

University of Kragujevac
Faculty of Engineering

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КРАГУЈЕВАЦ

**To: Teaching and Scientific Council
Faculty of Engineering**

Subject: Report of the Commission for assessing the thesis written part and the oral public defense of the Pavle Mijović's doctoral dissertation.

By the decision of the Teaching and Scientific council of Faculty of Engineering, University of Kragujevac no. 01-1/867-14 from 24. 03. 2016., we are appointed as members of the Commission for assessing the thesis written part and oral public defense of the Pavle Mijović's doctoral dissertation, entitled:

**"DEVELOPMENT AND IMPLEMENTATION OF MULTIMODAL SYSTEM
FOR ATTENTION MONITORING IN NATURALISTIC WORK
ENVIRONMENTS"**

After the insight to the doctoral dissertation and the Report of the Commission for assessing the eligibility of the candidate Pavle Mijović and the doctoral dissertation, approved by the Decision of the Faculty of Engineering in Kragujevac no. 01-1/3260-21 from 17. 09. 2015., according to the University of Kragujevac Regulations on the application, preparation and defense of the doctoral thesis, the Commission submits to the Teaching and Scientific Council the following

REPORT

1. The significance and contribution of the doctoral dissertation from the aspects of the current situation in a particular scientific field

The doctoral dissertation of the candidate Pavle Mijović, M.Sc. Mech. Eng., entitled „**Development And Implementation Of Multimodal System For Attention Monitoring In Naturalistic Work Environments**“, is a result of the candidate's scientific research in the current fields of science that covers the scientific areas of ergonomics, neuroergonomics and occupational health and safety. From the aspect of the research topic and the obtained results, the dissertation represents a unique scientific work.

The candidate has made the critical analysis and systematization of the existing knowledge and experiences and scientific results of competent research in the field of the research in this doctoral thesis. Based on the analysis of the advantages and disadvantages of the existing approaches, methods and models in this scientific area, the candidate has defined the subject and the purpose of this research.

From the aspect of the scientific field and obtained results, this dissertation represents unique scientific work at the national and international level, taking into account that the approach and obtained results has significant scientific value.

The significance and contribution of this doctoral dissertation is related to the development and implementation of the multimodal system for obtaining the objective parameters for attention monitoring of workers employed on monotonous and repetitive manual assembly tasks, by using physiological sensors, behavioral parameters and motion capture (MoCap) sensors.

The physiological parameters for the attention monitoring were defined as well as the multimodal interaction between all the parameters (obtained from all the sensors used in the study), namely: physiological, behavioral and motion signals.

Obtained results and conclusions from this dissertation are opening new research directions in the scientific fields of ergonomics, neuroergonomics and occupational health and safety, with the aim of increasing the overall workers' well-being.

2. The assessment that doctoral dissertation is the result of original scientific work of the candidate in the relevant scientific field

The commission finds that the doctoral dissertation of the candidate Pavle Mijović, M.Sc. mech. Eng., entitled „**Development And Implementation Of Multimodal System For Attention Monitoring In Naturalistic Work Environments**“, is the result of original scientific work. Analyzed topic is highly relevant and important for the development of science in the field of production and industrial engineering. The candidate has elaborated the topic thoroughly and in detail, using the theoretical basis of scientific disciplines relevant to this issue. Numerous scientific papers are critically analyzed and evaluated relating to issues considered with this thesis.

The originality of scientific work, research and the results obtained in the framework of this dissertation is reflected, among other things, in the following elements:

- Through literature review of the scientific papers in the areas of the ergonomics, neuroergonomics and occupational health and safety, the candidate noticed that the majority of methods that are used for the assessment of the worker's cognitive state are relying on the unreliable subjective and observational methods. As such, these methods are unable to provide objective parameters of covert mental processes of the workers, neither the attention level of the workers during the regular working operations. The candidate has showed that by using the proposed multimodal system can provide the objective information on cognitive state of the workers during the manual assembly tasks and in that view, this dissertation represents one of the first research on the international level.
- Candidate recognized the need for inclusion of the physiological sensors at the workplace, with the aim of determining the parameters that are reflecting the worker's cognitive state. Since the physiological sensors are nowadays wearable, the candidate has shown that it is possible to employ them in the workplace for acquiring the worker's physiological signals.

- Apart from physiological signals, the MoCap sensors that are based on the structured light technology, it is possible to acquire in real-time the postures of the operators, without the need for attaching the sensors to the worker's body. The candidate has used in this research the structured light sensor for recording the workers' movements during the manual assembly operation. Moreover, in one of the chapters of the presented thesis, the candidate has shown that it is possible to use the task unrelated movements (e.g. self-centered gestures) for the estimating of the attention level of the workers'.
- The candidate has shown how the alteration of the working condition can influence the worker's attention level. For that reason, the candidate has included a highly frequent micro-breaks during the working operation and he has shown that these micro-breaks may have positive influence on the worker's attention level. The similar result was obtained when the initiation of the working process was instructed, as compared to the case where the participants in the study were free to choose with which hand they will initiate the manual assembly operation.
- Finally, the candidate has presented the framework of the use of the proposed multimodal system in realistic working environments for the real-time attention monitoring of the workers. The final goal of the presented dissertation is to pinpoint to the future directions on the research of the worker's attention level, with the aim of preventing the industrial accidents that are caused by the worker's attention fluctuations.

3. An overview of the results of a candidate in a particular scientific field

Pavle Mijović was born on 03/10/1986 in Belgrade, Republic of Serbia. Pavle Mijović, is a Ph.D. student at the department for Production and Industrial Engineering at Faculty of Engineering, University of Kragujevac. He obtained his M.Sc. in Mechanical engineering at the Faculty of Mechanical Engineering, University of Belgrade, Serbia.

After graduating from university of Belgrade, Pavle Mijovic was enrolled at the Erasmus Mundus Master program EURHEO (European Masters in Engineering Rheology), where the main concept of the program was to gain advanced knowledge on rheology and its application in different fields of engineering. During this program, Pavle joined successfully three different universities: "KU Leuven", Belgium; "Universidade do Minho", Portugal and "Universitadella Calabria", Italy. Pavle graduated from the EURHEO program on September 2012 and obtained the dual degree as Master of Science in Chemical Engineering (Engineering Rheology).

In December 2013, Pavle Mijovic enrolled the "InnHF (www.innhf.eu)" European project within FP7 framework trough the initial training network as an early-stage researcher and PhD student at Faculty of Engineering, university of Kragujevac, Serbia. During his PhD studies, he is conducting research in the domain of Human Factors and Ergonomics (HFE); more specifically neuroergonomics. The main aim of his research is to investigate physiological correlates of various mental states of the operators while they are performing their everyday routine in variety of workplaces.

His research is conducted using physiological signals acquired with wearable sensors that are further processed in order to extract specific features of operators' vigilance level, attention, mental fatigue and mental stress.

The thesis entitled „**Development And Implementation Of Multimodal System For Attention Monitoring In Naturalistic Work Environments**“, was approved on 17. 09. 2015.

Pavle Mijovic published 11 scientific papers as an author and/or co-author, 3 of which in international scientific journals and 8 of which were presented in international conferences and are published in conference proceedings.

Scientific papers published in international journals of excellence (M21)

1. **Mijović, P.**, Ković, V., De Vos, M., Mačužić, I., Jeremić, B., & Gligorijević, I. (2016). Benefits of Instructed Responding in Manual Assembly Tasks: An ERP Approach, *Frontiers in Human Neuroscience*, April 2016, Vol. 10, Article 171, doi:10.3389/fnhum.2016.00171
2. Lupi, F. R., Gabriele, D., Baldino, N., **Mijovic, P.**, Parisi, O. I., & Puoci, F. (2013). Olive oil/policosanol organogel for nutraceutical and drug delivery purposes. *Food & Function*, Vol. 4, Issue 10, pp. 1512-1520. doi: 10.1039/C3FO60259A

Scientific papers published in prominent international journals (M22)

1. **Mijović, P.**, Ković, V., De Vos, M., Mačužić, I., Todorović, P., Jeremić, B., & Gligorijević, I. (2016). Towards Continuous and Real-Time Attention Monitoring at Work: Reaction Time versus Brain Response. *Ergonomics*, Published online 08. 03. 2016., pp. 1-14. doi:10.1080/00140139.2016.1142121

International conference papers printed in a whole (M33)

1. **Mijović, P.**, Ković, V., Mačužić, I., Todorović, P., Jeremić, B., Milovanović, M., & Gligorijević, I. (2015). Do Micro-Breaks Increase the Attention Level of an Assembly Worker? An ERP Study. *Procedia Manufacturing*, 3, 5074-5080.
2. **Mijović, P.**, Milovanović, M., Minović, M., Mačužić, I., Ković, V., & Gligorijević, I. (2015). Towards Creation of Implicit HCI Model for Prediction and Prevention of Operators' Error. In *Human-Computer Interaction: Interaction Technologies* (pp. 341-352). Springer International Publishing.
3. **Mijović, P.**, Giagloglou, E., Todorović, P., Mačužić, I., Jeremić, B., & Gligorijević, I. (2014, September). A Tool for Neuroergonomic Study of Repetitive Operational Tasks. In *Proceedings of the 2014 European Conference on Cognitive Ergonomics* (pp. 1-2). ACM.

4. **Mijović, P.**, Gligorijević, I., Giagloglou, E., Mačužić, I., & Jeremić, B. Psychophysiological Measurements in Real Working Environments - Wireless EEG Study of the Operators' Vigilance. In BIOSTEC conference proceedings, Doctoral Consortium, (March 2014):60-66
5. **Mijović, P.**, M. Milovanović, M. Stevanović, E. Giagloglou, P. Todorović, M. Minović, I. Macuzic, and I. Gligorijevic. Multimodal Approach in Neuroergonomic Studies. Brain Awareness Week conference, extended abstract. February 2014.
6. **Mijović, P.**, Mačužić, I., Gligorijević, I., Todrović, P., Jeremić, B., Ković, V., Milovanović, M., Minović, M., De Vos, M. 2015. Neuroergonomic Studies of Monotonous and Repetitive Operations on Manual Assemblz Tasks. Proceedings of the 49th ESREDA seminar, Brussels.
7. Giagloglou, E., Djapan, I., **Mijovic, P.**, Tsiafis, C., & Macuzic, I. 2014. Safety knowledge for professional engineers and students: A global scheme of education. SEFI 2014, 47th Global Conference Birmingham.
8. Veljković, D. Ž., Mačužić, I., Jeremić, B., **Mijovic, P.**, & Todorović, P. M. (2013). Investigation on the RLS and Kalman Based Adaptive Order Tracking Techniques for Rotating Machinery Analysis. Prognostic and System Health Management, Milan, Italy.

4. **Assessment of the scope and quality fulfillment with the respect to the topic**

The thesis entitled „**Development And Implementation Of Multimodal System For Attention Monitoring In Naturalistic Work Environments**“ corresponds to the scope and content of the topic accepted by the Teaching and Scientific Council of the Faculty of Engineering and Expert Council of the University of Kragujevac. The thesis fully satisfy all scientific, technical and legal requirements for doctoral dissertation by quality, scope and results of research.

The research results in the written part of a doctoral dissertation are presented in a total of 166 pages. The thesis presents 38 graphic illustrations and 256 referenced papers. The content is divided into 10 chapters:

1. Introduction
2. Human Factors and Ergonomics (HF/E)
3. Neuroergonomics
4. Motion Capture and its application in ergonomics
5. General Methodology: Towards Creation of Multimodal System for Cognition-aware Computing
6. Do Micro-Breaks Increase the Attention Level of an Assembly Worker? An ERP Study
7. Benefits of Instructed Responding in Manual Assembly Tasks: An ERP Approach

8. Towards Continuous and Real-Time Attention Monitoring at Work: Reaction Time versus Brain Response
9. Communicating the User State: Towards Cognition Aware Computing in Industrial Settings
10. General Conclusions

Chapter 1 briefly discuss the shortcomings of existing ergonomics methods for objective assessment of the operators' cognitive state in workplace environments. It further briefly discuss about the advantages of neuroergonomics methods over classical ergonomics approaches. This chapter outlines the importance of objective measurement of operators' cognitive state and it provides the outline of the main objectives and main objectives of the present dissertation. It further provides the brief theoretical background of the present work and ground hypotheses. Further, the used methodology for the data processing and statistical analysis was briefly presented.

In Chapter 2, a brief overview of scientific field of ergonomics is presented. Further, four main domains of ergonomics research are presented and the advantages and disadvantages of each domain are discussed.

Chapter 3 introduces the Neuroergonomics as a science discipline and the benefits of using neuroergonomics over solely ergonomics principles. Since the neuroergonomics relies on neuroimaging techniques, an overview of neuroimaging techniques that can be used for the neuroergonomics studies is provided. Further, the advantages and disadvantages of each methods for recording the brain activity in naturalistic environment are discussed. As the EEG was used in studies that constitute the present dissertation, special focus was on EEG and wearable EEG studies that were conducted with the aim of investigating the cognitive state of the operators. Moreover, since other physiological sensors (other than neuroimaging techniques) can be used for estimating the cognitive state of the operators', HR and GSR sensor are also introduced and literature review of studies that used these sensors in ergonomics studies is presented. Finally, studies that used multimodal approach, combining EEG, GSR and HR modalities were reviewed and benefit of using such recordings was outlined.

In Chapter 4, a literature review of using the MoCap technology for ergonomics studies was provided. The focus was on recently available consumer devices that uses structured light technology and thus does not require external markers for reliable motion tracking of a person. Finally, utilizing the MoCap technology for the aim of assessing the cognitive state of the workers' was proposed, which is based on automated quantification of task unrelated movements.

General methodology that was used in experimental studies, which were conducted for the aim of present dissertation, is provided in Chapter 5. This chapter begins with the introduction of the concept of the implicit human-computer interaction (HCI) and its possible application for cognition-aware computing in industrial settings. Further, a workplace replica is presented, where the participants in experimental studies simulated the manual assembly operations. In addition, the sensors used in the studies are presented, together with their

technical specifications. Finally, the overall system architecture of the multimodal system for estimating the operators' cognitive state is presented and discussed.

Chapters 6, 7, 8 and 9 are actual experimental studies that were conducted at the Department of production engineering (Faculty of Engineering, University of Kragujevac) as part of present dissertation. An experimental study in which it was investigated whether the introduction of frequent micro-breaks can have a positive influence on attention level is presented in Chapter 6.

Chapter 7 is consisted of an experimental study in which it was investigated whether the attention level of an assembly worker can be enhanced if the he is conditioned with which hand he should start the manual assembly operation.

In Chapter 8, the relationship between P300 component's amplitude and RTs was investigated and a general framework for the future real-time attention monitoring of the operators' attention is provided.

Chapter 9, presents an experimental study in which it was investigated whether the cognition-aware computing can be utilized in industrial environments. For that aim, a multimodal study, which consisted of EEG and Kinect sensor, was conducted. The main objective was to present the concept of ME and to investigate the correlation between P300 amplitude, EI and ME.

Finally, general conclusions from all experimental studies is presented in Chapter 10 and the directions of future studies are discussed.

5. Scientific results of the doctoral dissertation

Candidate Pavle Mijović, M.Sc. Mech. Eng., in the framework of the dissertation, completed systematization of existing knowledge and experience in the field of numerical analysis of structures made of shape memory alloys. Within the thesis the candidate came to the results and conclusions that have their place and importance in scientific world, and soon these results could be applied in industrial practice. The most important scientific results of the doctoral thesis are:

- The most important result of this doctoral dissertation is that it is shown how wearable physiological sensor could be applied for timely detection of fluctuation of attention of the worker on the workplace. In this way it may be possible to prevent industrial accidents that are mainly caused by inability of workers' to sustain their attention during regular working situations over prlonged period of time;
- In this dissertation it is also shown that it is possible to synhronously record multiple physiological signals, together with observation of workers movements and postures in real-time;
- This dissertation has presented innovative way for improving overal ergonomy of the workplace. This was shown through a series of experimental studies where some aspects of workplace were altered, while the physiological and movement signals were acquired. It was shown that inclusion of frequent micro-breaks can

have a positive effect on worker's attention. The similar result was obtained if the participants in the study were instructed with which hand they should initiate the manual assembly operation, as compared to the case where they can initiate the simulated manual assembly operation without any instructions;

- Finally, the overall framework for cognition-aware system was presented. Such a system could become the regular practice in the industrial workplaces, with the main aim of timely detection of the workers' mental states.

6. The applicability and usefulness of the results in theory and practice

The results of the Pavle Mijović's doctoral dissertation entitled „**Development And Implementation Of Multimodal System For Attention Monitoring In Naturalistic Work Environments**“ are currently mainly applicable for further theoretical research, with the possibility to become completely applicable in industrial practice.

This dissertation provides a 'new paradigm' in the broad field of ergonomics and the obtained results open a new pathway in the research fields of ergonomics, neuroergonomics, occupational health and safety, as well as in the areas of production and industrial engineering.

Scientifically, the contribution of this dissertation are twofold: a) The overall framework for cognition-aware computing for application in industrial environments was presented; and b) It was proposed that the physiological signals could be the main indicators for objectively assessing the workers mental states in real-time.

Currently the practical implementation of the results is not possible, mainly because the research was conducted with the wireless EEG system that uses the wet conductive gel for recording, which is uncomfortable for worker's everyday use. Moreover, there is an ethical issue that arises from the fact that if such a system would be applied in real world, the company's management would have unlimited access to the worker's physiological signals. However, stemming from the fact that this scientific work is innovative in Serbia, as well as in international scientific world, we believe that it is just a matter of time when the mentioned problems will be overcome, which may lead to ubiquitous implementation of such a system in industrial practice.

7. The dissemination of the results

Part of the scientific results, arising in the context of this dissertation, is presented by publishing scientific papers in international scientific journals and at international and national scientific conferences.

Practical aspects of realized scientific results were presented to the domestic and international community through the realization of the international project "Innovation Through Human Factors in Risk analysis and management", InnHF- FP7-PEOPLE-2011-ITN-289837), which was financed by the European Commission under the Marie Curie Foundation.

The commission considers that the results of research and doctoral dissertation provide comprehensive and useful material for future publication in high-ranking international and national journals and scientific conferences in the field of production and industrial engineering.

Based on all the above, the Commission issues the following.

CONCLUSIONS

Doctoral dissertation of the candidate Pavle Mijović, M.Sc. Mech. Eng., corresponds in scope and in quality to the approved dissertation topic, decision no. IV-04-390/17 from 08.07.2015. by the Teaching and Scientific Council of the Faculty of Engineering in Kragujevac.

The candidate used a common and standardized technical terminology and structure of the doctoral thesis and methodology exposure are in accordance with university standards.

During his doctoral thesis preparation, the candidate Pavle Mijović came to original research results, presented in the dissertation which represents a significant contribution to the field of production and industrial engineering.

The results has been partially published in several papers in international and scientific journals and conferences. The candidate has demonstrated that he can follow a methodology of scientific research and that he has systematic approach and the ability to access and use literature.

At the same time, using their professional education and personal experience, he has shown the ability to comprehensively solve complex problems in order to define integrative conclusions in obtaining specific and applicable results.

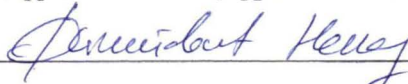
Based on the foregoing, the commission for the assessment of written part and oral public defense of the doctoral dissertation of the candidate Pavle Mijović, M.Sc. Mech. Eng., unanimously concluded that the doctoral dissertation, entitled

**"DEVELOPMENT AND IMPLEMENTATION OF MULTIMODAL
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completely satisfies all scientific, technical and legal criteria for doctoral dissertations in quality, scope and results of research. The commission is pleased to propose the Teaching and Scientific Council of the Faculty of Engineering in Kragujevac, on the basis of this report, acceptance of the doctoral dissertation as successful and to invite the candidate to the public, oral defense.

Commission members:

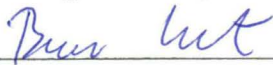
1. PhD Nenad Filipovic, Full Professor, Faculty of Engineering University of Kragujevac, Areas of expertise: Applied Mechanics, applied informatics and computer engineering



2. PhD Petar Todorovic, Associate Professor, Faculty of Engineering, University of Kragujevac, Area of expertise: Production Engineering, Industrial Engineering, Chairman of Commission



3. PhD Vanja Kovic, Assistant Professor, Faculty of Philosophy, Department for Psychology, University of Belgrade, Area of expertise: Psychology



4. PhD Miloš Milovanović, Assistant Professor, Faculty of Organizational Sciences, University of Belgrade, Area of expertise: Information Technologies



5. PhD Maarten De Vos, Associate Professor, Department of Engineering, Institute of Biomedical Engineering, University of Oxford, Area of expertise: Biomedical Engineering



6. PhD Micaela Demichela, Associate Professor, Dipartimento Scienza Applicata e Tecnologia, Politecnico di Torino, Areas of expertise: Decision analysis in risk assessment, Environmental Safety Technique & Hygiene and safety at work



Kragujevac,
May 2016.