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Design and Implementation of Monitoring and Evaluation of Healthcare Organization Management

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Abstract. The management of a healthcare organization is monitored using a suitably designed questionnaire to 271 nurses operating in Greek hospital. The data are fed to an automatic data mining system to obtain a suitable series of models to analyse, visualise and study the obtained information. Hidden patterns, correlations and interdependencies are investigated and the results are analytically presented.

INTRODUCTION

Organization management is under continuous critique from both employees and service consumers in both public and private sector. Especially in the field of healthcare the analysis of the impact Organization style is regarded on the basis of job and personal satisfaction of the employees. Modern approaches in health administration and economical management (Platis Ch. et. al. 2014), analysis of therapeutic methods (Zoulias E. et. Al 2011) take into account the employee, the personal performance, job satisfaction ant their correlation to workplace health risks for the patients and for the employees themselves. It is important to note that job performance is a dominant factor to safe and high quality health care services (Platis Ch. et. al. 2014).

The vast quantity of available data obtain in the evaluation process of the above factors can be analysed with sophisticated analytical tools from machine learning and data mining tools (David J. Hand 1999). Hidden patterns are discovered using a suitable "machine", as the collection of already implemented algorithms (Berry M. J. A. et al.). Data mining is not only based on a simple statistical analysis to calculate the moments of the data, but applies a variety of models and decides which is most suitable according to flexible criteria. This technology has been used throughout various domain and even in the medical area (Wang, H. et al. 2015, Alimisis Dimitris et al. 2013, Alimisis D.et al. 2013). Decision support systems is the next step after the discovery of these hidden patterns and therefore, tools for assisted diagnosis can be designed (G. Leroy et. al. 2007). The techniques include Artificial Neural Networks (ANNs) (Haykin S. et. al. 1999), evolutionary algorithms such as genetic algorithms (Goldberg D. 1989), fuzzy logic (Linkens D.A. et. al. 2001), zero knowledge systems (Bardis N. et al., 2010), various hybrid systems (Papageorgiou E.I. et. al. 2005), Artificial Immune Systems (AIS) (Timmis J. et. al. 2000), Support Vector Machines (Cristianini N. et. al. 2000), k-NN (Shakhnarovish et. al. 2005), boolean transformations (Stavroulakis et. Al., 2011), Majority vote, considered as one of the simplest and most intuitive methods for combining classifier outputs (Narasimhamurthy A. et. al. 2005, Kuncheva L.I. et. al. 2004, Aliasgar et. al. 2005).

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MATERIALS AND METHODS

National Centre of Public Administration performed this survey where public servants throughout Greece after having been trained and gained professional skills. Structured questionnaires were distributed to 300 nurses participating in training programs and 245 valid questionnaires were returned. Response rate is about 73%. Most nurses are female (79%) and the 52.4% of the respondents are between 35 and 45 years old. The 31% of the participants enjoyed from 1 to 5 years of experience in the same department/clinic. Most nursing staff (55.3%) has income ranging from 1,000 to 1,300 euros. The 33.6% of the respondents are working in a department occupying more than 20 employees.

The structured questionnaire was employed to carry out the survey. The measurement instrument was thoroughly evaluated before released. Ten head nurses of the hospitals involved examined it along with two experienced researchers; the instrument's cognitive relevance to the healthcare sector was confirmed prior to data collection. The instrument was developed by adapting existing multi-dimensional scales to capture opinion about leadership and employee job performance by providing respondents with 7-scale Likert scaled questions for each multi-item measure employed. The questioner has 15 questions for employee satisfaction, 8 questions for employee personal performance and 36 questions for organization type. The aim is to apply data mining methods to reveal any possible patterns on employee satisfaction and employee personal performance answers (targets) based on organization type answers (attributes). Within this application we tries two approaches, the first using all available organization type answers and we do not apply a feature selection technique, the second using the well-known a feature selection method of forward selection (Pudil P. et. al. 1994). The sample was transformed in the following rule, each answer of the 7-scale Likert converted to 0 for answers between 1 to 4 and 1 for 5 to 7. As a result all transformed answers are 0 or 1. This transformation was made taking into account that our aim in this work is to discriminate the answers in a way of in favors and opponents, the sample is rather small to perform 7 categories for the data and the performance of data mining algorithm using 7 categories with such a small sample is rather low as we tested (Zhou Z et al. 2005, Kuncheva L.I. et. al.2003).

The proposed decision method based on the comparison of four well-known classifiers, as depicted in Table 1.

TABLE 1. . Well-known classifiers used in machine learning systems.

Classifier	Acronym	Method used
Decision Trees	DT	splitting criterion gain ratio
K nearest neighbor	k-NN	Mixed Euclidean Distance
Naïve Bayes	NB	Laplace correction
Majority Vote Classification	MVC	Majority vote

In the present implementation, the performance of the proposed Decision Tree classifier was tested using as splitting criterion gain ratio, max depth of the tree 3, applying pruning, confidence 0,25, minimal leaf size 2 and minimal size for split 4. The KNN algorithm with number of nearest neighbors equal to 9, Mixed Euclidean Distance as measure type as rule used to decide how to classify each sample. The Naïve Bayes uses Laplace correction. Finally according to the methodology of the classification based on the majority vote (called hereafter as MVC – Majority Vote Classification), the three well-known classifiers, Decision Trees, k-NN, Naïve Bayes, were trained using the same training set. After the training phase, a test feature vector was classified using the outputs of the three classifiers according to the majority vote procedure, as shown in the following table:

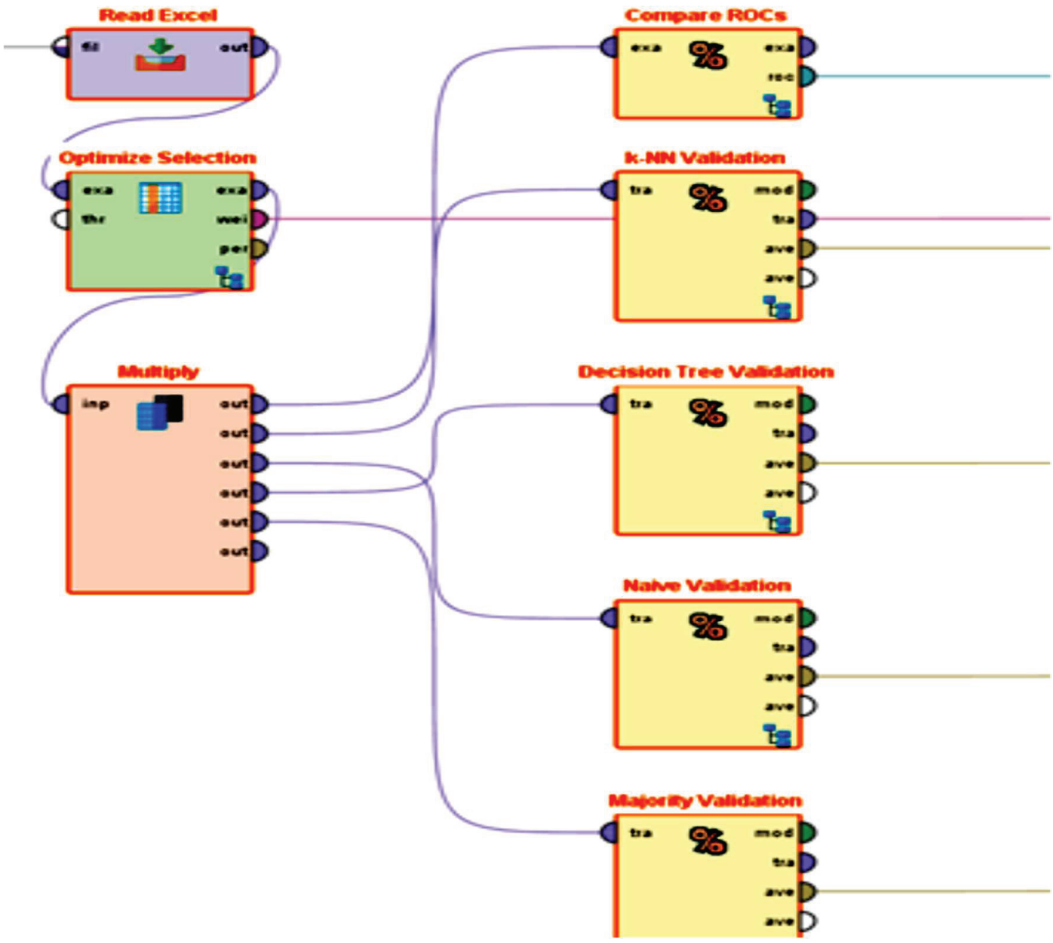

FIGURE 1. Data Mining Algorithm Methods.

TABLE 2. Classification of feature vector according to the majority vote procedure –MVC.

Decision Tree	k-NN	Naïve Bayes	Final decision based on Majority Vote
Class 1	Class 1	Class 1	Class 1
Class 1	Class 1	Class 2	Class 1
Class 1	Class 2	Class 1	Class 1
Class 1	Class 2	Class 2	Class 2
Class 2	Class 1	Class 1	Class 1
Class 2	Class 1	Class 2	Class 2
Class 2	Class 2	Class 1	Class 2
Class 2	Class 2	Class 2	Class 2

RESULTS

The application of the above proposed decision methods using a set of data mining techniques illustrates interesting results for the employee personal satisfaction (SAT8) and personal performance (PR9A) questions as depicted in Tables 3a and 3b.:

TABLE 3.a Employee personal satisfaction questions (SAT8).

1.	SAT8_01	job physical conditions, using the feature selection (FS) step
2.	SAT8_04	management style, using the feature selection (FS) step
3.	SAT8_05	freedom in work style, using the feature selection (FS) step
4.	SAT8_08	salary and bonus, without using the feature selection (WFS) step
5.	SAT8_11	opportunities to use your skills, using the feature selection (FS) step
6.	SAT8_13	the attention they give to your suggestions, using the feature selection (FS) step

TABLE 3.b Personal performance questions (PR9A).

7.	PR9A_2	amount of work, without using the feature selection (WFS) step
8.	PR9A_4	working time, without using the feature selection (WFS) step
9.	PR9A_6	personal goals achievement, both on using and without using the feature selection (FS - WFS) step
10.	PR9A_7	suggestions for improving the quality and productivity, without using the feature selection (FS) step
11.	PR9A_8	overall ability of job execution, without using the feature selection (FS) step.

Table 4 illustrates the overall performance of each algorithm to predict the answer of a future "subject" on the employee satisfaction and performance questions, based on the object's answers to the organization style questions. The interesting results in Table 1 are those that are bold and Italic. The explanation is that those results have both high overall accuracy as well as adequate specificity and sensitivity. All the other results might have high overall accuracy but they have low or even zero sensitivity or specificity.

The results in Table 4 visualize that SAT8_01, SAT8_04, SAT8_05, SAT8_11, SAT8_13 reveal valuable results using the Feature Selection step, SAT8_08, PR9A_2, PR9A_4, PR9A_7, PR9A_8 reveal valuable results without using Feature Selection step and PR9A_6 on both cases. In addition to that Decision Trees algorithm proved to be the worst algorithm selection since only one result can be categorized as valuable in SAT8_12, in this case Decision Tree gives the best results. On the other hand k-NN, Naïve Bayes and Majority Vote are proved to be efficient for SAT8_01, SAT8_04, SAT8_05, SAT8_11. Naïve and Majority Vote have good performance on SAT8_8, k-NN and Majority Vote for PR9A_6 and PR9A_7 Naïve Bayes for SAT8_13, PR9A_2, PR9A_4, PR9A_8.

TABLE 4. Overall Accuracy with Feature Selection (FS) and without Feature Selection (WFS)

	Decision Tree FS	*Decision Tree WFS*	*Comp arison*	*k-NN FS*	*k-NN WFS*	*Compa rison*	*Naïve Bayes FS*	*Naïve Bayes WFS*	*Compa rison*	*Majority Vote FS*	*Majority Vote WFS*	*Compa rison*
SAT8_01	*67.92*	*67.92*	*0*	*73.23*	*69.95*	*3.28*	*73.23*	*60.23*	*13*	*73.13*	*66.32*	*6.81*
SAT8_04	*64.67*	*61.83*	*2.84*	*72.72*	*64.63*	*8.09*	*73.58*	*68.78*	*4.8*	*72.35*	*65.88*	*6.47*
SAT8_05	*58.15*	*58.15*	*0*	*73.97*	*63*	*10.97*	*73.9*	*66.22*	*7.68*	*71.9*	*66.25*	*5.65*
SAT8_08	*83.67*	*93.12*	*-9.45*	*83.25*	*93.12*	*-9.87*	*63.33*	*73.6*	*-10.27*	*82.07*	*92.7*	*-10.63*
SAT8_11	*60.23*	*61.4*	*-1.17*	*71.08*	*65.38*	*5.7*	*70.75*	*65.05*	*5.7*	*71.15*	*67.88*	*3.27*
SAT8_13	*55.3*	*54.9*	*0.4*	*67.73*	*61.35*	*6.38*	*70.33*	*64.2*	*6.13*	*66.38*	*65.48*	*0.9*
PR9A_2	*93.08*	*93.08*	*0*	*93.08*	*93.08*	*0*	*93.08*	*73.1*	*19.98*	*93.08*	*93.08*	*0*
PR9A_4	*96.33*	*96.33*	*0*	*96.33*	*96.33*	*0*	*96.33*	*75.55*	*20.78*	*96.33*	*96.33*	*0*
PR9A_6	*79.67*	*97.67*	*-18*	*72.47*	*77.58*	*-5.11*	*79.67*	*58.43*	*21.24*	*79.67*	*78.05*	*1.62*
PR9A_7	*81.3*	*81.3*	*0*	*81.3*	*78.88*	*2.42*	*81.3*	*59.35*	*21.95*	*81.3*	*80.5*	*0.8*
PR9A_8	*95.12*	*95.12*	*0*	*95.12*	*95.12*	*0*	*95.12*	*74.77*	*20.35*	*95.12*	*95.12*	*0*

In the following tables the confusion matrices of the best overall result are presented, based on the most efficient algorithm and for each personal satisfaction (SAT8) and personal performance (PR9A) question according to Table 4.

TABLE 5a. Confusion Matrices for SAT8_01, SAT8_04, SAT8_05, SAT8_08, SAT8_11 SAT8_13

Question	SAT8_01		SAT8_04		SAT8_05		SAT8_08		SAT8_11		SAT8_13	
Algorithm	k-NN and Naïve Bayes		Naïve Bayes		k-NN		Majority Vote		Majority Vote		Naïve Bayes	
Over Accuracy	73.23%		73.58%		73.97%		92.70%		71.15%		70.33%	
True	1	0	1	0	1	0	1	0	1	0	1	0
1	21	8	135	40	123	44	228	17	42	17	72	34
0	58	159	25	46	20	59	1	0	54	133	39	101

TABLE 5b. Confusion Matrices for PR9A_2, PR9A_4, PR9A_6, PR9A_7, PR9A_8

Question	PR9A_2		PR9A_4		PR9A_6		PR9A_7		PR9A_8	
Algorithm	Naïve Bayes		Naïve Bayes		Majority Vote		Majority Vote		Naïve Bayes	
Over. Accuracy	73.10%		75.55%		78.05%		80.50%		74.77%	
True	1	0	1	0	1	0	1	0	1	0
1	174	11	181	4	185	43	196	44	178	6
0	55	6	56	5	11	7	4	2	56	6

DISCUSSION

The study of the confusion matrices can visualize the suitable use of Feature Selection. Taking into account these results method Decision is more effective and reveals interesting results for employee personal satisfaction (SAT8). Personal performance (PR9A) questions are more accurate without using any Feature Selection Method.

Another finding is that for all algorithms used within this work, Decision Trees, k-NN, Naïve Bayes and Majority Vote we observe high overall accuracy on various tests but also very high sensitivity and extremely low specificity or vice versa. Those results lead to the result that those methods can predict very well answers signed as one (zero respectively), in other words answers of 6 to 7 (1 to 5) in the 7-scale. As an example for question working time overall accuracy for Naïve Bayes is 96.33% with feature selection and 75.55% without feature selection. In addition to that, sensitivity is 1, 0.76 and specificity is 0, 0.44 respectively (see table 4). In particular the above mentioned results illustrate that that Naïve Bayes algorithm for working time question although gives very high overall accuracy using feature selection the negative answers cannot predict sufficiently, zero specificity. As a result Naïve Bayes algorithm for working time question gives adequate overall accuracy without using feature selection and negative answers can predict better, 0.44 specificity.

TABLE 6. Confusion Matrices for PR9A_4 using Naïve Bayes Algorithm

	With Feature Selection		Without Feature Selection	
Over. Accuracy	96.33%		75.55%	
True	1	0	1	0
1	237	9	181	4
0	0	0	56	5

Furthermore, we can conclude that Decision Trees algorithm is not effective as an algorithm for questions of this work. On the contrary we can propose the use of Naïve Bayes method for the detection and forecasting of possible answers on subjects of Organization style and its effect on employee satisfaction and personal performance regarding samples of particular characteristics followed by k-NN and Majority Vote Algorithm.

The approach will be tested on other parameters of organizational psychology, like motivation, communication, and group dynamics, combined with more various feature selection methods and other data mining algorithms.

CONCLUSION

The proposed methodology reveals that reliable conclusion and predictions can be obtained from collected feedback form employees. Their point of view of the health care services and the expected relation between the organizational style, personal expectations and satisfaction can be modeled and expressed. The system will be integrated with a decision support tool that can justify the actions of the management and it can provide a compact documentation for health care marketing.

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