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WEB-BASED BIOMETRIC MOUSE INTELLIGENT SYSTEM FOR ANALYSIS OF EMOTIONAL STATE AND LABOUR PRODUCTIVITY

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ABSTRACT

This paper describes the Web-based Biometric Mouse Intelligent (WBMI) System developed by the authors for measuring and analysis of user's emotions and labour productivity with a biometric mouse. The research included development of the WBMI System, which works in the background and is able to assess user's emotional state and labour productivity during work with a computer. The system captures information about user's emotional state and labour productivity using three main biometric techniques: physiological (skin conductance, amplitude of hand tremble, skin temperature), psychological (e-self-reports) and behavioural/motor-behavioural (mouse pressure, speed of mouse pointer movement, acceleration of mouse pointer movement, scroll wheel turns, right- and left-click frequency). The system extracts physiological and motor-behavioural parameters from mouse actions and palm characteristics, and the user fills in the psychological (e-self-reports) data, which can be used to analyse correlations with user's emotional state and labour productivity. Main features of the WBMI System are discussed, and the final recommendations for future research and improvement are included.

KEYWORDS

Biometric Techniques, Web-based, Biometric Mouse, Intelligent System, Emotional and Labour Productivity Analysis, Subsystems, Historical Information

1. INTRODUCTION

Mouse actions of interest include general movement, drag and drop, point and click, and idle time. Such actions can provide a set of features, for example, the average speed against the distance travelled, and the average speed against the movement direction [1, 2]. Pusara et al. [17] describe a feature extraction approach in which they split the mouse event data into mouse wheel movements, clicks, menu and toolbar clicks. Click data is further subdivided into single and double click data. Gamboa et al. [5, 6]

have tried to improve accuracy of mouse-dynamics-based biometrics by restricting the domain of data collection to an online game instead of a more general graphical user interface environment. As a result applicability of their results is somewhat restricted and the methodology is more intrusive to the user. The system requires around 10-15 minutes of devoted game play instead of seamless data collection during the normal human-computer interaction. As far as the extracted features, x and y coordinates of the mouse, horizontal velocity, vertical velocity, tangential velocity, tangential acceleration, tangential jerk and angular velocity are utilized with respect to the mouse strokes to create a unique user profile [5]. Expanding on the idea of monitoring user's keyboard and mouse activity, Garg et al. [7] developed a system for collecting Graphical User Interface (GUI) interaction based data. Collected data allows for generation of advanced behavioural profiles of the system's users. Such comprehensive data may provide additional information not available from typically analysed command line data.

There are also a few existing projects dealing with motor behaviour in human-computer interaction, e.g. the analysis of mouse clicking behaviour after frustrating events during a computer task [19], where 4 distinct patterns of mouse clicking could be determined or the visual comparison of mouse movement patterns on an e-commerce site performed for user modelling [10].

There has been increasing interest in human-computer interaction research in building emotionally intelligent interactive systems that can express and respond to human emotions [14]. One of the challenges in building emotionally intelligent systems is the automatic recognition of affective states. Humans use different sources of information to assess a person's emotions, including causal information context and individual traits, as well as information on the person's recognizable bodily reactions. For a computer system, some of this information is difficult to access, e.g. the person's traits, and it is even more difficult to assess all the multifaceted information and to integrate it to a complete image of the users affective state. Nonetheless, there has been extensive research in the field of affect measurement that can be roughly grouped into three areas: physiological, behavioural and psychological approaches [24].

The article describes analysis of emotional state and labour productivity using the Web-based Biometric Mouse Intelligent (WBMI) System. If a system knows how its users feel, it can react to these moods appropriately and present concrete recommendations. The present research facilitates user's emotional and labour productivity analysis by detecting mouse micromotions and physiological characteristics of a palm, as well as by analysis of self-reports of each individual user.

2. EMOTIONS AND THEIR MEASUREMENT METHODS

Emotion is the transient psychological, physiological and behavioural response to thoughts, events and social activity. A typical classification of emotions might be the following primary families: anger/annoyance; fear/anxiety; sadness/loneliness; disgust/shame; surprise/shock; pleasure/joy; love/friendship. These feelings arise from neural excitement triggered by perception, cognition or memory. The emotional brain is the limbic system, including its functional compartments: thalamus, hypothalamus, hippocampus, amygdala and pituitary gland [22]. Emotions also can be defined as feelings such as happiness, sadness, anger, elation, irritation, etc. The specific definition of emotion is difficult to qualify as it is a completely subjective experience [18]. Diverse writers have proposed that there are from two to twenty "basic emotions" [16], such as joy, fear, love, surprise, sadness, etc.

Three main biometric techniques can be used to measure emotions: physiological, psychological and behavioural. A physiological trait tends to be a more stable physical characteristic, such as finger print, skin conductance, hand silhouette, heart rate, blood vessel pattern in the hand, blood pressure, respiration, face or back of the eye, electroencephalography or muscle action. A behavioural characteristic is a reflection of an individual's psychology.

Physiology is the study of the mechanical, physical, and biochemical functions of living organisms [23].

Physiological means of or relating to physiology, the science that studies the function of the body and the vital processes of living things [13]. Physiological signals such as skin conductance, heart rate, blood pressure, respiration, pupillary dilation, electroencephalography (EEG) or muscle action potentials can provide information regarding the intensity and quality of an individual's internal affect experience [24].

Psychology is an academic or applied discipline involving the scientific study of mental processes such as perception, cognition, emotion, personality, behaviour, and interpersonal relationships [23]. Self-reports are widely used and still serve as a primary method for ascertaining emotion and mood. There exist literally dozens of affect inventories: verbal descriptions of an emotion or emotional state, rating scales, standardized checklists, questionnaires, semantic and graphical differentials or projective methods. Many of these methods are based on the dimensional model of affect [24].

Behavioural is an expectations of how a person or persons will behave in a given situation based on established protocols, rules of conduct or accepted social practices [3]. Behaviour refers to the actions or reactions of an object or organism, usually in relation to the environment. Behaviour can be conscious or unconscious, overt or covert, and voluntary or involuntary. Human behaviour can be common, unusual, acceptable, or unacceptable. Humans evaluate the acceptability of behaviour using social norms and regulate behaviour by means of social control [23]. There exists a broad field of behavioural methods for the measurement of affect: facial expressions, voice modulation, gestures, posture, cognitive performance, cognitive strategy, motor behaviour (e.g. hand muscles, head movement), etc. Behavioural measurement methods are based on the fact that the body usually responds physically to an emotion (e.g. changes in muscle tension, coordination, strength, frequency) and that the motor system acts as a carrier for communicating affective state [24]. Different methods (voice stress analysis, face recognition, etc.) are used in practice.

Our research included all three methods (physiological, psychological and behavioural).

The afore-mentioned methods can be analysed in more detail according to goals, objectives and activities of stakeholder groups. For example, as described in [8], there are three main keystroke analysis methods for the purposes of identity verification. These are fuzzy logic, neural networks and statistical techniques as well as combinations of these approaches. As shown in [8], of all the approaches statistical methods prove to be the most accurate. The statistical methods used can vary from comparing the digraphs of the entered text to the digraph means in the template, to classification methods, such as Bayes Classification algorithms [15] that use probability density functions. Using neural networks can prove effective but have the fundamental limitation that the networks require to be retrained each time that a user is added to the database [12].

3. LABOUR PRODUCTIVITY

Labour productivity is output per worker or worker-hour. This will vary as a function of both other input factors and the efficiency with which the factors of production are used. Labour productivity can be defined and measured in different aspects [23]: the intensity of labour-effort, and the quality of labour effort generally; the creative activity involved in producing technical innovations; the relative efficiency gains resulting from different systems of management, organisation, co-ordination or engineering; the productive effects of some forms of labour on other forms of labour. These aspects of productivity refer to the qualitative, rather than quantitative, dimensions of labour input. Management may be very preoccupied with the productivity of employees, but the productivity gains of management itself might be very difficult to prove. Modern management literature emphasizes the important effect of the overall work culture or organisational culture that an enterprise has. But again the specific effects of any particular culture on productivity may be unprovable [23].

The factors affecting labour productivity or the performance of individual work roles are of broadly the same type as those that affect the performance of manufacturing firms as a whole. They include: (1) physical-organic, location, and technological factors;

(2) cultural belief-value and individual attitudinal, motivational and behavioural factors; (3) international influences – e.g. levels of innovativeness and efficiency on the part of the owners and managers of inward investing foreign companies; (4) managerial-organizational and wider economic and political-legal environments; (5) levels of flexibility in internal labour markets and the organization of work activities – e.g. the presence or absence of traditional craft demarcation lines and barriers to occupational entry; and (6) individual rewards and payment systems, and the effectiveness of personnel managers and others in recruiting, training, communicating with, and performance-motivating employees on the basis of pay and other incentives [11].

4. WEB-BASED BIOMETRIC MOUSE INTELLIGENT SYSTEM

Web-based Biometric Mouse Intelligent (WBMI) System consists of seven subsystems:

- Data Capture and Collection Subsystem;
- Feature Extraction Subsystem
- Database Management Subsystem;
- Model-base Management Subsystem;
- Equipment Subsystem;
- e-Self-reports Subsystem;
- Graphic Interface.

The Data Capture and Collection and the Equipment Subsystems are briefly analysed below as examples.

The Data Capture and Collection (DCC) Subsystem captures data when a user starts using the biometric mouse for accomplishing his/her tasks. Each time the user clicks and moves the mouse the DCC Subsystem collects the biometric mouse movement and click data. When the WBMI System is working, the DCC Subsystem is recording user's biometric data constantly. The data collected by the DCC Subsystem is stored in a .csv file and contains the different data for each user (see Fig. 1).

Our research identified several features (see Fig. 1), which can be used to create a user's emotional state and labour performance model. Figures 2 through 4 show the graphic results of biometric mouse pressure, palm skin temperature and palm humidity measurements by minutes captured within one hour.

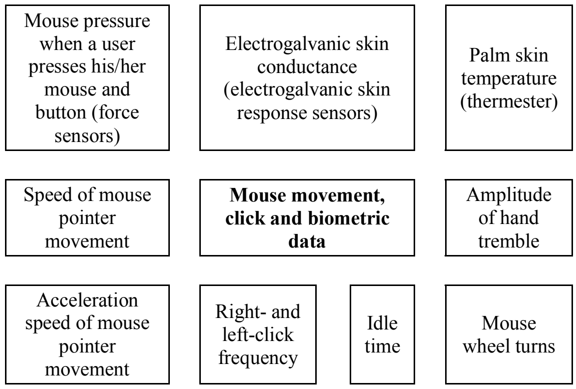

Figure 1. A set of user data captured using a biometric mouse

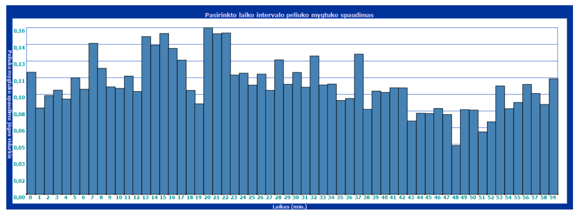

Figure 2. Diagram of biometric mouse pressure when a user presses his/her mouse and button

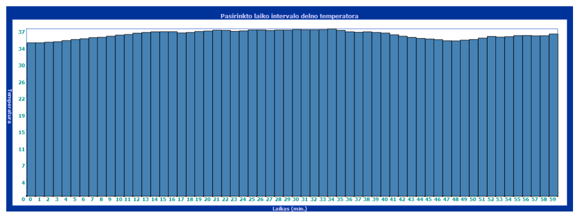

Figure 3. The results of palm skin temperature measurements within one hour

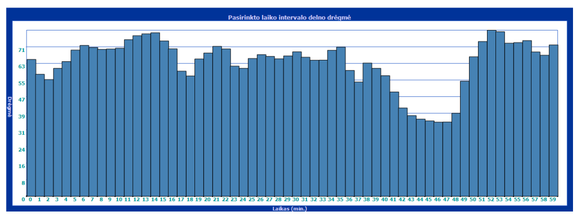

Figure 4. The result of palm skin humidity measurement within one hour

The standard mouse of type RX-1000 (Logitech) was modified for detection of emotional state of users and students. Four sensors were embedded into the mouse. Humidity and temperature sensors were mounted in the rearward side of mouse to control the temperature of palm and sweat of palm respectively. One force sensor was mounted in the left sidelong part of mouse to measure the force acted by the thumb. The other force sensor was mounted in the left button of the mouse to measure the force acted by the finger to this button (Figure 1).

The capacitive humidity sensor with DC voltage output and 20-100 percent relative humidity measurement range of type 808H5V5 (Sencera Co. Ltd., Taiwan) [9] was used in the mouse. The temperature sensor of type TC1047A (Microchip Technology Inc., USA) was used similarly. The TC1047A is a linear output temperature sensor whose output voltage is directly proportional to measured temperature [21] (see Figures 3 and 4).

The pressure sensors of type HSSF015 (Hope Microelectronics Co. Ltd., China) [20] were modified to measure the force. The design of force sensor is shown in Fig. 5. The pressure sensor HSSF015 which consists of silicon chip 1, FR4 epoxy fibreglass carrier 2, with contact pads 3, metallic cap 4 and protecting gel 5, was supplemented by plastic tube 6 and external plastic plate 7. This plate was fastened by means of silicon rubber 8 to the tube 5. When the finger acts on the external plate, it moves epoxy layer 9 and acts the silicon chip through the gel. It was found out that the force sensor of such design has linear characteristic up to 4 N.

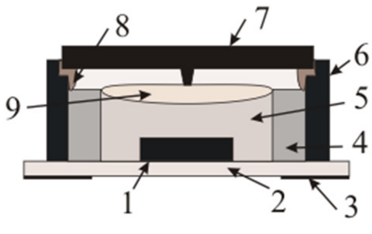

Figure 5. Design of force sensor

USB connection provided all the sensors with a voltage of 5 V DC. The signals of these four sensors were conditioned and the sensor-computer interface was realized by use of 8-bit architecture microcontroller PIC18F2458 (Microchip Technology Inc., USA) with 12-bit Analog-to-Digital Converter [15].

The signals from pressure (force), temperature and humidity sensors were read by microcontroller PIC18F2458 with internal 12-bit ADC. After reading signals, the microcontroller calculates pressure (force), temperature and humidity values and sends the data to the computer through USB port. The microcontroller is connected to the computer through USB hub, which multiplexes data from microcontroller and mouse IC to one channel, so the mouse can have only one USB cable for both sensors and mouse. USB communications are realized using virtual COM port emulation, so the application can send commands and receive data thought this virtual COM port.

To start reading data from the sensors, the application must send the following command to the selected virtual COM port: d[Delay]CR. Here [Delay] is the delay between sensor data readings in milliseconds, CR - Carriage Return code in ASCII table (0D in hexadecimal format). For example, d250CR - start reading data with 250 ms delay before each next reading (4 times per second). For testing purposes this device can be run through Hyper Terminal programme. Here we need to write command d[Delay] and hit the Enter key, because the Enter key sends the CR symbol. The application must send the letter “s” to stop data transmission.

The format of returned data is as follows: [Pressure1], [Pressure2], [Temperature], [Humidity] LF CR. Here LF is Line Feed code in ASCII table (0A in hexadecimal). LF and CR codes are needed for correct data formatting in HyperTerminal programme.

5. CONCLUSIONS

The article describes the analysis of user’s emotional state and labour productivity using the Web-based Biometric Mouse Intelligent (WBMI) System. If a system knows how its users feel, it can appropriately react to these moods and present concrete recommendations. The present research facilitates user’s emotional and labour productivity analysis by detecting mouse micromotions and physiological characteristics of the hand, as well as by analysis of self-reports of each individual user. A set of user data characterizing a particular way of mouse manipulation is captured and processed. The set of data is then compared with the information in the database comprising micromotions, physiological characteristics of the palm and the self-reports to determine the emotional state and labour productivity of a particular user. It is planned to integrate the WBMI System with other operating Voice and IRIS analysis intelligent systems developed by the authors. Such integrated solution of intelligent systems would create better conditions for assessment of user's emotional state and labour productivity and to provide specific recommendations.

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