Acta Technica *62* (2017), No. 7A, 939–950 © 2017 Institute of Thermomechanics CAS, v.v.i.

Risk prediction of offshore oil engineering project based on normal cloud model

Yuqiang Tu[1]

Abstract. In order to improve effectiveness of risk prediction for offshore oil engineering project, a kind of risk prediction method for offshore oil engineering project based on normal cloud model was proposed. Firstly, index selection principle for risk prediction of offshore oil engineering project was analyzed; moreover, predictive index system used in the thesis was given; then, cloud model and finite-state machine were introduced in the thesis so as to describe and check risk prediction of offshore oil engineering project. In addition, risk prediction evaluation and prediction model for offshore oil engineering project based on cloud model was proposed; detailed analysis and confirmation were made in theory; finally, feasibility and rationality of model researched in the thesis were further illustrated through simulation experiment and analysis, which provided a new valuable thought for risk prediction of current offshore oil engineering project.

Key words. Normal cloud model, Offshore oil engineering, Project risk, Prediction.

1. Introduction

There is great investment, long construction period and wide involved areas in the construction of offshore oil engineering project, which makes it inevitably face various risks in the process of construction. The risks will result in the runaway phenomenon in the construction of offshore oil engineering project, which may result in the decrease of economic benefit of the Project and even the failure of offshore oil engineering project. The modern offshore oil engineering project is characterized by its large scale, new technology, long duration, many participating units and complicated environment interface, which can be said to be dangerous in the process of offshore oil engineering project. At present, the weights are determined mainly by scoring method, but due to the different sensory evaluation of the scoring team members for the same sample, the stronger subjective arbitrariness and the unquantifiable

---

[1] Offshore Oil Engineering Co., Ltd, Project Management Center, Tianjin, China, 300461

evaluation indexes, it leads to the influence of human factors in the evaluation to a large extent and the more uncertainty of the evaluation result.

Cloud model is the specific realization method for cloud, which is the basis based on cloud computation, inference, control, and etc. It can be used to indicate the process from qualitative concept to quantitative denotation (forward cloud generator) and can be used to indicate the process from quantitative denotation to qualitative concept (backward cloud generator). The model is the concept proposed by Li DeYi, an academician of the Chinese Academy of Engineering, in 1995, which is used to process uncertain transformation model of qualitative concept and quantitative description. It has been successfully used in natural language processing, data mining, decision analysis, intelligent control, picture processing, and other fields since it was proposed. Cloud model and finite-state machine are proposed to be introduced in the thesis so as to research risk prediction evaluation and prediction model of offshore oil engineering project and to establish feasible risk prediction evaluation and prediction realization mechanism for offshore oil engineering project for providing a new valuable thought for survivability research on intricate engineering project at present.

2. Cost risk prediction index for offshore oil engineering project in the construction stage

2.1. Index selection principle

Establishment of risk prediction index system for offshore oil engineering project can accurately make risk prediction and can effectively prevent occurrence of risks. Therefore, the following basic principles are required to be abided by at the time of establishing index system:

(1) Operability principle. Risk prediction can be better made through establishing cost risk prediction system, thus cost risk prediction system of offshore oil engineering project has to be based on establishment of risk prediction system of external construction project and internal conditions. External conditions mainly include some natural conditions of force majeure, government regulation policies, and etc., while internal factors mainly include labor forces, materials, increase of mechanical consumption, various overspending, and etc.

(2) System principle. Cost risk prediction system of offshore oil engineering project is a kind of new management thinking method, which perfectly integrates cost management and risk prediction so as to establish an index system that can truly reflect cost risk prediction of construction engineering based on system theory for ensuring reliability of prediction result.

(3) Scientific principle. In terms of offshore oil engineering project, cost occurrence is absolutely and truly existing, thus selection of index which influences cost factor cannot be determined with subjective consciousness but should have scientific theoretical basis. In addition, conceptual definiteness of index should be concerned so as to establish cost risk prediction index system which can objectively reflect actual conditions, thus effectiveness and reliability of relevant information obtained

about cost risk index system should be ensured.

(4) Elasticity principle. Due to uncertainty of cost risk occurrence for offshore oil engineering project, it is impossible to monitor all cost risk factors involved in actual running process of offshore oil engineering project, thus cost risk prediction system has certain stretch space in actual operation process, which makes cost risk management system have certain flexibility and be not deviated from the whole offshore oil engineering project.

(5) Predictability and comparability principle. Establishment of cost risk index should have certain predictability on the premise of satisfying current conditions and should make effective responses to risk change. Meanwhile, offshore oil engineering project should be in the running status for a long time. Comparative analysis should be made in the whole index inspection process. Longitudinal comparison analysis of the identical index at different time should be considered; moreover, horizontal comparison analysis of different indexes at the same time should be considered.

(6) Qualitative and quantitative integration principle. Some indexes are qualitative, while other indexes are quantitative at the time of selecting evaluation indexes. Meanwhile, due to private feature of all indexes, qualitative and quantitative methods are integrated to make an evaluation so as to ensure that evaluation result is more convincing. Therefore, expert scoring and questionnaire investigation are usually considered being used for quantification of some natural conditions, environmental factors, behavior subject, and other index systems at the time of quantification of evaluation indexes.

2.2. Establishment of prediction index system

Cost risk factor index system of offshore oil engineering project is constituted by a series of indexes which reflect costs that influence offshore oil engineering project in the construction stage. According to establishment principle of index system, cost risk prediction index system for offshore oil engineering project in the construction stage is established in the thesis, which is shown in Fig. 1. In terms of various indexes, some indexes, such as political risks, economic risks, social risks, natural risks, and etc. belong to qualitative indexes. It is hard to collect specific numerical value. In order to transform them into quantitative indexes, expert scoring method is used in the thesis. They are respectively expressed by excellent, good, and bad. Quantitative value is set according to score. The minimum score is set to be 1, while the maximum score is set to be 5. Therefore, value ranging of qualitative index for specific numerical value which is hard to be determine is expressed as [1,5]. In terms of those quantitative indexes, value ranging should be delimited according to the form of attached list; in addition, value ranging of various indexes is shown in Table 1:

Table 1. Value domain of cost risk evaluation index for offshore oil engineering project in the construction stage

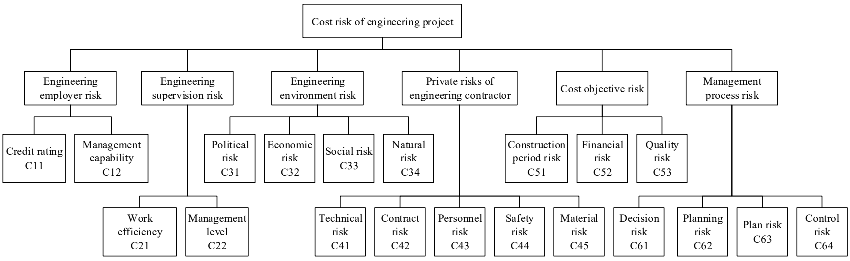

Fig. 1. Cost risk prediction index system of offshore oil engineering project in the construction stage

Index category	Index	Value domain	Index category	Index	Value domain
Engineering employer risk	Credit rating management capacity	$[0, 100\%]$ $[1, 5]$	Private risks of engineering contractor	Technical risk	[0,100]
				Contract risk	[0,100]
				Personnel risk	[0,100%]
				Safety risk	[0,100%]
				Material risk	[0,100]
Engineering supervision risk	Work efficiency management level	$[0, 100\%]$ $[1, 5]$	Cost objective risk	Construction period risk	[1,5]
				Financial risk	[1,5]
				Quality risk	[1,5]
Engineering environment risk	Political risk	[1,5]	Management process risk	Decision risk	[0,100]
	Economic risk	[1,5]		Design risk	[0,100]
	Social risk	[1,5]		Plan risk	[0,100]
	Natural risk	[1,5]		Control risk	[0,100]

3. Risk prediction mode of offshore oil engineering project based on cloud model

3.1. Model description

Cloud refers to uncertain transformation model[13] which is used to express qualitative concept and quantitative denotation with natural language value in cloud model theory. It mainly reflects two kinds of uncertainties of concept for matters or human knowledge in the universe: probability of occurrence for ambiguity ("either the one or the other" of border) and randomness.

Definition 1: It is hypothesized that U refers to a domain of discourse which is expressed with accurate numerical value; C refers to the corresponding quantitative value on U, in case quantitative value $x \in U$, x refers to a random realization of qualitative concept C; x refers to random number with stable tendency for certainty degree (membership degree) $\mu(x) \in [0,1]$ of C:

$$\mu : U \to [0,1], \forall x \in U, x \to \mu(x)\,. \tag{1}$$

Distribution of x on domain U is called membership cloud, which is hereinafter referred to as cloud. Each x will become a cloud droplet.

Cloud is constituted by lots of cloud droplets. Each cloud droplet is a point of C mapped on domain space. A single cloud droplet may be insignificant, but the whole shape of cloud reflects important features of qualitative concept, which indicates uncertainty mapping between qualitative and quantitative. Numerical characteristics of cloud are represented by expected valueE_x, entropy E_n, and excess entropy H_e, which reflects quantitative performance of qualitative knowledge.

(1) Expected valueE_x: indicates the value which can better represent the qualitative concept, which usually is corresponding x value to cloud gravity center. It should be 100% attached to the qualitative concept, which means that$E_x$reflects information center value of corresponding qualitative knowledge.

(2) EntropyE_n: refers to measurement of ambiguity for qualitative concept. Size of entropy directly determines cardinal number which can be accepted by qualitative knowledge in the domain and reflects vague measurement of qualitative concept.

(3) excess entropy H_e: refers to entropy of entropy E_n, which reflects dispersion degree of cloud. Size of excess entropy indirectly reflects thickness of cloud.

Based on that, definition of cloud model for engineering project risk point status in the section is described as:

Definition 2 (credibility cloud droplet): It is hypothesized that p basic risk points can be provided in P risks (B) of certain engineering project at certain moment; q extension risk points can be obtained in Q extension risk points (E); matrix $\boldsymbol{S}$ refers to risk points provided in the engineering project (1 indicates risk point which can be provided, while 0 indicates risk point which cannot be provided); corresponding matrix $\boldsymbol{S}$ has $P+Q$ row; corresponding value of the row $P+Q$ is 1. Meanwhile, the first-order matrix of corresponding basic risk point weight (which indicates significance of all risk points in basic risk points or dependence of other risk points) is $\boldsymbol{T}$, then $\boldsymbol{S}\times \boldsymbol{T}=\boldsymbol{V}$. In addition, $\sum\limits_{i=1}^{P+Q} v_i$ is recorded as$L$. Therefore, credibility cloud composed by cloud droplet reflects state of the engineering project.

It can be calculated through statistical status of engineering project at the moment$n$:

$$\begin{gathered} E_x = \frac{1}{n}\sum_{i=1}^{n} L_i, E_n = \sqrt{\frac{\pi}{2}} \times \frac{1}{n}\sum_{i=1}^{n} |x_i - E_x|, \\ S^2 = \frac{1}{n-1}\sum_{i=1}^{n} (x_i - E_x)^2, H_e = \sqrt{S^2 - E_n^2}\,. \end{gathered} \tag{2}$$

Where E_x indicates general status engineering project; E_n indicates corresponding membership degree to general status of engineering project; H_e indicates stability of risk point status provided in engineering project. Therefore, the three parameters can be used to measure status of a engineering project so as to find vulnerability of risk point status for engineering project and even vulnerability of the whole system for further improvement of risk point quality of engineering project. In order to further illustrate rational feasibility of the model research in the section, simulation experiment research is conducted in section 4.

3.2. System state inspection method

In fact, risk point of engineering project can be used to better describe status of engineering project, which makes better risk prediction for offshore oil engineering project so as to make an evaluation and prediction and plays a significant role in restoration of final engineering project. As deterministic finite automaton (DFA) can be used to conveniently process transformation relation between states[14], thus deterministic finite automaton is planned to be used in the section so as to describe risk prediction for complex offshore oil engineering project. Risk prediction of offshore oil engineering project can be expressed as a quintuple:

$$M = (Q, \sum, \delta, q_0, F)\,. \tag{3}$$

Where Q indicates nonempty finite set. Each element of it can indicates a status in provided risk point of engineering project; $\sum$ indicates possible condition set of the system; δ indicates state transition function, which is expressed as $Q \times \sum \to Q$; q_0 indicates initial state of M; F indicates state transition set (including completion state of risk point and termination state of risk point).

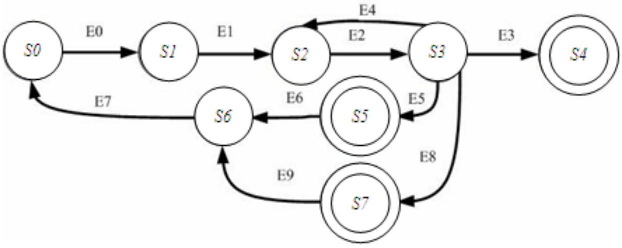

Fig. 2. Identification of SYN-Flooding risk point process in engineering project

Theorem (state judgment theorem of risk point): the engineering project has necessary and sufficient conditions for risk point state: current state of engineering project is $q_a \in F$ and its corresponding out-degree to DFA is 0 in corresponding DFA model $M = (Q, \sum, \delta, q_0, F)$ to certain risk point provided by the engineering project, which is $\exists \sum a \in \sum (q_a \times \sum a \to q_x | q_a \in F, q_x \in Q)$.

Proof: (1) sufficiency: current state of engineering project is $q_a \in F$ and its corresponding out-degree to DFA is 0, which indicates that engineering project is in the termination state and cannot be transformed into any other state. As identification of Q_a is completed, resources have been consumed and cannot be released, thus it can be judged that the engineering project is in the risk point state;

(2) Necessity: proof by contradiction. It is hypothesized that $\exists \sum a \in \sum (q_a \times \sum a$

$\rightarrow q_x | q_a \in F, q_x \in Q)$, current engineering project is sure of passing $q_a \times \sum a \rightarrow q_x$ to enter other state. Finally, it enters other termination state and releases resources. However, it is in the risk point state of the engineering project and can neither provide risk point nor release resources. DFA may be restored to the initial state or any other middle state, thus conflict may be cause.

In case the engineering project can normally provide certain risk point, state set Q_s of the engineering project at the time of executing the risk point may make $M_a = (Q_s, \sum_s, \delta_s, q_{0s}, F_s)$ be identified by correspondingQ_a. In case its termination state is normal termination state of risk point, it shall be recorded as $C(M_s, k)$; in case its termination state is completion state of risk point, it shall be recorded as $A(M_s, k)$.

3.3. Risk prediction of offshore oil engineering project based on cloud model

Prediction evaluation and prediction model for offshore oil engineering project based on cloud model are researched in the section. Specific practices are: state of the engineering project is risk prediction cloud model for offshore oil engineering project established by cloud droplet. Weight shall be set for different risk points in engineering project according to importance; then, risk prediction (conditions about risk points) evaluation of current offshore oil engineering project is given; expectationE_x, entropy E_n, and excess entropy H_e of risk prediction cloud for offshore oil engineering project are used to describe risk prediction of offshore oil engineering project.

Specifically, E_x indicates general state of risk points provided in the engineering project; E_n indicates deviation degree of general state from commencement of statistics to current engineering project; H_e indicates deviation degree of state for engineering project when current cloud model is used to describe risk prediction of offshore oil engineering project. The smaller the numerical value is, the more stable the engineering project is.

Each risk point in the engineering project can be used to establish a cloud model. As each risk point has been subject to redundancy in actual engineering project, the identical risk point has been copied for several times on different risk point counters of the engineering project. Cloud model is used to inspect working state of each risk point in the engineering project. Meanwhile, redundant points can be used to evaluate the risk point so as to find the most appropriate redundancy times and method.

In addition, relevancy between different risk points is required to be considered in the process of restoring risk points of engineering project. In case relevancy between different risk points is smaller than 2, it indicates that certain risk point of certain engineering project at most is related to other risk point. In case the risk point has fault, the other risk point may be in fault state; in case the risk point is required to be restored, normal supply of the other risk point is required to be firstly ensured; E_x has the best effect at the time of restoring engineering project.

3.4. Realization of risk prediction evaluation and prediction model for offshore oil engineering project based on cloud model

It is indicated in previous research that state parametersE_x, E_n, and H_e can make a comprehensive description for risk points of engineering project. In addition prediction for risk point of engineering project can be made according to the three parameters. AsE_x,E_n, and H_e are processes of cloud characteristics solved by cloud droplet, thus prediction made with the three parameters is the process for cloud characteristics to generate and predict cloud droplet. It is know from definition of cloud mode that cloud droplet of working state for certain determined engineering project basically abide by normal distribution, thus risk prediction evaluation and prediction (model) algorithm $F(E_x, E_n, H_e, n)$ for offshore oil engineering project based on cloud model is researched and proposed in the section on the basis of previous researches. Detailed conditions are as follows:

Input: numerical characteristics (numerical characteristics) so as to generate No. n of cloud droplet.

Output: n cloud droplet and its certainty degreeμ.

Detailed realization steps for algorithm:

(1) Generate a normal random number $E'_{n_i} = Norm(E_n, H_e^2)$ which takes E_x as the expected value and takes H_e^2 as variance;

(2) Generate a normal random number $x_i = Norm(E_x, E'^2_{n_i})$ which takes E_x as the expected value and takes $E'^2_{n_i}$ as variance;

(3) Calculate $\mu_i = e^{-\frac{(x_i - E_x)^2}{2E'^2_{n_i}}}$;

(4) x_i with certainty degree will become a cloud droplet in the number field;

(5) Repeat above-mentioned step 1 to step 4 until n required cloud droplets are generated.

It is known from above-mentioned algorithm that working state of engineering project during certain period can be evaluated through setting interval time t of cloud droplet and generating n cloud droplet.

4. Experimental analysis

4.1. Risk data acquisition

(1) Employer risk: The Engineering is the mat endowment engineering. The Contractor is agreed in the contract clauses to pay money in advance for construction according to certain proportion and shall pay performance bond. In case the Employer has poor credit standing and defaults on progress payment with various excuses and the Employer's fund is worsen without solvency, the Contractor shall take the risk of taking back advanced payment.

(2) Supervision engineering. In case the Supervision Engineer cannot immediately sign concealed work, does not reply work contact letter, delays to sign payment on purpose, or cannot propose suggestions or make decisions for some claim prob-

lems with low management level, the Contractor shall suffer economic losses and engineering cost shall be increased.

(3) Engineering environment risk: ① In terms of economic risk, currency inflation will lead to economic disorder, constant increase of price for labor forces, materials, and equipment, and dramatic improvement of engineering cost. The Contractor shall undertake cost losses caused by dramatic fluctuations in material prices. Meanwhile, increase of national interest on loan has bad influences on cost and interest of the Contractor. ② In terms of natural risk, the region is cold and dry with wind, which is in rainy season from every July to every September and is in the winter from middle of November to March in the next year, thus construction organization is in face of tense construction period and takes the risk of heavy task.

(4) Private risk of engineering contractor: ①In terms of technology, wall of the Engineering is subject to mixed soil, plaster brush, white paint, aluminum alloy keel, mineral-wool acoustic board, and furred ceiling. Terrace classroom is subject to ready mixed paint wainscot. As perennial temperature of Zhangjiakou is in low-temperature state, causing that it is not easy to dry wall decoration. The Contractor is required to take new technology to solve it, thus the Contractor takes the risk of rework caused by falling off of wall surface in a large area due to quality problems out of immature technology. Technical risk checklist is used in the thesis so as to quantify it. ② In terms of contract, contract clause has the risk of omission, wrong expression, weak claim awareness and poor claim and counterclaim capacity of contract management personnel, thus material risk checklist is used in the thesis so as to quantify it. ③ In terms of safety, as the Engineering is constructed on campus with great staff mobility, improper safety measures or weak safety awareness of personnel will lead to structural safety hazard, industrial accident, and other risks. ④In terms of personnel, the Contractor does not have a fixed construction team under the influence of market economy; moreover, the engineering construction team is temporarily constructed; on-site worker has low quality and lacks professional knowledge and safety awareness. ⑤ In terms of equipment material risk, at present, in order to reduce cost and to obtain higher profits, there is deviation phenomena for specification and size of some materials in the material market; in addition, offshore oil engineering project leads to wrong brand and specification of materials; material risk checklist is used in the thesis so as to quantify it.

(5) Cost objective risk: Cost objective refers to objective pursued in the aspect of cost. Cost objective is quantized and measurable and is a cost index in certain level which should be reached by the organization within certain period in the aspect of cost. In case objective of total cost for the organization is prepared (back push method) according to caliber of objective profit, it shall be called “objective cost”, which indicates that objective cost = objective income - objective profit.

(6) Management process risk: Management process includes complex contents, which is usually considered as an important basis to analyze risk responsibility. Defect and failure of management process will directly lead to cost losses, thus cost checklist is used in the thesis so as to quantify it.

4.2. Cost risk prediction of offshore oil engineering project

According to data collection of above-mentioned steps, obtained cost risk prediction index value of certain domestic offshore oil engineering project is show in Table 2:

Table 2. Cost risk prediction index value of offshore oil engineering project

Cost risk index	Index value	Cost risk index	Index value	Cost risk index	Index value	Cost risk index	Index value	Cost risk index	Index value
C11	0.56	C31	Good	C41	85	C45	86	C61	80
C12	Good	C32	Good	C42	75	C51	Good	C62	85
C13	0.86	C33	Good	C43	70	C52	Good	C63	78
C14	Excellent	C34	Bad	C44	88	C53	Excellent	C64	85

Data is subject to pretreatment through establishing cost risk prediction mode which is a normal cloud model for offshore oil engineering project. Cost risk index value of project to be inspected is input to trained support vector regression. Result of risk value after calculation is 0.4663, which is in the lower risk area and is in the acceptable risk range.

It is shown in Fig. 3 that entropy (membership degree of state to expected value E_x) and excess entropy H_e (work stability degree of engineering project) of state for risk point of engineering project are convergent to be in stable state with the increase of cloud droplet, which indicates that intensive degree of core cloud droplet, cloud border, and cloud droplet in the cloud formed by work conditions of engineering project is more and more explicit with increase of risk prediction cloud droplet for offshore oil engineering project, thus it is not hard to see that conditions of risk points for engineering project can be determined through survivability evaluation of engineering project based on cloud model and E_x, E_n, and H_e.

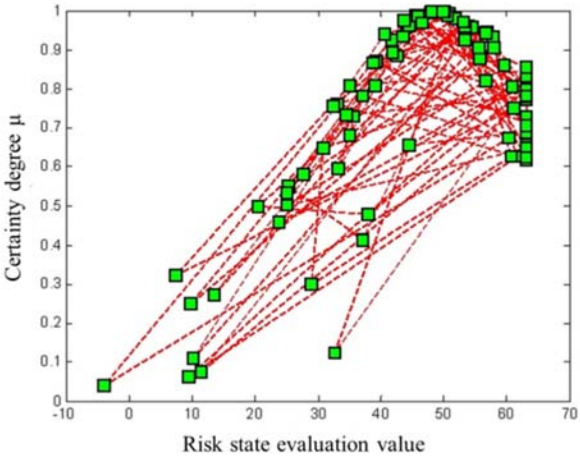

Fig. 3. Risk prediction of offshore oil engineering project

5. Conclusion

Cloud model and finite-state machine theory are introduced in the thesis so as to describe and inspect risk prediction of offshore oil engineering project and to research and analyze survivability evaluation of risk for offshore oil engineering project. Risk prediction algorithm for offshore oil engineering project based cloud model is proposed; detailed analysis and proof is conducted in theory. Feasibility and rationality of risk prediction evaluation of offshore oil engineering project based on cloud model researched in the thesis are further illustrated through simulation experiment and analysis.

References

[1] Y. J. Zhao, L. Wang, H. J. Wang, and C. J. Liu: *Minimum Rate Sampling and Spectrum Blind Reconstruction in Random Equivalent Sampling.* Circuits Systems and Signal Processing, *34* (2015), No. 8, 2667–2680.

[2] S. L. Fernandes, V. P. Gurupur, N. R. Sunder, N. Arunkumar, S. Kadry: *A novel nonintrusive decision support approach for heart rate measurement*, (2017) Pattern Recognition Letters. https://doi.org/10.1016/j.patrec.2017.07.002

[3] N. Arunkumar, K. Ramkumar, V. Venkatraman, E. Abdulhay, S. L. Fernandes, S. Kadry, S. Segal: *Classification of focal and non focal EEG using entropies.* Pattern Recognition Letters, *94* (2017), 112–117

[4] W. S. Pan, S. Z. Chen, Z. Y. Feng: *Investigating the Collaborative Intention and Semantic Structure among Co-occurring Tags using Graph Theory.* International Enterprise Distributed Object Computing Conference, IEEE, Beijing, (2012), 190–195.

[5] Y. Y. Zhang, Q. Li, W. J. Welsh, P. V. Moghe, and K. E. Uhrich: *Micellar and Structural Stability of Nanoscale Amphiphilic Polymers: Implications for Anti-atherosclerotic Bioactivity*, Biomaterials, *84* (2016), 230–240.

[6] L. R. Stephygraph, N. Arunkumar, V. Venkatraman: *Wireless mobile robot control through human machine interface using brain signals*, 2015 International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials, ICSTM 2015 - Proceedings, (2015), art. No. 7225484, 596–603.

[7] N. Arunkumar, V. S. Balaji, S. Ramesh, S. Natarajan, V. R. Likhita, S. Sundari : *Automatic detection of epileptic seizures using independent component analysis algorithm*, IEEE-International Conference on Advances in Engineering, Science and Management, ICAESM-2012, (2012), art. No. 6215903, 542–544.

[8] Y. Du, Y. Z. Chen, Y. Y. Zhuang, C. Zhu, F. J. Tang, J. Huang: *Probing Nanostrain via a Mechanically Designed Optical Fiber Interferometer.* IEEE Photonics Technology Letters, *29* (2017), 1348–1351.

[9] W. S. Pan, S. Z. Chen, Z. Y. Feng: *Automatic Clustering of Social Tag using Community Detection.* Applied Mathematics & Information Sciences, *7* (2013), No. 2, 675–681.

[10] Y. Y. Zhang, E. Mintzer, and K. E. Uhrich: *Synthesis and Characterization of PEGylated Bolaamphiphiles with Enhanced Retention in Liposomes*, Journal of Colloid and Interface Science, *482* (2016), 19–26.

Received May 7, 2017