Improving the Quality of Transport Management Services with Fuzzy Signatures

Csaba I. Hencz, István Á. Harmati

***Abstract*—**Nowadays the significance of road transport is gradually increasing. All transport companies are working in the same external environment where the speed of transport is defined by traffic rules. The main objective is to accelerate the speed of service and it is only dependent on the individual abilities of the managing members. These operational control units make decisions quickly (in a typically experiential and/or intuitive way). For this reason, support for these decisions is an important task. Our goal is to create a decision support model based on fuzzy signatures that can assist the work of operational management automatically. If the model sets parameters properly, the management of transport could be more economical and efficient.

***Keywords*—**Freight transport, decision support, information handling, fuzzy methods.

I. Introduction

THE significance of road transport in recent decades showed a gradual increase and it is not expected to decline significantly in the next decade.

In our constantly developing world goods must be transported quickly due to the short lead time. Thereby the freight sector is constantly evolving. The direction of improvement should be closely linked to the flow of information because of customers' growing information needs. Unfortunately, enterprises are not able to satisfy this demand properly and on time.

The development of Information Technology allows companies to satisfy customer's needs in a flexible way and at a high standard. Currently, use of information and communication technologies is only implemented at a local level and/or on an occasional basis. In the vast majority of cases, several available techniques/technologies have not been integrated into the management system of the company.

II. The Transport Activity

It is necessary to clarify who might be in the process of transport participants. The roles are typically divided between the sender, the carrier and the consignee.

The client asks for an offer from the carrier who gives a relevant offer (it contains a detailed transport task). Based on this they can decide to accept or reject the offer. If the client accepts the offer they indicate that to the carrier. The freight organizer of the carrier confirms the order and start to record the freight task in its own ERP system. The consignment mandates may arrive in writing (fax, email); special cases will be accepted by phone. Of course, the orders received by phone later must be confirmed in writing. After receiving the recording of orders takes place in a central database (where available). These data are a good basis for an ERP system or a freight management system. However, beside of using ERP systems, the forwarding companies record the shipment data in digital and/or in paper form. Unfortunately, in many cases a transport coordinator will receive a shipping order in a verbal form.

A. Normal Transport Process

The "normal" transport process will always start from a sender who selects an appropriate carrier based on individual needs. These expectations may be cost, speed, reliability, quality, and environmental, etc. based. Upon receiving the order, the carrier shall organize the transport (according to the principle of PULL). Then the transport vehicle arrives at the designated address (according to the principle of 5R) and after the loading is complete, the driver starts his journey with the transport documents.

It is very important that the unloading at the consignee's park can only be done - under the conditions laid down in the contract - by one of the following persons:

- consignee
- driver
- consignee and the driver together

After unloading, necessary documents are issued which then form the basis of accounting. At the end of the freight task, the carrier shall issue an invoice. Flowchart of detailed description of the "normal" transport processes helps to understand each steps of the road transport behavior.

B. Special Transport Processes - Freight Exchange

During special transport processes, the freighter chooses (by electronic means) the assignment based on individual preferences. These expectations may be cost, speed, reliability, quality, and environmental based. In this case, the freight is undertaken by electronic means, confirmation is received in digital format to the sender. Process is hereinafter referred to as a standard cargo-taking process.

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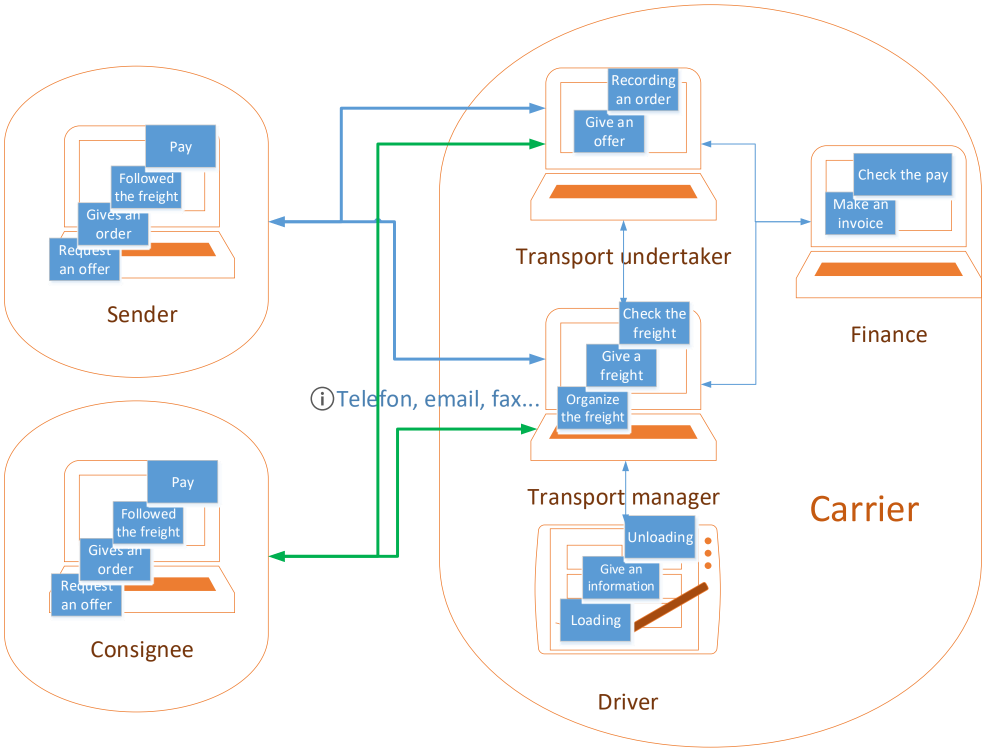

Fig. 1 Relationship model of the transport processes

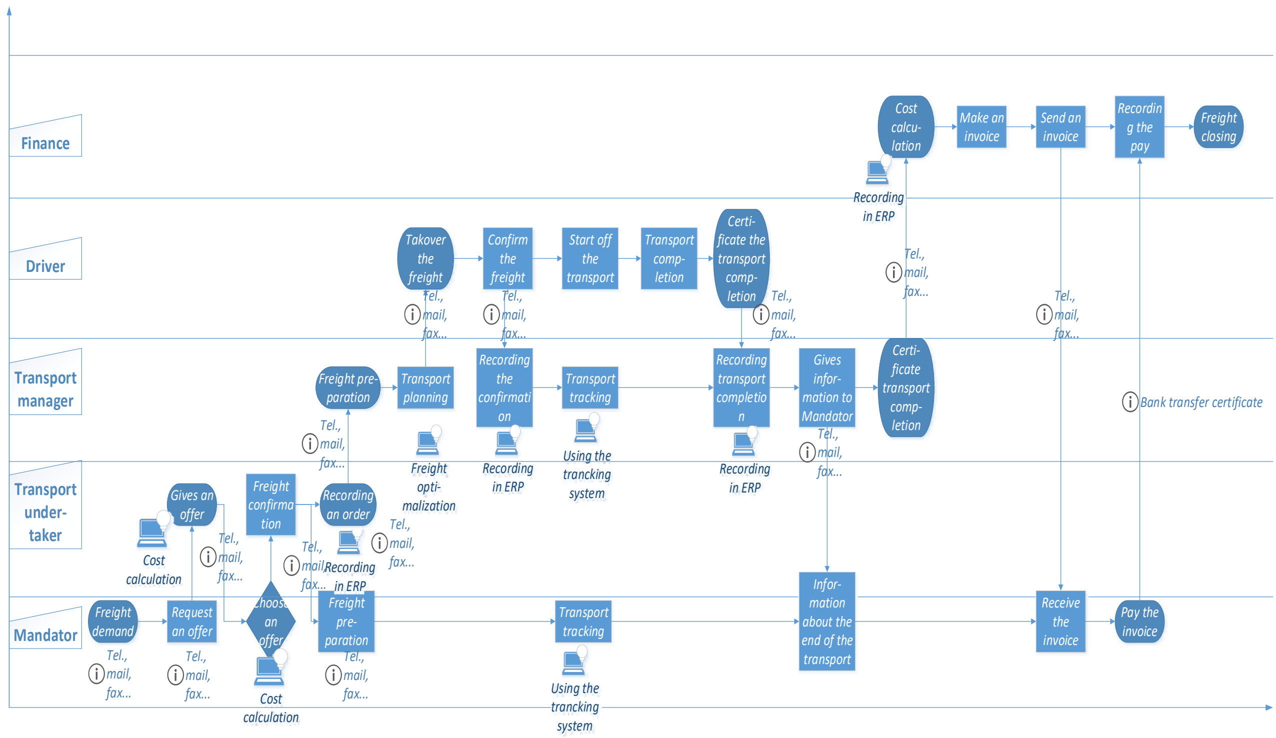

Fig. 2 Detailed description of the “normal” transport processes

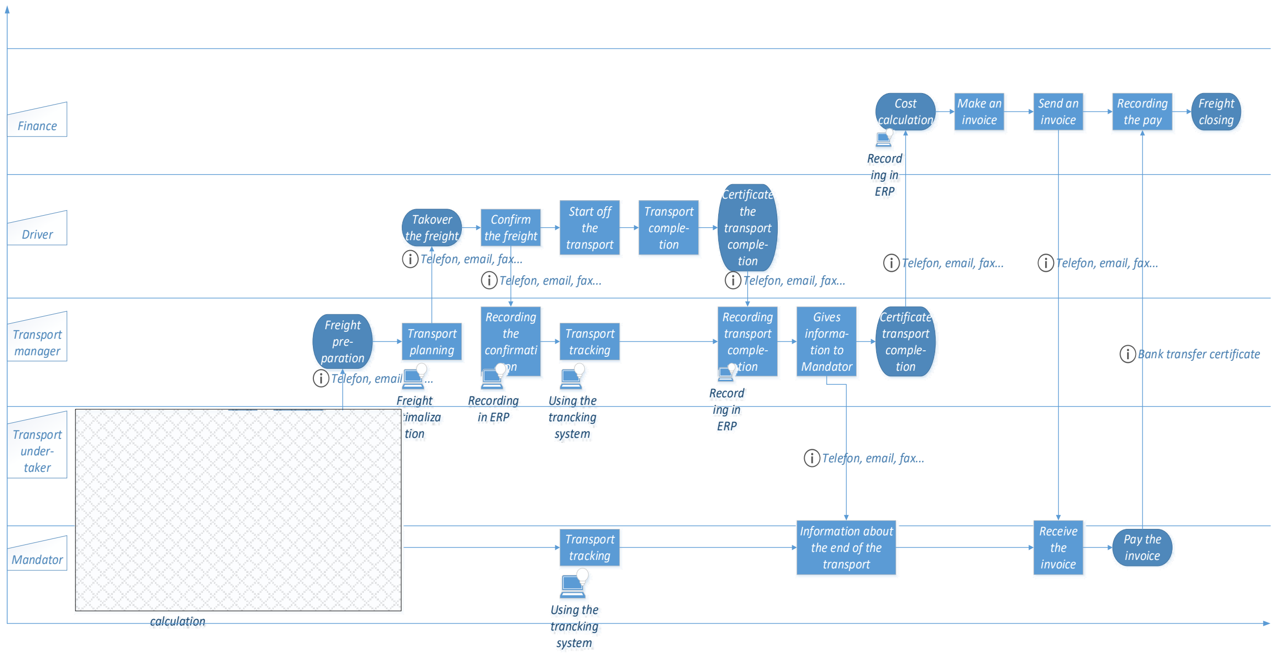

Fig. 3 Detailed description of the "special" transport processes

III. Potential Difficulties of Transport Processes

Managing the transport process is based on decades of practice. Although in the meantime major changes have occurred in the field of information-communication and decision-preparation techniques, their use is still superficial. Furthermore, there are computer programs that are applied in transportation management, but we do not take advantage of the potential of these opportunities despite the fact that the decision problem is one of the most important issues of the transportation process. It is also true that these programs are not able to appropriately support the transport processes.

A. Difficulties in Decision-Making

Acceptance of a freight order especially on an online market only depends on how fast the freight manager can decide to accept or not to undertake the freight task. Because of this, the freight managers often decide based on their individual experiences without any algorithm to support their choices. They have to make right decisions within a short period of time, approximately 30-60 seconds.

The background of decisions is as follows:

- carriage charges,
- destination,
- delivery volume,
- whole truck (high priority),
- palette (low priority),
- deadline,
- weather conditions,
- route details,
- driver's needs,
- driving time,
- family background,
- health and psychological background,
- vehicle maintenance
- service, tire change, MOT test, etc.

These decisions depend only on professional experience and routine.For that reason, several authors suggest a heuristic approach to solve large, practical problems. [23] To this end, providing support for these decisions is an important task. The Section IV describes the properties and possible application of the fuzzy signature based model.

IV. Fuzzy Signatures

The paradigm of fuzzy sets was introduced by Zadeh [1] as a tool for modeling and analyzing data with imprecise information where this uncertainty is a built-in feature, usually related to human opinions or not well-defined properties. In classical set theory (which is the origin of all of classical the mathematical modeling tools) an element belongs to a set or not. In terms of the characteristic function of a set A:

$$\chi_A(x) = \begin{cases} 1 & if\ x \in A \\ 0 & if\ x \notin A \end{cases}$$

In the fuzzy environment the role of the characteristic function is replaced by special function (membership function) which gives the grade of being the member of a set or having a specific property:

$$\mu_A(x) :\rightarrow [0,1]$$

This smooth transition between having a property or not is much more suitable for modeling human influenced, in a classical sense, not definable problems, and it made fuzzy logic an essential tool in these fields. The concept of linguistic variables [2]-[4] established the basis of taking into consideration the experiences of experts which are usually very difficult or almost impossible to turn into a classical mathematical form. The wide variety of applications embraces almost all of the fields of engineering and decision support. The range of logistics and transportation related applications is also enormously large, see for example [5]-[7].

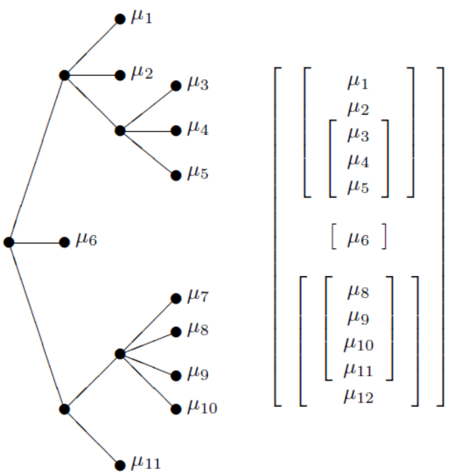

Fig. 4 An example of a fuzzy signature graph and the corresponding nested vectors

Engineers are often faced with problems of modeling complex systems where the exact mathematical model is not known or too difficult to deal with, due to lack of detailed knowledge of the parameters or the behavior of the system. Moreover, the system or process to be modelled usually cannot be reproduced exactly, and the interdependencies between the internal and external variables are also not known. Fuzzy signatures are useful tools in modeling such complex systems and objects. In this kind of approach, the complex systems are described by a set of qualitative measures, which are also arranged into a hierarchical framework expressing interconnections and dependencies and modeling the human approach to the problem. In the literature, there is a wide variety of applications, for example in the economy, in the medical field [8], and in several fields of engineering and informatics, for example, robotics [9], data mining [10] and civil engineering [11], [12].

In a mathematical point of view, fuzzy signatures are hierarchical representations of data structuring into vectors of fuzzy values [13]. A fuzzy signature is defined as a special multi-dimensional fuzzy data structure, which is a generalization of vector valued fuzzy sets [15]. Vector valued fuzzy sets are special cases of L-fuzzy sets which were introduced in [14].

A fuzzy signature is defined by

$$A : X \to S^{(n)} \qquad (1)$$

where X is the universe of discourse, $1 \le n$ and

$$S^{(n)} = x_{i=1}^{n} S_i \qquad S_i = \begin{cases} [0,1] \\ S^m \end{cases} \qquad (2)$$

Although a fuzzy signature can be represented by nested vector value fuzzy sets and by a tree graph also (see Fig. 1), the tree graph representation gives a transparent view of the structure of the model [15].

The input values (a.k.a. the 'leaves' of the tree) are usually estimated by human experts or estimation methods. The output of the fuzzy signature (the 'root' of the tree) is computed from the input values applying suitable aggregation operators, this is the membership value of the whole fuzzy signature. The multivariate function, which produces a single fuzzy set from multiple fuzzy sets is the so-called aggregation operation. [22]

Definition. An aggregation operation on n fuzzy set ($n \ge 2$) is defined by a function h: $[0;1]^n \to [0;1]$ with the following properties:

1. Boundary conditions:

$$h(0,\ldots,0) = 0 \text{ and } h(1,\ldots,1) = 1$$

2. Monotonicity: h is monotonic increasing in all its arguments i.e. for all $a_i; b_i \in [0,1]$ if $a_i < b_i$ (i=1,…,n) then

$$h(a_1,a_2,\ldots,a_n) \le h(b_1,b_2,\ldots,b_n)$$

3. Continuity: h is a continuous function.

In addition to the conditions above, sometimes the following two properties are also required:

4. Symmetricity: h is symmetric in all its arguments, i.e.

$$h(a_1, a_2, \ldots, a_n) = h(a_{p(1)}, a_{p(2)},\ldots,a_{p(n)})$$

where p is an arbitrary permutation of the indices.

5. h is idempotent: for all $a \in [0,1]$:

$$h(a,a,\ldots,a) = a$$

It can be proved, that if an aggregation operator *h* fulfills condition 2) and 5) then the following inequality holds for all $(a_1,a_2,\ldots,a_n) \in [0,1]^n$:

$$\min(a_1,\ldots,a_n) \le h(a_1,\ldots,a_n) \le \max(a_1,\ldots,a_n)$$

The most commonly used aggregation operators are fuzzy t-norms, fuzzy s-norm (t-conorms), ordered weighted averaging (OWA) operators and weighted general means.

Definition. Let $x_1,\ldots,x_n$ and $w_1,\ldots,w_n$ be non-negative real numbers,

$$w_i \ge 0, \sum_{i=1}^{n} w_i = 1 \qquad and \qquad p \in \Re \, (p \ne 0).$$

Then the weighted generalized mean of $x_1,\ldots,x_n$ with weights $w_1,\ldots,w_n$ and with parameter p:

$$M_p^w(x_1,\ldots,x_n) = \left[\sum_{k=1}^{n} w_k x_k^p\right]^{\frac{1}{p}}$$

The limits at $\pm\infty$ regardless to the weights:

$$\lim_{p\to\infty} = \left[\sum_{k=1}^{n} w_k x_k^p\right]^{\frac{1}{p}} = \max(x_i)$$

$$\lim_{p\to-\infty} = \left[\sum_{k=1}^{n} w_k x_k^p\right]^{\frac{1}{p}} = \min(x_i)$$

So this operator class includes max and min as limit cases, too. Because of the natural ex-presence of uncertainty or lack of detailed information about the complex system that we are going to model, different human experts or different kind of estimation methods may give different labels or scores to the same situation. This implies that in real applications a fuzzy signature based model should have some robustness, so the output should not change too much if the input values change a little, which means that it should not be extremely sensitive to small perturbations of data. The sensitivity of weighted aggregation operators was discussed in [16], for a sensitivity of the OWA and other similar operators, see [17] and [18]. The sensitivity of weighted general mean aggregation operators was discussed in details in [19]-[21].

V. Conclusion

In this research, we demonstrated how to use the fuzzy signatures in support of operational management work. We tried to illustrate how complex this area is and how important it is to create a helpful decision-making model.

Our ultimate goal is creating a complex appropriate freight management system, which supports the work of all freight participant.

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References

[1] L. A. Zadeh, Fuzzy Sets, Information and Control 8 (3) (1965), pp. 338-353.
[2] L. A. Zadeh, The concept of a linguistic variable and its application to approximate reasoning I, Information Science 8 (1975), pp. 199-251.
[3] L. A. Zadeh, The concept of a linguistic variable and its application to approximate reasoning II, Information Science 8 (1975), pp. 301-357.
[4] L. A. Zadeh, The concept of a linguistic variable and its application to approximate reasoning III, Information Science 9 (1975), pp. 43-80.
[5] G. Zhang, L. Jie, Model and approach of fuzzy bilevel decision making for logistics planning problem, Journal of Enterprise Information Management 20 (2) (2007), pp. 178-197.
[6] Liu Hao-Tien, Wei-Kai Wang An integrated fuzzy approach for provider evaluation and selection in third-party logistics, Expert Systems with Applications 36 (3) (2009), pp. 4387-4398.
[7] C.T. Chen, A fuzzy approach to select the location of the distribution center Fuzzy sets and systems, 118 (1) (2001), pp. 65-73.
[8] K. W. Wong, T. D. Gedeon, L. T. Kóczy, Construction of fuzzy signature from data: an example of SARS pre-clinical diagnosis system, in: Proceedings of the IEEE International Conference on Fuzzy Systems (FUZZ-IEEE2004), Budapest, Hungary, 2004, pp.1649-1654.
[9] Á. Ballagi, L. T. Kóczy, T. D. Gedeon, Robot cooperation without explicit communication by fuzzy signatures and decision trees, in: Proceedings of the Joint 2009 International Fuzzy Systems Association World Congress and 2009 European Society of Fuzzy Logic and Technology Conference (IFSA-EUSFLAT2009), Lisbon, Portugal, 2009, pp.1468-1473.
[10] T. Vámos, L. T. Kóczy, G. Biró, Fuzzy signatures in datamining, in: Proceedings of the Joint 9th IFSA World Congress and 20th NAFIPS International Conference, Vancouver, BC, Canada, 2001, pp. 2842-2846 (5).
[11] G. Molnárka, L. T. Kóczy, Decision Support System for Evaluating Existing Apartment Buildings Based on Fuzzy Signatures, Int. J. of Computers , Communications & Control, 2011, No. 3, pp. 442-457.
[12] Á. Bukovics, L.T. Kóczy, Fuzzy Signature-based Model for Qualification and Ranking of Residential Buildings, XXXVIII. IAHS World Congress on Housing, Istanbul, Turkey, 2012. pp. 290-297.
[13] C. Pozna, N. Minculete, R. E. Precup, L. T. Kóczy, Á. Ballagi, Signatures: Definitions, operators and applications to fuzzy modelling, Fuzzy Sets and Systems 201 (2012), pp. 86-104.
[14] J.A.Goguen, L-fuzzy sets, J. Math. Anal. Appl. 18(1) (1967), pp. 145-174.
[15] L. T. Kóczy, T. Vámos, G. Biró, Fuzzy signatures, in: Proceedings of the 4th Meeting of the Euro Working Group on Fuzzy Sets and the 2nd International Conference on Soft and Intelligent Computing (EUROPUSE-SIC99), Budapest, Hungary, 1999, pp. 210-217.
[16] U. Kaymak, H.R. van Nauta Lemke, T. Boer: A sensitivity-based analysis of weighted fuzzy aggregation, In: Proceedings of the IEEE World Congress on Computational Intelligence, IEEE International Conference on Fuzzy Systems, IEEE, 1998. pp. 755-760.
[17] V. Torra: Sensitivity analysis for WOWA, OWA and WM operators, In: Proceedings of ISIE 2001, IEEE International Symposium on Industrial Electronics, IEEE, 2001. pp. 134-137.
[18] M. Zarghami, F. Szidarovszky: Fuzzy quantifiers in sensitivity analysis of OWA operator, Computers & Industrial Engineering 54 (2008), pp. 1006-1018.
[19] I. Á. Harmati, Á. Bukovics, L. T. Kóczy, Sensitivity Analysis of the Weighted Generalized Mean Aggregation Operator and its Application to Fuzzy Signatures, IEEE World Congress on Computational Intelligence (WCCI 2014 - FUZZ-IEEE 2014). Beijing, China, 2014.07.06-2014.07.11. New York: IEEE, 2014. pp. 1327-1332.
[20] I. Á. Harmati, Á. Bukovics, L. T. Kóczy, Sensitivity Analysis of Fuzzy Signatures Using Minkowski's Inequality, Proceedings in Adaptation, Learning and Optimization: Proc. of the 18th Asia Pacific Symp. on Intell. and Evol. Systems, Singapore, 2014.11.10-2014.11.12. (s. l.): Springer International Publishing Switzerland, 2014. pp. 587-596.
[21] I. Á. Harmati, Á. Bukovics, L. T. Kóczy, Minkowskis inequality based sensitivity analysis of fuzzy signatures, Journal of Artificial Intelligence and Soft Computing Research 6 (4) (2016), pp. 219-229.
[22] Timothy J. Ross: Fuzzy Logic with Engineering Applications, Fourth edition. 2017. pp.45.
[23] T. Hartványi, A. Bakó: Transportation network realization with an optimization method, 2009 4th International Symposium on Computational Intelligence and Intelligent Informatics, 21-25 Oct. 2009