Conceptual design of real time and adaptive measure of mental workload using galvanic skin respond

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Abstract. Mental workload, defined as difference between task demand and mental capacity of the worker, is crucial in providing effective mental workload that ensure productivity and safety of the worker. Thus, mental workload measures are crucially important. Besides requirements of mental workload measures that must be sensitive, diagnostic, non-intrusive, ease to implement, and acceptable; recently, there is another important requirement of the mental workload measure that is adaptive and real time. Purpose of this paper is to describe conceptual design of real time and adaptive measure of mental workload using galvanic skin response. Implication of the proposed conceptual design in discussed.
Keywords: real time, adaptive, mental workload, galvanic skin response

1. Introduction

The rapid growth of information technology and information system in daily life and work environment has changed to nature of work from physically to mentally demanding task. In the end it raised the need to take into account cognitive or mental workload, defined as the differences between cognitive demand of the task and capacity of the human [1] or mental capacity used during completing task [2], in order to ensure optimal performance of human.

There are criteria for mental workload measures. O Donnel and Eggemeier [2] stated five criteria for assessing the mental workload measures that are sensitivity (refers to the capability of measures to reflect changes in workload), diagnosticity (refers to the ability to identify changes in workload and the cause of these changes), intrusiveness (refers to the extent to which a measure interferes with normal task performance), ease of implementation (refers to easiness of implementation due to practical reason) and acceptability (refers to the degree of approval and acceptance by participants). In addition, Eggemeier et al. [3] proposed two additional criteria namely validity (refers to the ability to reflect the concept of mental workload only, not reflect other concept) and reliability (refers to the consistency of mental workload measures).

There is a body of literature describe the measurement of mental workloads that are performance measures, objective measure (based on physiological indices), and subjective measures (based on perceived load of human). Performance measures was conducted based on reaction time and error. Phsyiological indices include heart rate variability /HRV [4], Galvanic Skin Response/GSR [5], eye blink rate [6] and such advances of brain activity measures for example electroencephalogram (EEG) and functional magnetic resonance (fMRI [7]). Subjective measures includes the NASA-TLX [8,9] and the RSME [10].

It is worth noting that both objective and subjective mental workload measures mentioned above are conducted during and after the task has been completed and the more important thing is that the analysis of the result of the measures are conducted after the completion of the task. Considering that providing optimal mental workload should be conducted in real time condition, there is an urgent call of the need of real time measurement of mental workload.

In addition, there is also one new requirement for mental workload measures that is adaptive. Adaptive measures of mental workload is crucial to keep the workload in appropriate levels in order to avoid conditions of under-load or over-load, so that overall performance and safety of human can be enhanced [11]. Furthermore, in relation between adaptive and system, Djiksterhuis [12] stated that a system should adapt based on critical event driven, performance driven, and physiological driven.

In Indonesia, the need to measure mental workload is increasing recently, in particular in line with the use of technology and information technology that makes the job in industries more and more mentally demanding. Coupled with the fact that mental workload measures are influenced by factors such as culture [13], it is worth noting to develop mental workload measures that fulfill all criteria mentioned above (in particular real time and adaptive criteria) and suit with Indonesian condition.

This paper is aimed to describe conceptual design of real time and adaptive mental workload measures to be used in Indonesia. Some criteria and feasibility of the measures were described. Since subjective mental workload is culturally biased when used in Indonesia, objective measures were used as a base in developing real time and adaptive measures of mental workload in Indonesia.

2. Method

To be effectively used in Indonesia, price has been considered as an important factor. Such objective mental workload measures are high cost, for example Electroencephalograph (EEG) and Magnetic Resonance Image (MRI). In contrast, such objective measures are cost effective, for example Heart Rate Variability (HRV) monitor, Galvanic Skin Response (GSR), and eye tracker. A series of experiments was conducted before reveals that HRV, GSR, and eye blink rate has similar sensitiveness in detecting mental workload. Due to its practical in both laboratory and industrial application, the GSR was chosen as a basis of development of real time and adaptive mental workload measures.

As described in Widyanti et al. [5], GSR is a form of Electrodermal Activity (EDA) that is capable of detecting electrical changes in the skin caused by external stimuli [13]. The underlined process in GSR measure is that several layers in human skin consists of layer called epidermis which has a thick layer consisting of dead cells that result in high resistance of the skin. When the skin produce sweat, which contains about 0.3% salt NaCl, skin resistance will decrease [17]. This is because NaCl is an electrolyte and a good conductor, therefore the NaCl will leads to increased skin conductance. Since sweat glands are concentrated in the palms of the hands therefore the GSR measurements are usually performed at the palms. The GSR measure can be seen in Figure 1.

Figure 1. The GSR measure

3. Result
The conceptual design begin with analysis of the result of the GSR as can be seen in Figure 2. The development process is started by feature extraction of GSR data. Artefact removal and filtering are applied to get data that are clean from noise. After the extraction, norm of low, medium, and mental workload is proposed based on combination of previous experiment both using subjective and objective measures. The adaptive algorithm is developed based on detection of mental workload classification. Feedback mechanism is given when low or high mental workload level is achieved.

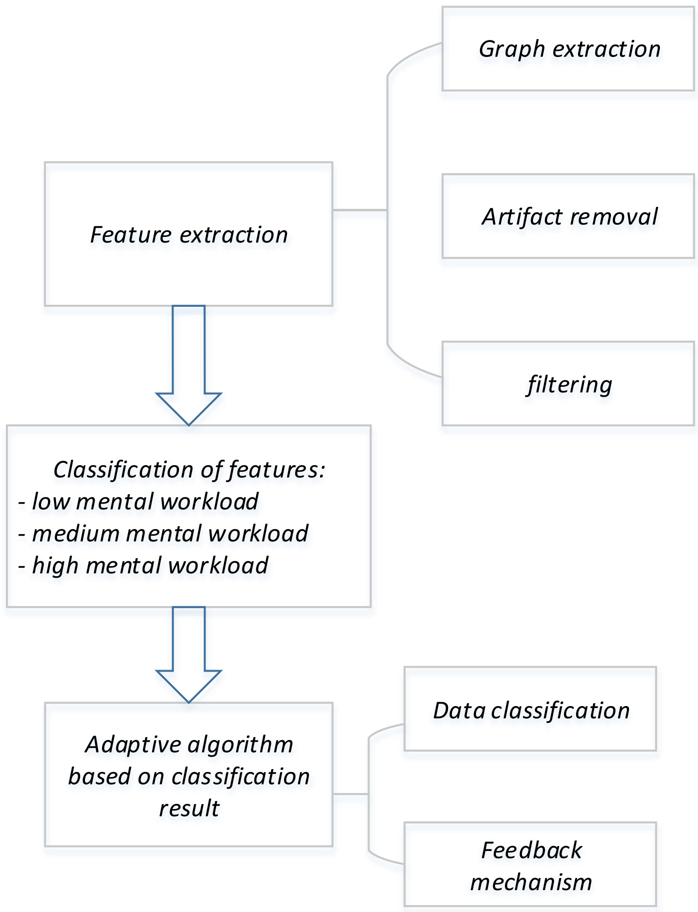

Figure 2. The conceptual design of real time and adaptive mental workload measures

Effectiveness of the proposed design will be assessed in a series of experiment. The designed adaptive measures will be activated when workload level was overload or underload.

4. Discussion
This paper is aimed to describe conceptual design of the development of real time and adaptive mental workload measures based on GSR. The design process is started with filtering data and is continued with classifying the norm of low, medium, and high mental workload. The proposed conceptual design will be implemented in the form of prototype. The effectiveness of the proposed design will be evaluated based on the success of mental workload detection and feedback mechanism.

The proposed conceptual design as well as the prototype that will be developed based on the conceptual design will be valuable in providing mental workload measures, which in the end can be used as a tool in providing optimal mental workload that enhance performance and safety of the worker.

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