nursing logistics activities, classification system
learning vector quantization,
self-organizing maps

Dragan SIMIĆ

NURSING LOGISTICS ACTIVITIES IN MASSIVE SERVICES

Hybrid patient classification system in nursing logistics activities is discussed in this paper. Hybrid classification model is based on two of the most used competitive artificial neural network algorithms that use learning vector quantization models (LVQ) and self-organizing maps (SOM). In general, the history of patient classification in nursing dates back to the period of Florence Nightingale. The first and the foremost condition for providing quality nursing care, which is measured by care standards, and determined by number of hours of actual care, is the appropriate number of nurses.

It is possible to discus three types of experimental results. First result type could be assessment for *risk of falling* measured by Mors scale and *pressure sores risk* measured by Braden scale. Both of them are assessed by LVQ. Hybrid LVQ-SOM model is used for second result type, which presents the time for nursing logistics activities. The third type is possibility to predict appropriate number of nurses for providing quality nursing care. This research was conducted on patients from Institute of Neurology, Clinical Centre of Vojvodina.

1. INTRODUCTION

Questions concerning patient safety and the quality of nursing care have been raised by quick and dynamic changes in the health care domain [27]. The first and the foremost condition for providing quality nursing care, which is measured by care standards, and determined by number of hours of actual care, is the appropriate number of nurses [32]. The continuous challenge here is to establish an objective and reliable way for determining how many nurses will be needed to satisfy patients' needs, wishes and expectations. With this purpose, many different classification systems (grouping of patients into a certain category for a certain purpose) that is, classification of patients according to their need for care, have been created. Patient classification provides a quick insight into the gravity of condition of a ward patient, and indicates what kind of care is to be given to that patient, and how many nurses will be necessary for adequate health care in massive hospital services.

The rest of the paper is organized in the following manner: the following sections provide a brief overview of hybrid artificial intelligence systems and some background patient classification system in nursing logistics activities. Section 3 overviews challenges in patient classification modelling, and Section 4 elaborates concept and designs of patient classification in Republic of Serbia and Republic of Croatia. Section 5 shows purpose hybrid classification model, implemented methods and usage data set. Section 6 describes experimental results while Section 7 overviews future work and concludes the paper.

2. BACKGROUND

Artificial intelligence techniques have demonstrated capability to solve real-world problems in science, business, technology, and commerce. The integration of different learning techniques and their adaptation, which overcomes individual constraints and achieves synergetic effects through hybridisation or fusion, has in recent years contributed to a large number of new intelligent system designs [1].

The hybridisation of intelligent techniques, drawn from different areas of computational intelligence, has become prevalent because of the growing awareness that they outperform individual computational intelligence techniques. In a hybrid intelligence system, a synergetic combination of multiple techniques is used to build an efficient solution to deal with a particular problem [5]. Evolutionary algorithms, instance selection and feature selection as the most known techniques, for data reduction in data mining problems have been successfully used. Their aim is to eliminate irrelevant and/or

redundant features and to obtain a simpler classification system. This reduction can improve the accuracy of this model in classification [10]. Multiple classifier systems (MCSs) are currently the focus of interest research. The main motivations for using MCSs are following: (1) for small samples, MCSs could avoid selections of the worst classifier; (2) there is a large amount of evidence that classifiers combinations can improve the performance of the best individual ones and they can exploit unique classifier strengths; (3) additionally combined classifier could be used in distributed environment [39]. In medical domain, typically, that hospital's activities are followed by large datasets. The reduction of large dataset could be done by adaptation and optimization of existing methods. Then the smaller dataset can be used in simple and fast classifier types [25].

There are studies which discuss patient classification systems. Development of a prototype patient classification instrument designed specifically for rehabilitation patients is focus in [28]. This research is based on, and continues one of the early papers about nursing workload measurement as management information [33]. The process of instrument development strategies is discussed and it includes: staff education, management support, data analysis including the development of supporting information systems, and ongoing use of the rehabilitation patient classification system.

Personal dimensioning in psychiatric nursing was the motivation for the development of an instrument to classify the level of dependence in psychiatric nursing based on statistical methods, Kappa coefficient and the Spearman correlation, proposed in [17]. The emergency department is a dynamic environment with a high throughput of patients. A responsive staffing pattern is required in order to provide optimal care for patients, according to the clinical stability of patients which can vary considerably. In [35], twelve patient classification systems are discussed, but only three systems reported evidence of good validity and reliability: the ED Patient Needs Matrix developed in the US, the Conner's Tool (a modified version of the Patient Needs Matrix) developed in Australia and the Jones Dependency Tool developed in the UK.

3. CHALLENGES IN MODELLING PATIENTS CLASSIFICATION

The history of patient classification in nursing dates back to the period of Florence Nightingale (1820-1910), when an informal classification method reflecting nursing workload was used. Based on intuition, perhaps, the most seriously ill patients on the large open Nightingale wards were placed near to the ward sister's office to facilitate their observation. On the other hand, those patients who could take care of themselves tended to be located at the far end of the ward, indicating their decreased dependency on the nursing staff [13]. Florence Nightingale is presented as a woman who single-handedly reformed nursing and introduced matrons into hospitals, as part of new regime which constituted clean break with previous traditions.

During 1950s and 1960s great emphasis and attention have been given to adequate health care because of greater health care costs and the shortage of work force [8]. In 1973 Mary Ellen Warstler defined 5 patient categories according to the care needed in 24 hours which is presented in Table 1 [34].

Table 1. Patient classification by Mary Ellen Warstler.

	Category	Hours	Average hours
I	Self care	1 to 2	1.5
II	Minimum care	3 to 4	3.5
III	Intermediate care	5 to 6	5.5
IV	Modified intensive care	7 to 8	7.5
V	Intensive care	10 to 14	12

The nursing workforce is discussed in different views but in general it could be divided in the following way: (1) patient dependency and nursing workload; (2) nursing team size and mix; (3) measuring patient dependency, nursing workload and quality; (4) nursing logistics activity; (5) nursing costs and quality; (6) implementation of information technologies. Relationship between nursing workload, staffing, nursing quality and evidence conflicts are equally important and discussed in [2,4,12,21].

The relationship between patient dependency, nursing workload, and ward workload/bed acuity and quality issues has been explored from different angels in [14,15,7,19,24]. It has also been demonstrated who challenged the primacy of patient dependency as a way of explaining nursing workload, staffing and quality. These debates probably explain why contemporary nursing workforce planning methods attach equal relevance to three demand-side measures: patient dependency, nursing logistics activity and quality of the services.

Less of an issue, but still important for workforce planners, is the best way of classifying patients when it comes to estimating nursing workload. There is a variety of approaches in [3,21]. In their North American studies, they use, case-mix based on diagnosis-related groups (DRGs) to categorize patients for nurse staffing purposes. In the UK, on the other hand, patients are usually classified from least to most dependent on nurses for their activities of living (ADL) needs [12]. Both approaches have strengths and weaknesses. On one hand DRG methods hit a stumbling block when there is co-morbidity making a decision about which illness or treatment takes priority for workload assessment purposes. The ADL method, on the other hand, is prone to inflated scores by nurse assessors who know that higher acuities indicate that wards may be short staffed [16,36].

The nature and value of dependency-acuity-quality (DAQ) demand-side nursing workforce planning methods are set in the context of nursing workforce planning and development. A major variable in DAQ staffing approach is the amount of time nurses spent directly (face-to-face) caring for patients, but the appropriate direct care percentage has never been established. Levels around 35 % are often used [22] although it is noted that direct care time greater than 50 % was associated with higher-quality care [4]. Confusion and uncertainty were increased when recent data indicated that direct nursing care time was falling yearly without a corresponding reduction in nursing quality [16,18]. Consequently, dependency-acuity-quality approach is usually required for all care groups, which adds to expense of demand-side nursing workforce planning but, on the other hand, generates comprehensive data sets.

The lack of robust economic evaluations of ward staff-mix, which seems odd considering the overall cost of nursing, is presented in [26]. Also, a clear relationship between quality and cost from a permanent staff standpoint was shown in [11,23]. On the other hand, it was not possible to fully connect nursing cost and quality partly owing to high cost wards achieving low-quality scores – a finding corroborated by [4], and confirmed a decade later in [16].

4. CONCEPT AND DESIGNS OF PATIENT CLASSIFICATION

It is important to determine classification criteria in order to place patients in categories according to the amount of health care that is necessary. These criteria indicate the states or activities that most influence time spent on providing adequate health care [13]. The choice of criteria for patient classification is based on Virginia Henderson's health care definition, which defines the role of a nurse as providing assistance to a patient in satisfying 14 basic human needs, and Dorothea Orem's health care definition which is based on the idea of self – care [37].

When choosing classification criteria concerning patient health care needs, therapeutic and diagnostic procedures should be taken into account. When classifying patients, authors use two approaches – description of specific criteria characteristic to certain category - an example of patient classification in Republic of Serbia. The separate scoring of individual criteria and calculating average value which then represents patient category - an example of patient classification in Republic of Croatia.

Patient classification criteria in Republic of Serbia is placed in five categories with the purpose of providing quality health care: 1) General care; 2) Semi-intensive care; 3) Intensive care; 4) Special intensive care; 5) Special care [9].

General care is defined with the following classification criteria: (1) Preserved consciousness; (2) Time - space orientation; (3) Vital signs are checked every 12 hours; (4) Absence of bleeding; (5) Ability to move; (6) Ability to feed themselves; (7) Does not regurgitate; (8) Able to satisfy physiological needs without assistance; (9) Able to maintain personal hygiene; (10) Does not need other person's help; (11) Adequate medical treatment. Six of these criteria are sufficient to define patients in general care.

Other four patient categories are based on the same type of definition, for each category respectively. Peculiarity of this classification is that the decision on the degree of necessary health care is based on the fulfilment of a number of linguistics characteristics.

Patient classification criteria in Republic of Croatia is made in the following way. Patients are placed in five categories, and under this classification there are: 1) Self care; 2) Minimum care; 3) Intermediate care; 4) Intensive care; 5) Special care [6]. For all patient categories 16 patient's activities are defined and rated on 4-point scale.

Evaluation of patient's ability to maintain his/her: (1) Personal hygiene; (2) Dress; (3) Feed; (4) Evaluation of elimination – other person's assistance; (5) Walking and standing; (6), Sitting; (7) Moving and Turning; (8) Risk of falling; (9) State of consciousness; (10) Pressure sores risk; (11) Vital signs; (12) Communication; (13) Specific health care procedures; (14) Diagnostic procedures; (15) Therapeutic procedures; (16) Education undertaken and type of knowledge.

Risk of falling - If there is no risk of falling, the patient is placed in Category 1, if there is risk of falling the patient is evaluated by Mors scale. This scale performs an evaluation based on the following risk factors: (1) Previous falls (0–25 points), (2) Other medical diagnoses (0–15 points), (3) Walking aids (0–30 points), (4) Infusion (0–20 points), (5) Posture/movement (0–20 points), (6) Mental status (0–15 points). The point scale that measures the risk of falling goes between 10 and 125 points. Depending on the number of points, patients can be placed in three following sub-selections: low risk (10–24 points), moderate risk (25–44 points), and high risk (44 plus points). Successfully conducted research on risk of falling of clinical patients is presented in [20].

Pressure sores risk - is evaluated by Braden scale. This scale performs an evaluation based on the following risk factors: (1) Sensory perception (1–4 points), (2) Moisture (1–4 points), (3) Activity (1–4 points), (4) Mobility (1–4 points), (5) Nutrition (1–4 points), (6) Friction & Shere (1–3 points). Depending on the number of points on the scale, patients are placed in five sub-selections. According to Braden scale there are following categories: no risk (19–23 points), risk present (15–18 points), moderate risk (13–14 points), and high risk (10–12 points) and very high risk (9 points and less).

According to Critical factors table in patient classification, Braden scale and Mors scale included, each of 16 factors of classification can be evaluated on 4-point scale. This means that overall minimum number of points can be 16 and overall maximum number of points can be 64. Modified normal distribution was used when placing points into categories. Finally, point distribution for each category is following: First category 16 – 26 points; Second category 27 – 40; Third category 41 – 53; Fourth category 54 – 64 points.

5. HYBRID CLASSIFICATION MODEL, METHODS AND DATA SET

The aim of this research is to evaluate patient categories and amount of health care, then determine the number of hours of actual care, and in the end, the appropriate number of nurses for providing quality nursing care. We purpose hybrid artificial neural networks (ANN) for this complex analysis. As with any system, simple ANN has its limitations: (1) The learning stage can be very drawn out; (2) The system might not achieve a stable absolute minimum configuration, but could stay with local minimums; (3) The system may begin to oscillate in the learning phase; (4) It is necessary to repeat the learning phase when significant changes take place in the actual situation; (5) The analysis of the weightings is complex and difficult to interpret.

Two of the most competitive ANN algorithms used are learning vector quantization (LVQ) and self-organizing maps (SOM). LVQ and SOM models have been successfully used in different scientific fields [31]. According to previous limitations in this research the great advantages of a hybrid ANN model is proposed, particularly LVQ and SOM.

Learning vector quantization networks can classify any set of input vectors, not only linearly separable sets. LVQ models classify input vectors into target classes by using a competitive layer to find subclasses of input vectors, and then, combine them into the target classes defined by the user. The only requirement is that the competitive layer must have enough neurons, and each class must be assigned enough competitive neurons. To ensure that each class is assigned an appropriate amount of competitive neurons, it is important that the target vectors used to initialize the LVQ network have the same

distributions of targets as the training data the network is trained on. If it is done, target classes with more vectors will represent union of more subclasses.

Self-Organizing Map (SOM) algorithm is probably the best known ANN technique. It is based on type of unsupervised learning called competitive learning, and adaptive process in which the neurons in neural networks gradually become sensitive to different input categories or sets of samples in a specific domain of the input space. Competitive networks also learn the distribution of input vectors by dedicating more neurons to classifying parts of the input space with higher densities of input. SOM learns to categorize input vectors and also learns the distribution of input vectors. Features maps allocate more neurons to recognize parts of the input space where many input space and few input vectors occur. Self-Organizing Maps (SOMs) also learn the topology of their input vectors. Neurons next to each other in the network learn to respond to similar vectors. The layer of neurons can be imagined as a rubber net that is stretched over the regions in the input space where vectors occur. SOMs allow neurons that are neighbours to the winning neuron to output values. Thus the transition of output vectors is much smoother than that obtained with competitive layers, where only one neuron at a time has an output.

Data set - Patient classification criteria characteristic for Republic of Croatia is discussed in this research. This patient classification is better suited for hybrid ANN model then patient classification criteria of Republic of Serbia. Data set used here is taken from Institute of Neurology, Clinical Centre of Vojvodina, Novi Sad, Serbia. The data set is collection of data for 27 different patients observed for two weeks. The spinal diseases ward, whose patients have been observed for the purposes of this research, has only 20 beds, but in the two week period, 27 patients occupied the beds. Every day nursing, staff classified the patients, individually, according to their need for care in the following manner. First, *risk of falling* was evaluated by Mors scale. Then, *pressure sores risk* was evaluated by Braden scale. The combined data taken from both scales then determined classification criteria in order to place patients in categories according to the amount of necessary health care based on patient classification criteria in Republic of Croatia. The output of *risk of falling* and *pressure sores risk* with other 14 previously mentioned classification factors, education undertaken and type of expert knowledge now become the input to the SOM. Patients are placed in five categories under this classification: 1) Self care; 2) Minimum care; 3) Intermediate care; 4) Intensive care; 5) Special care. Although the number of observed patients is not particularly large, data set has 26 attributes. Such a large data set is not easy to present specially, that is why Table 2 presents only a part of summarised input data set and only for one week.

6. EXPERIMENTAL RESULTS

Risk of falling and *pressure sores risk* are classified by LVQ networks. Training process was performed with artificial data set created by expert physicians and nurses staff. The output of *risk of falling* and *pressure sores risk* data that are used in LVQ now become the input to the SOM with other 14 input data: (1) Personal hygiene; (2) Dress; (3) Feed; (4) Evaluation of elimination; (5) Walking and standing; (6), Sitting; (7) Moving and Turning; (9) State of consciousness; (11) Vital signs; (12) Communication; (13) Specific health care procedures; (14) Diagnostic procedures;

Table 2. A part of summarised input data set – for one week.

		Mo	Tu	We	Th	Fr	Sa	Su
General care	patients	9	10	10	10	10	10	10
(1 hour)	hours	9	10	10	10	10	10	10
Semi-intensive care	patients	8	7	7	7	8	8	8
(3 hours)	hours	24	21	21	21	24	24	24
Intensive care	patients	3	3	3	3	2	2	2
(6 hours)	hours	18	18	18	18	12	12	12
Special intensive care	patients	0	0	0	0	0	0	0
(12 hours)	hours	0	0	0	0	0	0	0
Special care	patients	0	0	0	0	0	0	0
(24 hours)	hours	0	0	0	0	0	0	0
Total number of patients		20	20	20	20	20	20	20

(15) Therapeutic procedures; (16) Education undertaken and type of knowledge now become the input to the SOM. Then hybrid LVQ-SOM is used to provide the time needed for logistics nursing activities and to predict appropriate number of nurses for providing quality nursing care.

The basic usage of the SOM has following steps: (1) construct data set; (2) normalize it; (3) train the map; (4) visualize the map; (5) analyze results. The batch training algorithm is used in this process [30]. SOM is used for probability density estimation. Each map prototype is the centre of a Gaussian kernel whose parameters are estimated from the data. The Gaussian mixture model is estimated and the probabilities can be calculated. The map grid is in the output space.

It is possible to discus three types of results. The First one could be assessed on Mors scale and Braden scale. This result shows that LVQ networks, on the average, provide correct estimation for 95% of the cases relative to the values assessed and calculated by expert physicians and nurses . The Second one could be assessed for providing quality nursing care, and the time for nursing logistics activities. These results could be discussed in several different ways. The basic reason is that the right time is not exactly defined, rather expected range of time calculation based on patient categories. This result can vary to a great extent and its limitations must be taken into account, and, it is very error sensitive. That is why the results in Table 3 are given for average and minimum care time.

And finally, the third result predicts the appropriate number of nurses for providing quality nursing care. These estimation results depend on previous (second) results for assessment of care time, but the results gained are less error sensitive. The hybrid LQV-SOM gives experimental results which are between minimum and average hours for nursing logistics activities.

Table 3. Calculated and LVQ-SOM results – for nursing logistics activities – for one week.

	Mo	Tue	We	Thu	Fr	Sa	Su
Total number of patients	20	20	20	20	20	20	20
Number of hours of necessary care	51	49	49	49	46	46	46
Number of nurses in 3 shifts	5	5	5	5	5	4	4
Number of hours (nurses x 8 hours)	40	40	40	40	40	32	32
Variation (+ / -)	-11	-9	-9	-9	-9	-12	-12
Number of nurses – minimum	6.4	6.1	6.1	6.1	5.8	5.8	5.8
Number of nurses – minimum (full-time + part time)	6.5	6	6	6	6	6	6
Number of nurses – minimum (full-time)	6	6	6	6	6	6	6
Number of nurses – average	8.6	8.2	8.2	8.2	7.8	7.8	7.8
Number of nurses – average (full-time + part time)	8.5	8	8	8	8	8	8
Number of nurses – average (full-time)	9	8	8	8	8	8	8
LVQ – SOM; assess nurses number (full time + part time)	*8*	*7.5*	*7.5*	*7.5*	*7*	*7*	*7*

Moreover, this research shows how necessary number of nurses for providing quality nursing care differs from the actual number of hired nurses. This represents a very important conclusion of our research. It is a well known fact that workers do not have to be hired full time, only part time as well. This means that, after quality nursing care assessment has been conducted, there is no need to hire a full time nurse, and that it is possible to optimize care time and expenses only for necessary logistic activities. To improve presented experimental results one innovative research area that uses fusers as part of a multiple classifier system, which is discussed in Designing fusers on the basis on discriminants – evolutionary and neural network methods [38], could form part of future research in hybrid patient classification system.

In general, tools and instruments for the type of classification and patient follow up, although well described and useful in clinical practice, are not represented in a satisfying way. Raising awareness about

its usefulness through interdisciplinary studies and medical staff, physicians and nurses [29], collaboration can make significant contribution to wide spread acceptance of this method. Contribution of this paper presents a way to use artificial intelligent system, hybrid purpose ANN model, particularly LVQ-SOM instead of statistical methods that have been widely used so far to solve real-world problem of nurses.

7. CONCLUSION AND FUTURE WORK

The aim of this research is to evaluate patient categories and the health care needed then, determine the number of hours of actual care, and at the end, the foremost condition, the appropriate number of nurses for providing quality nursing care. Hybrid classification model based on learning vector quantization models and self-organizing maps is proposed. Assessment of *risk of falling* measured by Mors scale and pressure sores risk measured by Braden scale used LVQ networks. This result provides correct estimation for 95% of the cases. Hybrid LVQ-SOM model is used for next forecast. Second result provides the time needed for nursing logistics activities in massive services. The third result is able to predict appropriate number of nurses for providing quality nursing care. Experimental results are shown not just in respect to minimum hours for nursing logistics activities, but for the average as well. The acquired experimental results used by hybrid classification model LVQ-SOM are between minimum and average values for patient classification criteria. This research was conducted on patients from Institute of Neurology, Clinical Centre of Vojvodina.

Although the experimental results we have gained are valid, the research of hybrid classification system could be continued. Classification model presented here is not limited to this case study. Patient classification criteria characteristic for Republic of Serbia is fuzzier then patient classification discussed in this research. That is a reason why this research could be improved by soft computing techniques utilization, as well as fuzzy logic and genetic algorithm.

8. ACKNOWLEDGMENTS

This research is supported by the Ministry of Science and Technological Development of Republic of Serbia project No. TR 3036.

BIBLIOGRAPHY

[1] ABRAHAM A., CORCHADO E., CORCHADO J.M., Hybrid Learning Machines, Neurocomputing, Vol. 72, No. 13–15, 2009, pp. 2729-2730.
[2] AUDIT COMMISSION, Acute hospital portfolio: ward staffing management tools, Practical Tips for Budget Setting, HMSO, London, 2003.
[3] CAMBELL T., TAYLOR S., CALLAGHAN S., SHULDHAM C., Case mix type as a predictor of nursing workload, Journal of Nursing Management, Vol. 5, No. 4, 1997, pp. 237–240.
[4] CARR-HILL R.A., DIXON P., GRIFFITHS M., HIGGINS M., McGAUGHAN D., RICE N., WRIGHT K., The impact of nursing grade on the quality and outcome of nursing care, Health Economics, Vol. 4, No. 1, 1995, pp. 57–72.
[5] CORCHADO E., ABRAHAM A., de CARVALHO A., Hybrid intelligent algorithms and applications, Information Science, Vol. 180, No. 14, 2010, pp. 2633–2634.
[6] CROATIAN CHAMBER OF MEDICAL NURSES, Patient classification according to their health care needs, http://www.hkms.hr, 2006.
[7] CZAPLINSKI C., DIERS D., The effect of staff nursing on length of stay and mortality, Medical Care, Vol. 36, No. 12, 1998, pp. 1626–1638.
[8] ĆORLUKA V., Standardized care purport – new nursing care quality, Health Care, Vol. 34, No. 3, 2005, pp. 25–35.
[9] ĆORLUKA V., ALEKSIĆ Ž., SAVIĆEVIĆ M., Instruction on record keeping in health protection, family care, field nurse care and health care, Federal Institute for Health Improvement and Protection, Belgrade, 2000.

[10] DERRAC J., GARCIA S., HERRERA F., A first study on the use of coevolutionary algorithms for instance and feature selection, LNCS (LNAI), Springer, Heidelberg, Vol. 5572, 2009, pp. 557–564.
[11] DONEVAN M., LEWIS G., Increasing productivity and decreasing costs: the value of RNs, Journal of Nursing Administration, Vol. 17, No. 9, 1987, pp. 16–18.
[12] GIBBS I., McGAUGHAN M., GRIFFITHS M., Skill mix in nursing: a selective review of the literature, Journal of Advanced Nursing, Vol. 16, No. 2, 1991, pp. 242–249.
[13] GIOVANNETTI P., Understanding patient classification systems, Journal of Nursing Administration, Vol. 9, No. 2, 1979, pp. 4–9.
[14] GIOVANNETTI P., MEYER G., Building confidence in patient classification systems, Nursing Management, Vol. 15, No. 18, 1984, pp. 31–34.
[15] JONES W.J., Management by crisis or by objectives?, Nursing Times, Vol. 73, No. 11, 1977, pp. 388–390.
[16] KANE R., SHAMLIYAN T., MUELLER C., DUVAL S., WILT T.J., Evidence Report/Technology Assessment Number 151, Nurse staffing and quality of patient care, AHRQ Publication, No. 07-E005, March 2007.
[17] MARTINS P.A., ARANTES E.C., FORCELLA H.T., Patient classification system in psychiatric nursing: clinical validation, Journal of School Nursing, Vol. 42, No. 2, 2008, pp. 223–241.
[18] McKENNA H.P., Nursing skillmix substitutions and the quality of care: an exploration of assumptions from the research literature, Journal of Advanced Nursing, Vol. 21, No. 3, 1995, pp. 452–459.
[19] MILLER A., Does dependency count?, Senior Nurse, Vol. 1, No. 29, 1984, pp. 10–11.
[20] MILUTINOVIĆ D., MARTINOV-CVEJIN M., SIMIĆ S., Patients' falls and injuries during hospitalization as quality indicators of work in hospital, Medical Review (Medicinski pregled, Serbia), Vol. 62, No. 5-6, 2009, pp. 249-257.
[21] NEEDLEMAN J., BUERHAUS P., MATTKE S., MAUREEN S., ZELEVINSKY K., Nurse staffing levels and quality of care in hospitals, New England Journal of Medicine, Vol. 346, No. 22, 2002, pp. 1715–1722.
[22] O'BREAN G., The intuitive method of patient dependency, Nursing Times, Vol. 82, No. 23, 1986, pp. 57–61.
[23] OSINSKI E.G., POWALS J.G., The cost of an all-RN staffed primary nursing, Supervisor Nurse, Vol. 11, No. 1, 1980, pp. 16–21.
[24] PROCTOR S., HUNT M., Using the Delphi survey technique to develop a professional definition of nursing for analysing nursing workload, Journal of Advanced Nursing, Vol. 19, No. 5, 1994, pp. 1003–1014.
[25] RANISZEWSKI, M., Fast reduction of large dataset for nearest neighbour classifier. Journal of Medical Informatics and Technologies, Vol. 16, 2010, pp. 111–116.
[26] RICHARDSON G., Identifying, evaluating and implementing cost-effective skill mix, Journal of Nursing Management, Vol. 7, No. 5, 1999, pp. 265–270.
[27] RIMAC B., BIŠĆAN J., Nursing paradigm and patient Safety, Medix 2010, Vol. 86, 2010, pp. 167-170.
[28] SARNECKI A., HAAS S., STEVENS K.A., WILLEMSEN J., Design and implementation of a patient classification system for rehabilitation nursing, Journal of Nursing Administration, Vol. 28, No. 3, 1998, pp. 35–43.
[29] SIMIN D., MILUTINOVIĆ D., BRESTOVAČKI B., SIMIĆ S., CIGIĆ T., Attitude of health science students towards interprofessional education, HealthMED Journal, Vol. 4, No. 2, 2010, pp. 461–469.
[30] SIMIĆ D., KOVAČEVIĆ I., SIMIĆ S., Insolvency prediction for assessing corporate financial health, Logic Journal of IGPL, doi: 10.1093/jigpal/jzr009, 2011.
[31] TORRECILLA J., ROJO E., OLIET M., DOMINGUEZ J.C., RODRIGUEZ F., Self-organizing maps and learning vector quantization networks as tools to identify vegetable oils and detect adulterations of extra virgin olive oil, Proc. 20th European Symposium on Computer Aided Process Engineering, Elsevier, 2010.
[32] TWIGG D., DUFFIELD C., A review of workload measures: a context for a new staffing methodology in Western Australia, International Journal of Nursing Studies, Vol. 46, No. 1, 2009, pp. 131–141.
[33] VRIES G, Nursing workload measurement as management information, European Journal of Operational Research, No. 29, 1987, pp. 199-208.
[34] WARSTER M.E., Cyclic work schedules and a nonnurse coordinator of staffing, Journal of Nursing Administration, Vol. 3, No. 6, 1973, pp. 45–51.
[35] WILLIAMS S., CROUCH R., Emergency department patient classification system: a systematic review, Accident and Emergency Nursing, Vol. 14, No. 3, 2006, pp. 160–170.
[36] WHITNEY J.A., KILLIEN M.G., Establishing predictive validity of a patient classification system, Nursing Management, Vol. 18, No. 5, 1987, pp. 80–86.
[37] WILLS E.M., Grand nursing theories based on human needs, In: MCEWEN M, WILLS E.M., Theoretical Basis for Nursing, Lippincot Williams & Wilkins, 2010.
[38] WOZNIAK M., ZMYSLONY M., Designing fusers on the basis of discriminants - evolutionary and neural methods of training, LNCS (LNAI), Springer, Heidelberg, Vol. 6076, 2010, pp. 590–597.
[39] WOZNIAK M., Combining classifiers – concept and applications, Journal of Medical Informatics and Technologies, Vol. 15, 2010, pp.19–28.