GIS and Image Processing

Dana Klimešová, Eva Ocelíková

Abstract **—** The paper discusses the contribution of image processing techniques to improve cognitive processes, acquire vector data and support decision making. Also the problem of knowledge management is addressed and the different ways of knowledge integration is discussed. The paper is focused on the possibility to support our decisions using GIS and knowledge database in combination with raster oriented advanced methods to acquire, analyze and evaluate data. The satellite data can bring new aspects into landscape evaluation including temporal point of view and understanding various contexts.

Keywords **—** Architectures for composed classifiers, bagging, boosting, decision making.

I. INTRODUCTION

A single piece of data has no meaning unless the context is considered. The quality of decision-making is always dependent on the quality and quantity of information about issues and on the suitable classification methods enabling to select the best alternative from the set of all available solutions [1], [2].

A sufficient amount of the quality information about the issues to be decided is needed and the quality decision can be made. For this reason certain properties of objects are observed, which are important from the decision-making process aspect, it means, they are being evaluated according to certain evaluation criteria.

Information about the significance of evaluation criteria has, in many multi-criteria decision making methods and approaches, significant importance. Our decisions are becoming increasingly dependent on understanding of complex relations, deep context and dynamics of phenomena in the world around [3], [4].

Manuscript received in February 7, 2011. Revised version received in March 23, 2011. This paper was supported by the grant project of the Ministry of Education of the Czech Republic No. MSM 6046070904 – Information and Knowledge Support of Strategic Management. This support is very gratefully acknowledged.

D. Klimešová is with the Czech University of Life Sciences, Prague, Faculty of Economics and Management, Department of Information Engineering, Kamýcká 129, 165 21 Prague, CZECH REPUBLIC, (e-mail: klimesova@pef.czu.cz), and with the Institute of Information Theory and Automation, Czech Academy of Sciences, Pod vodárenskou věží 4, 182 00 Prague 8, (email: klimes@utia.cas.cz).

E. Ocelíková is with Technical University Košice, Faculty of Electrical Engineering and Informatics, Dept. of Cybernetics and Artificial Intelligence, Letná 9, 042 00 Košice, SLOVAK REPUBLIC, (e-mail: ocelike@ccsun.tuke.sk).

A. GIS Technology

GIS technology provides essential marketing and customer intelligence solutions that lead to better business decisions. Geography is a framework for organizing our global knowledge and GIS is the technology for being able to create, manage, publish and disseminate this knowledge for whole society [5].

GIS help our business saving time and money, while improving access to information and realizing a tangible return on our GIS investment. GIS technology provides essential marketing and customer intelligence solutions that lead to better business decisions [6].

Information must be structured and knowledge must be represented so that answers can be found among the information in the system or derived from the information in the system [7]. GIS can be easily considered as knowledge management platform.

B. Web Services

The evolution of the Internet and Intranet applications contributes to effective information and knowledge acquisition, incorporation and significantly shapes the role of the technological infrastructure [7], [8].

We need the system that is able to ask for more information if it is needed to derive a good answer and to answer in easily understood format.

The system assists in knowledge acquisition, is able to learn and accept different information structures and to have in disposal a wide range of information processing techniques and methods, and appropriate knowledge presentation tools [9].

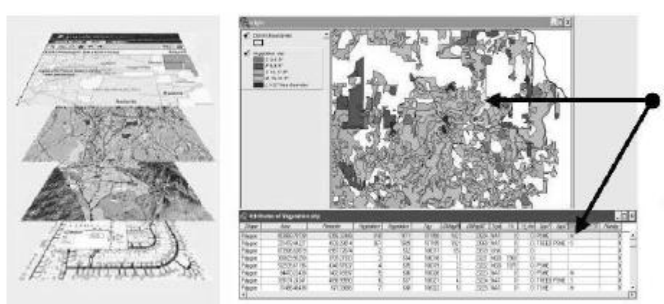

Fig. 1 Information layers, parts of geometry and attributes.

GIS is able to evaluate the context between information layers. Every object is localized and consists from two parts: geometry – point, line, polygon and attributes (fig. 1b).

The geography plays a very important role in many situations. Spatial decision making, targeting market segments, planning distribution networks, responding to emergencies, and many others - all of these problems involve questions of geography.

GIS technology illustrates relationships, connections, and patterns that are not necessarily obvious in any one data set, enabling organizations to make better decisions based on all relevant factors[10], [11]. GIS technology is also being used via the Internet and Web services.

C. Remote Sensing

The progress in new sensor technology for Earth observational remote sensing continues and increasingly high spectral resolution multispectral imaging sensors are developed and these sensors give more detailed and complex data for each picture element [12]. The increasing resolution of the data sources results in the increasing number of imaged objects (classes).

The dimensionality of data and the complexity of objects structure hierarchy are rapidly growing. The higher resolution of multispectral data makes possible not only improves the recognition of geo-objects, it makes possible to deduce selected attributes of geo-objects.

D. Control GIS

GIS and its constructions are based on the models. These models are an approximation of reality and are dependent on the subjective interpretation of the knowledge. It means that new observations may lead to a refinement, modification, or completion of the already constructed model. On the other hand, the models may guide further acquisition of knowledge and the knowledge is the base for decision support [13].

The integral part of control GIS [5], is the modeling where the information layers from real, artificial and virtual world are composed together to select optimal scenario or verify given hypothesis or assumptions.

II. KNOWLEDGE MANAGEMENT

A. Knowledge Structure

Knowledge management recognizes the need to exploit intellectual capital, but many practices fall short by only concentrating on individual knowledge components. Integrated knowledge has multiform structure, appropriate links with possibility to aggregate, separate and generalize parts and wholes in *temporal dependence*.

Moreover, knowledge management needs the tool that can help to supply users by relevant and suitable knowledge in appropriate time and in consumable integrated form when they solve tasks like process improvement, decision support, training, risk management and others [14].

Mentioned tool would be effective used in future to auto-learning enhancement and integration of knowledge base instead of storing and accessing information from a central repository.

However, the specific introduction of the term knowledge creates a different viewpoint and allows more sophisticated ways of the use. It is no longer sufficient to deliver huge amounts of information to users instead it is important to support them in doing their knowledge work.

Knowledge management is a holistic approach, which can be analyzed in different ways. For this reason, it is difficult to give an exact definition.

B. Decision Making

Knowledge is an important resource for successful decision-making process in the whole society. The special procedures of control and management of knowledge therefore have to be used. In the area of knowledge management and knowledge engineering basic terms of these disciplines are data, information, knowledge and knowledge transformation [15], [16].

Knowledge is a product of successful decision-making process and knowledge modeling and knowledge representation is an important field of research also in Computer Science and Artificial Intelligence.

The development of knowledge-based systems was seen as a process of transferring human knowledge to an implemented knowledge base.

Geographical Information Systems (GIS) support decision-making process, therefore they also produce a new knowledge. They are an interactive computer-based systems helping decision makers complete decision process. Geographic Information Systems provide essential marketing and customer intelligence solutions that lead to better business decisions.

C. Context Understanding

Applying context it is possible to derive new quality of information that can be used to support decisions. While information reflects an understanding of the relations between data, it generally does not provide a foundation for why the data is what it is and how the data is changed over time.

Information has a tendency to be relatively static in time and linear in nature. Information is a relationship between data with great dependence on context for its meaning. Information relates to description, definition, or perspective (what, who, when, where).

Instead of knowledge that contains the method or approach (how to do things), include practice and strategy. Thinking about upper mentioned facts what type of structure would be appropriate to follow the context?

It seems that to fulfil drawn imagination we have to consider dynamic structure where the *dynamic* means that the move will be inherent part of that structure. It could be some structure derived for example from *Brownian web* [17].

Knowledge is a multifaceted concept with multi-layered meaning.

Furthermore, new customer-oriented management [18], [19] quality principles and new information technologies promote new styles of communication and decision-making in company departments.

Knowledge cannot be defined without its context, experience, interpretation, and reflection.
Knowledge has the following aspects [20].

- represents solution of problem
- has a normative function
- is internally and externally networked
- is dynamic and contextual

To gain the relevant answer it is necessary incorporate the various contexts into the analysis of objects, phenomena, events and processes and connect up uncertainty into the knowledge-construction and decision-making process through context cognition.

Open systems are using frequently various models but the model is only an approximation of reality and the modeling process is dependent on the subjective interpretation of the knowledge.

It means that new observations may lead to a further refinement, modification, or completion of the already constructed model. And the model may guide further acquisition of knowledge and the knowledge is the base for decision support.

Moreover, besides knowledge modeling also knowledge representation is very important field of research.

Data are not perfect from many reasons:

- Incomplete data
- Precision of measurements
- Discreet description of connective phenomena
- Inherent part reflecting our understanding of things [21].

On the other hand the current top level of GIS usage, it is control GIS, where the large ability is aided to implement knowledge models from different branches of scientific investigation, wide context implementation including less evident connections, models of trends, objects and expected or predicted relations.

III. PROBLEM FORMULATION

Many GIS users face the problem of acquiring accurate and timely suitable data at a cost effective price. Finding features in remotely sensed imagery can be a time-saving way to define and update geographical layers.

Space technology has been gaining more and more ground in our life. Earth observation images sometimes turn into an irreplaceable source of independent and up-to-date information about the condition of an area.

The *multispectral images* are image data at specific frequencies across the electromagnetic spectrum.

The wavelengths may be separated by filters or by the use of instruments that are sensitive to particular wavelengths, including light from frequencies beyond the visible light range, such as infrared.

Multispectral imaging can allow extraction of additional information that the human eye fails to capture with its receptors for red, green and blue. It was originally developed for space-based imaging.

Advanced sensor technology can provide data in much higher dimensions than previous sensors and such high dimensional data will present a substantial potential for deriving greater amounts of information.

A. Application Possibilities

Satellite data as well as aerial data is used to monitor fire situation, seasonal and flash floods, construction activities, forest management, environmental and navigation situation, urban management, agricultural activities, municipal field services, investment, and etc. [22].

- Satellite imagery are the tool of an efficient modernization of economy (application in large industrial projects, investment, communication)
- Operational services for emergencies monitoring, control and response (strategy planning, fire situation, seasonal floods and flash floods, water areas)
- Application of satellite data for solution of nature protection tasks
- Integration of satellite data, GIS and Web technologies

When raster images with spectral information are available, so called multispectral images (usually satellite data with multiple wavelength channels), we can use a lot of methods for classification pixel by pixel into specific classes.

B. Conversion to Vector

Raster data classified in this way can then be converted to vector layers, and output to a variety of vector formats.

This process is usually much faster and easier than manually digitizing from the raster image. It is a cost effective way to update our GIS with accurate and timely layers and add new vector layers to geo-database.

Frequently used raster classifiers in image processing include standard approaches such as Bayesian classification, maximum likelihood and minimum distance classifiers as well as more sophisticated.

For example ESRI together with ENVI has in disposal the package focused on less and more sophisticated classification methods, including neural network and decision tree classifiers [23].

IV. CLASSIFICATION

A. Statistical Pattern Recognition

Recognition (classification) it is assigning a pattern/object to one of pre-defined classes.

Two basic approaches:

♦ Supervised classification when training set is available for each class (Minimum distance to means, Bayes classification, Maximum likelihood, K-NN classification, Decision tree, …)

♦ Unsupervised classification (clustering) when training set is not available (Hierarchical methods, Non-hierarchical methods, Distribution methods, methods based on the Density of elements, Lattice methods, …)

Desirable properties of the training set [24]

♦ It should contain typical representatives of each class including intra-class variations
♦ Reliable and large enough
♦ Should be selected by domain experts

Than it is necessary to setup the classification rule it means the way of the feature space partitioning.

Each class is characterized by its discriminate function *g(x)* and classification, it means maximization of *g(x),* where feature x is a point in n-dimensional metric space (usually Euclidean space) that describes the object.

We assign x to class i if

$$g_i(x) > g_j(x) \tag{1}$$

Discriminate functions define decision boundaries in the feature space, see fig. 2.

B. Clustering Techniques

Having no training set in disposal the unsupervised classification (clustering) is used.

We can say that clusters are:

♦ Compact, well-separated subsets or
♦ Any partition of the data into disjoint subsets, see fig. 3.

Clustering methods:

♦ Iterative methods, when the number of classes is given.
♦ Hierarchical methods - typically when number of classes is unknown (agglomerative and divisive cluster
♦ Other methods - sequential, fuzzy or genetic focused, etc.

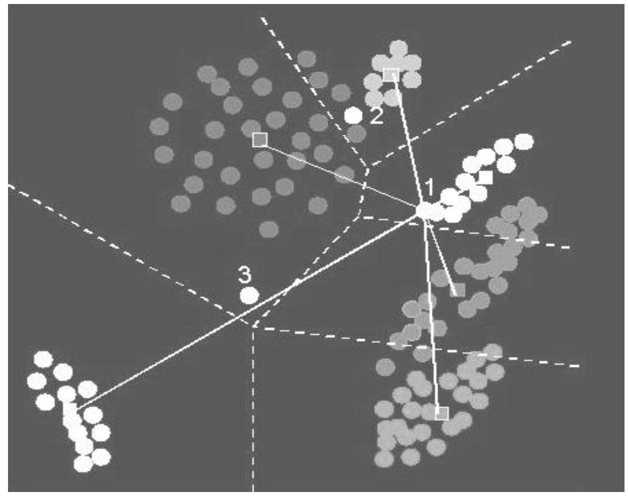

Fig. 2 Supervised classification – minimum distance to means.

In other words cluster analysis is an exploratory data analysis tool which aims at sorting different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise.

Given the above, cluster analysis can be used to discover structures in data without providing an explanation or interpretation.

In other words, cluster analysis simply discovers structures in data without explaining why they exist.

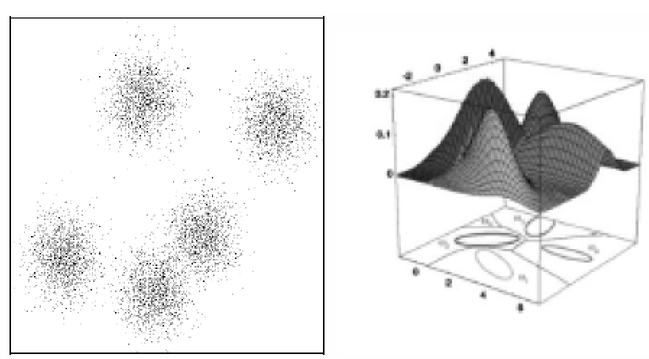

Fig. 3 Five clusters and clusters determination.

V. COMPOSED CLASSIFIERS

Great amount of tasks is focused on special factors monitoring, analysis and evaluation and new requirements result in new methods development.

Precision of classification can be increased by the best properties of few classifiers united (**weak classifiers**) to one component classifier (**strong classifier**).

The advantage of the component classifier is: union of different approaches, for example statistical approaches, neuron network or decision trees. Composed classifier is a composition of component classifiers, which predictions are connecting by combining classifier [25], [26].

A. Architectures

Main architectures for combination of classifiers:

- **Bagging** - creates individuals for its ensemble by training each classifier on a random redistribution of the training set.
- **Boosting** - tries to increase the precision of classifier by creating a complementary component classifier [27] by filtration of a training set.
- **Stacked Generalization** - classifiers on a higher level combine prediction of classifiers immediate on the lower level.

Main simple classifiers: k-nearest neighbors, Bayesian classifier, Decision tree.

AdaBoost (adaptive boosting) is an algorithm for constructing a **strong** classifier as linear combination

$$f(x) = \sum_{t=1}^{T} \alpha_t h_t(x) \qquad (2)$$

of **weak** classifiers $h_t(x): \chi \to \{-1, +1\}$ (3)

Composite Classifier Design Criteria [28]

- **Accuracy** of the component classifiers (independently accurate).
- **Diversity** of the component classifiers - combining the predictions of a set of classifiers that all make the same errors cannot lead to any improvement in the accuracy of the composite prediction.
- **Efficiency** of the entire composite classifier – general requirement that a classifier should use only reasonable amounts of time and memory for training and application.

B. Post Classification

After pixels in a raster dataset have been assigned to classes, post-classification methods can clean up the resulting raster image in preparation for conversion to vector data [29].

Raster classification often contains scattered individual pixels of one class surrounded by a larger area of another class.

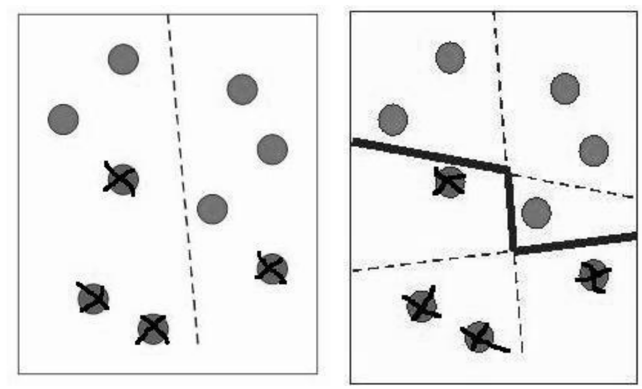

Fig. 4 The weak and strong classifier.

Post classification improves raster analysis. The raster image with the classes is than converted to vector layers. Classifying images can be used as outputs in reports or analyses and more this approach help us:

- to replace or accelerate manual digitization processes
- manage multiple types of geographic data
- improve workflow processes, from data gathering and analysis to publication and distribution of findings

In the last years, also fuzzy logic is often implemented successfully in various GIS processes [30]. Important implementations were made in the fields of classification, analysis, data collection and in remote sensing.

C. Fuzzy Approach

The GIS practice deals with many activities with fuzzy behavior and this is the reason why fuzzy knowledge should be modeled appropriately.

Most of the decision problems are multi-criteria. The problem of the selection or the ranking of alternatives submitted to a multi-criteria evaluation is not easy problem [31] - [34]. Since every decision-making affects the course of further events, it is necessary to pay attention with an appropriate respect to the decision-making process.

Than will pay that GIS

- shows data, information and knowledge and their relationships, patterns and trends in the form of maps, scenarios, reports and charts

- helps to solve problems using data which are quickly looked up, easily shared and internally and externally networked
-
- information layers can follow the local, temporal, thematic, spatial, and other types of context

Since the knowledge is specified independently from the application domain, it means that reuse of the knowledge is enabled for different domains and applications [35], [36]. The knowledge modeling connected with knowledge based systems is influenced everyday by new research results.

V. RESULTS

Experimental data is special data which can be used to verified results of simple and composed classification methods.

Table 1. Specification of training and testing data sets.

Name	Circles	Synth
Number of objects of training data set	2250	250
Number of objects of test data set	250	1000

The best result is achieved using **Boosting** with classifier composed from simple classifiers: 1- nearest neighbor, 9 – NN and 8 – NN, see table 3.

Even architecture **Stacked generalization** gives good result using the classifier composed from 3-NN, Bayesian classifier (38,40%) and decision tree classifier (61,59%). We have to take into consideration that data set Circles has 2250 training object in disposal [37] - [39].

A. Experimental data Circles

Table 2. Results on training data Circles – simple (weak) classifiers.

Train data set Circles		
Simple classifiers		
1-NN classifier	99,19%	
3-NN classifier		99,59%
4-NN classifier		99,59%
5-NN classifier		99,59%
6-NN classifier		99,59%
7-NN classifier		99,59%
8-NN classifier		99,59%
9-NN classifier	99,19%	
10-NN classifier		99,59%
Bayesian classifier	38,40%	
Decision tree	61,59%	

Table 3. Composed classifiers in three different architectures.

Composed classifiers	
Bagging C:9-NN,Bags:95%, 90%	99,59%
Boosting C1:1-NN, C2:9-NN, C3:8-NN	99,95%
Stacked generalization C1: 3-NN, C2: Bayesian classifier, C3: Decision tree	99,59%

Moreover, we cannot increase the precision using in composition the classifiers (weak) with the same percentage of success.

Table 4. Simple classifiers on data set Synth.

Train data set Synth		
Simple classifiers		
1-NN classifier		85,00%
3-NN classifier		86,59%
4-NN classifier		87,30%
5-NN classifier		87,00%
6-NN classifier		87,09%
7-NN classifier		88,90%
8-NN classifier		88,40%
9-NN classifier		88,80%
10-NN classifier	89,40%	
Bayesian classifier		50,00%
Decision tree		48,59%

Table 5. Results of composed classifiers in different architectures.

Composed classifier	
Bagging	89,50%
C:3-NN, Bags: 95%, 97%, 94 %	
Boosting C1:3-NN, C2:6-NN, C3:9-NN	50,00%
Stacked generalization C1:10-NN, C2: Bayesian classifier, C3: Decision tree	89,40%

Composed Classifier:

- Improves classification accuracy

- Can be used with many different classifiers
- Commonly used in many areas
- Simple to implement
- Not prone to over-fitting

VI. CONCLUSION

In this paper, the problem of multi-criteria evaluation is addressed and the different ways of knowledge integration is discussed as well as the problem of wide spatial and temporal context.

The contribution deals with more abstract level for reflection and understanding of the various modeling processes. The great possibilities of satellite and aerial data to be incorporated not only as layer that visualize the scene but as a valuable source of irreplaceable information that can be transformed into knowledge.

Our decisions are becoming increasingly dependent on understanding of complex relations, deep context and dynamics of phenomena in the world around and geographic information technology is able to incorporate these new requirements and produce more valuable results.

The paper shows the architecture of composed classifier gives the space where it is possible to incorporate the additional aspects and refine our decision rules. The main goal has been to show selected aspects of this process.

ACKNOWLEDGMENT

The paper was supported by the grant project of the Ministry of Education of the Czech Republic No. MSM6046070904 – **Information and Knowledge Support of Strategic Management.** This support is very gratefully acknowledged.

REFERENCES

[1] Heflin, J., 2001. Towards the Semantic Web: *Knowledge Representation in a Dynamic, Distributed Environment*. Ph.D. Thesis, University of Mary land, College Park.

[2] Klimešová, D., Ocelíková, E., 2010. Study on Context Understanding, Knowledge Transformation and Decision Support Systems. *Wseas Transactions on Information Science and Applications*, 7 (7) 2010, pp. 985-994.

[3] Klimešová D- Ocelíková, E**.,** 2007. Study of Uncertainty and Contextual Modelling. *International Journal of Circuits, Systems and Signal Processing*, Issue 1, Volume 1, 2007, pp. 12-15.

[4] Muntean, M. I., Reflections Concerning Some Collaborative Systems Portal-Based Approaches, *WSEAS Transactions on Business and Economics*, Issue 3, Volume 7, July 2010.

[5] Andrade, J., Ares, J., Garcia, R., Rodriguez, S., Suarez, S., A Knowledge-Based System for Knowledge Management Capability Assessment Model Evaluation, *WSEAS Transactions on Computers*, Issue 5, Volume 9, May 2010.

[6] Tarnaveanu, D. A., A Model of Decision Support System in Economy, WSEAS Transactions on Business and Economics, Issue 4, Volume 7, October 2010.

[7] Brinkmann, A., Knowledge Maps – Tools for Building Structure in Mathematics, *Int. Journal for Mathematics Teaching and Learning*, 2005, [online journal], available at: http://www.cimt.plymouth.ac.uk/journal/brinkmann.pdf, [cit. 2009-08-25].

[8] Leibold, M., Probst, G. and Gibbert, M. (2001): Strategic Management in the Knowledge Economy, Wiley, Erlangen.

[9] Martensson, M. 2000. A critical review of knowledge management as a management tool. *Journal of Knowledge Management*, 4, 204-216.

[10] Muntean, M. I., Reflections Concerning Some Collaborative Systems Portal-Based Approaches, *WSEAS Transactions on Business and Economics*, Issue 3, Volume 7, July 2010.

[11] Papageorgiou, G., Hadjis, A., Abrosimova, K., Management Flight Simulators; a New Approach to the Development of Decision Support Systems, *WSEAS Transactions on Systems*, Issue 5, Volume 7, May 2008.

[12] Sherman, A. T., and McGrew, D. A.: Key Establishment in Large Dynamic Groups Using One-Way Function Trees," *IEEE Transactions On Software Engineering*, Vol. 29, No. 5, 2003, pp. 444-458.

[13] Klimešová D., 2006. Study on Geo-information Modelling, 5 (2006), *WSEAS Transaction on Systems,* pp. 1108-1114.

[14] Šubrt, T., Brožová, H., Knowledge Maps and Mathematical Modelling, *The Electronic Journal of Knowledge Management*, Volume 5, Issue 4, pp. 497 - 504, 2007, [online journal], available at: http://www.ejkm.com/,[cit. 2009-10-02].

[15] Kwak, D. W., Lee, S. J., Kim, J. W., and Jung, E. J., 2006. An Efficient LKH Tree Balancing Algorithm for Group Key Management," *IEEE Communications Letters*, Vol. 10, No. 3, pp. 222-224.

[16] Milton, N., Clarke, D. and Shadbolt, N., 2006. Knowledge Engineering and Psychology: Towards a closer relationship. *International Journal of Human-Computer Studies*, Volume 64(12), 1214-1229.

[17] J.M. Swart (2003): Uniqueness for isotropic diffusions with a linear drift (Prob. Theory Relat. Fields 128 (2004) 517-524).

[18] Martensson, M. 2000. A critical review of knowledge management as a management tool. *Journal of Knowledge Management*, 4, 204-216.

[19] Sherman, A. T., and McGrew, D. A.: Key Establishment in Large Dynamic Groups Using One-Way Function Trees," *IEEE Transactions On Software Engineering*, Vol. 29, No. 5, 2003, pp. 444-458.

[20] Gottschalk-Mazouz, N., Internet and the flow of knowledge, In: Hrachovec, H.; Pichler, A. (Hg.): *Philosophy of the Information Society. Proceedings of the 30. International Ludwig Wittgenstein*

Symposium, Volume 2, Kirchberg am Wechsel, Austria, 2008Lynch P.J., Horton S., *Web Style Guide: Basic Design Principles for Creating Web Sites*, New York, 2002.

[21] Parent C., Spaccapietra S., and Zimanyi E.,2000. MurMur: database management of multiple representations. Proceedings of AAAI-2000 Workshop on Spatial and Temporal Granularity, Austin, Texas.

[22] .

[23] <http://www.cyberartsweb.org/cpace/ht/thonglipfei/ct_dfn1.html>.

[24] Russell, S. J., P. Norvig P., 2002. *Artificial Intelligence: A Modern Approach,* 2nd ed. Prentice Hall, December 2002.

[25] Raudys, S., 1997. Intrinsic Dimensionality and Small Sample Properties of Statistical Classifier. *1st International Workshop on STRIP '97,* Prague, June, pp. 85-90.

[26] Wilson, d. R., Martinez, T. R., 1997. Improved Heterogeneous Distance Functions. *Journal of Artificial Intelligence Research,* No. 6, pp. 1-34.

[27] Bin, W.; Zhongzhi, S. *A clustering algorithm based on swarm inteligence.* Info-tech and Info-net, 2001. Proceedings. ICII 2001, vol. 3, pp. 58–66, 2001

[28] Hual, L.; Hiroshi, M. *Extraction, Construction and Selection*. Kluwer Academic Publishers,Boston, 1998.

[29] Juang, W. S., and Wu, J. C., 2006. An Efficient and Flexible Decentralized Multicast Key Distribution Scheme, *International Journal of Computer Science and Network Security*, Vol. 6, No. 8B, pp. 141-150.

[30] Baraldi, A.; Blonda. P. *A Survey of Fuzzy Clustering Algorithms for Pattern Recognition*. ICSI, TR-98-038, 1998.

[31] Klimešová, D., Brožová, H., 2009. DSS and GIS in Knowledge Transformation Process, *Journal on Efficiency and Responsibility in Education and Science*, 2 (1), 2009, pp.1 – 15.

[32] Kwak, D. W., Lee, S. J., Kim, J. W., and Jung, E. J., 2006. An Efficient LKH Tree Balancing Algorithm for Group Key Management," *IEEE Communications Letters*, Vol. 10, No. 3, pp. 222-224.

[33] R.E. Schapire, Y. Singer. Improved Boosting Algorithms Using Confidence-rated Predictions. Machine Learning. 1999

[34] Levin, Mark Sh., 2006. *Composite Systems Decisions*, New York: Springer.

[35] Store, R., Kangas, J., Integrating spatial multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modelling, *Landscape and Urban Planning*, 55, pp. 79–93, 2001.

[36] Muntean, M. I., Reflections Concerning Some Collaborative Systems Portal-Based Approaches, *WSEAS Transactions on Business and Economics*, Issue 3, Volume 7, July 2010.

[37] Martensson, M. 2000. A critical review of knowledge management as a management tool. *Journal of Knowledge Management*, 4, 204-216.

[38] Milton, N. R. *Knowledge Acquisition in Practice: A Step-by-step Guide*. London: Springer, 2007.

[39] Milton, N., Clarke, D. and Shadbolt, N., 2006. Knowledge Engineering and Psychology: Towards a closer relationship. *International Journal of Human-Computer Studies*, Volume 64(12), 1214-1229.