# Toward Emotional Internet of Things for Smart Industry

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***Abstract*—In this paper, an approach to design and implement non-invasive and wearable emotion recognition technologies in smart industries is proposed. The proposed approach benefits from the interconnectivity of Internet of Things (IoT) to recognize and adapt to complex negative emotional states of employees (e.g., stress, frustration, etc.). Two types of connected objects are proposed: *emotional detectors* and *emotional actors*. The steps to design and implement these connected objects are described. The proposed approach is expected to ensure and maintain a healthy work environment in smart industries.**

***Keywords–Emotion recognition; Internet of Things; Smart Industry.***

## I. INTRODUCTION

The proposed approach contributes to the development of new smart interfaces capable of adapting efficiently to users' emotions in the context of smart industries. Smart industry (also called Industry 4.0) is the current trend in which the industrial production, computing and communication technologies converge [1]. Smart industries are expected to increase operational effectiveness of employees as well as provide new services, new types of products, business models and reduction of pollution [2]. In order to work efficiently, smart industries must support interconnection of wireless devices, sensors, and people through the Internet of Things (IoT) [3]. Interconnected objects will provide new ways of collaboration between humans and machines in order to reach common goals in the manufacturing process. Studies have shown that the productiveness of employees are heavily influenced by their emotional states [4]. Negative emotions, such as stress, frustration and anxiety are strongly correlated with counter-productive work behavior [5]. Automatic emotion recognition could be an important requirement in smart industries in order to ensure and maintain the well-being of employees during the manufacturing process. However, despite recent advances in affective computing, emotion recognition in real-world conditions remains a challenging task. Existing sensors that can extract physiological signals associated to emotions (e.g., hearth rate (HR) [6], skin conductance [7], blood volume pressure [8], etc.) often require invasive technologies (e.g., electrodes), and hence may interfere with the users' production tasks. Smart interfaces could benefit from IoT devices in order to provide emotion recognition from employees using non-invasive and wearable devices (e.g., cameras, microphones, wearable hearth rate monitors, smartphones, etc.). These interconnected devices could be able to collect and exchange multi-modal signals associated with specific emotions of employees. Once a negative emotion is recognized, the interconnected objects can control actions to respond and adapt to this emotion in order to maintain a healthy working environment.

In this paper, a proposed approach to design and implement emotional IoT devices in smart industry is described. Section 2 reviews the state of the art regarding emotion recognition from non-invasive and wearable technologies. Section 3 describes the proposed approach. Conclusions and perspectives are discussed in Section 4.

## II. EMOTION RECOGNITION FROM NON-INVASIVE AND WEARABLE TECHNOLOGIES

A number of researchers in affective computing seek to recognize emotional states through the use of wearable and/or non-invasive technologies. Many of these technologies could be used in the context of industries or manufacturing tasks since they do not interfere with the user behavior. Recent advances in computer vision and speech recognition have led to the design of non-invasive systems capable of inferring user's emotions from voice [9], facial expressions [10], gestures [11], and body movements [12]. The advantage of these systems is that they do not require users to wear any sensors on their bodies since only cameras or microphones are needed. However, these techniques could not be precise under certain manufacturing tasks as they require users to face a camera (or a kinect) to recognize the emotion correctly. In addition, speech recognition systems require to isolate the user's voice from backgroung noise. The recent development of wearable computing devices has prompted a growing interest in using them for emotion recognition. Recent works [13] [14] have proposed intelligent wristbands including multiple sensors capable of acquiring physiological signals related to different emotions. Gao et al. [15] used wearable EEG headset technology to detect the brain's activity in response to different emotional states. Olsen et al. [16] showed that the accelerometer data recorded from a smartphone can be used to infer the user's emotional state. Despite many advances in emotion recognition through wearable and/or non-invasive technologies, few works have been interested in detecting more complex emotional states such as stress, frustration, depression, pain etc. In addition, most of the proposed approaches do not beneffit of the interconnectivity of these devices to improve the recognition accuracy. Finally, using emotion recognition technologies in the context of industries or real-world manufacturing tasks is still unexplored.

## III. PROPOSED APPROACH

The proposed approach consists in harnessing the interconnectivity of the Internet of Things to detect and respond to negative complex emotions of employees performing manufacturing tasks, thus ensuring a healthy working environment. In order to implement this approach, two types of connected objects are proposed: *emotional detectors* and *emotional actors*. *Emotional detectors* are wearable and/or non-invasive devices (e.g., cameras, microphones, wristbands, smartphones, etc.) capable of recognizing, in real-time, complex negative emotions (e.g., stress, frustration, anxiety, etc.) during the realization of several tasks involved in manufacturing processes. *Emotional actors* are smart systems or devices capable to respond properly to negative emotions of the employees. For example: adapting the difficulty of the task with respect to frustration levels of employees or activating stress management training systems installed in smartphones of employees. In order to design and implement *emotional detectors* and *emotional actors*, the following steps are proposed:

1) **Task identification:** manufacturing tasks inducing negative emotions will be identified. This identification can be achieved by applying psychological questionnaires to employees (e.g., anxiety scores [17]) before and after each task.
2) **Emotion induction protocols:** protocols capable of inducing identified negative emotions will be designed based on identified tasks. In these protocols, negative emotion-induction tasks will be similar to real-world manufacturing tasks.
3) **Multimodal data collection:** emotional induction protocols will be tested with a large population of employees. During these protocols, wearable and non-invasive devices will be used to collect multimodal data (e.g., physiological signals, video, audio, psychological questionnaires) from these employees.
4) **Analysis of emotional features:** multimodal data collected in the previous step will be processed and analyzed in order to find the most relevant features (e.g., facial expressions, body movements, hearth rate variability, etc.) associated with different negative emotions.
5) **Recognition of negative emotions:** the relevant features found in the previous step will be used to train machine learning models capable of reconizing negative emotions from different wearable and/or non-invasive devices.
6) **Emotional detectors:** wearable and non-invasive devices will be integrated into real-world manufacturing tasks. Wearable devices will be used by employees while non-invasive devices will be located in specific positions where they will capture data from employees. Each device will integrate a computer system capable of extracting relevant features associated to negative emotions as well as providing synchronization (interconnectivity) with other devices. Each relevant feature extracted will be sent to a central computer system capable of recognizing negative emotional states using trained machine learning models.
7) **Emotional actors:** IoT systems capable of decreasing levels of negative emotions will be designed and integrated into manufacturing tasks or wearable devices of employees (e.g., applications installed on smarthphones of employees).

## IV. Conclusions and Perspectives

A novel approach to integrate emotion recognition IoT devices in smart industries is presented and described. The main objective of the proposed approach is to increase the productiveness of employees by maintaining a healthy work environment. Two types of IoT devices are proposed: *Emotional detectors* and *Emotional actors*. *Emotional detectors* will be used to recognize negative emotions from employees, while *emotional actors* will be used to decrease levels of negative emotions. Before implementing the proposed approach in real industries, a more detailed study of different IoT devices and manufacturing tasks will be required. In this study, several characteristics will be considered, such as perceived comfort of wearable devices, possibility of integration in different manufacturing tasks, etc. Finally, the social acceptability of using emotional IoT devices in industries must be considered.

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