TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 10
Number 2
June 2016

DOI: 10.12716/1001.10.02.13

Monitoring System for Evaluation of Operator Functional Status on Sea Ships

G. Varoneckas, A. Martinkenas, J. Andruskiene, A. Stankus, L. Mazrimaite & A. Livens
Klaipeda University, Klaipeda, Lithuania

ABSTRACT: This paper introduces the basic concept of a new developed web-based databank for an assessment of seafarers' functional status during the sea missions. The Web system is based on client-server architecture and the international open source technologies including Apache web server, PHP scripts and MySQL database. The paper focuses on the aspects and first results of the initial practical realization of the web-based databank. The main operational advantage of the developed system is the capability to on-line handle up to a dozen users at the same time. The system includes administrative data and questionnaires. Electronic data entry saves the time and material resources.

1 INTRODUCTION

In spite of the development of the modern technology the sea transport depends largely on the human action. Crews of the cargo and passenger ships' have high responsibility, which requires good health, to perform their duties. A tight ship working environment, limited sleep duration, working time by shifts, difficulties in communicating with colleagues, nostalgia, isolation feeling; they all are considered to be factors of fatigue and stress that can lead to various consequences [1].

In order to prevent human caused accidents and to increase the safety awareness among the crews it is obligatory to measure, control and manage functional status of seafarers in maritime work-environment. The sea transport leaders drew attention to the factors causing fatigue and stress, since only by reducing or eliminating them the safety of navigation could be ensured and more workers attracted. The leaders also pointed out the need to initiate a new crew views toward maritime education and training. Such measures would help to create better working and living environment, increase efficiency, productivity and safety for crew members. Assessment of seafarers' functional status during marine missions requires tele informatic system, which should be based on the online access [2].

The most modern online database management systems (DBMS) were designed to work in a global network, using Web technologies. Database management systems are multifunctional enabling to store structured data, edit the existing data, and to perform a quick search for the desired criteria. The main feature of such systems is integrity – a possibility to collect data from different users (databanks) and to get access to the database independently from other users. Database management tools not only allow at any time quickly to get complete and accurate information, keep it in compact format, but also provide an opportunity to deal with automated data overload, consistency, integrity and standardization security problems.

One of the most widely used types of DBMS – relational model, based on the mathematical theory of relational algebra. The relational model is special because it provides data tables and performs specific operations with these tables. Another important feature of this model - structural independence, i.e., the data can be changed without changing the structure of the software or data processing procedures.

Such DBMS becomes available to consumers from virtually any location and requires minimum cost, but gives a lot of comfort, especially when working for many users simultaneously. The data of research are collected from the variety of tests and questionnaires; because of that the central storage of data is more efficient and less costly, especially using them for statistical analysis [3].

This paper concentrates on the development of data bank for seafarers' functional status assessment. In section 2 and 3, which are the main parts of the paper, the initial practical realization of the Web-based databank for assessment of seafarers' functional status during sea missions is presented.

2 WEB-BASED DATABANK CONCEPT

Database was created using MySQL, Apache, PHP, Java scripts (Fig. 1) and placed on the server. To connect to the server the user can use any web browser. Apache web server – the most widely used web server software. Apache performs a key role in the initial growth of the World Wide Web function.

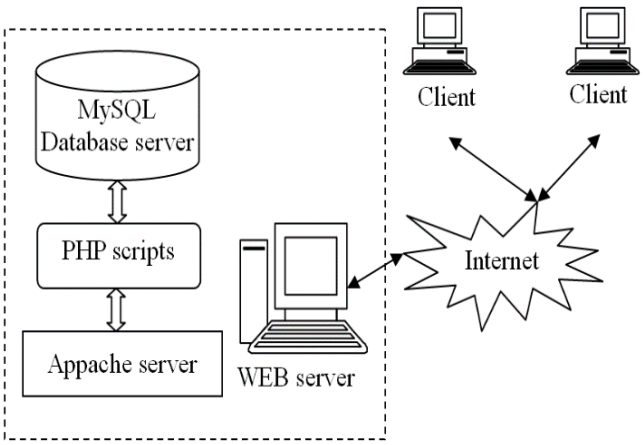

Figure 1. Web-based tool for the databank management

Apache Web server applications communicate to the data bank using PHP. The main advantage of the Apache server is the system's independence from the operating system.

Website was developed using PHP – dynamic programming language. This open-source language supports number of relational databases and runs on most operating systems and with most web servers. This DBMS runs on MS Windows operating system platform. PHP code (command) inserted into the HTML code generates mapping results in the same HTML page and displays it in a Web browser.

Database administration intended for running MySQL GUI (graphical user interface) tool – dbForge Studio for MySQL [4]. The database system's block diagram is presented in Figure 2.

JavaScript – an object oriented scripting programming language, which, like PHP, added to HTML pages, extends the static HTML pages. Java scripts are used for control of the parameters of the questionnaires.

Algorithms based on SQL language were developed for analysis and interpretation of the standard questionnaires. The data bank was developed taking into account that it should work as quickly as possible, expanding system's functionality.

A Web-based tool is easy to maintain and guarantees user access to the latest, most recent version. The user can connect to the Web server using convenient Web browser. For user interface interaction between the system's components and data flow the Web server uses PHP, Java and other programming techniques.

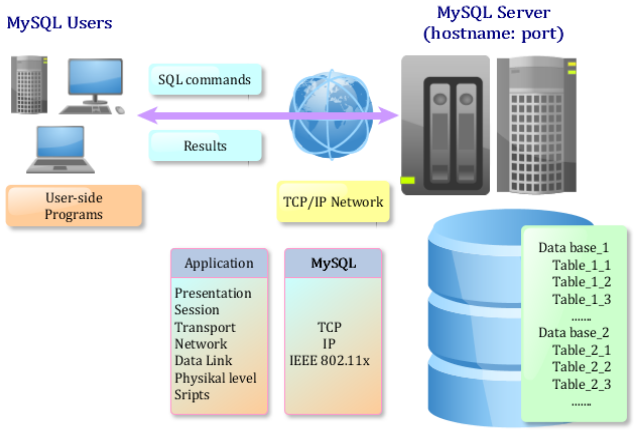

Figure 2. MySQL Database Management System (DBMS)

The data depending on the security level and user's role are accessible at different communication levels only to physicians and specialists of strongly defined field and group is presented in Figure 3. The system recognizes user's four roles:

1 Information system administrator;
2 Databank manager;
3 Reviewer;
4 Seafarer (interviewed).

Each role has a particular set of transaction capabilities. Information system administrator's capabilities are following: input, update, delete, review system users and patient's administrative and biomedical data. The user, having manager role of person's data can upload, modify and delete data. The user having prescribed reviewer role can review data and generate reports. Individual interviewer can review his own data of the different treatment stages.

The elaborated database is in compliance with national (Lithuanian) and EU regulations on safety and data protection. Data are kept strictly confidential. Electronic transfers of data precisely follow the data protection guidelines.

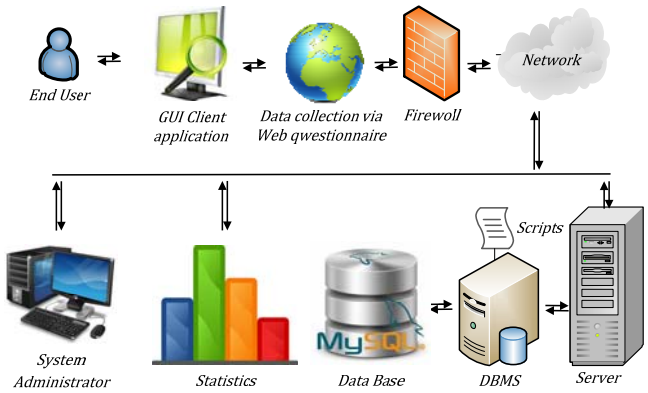

Figure 3. Interactions between the users and the data base

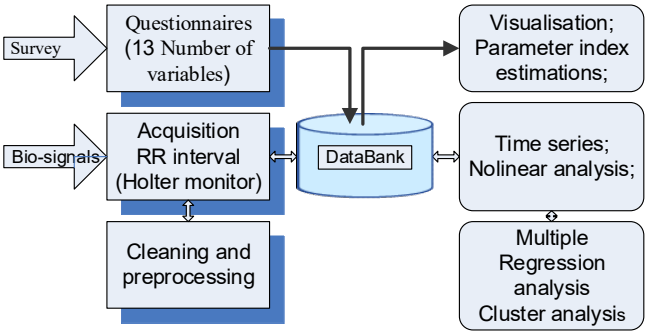

Figure 4. Database system and data management of functional and physiological testing, signal inputs and data analysis

3 DATA OF SEA-FARERS' FUNCTIONAL STATUS

3.1 *Questionnaires*

Data of the specialized questionnaires (n=13) and physiological recordings of the heart rate during active orthostatic test as well as during Holter monitoring were used for assessment of sea-farers' functional status. The data of following questionnaires are stored in the databank for assessment of:

- Anxiety and depression using Hospital Anxiety and Depression Scale, and Beck Depression Inventory [5, 6];
- Subjective sleep quality using Pittsburgh Sleep Quality Questionnaire [7-8];
- Daytime sleepiness using Epworth sleepiness scale [9];
- Health-related quality of life using SF-36 questionnaire "Short Form Medical Outcomes Study Questionnaire" [10, 11];
- Fatigue using Multidimensional fatigue inventory, fatigue scale DUFS (Dutch Fatigue Scale), and effort fatigue scale DEFS (Dutch Exertion Fatigue Scale) [12, 13];
- Work experiences and health indicators using WEMS (Work Experience Measurement Scale) and SHIS (The Salutogenic Health Indicator Scale) [14, 15];
- Encountered stress and stress at work place using special questionnaire (V. Reigas, 2012);
- Subjectively estimated by operator workload intensity at work place using special questionnaire (J. Andruškienė, 2012, General data form);
- Harassment at the workplace using WHS (Work Harassment Scale) [16].

Attribute groups and number of variables in each group are presented in the Table 1.

In database the raw data of physiological signals obtained during functional testing are collected and prepared for further analysis using self-developed statistical tools is presented in Figure 4.

The possibility to provide convenient statistical analysis as well as sophisticated HR analysis using power spectra or Poincare plots is foreseen and might be performed remotely.

Table 1. Attribute groups and number of variables in web-based databank for assessment of seafarers' functional status

	Attribute groups	Number of variables
1.	Administrative data	80
2.	Hospital Anxiety and Depression Scale	14
3.	Beck Depression Inventory	23
4.	Pittsburgh Sleep Quality Questionnaire	24
5.	Epworth sleepiness scale	9
6.	SF-36 Short Form Medical Outcomes Study Questionnaire	47
7.	Dutch Fatigue Scale	10
8.	Dutch Exertion Fatigue Scale	10
9.	The Multidimensional Fatigue Inventory, MFI-20	22
10.	WEMS	34
11.	SHIS	14
12.	Stress at Work	47
13.	Heart rate data during active orthostatic test	52
14.	Heart rate data during Holter monitoring	62
Total		448

3.2 *Heart rate data*

Assessment of operator's (seafarer's) functional status is based on objective evaluation of human autonomic heart rate (HR) control which determines the adaptation of cardiovascular function to different stressors, such as mental and physical work. HR recording during active orthostatic test or Holter monitoring is used for assessment of autonomic HR control.

The parameters of HR variability are stored in the data base: the average value of the R-R interval (RR, ms) and its standard deviation (σRR, ms); root mean square difference between the value of the successive RR interval duration (RMSSD, ms); percentage of the adjacent RR intervals differing from each other by more than 50 ms (pNN50%) and the number of successive RR intervals differing by more than 50 ms, (NN50, n); very low frequencies component (VLFC, from 0.003 to 0.04 Hz), low frequency component (LFC, from 0.04 to 0.15 Hz) and high frequency component of heart rate (HFC, from 0.15 to 0.4 Hz), absolute values (VLFC ms, LFC ms HFC ms) and normalized values (LFC norm, HFC

norm) and percentage values (VLFC%, LFC% and HFC%), and LFC and HFC ratio (LFC/HFC, %) [17].

Poincare´ plot indexes of heart rate variability (HRV). Minor axis (SD1, ms), major axis (SD2, ms) and the SD1/SD2 ratio indices; RR histogram triangular interpolation (TINN, ms) and triangular index (Trl); heart rate level in A, B and C points (RR_A, ms, RR_B, ms, RR_C, ms); maximum heart rate response to active orthostatic test), absolute values (dRRB, ms) and percentage values (dRRBpr, %), the duration of the transition process (T_AB, s, T_BC, s) [18-20].

3.3 *Data extraction from web-based database*

Interviewer (user) before starting to fill in the questionnaires for the first time must register and identify himself in the information system. After completing a questionnaire in the database, the management system generates the conclusion and submits results to the user. Response model from one of the 13 questionnaires, i.e., Anxiety and Depression Scale (HAD), is shown in Figure 4.

A problem of feature extraction from heart rate data related to the diagnosis of sleep disorders and diseases is considered. Raw data of heart rate interval (RR, ms) sequences are taken from web-based database. The standard methods for time series analysis, e.g. statistical inference, hypotheses testing, correlation analysis, spectral analysis, etc., are included in the developed tool.

Hospital Anxiety and Depression Scale

Test No.1 Time & Date: 06/05/2013 Code: 100

	Score	Assessment
Anxiety	**12**	**Moderate**
Depression	**4**	**Non-case**

Estimation: Grading: Non-case (0-7), moderate (8-10) and severe (10-21)

Figure 4. The example of the conclusion from the test using Anxiety and Depression Scale.

Algorithm for diagnostics of sleep quality and disturbed sleep is based on evaluation of sleep structure (sleep stages) using sophisticated analysis of parameters of RR interval time series recorded during Holter monitoring.

Different statistical, spectral and non-linear dynamic parameters of RR interval time series are stored in the databank.

After HR data analysis, a verbal conclusion regarding the functional state of autonomic HR control reflecting seafarer's functional status is presented.

The results of analysis of questionnaires' data and physiological signals from the heart (RR intervals) provide useful information of seafarer's functional status, including mental and physical fatigue, stress and ability to perform the daily duties as well as changes of functional status to extreme environmental and labour factors. The developed system allows detecting the crew working capacity and proposes measures that can be faster and more efficient in restoring function status and improving management of the human factors during sea missions.

4 PILOT STUDY

The pilot study, in which 25 seafarers were investigated during their sea mission, was performed.

A database testing - the testing of 25 seafarers. The system's testing results confirmed that Web based databank for practical use is convenient; users give priority to electronic data entry.

All the test data collection in one database allows them to quickly export data and to perform statistical analysis.

The study results demonstrated that sea farer's functional status mostly depends on the physical and mental fatigue during operational activity. The functional status is also influenced by gender, age, physical fitness, pain, boredom and emotions.

The limitation of the pilot study is a relative small number of investigated persons, including monitoring of HR during sea missions.

5 CONCLUSIONS

The developed Web system was based on the client-server architecture and international open source technologies, including Apache web server, PHP scripts and MySQL database. The system is implemented in client server architecture. The server stores the data and controls system's basic functions.

The main operational advantage of the developed system is the access to the data bank for several users at the same time. Users give priority to electronic data entry against filling questionnaires on paper. Electronic data entry saves operational time and material resources.

ACKNOWLEDGMENTS

Presented research was carried out in Klaipeda University and funded by a European Social Fund Agency grant for national project "Lithuanian Maritime Sectors' Technologies and Environmental Research Development" (VP1-3.1-SMM-08-K-01-019)

REFERENCES

[1] OECD Health Data 2013, http://stats.oecd.org/index.aspx?DataSetCode=HEALTH_STAT

[2] Varoneckas A., Mackutė-Varoneckienė A., Martinkėnas A., Žilinskas A., Varoneckas G. Web-based tool for management of CAD patients after coronary bypass

surgery//Computers in Cardiology 2005: 32nd Annual Conference on Computers in Cardiology, Lyon, September 25-28, 2005. vol. 32, p. 155-158.
[3] Varoneckas G., Martinkenas A., Podlipskytė A., Varoneckas A., Žilinskas A. A web-based data bank of heart rate and stroke volume recordings during sleep // E-Health: proceedings of Med-e-Tel 2006: the international trade event and conference for eHealth, telemedicine and health ICT: April 5-7, 2006. p. 371-375.
[4] dbForge Studio for MySQL// https://www.devart.com/dbforge/mysql/studio/
[5] Zigmond A.S., Snaith R.P. The Hospital anxiety and depression scale. Acta Psychiatrica Scandinavica 1983, 67: 361-70.
[6] Beck A.T, Steer R.A, Brown G.K. 1996. Beck Depression Inventory. Second Edition manual. San Antonio, TX: The Psychological Corporation.
[7] Varoneckas G. The subjective assessment of sleep by the Pittsburgh Sleep Quality Index (Lith.). Nervų ir psichikos ligos [Nervous and Mental Illness]. 2003, 4 (12), 31-33.
[8] Buysse D.J., Reynolds III C.F., Monk T.H. et al. The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. Psychiatry Research 1988, 28: 193-213.
[9] Murray W. Johns. A New Method for Measuring Daytime Sleepiness: The Epworth Sleepiness Scale. Sleep 1991, 14(6): 540-545.
[10] Jenkinson C., Layte R., Wright L., Coulter A. The U.K. SF-36: an analysis and interpretation manual. A guide to health status measurement with particular reference to the Short Form 36 health survey. University of Oxford. - 1996. 65 p.
[11] Puzaras, P., Ančerytė, D., Martinkėnas, A., Varoneckas, G. Catholic faith and life quality (Lith). Sveikatos mokslai. – 2000, 2: 28-35.
[12] Stankus A. Multidimensional Fatigue Inventory (Lith). Biologinė psichiatrija ir psichofarmakologija [Psychopharmacology and Biological Psychiatry]2007, 9 (2): 86-87.
[13] Tiesinga L.J, Dassen T.W.N, Halfens R.J.G. et al. 1997. Measuring fatigue with the Dutch Fatigue Scale (DUFS) and measuring exertion fatigue with the Dutch Exertion Fatigue Scale (DEFS): Manual. University of Groningen: Department of Health Sciences.
[14] Bringsén Å, Andersson HI, Ejlertsson G. Development and quality analysis of the Salutogenic Health Indicator Scale (SHIS). Scand J Publ Health 2009, 37: 13-9.
[15] Nilsson P, Bringsén Å, Andersson HI, Ejlertsson G. Development and Quality analysis of the Work Experience Measurement Scale (WEMS). WORK 2010, 35: 153-161.
[16] Björkqvist, Österman, 1992. Work Harassment Scale. Vaasa, Finland: Department of Psychology, Abo Akademi University.
[17] M Malik, A.J. Camm, Heart rate variability. Clinical Cardiology, 13 (1990), pp. 570–576
[18] Pincus S. Approximate entropy as a measure of system complexity, Proc. Nat. Acad. Sci. USA, 88, (1991), 2297-2301.
[19] Chen Z, et all. Effects of nonlinearities on detrended fluctuation analyzis, Phys. Rev. E, 65, (2002), p. 1-15.
[20] Goldberger AL, et all. Fractal dynamics in physiology: alterations with disease and aging. Proceedings of National Academy of Sciences, v.99, (2002), 2466-2472