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Workplace monitoring of employee health using the workstation PC as a platform

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Abstract— **A country's biggest asset is its workforce, given the fact that a healthy workforce can contribute to rapid growth of the economy. Chronic illnesses reduce productivity, are responsible for rising healthcare costs, and should be managed by the employer to reduce healthcare expenditures. This can be done through employee health and wellness programs, and well-designed health management initiatives. In addition, new information and communication technologies make it possible to monitor employee health with wearable devices and tele-health assisted surveillance techniques. This paper introduces a unique new approach to workplace healthcare monitoring, using the office workstation PC itself to monitor worker health. The main benefits are: reduction in the number of visits to the doctor during office hours; reduced dependency on institutionalized health setting such as hospitals for check-ups; and prior knowledge of worsening symptoms, thereby leading to timely cure rather than last minute hospital visits, nursing home admissions, all of which result in lesser sick leaves, and more productivity per employee.**

I. Introduction

The work force is the back-bone to a country's economy, as it contributes significantly to its overall GDP growth. Ensuring employee health therefore plays a determining role in ensuring that productivity remains at satisfactory levels. It is believed that the average American employee suffers from at least one chronic disease during their lifetime (Figure 1), causing an impact on working capacity and sometimes leading to forced resignation. These diseases such as COPD, diabetes, epilepsy, Parkinson's pose a major danger to employee health and are a cause of concern for employers, because earnings depend directly on a healthy working force. Ways to reduce the impact of chronic diseases is a major research topic today with scientists trying to find solutions which if implemented can improve industry earnings by bettering employee health outcome and quality of life. This however, requires that the preventive model be favored over the current curative model to healthcare, which relies on institutionalized form of care-giving in hospital beds, clinics, nursing homes etc. The preventive model means bringing health care infrastructure directly to the office without necessarily requiring the same level of financial investments, as is in traditional system. Previous work in this field has yielded several solutions with algorithms that enable them to pre-detect the likelihood of an emergency health situation. Furthermore, these systems most often exhibit extra capabilities of being able to alert first responders.

Some examples of such systems are: the smart shirt developed by Sriraam et al. [1] which relies on sensors embedded on the wearable shirt to pick up vital signs such as ECG, respiratory signals and temperature from the patient's body or the CHRONIOUS system developed by researchers at University of Barcelona, funded by the European Union, as part of a project which uses a smart wearable platform to monitor patients suffering from conditions such as Chronic Order Pulmonary Disease (COPD), Chronic Kidney Disease (CKD) [2]. Other such systems include the one developed by Jin Jang et al. which provides health wellness services for the elderly and terminally ill, and also runs a separate early warning system to report the decline in health status [3]. Also, Bonato et al. discuss the new era of resulting out of an effort to merge home robots and wearable technology together to monitor patient's health status in their work [4]. None of these technologies are ideally suited to employee monitoring at the workplace due to several reasons. None capitalize on ergonomics or ease of usage, and many are too bulky to carry around as a whole system. Some require the patients to wear them continuously, often leading to skin irritation or discomfort, and in some extreme cases stigmatization, as the patient feels he is easily distinguishable when in the crowd. As such, new generation monitoring devices are required to have small form factor and reduced power consumption, yet be able to run for longer duration on rechargeable batteries - thus eliminating the need to have them charged always or carry the charger adapter around. Also, these devices should be made by embedding health monitoring functionalities into already existing appliances and gadgets which the user is likely to use in their day to day lives - such as remotes, smart phones, smart tablets etc. This work proposes such a solution by aiming to use the workstation (laptop or desktop) as an in-office monitoring system, a custom made mouse acting as a sensor hub, and a software application.

The proposed solution offers following benefits:

Benefit for employees: missed appointments are minimized, transportation costs reduced, less money spent on emergency visits to hospitals, or costly medication.

Benefit to the employer: reduction in sick leaves, productivity/ employee increases, and employee well-being goals achieved. Finally financial losses minimized, healthy workplace.

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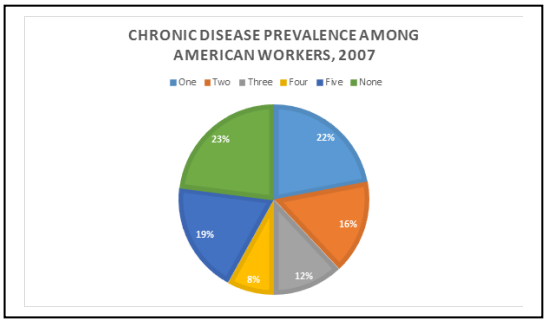
Apart from the main targeted benefits of the system, there are additional benefits. One can attend to multiple patients simultaneously, without being physically present at all locations, resulting in efficient operation and possibly increased earnings. Family members of patients can relax and log in to the system anytime in order to view patient info using the phone or desktop app.

Figure 1: Prevalence of chronic diseases in the American workforce – 2007



(Source: U.S. Workplace Wellness Alliance [5])

The remaining portion of the paper is organized as follows: Section II provides an insight to the system architecture, Section III provides details of the system working, Section IV discusses the need for a system like this and the benefits and possible and also concludes the work.

II. SYSTEM ARCHITECTURE

Figure 2 illustrates the system which consists of following modules: Data Collection (DC) Module (Hardware), Data Processing (DP) Module (Software), Data Storage (DS) Module (Software), Decision Support System (DSS) (Software), Data Presentation and User Interaction (DPIU) Module (Software). Apart from this, there are two layers: ENC/ DEC and SEC to enforce data security.

A. Data collection module

This is the only hardware module and consists of a mouse, physiological sensors which measure– temperature, pressure, pulse rate, and SpO2.

The computer mouse provides a convenient interface for the collection of physiological data, while the worker completes their normal tasks. The computer mouse offers at least two advantages for this application: 1) Proximity to hand and surrounding areas to which the above mentioned sensors can plug into to tap vital patient data. 2) Less complicated to use compared to a new-in-the-market complicated-to-learn health gadget. The mouse attaches to the computer and communicates with it through the USB interface. This mouse requires an off the shelf microcontroller board such as Texas Instruments Launchpad or Arduino Uno. These boards come with software libraries which allow them to be turned into working Human Interface Devices or HIDs. The communication between the PC and the sensor hub occurs over a USB interface, and shall be one of the two types:

1) **Command messages**: intended to issue commands to the HID

2) **Data messages**: contain raw patient data, related to one of the following: Spo2, temp, pressure, pulse rate.

B. Data processing module

This module is entrusted with performing multiple tasks of filtration, extraction, conversion.

- **Filtration**: Clear raw data of 'noise' and redundancy.
- **Extraction**: Derive meaningful and useful pattern from data.
- **Conversion**: Convert data into an understandable format such as JSON, XML for easy, reliable and efficient inter-change between modules. These formats are also easily understood by the presentation layer, and by the graphic and visualization algorithms.

C. Data storage module

This module stores two kind of data:

1) User related info which is further sub-divided into: a) user profile b) who can access patient data and c) in what roles

2) Patient's processed health data.

User related information enters this module through the interaction between a user and interaction module, whereas processed patient data comes directly from the decision support module. The database used for this purpose could be relational, non-relational or cloud based depending upon the requirement. Examples of traditional databases include: MYSQL and SQL while No-SQL databases like Mongo DB which make it easy to store and retrieve machine generated data can also be used for the purpose. Furthermore, cloud based databases such as Amazon WS, Google Cloud SQL, and Microsoft Azure provide scalable data storage and can be used only when large number of patients are involved, and the data space requirement is expected to grow rapidly. However while using any of these it should be remembered that, health data should be kept confidential hence, extra care must be taken to encrypt/ decrypt it before every storage/ retrieval process, in accordance with HIPAA/ HITECH security policies. The security (SEC) and encryption/ decryption (ENC/ DEC) layers take care of this requirement.

D. Decision support system

This module has three threads running simultaneously:

(Thread 1) collects incoming data from data collection module, and pushes it to data processing module; (Thread 2) collects processed data, checks for anomalous conditions, informs alarm generator module if something is wrong and (Thread 3) Collects processed data, passes to data storage module.

In case of emergency only (Thread 2) is performed because (Thread 3) is not required.

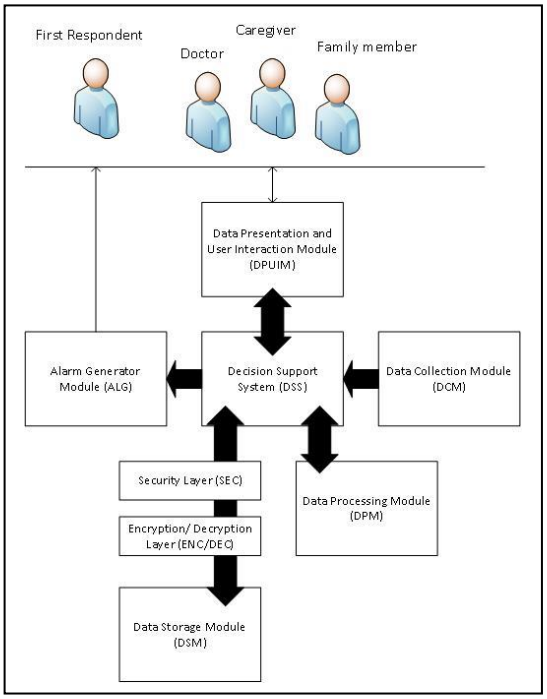


Figure 2 System module diagram

E. Data Presentation and User Interaction Module

The two most important functions which this module performs are: enable user interaction and, present data to the user.

User Interaction: interaction can be in two ways, user → system: obtaining user related information through web-forms, permitting the user to communicate with the patient by writing an electronic prescription, sending an email or note over the internet. Or it can be system → user: emails, phone calls, texts directed towards a single user or a group of users, during emergency situations, based on settings pre-configured into the system.

Data presentation: involves obtaining formatted data XML/ JSON and converting them into visual representations, to in-order to help the end-user interpret patient related data. The end user can be presented with Visual Representations such as charts, bar-graphs, real time feeds.

Data Presentation and User Interaction Unit can be a secure web app, running on a desktop or mobile version of web-browser such as Firefox Mozilla, Google Chrome or Safari.

F. Alarm Generator Module

This module is responsible for alerting first responders, or family members through phone calls, texts or emails when the patient requires urgent attention, during an emergency situation.

III. SYSTEM WORKFLOW

Figure 3 shows the system working and data flow as t is anticipated to occur between modules. The data collection module is responsible for collecting vital data. It consists of physiological sensors, connected to a mouse. A computer mouse provides a convenient host for the sensors that monitor vital signs. The sensors non-invasively collect and transmit data to the decision support system (DSS), which is part of a larger application running in the PC workstation. DSS is the core of the whole system, and capable of taking various decisions in real-time. The incoming data from Data Collection Module (DCM) is fed to DSS which in turn passes the raw data to Data Processing Module (DPM). After this, stage, the processed 'useful data' makes its way to the Data Storage Module (DSM), while the 'useless data' is discarded. The 'useful data' needs to pass through DSS during the previous step, mainly because DSS runs a separate thread to check for anomalous health situations. In the event, that an abnormal condition is detected, the DSS immediately calls, emails, or texts emergency responders and/ or family members via the Alarm Generation Module (ALG). If everything is normal, another thread running on the DSS pushes the cleaned data to Storage Module for back up. This Data Presentation and User Interaction Module (DPIU) use stored data to present bar graphs, charts, to the end-user, or to send auto-generated health reports to the doctor or patient family member.

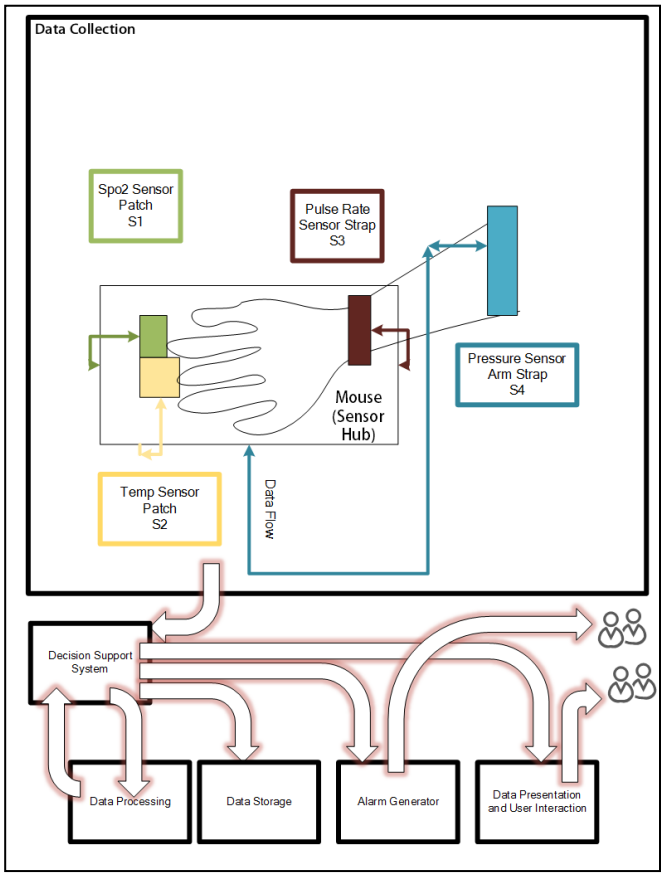


Figure 3. System Workflow Diagram

IV. Conclusion

The proposed solution enables workplace health status monitoring, potentially reducing the impact of chronic diseases in office environments by utilizing the office workstation PC itself so it becomes a powerful health monitoring system. The main benefits are: reduction in the number of visits to the doctor during office hours; reduced dependency on institutionalized health setting such as hospitals for check-ups, advanced knowledge of worsening symptoms, leading to timely cure rather than last minute hospital visits. Together these will result in fewer sick leaves, and more productivity achieved per employee contributing a healthy work environment, minimized revenue losses for the companies, maximized overall output, and improved health outcome for the employees, all with minimum impact on their day-to-day activities.

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