Chapter 29
Recent Advances in Minimally-Obtrusive Monitoring of People's Health

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ABSTRACT

Monitoring people's health is useful for enhancing the care provided to them by others or self-management of health. This article is a survey of the latest research on monitoring parameters indicating a person's current health or having potential to affect the person's health in future, using various physical sensors. These sensors include accelerometers, gyroscopes, electromyography sensors, fiber optic sensors, textile electrodes, thermistors, infrared sensors, force sensors, and photo diodes. The health parameters monitored include heart rate, respiration rate, weight, body mass index, calories burnt, pressure distribution, diet, blood pressure, blood glucose, oxygen saturation, posture, duration of sleep, quality of sleep, hand movement, body temperature, skin conductance, exposure to ultraviolet light, adherence to medication-intake schedule, gait characteristics, and steps taken. The population monitored includes elderly people, miners, stroke survivors, osteoarthritis patients, people suffering from anorexia nervosa, obese people, people with Parkinson's disease, people having panic attacks, and wheelchair users.

INTRODUCTION

Monitoring parameters affecting or indicating people's health is important for several reasons. Automatically or semi-automatically monitoring lonely people with serious health problems can save lives by alerting their caregivers in case of an emergency. Monitoring other people can help in self-management of health. Major advances in monitoring people's health automatically or semi-automatically with physical sensors and algorithms using sensory data have occurred in the last ten years, in academics as well as industry, e.g. Jawbone, a company, offers multiple fitness trackers, and Textronics Inc. offers clothes with electronics that monitor the body. This paper is a survey of such advances reported in research articles. It does not cover research on monitoring people without using any physical sensor, like

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monitoring them only by reasoning over the information provided by them, like surveys filled by them, their posts on social-media accounts like those on Facebook or Twitter or information gathered about them during interactive sessions like computer gaming sessions or computerized tutoring sessions. It does not cover traditional monitoring like monitoring by medical staff when a patient is hospitalized. It does not cover systems that do not directly relate any of the monitored features to health parameters. There are a lot of systems which monitor comfort, safety, location, or physical activity without directly relating these to health parameters. This survey does not cover such systems. The survey covers different physical sensors used in monitoring health parameters, kinds of people monitored, and the health parameters that are monitored.

The work closest to this paper is (Pantelopoulos & Bourbakis, 2010a), which too is a survey of research on monitoring people's health. There are several differences between this survey and (Pantelopoulos & Bourbakis, 2010a). Pantelopoulos and Bourbakis (Pantelopoulos & Bourbakis, 2010a) survey wireless communication standards and propose sixteen criteria for evaluation of wearable health-monitoring systems (WHMSs). This survey does not have this material. The health parameters in this survey also include weight, diet, sleep, pressure distribution, adherence to medication-intake schedule, body mass index, and exposure to ultraviolet radiation which are not considered in (Pantelopoulos & Bourbakis, 2010a). Yet another difference between (Pantelopoulos & Bourbakis, 2010a) and this survey is that they focus on wearable health-monitoring systems and this survey also includes systems that humans do not wear (e.g. monitoring sleep based on patterns of smartphone usage (Chen et al., 2013)) as well as systems that have no contact with the body or clothing of the monitored human at all (e.g. medical mirror for estimating heart rate (Poh et al., 2011)). Another work close to this survey is (Pantelopoulos & Bourbakis, 2010b). (Pantelopoulos & Bourbakis, 2010b) is not a survey. One of its contributions is a mapping from many health parameters to detectable health symptoms. They also classify health parameters as measurable and non-measurable, e.g. their set of non-measurable parameters includes consciousness level. All health parameters in this survey are measurable, though some cannot be quantified with one number. Pantelopoulos and Bourbakis (Pantelopoulos & Bourbakis, 2010b) also propose *Prognosis,* which is a formal language for representing health parameters in order to support reasoning about them in order to derive more information about a person's health. Representations for supporting inference are outside the scope of this survey.

MONITORING MULTIPLE HEALTH PARAMETERS

Sun and others (Sun et al., 2014) report on a wristwatch prototype which records heart rate and skin temperature. A significant number of people working in information technology (IT) sector spend a lot of time using computers. Maria and Munipriya (Maria & Munipriya, 2011) report the following work-related health problems in this population: fatigue, back pain, upper-body pain, eye strain, hand or wrist pain, neck pain, watery eyes, redness or burning sensation or itching in eyes, and soreness in hand or arm. Posture, time spent in front of a computer without any break, brightness, contrast, positioning, height, and width of the monitor, and position of the computer user's chair are relevant to the health of IT professionals. A system for monitoring and evaluating gestures and postures of IT professionals using web cameras fixed to their desktops/laptops, and displaying warning messages on desktops/laptops is proposed in (Maria & Munipriya, 2011).