

DEVELOPMENT OF REAL TIME WELDER MONITORING SYSTEM USING WEARABLE SENSORS

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SUMMARY

This thesis presents a study of potential application of wearable sensors installed within with accelerometer, gyroscope, and magnetometer to monitor and control the wrist hand motion of manual welders to improve the productivity performance of skill welders in shipbuilding industry.

It is a fact that many countries still have human resources who are willing to be skilled welders and use manual welding process in the steel construction project including shipbuilding beside the other countries have difficulties in providing skilled welders that are driven to use automation and robotic welding. To some extent, the use of manual welding process is preferred because of low investment and may overcome unemployment problems. However, some weaknesses of manual welding process in terms of low productivity and producing quality of weldments shall be continuously improved using cost-effective available technology instead of high-cost complicated technology. This idea has motivated to study the use of available wearable sensors for monitoring and controlling the wrist hand motion of welders to maintain the productivity and quality of weldment.

The idea of wrist hand welder motion-based monitoring system aims to alleviate the complexity of variables during in-process welding while the other input and output variables are maintained to be constant by reference to the welding procedure specification (WPS). These variables are torch speed, tip distance, weaving technique, angle of electrode that are manipulated manually by hand welders. The implementation of the concept delivers a new approach in addressing the problems. A thorough wrist-hand motion analysis is carried out during laboratory experiment to identify potential aspects that can be monitored and controlled to maintain the productivity performance of welders and resulting weldment quality.

The methodology framework incorporates analysis of wrist hand motions to classify and to recognize the various welder activities and applied skill levels of welders, data acquisitions by smartphone and wearable sensors, video analysis and hand motion recognition analysis using three machine learning (ML) techniques, namely Support Vector Machines (SVM), Multilayer Perceptron (MLP) and Deep Learning Convolutional Neural Network (CNN) Long Term Short Time Memory (LSTM). When the SVM and the MLP used, raw data acquisitions are in the form of time series signal can then be processed by extracting certain features of signals to identify typical pattern of wrist hand motion during process of manual metal arc welding. The CNN-LSTM network has specific layers functioning for extracting features from raw data. Using algorithms of the Supervised ML is made possible to train a known input and output data to

predict or classify future outputs.

First experiments are focused on the identification of typical wrist hand motion signals that are reflecting several welder activities such as preparation, grinding, real welding of three butt welding position: flat, horizontal, and vertical. Second experiments are conducted to identify some typical hand motion of welders that can represent discontinuities of hand motion signal because welders experiencing fatigue, and less focus such that lowering their skills. Third experiments are performed to classify various grade levels of hand motion skills applied by a welder. If the applied skill level of a welder can be monitored and maintained during welding process may increase productivity and quality at the same time. Finally, a prototype of implementation of the proposed system to monitor and to control the productive performance of welders and related weldment quality is presented to evaluate its practical application.

The thesis consists of seven chapters, and the outline is described as follows:

Chapter 1 presents a brief introduction of the research topic, which is the overview of evolution welding process development led to the need of real time welder monitoring system. This chapter also describes the research motivation, objectives, and main contributions of publications throughout this research.

Chapter 2 describes in detail the historical review of the shipbuilding welding process development. It starts with some basic theory of welding process, and the present development toward robotic technology to replace welders in modern countries to overcome the scarcity of skills welders and the use of welding simulation using the present advances in virtual reality (VR) and augmented reality (AR) technology to increase the effectiveness of welder training. However, these two developments are still considered expensive especially in countries with sufficient skill welders. In the end of this chapter, the need of real time monitoring system based on wearable sensors and the artificial intelligence are highlighted to improve productivity of skill welders.

In Chapter 3, experiences from earlier cases and information background from literature research on the development real time monitoring of activities in the use of wearable sensors and activity recognition using the AI techniques implemented in other activities are presented.

According to the results, a framework for welder activity monitoring system and recognition is introduced in Chapter 4. This chapter explores the experiments, analysis, data processing and data training and testing using the three machine learning techniques that are required to study the use of wearable sensors and the ML techniques for real time monitoring of wrist hand motion of welders in shipbuilding process.

Chapter 5 presents the application of the proposed approach to monitor the welder performance in real time. In this case, the skilled welder performance includes skill acquisition during the basic welding training, and finally to characterize the performance of professional welders to Un-Qualified (UQ) and Qualified (Q) welders or qualified welders executing the welding process under their performance.

Chapter 6 outlines a formulation of critical issues and further experimental works that must be done toward the practical implementation of the proposed system.

Finally, Chapter 7 presents the conclusions and recommendations for future research direction.