for free and it is called TESCO bus. Other lines are called MAX BUS and MIRAGE BUS that serves the area of ZOC MAX and OC MIRAGE. To enable its services to more customers, owners of ZOC MAX and OC MIRAGE, supports these lines.

OC Atrium Dubeň offers seventy-four shops and services for its customers. ZOC Max offers even more – over eighty shops and services and five cinemas. This represents huge concentration of potential digital media network advertisers on one place. OC Mirage is new shopping mall situated in the centre of Žilina town. It offers ninety shops and four cinemas for its customers.

There are also future plans for other shopping malls in Žilina. One of them called multipurpose project Štadión will be completed in next five years. Not only can shopping malls exploit the opportunities of digital signage in public transport. Cultural and sports centres can display advertising for their events as well. However shopping malls represent areas with great density of shops and services in more or less small place. Therefore bus lines, which serve shopping malls areas, create great opportunity for digital media network.

3.4. Awareness of digital signage

The second part of questionnaire is dedicated to awareness of digital signage. Although people come across this type of marketing tool they often do not realize it is digital media network. Digital signage is mostly compared with printed posters as we have already mentioned in introduction section. As printed posters have been here for a long time so far it is necessary to understand whether people are ready to accept new type of advertising media. Another aspect that is investigated by these questions is interest in present advertisement in urban mass transportation. If we want to implement new type of advertising tool we need to be sure that the previous one draws enough attention. Afterwards digital signage with its target marketing and interactive content will create even greater effect.

If investors in digital signage make decision about the project they need to know whether it will have sufficient response. GEM System offers two opportunities for viewers how to interact with it. SMS field which enables displaying content created by customers e.g. greetings and interactive field which navigates viewers how to communicate with GEM System. Both services are provided by SMS communication.

3.5. Collecting the information

Survey was conducted online and was available at: http://fped.uniza.sk/. It was created on April 3rd 2012. To reach relevant results, we needed to collect two hundreds responses all together, one hundred for each age segment. Another specification was that respondents have to live in Žilina so they are familiar with situation in urban mass transportation.

In order to be able to accurately project the results of a survey question from the sample to the entire population of the target market, the correct sample size must be used. The correct sample size can be calculated using this formula:

$$n = \frac{z^2_{1-\alpha/2} \times \sigma^2}{H^2} = 195 \tag{1}$$

in which:

n = Sample Size;
Z = Level of Significance (Expressed as a Z-Score);
σ = Population Standard Deviation (σ2 = Population Variance);
H = Acceptable Amount of Sampling Error.

The respondents of the questionnaire were the representative sample of population from Žilina (we set confidence interval estimate at 95% (a probability of a sample error of 0.05 has an associated Z-score of 1.96)and acceptable margin of error at ± 7%). The minimum numbers of respondents was set at 195.

We used many types of communication tools to reach people. Facebook as social network offers lot of possibilities for marketers. We could send the link directly to people who live, work or study in Žilina. Not only to those who are in our private network but also to anyone else who has created online profile on Facebook and filled the information about the hometown or joined the group that is connected with Žilina. Good example is group Žilina Slovakia that connects people living in this city. We could utilize the so-called wall to place the link publicly or choose members of this group to send them private message. As we needed just certain age segment we chose the second option – private message to people.

We had to control proportion of each age segment to have enough responses for both. At the end of this step of marketing research process we were ready to analyse the information.

4. The Results of Survey

4.1. Analyzing the information

When we collected enough responses we could move to the fourth step of marketing research process – analyse the information. At the beginning we needed to create the code list for the questionnaire. We set numerical codes to every question. To easily work with the responses we did the same with the answers. After that every word answer was transformed into numerical answer. When code list was done we started to process the responses. Last question was about the age of participants. This helped us to divide the Millenials group into two subgroups. Segment A included responders in the age

15 to 21 years. This subgroup got numerical code 1 in last question. Numerical code 2 was given to segment B that included the older subgroup, responders in the age 22 to 30 years.

Outcome of the fourth step of marketing research process was research matrix. It gave us greater opportunity to work with the responses much faster and use simple mathematic calculations to get the results. We used spreadsheet program to analyze the responses and create outputs. When the responses are in the form of research matrix we can use different angles of vision on the problems and find the best possible solution.

4.2. Presenting the findings

As we have already mentioned in previous chapter, we aggregated questions into four parts. Last part has already helped us to separate respondents into segment A and segment B so we can compare them. Average age of segment A was nineteen years and eight months. Average age of segment B was twenty-three years and four months. Other three parts are composed to find the answers on these problems:

- Do customers use urban mass transportation lines in Žilina, which can be effectively involved in digital media network?
- Do customers know about digital signage and how do they perceive it in comparison with printed posters?
- Would passengers use the opportunities which are offered by digital signage?

As investment into digital media network requires lot of money and effort we wanted to be sure that urban mass transportation is suitable for that. Advertisers are looking for places with big amount of passing people who spend some time there. 85% of respondents use urban mass transportation in Žilina on a regular basis. 3,5% of respondents use it sporadically and only 11,5% of respondents do not use urban mass transportation at all. On Figure 6.we can see the frequency of travelling. We can state that in town Žilina exists potential for usage of digital signage advertising in urban transport.

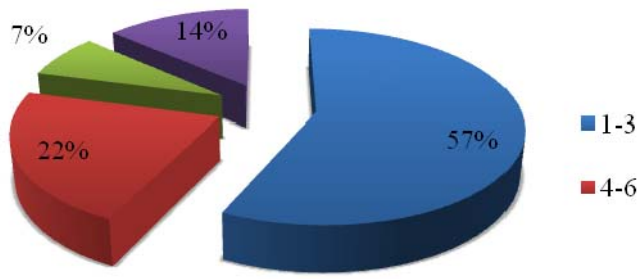

Figure 6. Frequency of travelling

The most utilized bus line is number fourteen which serves the area of ZOC MAX and TESCO hypermarket. Second one is line number four which serves the same area. The bus lines number three and five are on the third place that operates in the area of OC Aupark. On the fourth place is the bus line number six, which operates in the area of OC Atrium Dubeň. As we can see the most utilized lines serve areas with existing shopping malls. Implementing the digital signage in these lines at the beginning of the project would have impact on many passengers and potential customers of shopping malls. It might be interesting to investigate whether the amount of passengers of lines, which will serve, are of Štadión project would increase when the shopping mall will be finished.

Digital signage is implemented in many different spheres of use. However people often do not realize it actually is digital signage. Average age gap between segment A and segment B was three years and eight months. This age gap represents considerable difference in awareness of digital signage between the segments. 59% of all respondents did not come across digital signage or were not sure about that. However, it was 64% in the segment A. On the other hand in the segment B it was 10% less that means 54% respondents of segment B did not have experience with digital signage. This might be caused by greater opportunities of the older segment to travel abroad, for example, because of exchange studies or internships. This segment contributes of employed members more than segment A. As we have already mentioned digital signage is utilized in companies to inform their employees about actual events in the company or on the market.

Figure 7 shows awareness of the digital signage and places where respondents came across it. As we can see people have already noticed multimedia screens in shops. Many of them, especially in segment B, know digital signage from foreign countries. Many respondents commute to Žilina and have noticed the screen in train station, which displays short informative presentations about railways.

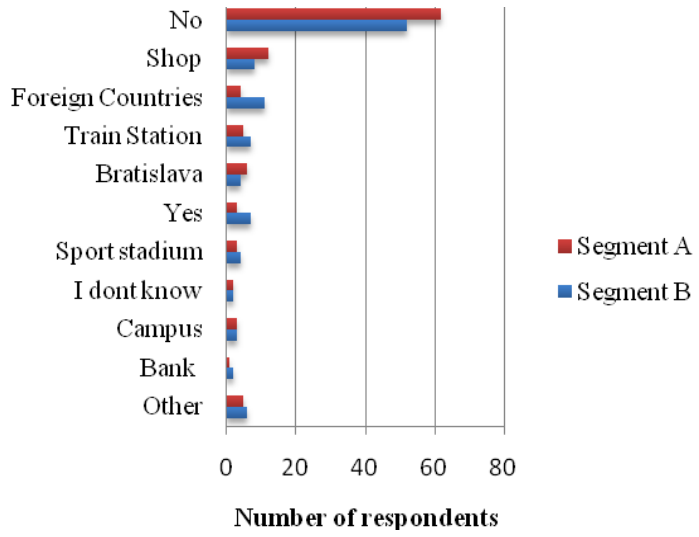

Figure 7. Contact with the digital signage. Segment A and B

Printed posters still have strong position on the advertising market. However the power of moving pictures is stronger. Both segments, as we can see on Figure 8, are attracted with digital signage more than with printed posters.

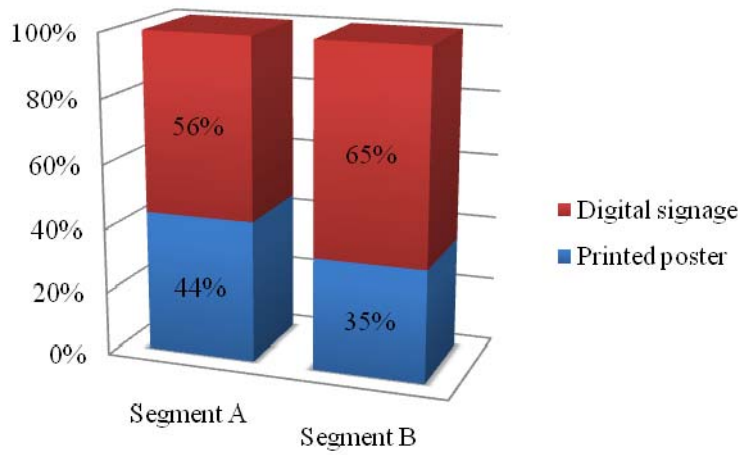

Figure 8. Digital signage versus printed poster

Another question was dedicated to interest in printed posters in buses. This helped us to ensure that advertisement in urban mass transportation has impact on viewers and still captures their attention. 25% of respondents notice printed posters regularly and 71% notice just sometimes. Only remaining 8% do not pay attention to printed posters in buses at all. When advertisers would be able to bring more attractive commercial content to the buses they could gather even more viewers and therefore customers. Digital signage offers this in one solution and urban mass transportation provides viewers, which have to stay at the same place for a longer time.

It is necessary to make sure whether passengers even want to have digital media network in buses and whether they would utilize the services that are offered by digital signage. It is common that younger generation is more open for new technologies and new appliances (Madleňák and Švadlenka, 2009). They connect with their friends online and share their opinions and feeling publicly.

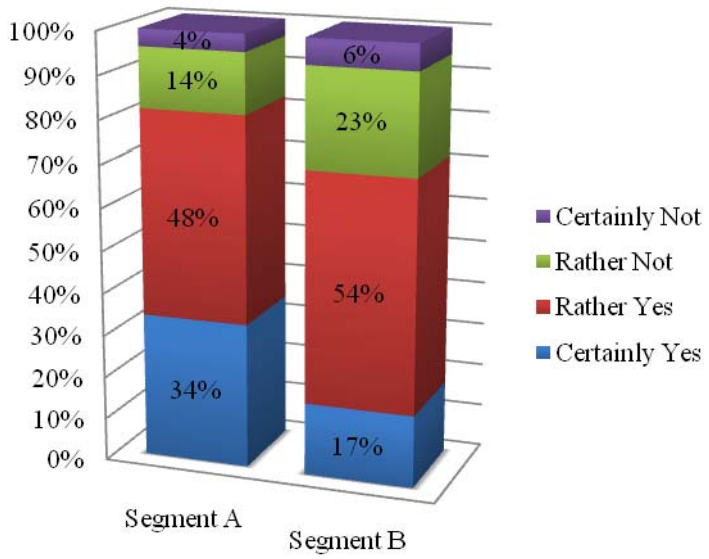

Figure 9. Interest in digital signage

As Figure 9 shows more than three quarters of all respondents would appreciate digital signage in public transport in Žilina. The difference between segment A and segment B is 11%. This confirms *the theory that younger generation is waiting for new trends and is ready to implement them in their daily life*. More than three quarters of all respondents also give investors good point to think about the digital media project more deeply.

GEM System offers *two opportunities* for passengers how to interact with it. The first is *entertainment SMS*. Interest in this service is almost the same in both segments. 53% members of segment A and 52% members of segment B would use this service. However, the difference is in the certainty. More members of segment A are sure they would use entertainment SMS if available than members of segment B. Figure 10 shows us the opinions of respondents about entertainment SMS.

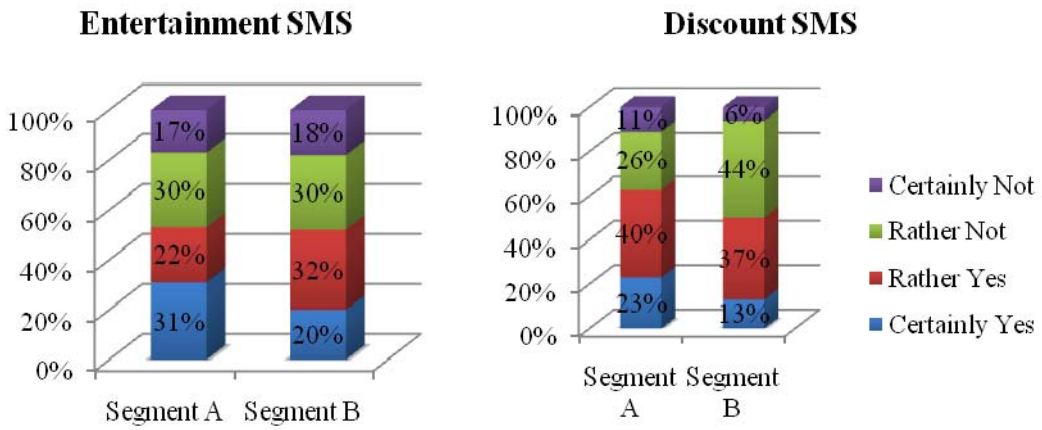

Figure 10. Entertainment SMS versus Discount SMS

The second opportunity for passengers offered by GEM System is *discount SMS*. This service is offered in cooperation with advertisers. 63% respondents from segment A are ready to use the opportunity to obtain discount as a counter value for sending SMS according to instruction on digital signage. 50% respondents from segment B are ready to do the same. Offering discount and small presents would lure more customers to the shopping malls. Figure 10 shows us the amount of respondents, which are or are not ready to utilize the opportunity of discount SMS.

4.3. Economic Evaluation – Calculation of ROI

The most similar advertising method to digital signage is printed poster. To understand advantages of digital signage in comparison with printed poster we have to take a look on ROI (return on investment) of both advertising tools more deeply.

In a short time period it might appear that printed posters have more favourable ROI. However we cannot consider building of digital media networks as short-term project. As digital signage is mostly applied in food, retail, transport and entertainment sectors for sales promotion we will compare the ROI for them.

As it is suggested for bigger networks, minimum number of locations is 500. Commercials for mentioned sectors change more frequent intervals. However digital signage has not been implemented broadly in Slovakia therefore we will choose weekly content update interval. Investment in digital signage is long-term business, especially in urban mass transportation, as we will consider on implementation of this technology in vehicles of urban mass transportation Žilina. Five years operation lifecycle is therefore the most suitable. Calculation is made for 32" full-colour screens. As the prices of screens are decreasing companies can even reduce the initial installation cost. The calculation is made in euro. The cost of digital signage project is calculated on 100000 €. Average cost per digital sign is 2000 € and monthly maintenance fee per digital sigh is 35 €.

On the other hand average cost of printing per poster is 25 € and average distribution cost per location is 36€. For the conditions we have chosen we get 2150000 € cost savings for digital signage in comparison with printed posters. ROI represents 263%.

We can see a lot of the reasons of printed posters' inefficiency. The poster holder is not working properly and the poster is therefore dropping out. Such a problem cannot happen on digital screen. Commuting to work is everyday occasion and printed posters in mass transportation do not have strong enough impact. Changing posters every day on 500 locations during 5 years period would cost 54750000 €. When we compare it with 2150000 €, which are needed for digital media network at the same size, we can definitely understand the advantage of investment into new technologies.

5. Conclusions

This research is dedicated to the advertisement and new methods of delivering commercial content to the customers. We mentioned many possibilities that can be utilized to capture people "on the go". This gave us good overview of the present and future situation on the commercial market. We introduced very effective digital signage system called GEM Interactive. We consider on the implementation of this media in urban mass transportation in Žilina. We conducted survey among "Millenials" in order to gather the necessary information. It is group set by the age of its members. It contributes only by people who were born between the year 1979 and 1994. It is a segment of people who are very open to new technologies. According to the responses we were able to help to find the answers to the problems we had set at the beginning of the marketing research process.

However the results presented in this paper are only introduction to the whole concept. Before the investment into digital media network in urban mass transportation further investigation is needed. We considered only on passengers. Whether there even is interest into digital signage. Now as we know that people are ready to accept this type of advertisement and would like to use its opportunities it is desirable to focus on advertisers, shopping malls and provider of public transport in Žilina. This might be topic of another research. Financial calculations are needed as well. Although we pointed out that ROI of digital signage is much bigger that ROI of printed posters it is necessary to support the project with other calculations according to the conditions in Slovakia and Žilina.

Findings on survey verify the interest in digital signage among people living in Žilina. Interest in GEM System's products for passengers is over 50% in both cases. This means that conditions of Žilina town are suitable for implementing digital signage advertising system in urban transport. Most utilized bus lines serve the areas of shopping malls that even strengthen the impact of digital media network. The significant challenge is in knowledge of digital signage forms. A lot of respondents from both segments do not know the digital signage advertising system, so there is a key success factor of this project. If the passengers will know then they will trust these forms of advertising in urban transport system. The great opportunity for passengers is a possibility to interact with this advertising system. There are two forms of interaction entertainment and discount SMS. The results of the research shows that passengers want to use these forms of sales support. They prefer the discount SMS more than entertainment SMS. But there is a significant finding that passengers from older segment do not accept discount SMS rather younger segment. It looks that older population of Žilina town has a more experiences with discounts and they are a little bit conservative with discounts. Again there is more space to convince

citizens of Žilina town about the credibility of the digital signage advertising system. All these findings ensure us that implementation of digital signage in urban mass transportation would be a success among passengers.

This article also suggests future development of transport advertising system in Žilina town. Development of urban transport advertising system should bring the new forms of interaction between passengers and urban transport system. Therefore, the authors aim to trigger further investigations in the areas of interaction between passengers and transport advertising technology in two ways, (1) the relations between the advertising technology and passengers (I-It relation); and (2) passengers' perception and acceptation of shopping activities on the basis of advertising in different forms of digital signage medias. This agenda aims to contribute for future development on urban transport advertising technology in correlation with shopping practices and to suggest a viable research direction for further investigation on this topic.

Acknowledgements

- KEGA-053ŽU-4/2013 – Improving and interconnection key subjects of the study program: "E-commerce and Management".
- IMTS 26110230083 – The quality of education and human resources development as pillars of the knowledge society at the Faculty PEDAS of University of Žilina.
- VEGA 1/0421/12 – Modelling of diffusion of knowledge in corporate value chains.

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Transport and Telecommunication, 2014, volume 15, no. 3, 227–232
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/ttj-2014-0020

ANALYSIS OF INTRA-URBAN TRAFFIC ACCIDENTS USING SPATIOTEMPORAL VISUALIZATION TECHNIQUES

Ali Soltani[1,2], Sajad Askari[1]

[1]Department of Urban Planning, Shiraz University, Iran, Goldasht St., Maaliabad, Shiraz
Phone: +987116230453. E-mail: soltani@shirazu.ac.ir

[2]Urban Research program, Griffith University, QLD, 400, Australia
Phone: +61737357003. E-mail: a.soltani@griffith.edu.au

Road traffic accidents (RTAs) rank in the top ten causes of the global burden of disease and injury, and Iran has one of the highest road traffic mortality rates in the world. This paper presents a spatiotemporal analysis of intra-urban traffic accidents data in metropolitan Shiraz, Iran during the period 2011–2012. It is tried to identify the accident prone zones and sensitive hours using Geographic Information Systems (GIS)-based spatio-temporal visualization techniques. The analysis aimed at the identification of high-rate accident locations and safety deficient area using Kernel Estimation Density (KED) method. The investigation indicates that the majority of occurrences of traffic accidents were on the main roads, which play a meta-region functional role and act as a linkage between main destinations with high trip generation rate. According to the temporal distribution of car crashes, the peak of traffic accidents incident is simultaneous with the traffic congestion peak hours on arterial roads. The accident-prone locations are mostly located in districts with higher speed and traffic volume, therefore, they should be considered as the priority investigation locations to safety promotion programs.

Keywords: Accident; Traffic; Spatio-temporal Analysis; Shiraz

1. Introduction

Road Traffic Accidents (RTAs) have been and are continuing to be a major contributor of human and economic costs to requiring concerted multi-disciplinary efforts for sustainable effective prevention. RTAs rank in the top ten causes of the global burden of disease and injury, and will probably be in third place by 2020, when measured in disability-adjusted life years lost (WHO, 2013). With only 25 percent of all motorized vehicles, developing countries account for 86 percent of all road traffic deaths (Lagarde, 2011). Approximately 1.24 million people die every year on the world's roads (WHO, 2013), and the estimated costs of $518 billion (Ivers, Stevenson, Norton, & Yu, 2008) and another 20 to 50 million sustain non-fatal injuries as a result of RTAs. Early in this decade, some 20 to 50 million people in the world became totally or partially incapacitated due to injuries caused by traffic accidents. Injured and trauma victims took 10 per cent of all hospital beds that year (Ivers, Stevenson, Norton, & Yu, 2008). Current trends suggest that by 2030 road traffic deaths will become the fifth leading cause of death unless urgent action is taken (WHO, 2013). A great number of patients are transported to the emergency ward due to traffic accident injuries. These cases are a daily challenge for the teams working in pre and intra-hospital settings, especially due to the severity of the injuries and to the time it takes to reach the hospital and forward patients to surgery (Calil et al., 2009). Unless appropriate action is taken urgently, the problem will worsen globally. This will particularly be the case in those developing countries where rapid motorization is likely to occur over the next two decades (Mohammadi, 2013). The main reasons behind the dramatic increases of the number of RTAs can be listed as an insufficient road system, a rapid increase in the number of motorized vehicles, inadequacy of road safety policies, reckless driving and poor emergency services (Akgüngör, 2007).

Iran has one of the highest road traffic mortality rates in the world. Motor vehicle–related accidents account for more than 1'300'000 years of lost life around the country each year (Tavafian, Aghamolaei, Gregory, & Madani, 2011). The mortality rate due to traffic injuries has become considerable particularly during the last decade along with the industrialization process (Bahadorimonfared, et al., 2013).

The primary objective of this paper is to determinate hotspots location and sensitive times for Shiraz. It provides a manifest to policies assembling and implementation plan in urban road safety planning. The rest of this paper is structured as follows. In the second section, the relevant literature and methodology are reviewed. In Section three, the case study area and traffic accidents data are described. Section four discusses estimation methodologies, and presents the empirical results. The last section concludes.

2. Literature Review

RTAs result in injuries and death, but many are preventable, however they are commonly anticipated to form clusters in the geographic space and over time for the reason that their occurrence is tied to traffic volumes (Yamada & Thill, 2004). To developing strategies to prevent them, reducing traffic accidents, and improving road safety, an imperative need to understand how, where and when RTAs occurred and distributed across space and time (Brunsdon, Cocoran, & Higgs, 2007; Xie & Yan, 2008; Plug, Xia, & Caulfield, 2011), and utilize spatiotemporal patterns in road safety policy capturing. The importance of having a comprehensive crash map has been highlighted as a significant component of safety data management in strategic highway safety plans (Qin, Parker, Liu, Graettinger, & Forde, 2013). Injuries due to RTA depend upon a number of factors-human, vehicle and environmental factors play vital roles before, during and after a serious RTA. The significant factors are human errors, driver fatigue, poor traffic sense, poor condition of vehicle, speeding and overtaking violation of traffic rules, poor road infrastructure, traffic congestion, and road encroachment. In terms of severity of accident, driving speeds are of major importance as well. Environmental factors include the condition of the road network, road type and design, spatial context (e.g. density and land-use; plantation etc.), temporal context (e.g., darkness) and transport context (traffic density, speed and behaviour of other transport users). Social and psychological factors include socio-demographic and socio-economic structures, risk attitudes, lifestyles and 'mobility styles' and associated behaviour (Holz-Rau and Scheiner, 2013).

Identifying accident hotspots and appending value added data to understand the processes happening in these hotspots are important for the appropriate allocation of resources for safety improvements. By identifying road accident, a more robust understanding can be gained, with regards to indicators of casual effects (Anderson, 2009). In order to conduct a reliable analysis of the RTAs develop control strategies, it is required to investigate firstly how the accidents are geographically distributed, secondly regions where accident is observed more dense, and thirdly their geo-statistical aspects (Ozkan, Tarhan, Eser, Yakut, & Saygin, 2013). An improved understanding of the spatial patterns of RTAs can make accident reduction efforts more effective (Xie & Yan, 2008). Spatiotemporal GIS analysis complements and adds value to the traditional methods of identifying accidents patterns in time and space (Asgary, Ghaffari, & Levy, 2010). There are some important factors that may impact the distribution of traffic accidents, including natural and environmental characteristics such as physical environment (steep slope, sharp turn), weather (rain, snow, wind, and fog), configuration of highway networks such as the locations of access and egress points, deficient design and maintenance of highways, etc. All of these factors more or less are associated with distinct spatial patterns as well (Xie & Yan, 2008).

Currently, three major spatiotemporal pattern analyses and visualization techniques have been applied in vehicle crash research: map animation, iso-surface method and co-map (Asgary, Ghaffari, & Levy, 2010). The co-map method is useful for highlighting differences in a crash pattern using ‘small multiples’ of diagrams (Brunsdon, Cocoran, & Higgs, 2007). A time period, as a third dimension, is broken down into a series of time intervals and a spatial pattern can then be analyzed and illustrated for each time interval (Plug, Xia, & Caulfield, 2011). This paper amplified one of the visualization techniques to investigate spatiotemporal structures of RTAs. First, for spatial analysis of RTAs, the Kernel Density Estimation (KDE) in a GIS environment is used to determinate critical areas with high RTAs risk.

There are a variety of spatial tools developed to assist the understanding of the changing geographies of point patterns. The most promising of these tools is KDE. The KDE is one of the most common and well-established methods in identifying spatial patterns, and a non-parametric method that involves introducing a symmetrical surface over each point feature, assessing the distance from the point to a reference location based on a mathematical function, and subsequently, adding the value of all the surfaces for that reference location (Blazquez & Celis, 2013). The main benefit of this approach lies in recognizing the risk spread of an accident (Anderson, 2009). KDE calculates the density of events in a neighbourhood around those events. KDE allows some events to weigh more heavily than others, depending on their meaning, or to allow one event to represent several observations (Asgary, Ghaffari, & Levy, 2010).

The spread of risk can be defined as the area around a defined cluster in which there is an increased probability for an accident to happen based on spatial dependency. Secondly by using this density measure, an arbitrary spatial unit of analysis can be defined and be homogenous for the whole area which makes comparison and ultimately a taxonomy possible (Anderson, 2009).

KDE includes placing a symmetrical surface over each point and then measuring the distance from the point to a reference location based on a mathematical function and then summing the value for all the surfaces for that reference location. This procedure is repeated for successive points. This therefore allows us to place a Kernel over each observation, and summing these individual Kernels gives us the density estimate for the distribution of accident points (Eq. 1) (Fotheringham, Brunsdon, & Charlton, 2000; Anderson, 2009).

Eq. 1:

$$f(x,y) = \frac{1}{nh^2}\sum_{i=1}^{n} k\left(\frac{d_i}{h}\right),$$

where $f(x, y)$ is the density estimate at the location (x, y); n is the number of observations, h is the bandwidth or kernel size, k is the kernel function, and d_i is the distance between the location (x, y) and the location of the *i*th observation. The effect of placing these humps or kernels over the points is to create a smooth and continuous surface. The method is known as KDE because around each point at which the indicator is observed a circular area (the Kernel) of defined bandwidth is created. This takes the value of the indicator at that point spread into it according to some appropriate function. Summing all of these values at all places, including those at which no incidences of the indicator variable were recorded, gives a surface of density estimates (Silverman, 1986).

Kernel Density may also be used for calculating the density of linear features in the neighbourhood of each output cell. A smoothly curved surface is conceptually fitted over each line. Its value is biggest on the line and diminishes as you move away from the line, reaching zero at the specified search radius distance from the line. The surface is defined so the volume under the surface equals the product of line length and the population field value. The density at each output raster cell is calculated by adding the values of all the kernel surfaces where they overlay the raster cell centre (Silverman, 1986).

3. The Study Area and Data

Metropolitan Shiraz located in the southwest of Iran and is the capital city of Fars Province. According to the report from Iranian Bureau of Statistics (IBS, 2013), the population of the metropolitan area is about 1'460'000. Due to a long historical background and rich cultural adventure, Shiraz has been one of the most attractive destinations for seasonal domestic holiday-makers. However, Shiraz has suffered from intra-urban traffic accidents due to a considerable increase of vehicle ownership and private car users (Soltani, Zargari and Esmaeili, 2013). Essentially, one of the main factors contributing to the increase in intra-urban traffic accidents is the improving of social welfare in recent years.

Intra-urban traffic accidents data were collected using the secondary database of the Road Police Department, Shiraz Branch. These data was originally recorded by police officers from March 2011 to March 2012. The information on street network was obtained in a GIS format from the Municipality of Shiraz, Department of Traffic.

Table 1 details the frequencies of different types of crash. The majority of accidents occurred as crashing a car with another car (73 per cent) followed by a car hitting an object (5 per cent) and a car hitting a pedestrian passing through (5 per cent).

Table 1. The distribution of the intra-urban traffic accidents based on the type of crash

Crash Types	Damaged	Injured	Death	Total Accidents	Share
Car with motorcycle	403	2414	11	2828	10%
Car with bicycle	16	36	0	52	0.2%
Car with another car	19091	947	9	20047	73%
Car with other cars	927	168	9	1104	4.0%
Car hitting a parked car	56	23	2	81	0.3%
Car hitting a pedestrian	18	1198	18	1234	5%
Car hitting an object	1150	144	5	1299	5%
Rollover	117	69	3	189	0.7%
Motorcycle hitting a pedestrian	1	63	1	65	0.2%
Motorcycle with motorcycle	1	63	1	65	0.2%
Motorcycle hitting a bicycling	5	9	0	14	0.1%
Other	330	32	1	363	1%
Total	22115	5166	60	27341	100%

4. Results and Discussions

The results of this study could give an insight into the present scenario of the traffic condition of the metropolitan and shows out the most potentially accident prone roads in the district. It would also describe some causes of accident.

According to the literature of accident analysis, time is an important factor which contributes to road traffic accidents. The temporal analysis aims to discover the relative risk pattern temporally and can be used as prerequisite for spatial analysis targeting spatial patterns in different time periods

This study focuses on urban areas at a specific time of day; demonstrates spatiotemporal variations in RTAs incidents. Figure 1 illustrates how the number of RTAs across Metropolitan Shiraz areas varied from 2009 to 2010 throughout the day. This shows that a few RTAs occurred during early morning particularly they dipped between 4 and 6 AM when traffic volume is quiet low and drivers are less likely to hit another car. On the other hand, the number of traffic accidents significantly increased after 8 AM coinciding with the beginning of activities during a typical day. This is consistent with the findings of (Heydari et al., 2013) the time distribution of fatal traffic accidents in Fars Province of Iran. They found that traffic accident deaths of students, clerks, workers and house-keepers increased dramatically at 8–12 AM.

For the spatial analysis of RTAs, this study employed KDE method to generate maps to determining RTA hotspots in Shiraz applying linear analysis supported by GIS. The Spatial Analyst KDE tool in ESRI's ArcGIS 9.3 software was used to calculate the KDE. Figure 2 shows RTAs incident patterns broken down by the day of the week. According to the spider plot, RTAs have uniform patterns during the weekdays. Figure 3 depicts the stable patterns when the month of the year is used. There is significant issue in monthly distribution that RTAs peak off period occurred in summer months and early fall months in Shiraz. As previously mentioned, this may be explained by the presence of tourists in the city because good weather conditions allow people to come to Shiraz in summer more frequently than other times of the year.

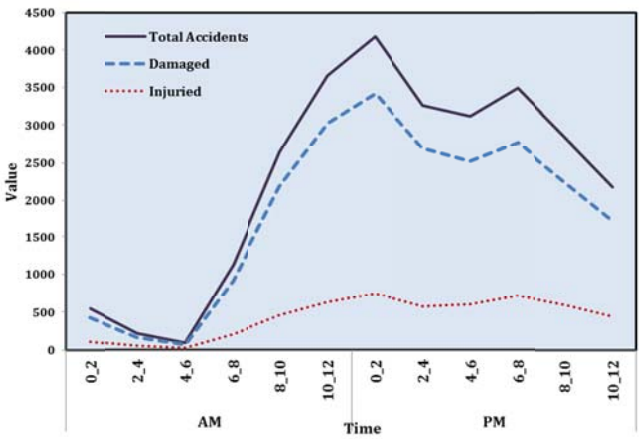

Figure 1. Hourly patterns of RTAs incidents in Shiraz, 2009–2010

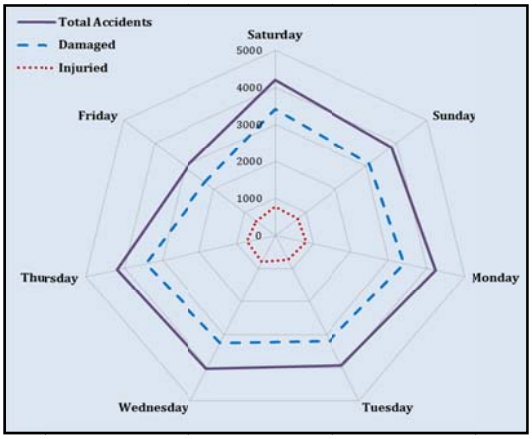

Figure 2. Patterns by day of the week

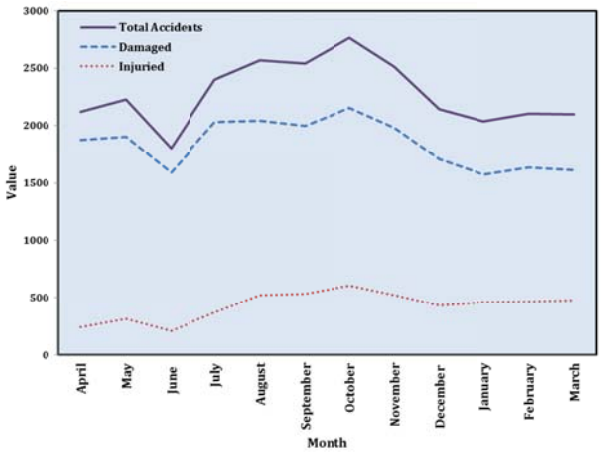

Figure 3. RTAs patterns by month of the year

Figure 4 displays the results the KDE analysis for RTAs during the study period in Shiraz. Like the temporal patterns, the spatial patterns of RTAs incidents of different causes show some variations across the metropolitan regions. RTAs incidents were more frequent in main arteries where more urban activities are taking place and clustered in the areas of urban that have high traffic volume and provided more accessibility to other road. There are a few hotspots in downtown area and some on the major streets and roads in the North-western and South-eastern parts, of the metropolitan. This map highlights, the highest RTAs incident intensity is found in the North-western parts of the metropolitan. These areas represent neighbourhoods with low population densities, newer developments, and higher quality.

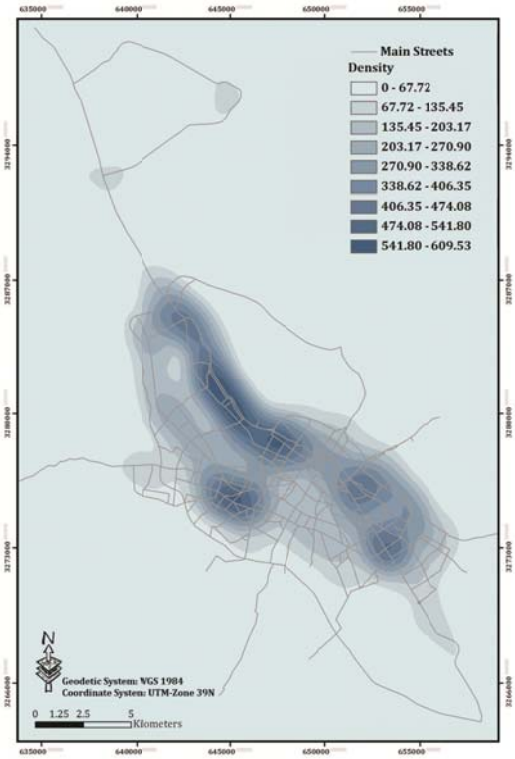

Figure 4. Intra-urban traffic accidents density using 2 km bandwidth of main streets

5. Conclusions

The analysis of spatiotemporal distribution of accidents in Metropolitan Shiraz, focuses on the total number of accidents as well as accidents happened during night and day hours (temporal) and accidents in areas with high traffic congestion (spatial). The advantages of such two dimensional hotspot surface representations, especially on intra-urban traffic accidents, can provide a more realistic

continuous model of accident hotspot patterns, over space and time. The findings of this paper propose that RTAs trends differ according to incident type and can provide important exploratory analysis prior to more detailed investigations including the use of contextual data (e.g., land use, type of road). The results of this paper presumably have important implications for RTAs prevention planning, and RTAs intervention policies, including the identification of hotspots, which geographically define acute problem areas. Within these hotspots, traffic and police departments could focus on regions that are statistically likely to have higher levels of the repeated road traffic accidents. This study can be developed further by investigating the potential causes of traffic occurrence throughout the metropolitan area.

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Transport and Telecommunication, 2014, volume 15, no. 3, 233–242
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/ttj-2014-0021

ADAPTIVE TECHNOLOGY APPLICATION FOR VIBRATION-BASED DIAGNOSTICS OF ROLLER BEARINGS ON INDUSTRIAL PLANTS

Aleksey Mironov[1], Pavel Doronkin[1], Alexander Priklonskiy[1], Sergey Yunusov[2]

[1]D un D centrs Ltd.
Margrietas Str. 7, Riga, LV-1046, Latvia
Phone: +371 67 468850. Fax +371 67 468856
E-mails: aleksei@ddcentrs.lv, pavel@ddcentrs.lv, pai_ev@inbox.lv

[2]Transport and Telecommunication Institute
Lomonosov Str. 1, Riga, LV-1019, Latvia
Phone: +371 26435655. E-mail: yunusov@inbox.lv

Roller bearings are widely used in equipment of different applications; therefore, the issues related to the assessment of bearing technical state and localization of bearing faults are quite important and relevant. The reason is that technical state of a bearing is a critical component, which determines efficiency of a mechanism or equipment. For bearings inspection and diagnostics, various methods of vibration-based diagnostics are used. The adaptive technology for vibration-based diagnostics developed in „*D un D centrs"* is an effective tool for evaluation of technical state of bearings in operation compared to the existing SKF method.

Keywords: roller bearing, vibration-based diagnostics, SKF method, deterioration, adaptive technology

1. Introduction

Many industrial plants comprise rotor-type mechanisms such as electric motors, pumps, fans, turbines, generators etc. operating at high rotation frequencies and, therefore, using roller bearings in their design accordingly. Being high-precision mechanisms, they can operate for many years under favourable operating conditions. However, roller bearings cannot use their potential resource in full for various reasons like severe operating conditions and the established maintenance strategies. On the one hand, any failure of a bearing may lead to a long-lasting downtime of equipment and economic losses. On the other hand, bearings are often replaced in order "to be on the safe side", leaving a great portion of the resource unrealized.

The problem can be solved by transition to condition-based maintenance, which requires improvement of instrumentation and diagnostic methods development. To this end, methods of vibration-based diagnostics are used as the most efficient ones for evaluation and prediction of technical state. The advantage of vibration-based diagnostics is that it allows arranging the operating equipment technical state monitoring without affecting production cycle.

Currently, there is a consistent trend of transition to condition-based maintenance of equipment, aimed at operating costs cutting down and improving the equipment efficiency without any loss in its reliability, ensuring the required safety level at the same time. A necessary pre-requisite for the implementation of condition-based maintenance is the availability of monitoring and diagnostics means which would allow timely and precisely determine the technical state of the object, therefore, precluding its failure.

2. Vibration-Based Diagnostics of Roller Bearings Traditional Methods Efficiency

Roller bearings having faults on bearing tracks, balls, or bearing cage generate some additional dynamic forces which are transferred onto the outside bearing housing assembly and the surrounding structure. These forces can be periodic or stochastic by nature and appear mainly within high-frequency vibration range. However, it is quite difficult to identify any fault symptoms of a bearing inside of various mechanisms and machines using vibration characteristics due to the fact that, apart from the bearings,

other machine assemblies act as vibration sources, too. Nonlinear interaction of a set of vibration sources produces a complicated picture of fluctuations at the measurement point on bearing housing assembly.

The main approach used in traditional, vibration-based methods for bearing diagnostics is based on the relationship between the frequencies of typical components of vibration spectrum and the common-type defects of a roller bearing. The presence and the intensity of defects in a bearing are estimated by composition and ratio of spectral components of the measured directly or post-processed vibration signal.

There exist various methods for analyzing vibration of roller bearings, aimed at the solution of the two main problems: 1) extracting the bearing-generated signal, thereby separating it from other aggregates, and minimizing "noise", that may conceal the bearing-generated signal – especially at early stages of the fault propagation, and 2) identifying the technical state of the bearing – i.e., distinguish between generally normal bearings and defective ones, defining faulty components of the latter. Frequency domain analysis is the most widely-used method of localization of bearings' faults. Most of the methods of this category analyze energy spectrum of vibration signal using Fast Fourier Transform which has some specific shortcomings (Barkova, 2000).

The non-uniformity of spectral behaviour when approaching a state of emergency (Barkov et al.) requires some more efficient diagnosing methods – in particular, those based on demodulation of high-frequency random vibration waveform envelope. The vibration envelope method analyses only the vibration power of components of the same nature which are preliminary extracted from vibration signal. If the extracted part of vibration has many different components with an impact-type dominating component available – the power of the extracted vibration components is changed by periodical bursts. Then, a large number of multiple harmonics missing in the spectrum of a high-frequency vibration signal occurs in the spectrum of power fluctuations of high frequency vibration. The analysis of power fluctuations of preliminary extracted vibration components of similar nature is exactly the vibration envelope spectral analysis. However, the spectral analysis of vibration envelope is sometimes construed not as power fluctuations analysis but rather as the analysis of root-mean-square value of high-frequency vibration, which in principle doesn't change the physical basis of obtained results in any way.

Usage of vibration enveloping method can effectively solve the problem of diagnosis of roller bearings and other components of rotary machines (Barkov, 2000) operating mainly at low rotation speeds. At the same time, this method has some bottlenecks – like for instance, different flaw sensitivity of bearing elements, which determines different hazard thresholds of defect populations; the existence of a few progressing defects desensitizes the method etc.

Bearing monitoring and diagnostics tools are developed by many companies and organizations, and one of the leaders in this field is the Swedish *SKF* – a leading global supplier of products and services associated with roller bearings. Within the framework of the study carried out on industrial plants to assess the technical state of their roller bearings, an SKF-manufactured device CMAS 100-5L was used (Fig. 1).

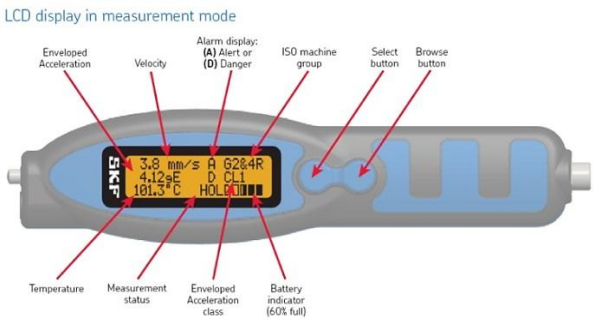


Figure 1. SKF Machine Condition Advisor CMAS-100

In this device, the measurement of a couple of testing parameters has been implemented: the absolute level of machine vibration in the low-frequency range and the vibration envelope acceleration value.

In the course of the study, the technical state of 12 bearings from various industrial plants, including those of *RigasUdens* – the main water supplier of the city of Riga – was analyzed.

The study of the bearings of each plant was carried out in several stages. Initially, the instrumental monitoring of plant vibration on the bearing housing assembly was carried out using CMAS 100-5L

device. Then, the bearings were dismantled for the subsequent fault localization. On completion of maintenance of the plant, a new bearing of the same type as the dismantled one was installed therein. After the plant maintenance and putting it into operating mode, the vibration was measured again by CMAS 100-5L on the bearing housing assembly (at the same point where the vibration of the replaced bearing was measured).

According to the fault detection results, all the bearings were divided into two groups. The first group included the bearings with minor wear in the form of visible traces of bearing tracks of uniform character. The second group included bearings with substantial damage in the form of spots of varying size and depth over 0.05 mm. To assess the extent of damage of the bearing tracks, the bearing track damage ratio was introduced, which characterizes the relative length of the damage:

$$k_d = l/\pi d,$$

where l is the cumulative length of damaged sections of bearing track;

d – diameter of bearing track.

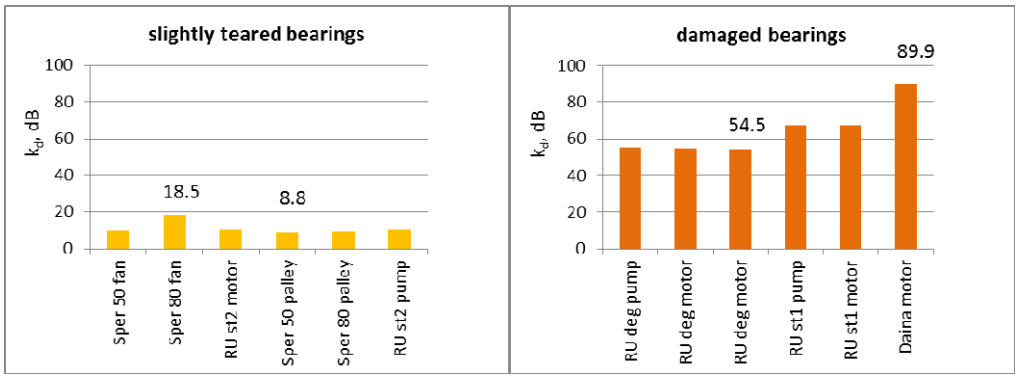
The damage ratios, calculated for bearing elements, have shown that the damage extent of the elements may differ substantially. For example, with respect to one bearing, k_d for the bearing inner race is 60%, while k_d for the bearing outer race is 5% and for roller elements (rollers) – 0% (Fig. 2).

Figure 2. Faults of the inner and the outer race of bearing

To form bearing groups with substantial and insubstantial faults, a complex damage ratio was introduced, which takes into account intensity (relative depth) $i = depth/50$ um of the damaged section of bearing track (in um):

$$k_d^i = 20\lg\left(i^2 d\right).$$

The damage ratio diagrams describing two groups of bearings – those with substantial and insubstantial wear – are presented on Figure 3.



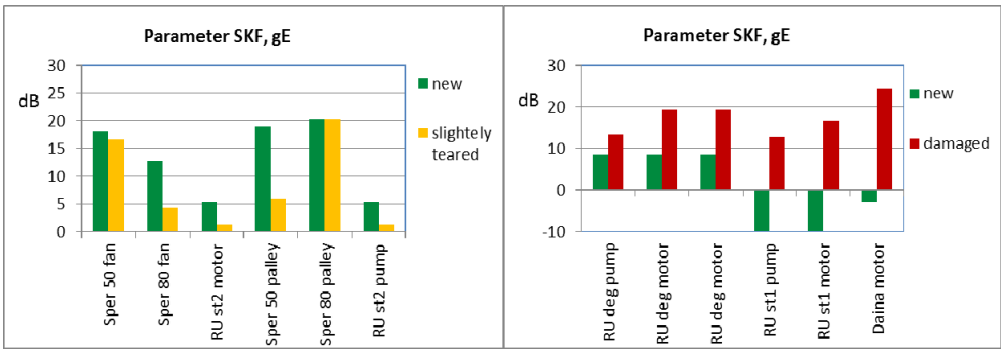
a) b)

Figure 3. Bearings split-up by groups: a) those with insubstantial wear; b) those with substantial wear

As it can be seen from the diagrams, the bearings with substantial wear are characterized by the value k_d^i within the range 54…90 dB; with respect to the bearings with insubstantial wear k_d^i lies within the range 8…20 dB**.**

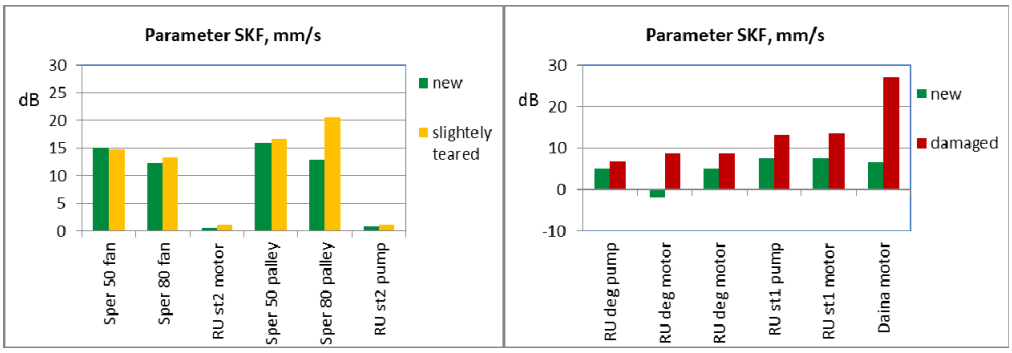
The efficiency of the parameters measured by SKF device was assessed by analysing diagnostic messages from the device and numerical values of the parameters measured by it, with the subsequent comparison with the calculated assessments of actual faults stated above. The device produced diagnostic messages of two kinds: "Alert" – recommendation to halt the aggregate and investigate it, and "Danger" – the message signalizing about a fault of the bearing.

The results of measurement of the two SKF parameters at all the investigated objects are shown on Figure 4 and 5.



a) b)

Figure 4. The results of SKF-performed measurement of **gE** parameter of the bearings split up by groups: a) with insubstantial wear; b) with substantial wear



a) b)

Figure 5. The results of SKF-performed measurement of **mm/s** parameter of the bearings split up by groups: a) with insubstantial wear; b) with substantial wear

To facilitate the comparison with fault detection results, the SKF-performed measurement data are presented in decibel scale.

Comparing the bearing fault detection results and the measurement data obtained by SKF device, one may come to the conclusion that the device has made errors of first kind (false alarm) and second kind (non-detection).

For example, in 12 tests where technically sound bearings were investigated, SKF device had identified presence of faults or their probability in brand-new bearings, in particular: the device had reported the occurrence of a fault three times (*Danger*) and once – by issuing breakdown prevention signal (*Alert*). When the group of 6 used bearings was investigated where no visible defects were found after the dismantling (i.e. the bearings were sound), the device issued *Danger* twice and *Alert* – once. Therefore, the device incorrectly identified technical state of bearings in 7 cases out of 18, i.e., the false response percentage of the device made up about 39% accordingly.

The device has shown the following results of operation with the group of bearings having substantial faults. In process of investigation of 6 bearings with substantial faults, the device has made

the correct diagnosis thrice: it suggested preventive maintenance (*Alert*) twice – with respect to bearings which have shown traces of corrosion indeed in process of their dismantling; once, the device has highlighted a defect (*Danger*) which was confirmed when the bearing fault detection took place. As regards the remaining three bearings with substantial defects, the device has even failed to issue the signal *Alert,* which may be interpreted as defect skipping. Therefore, with respect to that group of bearings, the probability of correct identification of their technical state by SKF device constituted 50% only.

The total number of test runs performed by SKF device was 24 (12 of them were performed for testing used bearings, and 12 – for testing new ones). Based on the yielded results, 10 errors were recorded, 7 of which were false response with technically sound bearings (error of the 1st kind) and 3 – "non-detection of target" (error of the 2nd kind) with the bearings having substantial defects which may lead to the bearing's failure in future. In this case, the error of the 2nd kind constituted 40% which is generally intolerable to ensure reliability of the plant.

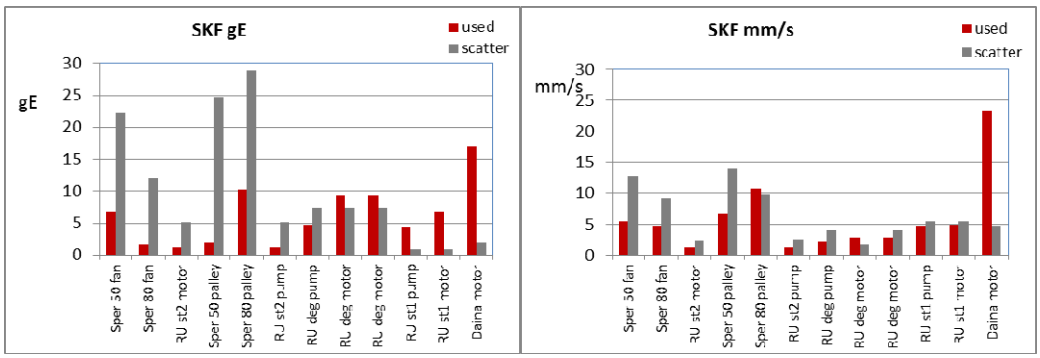
These results suggest that the vibration analysis methods used in SKF device cannot be considered acceptable, since a high percentage of errors of the first and the second kind leads to unsubstantiated prevention maintenance jobs and uncontrolled failures, which ultimately increases the operating costs for the plant maintenance.

One reason of the low efficiency of roller bearings' technical state identification by SKF device is dependence of measured parameters (*gE* and *mm/s*) from the design features of the plant. The diagrams (Figs. 4a and 5a) clearly show how far the measured parameter levels differ from each other for new bearings (or those with minor damage) in different industrial plants. It can be seen from Fig. 4a that *gE* parameter obtained through the envelope monitoring method was often smaller for bearings having a minor wear than for technically sound bearings. We should note at this point that the *mm/s* parameter compatibility between new bearings and those with minor wear (Fig. 5a) was sensibly better. The values shown by the bearings with a minor wear were a little higher than those shown by the new bearings. However, this parameter which is the generalized vibration parameter related to the plant as a whole does not highlight vibration of bearing and, therefore, it become non-diagnostic if other vibration sources present.

As regards the bearings with substantial defects, SKF parameters of defective bearings were higher than those of the new ones (Figs. 4b and 5b) in terms of the two parameters. It should be noted at the same time that all the defective bearings made such a loud noise that it could be heard even without the device.

The method applied in SKF devices is quite fit for the bearings technical state monitoring, provided, however, that any change in the state of a bearing is controlled by comparing of the current vibration parameters with the values recorded at the beginning of their operation. However, initial values of vibration parameters corresponding to the beginning of operation are missing as a rule and it may impose constraints on the method usage with respect to millions of bearings already in operation. Thus, bearing diagnosis should be based on one-time measurements of the parameters providing reliability of making decision on defect appearance. Therefore, in order to unify the application of SKF method to all bearings without taking their prehistory into account, it is necessary to consider the SKF parameter spread, which happens due to the design features of different units.

The diagrams (Fig. 6) show the correlation between used bearings parameter values (in red) and the calculated value (in grey), which takes into account parameter spread with respect to values characterizing new bearings in different units. In cases where the red values are substantially higher than the grey ones, defect identification is ensured; otherwise, an error is possible.



a) b)

Figure 6. Measured values of parameter **gE** (a) and **mm/s** (b) of waste bearings and the parameters spread with respect to new bearings

As can be seen from the diagrams, the boldface identification based on *mm/s* parameter was possible only with regard to the bearing having the largest faults. The *gE* parameter ensured a reliable identification with respect to three bearings having the largest defects. However, in all other cases, both parameters were not able to identify the defect with confidence. The obtained results of the bearings technical state diagnosing using SKF device attest to the fact that the method used is not efficient enough; therefore, new methods aimed at enhancing the certainty of bearings diagnosis should be developed, or the existing methods of the type should be improved.

As an alternative to the existing methods, an adaptive technology for vibration-based diagnostics of roller bearings, developed in „*D un D centrs*" was evaluated. The description of the technology and the obtained findings are stated in the next section.

3. Adaptive Technology for Roller Bearings Technical State Monitoring

3.1. The concept of adaptive technology for bearing monitoring

The adaptive technology for bearing monitoring bases on a joint processing of vibration signals synchronized with rotation speed, where kinematic parameters of a bearing are taken into account. The latter, in turn, are determined by the number and diameter of balls (rolling elements) and by the diameters of bearing tracks of the inner and the outer race. Figure 7 presents the example of measurement set up applied in the adaptive technology.

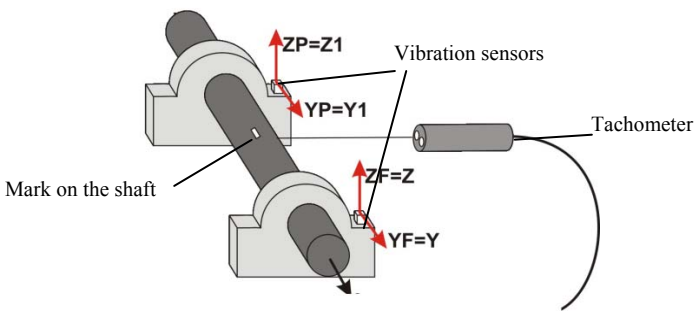
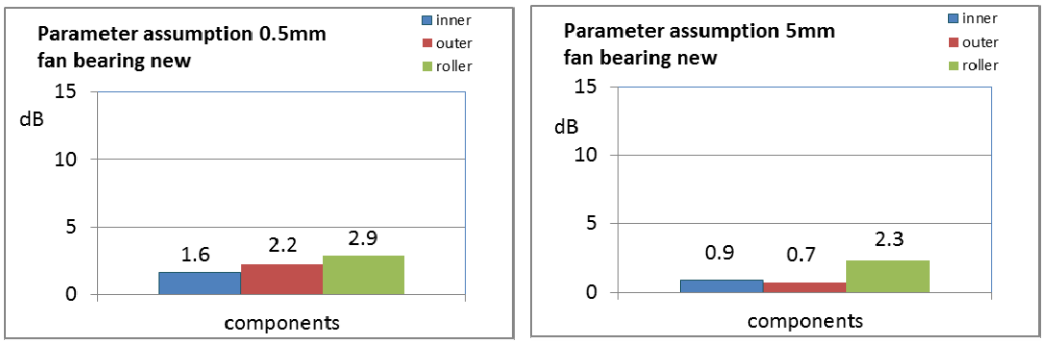


Figure 7. The adaptive technology parameters measurement diagram

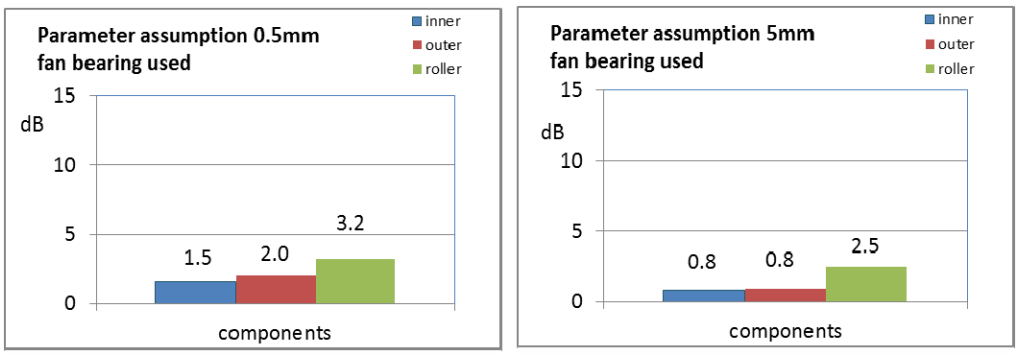
Recorded vibration signals and the rotation speed data is processed according to the methods developed in „*D un D centrs*".

The main feature of this method is that synchronous enhancing and averaging of signals is carried out in the time domain. Structural normalization of vibration signal is another feature of the method. The adaptive technology for vibration-based diagnostics of a bearing separately estimates states of inner and outer races as well as the balls (rolling elements). At the same time, due to normalization, the obtained estimates become indifferent towards the design features of the unit. The technique uses variational approach towards data processing, which allows one to make the technology insensitive to the bearing operation conditions the effect of which has a major impact on the vibration characteristics of any unit. Variational approach is used to improve the resolution of the method with respect to each component by calculating two or more options to assess the testing parameter, each of which is based on different assumptions about the scale of the alleged defect. Since the scale of a possible defect is not known a priori, the defect identification probability will be higher if the calculation is based on the assumption of two or more expected scales of the alleged defect. For example, in the study, sizes (scales) of hypothetical defects equal to 0.5 mm and 5 mm were selected respectively, serving subsequently as a basis for calculation of the testing parameter values for each component of the new and the waste bearings of the unit.

The graphs below (Figs. 8 and 9) show estimated state parameters (in decibel scale) calculated by adaptive method for plants, one of which comprised a bearing with minor wear, while the other – a bearing with significant wear. The numerical estimate of the inner race state is marked with blue on the diagram, while that of the outer race state is marked with maroon and that of the balls is marked with green.



a)

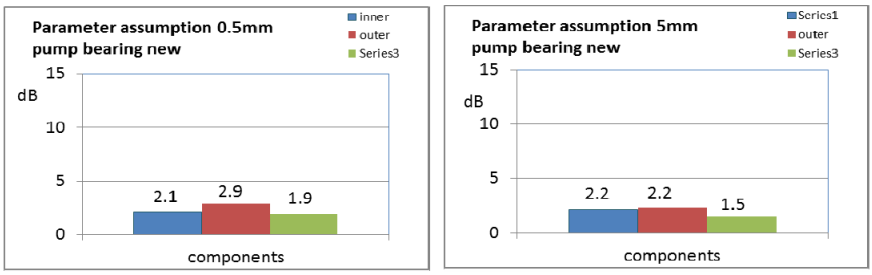


b)

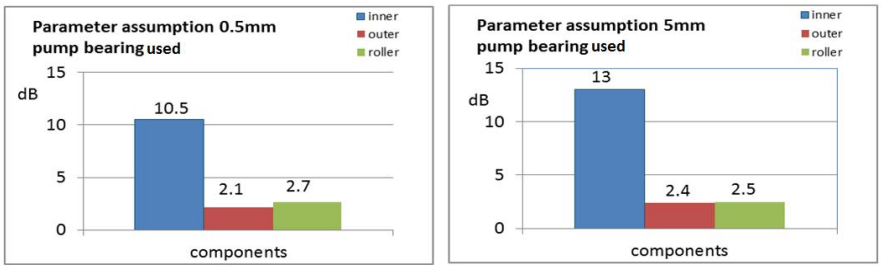
Figure 8. Results of calculation of testing parameter with respect to the plant with minor wear of bearing: a) – new; b) – used

The calculation results presented on Figure 8 show small differences of parameter values (0.2-0.3 dB) between the components of the new and the used bearing, which actually corresponds to their initial technical condition.

The diagrams of Figure 9 show that parameter values of the inner race of the *faulty* bearing are larger than those of the *new* bearing installed into the same unit. In terms of small-scale defects (0.5 mm) the difference in values constituted 8.4 dB, while in terms of the scale 5 mm, it constituted 10.8 dB.



a)



b)

Figure 9. Testing parameter calculation results for the unit with a substantial wear of the bearing: a) – new; b) – used

The obtained estimates correspond to small changes of balls (rolling elements) and the outer race state, and to substantial changes in the condition of the inner race. The inner race parameter changes, nearly similar in terms of scale, attest to intermediate (between 0.5 and 5 mm) scale of defects. Fault detection results (Fig. 2) had confirmed calculated estimates.

Therefore, state parameters of bearing components obtained by the adaptive technology enable one not only to identify bearing's faults at early stages of their propagation, but also to estimate their scale and identify the bearing part being most susceptible to deterioration.

3.2. Evaluating efficiency of the method of adaptive technology for bearings monitoring

To compare the efficiency of the adaptive technology and SKF method for monitoring there are state parameters obtained by both methods are collected in table 1. Samples collection is 12 technically sound bearing in start of its operation.

Table 1. Testing parameter values describing new bearings of units under study

Parameter	Comb adaptive	SKF	
Object	dB	"mm/s", dB	"gE", dB
Sper 50 fan	7,6	15,1	18,1
Sper 80 fan	9,3	12,3	12,8
RU st2 motor	7,0	0,6	5,4
Sper 50 palley	7,4	16,0	19,0
Sper 80 palley	10,6	12,9	20,3
RU st2 pump	6,8	0,8	5,4
RU deg pump	7,3	5,1	8,5
RU deg motor	7,5	-1,9	8,5
RU deg motor	7,5	5,1	8,5
RU st1 pump	10,9	7,7	-9,9
RU st1 motor	9,4	7,7	-9,9
Daina motor	5,3	6,7	-2,7
Average	8,0	7,3	7,0
Criteria			
Variation, dB	5,6	17,9	30,2
Max/Average, dB	2,8	8,6	13,3

To assess the state parameters spread in dB, two criteria – *Variation* and *Max/Average* – are calculated.

The parameter spread served as the criterion of information content: the larger the spread, the less informative is the parameter. Comparative assessment of efficiency is made for bearings that are in the same condition, technically sound.

In SKF method, two state parameters – *gE* and *mm/s* – are used, while the adaptive technology method uses the parameter *comb adaptive* for integrated assessment of a bearing as a whole. This parameter has the dimensions in dB and is the sum of parameter values of the three components of the bearing (inner and outer races and rolling elements):

$$A_{comb} = A_{ir} + A_{or} + A_b,$$

where A_{comb} A_{comb} – integral testing parameter of adaptive technology;

A_{ir} – testing parameter of inner race;

A_{or} – testing parameter of outer race;

A_b – testing parameters of rolling elements.

Table 1 shows the comparison of SKF state parameter values (converted into dB) and those of the adaptive technology for the units on which the study was conducted. Under the baseline measurements and calculations, their calculated average value is presented.

The last two rows in the table are the spread assessment criteria – *Variation and Max/Average*, which can evaluate the efficiency of SKF method and that of the adaptive technology method.

The smaller the value of these criteria, the more efficient is the method and the more informative is the testing parameter.

The table shows that the SKF parameter spread greatly exceeds the integral testing parameter spread. Thus, the spread of parameter "mm/s" exceeds the parameter *comb adaptive* spread by more than 4 times (12.3 dB), while the spread of "gE" parameter exceeds it by more than17 times (24.6 dB).

For a more detailed comparison between the resolutions of the two methods, parameter *Max / Average* was used, which shows how far the scatter of each of the parameters exceeds its average value. Such a ratio provides a rough idea of parameter sensitivity of the bearing condition monitoring, namely, how far the value of the parameter corresponding to the defect should exceed the average value of the serviceable condition to ensure that the probability of a correct diagnosis would be higher than the error probability. As can be seen from the Table, it would be sufficient for *comb adaptive* parameter to provide the 40% (2.8 dB) parameter increase in relation to the new bearing parameter value to identify a defect with confidence.

At the same time, with regard to SKF parameter, the "mm/s" parameter should increase by 2.4 times and SKF "gE" – by 2.8 times.

To compare the methods more in detail, we will illustrate the difference in their resolution with the aid of diagrams showing the relation of values corresponding to new and used bearings of the same units (Fig. 10).

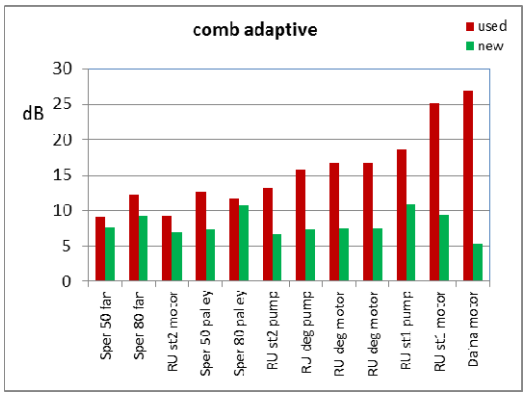


Figure 10. Relation of *comb adaptive* status parameter values for the used and the new bearings

Unlike SKF parameters (see Figure 6), the *comb adaptive* parameter values corresponding to all of the observed units with used bearings were higher than those corresponding to the same units with new bearings. Such a relation definitely ensures monitoring of the units' bearings, i.e., makes it possible to perform in-service inspection of their state. Importantly, the parameter value propagation areas for the new bearings (marked by green) – 5….11 dB – and those with the used bearings (maroon) – 9…27 dB almost do not overlap with respect to bearings of different types. The "overlapping" is observed only with three used bearings which had no defects whatever.

Now, let us analyse the relation of *comb adaptive* parameter values for used bearings and the calculated parameter *spread* values for new bearings (Fig. 11). Obviously, all bearings with major defects (six objects on the right) have the parameter values are at least by 6dB (twice) higher than those of the new bearings.

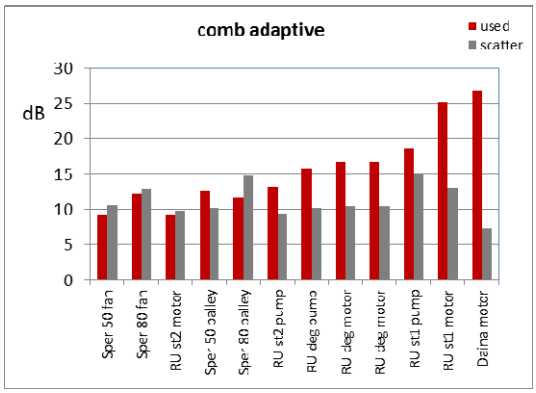


Figure 11. Relation between *comb adaptive* parameter values corresponding to units for used bearings and the calculated values of parameter spread for new bearings

Thus, the difference between the parameter values of the adaptive technology related to healthy and defective bearings allows one not only to monitor individual objects reliably but to identify bearing defects in any unit with a sufficient degree of confidence regardless of the unit design and operating conditions.

4. Conclusions

The adaptive technology for monitoring roller bearings developed by „*D un D centrs*" is an effective tool for assessing the technical condition of bearings in operation. This technology allows transition to condition-based maintenance of industrial installations, thereby ensuring reduction of unreasonable downtime, cutting down operating costs and improving the reliability and safety at the required level.

Acknowledgements

This article is written within industrial research study "Development of advanced vibration monitoring technology for rolling bearing of transport and energy machines" included in the project „Establishment of TRANSPORT MECHANICAL ENGINEERING COMPETENCE CENTER", contract No. L-KC-11-0002 with Investment and Development Agency of Latvia.

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3. Measurements and tests. (1981) In: V.N. Chelomey et al. (Eds.), Vibration in Engineering: Reference book, in 6 volumes. M.: Machine-building industry, 1981. 496 p.

Transport and Telecommunication, 2014, volume 15, no. 3
Transport and Telecommunication Institute, Lomonosov 1, Riga, LV-1019, Latvia

Authors' index

Igor V. Kabashkin (born in Riga, August 6, 1954)

- Professor of the Transport and Telecommunication Institute, President of Latvian Transport Development and Education Association, Member of Joint OECD/ITF Transport Research Committee
- **Education & Scientific and University degrees:** Ph.D. in Aviation (1981, Moscow Institute of Civil Aviation Engineering), Dr.Habil.Sc.Ing. in Aviation (1992, Riga Aviation University), Member of IEEE, Corresponding Member of Latvian Academy of Sciences, Member of the International Academy of Astronautics
- **Publications:** more than 445 scientific papers and 67 patents
- **Fields of research:** Transport Telematics and Logistics, Analysis and Modelling of Complex Systems, Operations Research, Information Technology Applications, Electronics and Telecommunication, Decision Support Systems

Irina V. Yatskiv (born in Krasnoyarsk, Russia)

- Vice-rector of Transport and Telecommunication Institute, Professor of Mathematical methods and Modelling Department
- **Education:** Riga Civil Aviation Engineering Institute, studied computer science and obtained an engineer diploma in 1982
- **Scientific and university degrees:** Candidate of Technical Science Degree (1990), Riga Aviation University, Dr.Sc.Ing. (1992)
- **Scientific activities:** Member of Classification Society of North America, Member of Latvian Simulation Modelling Society, Director of Latvian Operation Research Society, the leader of project BSR INTERREG III B Programme InLoC, and projects connected with transport system simulation in Latvia
- **Publications:** more than 100 scientific papers and teaching books
- **Fields of research:** multivariate statistical analysis, analysis, modelling and simulation of complex systems, transport and logistics, decision support system

Leonid O. Uryvsky (born in Volgograd, Russia, 1954)

- Professor, Doctor of Science, Head of Telecommunication Systems Department (TSD) in the Institute of Telecommunication Systems (ITS, NTUU "KPI")
- **Education:** Kiev Higher Military Engineering Communications School (KHMECS) (1976), radio engineer
- **Scientific degrees:** Ph.D., KHMECS (1983) ; Honorary status "The best young inventor of Ukraine" (1983), "Inventor of USSR" (1985); Dr.Sc.Ing., ITS NTUU "KPI" (2009)
- Professor of TSD, ITS, NTUU "KPI" (2011)
- **Publications:** 39 inventions, more than 130 scientific papers
- **Fields of research:** queuing system, information properties of modern telecommunication technologies, synthesis of optimal signal-code structures near the Shannon limit, self-similar flows

Serhii O. Osypchuk (born in Bondarivka, Ukraine, 1988)

- Ph.D. student in Telecommunication Systems Department, Institute of Telecommunication Systems (ITS, NTUU "KPI")
- **Education**: Master degree, ITS NTUU "KPI" (2011), information-telecommunication networks
- **Publications**: more than 15 papers in journals and conference proceedings
- **Fields of research:** information properties of modern telecommunication technologies, anti-noise coding, multiway transmission

Peter Kolarovszki (born in Komárno, April, 1982)

- Mg.Sc., Ph.D., Lector at the University of Zilina, The Faculty of Operation and Economics of Transport and Communications
- **University study**: Mg.Sc. in the field of postal and telecommunications operation (University of Zilina – 2006)
- **Scientific and university degrees**: Ph.D. in Postal technology (University of Zilina – 2009)
- **Publications:** 89 scientific papers including journal articles and domestic and international conference and congress contributions
- **Fields of research:** information technology applications, telecommunication and automatic identification and data capture specialized in RFID technology, member of EPC Global

Juraj Vaculík (born in Žilina, Slovakia, March 25, 1953)

- Professor at University of Žilina, The Faculty of Operation and Economics of Transport and Communications
- **Education:** Ms.C. in field postal and telecommunication operations at University of Žilina (previous University of Transport and Communications, UTC Zilina) in 1986, Scientific and university degree: Ph.D. in program of Transport and Postal Technology graduate at University of Žilina in 2002, habilitation in scientist program Transport and Postal Technology in 2004, Head of AIDC laboratory in the Centre of Excellencies of Intelligent Transport Systems, in 2013 appointed as a Professor
- **Publications**: 2 monographs, 10 text books and scriptum, more than 250 scientific papers including journal articles and domestic and international conference and congress contributions and presentations
- **Field of research**: application of information technology, mobile application and multimedia in services, e-learning, technology of RFID and the other automated identification technology, new services in transport and postal sectors, security management of information's systems, member of EPC Global

Alexey J. Aksenov (born in Saint-Petersburg, Russia, October 12, 1978)

- Junior researcher in the Laboratory of Research Automation of Saint-Petersburg Institute for Informatics and Automation of Russian Academy of Sciences
- **Education:** Saint-Petersburg Electrotechnical University "LETI" studied computer science and obtained an engineer diploma in 2001, was educated in SPIIRAS Post-graduate School
- **Fields of research:** signal processing, application of software defined radio (SDR)
- **Publications**: over10 scientific publications

Sergey V. Kuleshov (born in Kurgan, Russia, April 12, 1981)

- Leading researcher in the Laboratory of Research Automation of Saint-Petersburg Institute for Informatics and Automation of Russian Academy of Sciences
- **Education&Scientific and university degrees**: Software Engineering at Kurgan State University in 2003, Ph.D. (Tech) degree in 2006, Dr.Sc. (Tech) in 2011, Saint-Petersburg Institute for Informatics and Automation of RAS
- **Fields of research**: infology information systems, analytical Internet monitoring, video data streams processing, applications of software defined radio (SDR)
- **Publications**: over 50, including 2 monographs

Alexandra A. Zaytseva (born in Saint-Petersburg, Russia, September 12, 1978)

- Senior researcher in the Laboratory of Research Automation of Saint-Petersburg Institute for Informatics and Automation of Russian Academy of Sciences
- **Education&Scientific and university degrees**: MSc degree in System Analysis at Saint-Petersburg State Politechnical University in 2001, Ph.D. degree in 2009, Saint-Petersburg Institute for Informatics and Automation of RAS
- **Fields of research:** video data streams and image processing,digital technologies of cognitive programming and 3D prototyping of complex spatial forms
- **Publications**: over 20

Ali Soltani

- Associate Professor of Urban and Transport Planning, Shiraz University in Iran He also does work with Urban Research Program, Griffith in Australia as Senior Research Fellow
- His main research interest is land use-transportation connection; sustainable mobility and urban modelling
- He has published over 50 peer-reviewed papers in both the urban planning and the transportation either in English or Persian

Sajad Askari

- Master student in Urban Planning in Shiraz University in Iran
- He is an expert in spatial analysis, GIS and Multi-criteria decision-making models
- His Master thesis is about spatial-temporal analysis of car accidents throughout Shiraz metropolitan area

Lucia Madleňáková (born in Kežmarok, Slovakia, March 12, 1975)

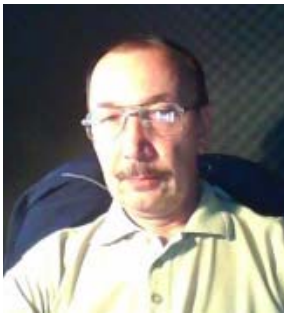
- **Education**: docent (Associate Professor 2013) in Postal Services, University of Žilina, Ph.D. degree (2004) in Postal Technology, University of Žilina and degree in Engineering (1998) (Operation of Postal and Telecommunication), University of Žilina
- **Scientific activitie**s: Program and Organizing Committee member and speaker of several international conferences, participation on different levels in many international and national level projects; Lector – Dual Degree Program • EU-US ATLANTIS – (UTEP El Paso – CVUT Prague – University of Žilina)
- **Publications**: more than 90 papers published on national and international journals and/or presented at scientific conferences
- **Field of research**: postal and logistics services, optimization process of postal and logistics systems, legislation and regulation in the postal and telecommunications sector

Radovan Madleňák (born in Námestovo, Slovakia, June 8, 1974)

- Vice-Dean for science and research, Faculty of Operation and Economics of Transport and Communications, University of Žilina, Žilina, Slovakia
- **Education**: Ph.D. degree (2004) in Postal Technology, University of Žilina and degree in Engineering (1997) (Operation and Economics of Communications), University of Žilina
- **Scientific activitie**s: Program and Organizing Committee member; presentation in a number of international conferences, participation on different levels in many international and national level projects
- **Publications**: more than 120 papers published in national and international journals and/or presented at scientific conferences
- **Field of research**: postal and logistics services, optimization process of postal and logistics systems, application of ICT in business, e-commerce and marketing

Aleksey G. Mironov (born October 15, 1954)

- Scientific director of "D un D centrs, Ltd." and Aviation Research centre in Riga
- **Education:** Riga Civil Aviation Engineering Institute, Mechanics Faculty (1972–978) **Scientific and university degrees:** Candidate of Technical Science Degree (1984), Riga Aviation University, Dr.Sc.Ing. (1992)
- **Publications:** Author of more than 30 publications, including articles and inventor's certificates
- **Fields of research:** vibration diagnostics of rotating machines, turbomachines, bearings, gears; structural analysis of static and dynamic structures; vibration monitoring of machines and structures; development of advanced technologies by dynamic parameters



Pavel G. Doronkin (born in Almata, May 27, 1956)

- Technical director of "D un D centrs, Ltd." and Aviation Research centre in Riga, Head of Vibroacoustic Laboratory
- **Education:** Riga Institute of Civil Aviation Engineering, Mechanical Department (1973–1979)
- **Publications:** Author of more than 30 publications, including papers and inventor's certificates
- **Fields of research:** Monitoring systems for aviation and civil structures applications. Vibration and structural analysis, design and development of experimental testing equipment, software development

Alexander I. Priklonskiy (born in Riga, Latvia, February 14, 1948)

- Senior research manager, "D un D centrs, Ltd."
- **Education:** Riga Civil Aviation Engineering Institute, Mechanics Faculty (1966-1972)
- **Scientific and university degrees:** Candidate of Technical Science Degree (1982), Riga Aviation University, Dr.Sc.Ing. (1992)
- **Publications:** Author of more than 20 publications, including articles and inventor's certificates
- **Fields of research:** dynamics and durability, diagnostics of the technical state, research and analysis of vibrations, finite element method

Sergey M. Yunusov (born in Ukraine, April 26, 1956)

- Lecturer at Transport and Telecommunication Institute
- **University study**: Air Forces Engineering Academy named after Professor Zhukovsky (1981–1985)
- Mg.Sc.Comp. (2009) Transport and Telecommunication Institute
- Dr.Sc.Ing. (2014) Transport and Telecommunication Institute
- **Publications**: 18 scientific papers and 4 teaching books
- **Field of research**: diagnostics of gas turbine engine, expert system, neural network

CUMULATIVE INDEX

TRANSPORT and TELECOMMUNICATION, volume 15, no. 3, 2014 (Abstracts)

Uryvsky, L., Osypchuk, S. The Analytical Description of Regular LDPC Codes Correcting Ability, *Transport and Telecommunication*, vol. 15, no. 3, 2014, pp. 177–184.

The analytical description of regular LDPC (Low-Density Parity Check) codes correcting ability has been investigated. The statistical dependencies for the maximum number of corrected bits per the code word as a function of LDPC code word length and code rate are given based on multiple experimental analyses of LDPC check matrices. The analytical expressions are proposed for the cases of linear, exponential and polynomial approximations of given results. The most exact analytical formula is proved by criterion of the minimum divergence between the experimental and theoretical results.

Keywords: LDPC code, correcting ability, analytical description

Kolarovszki, P., Vaculík, J. Intelligent Storage System Based on Automatic Identification, *Transport and Telecommunication*, vol. 15, no. 3, 2014, pp. 185–195.

This article describes RFID technology in conjunction with warehouse management systems. Article also deals with automatic identification and data capture technologies and each processes, which are used in warehouse management system. It describes processes from entering goods into production to identification of goods and also palletizing, storing, bin transferring and removing goods from warehouse. Article focuses on utilizing AMP middleware in WMS processes in Nowadays, the identification of goods in most warehouses is carried through barcodes. In this article we want to specify, how can be processes described above identified through RFID technology. All results are verified by measurement in our AIDC laboratory, which is located at the University of Žilina, and also in Laboratory of Automatic Identification Goods and Services located in GS1 Slovakia. The results of our research bring the new point of view and indicate the ways using of RFID technology in warehouse management system.

Keywords: RFID technology, warehouse, management, automatic identification, processes

Kolarovszki, P. Research of Readability and Identification of the Items in the Postal and Logistics Environment, *Transport and Telecommunication*, vol. 15, no. 3, 2014, pp. 196–208.

This article deals with RFID technology, which is a part of automatic identification and data capture. Nowadays, the identification of parcels in postal sector is carried through barcodes. In this article we would like specify, how can be postal parcels located in postal container identified in the transmission process of postal main processing centre by UHF RFID technology. All results are verified by measurement in our AIDC laboratory, which is located at the University of Žilina. Our research contains 12 different types of orientation tags and antennas and more than 1000 tests. Our identification performance was close to 100%. All tested parcels were located in postal container. The results of our research bring the new point of view and indicate the ways using of UHF RFID technology in postal applications. At the end of this article the utilization of the RFID technology in postal logistics chain is characterized.

Keywords: RFID technology, logistics chain, parcels, identification, postal container

Aksenov, A. Y., Kuleshov, S. V., Zaytseva, A. A. An Application of Computer Vision Systems to Solve the Problem of Unmanned Aerial Vehicle Control, *Transport and Telecommunication*, vol. 15, no. 3, 2014, pp. 209–214.

The paper considers an approach for application of computer vision systems to solve the problem of unmanned aerial vehicle control. The processing of images obtained through onboard camera is required for absolute positioning of aerial platform (automatic landing and take-off, hovering etc.) used image processing on-board camera. The proposed method combines the advantages of existing systems and gives the ability to perform hovering over a given point, the exact take-off and landing. The limitations of implemented methods are determined and the algorithm is proposed to combine them in order to improve the efficiency.

Keywords: computer vision, unmanned aerial vehicle control

Madleňák, R., Madleňáková, L. Digital Advertising System in Urban Transport System of Žilina Town, *Transport and Telecommunication*, vol. 15, no. 3, 2014, pp. 215–226.

The Internet and information and communication technologies (ICT) have changed everything: news, commerce, advertising, relating to others, getting information and transport too. It has changed how the people work, how they practice religion, how they date, how they spend the free time and how they travel. One of the technological innovations that are based on usage ICT in advertising space is digital signage. This article presents the results of research dedicated to investigate the relationships between customers-passengers and this new ICT technology in real environment. The results of the research stimulate the discussion about the future advertising practices in Žilina town. Based on the wide analysis of opportunities the digital signage technology in advertising practices, the presented marketing research investigates how passengers accept virtual advertising technology in urban transport system of Žilina town. Authors highlight the advantages of interactivity between digital signage technology and consumers. The conclusions of this article triggers further investigations in the area of the interactions between the digital advertising technology and passengers, and the passengers' perception and acceptation of shopping activities on the basis of advertising in digital signage medias.

Keywords: digital signage, marketing digital media, transport system, calculation, ROI

Soltani, A., Askari, S. Analysis of Intra-Urban Traffic Accidents Using Spatiotemporal Visualization Techniques, *Transport and Telecommunication*, vol. 15, no. 3, 2014, pp. 227–232.

This paper presents a spatiotemporal analysis of intra-urban traffic accidents data in Metropolitan Shiraz, Iran during the period 2009–2010. It is tried to identify the accident prone zones and sensitive hours using Geographic Information Systems (GIS)-based spatiotemporal visualization techniques. The analysis aimed at the identification of high-rate accident locations and safety deficient area using Kernel Estimation Density (KED) method. The investigation indicates that the majority of occurrences of traffic accidents were on major streets which play a meta-region functional role and are linkage between main destinations with high trip generation rate. According to the temporal distribution of car crashes, the peak of traffic accidents incident is simultaneous with traffic congestion peak periods in the main arterial roads. The accident-prone locations are located in districts with high speed and traffic volume, therefore, they should be considered as the priority investigation locations to safety promotion programs.

Keywords: accidents, traffic, GIS, spatiotemporal analysis, Shiraz

Mironov, A., Doronkin, P., Priklonskiy, A., Yunusov, S. Adaptive Technology Application for Vibration-Based Diagnostics of Roller Bearings on Industrial Plants, *Transport and Telecommunication*, vol. 15, no. 3, 2014, pp. 233–242.

Roller bearings are widely used in equipment of different applications; therefore, the issues related to the assessment of bearing technical state and localization of bearing faults are quite important and relevant. The reason is that technical state of a bearing is a critical component, which determines efficiency of a mechanism or equipment. For bearings inspection and diagnostics, various methods of vibration-based diagnostics are used. The adaptive technology for vibration-based diagnostics developed in "*D un D centrs*" is an effective tool for evaluation of technical state of bearings in operation compared to the existing SKF method.

Keywords: roller bearing, vibration-based diagnostics, SKF method, deterioration, adaptive technology

TRANSPORT and TELECOMMUNICATION, 15. sējums, 3. nr., 2014. g. (Anotācijas)

Urivskis, L. Osipčuks, S. Analītisks apraksts par regulāra zema blīvuma paritātes pārbaudes kodu labošanas spēju, *Transport and Telecommunication,* 15. sēj., 3. nr., 2014. g., 177.–184. lpp.

Rakstā tiek izpētīta regulāra zema blīvuma paritātes pārbaudes (ZBPP) kodu labošanas spēja. Statistikas atkarības par laboto bitu uz koda vārdu maksimālo skaitu kā ZBPP koda vārda garuma funkciju un koda ātrumu ir dotas, pamatojoties uz vairākām eksperimentālām ZBPP pārbaudes matricu analīzēm. Rakstā tiek ierosinātas analītiskās izteiksmes doto rezultātu lineāros, eksponenciālos un polinoma aproksimāciju gadījumos.Visprecīzākā analītiskā formula ir pierādīta ar minimālo atšķirību starp eksperimentāliem un teorētiskiem rezultātiem kritēriju.

Atslēgvārdi: ZBPP kods, labošanas spēja, analītisks apraksts

Kolarovskis, P., Vaculiks, J. Inteliģentas uzglabāšanas sistēma, kuras pamatā ir automātiskā identifikācija, *Transport and Telecommunication*, 15. sēj., 3. nr., 2014. g., 185.–195. lpp.

Šajā rakstā tiek parādītas RFID tehnoloģijas kopā ar noliktavas vadības sistēmām. Rakstā arī tiek diskutēts par automātiskās identifikācijas un datu iegūšanas tehnoloģijām un procesiem, kas tiek izmantoti noliktavu vadības sistēmā. Tā apraksta procesus no preču iekļūšanas ražošanā, līdz preču identificēšanai un arī izvietošanai uz paliktņiem, uzglabāšanai, tvertņu nodošanai un preču izņemšanai no noliktavas.

Visi rezultāti tiek pārbaudīti ar mērījumiem mūsu laboratorijā, kas atrodas Žilinas universitātē, kā arī Preču un pakalpojumu automātiskās identifikācijas laboratorijā, kas atrodas *GS1* Slovākijā. Mūsu pētījuma rezultāti sniedz jaunu viedokli un norāda veidus RFID tehnoloģiju izmantošanā noliktavas vadības sistēmā.

Atslēgvārdi: RFID tehnoloģijas, noliktava, vadība, automātiskā identifikācija, procesi

Kolarovskis, P. Pasta un loģistikas vides vienību lasāmības un identifikācijas izpēte, *Transport and Telecommunication*, 15. sēj., 3. nr., 2014. g., 196.–208. lpp.

Šis raksts risina RFID tehnoloģiju jautājumus, kas ir daļa no automātiskās identifikācijas un datu ieguves. Mūsdienās paciņu sūtījumu identifikācija pasta nozarē tiek veikta, izmantojot svītrkodus. Šajā rakstā autors gribētu parādīt, kā pasta pakas, kas novietotas pasta konteinerā, var būt identificētas nosūtīšanas procesā ar UHF RFID tehnoloģiju pasta galvenā apstrādes centrā. Visi rezultāti tiek pārbaudīti ar mērījumiem mūsu laboratorijā, kas atrodas Žilinas universitātē. Mūsu pētījumi satur 12 dažāda veida orientācijas tagus un antenas, un vairāk nekā 1000 testu. Mūsu identificēšana bija tuvu 100% . Visi testētie pasta sūtījumi atradās pasta konteinerā. Mūsu pētījuma rezultāti sniedz jaunu viedokli un parāda UHF RFID tehnoloģiju veidus pasta lietojumprogrammu izmantošanā . Šī raksta beigās ir raksturota RFID tehnoloģijas izmantošana pasta loģistikas ķēdē.

Atslēgvārdi: RFID tehnoloģija, loģistikas ķēdes, pakas, identifikācijas, pasta konteineri

Aksenovs, A., Kuļešovs, S., Zaiceva, A. Datoru vīzijas sistēmu piemērošana, lai atrisinātu bezpilota lidaparātu vadības problēmu, *Transport and Telecommunication*, 15. sēj., 3. nr., 2014. g., 209.–214. lpp.

Pētījumā analizēta pieeja datoru vīziju sistēmu piemērošanai, lai atrisinātu bezpilota lidaparātu kontroles problēmu. Ar borta kameru iegūto attēlu apstrāde pieprasa areālas platformas absolūtu pozicionēšanu (automātiska nosēšanās un pacelšanās, svārstības u.c.). Piedāvātā metode apvieno esošo sistēmu priekšrocības un dod iespēju lidināties virs noteiktā punkta, kā arī precīzu pacelšanos un nosēšanos. Īstenotās metodes ierobežojumi ir noteikti un algoritms tiek piedāvāts, lai tos apvienotu, uzlabojot efektivitāti.

Atslēgvārdi: datora vīzija, bezpilota lidaparāta vadība

Madlenaks, R., Madlenakova, L. Digitālā reklāmas sistēma žilinas pilsētas transporta sistēmā, *Transport and Telecommunication*, 15. sēj., 3. nr., 2014. g., 215.–226. lpp.

Internets, kā arī informācijas un komunikācijas tehnoloģijas (IKT) ir mainījušas visu: ziņas, komercijas, reklāmas, kas attiecas uz citiem, informācijas ieguvi un arī transportu. Tas ir mainījis to,

kā cilvēki strādā, kā viņi praktizē reliģiju, kā viņi iepazīstas, kā viņi pavada brīvo laiku un kā viņi ceļo. Viens no tehnoloģiskiem jauninājumiem, kura pamatā ir IKT reklāmas laukuma lietošana, ir digitālās zīmes. Šis raksts piedāvā pētījuma rezultātus, kas paredzēti, lai izpētītu saistību starp klientiem-pasažieriem un šo jauno informācijas un komunikācijas tehnoloģiju reālā vidē. Pētījuma rezultāti stimulē diskusiju par nākotnes reklāmas praksi Žilinas pilsētā. Pamatojoties uz iespēju plašo analīzi, digitālo zīmju tehnoloģija reklāmas praksē, dotie mārketinga pētījumi pēta to, kā pasažieri pieņem virtuālo reklāmas tehnoloģiju pilsētas transporta sistēmā Žilinas pilsētā. Autori izceļ interaktivitātes priekšrocības starp digitālo zīmju tehnoloģiju un patērētājiem. Šī raksts secinājumi rada papildu pētījumus mijiedarbību jomā starp digitālo reklāmas tehnoloģiju un pasažieriem, un pasažieru uztveri un iepirkšanās darbību pieņemšanu, pamatojoties uz reklāmas digitālo zīmju medijiem.

Atslēgvārdi: digitālās zīmes, mārketinga digitālie mediji, transporta sistēma, aprēķins

Soltani, A., Askari, S. Iekšējo-pilsētas satiksmes negadījumu analīze, izmantojot telpas un laika vizualizācijas metodes, *Transport and Telecommunication,* 15. sēj., 3. nr., 2014. g., 227.–332. lpp.

Šis raksts atspoguļo iekšējo pilsētas satiksmes negadījumu datu *Metropolitan Shiraz* (Irāna) laika posmā no 2009.–2010. gadam telpas un laika analīzi. Tiek mēģināts identificēt pakļautās negadījumiem zonas un jutīgās stundas, izmantojot uz ģeogrāfiskās informācijas sistēmas (ĢIS) balstītas telpas un laika vizualizācijas metodes. Analīzes mērķis ir identificēt augstas likmes negadījumu vietas un drošības nepietiekamo platību, izmantojot *Kernel Estimation Density (KED)* metodi. Pētījums norāda, ka lielākā daļa satiksmes negadījumu bija galvenajās ielās, kuram ir meta-reģiona funkcionālā nozīme un ir saikne starp galvenajiem galamērķiem ar augstu ceļojuma paaudžu likmi. Saskaņā ar pašreizējo automobiļu avāriju izplatīšanos, satiksmes negadījumu skaita kulminācija ir vienlaicīga ar satiksmes sastrēgumu maksimuma periodu pamata maģistrālēs. Negadījumu skartās vietas atrodas rajonos ar liela ātruma un satiksmes apjomu, tāpēc tās būtu jāuzskata par prioritārām pētījumu vietām drošības veicināšanas programmās.

Atslēgvārdi: negadījumi, satiksme, ģeogrāfiskās informācijas sistēmas (ĢIS), telpas un laika analīze, Shiraz

Mironovs, A., Doronkins, P., Priklonskijs, A., Junusovs, S. Adaptīvās tehnoloģijas pielietošana uz vibrāciju-balstītai rullīšu gultņu rūpniecības uzņēmumos diagnostikai, *Transport and Telecommunication,* 15. sēj., 3. nr., 2014. g., 233.–242. lpp.

Rullīšu gultņi tiek plaši izmantoti iekārtās dažādiem lietojumiem. Tāpēc jautājumi, kas saistīti ar gultņu defektu tehniskā stāvokļa un izvietojuma novērtējumu, ir ļoti svarīgi un nozīmīgi. Iemesls ir tas, ka gultņu tehniskais stāvoklis ir nozīmīga sastāvdaļa, kas nosaka mehānisma vai aprīkojuma efektivitāti. Gultņu pārbaudei un diagnostikai tiek izmantotas dažādas uz vibrāciju-balstītas diagnostikas metodes. Adaptīvā tehnoloģija uz vibrāciju-balstītai diagnostikai, kas izstrādāta uzņēmumā „D un D centrs", ir efektīvs līdzeklis, lai novērtētu gultņu tehnisko stāvokli darbībā, salīdzinot ar esošo *SKF* metodi.

Atslēgvārdi: veltnīšu gultnis, uz vibrāciju-balstīta diagnostika, *SKF* metode, bojājums, adaptīvā tehnoloģija

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Acknowledgements (if present) mention some specialists, grants and foundations connected with the presented paper.

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1. Gibson, E.J. (1977) The performance concept in building. In: *Proceedings of the 7th CIB Triennial Congress*, Edinburgh, September 1977. London: Construction Research International, pp. 129–136.
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3. Ministerial Council on Drug Strategy. (1997) *The national drug strategy: Mapping the future*. Canberra: Australian Government Publishing Service.
4. Nikora, V. (2006) Hydrodynamics of aquatic ecosystems. *Acta Geophysica,* 55(1), 3–10. DOI:10.2478/s11600-006-0043-6.
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