ISSN 1407-5806

COMPUTER MODELLING AND NEW TECHNOLOGIES

Volume 10
No 1

2006

Transporta un sakaru institūts
(Transport and Telecommunication Institute)

Computer Modelling and New Technologies

Volume 10, No.1 – 2006

ISSN 1407-5806
ISSN 1407-5814
(On-line: www.tsi.lv)

Riga – 2006

THE JOURNAL IS DESIGNED FOR PUBLISHING PAPERS CONCERNING THE FOLLOWING FIELDS OF RESEARCH:

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COMPUTER MODELLING AND NEW TECHNOLOGIES, 2006, Vol. 10, No.1
ISSN 1407-5806, **ISSN** 1407-5814 (on-line: www.tsi.lv)
Scientific and research journal of Transport and Telecommunication Institute (Riga, Latvia)
The journal is being published since 1996.

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Editors' Remarks

This world is not conclusion

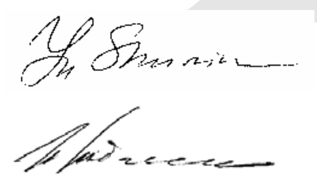
This world is not conclusion;
        A sequel stands beyond,
Invisible, as music,
        But positive, as sound.
It beckons and it baffles;
        Philosophies don't know,
And through a riddle, at the last,
        Sagacity must go.
To guess it puzzles scholars;
        To gain it, men have shown
Contempt of generations,
        And crucifixion known.

Emily Dickinson[1],
Poems, Series 3

The presented 10th volume continues our main activities in solid-state physics, applied statistics, computer modelling, computer technologies and transport technologies. In the No.1 we pay attention to problems of mathematical and applied statistics, solid-state physics, artificial intelligent information systems, some society and economy and transport technologies.

This edition is the continuation of our publishing activities. We hope our journal will be of interest for research community, and we are open for collaboration both in research and publishing.

EDITORS



Yu.N. Shunin

I.V. Kabashkin

[1] **Emily Dickinson (1830-1886)** was an American lyrical poet, and an obsessively private writer -- only seven of her some 1800 poems were published during her lifetime. Dickinson withdrew from social contact at the age of 23 and devoted herself in secret into writing. Dickinson was born in Amherst, Massachusetts, to a family well known for educational and political activity. She was educated at Amherst Academy (1834-47) and Mount Holyoke Female Seminary (1847-48). Around 1850 Dickinson started to write poems, first in fairly conventional style, but after ten years of practice she began to give room for experiments. Dickinson's works have had considerable influence on modern poetry. Her frequent use of dashes, sporadic capitalization of nouns, off-rhymes, broken metre, unconventional metaphors have contributed her reputation as one of the most innovative poets of 19th-century American literature.

Computer Modelling and New Technologies, 2006, Vol.10, No.1, 7-19
Transport and Telecommunication Institute, Lomonosov 1, LV-1019, Riga, Latvia

ADVANCED DECODING STRATEGY FOR A NOISY CHANNEL

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This paper deals with the issue of managing and controlling a noisy packet transmission channel. The paper offers a generic near optimal solution and strategy for two related critical issues: reducing the packet error probability and the synchronization failure probability in the channel. The core of this solution is a new adaptive and dynamic family of decoding algorithms that automatically regulate the number of correctable and detectable errors in any Data Unit, while for each offers the appropriate correcting method, if at all. We formulate the major objective of the proposed strategy, its formal mathematical set-up and appropriate avenues for its analysis and specifications. The examples wrapping this paper show the powerful potential of this approach.

Keywords: *noisy channel, class algorithm, advanced decoding strategy*

1. Introduction

1.1. MOTIVATION

The proper execution, operation and utilization of data communication networks are critically affected by the errors and failures at the physical layer. Therefore, it is of a special importance to have a maximum management and control over these almost in-avoiding error occurrences. The saving and the increase in the quality of the data transmission when better controlling these errors, come mainly from the higher application layers in the transmission stack. These errors and failures propagate to the higher layer protocols. Thus, on the one hand, the corresponding recovery procedures that should be applied at these higher layers require a considerable expenditure of network resources. While on the other hand, the processes that well identify the errors and failures are complicated and cannot always be formulated analytically, if at all. A more systematic analysis of the Physical Layer characteristics surface some serious issues related to error handling. In addition to that, there are complicated mathematical problems related to the physical models that attempt to better present the features of the packet physical layer that cannot be solved directly by modern mathematical and computer techniques. Nevertheless, there is a critical need to handle this situation, as a non-concise determination of the Quality of Service (QoS) characteristics causes wastes of network resources that can be evaluated by economical terms.

1.2. STATE OF ART

The problem of design of the error recovery techniques and algorithms is very important nowadays. The number of papers and researches devoted to the error control were published in recent years. The authors in [1] propose and report results on the efficiency of different error recovery and congestion control strategies over heterogeneous networks with both wired and wireless components. The relative impact of end-to-end delays and error patterns on protocol performance is investigated for different categories of protocol behavior. The paper [2] is devoted to the distributed error correction for digital libraries, where individual users can correct information in a database in real-time. The authors discuss issues including motivation to contribute corrections, barriers to participation, trust, recovery, detecting malicious changes, and the use of correction information to improve automated algorithms or predict the probability of errors. A simulation study of Forward Error Correction in ATM networks is presented in [3]. The authors use simulation to study the loss behavior of an output buffered multiplexer for the different traffic scenarios. They investigate the effectiveness of a Forward Error Correction scheme that can recover a fixed number of lost packets within a block of consecutive packets. For a heterogeneous traffic scenario consisting of video and burst sources, this scheme reduces the loss rate for the video sources by several orders of magnitude.

By reviewing the traditional and modern more progressive error recovery techniques, we can see that the basic error recovery principles are defined in the stages of a protocol or a protocol stack design. Any correction and changing of error correction code parameters, as well as standard code ability in implementation of the error detection/correction procedures, are principally impossible in the next stages of the protocol implementation. For example, the CRC (Cyclic Redundant Check) implemented on the basis of a Code Generating Polynomials in traditional HDLC protocol as well as in the Internet TCP/IP protocols that are based on the packets of variable length, is implemented in the error detection scheme only. This simplest error recovery approach is understandable because there are strict limitations imposed on the network resources and, therefore, on the error recovery time in the mentioned above traditional techniques. The same non-dynamic error recovery algorithm is applied also in the high speed ATM technology, which is based on the constant length packets that are called cells. Nevertheless, modern heterogeneous network applications such as data, voice, multimedia transmitted via the same Packet Switched Network, have different requirements to the Quality of Service characteristics (QoS). These critical issues under consideration are mean transmission time, jitter, packet loss probability, Data Unit retransmission probability, undetected error probability in any Data Unit, etc. Eventually, considering the Real time applications (voice, video, videoconferencing, etc.) the strict constraints are imposed on the mean transmission time and jitter, while in the non-Real time applications (computer data) the main issues are, in essence, minimization of the different error measures such as Data Unit undetected error probability, packet retransmission probability, etc. Therefore, the differentiated error recovery approach should be applied to the different traffic types transmitted over the same network. This paper presents a new error recovery strategy that considers different users' QoS requirements to the different traffic types and provides better utilization of the Packet Switched Networks.

2. Mathematical Model

2.1. RELEVANT FEATURES OF THE PACKET CHANNEL

For the purpose of the presented paper, the packet transmission channel is described as a flow of packets. Each Data Unit (DU), with a constant or variable length has some probability of being in error [4]. The bit errors may enjoy several distributions. The presented approach will use the memory-less Bernoulli model as well as the memory Markov model among others. Nevertheless, the error sources are not in the scope of the paper, especially when the error recovery procedures do not depend on the errors source.

2.2. DETERMINATION OF THE CHANNEL QUALITY

The approach of determining whether a transmitted data packet is a candidate to be in error, choice of the appropriate techniques or a process that will be applied for this error correction and the future influence of this error on the error packets transmitted via this channel, is determined by a classification of the packets into appropriate classes. According to the existing error recovery standards and techniques, the error correction/detection methods are applied in the homogeneous manner. We mean that the possible ways of applying the error recovery procedures, are not based on the basic relevant noisy channel characteristics. These characteristics under consideration are as follows:

1. Current noisy channel status that is determined by the Physical Layer characteristics such as Bit Error Rate (BER), error flow model, synchronization failure probability, etc.
2. Application type and user's requirements to the large range of the QoS characteristics such as mean transmission time, jitter, packet retransmission probability, etc.

This paper presents a new approach of the differential determination of the error recovery strategy that considers a cumulative approach for the near-optimal decoding scheme determination. The purpose of this paper is to present non-homogeneous treatment of the different types erroneous packets.

By relating an error packet into a class, it determines the possible set of algorithms that can be applied for a close-to-optimal correction. The methodology of defining or determining the number of class’s p', and the set of algorithms *al* where each of them hosts is a part of the discussion and analysis of this paper.

The error packets related to the given class, have the common features such as BER range, error syndrome type, requirements to the packet transmission time or packet retransmission probability. The set of the characteristics that determine the appropriating a packet to a given class, will be discussed hereafter.

2.3. CLASS CONCEPT MOTIVATION

The main advantages of the class concept are as follows:

1. Possibility to provide differentiated approach to error recovery for the erroneous packets of the different types as it was mentioned above.
2. Reducing the error recovery time. For this purpose a special parameter history that denotes the previous error recovery algorithms, is introduced. Evidently, history is determined on the basis of the Long Term Statistics. By means of the cumulative history of the noisy channel, the correction or changing of the error recovery scheme are possible within a certain class. We mean that based on the knowledge of the previous decoding algorithms, the near-optimal decoding scheme that better appropriates to the current transmission conditions, can be chosen with the sufficiently high confidence level. Moreover, each error recovery algorithm should be locally adaptive considering the channel history. In essence, such an algorithm is a function of the two main parameters:

a) historical decoding algorithms that have been applied previously;

b) time scale that describes dynamic changing of the transmission conditions.

As a matter of fact, the new parameter that determines class overload should be introduced. Based on this overload indication, the switch from the current error recovery scheme to the simplest and fastest one should be provided if a certain class is over-populated. The additional advantage of the Long Term Statistics using is, in essence, possibility to predict the set of future more probable error patterns. This prediction should be produced based on the Markov chain approach. Thus, the immediate switch to the near-optimal decoding algorithm that is appropriate to the predicted error pattern should be produced without visiting the other intermediate decoding schemes. Based on the described above assumptions, the presented strategy is, actually, random and is based on the Random Variables Theory approach [5].

3. One of the main parameters of the introduced strategy is, in essence, channel transmission rate that influences class overload and, therefore, determination of the complexity of the current near-optimal decoding algorithm.
4. The reject of the erroneous packet by the chosen analysis of the error pattern decoding algorithm and sending this packet to the other decoding algorithm (within a given class or in the other class), is possible in our strategic approach. Moreover, the visiting different decoding schemes in the same class or in the other classes should be considered. Therefore, the suggested strategy regulates the classes' external and internal structure according to the optimality principle. Thus, the probability of the erroneous error detection/correction is reduced. The packet' rejects pattern should be added to the error pattern in the determining of the channel history. Thus, the probability to receive Reject on a certain packet is reduced, whereas the complexity of the error recovery strategy is essentially simplified.

At the first cut, let us logically map the traffic packets on the communication channel into a number of classes following the guided principles.

Class Parameters. The Class is defined via several parameters. Some of these parameters are of the traffic related type, some of them are related to the application(s) that live in the top layers of the protocol stack and are served by the Transport Layer protocol. Therefore, for example, the applications' QoS requirements, is a relevant parameter candidate. Other parameters related to this one at the physical level are the BER, mean transmission time, jitter, Data Unit loss probability, etc. All the floating parameters will be derived dynamic from the optimal detection/correction solution that will be discussed hereafter.

The class might be defined in the static, but not dynamic, manner. It means that the class parameters determine a certain class in the strong manner and, moreover, are not the time functions. Nevertheless, the following actions are provided in order to reflect the different changes of the transmission conditions:

1. Creation of a new class if there exist a number of the new values of class parameters;
2. Dividing a certain class on a number of classes if the error recovery strategy implementation within a given class is rather complex and complicated;
3. Join of two or more classes into a single class. This action is logically approved if the given class (or classes) are not populated. Therefore, it is reasonable to simplify the error recovery strategy in this case.

Example. Let's assume multimedia Data Communication Network, such as Internet. Evidently, different user's applications require different QoS characteristics. For example, data transmission should be provided in the precise error-less manner, but there are no strict constraints on the packet transmission time. Whereas Real Time Traffic (RTT) transmission over Internet by means of H. 232 protocol requires minimal transmission time and, consequently, fast implementation of the error recovery procedure. Moreover, the Packet Error Rate may be rather high. We introduce the following classes' determination that is appropriate to this simple case:

Assume that the classes' number equals to 2. Erroneous packets that are appropriate to the class 1 are, in essence, voice (or other RTT) applications. Class 2 is populated by the data-NRTT packets.

Each class is defined via following parameters – Physical Layer Parameters:

a) Packet Error Rate (PER) (or BER);
b) Synchronization failure probability;
c) Application Layer parameters considering the users' requirements to QoS characteristics.

Mean error recovery time that influences the packet mean transmission time and, therefore, determines users' QoS characteristics. Now assume that the error detection/correction is implemented by a certain CRC by means of a code Generating Polynomial $G(x)$. The problem is to choice the error recovery procedure that will be applied in the near-optimal way considering each channel class and a current channel status. On the one hand, if a given data packet appropriates to the channel class 1 (for example, voice over Internet) then the appropriate error recovery techniques should be applied in the fastest and simplest manner. Hence, the relevant decoding scheme is to detect, but not to correct packet errors. The reason of this decision is that such error detection requires minimal processing time. On the other hand, if a packet channel is appropriate to the channel class 2 (computer data such as ftp, telnet, http services, etc.), then the error recovery procedure must be as concise as possible and, moreover, error recovery time is not critical. We suggest using the redundant code ability in the following flexible manner:

a) if current BER (or PER) is high than it is relevant to detect maximal number of random errors and, besides, error bursts;
b) if current BER (or PER) is rather small, then the single errors detection or correction of a small number of bit errors is preferable.

Consequently, the described error recovery strategy is adaptive and is determined via appropriating a data packet into a certain class. The more precise strategy for classes' generation is, essentially, the domain of this paper. In a general case, the classes' number depends on the different noisy channel features.

Class Characteristics. The class characteristics is defined as a continuous two-dimensional Random Variable (RV) $S(p,dist)$ that is derived from the communication channel status. In this definition, p denotes the specific BER range and dist represents the distance between the successive erroneous DUs. Evidently, dist represents the communication channel memory. For example, in the case of error burst non-qualitative communication channel, the channel errors are described by a complex Markov chain with the memory equals to *dist*. The parameter dist may be replaced by the other relevant parameters that describe channel memory: buffer size, error burst length, distribution of erroneous packets in the burst, etc.

We guess that the probabilistic approach will be useful in the class characteristics definition. The reason is that the described above class parameters are, in essence, not the constant values and, moreover, take different values with a certain probability.

In the general case, the random variable S has to be a multi--dimensional functional. Therefore, S must include parameters such as:

- Transport Layer Protocol, for example Transmission Control Protocol (TCP), User Datagram Protocol (UDP), ATM Adaptation Layer Protocol (AAL/5);
- Traffic type such as data-RTT, data-NRTT, voice, video, etc., among others [6, 7].

The Long Term Statistics, which describes the accumulated channel history, should influence the classes' structure as well.

2.4. THE CLASS ALGORITHM CONCEPT

In the general case, the class concept should have all the needed ingredients to be extended into the so-called class-algorithms. The chosen algorithm should offer a correct determination of the decoding scheme that better suites the presented ranges of the RV S. Drilling down into more details, the class estimation is chosen with a certain confidence level. Moreover, the new parameter that determines choose of the decoding algorithm within a given class, should be included to the set of the RV S parameters [8]. Thus, the class-algorithm is defined by means of the multi-dimensional functional

$Alg = Alg(p1, p2, ..., pn;\ QoS,\ history)$. Here the parameter history denotes the historical decoding algorithms used so far in a specific channel. The correspondence between the class (and class-algorithm) and the decoding algorithm is determined by the Strategic Mapping Matrix (Figure 1).

Algorithm\Class	1	2	. . . .	m
1				
2				
3				
. . . .				
A				

Figure 1. Strategic Mapping Matrix

3. Determination of the Decoding Strategy

3.1. GENERAL PRINCIPLES

Define R_i as a Decoding Table area that corresponds to a certain number of detectable and correctable errors. In order to generate a decoder that is invariant to the transition conditions (i.e., to the channel state), let us divide the co-sets set of the Decoding Table on the areas $R_1,...,R_a$, which, in a regular case, can intersect [9]. Yet, the decoding algorithm corresponding to a given area R_j.

1. There is an exact correspondence between any class and the decoding strategy that is appropriate to a given class.

2. In general, a given class might include a number of different decoding algorithms. Then the issue is to properly choose the near optimal algorithm that is most appropriate to the current conditions and situation. That means, for example, that a relevant consideration of such an algorithm choice is the class load or how heavily it is populated: if a specific class hosts a large number of DUs, then a trivial algorithm choice will be to use the simplest and fastest algorithm, so as to implement the decoding procedure more quickly. A more complex example from the Internet (IP) over ATM networks will be elaborated later on.

3. Let's define an error recovery strategy as a functional: *Correction = Correction(a,dist,K,Previous)*, where *a* and *dist* are defined as above. Actually, *K* equals the number of sequential researched DUs under consideration. At the first cut, *K* may be thought of as being a function of the upper layer application, since, it should reflect the channel memory as well as correction procedure time. Let's denote the channel memory as the maximal distance between erroneous DUs, which is covered by the presented model. For instance, the channel memory that is appropriate to the simple Markov chain is equal to one. The parameter *Previous* determines the decoding algorithm that has been applied on the previous erroneous DU. The possibility of re-visiting and correcting the previous DU by means of the current optimal decoding algorithm, should be taken into consideration.

Mathematically, the error recovery strategy can be defined in the following recursive fashion [9]:

$$Correction_j = \sum_{i=1}^{j-1} w_i Correction_i, \sum_{1}^{z} w_i = 1.$$

In the simplest case when $z = 2$, the following formula is used:

$$Correction(a,dist,K,Previous) = w*f(a,dist,K,Previous) + (1-w)*Correction(a,dist,K,Previous). \quad (1)$$

1. The functional *f* in this formulation determines the decoding algorithm that is appropriate to the current channel status. In the simple case, *f* has to be sensitive to the Short Term Statistics. Nevertheless, some influence of the Long Term Statistics has to be considered as well, and this is expressed in the second term of the *f* definition. The obvious way of determining the recursion basis for f is by a deterministic methodology. Nevertheless, the more attractive and adequate method is via a probabilistic approach. Generally speaking, this may be based on the statistical distribution of each channel status, where initial probabilistic vector of the Markov chain, defines the initial distribution [10]. The Long Term Statistics is based on the ergodic simple Markov chain with the multidimensional Probability Transition Matrix (PTM) $M = (m_{ij},.,.,)$, such that *dimM = K*K*par*. The item par denotes the number of parameters in the defined above correction function. In the presented formula (1) *par* equals to 4. In the general case, the simple Markov chain has to be replaced by a more complicated one that takes into consideration the dependency not only between two sequential DUs, but also deals with large memory between *K* successive DUs. The methodology that this issue will be handled here is starting by introducing the

Markov chain model for the protocol that is based on DUs of constant length, such as ATM cells. In that case, the DU transmission time is nearly constant, leading to the Markov chain step to be defined as a DU transmission time. Yet, in the more general case the semi-Markovian process should be introduced since DU length is not constant. In that case, in addition to the basic Markov chain the set of DU transmission time distribution functions must be considered. In any case the PTM has to be corrected or updated after the DU(s) receipt. Finally, the parameter *w* in formula (1) defines the weight of each of the two statistical contributions. In the simple approach, w may be defined in a deterministic fashion, while a larger weight has to be applied to the Long Term Statistics due to its correction nature in real time. In the more precise approach, w should be determined as a function of the Transport Layer Protocol or Application Layer Protocol. The larger the time needed for the application execution, the smaller w has to be.

2. It has been mentioned above that the Correction functional is a fundamental of the composition of number of previous correction functions. Thus, the probability theory methodology that considers the probability density function of a random variable function can be systematically applied [5].

3. It is worthwhile adding some additional dimensions to the *Correction* function, such as the Transport (or Application) Layer Protocol. Trivially, in order to reduce some relevant probability measures, such as the re-transmission probability of TCP segment (or AAL/5 cells in the IP over ATM technology), the correction must be performed in the maximum precise fashion. In the case of Real Time Traffic (RTT) transmission such as voice by the means of UDP and H.323 protocols via Internet [6], the main *Correction* characteristics are represented by the error recovery time. Thus, the decoding procedure must be as simple and fast as possible.

4. The transition from any decoding algorithm to another one is executed without changes of the Header code parameters (for instance, in the ATM cells). This characteristic makes the suggested correction function adaptive. The basic feature of this algorithm is in essence a dynamic switching of the set of the detectable and correctable error vectors.

4. Example of the Adaptive Decoding Procedure in ATM Networks

Let's present an example of the adaptive decoding strategy for the IP over ATM network. Assume that for this case the classes' number is equal to 2 and the correction algorithms number is 3. The number of sequential examined DUs cells is 2, and thus the ergodic simple Markov chain is considered.

4.1. THE GENERAL SET-UP

In order to perform the statistical analysis on incorrect cells flow, a special experiment on the ATM backbone network was conducted [11].

1. The statistical data on incorrect cell flow have been produced.
2. Two basic random variables have been introduced in any data link:
   a) the data set is the number of ATM cells received with an error, which is corrected by Header Error Control (HEC).
   b) the data set is a number of the ATM cells received with an error that cannot be corrected by this mechanism.

Statistical evaluation of these random variables has been carried out.

- The probability of receipt of ATM cell Header with the error which is corrected and the probability of receipt of ATM cell header with the error which cannot be corrected, are used as the basic data in design and investigation of the general mathematical model. Based on this data, the following two possible channel classes during cell transmission are considered. The first class corresponds to random errors (class=Good) and the second one (class=Bad) corresponds to burst errors. The simple Markov chain describes the transitions from one class to another one.
- Based on the statistical analysis of the incorrect cell flow and on the two-state Markov model of the communication channel, an original dynamic decoding strategy is proposed which automatically regulates the number of correctable and detectable errors in the ATM cell Header. The decoding process is implemented on the basis of the algebraic architecture of the Decoding Table. This strategy improves the characteristics of ATM cell synchronization control as well as cell error recovery.

By definition, ATM cell consists of a 5-byte Header and a 48-byte Payload Field and, actually, is of constant length, while the last octet of the Header is the HEC, calculated from the first four octets of the Header. The HEC supports two incompatible processes:

1) the first process is protecting the ATM cell Header from random errors;
2) the second process is the identification of cell boundaries (Cell Delineation).

Following the recommendation in [12], the HEC generating polynomial is:

$$G(x) = x^8 + x^2 + x + 1 = (x+1)(x^7 + x^6 + x^5 + x^4 + x^3 + x^2 + x).$$

Here the second multiplier is, essentially, the primitive polynomial. This code is the Fire's shortened code. Based on the properties of the linear codes [13], it is obvious that the shortened cyclic code (40,32) can correct all error bursts of the length ≤ 4. Moreover, the code is able to correct all single error bursts of the length $\le b$ and simultaneously to detect all error bursts of the length $\le l$ ($l \ge b$) under the condition $b + l \le 8$.

4.2. THE GENERATION OF THE POSSIBLE ALGORITHMS

In order to produce a decoder that is invariant to the transition conditions (i.e., to the channel state), the co-sets set of the Decoding Table is divided into the areas In order to produce a decoder that is invariant to the transition conditions (i. e., to the channel state), the co-sets set of the Decoding Table are divided into the areas $R_1,...,R_a$ which, in the common case, may be intersected. Assume that the decoding algorithm corresponding to the area R_j is g_j. Thus, considering two different channel classes, the following correction strategy is proposed:
The first correction algorithm g_1 corresponds to the channel class- Good. This algorithm enables to detect all bursts of length ≤ 7 and to correct all single errors. The reason that the algorithm g_1 is suitable for the channel class *G* is that bit error probability in the class *G* is low. The decoding table for g_1 is presented in Table 1.

TABLE 1. Decoding Table in the case of the algorithm g_1, $N = 2^{32} - 1$

$A_0 = S_0 = 0...0$	A_1	A_2	A_3	...	A_N
$S_1 = 10...0$	B_{12}	B_{22}	B_{32}	...	$B_{N-1,2}$
$S_2 = 01...0$	B_{13}	B_{23}	B_{33}	...	$B_{N-1,3}$
...	...	...	...	...	...
$S_{40} = 00...1$	$B_{1,40}$	$B_{2,40}$	$B_{3,40}$	...	$B_{N-1,40}$

Here the area R_1 includes all rows that correspond to the co-set leaders $S_0,...,S_{40}$. The following notations will be used hereafter: {A} is the set of code combinations. A_0 is a zero code combination: $A_i \left(i = 1,...,2^{32} - 1\right)$ is the i- th code combination. B_{ij} is a Standard Array element and S_j is the j-th co-set leader. Each co-set leader S_j corresponds to a single error in the j-th bit. {B} is the set of the code illegal combinations, $B_{ij} \in \{B\}$ is the illegal combination that is appropriate to the legal combination A_i and the co-set leader S_j. In the presented case, each co-set leader S_j corresponds to a single error in the j-th bit. The reason that the algorithm g_1 is suitable for the channel class *G* is that the bit error probability in the class *G* is low. Moreover, for the real communication channels, the probability of single error in the code combination is higher than the probability of any multiple errors. Since, each co-set of the Decoding Table corresponds to a single error; the number of co-sets is equal to 40. Thus, the Decoding Table includes 41 rows. The number of the columns corresponds to the number of the legal code combinations, is 2^{32}.

4.3. ALGORITHMS SPECIFICATIONS FOR ERROR BURSTS

Let's consider now to the decoding algorithms g_2 and g_3, which are matched with the channel class B. As a matter of fact, this class is characterized by the Bernoulli (or Markov) type error distribution with a sufficiently high bit error probability. Therefore, the probability of error burst is comparatively high.

Yet, the algorithm g_2 enables to detect, but not to correct, the random errors. The maximal number of the possible detected errors equal to 8. This algorithm is more efficient in the periods of the channel's quality deterioration and high class overload because the correction procedure is implemented in the simplest way. In this case, the Decoding Table is defined as follows:

TABLE 2. Decoding Table in the case of the algorithm g_2, $N = 2^{32} - 1$

$A_0 = S_0 = 0...0$	A_1	A_2	A_3	...	A_{N-1}	A_N

The Decoding Table includes a single row with the legal code combinations. The number of columns is the same as in the algorithm g_1, where the detected error is identified by the computation of the non-zero syndrome, and the decoding procedure is faster. This feature is reasonable because the absence in the Receiver of the additional operations, which are related to an identification of incorrect combination. Yet, the algorithm g_3 executes the error bursts correction of the length ≤ 4. In this case, the Decoding Table is defined by Table 3. Here the sets {A} and {B} are defined as in the algorithm g_1. The first 301 rows including all erroneous vectors are appropriate to the error bursts of the length 1, 2, 3 and 4, consequently. Thus, the error vectors space $S_1,...,S_{40}$ coincide with the corresponding vectors of the Decoding Table defined for the algorithm g_1. The following error vectors $S_{41},...,S_{79}$ correspond to all error bursts of the length 2. The number of these vectors, accordingly, is 39. In a similar manner, the Decoding Table elements $S_{80},...,S_{156}$ correspond to the subset of error bursts of the length 3. At last, the co-set leaders $S_{157},...,S_{300}$ correspond to all error bursts of the length 4. There are 144 different erroneous combinations that correspond to the subset of error bursts of the length 4. As a result, it is needed to operate with the Decoding Table that contains 300 error vectors. It is reasonable to use this algorithm in the case of multiple errors, as their probability is sufficiently high and the load on the class in not high. It should be mentioned that in the general case there exist a number of correction algorithms that must be considered for each channel class.

TABLE 3. Decoding Table in the case of the algorithm g_3, $N = 2^{32} - 1$

$A_0 = S_0 = 0...0$	A_1	A_2	A_3	...	A_N
$S_1 = 10...0$	B_{12}	B_{22}	B_{32}	...	$B_{N-1,2}$
$S_2 = 01...0$	B_{13}	B_{23}	B_{33}	...	$B_{N-1,3}$
$S_3 = 001...0$	B_{14}	B_{24}	B_{34}	...	$B_{N-1,4}$
...	...	...	...	...	...
$S_{40} = 00...1$	$B_{1,40}$	$B_{2,40}$	$B_{3,40}$	...	$B_{N-1,40}$
$S_{41} = 110...0$					
$S_{42} = 011...0$					
$S_{43} = 0011...0$					
...	...	...	...	...	...
$S_{79} = 00...111$					
$S_{80} = 0101...0$					
$S_{81} = 00101...0$					
...	...	...	...	...	...

$S_{156} = 00...111$					
$S_{157} = 1111...00$					
$S_{158} = 01111...0$	The set $\{B_{ij}\}$				
$S_{159} = 001111...0$					
•••	•••	•••	•••	•••	•••
$S_{195} = 0...1111$					
$S_{196} = 10110...0$					
$S_{197} = 01011...0$					
•••	•••	•••	•••	•••	•••
$S_{300} = 00...101$					

Remark. The problem in the Receiver is to decide which decoding algorithm to use when receipting the current HEC. It is suggested to define the limit class overload Lim that determines the correction strategy within class Bad. Actually, the parameter Lim must be included in the Correction functional as the additional dimension. Obviously, the presented approach will be very useful considering the Wireless Communication Networks [13], where a number of problems arise in this context. These problems are caused by the several reasons:

1) the first reason is related to non-reliability of the radio channel. Sufficiently high BER and very high synchronization failure probability as opposed to the qualitative fiber optic channels, characterize these channels;

2) the second reason is that synchronization failure probability in the radio channel is not a constant value. As soon as the reliability of the wireless channel depends on a number of external reasons, synchronization failure probability is essentially a time function.

5. Minimization of the Undetected Error Probability in the Decoding Procedure

5.1. DECODER WITH THE NON-INTERSECTING DECODING DOMAINS

Assume that the number of channel classes within transmission (n, k) code combination is a. The goal is to construct decoder that is invariant to the transmission conditions. For this purpose let us divide the $x \le 2^{n-k} - 1$ co-sets set of the Decoding Table that correspond to the non-zero syndromes on the non-intersecting domains $R_1, R_2, \ldots, R_a$. It should be reminded that the decoding algorithm corresponds to the area R_j is q_j. Let's define the optimal division of co-sets set and corresponding decoding algorithms set by minimization of the average number of the erroneous corrected bits:

$$u = \min \sum_{q} \sum_{R_j} \sum_{i=1}^{2^k - 1} p_j(z_i) m_j(z_i).$$

Here $p_j(z_i)$ is the probability of error vector $z_i \in R_j$ and $m_j(z_i)$ is the number of non-correctly recovered in this case bits. As a matter of fact, R_j corresponds to the integration (summation) over the co-sets of the given domain. At last, q corresponds to the summing over the whole set $\{R\}$ including the zero syndrome. The problem under consideration is to conclude whether it is worth to apply different decoding algorithms and whether it is sufficient to use the single. Let's assume now that a single error recovery algorithm q_0 is applied for all co-sets.

Then $u_0 = \sum_{R_j} \sum_{i=1}^{2^k - 1} p(z_i) m_0(z_i)$. Evidently, the co-sets division by applying different decoding algorithms is relevant if $u \prec u_0$.

Example. Assume that the linear (*n*, *k*) code is defined by the check matrix: $H = \begin{pmatrix} H_1 & 0 \\ 0 & H_2 \end{pmatrix}$.

Here H_1, H_2 are the check matrices of the certain linear codes (n_1, k_1) and (n_2, k_2) respectively. The zero matrices in the right and in the left corners contain t_1 and t_2 elements in the rows respectively. The decoder with the divided co-sets is realized in the following way:

1) assume that the maximal number of the recoverable errors in the (n_1, k_1) and (n_2, k_2) code combinations is e_1 and e_2 respectively;
2) then the maximal number of correctable/detectable errors in the final code combination is equal to e_1 in the first t_1 bits, e_2 in the last t_2 bits and, at last, $e = e_1 + e_2 - \left[\frac{n_1 - t_1 - 1}{2}\right]$ within $n_1 - t_1 = n_2 - t_2$ internal bits;
3) evidently, the beginning t_1 bits are decoded by the matrix H_1. The last t_2 bits are by the matrix H_2. Lastly, the $n_1 - t_1 = n_2 - t_2$ internal bits of the code combination are decoded by two defined algorithms respectively. We mean that the code (n_2, k_2) check combinations are applied for additional control of error correction in the internal $n_1 - t_1$ bits under the condition that the code (n_1, k_1) has been applied on the previous stage;
4) in such a way, all co-sets leaders that correspond to the whole set of the detectable/correctable errors combinations, are divided on the three following domains: $A_1 \underset{(n_2)}{0\ldots0}\, \underset{(n_2)}{0\ldots0} A_2, \underset{(t_1)}{0\ldots0} A_3 \underset{(t_2)}{0\ldots0}$. Here A_1, A_2, A_3 are the sets of non-zero binary vectors of the length t_1, t_2 and $n_1 - t_1$ respectively.

5.2. DECODER WITH THE INTERSECTING DECODING DOMAINS

In a general case, it is possible to apply different error recovery strategies/algorithms within a given Decoding Table. For example, it is possible to apply different decoding algorithms within a certain class (or classes). Each decoding algorithm is defined on the basic of the current syndrome. The problem under consideration is to determine the error recovery strategy in the non-optimal way based on the current noisy channel state considering the minimization of the non-correct recovered bits. On the other words, the minimization problem of the probability of the bit non-correct decoding caused by applying the non-appropriated decoding scheme, is discussed.

For this purpose let's assume the following considerations:

- the erroneous code combination with the non-zero syndrome r_x has been received from the noisy channel;
- the error detection/correction within the corresponding to the r_x syndrome co-set, may be executed by applying different error recovery algorithms;
- the near-optimal strategy is determined by introducing the matrix $H(r_x) = \left(G(i, j)\right)$ such that $\dim H(r_x) = a \times c$. Here each item *G*(*i*,*j*) denotes the number of non-correct decoded bits in the combination under the condition that the *i*-th decoding algorithm have been applied within the channel class *j*;
- then the average number of the non-correctly recovered bits under the condition that the current syndrome is r_x, equals to

$$G_0(r_x) = \sum_{i=1}^{c} L_i(r_x) p^{(i)}. \quad (2)$$

Here the following notations are used: $L_i(r_x) = \sum_{j=1}^{a} G(i,j) p_j$;

where $p_1, \dots, p_a$ are the probabilities of each channel class; $p^{(1)}, \dots, p^{(c)}$ are the probabilities of applying each decoding algorithm in the decoder.

The problem under consideration is to determine the probabilities set $p^{(1)}, \dots, p^{(c)}$ that provide minimal $G_0(r_x)$ value regarding the constraint on the average number of correctly recovered bits:

$$B_0(r_x) = \sum_{i=1}^{c} K_i(r_x) p^{(i)} \ge B_0. \tag{3}$$

Here $K_i(r_x) = \sum_{j=1}^{a} B(i,j) p_j$ and the $B(i,j)$ meaning for the number of correctly recovered bits the same as $G(i,j)$ for non-correctly recovered bits.

Evidently,

$$\sum_{i=1}^{c} p^{(i)} = 1. \tag{4}$$

Therefore, the problem stated above is to minimize the linear form of c variables $p^{(1)}, \dots, p^{(c)}$ under the limitations (2) and (3) [14]. In order to solve the problem, the inequality (2) should be replaced by the equality by including the additional negative defined abstract variable $p^{(c+1)}$ that is presented in the linear form (2) with the zero ratios. Thus,

$$G_0(r_x) = \sum_{i=1}^{c} L_i(r_x) p^{(i)} + 0 \cdot p^{(c+1)}, \tag{5}$$

$$\sum_{i=1}^{c} K_i(r_x) - p^{(c+1)} = B, \tag{6}$$

$$\sum_{i=1}^{c+1} p^{(i)} = 1. \tag{7}$$

Keeping in mind that $c \ge 2,$ we conclude that the number of variables in the linear form (5) is greater than the number of linear constraints. Therefore, the system of equations (5)-(7) has infinite number of solutions [14]. Moreover, any $c - 1$ variables may be defined in any way. Based on the linear algebra methods, these $c - 1$ variables may be chosen equal to zero. Then the basic problem solution that corresponds to the min $G_0(r_x)$ contain only two non-zero probabilities. These probabilities are calculated by the solution of the equations (6) and (6) under the condition that the system determinant is differ from zero. Let's assume that the basic variables are $p^{(1)}$ and $p^{(2)}$ probabilities. By applying the linear algebra methods considering the solution of linear equations systems, we conclude that the defined above linear form contains the non-basic variables only with the new linear ratios:

$$G_0(r_x) = \sum_{i=1}^{c} \widetilde{L}(r_x) p^{(i)} + A, \tag{8}$$

where A is the free ratio. Keeping in mind that all the non-basic variables $p^{(3)} = \dots = p^{(c+1)} = 0,$ the minimal $G_0(r_x)$ value is equal to A under the condition that all $\widetilde{L}_i(r_x) \succ 0.$ Otherwise, if there exists any negative ratio $\widetilde{L}_M(r_x) \prec 0$, then the $\min(G_0(r_x))$ does not exist. The reason is that in the new system of basic variables that includes the $p^{(M)}$ probability, satisfies always the following condition: $G_0(r_x) \prec A$.

As a matter of fact, the minimization problem solution includes the respective determination of the basic variables, as well as the checking of positively of the linear ratios in the linear form (8). The near optimal order of the decoding strategy implementation is determined by the probabilities that correspond to the basic variables. If the basic variable $p^{(c+1)} = 0$, then the solution is possible considering the equality in the linear constraint (2); otherwise, if $p^{(c+1)} \succ 0$, then the constraint is realized by the inequality.

Remark. It should be mentioned that it is relevant to define the other linear (or in the general case non-linear) constraints on the $p^{(1)},\ldots,p^{(c)}$ variables. For example, the natural constraint is, essentially, the limitations applied on the number of binary operations N_0 during the decoding process execution, which is equivalent the limitation on the error recovery time. In such a way, the following inequalities should be considered:

$$\sum_{i=1}^{c} N_i(r_x)p^{(i)} \le N_0 \text{ and } N_i(r_x) = \sum_{j=1}^{a} R(i,j)p_j \ ,$$

where $R(i,j)$ determines the average number of operations required for error recovery by means of the i-th algorithm under the condition that the channel's current class is j. As in the previous case, by introducing the additional basic variable $p^{(c+2)} \succ 0$ the inequality defined above should be transformed into the equality as well as in the previous case. Then the basic solution will include three non-zero probabilities while the solution method will be the same as in the previous case. By virtue, if the constraints imposed on the system are in contradiction then it is impossible to design a decoder with given parameters.

Lastly, the near-optimal error recovery strategy may be defined for each non-zero syndrome as well as for the syndromes' set that are contained in the common domain of the different decoding algorithms.

Conclusions

The current error correction framework presents an advanced strategy that dramatically improves the overall performance of the packet transmission mechanism. It optimally corrects and fixes any deterioration in the performance caused by noisy channel, such as BER, undetected error probability and synchronization failure probability.

This strategy enjoys the following main advantages.

- In general, it matches any Packet Switched Networks technology. Moreover, these techniques may use packets variable and fixed length, respectively.
- The suggested strategy is adaptive. This feature implies that any derived technique from this practice, will optimally determine the number of classes, the algorithms contained in each class, the buffer length, etc.
- The implementation of any derived technique is simply and easily executed because the transitions between the various decoding algorithms are done by the same error correcting code without changing the code generating polynomial.
- The additional feature of the presented method is that it may be applied in the most near- optimal way considering different users applications and traffic types. Keeping in mind that the Packet Network is saving several users and applications, the present strategy is close to optimal in most of its parameters.

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Received on the 21st of September 2005

Computer Modelling and New Technologies, 2006, Vol.10, No.1, 20-27
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THE APPLICATION OF FUZZY LOGIC TO THE CONSTRUCTION OF THE RANKING FUNCTION OF INFORMATION RETRIEVAL SYSTEMS

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The quality of the ranking function is an important factor that determines the quality of the Information Retrieval system. Each document is assigned a score by the ranking function; the score indicates the likelihood of relevance of the document given a query. In the vector space model, the ranking function is defined by a mathematic expression such as:

$$score(q,d) = \sum_{t \in q} \text{tf(t in d) * idf(t) * getBoost(t.field in d) * lengthNorm(t.field in d) * overlap(q,d) * queryNorm(q)}$$

We propose a fuzzy logic (FL) approach to defining the ranking function. FL provides a convenient way of converting knowledge expressed in a natural language into fuzzy logic rules. The resulting ranking function could be easily viewed, extended, and verified:

- if (tf is high) and (idf is high) → (relevance is high);
- if (overlap is high) → (relevance is high).

By using above FL rules, we are able to achieve performance approximately equal to the state of the art search engine Apache Lucene (ΔP10 +0.92%; ΔMAP -0.1%). The fuzzy logic approach allows combining the logic-based model with the vector model. The resulting model possesses simplicity and formalism of the logic based model, and the flexibility and performance of the vector model.

Keywords: *Fuzzy Logic, fuzzy set, ranking function, information retrieval, vector space model, tf idf model, Boolean model*

1. Introduction

Information Retrieval (IR) model could be defined formally as a quadruple [*D, Q, F,* $R(q_i, d_j)$] where *D* is a set of logical views of documents, *Q* is a set of user queries, *F* is a framework for modelling documents and queries, and $R(q_i,d_j)$ is a ranking function which associates a numeric value to the document d_j according to a system assigned likelihood of relevance to a given user query q_i [1]. The quality of the ranking function is an important factor that determines the quality of the IR system.

Logic based Boolean model is one of the earliest models used in the IR systems. The Boolean model owes its former popularity to its clean formalism and simplicity. However, the Boolean model suffers from major drawbacks: binary decision criterion without any notion of a grading scale; difficulty of translating the query into Boolean expressions [1, 6, 4].

Vector model is a popular retrieval model. The main advantages of the vector model are: its term-weighting scheme improves retrieval performance; its partial matching strategy allows retrieval of documents that approximate the query conditions; it's weighting scheme sorts the documents according to their degree of similarity to the query [1]. However, vector model does not possess clean formalism and simplicity.

Fuzzy logic [13] allows combining the logic based model with the vector model. The resulting model possesses simplicity and formalism of the logic based model, and the flexibility and performance of the vector model.

2. Related work

Fuzzy logic has not been applied to defining ranking function directly; however, fuzzy set model has been used to define fuzzy queries [2], fuzzy relationships between query terms and documents [7,8]. Each query term defines a fuzzy set and each document has a degree of membership in the corresponding set. The Fuzzy Set model performs query expansion based on principles of fuzzy logic. A thesaurus is constructed by defining a term-term correlation matrix. The correlation matrix is used to define a fuzzy set associated to each index term k_i. Document d_j has a degree of membership $\mu_{i,j} = 1 - \prod_{k_i \in d_j}(1 - c_{i,j})$. The procedure to compute the document's relevance given a query is analogous to the procedure used by the Boolean model, except rules of fuzzy logic are used [8]. The fuzzy set model approach is not popular among the information retrieval community and has been discussed mainly in the literature dedicated to fuzzy theory [1]. Recent attempts utilizing fuzzy search were tried at TREC 2001 with the search engine NexTrieve. NexTrieve used a combination of the exact search and fuzzy search. The conference paper that describes NexTrieve [3] unfortunately does not provide details on the theoretical foundation and implementation of the system. It appears that application of the fuzzy logic was to the position, and to the scoring: terms in different parts of the document would get different scores and not all of the words would need to be present in order for the document to get a high score. According to the authors of NexTrieve, one of the biggest drawbacks of the system was that it did not take into account word frequency within a document and document length which has been shown to be a crucial part of the ranking score. Performance of NexTrieve system was substandard with average precision of 0.13; and after some additional modifications (adding word frequency, and document length parameters) were made, it went up to 0.19; which was still substandard [3].

3. Motivation

3.1. THEORETICAL FIT BETWEEN FUZZY LOGIC MODEL AND INFORMATION RETRIEVAL MODEL

The Information Retrieval system retrieves documents based on a given query. Both the documents and in most cases, the queries, are instances of natural language. Natural langue is often vague and uncertain [9]. It is difficult to judge something that is vague and uncertain with deterministic crisp formulas and/or crisp logical rules. Fuzzy logic is based on the theory of fuzzy sets, a theory which relates to classes of objects with un-sharp boundaries in which membership is a matter of degree [12]. Documents, queries and their characteristics could easily be viewed as fuzzy granular classes of objects with un-sharp boundaries and fuzzy memberships in many concept areas [14].

Fuzzy logic is a logical system, which is an extension of multi-valued logic [12]. Use of fuzzy logic provides the benefits of the Boolean method while overcoming its drawbacks. Since the concept of fuzzy logic is quite intuitive, the fuzzy logic model provides a framework that is easy to understand for a common user of IR system. Documents retrieved by a query are evaluated by the rules of the Fuzzy Inference System (FIS) that have precise semantics. Unlike the Boolean model that is based on binary decision criterion {relevant, not relevant}, fuzzy logic expresses relevance as degrees of memberships (e.g., document | query could have a relevance measure with the following degrees of membership: 0.7 highly relevant and 0.5 moderately relevant and 0.1 not relevant). Fuzzy logic is tolerant of imprecise data [1].

3.2. EXPERT KNOWLEDGE TRANSFER PROCESS

Since IR deals with natural language, many of the rules that are used to determine relevance of documents come from experts and from experience. Before the rules are converted to formulas, they are often communicated as observations in natural language (e.g., if most of the terms of the query are present in the document, then the document is likely to be relevant; if a term of a query occurs in a document often, that will increase the likelihood of the document being relevant, etc.). Fuzzy logic allows incorporating rules into the system in a natural way. The basic concept underlying FL is that of a linguistic variable, a variable whose values are words rather than numbers. FL may be viewed as a methodology for computing with words rather than numbers. Even though words are inherently less precise than numbers their use is closer to human intuition. Computing with words allows the tolerance for imprecision [12].

3.3. OPTIMIZATION/VERIFICATION PROCESS

Various graphical user interfaces such as Matlab Fuzzy Logic Toolbox provide a convenient way to view all the components of an FIS; to modify them easily; and to examine and verify the effects of changes. Parameters of FIS could be modified systematically by utilizing various optimization approaches. The fuzzy logic approach is a very flexible one. It is possible to make small improvements without disturbing the integrity of the system, by changing parameters of the parts of the system such as rules and membership functions. If more granularity is desired more rules and/or membership functions could be added.

3.4. IMPLEMENTATION

Baseline Model. The Ranking Fuzzy Inference System (R-FIS) could be based on various retrieval models that have well defined rules and provide access to underlying features. The vector model was chosen as the baseline model due to its good performance. The R-FIS input variables are typical variables that are used in tf.idf based systems: tf.idf, overlap. It is beneficial to use variables that have been established to be significant in determination of document's relevance, without them, the results would suffer [3].

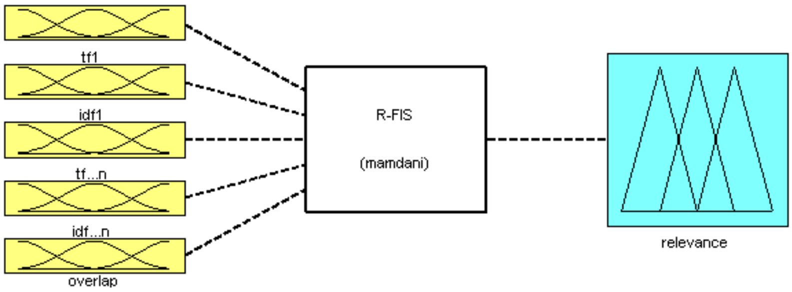

Figure 1. Fuzzy Inference System

3.5. FUZZY INFERENCE SYSTEM

Rules. Ranking Fuzzy Inference System (R-FIS) is constructed with the use of Matlab Fuzzy Logic Toolbox. The first step in construction of an FIS is to define rules. Rules will be derived from a common knowledge about information retrieval and the tf.idf weighting scheme. The order of the rules in FL does not affect the output.

If many of the terms of the query are found in the document (overlap), the document is likely to be highly relevant:

• if (overlap is high) → (relevance is high)

For each of the query terms the following rules are defined:

If a query term in a document has high tf and idf measures, the document is likely to be highly relevant:

• if (tf is high) and (idf is high) → (relevance is high)

We have found that the performance of the system is better if the rules that penalize low features are added. To achieve this we added the negated rules for each of the rules above:

• if (overlap is not high) → (relevance is not high)

• if (tf is not high) and (idf is not high) → (relevance is not high)

Approach to simply negate the rules is compact but it assumes that the opposing membership function is inversely symmetrical. Another approach to creating negated rules is by adding appropriate membership functions such as *low* and *high*.

Each rule has a weight associated with it. In case of R-FIS each tf.idf rule was assigned a weight of 1/t, where t is a number of terms in a query. Weight for the overlap rule was 1/6 of the weight of the tf.idf rule. Overlap rule weight is lower due to the fact that to some degree overlap rule is already represented in each of the tf.idf rules.

Fuzzy Sets / Membership Functions. It is necessary to give mathematical meaning to the linguistic variables mentioned in above rules: high relevance, low relevance, high tf, low tf, high idf, low idf. It is necessary to define fuzzy sets (see Figure 2). All input variables and output variables currently have two fuzzy sets associated with each variable: high, not high. If greater granularity is desired, more fuzzy sets could be defined such as for example: very low, low, medium, high, very high, etc. A membership function is a curve that defines how each point in the input space is mapped to a degree of membership of fuzzy set. There are various membership function types such as: sigmoid, Gaussian, trapezoidal (trapmf), triangular (trimf), etc. [5]. Gaussian and sigmoid based functions through a higher number of parameters provide for a higher flexibility.

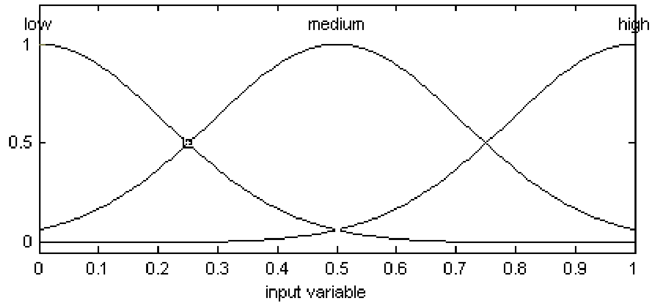

Figure 2. Fuzzy Sets / Membership Functions

Generally Gaussian function better models the underlying variables, but knowledge about variables that are being modelled is necessary in order to define parameters of the function appropriately. In this case, linear functions such as trapmf and trimf achieve suitable performance without the need for further tuning. In certain cases, it seems more beneficial to use linear membership functions such as trapezoidal and triangular membership functions. For example, in the case of idf; it appears to be more efficient to use trapmf. Trimmf since idf has already been normalized with log function: $idf = \log(\frac{N}{n})$. For each of the input and output variables of the R-FIS two triangular membership functions were defined: high, not high.

Fuzzy Inference Process. The Fuzzy Inference Process is performed automatically, but in order to explain how the system functions, each of the steps will be examined (see Figure 3).

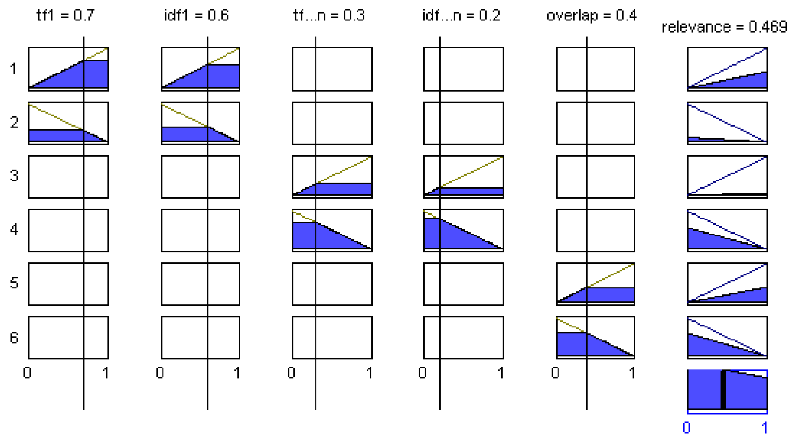

Figure 3. Fuzzy Inference Process

Input Fuzzification. The first step is to take the crisp numerical values of the inputs and determine the degree to which they belong to each of the appropriate fuzzy sets via membership functions [5]. For example: tf1 = 0.7, this would be translated into 0.7 degree of membership in fuzzy set “high” and 0.3 degree of membership in fuzzy set “not high”. Same procedure would be applied to all of the inputs (see Figure 4).

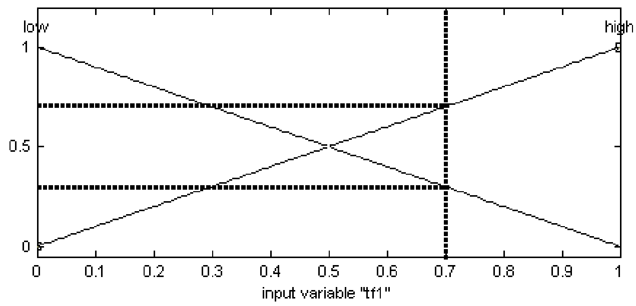

Figure 4. Input Fuzzification

Fuzzy Operator Application. Once the inputs have been fuzzified, the degree to which each part of the antecedent has been satisfied for each rule is known. If the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain a number that represents the result of the antecedent for that rule [5]. Let's examine rule: if (tf1 is high) and (idf1 is high) → (relevance is high). In this case the input to the fuzzy operator is two membership values from fuzzified input variables: e.g. tf1 has a 0.7 degree of membership in fuzzy set high and idf1 has a 0.6 degree of membership in fuzzy set high. For the R-FIS product (prod) was selected as a fuzzy operator *for* and method so the result is 0.7 * 0.6 = 0.42. This procedure is applied to every rule. *The and fuzzy* operator could be seen as an aggregation applied locally in this case to the terms of the rule. There are different operators *for* and operator such as: min, prod. Prod has a much better theoretical fit, since by using the prod operator, output is determined by all features of the terms and not just the minimum one. *Prod* has also been established to be an appropriate and method realized by a formula based tf.idf model; since in the formula tf and idf are combined through use of product operator:

$$score(q,d) = \sum_{t \in q} \text{tf(t in d) * idf(t) * } \ldots$$

Implication Method Application. The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set. A consequent of the implication method is a fuzzy set represented by a membership function, which weights appropriately the linguistic characteristics that are attributed to it (see Figure 5). The consequent is reshaped using a function associated with the antecedent (a single number) and the weight of the rule. Implication is applied to every rule [5].

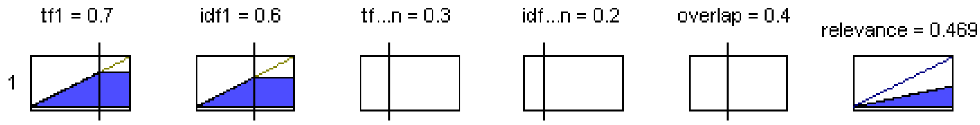

Figure 5. Implication Method

The implication operator determines the shape of the consequent fuzzy set. The prod operator appears to be a better fit in comparison with the min operator; since prod scales the consequent fuzzy set unlike min that truncates the consequent fuzzy set. The prod operator allows the output fuzzy set to retain its shape properties; unlike the min operator that alters the shape of the resulting fuzzy set.

Output Aggregation. Since decision is based on all of the rules in the FIS, the rules must be combined in order to make the decision. Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. The input of the aggregation process is the list of fuzzy sets that represent the outputs of each rule (see Figure 6). The output of the aggregation process is a fuzzy set [5].

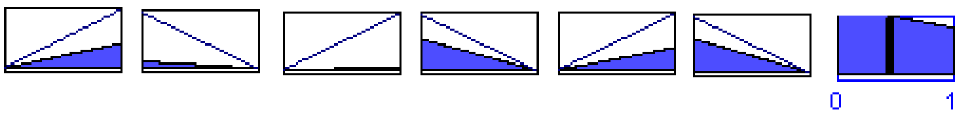

Figure 6. Output Aggregation

There are a number of different aggregation methods available, such as: max, sum, probabilistic or. The nature of the information retrieval dictates that the determination of the ranking should be done based on all of the rules. In this case the sum aggregation method appears to be a much better fit. Sum has also been established to be an appropriate aggregation method by a formula based tf.idf model since terms are combined through the sum operator: $score(q,d) = \sum_{t \in q} \ldots$.

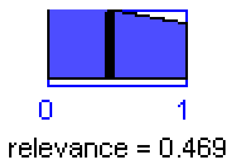

Figure 7. Output Defuzzification

Output Defuzzification. The input for the defuzzification process is the aggregate output fuzzy set and the output is a single number (see Figure 7). Fuzziness helps the rule evaluation during the intermediate steps; however the final desired output for each variable is generally a single number. Fuzzy set must be defuzzified in order to resolve a single output value from the set. There are various methods for defuzzification such as: centroid, bisector, middle of maximum (the average of the maximum value of the output set), largest of maximum, and smallest of maximum.

Centroid method is the most widely used method. In this case the centroid method is used, since it satisfies the underlying properties of the system and exhibits the best performance. The centroid method returns the centre of the area under the curve. In this case it is 0.469.

4. Evaluation

4.1. EVALUATION DATA SET

To evaluate the effectiveness of R-FIS, data from the NIST TREC 2004 Robust Retrieval Track was used. The robust retrieval track explores methods for improving the consistency of retrieval technology by focusing on poorly performing topics [10].

TABLE 1. Document Corpus

Source	# Docs	Size (MB)
Financial Times	210,158	564
Federal Register 94	55,630	395
FBIS, disk 5	130,471	470
LA Times	131,896	475
Total Collection:	*528,155*	*1904*

The Robust test set contains 250 topics: topics 301-450 (ad hoc topics from TREC 6-8), topics 601-650 (new topics for 2003 robust track), and topics 651-700 (new topics for 2004 robust track) [11].

TABLE 2. Relevant document statistics for topic sets

Topic Set	Number of topics	Mean Relevant per topic	Minimum Number Relevant	Maximum Number Relevant
Old	200	76.8	3	448
New	49	42.1	3	161
Hard	50	88.3	5	361
Combined	249	69.9	3	448

Baseline System. Apache Lucene version 1.4.3 [15] with query expansion module [16] was used as the baseline search engine. Lucene is an open source, high-performance, full-featured text search engine written entirely in Java.

System Configuration. FIS Rules:

• if (overlap is high) → (relevance is high)

For each of the query terms:

• if (tf is high) and (idf is high) → (relevance is high)

• if (tf is not high) and (idf is not high) → (relevance is not high)

TABLE 3. FIS Specifications

Fuzzy Inference System Type	Mamdani
And method	product
Implication method	product
Aggregation method	sum
Defuzzification	centroid
Membership Function Type	triangular [0,1]

Each rule has a weight associated with it. Each query term rule assigned a weight of 1/t, where t is a number of terms in a query. Weight for the overlap rule is 1/6 of the weight of the query term rule, due to the fact that to some degree overlap rule is already represented in each of the query term rules (see Figure 8).

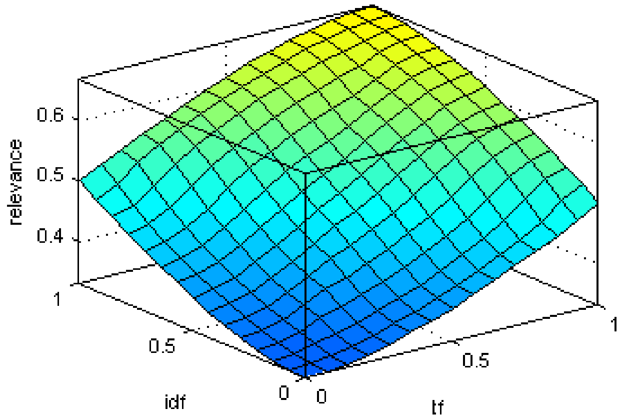

Figure 8. Rule Surface

4.2. PERFORMANCE EVALUATION

TABLE 4. Evaluation Results

Tag	Topic Set	MAP	P10	%no
Lucene	Old	0.2232	0.3945	15.00%
R-FIS	Old	-0.0061	+0.0035	-0.00%
Lucene	New	0.2738	0.4143	10.20%
R-FIS	New	+0.0201	+0.0326	-2.00%
Lucene	Hard	0.1374	0.286	28.00%
R-FIS	Hard	+0.0117	+0.026	-2.00%
Lucene	Combined	0.2332	0.3984	14.10%
R-FIS	Combined	-0.001	+0.0092	-0.40%

Values given are the mean average precision (MAP), precision at rank 10 averaged over topics (P10), the percentage of topics with no relevant in the top ten retrieved (%no).

R-FIS has slightly outperformed Lucene on all of the topic sets on the P10 and %no measures. MAP measure was slightly better for R-FIS on *New* and *Hard* topic sets and slightly worse for *Old* and *Combined* topic sets. Overall, we believe R-FIS performed very well, considering that Lucene is a state of the art vector based search engine.

Conclusion

We presented a new method of defining the ranking function by combining the logic based model with the vector model through the use of fuzzy logic. Fuzzy logic provides a convenient way of converting existing knowledge into fuzzy logic rules. To construct a system with a good performance, a basic understanding of the tf.idf principles and the basic principles of information retrieval theory appears to be sufficient. The resulting model possesses simplicity and formalism of the logic based model, and the flexibility and performance of the vector model.

For the baseline model we have used vector based model due to its speed and performance, but fuzzy logic approach could be applied to any retrieval model that has well defined rules and provides an access to underlying features.

Acknowledgments

The author would like to thank James Allan and William Kilmer for helpful discussions and suggestions. I would also like to thank *Open Source* community for providing the numerous tools and systems I have used to produce both my results and this paper.

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Received on the 21st of October 2005

Computer Modelling and New Technologies, 2006, Vol.10, No.1, 28-30
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DEPENDENCE OF THE ENERGY OF MOLECULES ON INTERATOMIC DISTANCE AT LARGE DISTANCES

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Earlier it was supposed that the energy of molecules increases monotonously with interatomic distance at large distances. However, dissociation of molecules (for example, $Te_2 \rightarrow 2Te$) often is a chemical reaction. According to chemical kinetics, chemical reactions overcome a potential barrier. Therefore, there must be a barrier at the energy – distance curve. Earlier it has been supposed that quantum chemical methods give a wrong result at big distances if the wave function does not turn to zero. It is shown that it must not obligatory turn to zero. The wave function can be a piecewise function.

***Keywords**: diatomic molecules, potential energy curves, wave function, dissociation of molecules*

1. Introduction

According to the traditional point of view, the energy of molecules depends on interatomic distance according to Curve 1, Fig. 1 (the energy of independent atoms is supposed to be zero). This dependence has the following disadvantages. Dissociation of molecules (for example, $F_2 \rightarrow 2F$) often is a chemical reaction. According to chemical kinetics, chemical reactions overcome a potential barrier. This barrier is absent at Curve 1.

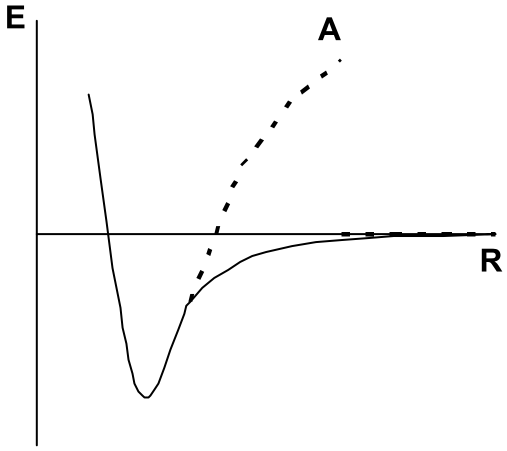

Figure 1. Dependence of the energy of molecule on the distance between atoms: 1 – traditional theory, 2 – according to this paper. Point A is the point where the bond begins to fail.

It is a very strong argument against Curve 1. Rupture is a transition from the less stable state to the more stable state, from the state with higher energy to the state with lower energy. According to non-equilibrium thermo-dynamics, the system being deflected greatly from equilibrium looses steadiness and the system changes to a qualitatively new steady state (with lower energy) [1]. In [2-4] it has been shown that failure of molecules during stretching of solids happens like this: at strong stretching of interatomic bonds, molecules loose stability and turn to a qualitatively new steady state with lower energy, resp. ruptured molecules. One can assume that dissociation of a single molecule also happens like this. According to the Curve 1 (see Figure 1), the energy must not be released during separation of interatomic bond. However, it has been found experimentally that during stretching of solids, chemical bond ruptures lead to micro-heating of substance to a few hundred grades [5].

2. Theory

The dependence of the energy of diatomic molecule on the distance between the atoms must be the following one: the Curve 2 (Figure 1). During stretching of molecule, its energy becomes larger than that of independent atoms and in the point A the molecule becomes greatly unstable and turns to the dissociated state. There are two possibilities: from the point A the curve tends smoothly to zero, or transition to the dissociated state happens by a jump. With this the energy of elastic stretching is released.

Pay attention that the function E(R) defined at $R_0 \leq R < R^*$ ($E(R_0)$ is minimal, $E(R^*) = 0$, Curve 2, Fig. 1) at $R \to \infty$ does not turn to zero. The energy E(R) at $R \to \infty$ has the sense of the energy of fictitious molecule being stretched to the infinitive distance. Dependence E(R) near the bottom of the potential well is found experimentally, behaviour of E(R) at big distances is an invention of physicists. It has been supposed that E(R) at $R \to \infty$ turns to zero. It is not obvious. Molecule must not obligatory fail if E(R) = 0.

In [6] the H2+ ion has been solved exactly taking into account that the energies of electron - nuclei interaction are

$$E_1 = 1/2K r_1^2, \tag{1}$$

$$E_2 = 1/2K r_2^2 \tag{2}$$

where K is the coefficient of proportionality, r_i is the distance between nucleus and the electron, and the energy of nuclei interaction is

$$E_3 = \lambda/R^2,\ \lambda > 0, \tag{3}$$

where R is the inter-nuclear distance. According to this calculation, the energy of the ground state is

$$E(R) = 3/2\cdot(2K/m)^{1/2} + KR^2/4 + \lambda/R^2, \tag{4}$$

where m is the hydrogen atom nucleus mass. The attraction force in such ion is greater than that in the real one, and the repulsion force is less. It means that the binding energy of such ion is bigger and dE/dR for it is bigger than that for the real ion. Let us build the following H2+ ion model: near the bottom of the potential well energy is described by (4), at bigger distances it is described by the same equation but K and λ depends on R. In this model E(R) behaves like the Curve 1, Figure 1. By fitting of K(R) and λ(R) in (4) one can ascertain that the depth of the potential well is the same as that with the real H2+. In such model dependence E(R) is stiffer and must reach zero by smaller R than that of the real ion. It is a contradiction: the ion with larger binding energy fails earlier than that with the smaller one. Therefore, the initial supposition that bond failure happens at E = 0, is not true. The rupture of chemical bond begins in the real ion at R_A, $E(R_A) > 0$, but the bond rupture in the model ion begins at $R_M > R_A$, $E(R_M) > E(R_A)$.

3. Results and Discussion

Earlier it was supposed that quantum chemical methods give a wrong result at big distances if the wave function does not turn to zero at $R \to \infty$. It is necessary to make the conclusion that the wave function must not turn to zero. This result explains the paradox: experimental dissociation energies usually are much bigger than theoretical ones [7, 8]. Mulliken in [9] predicted the existence of maxima at the energy – distance curves: „Here a theoretical calculation by Pauling on He_2^{++} should also be mentioned, in which he found that the potential energy curve should have a pronounced maximum … In view of these several examples where recognition of the existence of maxima has been practically *forced* on us, it seems likely that such cases may prove relatively frequent if we try to *seek* them. After all, maxima in potential energy curves are obvious necessities for polyatomic molecules, in view of the existence of activation energies, so that their occurrence also for diatomic molecules is not at all shocking."

In astrophysics the barriers at Curve 2 (Figure 1) are found experimentally for some molecules. They are barriers of chemical reaction [10]. Many dependencies in Nature are piecewise functions. For example, the dependence of strength of solids is a piecewise function of length and diameter of the specimen, scatter in strength in solids is a piecewise function of strength or the time the load is withstood

[2–5], the chemical reaction rate constant and equilibrium constant are piecewise functions of temperature [11–12]. It is very possible that the wave function is also a piecewise function of its arguments:

$$\psi(R) = \psi_1(R), \quad R_0 \le R < R_1;$$
$$\psi(R) = \psi_2(R), \quad R_1 \le R < R_2;$$
$$\psi(R) = \psi_3(R), \quad R_2 \le R < R_3;$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . \qquad (5)$$

One sees that $\psi_1(R)$ must not turn to 0 when R turns to infinity, even if there is no hump at the Curve 1 (Figure 1). Earlier, the authors added additional terms to $\psi_1(R)$ to secure $\psi_1(R) \to 0$ at $R \to \infty$. This trick seems doubtful now.

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Received on the 21sr of September 2005

Computer Modelling and New Technologies, 2006, Vol.10, No.1, 31-35
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СТРУКТУРНЫЙ АНАЛИЗ ДЕМОГРАФИЧЕСКОГО КРИЗИСА В ЛАТВИИ

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Рассмотрены основные признаки и причины демографического кризиса в Латвии. Анализ соответствующего знакового орграфа показал наличие в системе внутренней напряженности и конфликтов интересов. Без принятия действенных мер по преодолению демографического кризиса численность населения страны может катастрофически уменьшаться. Основной стратегией выхода из кризиса является увеличение инвестиций в экономику и в социальную сферу.

Ключевые слова: *демографический кризис в Латвии, когнитивная структуризация*

В переходный период последнего десятилетия XX века в Латвии имел место глубокий экономический кризис, произошло резкое расслоение общества и обнищание значительной части населения. Такие негативные социальные явления как безработица и бедность, присущие экономическим потрясениям, поразили общество. Особенно сильно это проявляется в небольших городах Латвии и в сельской местности.

Ухудшение условий жизни подавляющего большинства населения, естественно, отрицательно сказалось на демографической ситуации в стране. Уровень рождаемости в Латвии всегда был недостаточным даже для простого воспроизводства населения. Показатель рождаемости в Латвии был наиболее высоким в период 1986-1988 годов. Но, начиная с 1990 года, положение в этой сфере стало резко ухудшаться, и в 1998 году показатель рождаемости уменьшился почти в 2 раза. В настоящее время Латвия по этому показателю находится на одном из последних мест в мире [1]. По данным Всемирного банка средний ежегодный прирост населения в Латвии в 1990-98 годах составлял (-1.3%) – это предпоследнее место в мире. По этому показателю ежегодного прироста населения Латвия находится на последнем месте в Европе.

С другой стороны, ожидаемая продолжительность жизни людей в Латвии в 90-х годах уменьшалась (у мужчин снизилась на 4 года, у женщин – на 2 года), и она является одной из самых низких в Европе [2]. Начиная с 1991 года, число умерших людей стабильно превышает численность родившихся. Показатель младенческой смертности в Латвии в 1995 году по сравнению с 1989 годом увеличился в 1.7 раза. Приведенные факты говорят о том, что в Латвии в настоящее время имеет место глубокий демографический кризис.

Население любой страны является непосредственным производителем и потребителем производимых в государстве материальных благ, оно обеспечивает функционирование экономики. Поэтому развитие экономики во многом зависит от наличия в стране трудовых ресурсов, определяемых общей численностью населения. Среднегодовой прирост трудовых ресурсов в Латвии в 1990-98 годах составил (-1.6%) – это было предпоследнее место в мире [1]. По сравнению с 80-ми годами XX века этот показатель уменьшился в 2 раза.

Для планирования развития экономики государства и улучшения демографической ситуации в Латвии важное значение имеет анализ причин демографического кризиса и путей его преодоления. Население страны является составным элементом социально-экономической системы государства. Вместе с другими элементами население образует относительно замкнутую систему, в которой происходят экономические, социальные, технологические и другие процессы, определяющие жизнь страны. Отдельные элементы этой системы находятся в структурной взаимосвязи, а поэтому одним из эффективных способов анализа существующей ситуации является использование системного подхода. В настоящей работе была поставлена цель: разработать структурную модель, определяющую влияние на численность населения Латвии основных социально-экономических факторов, и последующий ее анализ.

Социально-экономическая система, включающая основные факторы, влияющие на численность населения, может быть описана следующими элементами: u_1 – численность населения; u_2 – уровень рождаемости; u_3 – уровень смертности; u_4 – средства, выделяемые государством на здравоохранение, образование, просвещение и социальную сферу; u_5 – уровень бедности; u_6 – уровень безработицы; u_7 – средства, выделяемые государством на оборону, охрану границ, безопасность и т.п.; u_8 – инвестиции в экономику. Рассматриваемая система относится к “мягким системам”. В этих системах человеческий фактор играет значительную роль, и они могут адаптироваться к внешним воздействиям [3].

Для качественного системного анализа социально-экономической системы в работе использована когнитивная структуризация: была построена структурная схема причинно-следственных связей в виде когнитивной карты (Рисунок 1).

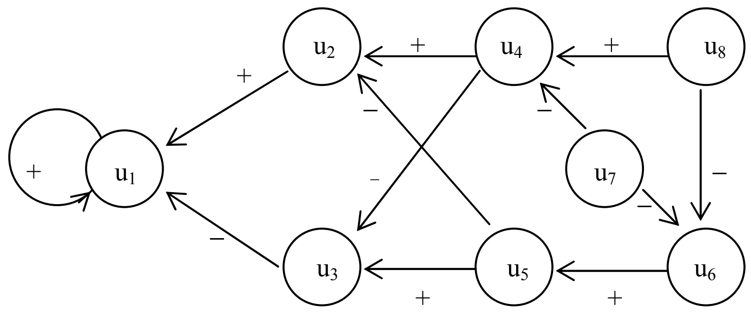

Рисунок 1. Когнитивная карта социально-экономической системы для анализа влияния различных факторов на численность населения

Вершины когнитивной карты (u_1, u_2, ... u_8) – это элементы системы, ориентированные дуги между вершинами (u_j, u_i) определяют влияние одних элементов системы на другие. Дуги характеризуют причинно-следственные связи элементов: дуга от вершины u_j к вершине u_i проводится тогда, когда изменение u_j вызывает значительное изменение u_i. Причинно-следственная связь будет положительной (знак “плюс”), если увеличение u_j приводит к увеличению u_i, а уменьшение u_j – к уменьшению u_i. Связь будет отрицательной (знак “минус”), если увеличение u_j приводит к уменьшению u_i, а уменьшение u_j – к увеличению u_i. На языке математики когнитивная карта является знаковым ориентированным графом (орграфом).

Рассматриваемый орграф является слабо связным и включает один контур – это петля при вершине u_1 и 9 полуконтуров. Контур-петля определяется логистической эволюцией человеческой популяции и представляет собой управляющую петлю положительной обратной связи [4]. Эта петля отражает нелинейность структурных изменений в системе, характеризующуюся ускорением роста численности населения при улучшении условий жизни.

Пять полуконтуров сбалансированы и имеют положительные обратные связи, так как число отрицательных дуг в них четное. Эти полуконтуры усиливают отклонения: увеличение (уменьшение) значения любой вершины в каждом из них в конечном счете приводит к его дальнейшему увеличению (уменьшению). Например, полуконтур u_1-u_2-u_4-u_8-u_6-u_5-u_3-u_1 является сбалансированным: увеличение инвестиций в экономику (u_8) снижает уровень безработицы (u_6) и уровень бедности (u_5). Если люди живут богаче, лучше питаются и заботятся о здоровье, то снижается уровень смертности (u_3), а численность населения (u_1) растет. Это способствует также увеличению рождаемости (u_2) и преодолению демографического кризиса. Инвестиции способствуют росту доходов бюджета и государство получает возможность больше средств выделять на образование, здравоохранение и социальную сферу (u_4). А увеличение этих средств (u_4) можно рассматривать как инвестиции в экономику (u_8), так как растущей экономике необходимы образованные, здоровые люди. Таким образом, данная стратегия преодоления демографического кризиса, заключающаяся в увеличении инвестиций в экономику (u_8) и в социальную сферу, здравоохранение, образование (u_4), является в существующих условиях перспективной.

Остальные четыре полуконтура имеют отрицательные обратные связи – число отрицательных дуг в них нечетное, а поэтому они несбалансированы и противодействуют отклонениям. Например, в полуконтуре u_1-u_2-u_4-u_7-u_6-u_5-u_3-u_1, который несбалансирован, имеют место противодействия отклонениям в вершинах орграфа. Увеличение средств, выделяемых на оборону, охрану границ и т.п. (u_7) в условиях Латвии с ее слабой экономикой приводит к уменьшению средств, выделяемых на здравоохранение, образование и социальную сферу (u_4). Это вызовет увеличение смертности населения (u_3) и снижение рождаемости (u_2). В итоге численность населения (u_1) будет уменьшаться, а уровни бедности (u_5) и безработицы (u_6) возрастают. Такая ситуация потребует от государства дополнительных средств на пособия, переобучение людей, организацию дополнительных рабочих мест и т.д. Естественно, эти дополнительные расходы препятствуют увеличению средств, выделяемых на оборону (u_7). Так действует механизм противодействия отклонению в вершине u_7.

Вершина u_7 в орграфе является специфической, потому что через нее проходят только полуконтуры с отрицательной обратной связью, являющиеся несбалансированными. Поэтому из-за наличия такой локальной несбалансированности в вершине u_7, согласно теореме Харари о структуре [5], знаковый орграф в целом не сбалансирован. Если бы эту вершину (u_7) можно было убрать совсем, то орграф был бы сбалансирован глобально. Однако, практически это невозможно, так как в любой стране есть затраты на оборону, полицию и т.п. Несбалансированность орграфа указывает на присутствие в рассматриваемой социально-экономической системе конфликтов интересов и внутренней напряженности. В странах с развитой экономикой при наличии достаточно больших средств увеличение значения вершины u_7 в меньшей степени, чем в Латвии, будет отрицательно сказываться на здравоохранении и социальной сфере, а, следовательно, и на демографической ситуации. Сбалансированность орграфа и снятие внутренней напряженности в системе были бы достигнуты при изменении с “минуса” на “плюс” либо знака дуги (u_7, u_4), либо дуги (u_7, u_6). Из-за слабой экономики первая стратегия – изменение знака дуги (u_7, u_4) – практически неосуществима. Вторая стратегия неосуществима по своей сути, так как средства, выделяемые на оборону, охрану границ, полицию и т.п., являются специфическими инвестициями, а поэтому обычно несколько увеличивают число рабочих мест и занятость населения.

С целью более глубокого анализа рассматриваемой системной модели выполнено исследование импульсных процессов в орграфе. Каждая из вершин орграфа (u_1, u_2, ... u_8) принимает некоторые значения $v_i(t)$ в дискретные моменты времени $t = 0$; 1; 2; 3 ... Импульсом является изменение значения вершины $v_j(t) - v_j(t\text{-}1) = p_j(t)$ при $t > 0$. Для проведения анализа использована квадратная матрица A смежности орграфа (Рисунок 2), составленная при следующих обозначениях дуг орграфа:

$$\mathrm{sgn}(u_j, u_i) = \begin{cases} 1, \text{ если дуга } (u_j, u_i) \text{ положительная,} \\ -1, \text{ если дуга } (u_j, u_i) \text{ отрицательная,} \\ 0, \text{ если дуга } (u_j, u_i) \text{ отсутствует.} \end{cases}$$

$$A = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & -1 & 0 & 0 \end{pmatrix}$$

Рисунок 2. Матрица смежности знакового орграфа

Рассматривались простые автономные импульсные процессы, в которых вектор импульсов P(0) имеет i-ю компоненту равную 1, а все остальные компоненты равны нулю. Начальный единичный импульс, введенный в вершину u_i распространяется за определенное время по всей системе. Автономный импульсный процесс в орграфе описывается уравнениями [5]:

$$P(t) = P(0) \cdot A^t,$$

$$v_j(t) = v_j(\text{исходное}) + (\text{элемент } i, j \text{ в матрице } I + A + A^2 + \cdots + A^t),$$

где I – единичная матрица, соответствующая А. Вектор исходных значений вершин V условно был принят равным V(исходное) = (0, 0, ... 0), за единицу времени взят год. В соответствии с установленной ранее перспективной стратегией улучшения демографической ситуации в стране в вершину u_8 вводится единичный начальный импульс P(0) = (0, 0, 0, 0, 0, 0, 0, 1). В результате расчетов было установлено следующее. В момент времени t = 3 единицам численность населения (вершина u_1) увеличивается на 2 условные единицы, а каждый следующий момент времени будет происходить увеличение численности населения на 4 единицы. При введении единичного начального импульса P(0) = (0, 0, 0, 1, 0, 0, 0, 0) в вершину u_4, начиная со второго момента времени t = 2, численность населения через каждую единицу времени увеличивается на 2 единицы.

При введении начального импульса P(0) = (0, 0, 0, 0, 0, 0, 1, 0) в вершину u_7 в момент времени t = 3 численность населения уменьшится на 2 единицы, а затем изменяться не будет. Увеличением уровней бедности (u_5) и безработицы (u_6) путем введения соответствующих единичных импульсов численность населения, начиная с момента времени t = 2, каждый последующий момент уменьшается на 2 единицы. Отсюда следует, что наилучшей стратегией для преодоления демографического кризиса в Латвии является увеличение инвестиций в экономику, а также в социальную сферу, здравоохранение и образование.

Для анализа орграфа важным является проверка его как на абсолютную устойчивость (устойчивость по значениям вершин), так и на импульсную устойчивость. При наличии неустойчивости орграфа в описываемой им системе могут происходить нежелательные процессы: при импульсной неустойчивости величины некоторых импульсов или значения каких-то вершин при абсолютной неустойчивости могут катастрофически увеличиваться [5]. Орграф считается абсолютно или импульсно устойчивым в импульсном процессе при устойчивости каждой его вершины.

При анализе знакового орграфа на устойчивость использовалась его матрица смежности А (Рисунок 2). Характеристический многочлен матрицы А можно записать в следующем виде:

$$C_A(\lambda) = \det(A - \lambda I) = a_8 \cdot \lambda^8 + a_7 \cdot \lambda^7 + \cdots + a_1 \cdot \lambda + a_0,$$

где a_i – коэффициенты при корнях λ_i характеристического многочлена, det – определитель матрицы. Скалярные параметры λ_i, удовлетворяющие характеристическому уравнению $C_A(\lambda) = 0$, это собственные значения матрицы А. Вычисления дали следующий спектр собственных значений рассматриваемой матрицы А: 1; $-1{,}405\cdot10^{-5}$; $5{,}865\cdot10^{-8}\pm1{,}399\cdot10^{-5}\cdot i$; $1{,}393\cdot10^{-5}$; 0; 0; 0. Поскольку получено, что все ненулевые собственные значения различны и не превосходят по абсолютной величине единицу, то орграф импульсно устойчив для всех простых импульсных процессов [5]. Отсюда, при введении какого-то начального импульса в систему величины импульсов во всех вершинах орграфа будут ограничены и не смогут бесконечно возрастать. Но поскольку есть одно собственное значение равное 1, орграф по значениям вершин (абсолютно) будет неустойчив для некоторого простого импульсного процесса. Изменение значений вершин ничем не ограничено, поэтому численность населения страны при неблагоприятных обстоятельствах может катастрофически уменьшаться.

Заключение

- Основные демографические показатели (коэффициент воспроизводства населения, показатель младенческой смертности, средний ежегодный прирост населения и др.) указывают на то, что Латвия находится в состоянии глубокого демографического кризиса.
- Знаковый ориентированный граф, определяющий влияние на численность населения страны основных социально-экономических факторов, является несбалансированным, что указывает на конфликты интересов и наличие внутренней напряженности в системе.
- Проверка орграфа на устойчивость показала, что он обладает импульсной устойчивостью, величины импульсов в его вершинах ограничены и не могут бесконечно возрастать. В то же время орграф неустойчив по значениям вершин (абсолютно), поэтому численность населения в условиях кризиса может катастрофически уменьшаться, она никак не ограничена.
- Основными потенциально приемлемыми стратегиями преодоления демографического кризиса в Латвии являются увеличение инвестиций в экономику и в социальную сферу.

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Received on the 21st of September 2005

Computer Modelling and New Technologies, 2006, Vol.10, No.1, 36-39
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COMPROMISE BETWEEN THE ACTIVE SYSTEMS WITH DISTRIBUTED CONTROL

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On the base of theoretical model the advisability of amalgamation of the two enterprises in 2001 is confirmed. The active system with two centres was analyzed as a hierarchic game. Conditions of the game equilibrium and effectiveness of the strategic cooperation of the centres in agent's dual control were investigated.

Keywords: *game, active system, Nash equilibrium, Pareto effectiveness, centre, agent, aim function, strategy, compromise multitude*

1. Introduction

In the complicated active systems management [1] decisions are developed by the centres. Amalgamation of two big enterprises "Zorya" and "Mashproekt" in Nikolaev, Ukraine in one scientific production complex is a good example for improving of their effectiveness. Substantiation of the amalgamation on the base of modern mathematical theory of the active systems has a very important practical and theoretical significance.

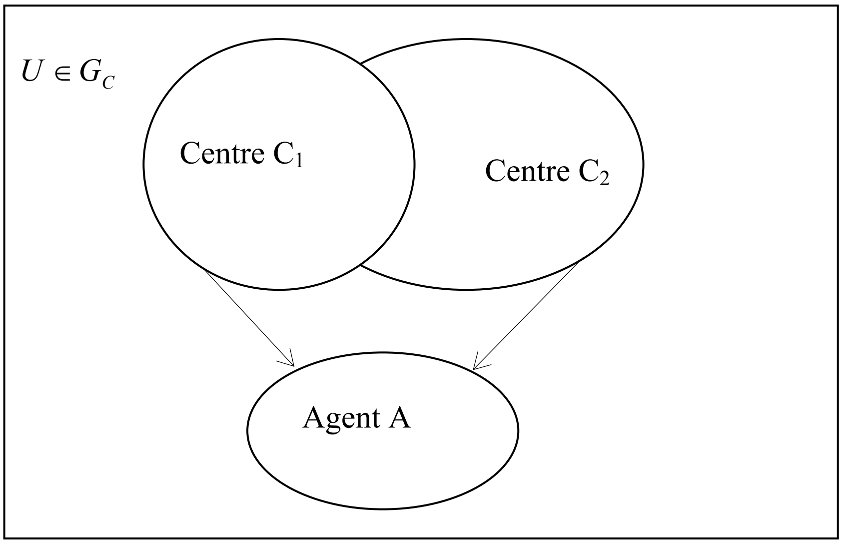

Figure. 1. Active system with two centres and one agent

On the base of the game theory which is modelling amalgamation of two scientific production enterprises manufacturing the same product (turbines) we prove that for the active systems with distributed control Nash equilibrium and Pareto effectiveness can be observed on the condition of cooperation or amalgamation of the two centres.

A formal usage of mathematical models in the management theory, economy, and sociology and so on is known for a long time. Intensive development of the game theory started after publishing the work [5] in the 1940-ies. At the last decade the theoretical game approach is also used in the organizational systems' theory [3,4]. Important results are got in the works [1,2,6], where Nash equilibrium and Pareto effectiveness are used.

In this paper the mathematical models, typical mechanisms and procedures of decisions development for the effective enterprise management are offered.

2. Amalgamation model

Let's consider the theoretical model of amalgamation of the two enterprises in terms of the game theory. For instance, we have an active system [2] *U* that consists of two centres C_1, C_2 and an agent *A*, then $U = \{C_1, C_2, A\}$, $K \neq \varnothing \Leftrightarrow \omega_1 + \omega_2 \leq \omega_\Sigma$.

We interpret system *U* as a game with tree players: C_1, C_2, *A*. Vectors of the centres action are forwarded to the common object of management – agent *A*. We introduce the ensembles of possible behaviour strategies [6] for each player in the system U:

$$X_{C_1} = \{x_1^{C_1}, x_2^{C_1}, ..., x_l^{C_1}\},\ X_{C_2} = \{x_1^{C_2}, x_2^{C_2}, ..., x_m^{C_2}\},\ X_A = \{x_1^A, x_2^A, ..., x_N^A\}.$$

The totality of the strategies is as follows: $x = \{x_i^{C_1}, x_j^{C_2}, x_k^A\} = \{x_1, x_2, x_3\}$, $x \in X_{C_1} \otimes X_{C_2} \otimes X_A$.

We indicate the aim function for each player in the system: $W_{C_1} = W_{C_1}(x)$ is the aim function of the centre C$_1$, $W_{C_2} = W_{C_2}(x)$ is the aim function of the centre C$_2$, $W_A = W_A(x)$ and is the aim function of the centre A. For every solution *x* the aim functions have the real number – profit: $W(x): x \to \Re$.

A normal form of hierarchic game *G* [6], which interprets an active system management, looks like as follows: $G = \{C_1, C_2, A, X_{C_1}, X_{C_2}, X_A, W_{C_1}, W_{C_2}, W_A\}$.

In the above matrix management structure, which is typical for majority of scientific production enterprises, the agents can be subordinated to several centres. Active systems in which such model of management is applied, are called as customary systems with distributed control [1]. The characteristic feature of the system with distributed control is the centres play in which equilibrium depends on the quality of the centres management applied to the agent, bearing in mind that it can be individual as well as common. The centres C_1 and C_2 play consists in the kind of stimulation choice for the agent *A.* the mentioned centres in their turn depend on the agent's behaviour.

The functional of the centres aim functions are as follows:

$$W_{C_1}(S(x), x) = P_{C_1}(x) - S_{C_1}(x),\ W_{C_2}(S(x), x) = P_{C_2}(x) - S_{C_2}(x),$$

where $P_{C_1}(x)$ is the profit C$_1$ from agent's *A* actions, $P_{C_2}(x)$ is the profit C$_2$ from agent's *A* actions $S_{C_1}(x)$ is the agent's stimulation from the centre C$_1$, $S_{C_2}(x)$ is the agent's stimulation from the centre C$_2$, $S(x) = \{S_{C_1}(x), S_{C_2}(x)\}$ is the vector function of profit. The aim functions of the agent $W_A(S(x), x) = S_{C_1}(x) + S_{C_2}(x) - C(x)$, where *C(x)* is the agent's expenditures as a result of strategy of the chosen behaviour. The aim function of the agent consists of a number of remunerations from the centres without its own expenditures. Depending on stimulation vector *S(x)* the agent chooses such an action strategy $x \in X^A$ that definitely maximizes its aim function – principle of the rational agent's behaviour:

$$\sup W_A = Arg \max_{x \in X^A} (S_{C_1}(x) + S_{C_1}(x) - C(x)) .$$

The centres come to the problem of the vector-function components stimulation choice. Each centre can choose its own behavioural strategy as to the agent's management. Depending on the centres suggestion the agent chooses the strategy which guarantees maximum income. If one of the centres chooses individual behavioural strategy the agent is not obliged to follow it as the second centre can offer greater remuneration. System *U* looses equilibrium and the centres are enlisted to the search of equilibrium. The equilibrium can be achieved with the help of the stimulation functions selection together with the forecast of possible reaction of the agent. From the classical theoretic game approach two kinds of equilibrium are known [3,4]:

- equilibrium according to Nash, that is not effective according to Pareto;
- equilibrium according to Nash, that is also effective according to Pareto.

The latter is the ideal state of the system, though it does not always take place. It is common knowledge that in the active systems with distributed control a Nash equilibrium multitude Ω_N intersects with a multitude of Pareto effective solutions Ω_P. It allows choosing from the Nash equilibrium multitude just Pareto effective ones [6].

There exists a functional group of remunerations of the centres, which guarantees effective equilibrium of the centres. They are as follows:

$$S_{C_1}(x, x^*) = \begin{cases} \lambda_1, x = x^*, \\ 0, x \neq x^*, \end{cases}$$

$$S_{C_2}(x, x^*) = \begin{cases} \lambda_2, x = x^*, \\ 0, x \neq x^*. \end{cases}$$

From the practical point of view such compensating functions support the agent's strategy $x^* \in X_A$ which in the active systems theory is called a plan. In connection with it the centres agree upon the remuneration. In other words: agent A chooses a plan x^*, then the first centre pays him remuneration λ_1 and the second centre - remuneration λ_2. If the agent chooses another strategy $x \neq x^*$ he does not get any remuneration. Hierarchic game essence of two centres and an agent was in choosing a vector-function stimulation $S(x)$. Due to such approach it comes to choosing the behavioural strategy for the agent $x^* \in X_A$ and the remuneration for the centres $\lambda_1 = S_{C_1}(x^*)$, $\lambda_2 = S_{C_2}(x^*)$. A principle of the rational agent's behaviour demands the condition of his aim function value inherency: $W_A(x^*, x) \geq 0$.

As $W_A(S(x), x) = S_{C_1}(x) + S_{C_2}(x) - C(x)$, then $S_{C_1}(x) + S_{C_1}(x) \geq C(x)$. For the plan $x = x^*$ $\lambda_1 + \lambda_2 \geq C(x^*)$ is the total value of the chosen behavioural strategy of the agent stimulation should be not less than its own expenditures for that.

From the other side the demand for Pareto effectiveness from the centres point of view is such amount of remuneration which is impossible to diminish without changing the agent's behavioural strategy. It means that the sum of the centres remuneration equals to the agent's expenditures:

$$\lambda_1 + \lambda_2 = C(x^*) \cdot$$

Now we find conditions for the game equilibrium that is such conditions, for which the centres come to an agreement concerning the agent. For that we introduce criterion parameters:

$$\omega_1 = \max_{x \in X^A}(P_{C_1}(x) - S_{C_1}(x)), \; \omega_2 = \max_{x \in X^A}(P_{C_2}(x) - S_{C_2}(x)).$$

In the case of individual actions of the centres and use of compensating system of their income stimulation ω_1 and ω_2 the condition of their mutually profitable cooperation in the management of the agent's structures looks like the following:

$$P_{C_1}(x) - S_{C_1}(x) \geq \omega_1, \; P_{C_2}(x) - S_{C_2}(x) \geq \omega_2.$$

The plan $x = x^*$ $P_{C_1}(x) - \lambda_1 \geq \omega_1$, $P_{C_1}(x) - \lambda_2 \geq \omega_2$ – for realization of the centres cooperation it is necessary that their incomes should be not less than in the case of their individual actions. Moreover, the following condition should be observed: the sum of the agent's remuneration equals to his expenditures $\lambda_1 + \lambda_2 = C(x^*) \cdot$

Multitude K of the agent's actions and compensation vectors under such conditions is called the multitude of compromise decisions. Analytical form of multitude K looks like as follows:

$$K = \{x \in X | \lambda_1 + \lambda_2 = C(x), P_{C_1}(x) - \lambda_1 \geq \omega_1, P_{C_2}(x) - \lambda_2 \geq \omega_2\}.$$

Choice of the definite point of the compromise multitude defines the start of cooperation or amalgamation for the centres. The result is choosing of the actions vector for the agent's management and stimulation. If the compromise multitude is an empty set $K \neq \varnothing$, a situation of competition between the centres is formed. There wins the centre which acts more effectively – pays more to the agent. Antagonistic relations in such situation show the absence of the system equilibrium according to Nash. As a result the members of the active system will search for equilibrium and we'll get analytical conditions of the centres cooperation that is an effective prerequisite for the system equilibrium. Let's introduce the maximum value of the centres total income: $\omega_{\Sigma} = \max_{x \in X^A}(P_{C_1}(x) + P_{C_2}(x) - S_{C_1}(x))$. It is the situation of amalgamation of the centres. As $\lambda_1 + \lambda_2 = C(x)$, $P_{C_1}(x) - \lambda_1 \geq \omega_1$, $P_{C_1}(x) - \lambda_2 \geq \omega_2$. Thus, the centres' amalgamation is possible only on the condition, that the compromise multitude is not empty. Condition $K \neq \varnothing$ is possible when the total sum of the individual incomes of the centres ω_1 and ω_2 , does not exceed their common income calculated value after amalgamation: $K \neq \varnothing \Leftrightarrow \omega_1 + \omega_2 \leq \omega_{\Sigma}$.

In other words, amalgamation of the centres for the agent's management is more effective than individual management. The whole is bigger than the sum of its parts: 1+1 >2. The latter can be interpreted as a qualitative support for the amalgamation advisability of two scientific production enterprises if they have lost production management effectiveness while producing the same products.

Conclusion

Theoretical game approach to the analysis of amalgamation of the two enterprises on the base of hierarchic game and search for effective equilibrium of the active system with distributed control confirmed advisability of the amalgamation and the task is fulfilled. It should be stressed that such "mega-associations" became the most effective structures in the time of the very hard economical situation in the country.

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Received on the 21st of December 2005

Computer Modelling and New Technologies, 2006, Vol.10, No.1, 40-47
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MODELLING FREIGHT FLOWS AT TRANSPORT TERMINAL AND VEHICLE FLEET OF OPTIMAL CARRYING CAPACITY

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Transportation of goods from the terminal to customers should be organized in such a way as to satisfy the demand of customers and to use vehicles efficiently. Freight flows distribution assignment model developed in the present investigation allows us to determine the capacity of a vehicle (i.e. its overall dimensions, carrying capacity, etc.), delivery time limits, time resources and overall costs. The methods of determining optimal lots of the transported goods as well as choosing the way and means of transportation are offered.

Keywords: *freight terminal; vehicle; lot of goods*

1. Introduction

The assignment is to take out goods from the transport terminal and to deliver them to customers in small lots which can not be made any smaller but can be transported together with other lots. Goods should be delivered in such a way as to satisfy the requirements of the customers and to ensure the efficient use of transport facilities. The problem of achieving more efficient freight transportation over long distances and carriage of goods about 20–40 tons by road transport have been analysed in various papers [1–4]. However, the data on the analysis of cases when the cargo of about 50–1500 kg is transported on the road network of a small area (i.e. a town), with bottlenecks on the roads and ecological limitations imposed, are scarce. Therefore, an attempt was made to investigate the outlined problem and to suggest some solutions to it.

2. Model of freight flow formation

Let M be a fixed number of vehicles used, N – fixed number of freight delivery points; I_M – $\{1, 2, ..., M\}$ set of indices of all transport facilities, with the particular vehicles further indexed by I ; I_N – $\{1, 2, ..., N\}$ set of indices of freight delivery points, with the particular points further indexed by j . Any transport facility i $(i \in I_M)$ is given: $G_{(i)}$ – cargo-carrying capacity; $T_{(i)}$ – time resource (planned period of transportation); $D_{(i,k)}$ – size k of the cargo section of vehicle $(k \in K_L = \{1, ..., L\}$; here, L – number of sections of various cargo-carrying capacities.

It should also be noted that a lot of goods to be delivered to point j is characterized by the following parameters: $(j \in I_N)$; $g(j)$ – cargo weight; $d(j,k)$ – cargo size k; $(k \in K_L)$; $T_{(j)}$ – specified delivery time. It is assumed that each lot of goods should be delivered to the particular point, while several lots to be delivered to the same point are combined together; therefore, each point j may be associated with lot of goods j .

It may be stated that the average speed of a vehicle carrying goods between the points j_1 and j_2 depends on the profile of the road as well as on vehicle index i and weight of cargo G . Then, the average speed of transportation will depend on parameters j_1, j_2, i and G and will be denoted further by $\bar{u}$ (j_1, j_2, i, G).

A matrix of distances A between the points of each pair (j_1 , j_2) is known. Relying on the distance $a(j_1, j_2)$ between the points of the pair (j_1 , j_2) and the average speed of vehicle between the above points $\overline{U}(j_1, j_2, i, G)$, it is possible to determine time of freight carriage from point j_1 to point j_2 for any vehicle i :

$$t(j_1, j_2, i, G) = a(j_1, j_2) / \overline{U}(j_1, j_2, i, G). \tag{1}$$

Let us formalize a series of transportation routes aimed to embrace all points or a set of cargoes to be delivered. Let us also assume that transport facilities are at the terminal which will be assigned an index $(N+1)$. Then, let us denote by $a(j, N+1)$ and $a(j, N+1, j)$ the distances from point *j* to point $(N+1)$ and from $(N+1)$ to *j*, respectively.

A series of routes will be characterized by the vectors x , y of integer numbers and the rearrangement $\pi = (\pi_1, \pi_2, ..., \pi_N)$ of the elements of the set I_N (i.e. the rearrangement of indices of the delivery points). Let us assume that the vectors x belong to the sets $X(m)$, here, $m - M$ is a size vector, with the components m_i and

$$X(m) = \{x \in E^M | 1 \le x_i \le m_i, \ i \in I_m\}. \tag{2}$$

here and further, E^q denotes a set of size vectors of all numbers q .

The vectors y belong to the sets $Y(|x|)$, here,

$$|x| = \sum_{i \in^l M} x_i \ \text{ and } \ Y(|x|) = \{y \in E^{|x|} = y_1 < y_2 < ... < y_{|x|} < N\}. \tag{3}$$

Physical meaning of the vectors introduced is as follows: the component x_i of the vector $x(i = 1, 2, ..., M)$ denotes a number of hauls for the vehicle i (while m_i is a prescribed estimate of the above number); the component y_l of $y(l = 1, 2, ..., |x|x|)$ denotes the first position of the route l . More exactly, the total of vectors $x \in X(m)$, $y \in Y(|x|)$ and rearrangements π determine the routes $|x|x|$, while each l from π_l is expressed in the following way:

$$\Pi_l = (N+1, \pi_{y_l}, \pi_{y_{l+1}}, ..., \pi_{y_{l+1}-1}, N+1). \tag{4}$$

All the routes (u) are allotted to M groups by the components of the vector x .

Each group of routes i refers to vehicle i , while the numbers of routes of this group belong to the interval $(\overline{x}_i, \overline{x}_{i+1})$; here, the values $\overline{x}$ may be obtained via the components of the vectors x in the following way:

$$\overline{x}_1 = 1, \ \overline{x}_{i+1} = \overline{x}_i + x, \ i = 1, 2, ..., M. \tag{5}$$

Let us denote each route l by $(l = 1, 2, ..., |x|)$:

$$G(\Pi_l) = \sum_{r=y_l}^{y_{l+1}-1} g(\pi_r), \ G(\Pi_l, q) = G(\Pi_l) - \sum_{r=y_l}^{y_{l+q}} g(\pi_r), \ q = 1, 2, ..., (y_{l+1} - y_l) - 1. \tag{6}$$

Let us set the constraints to a system of routes and their allotment to the particular transport facilities. The limitations are also distributed among the groups similarly to route distribution among the vehicles. Let the route l belong to group i , i.e. $l \in [\overline{x}_i, \overline{x}_{i+1})$, here $i \in I_M$.

First, the limitation on the total cargo weight is imposed on this route, implying that the above value can not exceed carrying capacity of vehicle i :

$$G(\Pi_l) \le G(i)\,. \tag{7}$$

Secondly, to the route l a restriction is applied for overall freight dimensions, which cannot exceed the dimensions of freight section of the vehicle i :

$$D_k(\Pi_l) \le D(i,k),\ k \in K_L\,. \tag{8}$$

The notation $D_k(\Pi_l)$ is similar to that introduced to denote the first relationship in the expression (6).

Third, time limits are imposed on the route l :

$$\begin{aligned} & t[N+1, \pi_{r_l}, i, G(\Pi_l)] \le T(\pi_{r_l}), \\ & t[N+1, \pi_{r_l}, i, G(\pi_l)] + \sum_{q=r_l}^{\bar{q}} t[\pi_q, \pi_{q+1}, i, G_q(\Pi_l)] \le T(\pi_{\bar{q}}), \\ & \bar{q} = r_l + 1, r_l + 2, ..., r_{l+1} - 1. \end{aligned} \tag{9}$$

Time limits are imposed on the total of the routes:

$$\sum_{l=\bar{x}_i}^{x_{i+1}-1} \left\{ t[N+1, \pi_{r_l}, i, G(\Pi_l)] + t[\pi_{r_{l+1}-1}, N+1, i, 0] + \sum_{l=r_l}^{\bar{x}_{i+1}-1} t[\pi_q, \pi_{q+1}, i, G_q(\Pi_l)] \right\} \le T(i)\,; \tag{10}$$

in expressions (9) and (10) the notation found in (1) and (6) is used.

Thus, overall costs $Z(x, y, \pi)$ depending on the system of routes and their distribution among the particular facilities defined by the vectors x , y and rearrangement π may be obtained as follows:

$$\begin{aligned} Z(x, y, \pi) = \sum_{i=1}^{M} \sum_{l=\bar{x}_i}^{\bar{x}_{i+1}-1} \Big\{ & Z[N+1, \pi_{r_l}, i, G(\Pi_l)] + Z[\pi_{r_{l+1}-1}, N+1, i, 0] + \\ & + \sum_{l=r_l}^{\bar{x}_{i+1}-1} Z[\pi_q, \pi_{q+1}, i, G_q(\Pi_l)] \Big\}\,. \end{aligned} \tag{11}$$

In the equation (11), the costs of carrying the cargo of the weight G from the point j_1 to the point j_2 by vehicle i , are denoted by $Z(j_1, j_2, i, G)$. Generally, the costs may be expressed in terms of the distance $a(j_1, j_2)$ between the points j_1 and j_2 or by multiplying the above distance by all carried goods. In other cases, the relationship between the costs considered and the parameters j_1 , j_2 , i , and G may be more complicated, for instance, if the costs are determined in terms of the fuel used.

In transportation, various types of costs should be taken into account. Therefore, the model considered is aimed to embrace various costs, denoting them by the index S and determining them as shown in the equation (11). Thus, let us determine the costs $(S+1)$ of the type:

$Z^{(s)}(x, y, \pi)$, here $s = 0, 1, 2, ..., S$

Then, let $Z^{(0)}(x, y, \pi)$ be overall costs to be minimized, while other kinds of expenses may be at the highest admissible level $Z(s)$. Then one more group of limitations referring to the overall costs will be added to the previously formulated constraints:

$$Z^{(s)}(x, y, \pi) \le Z(s),\ s = 1, 2, ..., S\,, \tag{12}$$

here, $Z^{(s)}(x, y, \pi)$ is found based on the values $Z^{(s)}(j_1, j_2, i, G)$ according to the formula (11), while the values $Z(j_1, j_2, i, G)$ are used to find overall costs $Z(x, y, \pi)$. Now, the problem associated with the flows of lots of goods between the terminal and customers may be formulated:
to find

$$\min_{x \in X(m)} \min_{y \in Y(|x|)} \min_{\pi \in \Pi_N} \{Z^{(0)}(x, y, \pi)\} \tag{13}$$

with the limitations (7)–(10), (12).

3. Determining the structure of the fleet of vehicles of optimal cargo-carrying capacity

The structure of the fleet of vehicles based on their cargo-carrying capacity should meet the requirements to transporting goods in lots of various sizes.

Let cargo-carrying capacity of a vehicle be represented by a series $q_1, \ q_2, \dots, \ q_j, \dots, \ q_m$. In addition, size distribution of the lots of goods is known. The probability of a lot of goods which would require the vehicle of $q_j \ (j = 1, \ 2, \ \dots, \ m-1)$ carrying capacity for transportation is as follows:

$$p_j = \begin{cases} \int_0^{(q_\gamma)_j} f(x)\,dx, & j = 1; \\ \int_{(q_\gamma)_{j-1}}^{(q_\gamma)_j} f(x)\,dx, & j > 1, \end{cases} \tag{14}$$

here, $f(x)$ – distribution density of lot sizes.

The probability of occurrence of a lot of goods requiring q_m capacity vehicle which would transport a lot of goods by i hauls $(i + 1, \ 2, \ \dots)$ is the following:

$$p_{m,i} = \begin{cases} \int_{(q_\gamma)_{m-1}}^{(q_\gamma)_m} f(x)\,dx, & j = 1; \\ \int_{(i-1)q_{\gamma_m}}^{i(q_\gamma)_m} f(x)\,dx, & i > 1. \end{cases} \tag{15}$$

A number of vehicles j of the type $(j = 1, 2, \dots, m-1)$ needed is as follows:

$$A_{ej} = \frac{\overline{N}_{v.r.} p_j}{T_{nj}} \left(\frac{l_{g.ej}}{\upsilon_{tj} \beta_j} + t_{npj} \right) \tag{16}$$

here, $\overline{N}_{v.r.}$ – average number of requests for goods transportation per 24 hours.

A required number of q_m capacity vehicles:

$$A_m = \frac{\overline{N}_{v.r.} \sum_{i=1}^{\infty} i p_{m,i}}{T_{nm}} \left(\frac{l_{g.em}}{\upsilon_{tm} \beta_m} + t_{npm} \right). \tag{17}$$

Total number of vehicles:

$$A_e = \sum_{j=1}^{m} A_{ej} = \overline{N}_{v.r}\left[\sum_{j=1}^{m-1}\frac{p_j}{T_{nj}}\left(\frac{l_{g.ej}}{\upsilon_{tj}\beta_j} + t_{t_{npj}}\right) + \frac{\sum_{i=1}^{\infty} ip_{m,i}}{T_{nm}}\left(-\frac{l_{g.em}}{\upsilon_{tm}\beta_m} + t_{npm}\right)\right]. \tag{18}$$

By dividing the left and the right sides of the equations (16) and (18), we get that:

$$\frac{A_{ej}}{A_e} = \frac{p_j}{T_{nj}B}\left(\frac{l_{g.ej}}{\upsilon_{tj}\beta_j} + t_{hpj}\right), \quad j = 1, 2, \ldots, m-1 . \tag{19}$$

Similarly, from the equations (17) and (18) we obtain that:

$$\frac{A_{ej}}{A_e} = \frac{\sum_{i=1}^{\infty} ip_{m,i}}{T_{nj}B}\left(\frac{l_{g.ej}}{\upsilon_{tj}\beta_j} + t_{hpj}\right). \tag{20}$$

and from (19) and (20) we get:

$$B = \frac{A_e}{\overline{N}_{v.r}} = \sum_{j=1}^{m-1}\frac{p_j}{T_{nj}}\left(\frac{l_{g.ej}}{\upsilon_{tj}\beta_j} + t_{npj}\right) + \frac{\sum_{i=1}^{\infty} ip_{m,i}}{T_{nm}}\left(\frac{l_{g.em}}{\upsilon_{tm}\beta_{mj}} + t_{npm}\right). \tag{21}$$

If $T_{nj} = T_{nm} = T_n$, then we should calculate:

$$T_n B = \sum_{j=1}^{m-1} p_j\left(\frac{l_{g.ej}}{\upsilon_{tj}\beta_j} + t_{npj}\right) + \left(\frac{l_{g.em}}{\upsilon_{tm}\beta_m} + t_{npm}\right)\sum_{i=1}^{\infty} ip_{m,i} . \tag{22}$$

Therefore, to determine the probability of requests for transporting goods by various capacity vehicles means to find the type of lot size distribution and the average output of the above vehicles per 24 hours.

Exponential distribution of lot sizes can be expressed in the following way:

$$f(x) = \frac{1}{\overline{g}} e^{-\frac{x}{\overline{g}}},$$

here, $\overline{g}$ – average lot size of goods, t.

$$p_1 = \frac{1}{\overline{g}}\int_0^{(q_\gamma)_1} e^{-\frac{x}{\overline{g}}}dx = 1 - e^{-\frac{(q_\gamma)_1}{\overline{g}}}, \tag{23}$$

$$p_j = \frac{1}{\overline{g}}\int_{(q_\gamma)_{j-1}}^{(q_\gamma)_j} e^{-\frac{x}{\overline{g}}}dx = e^{-\frac{(q_\gamma)_{j-1}}{\overline{g}}} - e^{-\frac{(q_\gamma)_j}{\overline{g}}}, \tag{24}$$

$$p_{m,i} = \frac{1}{\overline{g}}\int_{(i-1)(q_\gamma)_m}^{i(q_\gamma)_m} e^{-\frac{x}{\overline{g}}}dx = e^{-\frac{(i-1)(q_\gamma)_m}{\overline{g}}} - e^{-\frac{i(q_\gamma)_m}{\overline{g}}}. \tag{25}$$

If the lot sizes distributed according to the normal law, the probability of a random value q to be in the interval $\left[(q_\gamma)_{j-1}, (q_\gamma)_j\right]$ may be found in the following way:

$$p_j = P\left\{\left(q_\gamma\right)_{j-1} < g < \left(q_\gamma\right)_j\right\} = \Phi * \left[\frac{\left(q_\gamma\right)_j - \overline{g}}{\sigma_g}\right] - \left[\frac{\left(q_\gamma\right)_{j-1} - \overline{g}}{\sigma_g}\right], \qquad (26)$$

here, σ_g – mean square deviation of the random value.

$$p_{m,i} = \begin{cases} \Phi * \left[\dfrac{\left(q_\gamma\right)_m - \overline{g}}{\sigma_g}\right] - \Phi * \left[\dfrac{\left(q_\gamma\right)_{m-1} - \overline{g}}{\sigma_g}\right], & i = 1; \\ \Phi * \left[\dfrac{i\left(q_\gamma\right)_m - \overline{g}}{\sigma_g}\right] - \Phi * \left[\dfrac{(i-1)\left(q_\gamma\right)_m - \overline{g}}{\sigma_g}\right], & i > 1. \end{cases} \qquad (27)$$

In some cases, transporters and shippers relate the lot size of goods to cargo-carrying capacity of a vehicle. Then an average lot size of goods to be transported will be:

$$\overline{g} = \sum_{j=1}^{m-1} p_j \left(q_\gamma\right)_j + \left(q_\gamma\right)_m \sum_{i=1}^{\infty} i p_{m,i}, \qquad (28)$$

here, $\left(q_\gamma\right)_j, \left(q_\gamma\right)_m$ – the largest vehicle capacities based on vehicle body capacity and the kind of transported goods.

An average lot size of goods carried in a haul:

$$\overline{g}_e = \sum_{j=1}^{m-1} p_j \left(q_\gamma\right)_j + \left(q_\gamma\right)_m \sum_{i=1}^{\infty} p_{m,i}. \qquad (29)$$

An average vehicle cargo-carrying capacity calculated per haul:

$$\overline{q}_e = \sum_{j=1}^{m-1} p_j q_j + q_m \sum_{i=1}^{\infty} p_{m,i}. \qquad (30)$$

An average value of the static coefficient of the utilized vehicle fleet capacity:

$$\gamma_{st} = \frac{\overline{g}_e}{\overline{q}_e} = \frac{\sum_{j=1}^{m-1} p_j \left(q_\gamma\right)_j + \left(q_\gamma\right)_m \sum_{i=1}^{\infty} p_{m,i}}{\sum_{j=1}^{m-1} p_j q_j + q_m \sum_{i=1}^{\infty} p_{m,i}}. \qquad (31)$$

A number of hauls made by the vehicles of the fleet in a considered period:

$$n_e = \frac{P}{\overline{q}_e \overline{\gamma}_{st}}, \qquad (32)$$

here, P – total volume of transported goods, tons.

A number of hauls made by j – type vehicles:

$$n_e = \frac{P}{\overline{q}_e \overline{\gamma}_{st}}, \qquad (33)$$

and by the largest capacity vehicles:

$$n_{em} = n_e \sum_{i=1}^{\infty} p_{m,i} = n_e - \sum_{j=1}^{m-1} n_{ej} \ . \tag{34}$$

Total volume of goods carried by q_j capacity vehicles:

$$P_j = n_{ej} \left(q_\gamma \right)_j, \quad j = 1, 2, \ldots, m \, . \tag{35}$$

The required number of q_j capacity vehicles:

$$\overline{A}_j = \frac{P_j}{D\alpha_j P_{\text{par}.j}}, \quad j = 1, 2, \ldots, m \, , \tag{36}$$

here, $P_{\text{par}.j}$ – vehicle output per 24 hours

$$P_{\text{par}.j} = \frac{\upsilon_{tj} \beta_j q_j \gamma_{stj} T_{nj}}{l_{g.ej} + \upsilon_{tj} \beta_j t_{npj}} \, . \tag{37}$$

The investigation has shown that the size of a lot of goods carried from the manufacturers' terminals to the distribution network distributed according to the exponential law (Fig. 1). The distribution density is as follows:

$$f(x) = 0{,}0675 e^{-0{,}0675x} \, .$$

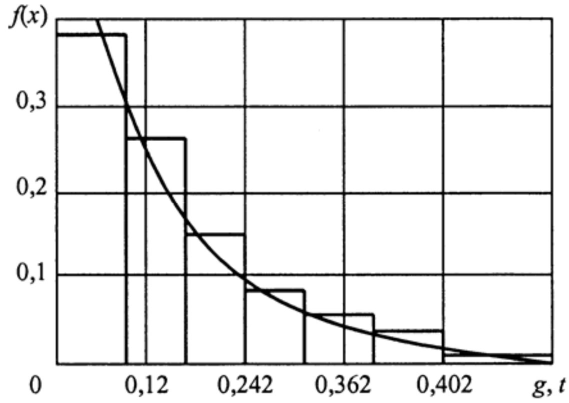

Figure 1. Size distribution of lots of goods

Conclusions

- The assignment model offered for distributing freight flows at the transport terminal allows us to determine the dimensions and cargo-carrying capacity of a transport facility, delivery time and time resource limitations of a vehicle as well as overall costs.
- In order to determine the optimal structure of the fleet of vehicles and the particular organizational form of transportation, the total volume and a lot of the transported cargo should be analysed in terms of time. Since the demand for transportation and lot sizes are random values, approaches of mathematical statistics are preferable for their analysis in time.
- The methods for determining the optimal size of a lot of goods and way of transportation based on general costs of their storage and carriage are suggested.

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Received on the 5th of January 2006

Computer Modelling and New Technologies, 2006, Vol.10, No.1, 48-51
Transport and Telecommunication Institute, Lomonosov 1, LV-1019, Riga, Latvia

MODEL FOR THE COMPARISON OF INFRASTRUCTURE COSTS CAUSED BY USE OF DIFFERENT TRANSPORT MODES

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For many years authorities of the EU believe that combined transportation is able to reduce negative impacts caused by increasing use of road transport. But still there is no scientific background of how this form of transportation can reduce constantly increasing infrastructure costs. The main aim of this article is to propose method for the comparison of infrastructure costs generated by different transport modes.

Keywords: *transport modes, infrastructure costs, transport flows*

1. Introduction

In this article we assume, that infrastructure costs are generated by flow of vehicles passing that particular road. At the same time we assume, that all other factors, for instance, climate conditions, etc., have no impact on the infrastructure. This simply means – the greater flows of vehicles go through the certain segment of infrastructure, the greater damage it causes, the greater are infrastructure costs. So the main task is to write down mathematical formulation of the method which will allow calculation and comparison of infrastructure costs generated by different transport alternatives.

2. Mathematical formulation of the method

As we can observe in different literature sources, many of the scientists point out, that every transport network consists of the set of links $a \in A$, set of transport modes $m \in M$ operating on the given links, and set of transfer links $t \in T$. So to every network link we can attach infrastructure cost function s_a which depends on the freight flow (or in our case on the vehicle flow) on a given link. Analogically, cost function s_t can be attached to every possible transfer link t.
Generally, freight flow consists of products $p \in P$. Every single product is transported between transport origin and transport destination points o and d.

Flows of product p on the network are denoted υ^p and consist of flows of that product on the network and transfer links:

$$\upsilon^p = \begin{pmatrix} \left(\upsilon_a^p\right), & a \in A \\ \left(\upsilon_t^p\right), & t \in T \end{pmatrix}. \qquad (1)$$

Flow of all products on the network is denoted $\upsilon = \sum \upsilon^p$. Infrastructure costs stipulated by product p are s^p:

$$s^p = \begin{pmatrix} \left(s_a^p\right), & a \in A \\ \left(s_t^p\right), & t \in T \end{pmatrix}. \qquad (2)$$

Then, analogically infrastructure costs stipulated by all products are $s = \sum s^p$.

If we institute an assumption that infrastructure costs do not depend on any other factor except freight flow, we can denote, that $s_a^p = f(\upsilon_a^p)$, and $s_t^p = f(\upsilon_t^p)$.

General infrastructure costs generated by all freight flows are function F, which expression is presented in formula (3):

$$F = \sum_{p \in P} \left(\sum_{a \in A} s_a^p (\upsilon_a^p) + \sum_{t \in T} s_t^p (\upsilon_t^p) \right) . \qquad (3)$$

This is the function that we seek to minimize.

But in our case, when we calculate infrastructure costs generated by flow of vehicles not underrating what type of products the vehicles transport, $p = 1$. This allows simplifying formula (3) to expression (4):

$$F = \left(\sum_{a \in A} s_a (\upsilon_a) + \sum_{t \in T} s_t (\upsilon_t) \right) . \qquad (4)$$

The last task now is to identify what infrastructure costs are generated by one vehicle passing 1 kilometre of the certain road.

We know that average intensity of transport flow on the given link during the day is υ_d. Then we can denote that on this link average yearly intensity of transport flow is as follows:

$$\upsilon_y = 365 \times \upsilon_d . \qquad (5)$$

Also we know that whole network of particular transport mode is of length L_{net} and consists of the sum of all links having lengths l_i forming that network. Mathematically this could be written in the following way:

$$L_{net} = \sum_1^n l_i . \qquad (6)$$

Government of every country every year spend a certain amount of money in order to renew countries transport network (for every transport mode this amount is different). Let's denote the sum issued for particular transport infrastructure X. If we institute an assumption that this amount of money is distributed gradually to all the network of certain transport mode, consequently we can state, that the sum of money given to 1 kilometre of infrastructure is as follows:

$$x_{1km} = X / L_{net} . \qquad (7)$$

In this case every link of length l every year gets a sum calculated by the following formula:

$$x_l = l \times x_{1km} = l \times X / L_{net} . \qquad (8)$$

We already know that average yearly intensity of transport flow on that given link is υ_y. Assuming that amount of money for renewal of this link does not depend on any other factor except quantity of vehicles passing that link during the year (i.e. flow of vehicles) we can state, that exactly this flow stipulates sum of money x_l. So:

$$x_1 = x_l / \upsilon_y . \qquad (9)$$

This means, that one vehicle passing link of length l_i generates infrastructure costs x_1. So we can write down that the same vehicle to one kilometre of the certain link generates infrastructure costs:

$$x_{t.m./km} = x_1 / l \ . \tag{10}$$

Then flow υ_{met} stipulates infrastructure costs to 1 kilometre S_{1km}:

$$S_{1km} = x_{t.m./km} \times \upsilon_y \ . \tag{11}$$

The same flow υ_y to whole link of the given length l stipulates infrastructure costs S_l :

$$S_l = S_{1km} \times l \ . \tag{12}$$

Recalling that $s_a = f(\upsilon_a)$, we can write the following:

$$s_a(\upsilon_a) = s_l \ . \tag{13}$$

Analogical situation we have with the infrastructure costs on the transfer link, i.e. because $s_t = f(\upsilon_t)$, we can denote that:

$$s_t(\upsilon_t) = s_k \ , \tag{14}$$

where s_k – infrastructure costs on the transfer link stipulated by yearly flow that passed through the certain transfer link in the intermodal terminal. Expressions (13) and (14) allow writing equation (7) in the following way:

$$F = \left(\sum_{a \in A} \mathrm{s_l} + \sum_{t \in T} \mathrm{s_k}\right) . \tag{15}$$

With the help of this formula or its variations we can perform calculation, analysis and comparison of infrastructure costs stipulated by transport flows in the case of only road and only rail as well as in the case of combined road-rail transportation.

3. Practical application of the proposed model in case of Lithuania

Results of the analysis of Lithuanian transport sector capabilities showed that at present situation the only rout where combined road-rail carriages through the territory of Lithuania could take place is North-South corridor between the borders of Latvia and Poland. Hence, first of all possible transport routs in the case of road and rail transport in this direction were determined. Also, performed calculations by applying created method showed that one freight car per 1 kilometre of road network stipulates infrastructure costs of 0,22 Lt, and one freight wagon per 1 kilometre of the railway network causes infrastructure costs of 0,14 Lt.

These results tell us – the bigger is the flow of vehicles, the bigger is the difference between infrastructure costs in the case of road and railway transport. With every 1000 vehicles this difference increases by 80 Lt in the favour of railway transport. Such a consideration lead to hypothesis that if the certain amount of vehicles would be shifted from road to railway (case of CT), we could expect decrease of infrastructure costs in road transport, because of the decreased number of vehicles that exploit the given rout.

In order to check this hypothesis, variations of formula (15) were applied to calculate infrastructure costs in every case of possible transportation alternatives. Comparison of the obtained results presented in the Figure 1. Calculations show, that the total infrastructure costs in the case of CT are lower than the total infrastructure costs in the case of road transport. This means, that shift of one vehicle from road to rail can decrease infrastructure costs by approximately 0,95 Lt. So each thousandth vehicle shifted from road to rail on the rout north-south on the territory of Lithuania can help to save 955 Lt a year.

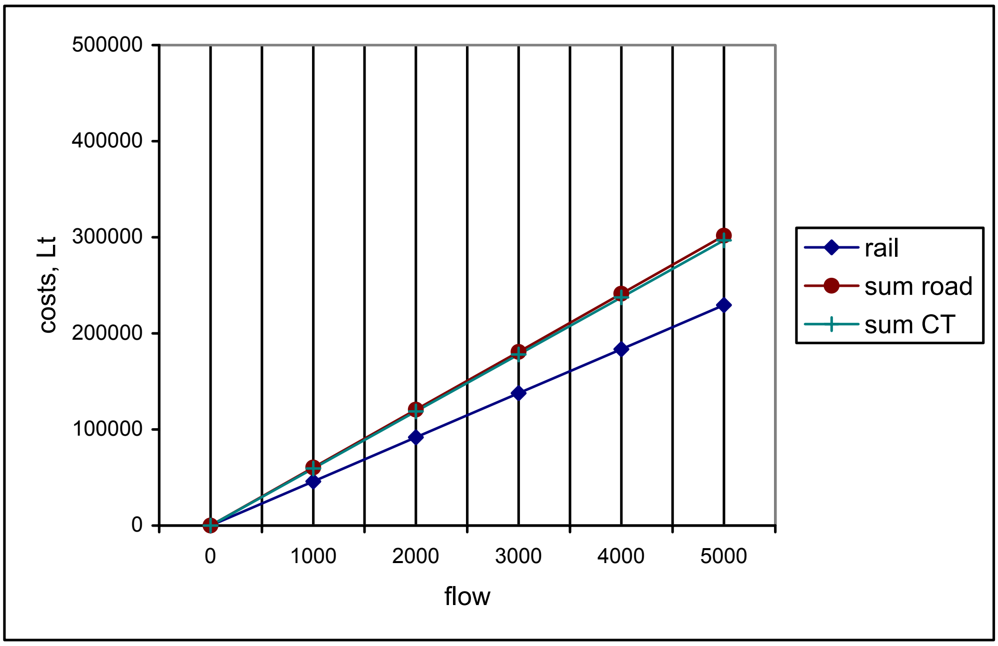

Figure 1. Comparison of infrastructure costs stipulated by different transportation alternatives

Conclusions

- For many years authorities of the EU declared that combined transportation could reduce negative impacts caused by increasing use of road transport. But there were no evidence of how this form of transportation could reduce infrastructure costs.
- This article proposes method (its mathematical formulation) for the comparison of infrastructure costs generated by different transport modes.
- In this article the assumption was made that infrastructure costs are generated by flow of vehicles passing that particular road (at the same time we assume, that all other factors have no impact on the infrastructure costs).
- Performed calculations by applying created method in the case of Lithuania showed that one freight car per 1 kilometre of road network stipulates infrastructure costs of 0,22 Lt, and one freight wagon per 1 kilometre of the railway network causes infrastructure costs of 0,14 Lt.
- Calculations showed that total infrastructure costs in the case of CT on the analyzed rout are lower than total infrastructure costs in the case of road transport. This means, that shift of one vehicle from road to rail can decrease infrastructure costs by approximately 0,95 Lt.
- Performed modelling and calculations proved that alternative of combined transportation is acceptable (at least in case of Lithuania) because it really can reduce infrastructure costs and decrease negative impact of increasing road transport performance.

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Received on the 21st of January 2006

Computer Modelling & New Technologies, 2006, Volume 10, No. 1
Transport and Telecommunication Institute, Lomonosov Str.1, Riga, LV-1019, Latvia

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CUMULATIVE INDEX

COMPUTER MODELLING and NEW TECHNOLOGIES, volume 10, No. 1, 2006 (Abstracts)

M. Kopeetsky, Avi Lin. Advanced Decoding Strategy for a Noisy Channel, *Computer Modelling and New Technologies,* vol. 10, No 1, 2006, pp. 7–19.

This paper deals with the issue of managing and controlling a noisy packet transmission channel. The paper offers a generic near optimal solution and strategy for two related critical issues: reducing the packet error probability and the synchronization failure probability in the channel. The core of this solution is a new adaptive and dynamic family of decoding algorithms that automatically regulate the number of correctable and detectable errors in any Data Unit, while for each offers the appropriate correcting method, if at all. We formulate the major objective of the proposed strategy, its formal mathematical set-up and appropriate avenues for its analysis and specifications. The examples wrapping this paper show the powerful potential of this approach.

Keywords*: noisy channel, class algorithm, advanced decoding strategy*

N.O. Rouben. The Application of Fuzzy Logic to the Construction of the Ranking Function of Information Retrieval Systems, *Computer Modelling and New Technologies,* vol. 10, No 1, 2006, pp. 20–27.

The quality of the ranking function is an important factor that determines the quality of the Information Retrieval system. Each document is assigned a score by the ranking function; the score indicates the likelihood of relevance of the document given a query. In the vector space model, the ranking function is defined by a mathematic expression such as:

$score(q,d) = \sum_{t \in q}$ tf(t in d) * idf(t) * getBoost(t.field in d) * lengthNorm(t.field in d) * overlap(q,d) * queryNorm(q)

We propose a fuzzy logic (FL) approach to defining the ranking function. FL provides a convenient way of converting knowledge expressed in a natural language into fuzzy logic rules. The resulting ranking function could be easily viewed, extended, and verified:

- if (tf is high) and (idf is high) $\rightarrow$ (relevance is high);
- if (overlap is high) $\rightarrow$ (relevance is high).

By using above FL rules, we are able to achieve performance approximately equal to the state of the art search engine Apache Lucene (ΔP10 +0.92%; ΔMAP -0.1%). The fuzzy logic approach allows combining the logic-based model with the vector model. The resulting model possesses simplicity and formalism of the logic based model, and the flexibility and performance of the vector model.

Keywords: *Fuzzy Logic, fuzzy set, ranking function, information retrieval, vector space model, tf idf model, Boolean model*

I.A. Stepanov. Dependence of the Energy of Molecules on Interatomic Distance at Large Distances, *Computer Modelling and New Technologies,* vol. 10, No 1, 2006, pp. 28–30.

Earlier it was supposed that the energy of molecules increases monotonously with interatomic distance at large distances. However, dissociation of molecules (for example, $Te_2 \rightarrow 2Te$) often is a chemical reaction. According to chemical kinetics, chemical reactions overcome a potential barrier. Therefore, there must be a barrier at the energy – distance curve. Earlier it has been supposed that quantum chemical methods give a wrong result at big distances if the wave function does not turn to zero. It is shown that it must not obligatory turn to zero. The wave function can be a piecewise function.

Keywords: *diatomic molecules, potential energy curves, wave function, dissociation of molecules*

Y.Kochetkov. Structural Analysis of the Demographic Crisis in Latvia, *Computer Modelling and New Technologies,* vol. 10, No 1, 2006, pp. 31–35. (in Russian)

Main features and reasons of a demographic crisis in Latvia are considered. The method of cognitive structurization for the quality analysis of a social economic system called as 'soft systems' is used. The analysis appropriate sign organizing graph has shown presence in system of internal intensity and conflicts of interests. Without acceptance of effective measures on overcoming demographic crisis the population of the country can be catastrophically decreased. The basic strategy of output from crisis is the increase of the investments in economy and in social sphere.

Keywords: *demographic crisis in Latvia, cognitive structurization*

S.D. Chernov, S.K. Titov. Compromise between the Active Systems with Distributed Control, *Computer Modelling and New Technologies,* Vol. 10, No 1, 2006, pp. 36–39.

On the base of theoretical model the advisability of amalgamation of the two enterprises in 2001 is confirmed. The active system with two centres was analyzed as a hierarchic game. Conditions of the game equilibrium and effectiveness of the strategic cooperation of the centres in agent's dual control were investigated.

Keywords: *game, active system, Nash equilibrium, Pareto effectiveness, centre, agent, aim function, strategy, compromise multitude*

A. Baublys. Modelling Freight Flows At Transport Terminal and Vehicle Fleet of Optimal Carrying Capacity, *COMPUTER MODELLING AND NEW TECHNOLOGIES,* Vol. 10, No 1, 2006, pp. 40–47.

Transportation of goods from the terminal to customers should be organized in such a way as to satisfy the demand of customers and to use vehicles efficiently. Freight flows distribution assignment model developed in the present investigation allows us to determine the capacity of a vehicle (i.e. its overall dimensions, carrying capacity, etc.), delivery time limits, time resources and overall costs. The methods of determining optimal lots of the transported goods as well as choosing the way and means of transportation are offered.

Keywords: *freight terminal; vehicle; lot of goods*

A. V. Vasiliauskas. Model for the Comparison of Infrastructure Costs Caused By Use of Different Transport Modes, *COMPUTER MODELLING AND NEW TECHNOLOGIES,* Vol. 10, No 1, 2006, pp. 48–51.

For many years authorities of the EU believe that combined transportation is able to reduce negative impacts caused by increasing use of road transport. But still there is no scientific background of how this form of transportation can reduce constantly increasing infrastructure costs. The main aim of this article is to propose method for the comparison of infrastructure costs generated by different transport modes.

Keywords: *transport modes, infrastructure costs, transport flows*

COMPUTER MODELLING and NEW TECHNOLOGIES, 10.sējums, Nr.1, 2006 (Anotācijas)

M. Kopeetsky, Avi Lin. Uzlabotā dekodēšanas stratēģija trokšņainam kanālam, *Computer Modelling and New Technologies,* 10.sēj., Nr.1, 2006, 7.–19. lpp.

Šajā rakstā tiek izskatīta vadības un kontroles trokšņaina paketes transmisijas kanāla atvere. Raksts piedāvā vispārēju gandrīz optimālu risinājumu un stratēģiju divām saistītām kritiskām atverēm: samazinot paketes kļūdas varbūtību un sinhronizācijas neveiksmes varbūtību kanālā. Šī risinājuma būtība ir dekodēšanas algoritmu jauna un dinamiska saime, kas automātiski izlabo labojamo un detektējamo kļūdu skaitu jebkurā Data Unit, kamēr katram piedāvā atbilstošu labošanas metodi, ja vispār tas tiek darīts. Mēs formulējam galveno piedāvātās stratēģijas mērķi, tā formālo matemātisko izveidi un atbilstošus līdzekļus tā analīzei un specifikācijai. Piemēri, kas ietverti šajā rakstā, parāda šīs pieejas spēcīgo potenciālu.

Atslēgvārdi*: trokšņains kanāls, klases algoritms, uzlabotā dekodēšanas stratēģija*

N.O. Rubens. Faziloģikas pielietošana informācijas meklēšanas sistēmu sakārtotās funkcijas konstrukcijai, *Computer Modelling and New Technologies,* 10.sēj., Nr.1, 2006, 20.–27. lpp.

Ranžēšanas funkcijas kvalitāte ir svarīgs faktors, kas nosaka Informācijas meklēšanas sistēmas (IMS) kvalitāti. Katram dokumentam ir piešķirts punktu skaits pēc ranžēšanas funkcijas; punkti norāda sakarības iespējamību dokumentam, kurš tiek apšaubīts. Vektora telpas modelī ranžēšanas funkcija tiek noteikta ar šādu matemātisku izteiksmi:

$$score(q,d) = \sum_{t \in q} \text{tf(t in d) * idf(t) * getBoost(t.field in d) * lengthNorm(t.field in d) * overlap(q,d) * queryNorm(q)}$$

Ranžēšanas funkcijas definēšanai mēs ierosinām faziloģikas pieeju. Rezultējošā ranžēšanas funkcija var tikt viegli apskatīta, paplašināta un pierādīta:

- ja (tf ir augsts) un (idf ir augsts) → (sakarība ir augsta);
- ja (pārklājums ir augsts) → (sakarība ir augsta).

Pielietojot iepriekšminētos faziloģikas likumus, mums ir iespēja sasniegt veiktspēju, kas gandrīz ir vienāda dzinēja meklēšanas mākslīgam stāvoklim Apache Lucene (ΔP10 +0.92%; ΔMAP – 0.1%). Faziloģikas pieeja atļauj apvienot loģikas bāzētu modeli ar vektora modeli.. Iegūtam modelim piemīt loģikas bāzētā modeļa vienkāršība un formālisms, un vektora modeļa pielāgojamība un veiktspēja.

Atslēgvārdi: *faziloģika, fazirinda, ranžēšanas funkcija, informācijas meklēšana, tf idf modelis, Boolean modelis*

I. Stepanovs. Molekulu enerģijas atkarība no interatomiskā attāluma pie lielām distancēm, *Computer Modelling and New Technologies,* 10.sēj., Nr.1, 2006, 28.–30. lpp.

Agrāk tika uzskatīts, ka molekulu enerģija palielinās monotoni ar interatomisko attālumu pie lielām distancēm. Tomēr molekulu disociācija (piem., $Te_2 \rightarrow 2Te$) bieži vien ir ķīmiska reakcija. Saskaņā ar ķīmisko kinētiku, ķīmiskās reakcijas pārvar potenciālu barjeru. Tādēļ ir jāpastāv enerģijas barjerai – attāluma līknei. Agrāk tika uzskatīts, ka kvantu ķīmiskās metodes dod nepareizu rezultātu pie lielām distancēm, ja viļņa funkcija nepagriežas uz nulli. Pētījumā tiek parādīts, kas tai ne vienmēr ir jāpagriežas uz nulli. Viļņa funkcija var būt daļveida funkcija.

Atslēgvārdi: *diatomiskās molekulas, potenciālās enerģijas līknes, viļņa funkcija, molekulu disociācija*

J. Kočetkovs. Demogrāfiskās krīzes Latvijā struktūranalīze, *Computer Modelling and New Technologies,* 10.sēj., Nr.1, 2006, 31.–35. lpp.

Rakstā tiek izskatītas demogrāfiskās krīzes galvenās iezīmes un iemesli Latvijā. Tiek lietota kognitīvās strukturizācijas metode sociālās ekonomiskās sistēmas, kas tiek saukta kā „mīkstā sistēma", kvalitātes analīzei. Atbilstošā zīmju organizējošā tabula parāda, ka sistēmā pastāv iekšējā spriedze un interešu konflikts. Nesperot atbilstošus soļus demogrāfiskās krīzes novēršanai, var katastrofiski samazināties iedzīvotāju skaits valstī. Pamatstratēģija izejai no krīzes ir investīciju palielināšana kā ekonomikā, tā arī sociālajā sfērā.

Atslēgvārdi: *demogrāfiskā krīze Latvijā, kognitīva strukturizācija*

S. Černovs. Kompromiss starp aktīvām sistēmām ar sadalīto kontroli, *Computer Modelling and New Technologies,* 10.sēj., Nr.1, 2006, 36.–39. lpp.

Teorētiskā modeļa pamatā ir apstiprināta 2001.gadā divu uzņēmumu saplūšanas lietderība. Rakstā autors analizē aktīvo sistēmu ar diviem centriem kā hierarhisku spēli. Autors izpēta spēles līdzsvara un efektivitātes apstākļus centru stratēģiskai kooperācijai pārstāvja duālā kontrolē.

Atslēgvārdi: *spēle, aktīva sistēma, Neša līdzsvars, Pareto efektivitāte, centrs, pārstāvis, mērķa funkcija, stratēģija*

A. Baublis. Kravu plūsmu modelēšana transporta terminālā un transporta līdzekļu parka optimālās pārvadāšanas kapacitātes modelēšana, *COMPUTER MODELLING AND NEW TECHNOLOGIES,* 10.sēj., Nr.1, 2006, 40.–47. lpp.

Rakstā autors pievēršas problēmai par preču transportēšanas organizēšanu tā, lai apmierinātu pieprasījumu un tanī pašā laikā efektīvi lietotu transporta līdzekļus. Kravu plūsmu distribūcijas asignējuma modelis šajā pētījumā atļauj mums noteikt transporta līdzekļa kapacitāti (t.i., tā vispārējos izmērus, pārvadāšanas kapacitāti u.c.), piegādes laika limitus, laika resursus un vispārējas izmaksas. Rakstā tiek izstrādātas metodes, kas nosaka transportējamo preču optimālo daudzumu, kā arī tiek piedāvāta transportēšanas līdzekļu un veida izvēle.

Atslēgvārdi: *kravu termināls, satiksmes līdzeklis, preču daudzums*

A. V. Vasiliauskas. Infrastruktūru izmaksu, ko rada dažādu transporta veidu lietošana, salīdzinājuma modelis, *COMPUTER MODELLING AND NEW TECHNOLOGIES,* 10.sēj., Nr.1, 2006, 48.–51. lpp.

Eiropas Savienības varas institūcijas jau daudzus gadus uzskata, ka kombinētie pārvadājumi ir spējīgi samazināt negatīvās ietekmes, ko izraisa ritošā transporta lietojuma palielināšanās. Bet tomēr tam nav zinātniskā pamatojuma, kā šis pārvadāšanas veids var samazināt infrastruktūras izmaksas, kas nepārtraukti palielinās. Šī raksta galvenais mērķis ir piedāvāt salīdzinājuma metodi infrastruktūru izmaksām, ko rada dažādie transporta veidi.

Atslēgvārdi: *transporta veidi, infrastruktūras izmaksas, transporta plūsmas*

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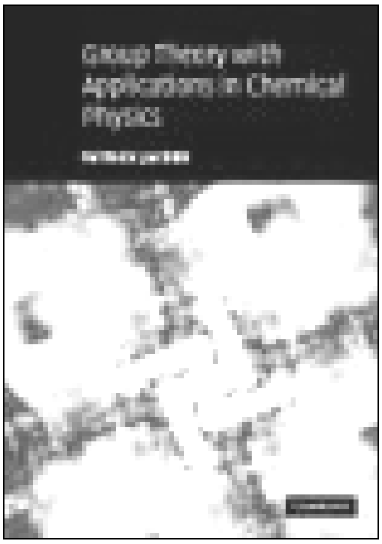

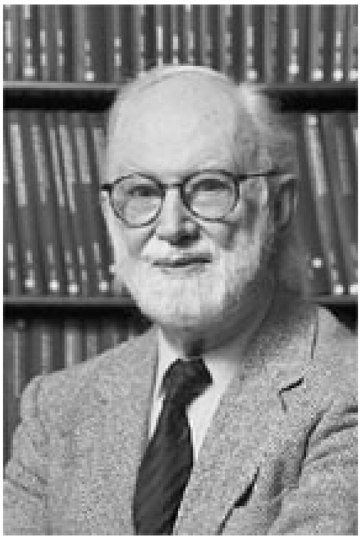

Group Theory with Applications in Chemical Physics

by **P.W.M. Jacobs**

Hardcover; 556 pages (February 2005)

Patrick W.M. JACOBS was born on September 15, 1923, Durban, South Africa, Dr.Sc., Professor Emeritus, Department of Chemistry and Centre for Chemical Physics, The University of Western Ontario, London, ON, Canada, N6A 5B7

US List Price: USD $100.00
CDN Equivalent: CDN$ 117.11

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1. The elementary properties of groups; 2. Symmetry operators and point groups; 3. Matrix representations; 4. Group representations; 5. Bases of representations; 6. Molecular orbitals; 7. Crystal field theory; 8. Double groups; 9. Molecular vibrations; 10. Transitions between electronic states; 11. The rotation group; 12. Projective representations; 13. Time-reversal symmetry; 14. The crystallographic magnetic point groups; 15. Macroscopic properties of crystals; 16. Space groups; 17. Electronic energy states in crystals; 18. The vibration of atoms in crystals; Appendices.

COMPUTER MODELLING & NEW TECHNOLOGIES

ISSN 1407-5806 & ISSN 1407-5814 (on-line)

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COMPUTER MODELLING AND NEW TECHNOLOGIES, 2006, Vol. 10, No.1

Scientific and research journal of Transport and Telecommunication Institute (Riga, Latvia)
The journal is being published since 1996.

PREPARATION OF CAMERA-READY TYPESCRIPT: COMPUTER MODELLING AND NEW TECHNOLOGIES

A Guide for Authors

A.N. AUTHOR
Affiliation
Institute address

Abstract reviews the main results and peculiarities of a contribution. Abstract is presented always in English or in English and the second (presentation) language both.
Keywords: main terms, concepts

1. Introduction

These instructions are intended to provide guidance to authors when preparing camera-ready submissions to a volume in the **CM&NT**. Please read these general instructions carefully before beginning the final preparation of your camera-ready typescript.

Two ways of preparing camera-ready copy are possible:
(a) preparation on a computer using a word processing package;
(b) printed copy fitted for scanning.

2. Printer Quality, Typing Area and Fonts

IMPORTANT:

If you produce your camera-ready copy using a laser printer, use a 15 x 23 cm typing area (in A4 format: 30 mm – left, 30 mm – right, 30 mm – top, 30 – bottom, line spacing – single), as in these instructions, in combination with the **10 points Times** font. The pages will then be reproduced one to one in printing.

Fonts

The names and sizes of fonts are often not the same on every computer system. In these instructions the Times font in the sizes 10 points for the text and 8 points for tables and figure legends are used. The references section should be in the 10 points font.

3. Format and Style

The text should be in clear, concise English (or other declared language). Please be consistent in punctuation, abbreviations, spelling (***British English***), headings and the style of referencing.

Camera-ready copy will be printed exactly as it has been submitted, so please make sure that the text is proofread with care.

In general, if you prepare your typescript on a computer using a word processing package, use styles for the font(s), margin settings, headings, etc., rather than inserting these layout codes every time they are needed. This way, you will obtain maximum consistency in layout. Changes in the layout can be made by changing relevant style(s).

4. Layout of the Opening Page

A sample for the opening page of a contribution is shown in Figure 1 on page 3.

Requirements for the opening page of a contribution are (see also Figure 1): the titles should always be a centered page and should consist of: the title in capital letters, bold font, flush center, on the fourth text line; followed by the subtitle (if present) in italics, flush center, with one line of white above. The author's name(s) in capitals and the affiliation in italics should be centered and should have two lines of white space above and three below, followed by the opening text, the first heading or the abstract.

5. Headings

Please distinguish the following four levels of headings:

1. First-order Heading

This heading is in bold, upper and lowercase letters, numbered in Arabic figures, and has two lines of space above and one line below. The text begins full out at the left margin.

1.1. SECOND-ORDER HEADING IN CAPITALS

This heading is in roman capitals, numbered in Arabic figures and has one line of space above and below. The text begins full out at the left margin.

1.1.1. *Third-order Heading in Italics*

This heading is in italics, upper and lower case letters, numbered in Arabic figures and has one line of space above and no space below. The text begins full out at the left margin.

Fourth-order Heading in Italics. This heading is in italics, upper and lowercase letters, with one line of space above the heading. The heading has a full stop at the end and the text runs on the same line.

↕ 3 blank lines

TITLE OF CONTRIBUTION

Subtitle of Contribution

↕ 2 blank lines

A.N. AUTHOR

Affiliation

Institute address

↕ 3 blank lines

Abstract

↕ 2 blank lines

First text line

Figure l. Example of an opening part of contribution to a Volume of CM&NT

6. Figures and Photographs

- *Line drawings* must be submitted in original form, on good quality tracing paper, or as a glossy photographic print.
- *Halftone photographs* must be supplied as glossy prints.
- *Colour illustrations.* Colour illustrations are more expensive and the author is expected to cover the extra costs. Please consult with Editors about this.

Mount all illustrations directly into the text at the appropriate places. Alternatively, it is acceptable to leave the appropriate space blank in the text, and submit the illustrations separately. In this case You must put the figure numbers in pencil in the open spaces in the text and on the back of the figures. Also indicate the top of the illustration.

For computer plotting the ORIGIN Software is preferable.

- Legends for figures/illustrations should not be incorporated in the figure itself and they should be listed in numerical order (headed as "*Figure 1.*", "*Figure 2.*" etc.). The legends should be set centered, below the figure.

7. Displayed Equations

Displayed equations should be in the left side of the page, with the equation number in parentheses, flush right.

$$E_{int} = \iint \psi^{+}(\mathbf{x})\psi(\mathbf{x})K(\mathbf{x}-\mathbf{x}')(-div\mathbf{P}(\mathbf{x}'))d^3xd^3x' , \quad (1)$$

$$K(\mathbf{x}-\mathbf{x}') = C_0 \frac{exp(-\lambda(|\mathbf{x}-\mathbf{x}'|)}{|\mathbf{x}-\mathbf{x}'|} . \quad (2)$$

Font sizes for equations are: 12pt – full, 7pt – subscripts/superscripts, 5pt – sub-subscripts/superscripts, 18pt – symbols, 12pt – subsymbols.

8. Tables

Please center tables on the page, unless it is necessary to use the full page width. Exceptionally large tables may be placed landscape (90^0 rotated) on the page, with the top of the table at the left-hand margin. An example of a table is given below:

TABLE 1. National programs of fusion research [1]

Experiment	Type	Laboratory	Task	Begin of operation
JET	tokamak	Joint European Torus, Culham, UK	Plasma physics studies in the region close to ignition	1983
TEXTOR	tokamak	FA, Jülich. Germany	Studies of plasma-wall interaction	1982
TORE SUPRA	tokamak	CEA, Cadarache, France	Testing of super-conducting coils, stationary operation	1988
ASDEX Upgrade	tokamak	IPP, Garching, Germany	Plasma boundary studies in divertor plasmas	1990
WENDELSTEIN 7-AS	stellarator	IPP, Garching, Germany	Testing the principles of ”advanced stellarator”	1988
WENDELSTEIN 7-X	stellarator	IPP, Greifswald, Germany	Testing feasibility of ”advanced stellarator” for power station	2004

9. References

The References should be typeset in a separate section as a numbered list at the end of your contribution in the following style:

Journal articles should consist of as follows: author's name, initials, year, title of article, journal title, volume number, inclusive page numbers, e.g.:

[1] Dumbrajs O. (1998) Nuclear Fusion. *RAU Scientific Reports & Computer Modelling & New Technologies* **2**, aa-zz
[2] Kiv A.E., Polozovskaya I.A., Tavalika L.D. and Holmes S. (1998) Some problems of operator-machine interaction. *RAU Scientific Reports & Computer Modelling & New Technologies* **2**, aa-zz
[3] Shunin Yu.N. (1996) Elementary excitations and radiation defects in solids induced by swift heavy ions. *RAU Scientific Reports & Solid State Electronics & Technologies* **1**, 15-35
[4] Schwartz K. (1996) Excitons and radiation damage in alkali halides. *RAU Scientific Reports & Solid State & Electronics & Technologies* **1**, 3-14

Book references should consist of as follows: author's name, initials, year, title of book, publisher, place of publication, e.g.:

[5] Schwartz K. (1993) The Physics of Optical Recording. Springer-Verlag, Berlin Heidelberg New York
[6] Shunin Yu.N. and Schwartz K.K. (1997) Correlation between electronic structure and atomic configurations in disordered solids. In: R.C. Tennyson and A.E. Kiv (eds.). Computer Modelling of Electronic and Atomic Processes in Solids. Kluwer Academic Publishers, Dordrecht, pp. 241-257 .

Unpublished papers should consist of as follows: author's name, initials, year (or: in press), title of paper, report, thesis, etc., other relevant details, e.g.:

[7] Shunin Yu.N. (1995) Elementary Excitations in amorphous solids accompanying the swift heavy ions passages. Private communication. GSI Seminar. Darmstadt

The references above should be cross-referenced by numbers within square brackets:
...as cited in [1], or Kiv *et al.* [2]... The use of author's initials for cross-references is not encouraged.

10. Authors Index

Editors form the author’s index of a whole Volume. Thus, all contributors are expected to present personal colour photos with the short information on the education, scientific titles and activities.

11. Submission

Check your typescript very carefully before it is submitted. Submit two copies of the typescript to the Editors of the Volume. Always retain a copy of all material submitted as backup.

11.1. DISK FORMATS AND WORD PROCESSING PACKAGES

If you want to present contributions electronically please before submitting accord with the Editors the details on your computer system, your word processing package and version (MS Word 6 and above versions are preferable) and the way of transfer on the information (disk or Internet).

Acknowledgements

Acknowledgements (if present) mention some specialists, grants and foundations connected with the presented paper. The first page of the contribution should start on page 1 (right-hand, upper, without computer page numbering). Please paginate the contributions, in the order in which they are to be published. Use simple pencil only.

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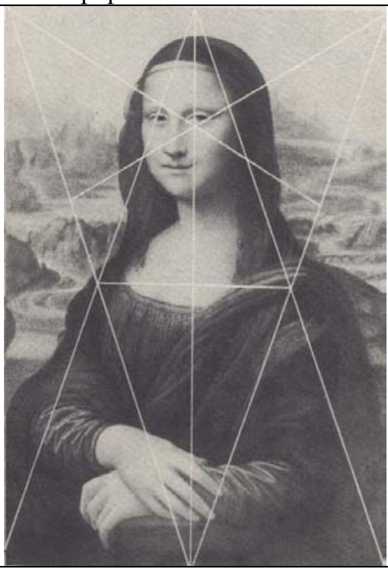

PUBLISHERS:
TRANSPORT AND TELECOMMUNICATION INSTITUTE
TRANSPORTA UN SAKARU INSTITŪTS *(TSI)*
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INFORMATION SYSTEMS MANAGEMENT INSTITUTE
INFORMĀCIJAS SISTĒMU MENEDŽMENTA AUGSTSKOLA *(ISMA)*

NATURE AND COMPUTER WORLD,
PUBLISHED SINCE 2001
ISSN 1407-8422
ISSN 1407-8422 **- on-line**

Editorial office:
Nature and Computer World,
Lomonosov 1, Build. 4, LV-1019, Riga, Latvia
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