AN IOT-BASED SYSTEM FOR MEASURING PENIBILITY AT WORK

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ABSTRACT

The reporting of arduous work conditions in the workplace is a legal requirement in France. We present an IoT-based system that is designed to automatically collect most of the penibility factors as required by regulations, thus able to replace the declarative-only reporting that is currently in use. Another goal of our system is to investigate which of the hardship factors contribute most to the work penibility as perceived by the workers themselves.

KEYWORDS

Occupational Health, IoT

1. INTRODUCTION

Although the term “work penibility” is seldom found in the international scientific literature, it is of quite common use in France, both in the media and in the occupational medicine or in work sociology fields. It has been an important topic of discussion in the new retirement regulations that have recently been put in place. We have therefore chosen to use “work penibility” rather than “work hardship” or “word arduousness” that are more common in the English language.

France’s workplace regulations make it an obligation for the employer to report on the arduous conditions endured by the workers, by maintaining a so-called “personal penibility account” (Compte Personnel de Pénibilité, CPP) for them, that may allow for compensations such as earlier retirement (up to 2 years), part-time work without wages reduction or benefit for professional education.

The identification of employees subject to a declaration is incumbent to the employer, who needs assessing the extent of each worker's exposure based on their typical working conditions, which are evaluated on an average basis over the course of a year.

We present an IoT-based system that is designed to automatically collect most of the penibility factors as required by regulations, thus able to replace the declarative-only reporting that is currently in use. Another goal of our system is to investigate which of the hardship factors contribute most to the work penibility as perceived by the workers themselves.

The paper first presents the various arduousness factors considered. It then presents the IoT-based architecture of the system we propose in order to monitor these factors automatically.

2. FACTORS OF WORK PENIBILITY

The arduous nature of work is distinguished by the exposure of employees to one or more occupational risk factors associated with significant physical constraints, a hostile physical environment, or specific work rhythms. The Labor Code enumerates ten such risk factors, that we classify into two categories: Ambient penibility factors, related to the environmental conditions at the workplace, and Task-related penibility factors, related to the physical aspects of the task performed.

- Ambient penibility factors
- Mechanical vibrations: Refers to vibrations transmitted to the hands and arms, as well as those transmitted to the entire body, which may result in adverse effects.
- Hazardous chemical agents: Includes substances such as dust and fumes that have the potential to cause harm or adverse health effects to individuals exposed to them.
- Activities in hyperbaric environments: Refers to work performed in conditions of high pressure, such as underwater or in pressurized chambers.
- Extreme temperatures: This refers to extreme temperature conditions encountered within the work environment, irrespective of external temperatures.
- Noise: Denotes excessive or prolonged exposure to loud sounds or noise levels that may have detrimental effects on hearing and overall well-being.
- Task-related penibility factors
- Marked physical constraints: This encompasses the manual handling of loads, which involves the transportation or support of objects through activities such as lifting, placing, pushing, pulling, carrying, or moving. These tasks require the physical exertion of one or more workers.
- Awkward postures: Refers to forced positions of the joints that may be required during work, leading to discomfort or strain.
- Work rhythms: Refers to the specific pace or pattern of work, including factors such as the duration of shifts and breaks, which can influence the physical and mental strain experienced by workers.
- Night work under certain conditions: Relates to work performed during nighttime hours, subject to specific criteria or requirements that can impact the well-being and health of employees.
- Work in successive alternating teams: Refers to shift work schedules, such as those involving three eight-hour shifts or two twelve-hour shifts, which can lead to challenges in maintaining regular sleep patterns and overall fatigue.
- Repetitive work: Describes tasks that involve the execution of repeated movements, placing strain on some or all parts of the upper limb, typically performed at a high frequency and under constrained cadence.

The Labor Code mandates in great detail under which conditions the exposure to penibility factors should be taken into account in the personal penibility account (CPP), in terms of intensity and cumulative yearly duration. Table 1 gives an excerpt of these regulations for several of these ambient and task-related factors.

Table 1. Arduousness factors to be considered for inclusion in the CPP (excerpt)

Arduousness factor	Intensity	Minimal duration
Exposure to noise	8 hours above 81db	600 hours / year
	peak above 135 db	200 times / year
Repetitive movements	> 15 actions with a cycle time of less than 30s	900 hours / year
	> 30 technical actions / minute	
Extreme temperatures	outside of the 5°C-30°C range	900 hours / year

3. AN IOT SYSTEM TO MONITOR WORK PENIBILITY FACTORS

We have designed an IoT-based system that allows to automatically collect most of the penibility factors as presented above. The goals of this systems are twofold: It can be used to automatically collect the information needed for inclusion in the CPP, thus replacing the manual bookkeeping currently in place, that often requires approximative evaluations by the employer. Our second goal is to use the collected data to investigate which of the monitored factors contribute most to the penibility as perceived by the workers themselves.

3.1 Collecting Ambient Penibility Factors

The ambient penibility factors as defined in §2.1 are collected by an IoT node equipped with ad-hoc sensors. We have chosen to use Raspberry Pi™ as the hardware platform, due to its ease of use, low cost, and to the variety of off-the-shelf inexpensive sensors it can be equipped with. The device is equipped with temperature, humidity, noise, light, vibrations, and air quality sensors that collect all the measurements needed to assess ambient penibility. The measurements of these sensors are fed to a remote time-series database for real-time visualization and further data analysis.

3.2 Collecting Task-Related Penibility Factors

The penibility factors related to work schedules and shifts can in general be collected using the information system of the business under examination. However, we have chosen to collect more fine-grained data by using proximity sensors: the workers are equipped with a Bluetooth Low Energy (BLE) beacon, and the Raspberry Pi™ device tracks the proximity of the beacons, thus providing very detailed information on the actual time of presence of each worker in the workplace environment, allowing for an accurate calculation of the time of exposure to the ambient penibility factors stated in §3.1. The proximity sensors data is fed to the same time-series database used for sensors.

The repetitive movements are tracked by inertial sensors, in our case the sensors embedded in a commercial smartwatch (fitbit™) given to each user. Detailed information on the actual activity performed can be reconstructed from this inertial data (Lara and Labrador 2013)(Curone et al. 2010). The smartwatch moreover provides real-time information on heart rate, steps taken, calories burnt, skin temperature and oxygen saturation that give useful insights on the level of activity and stress of the worker. Although the data collected by the smartwatch is stored in a proprietary system, an API is provided to access it and store it at the same time-series database used for the other sensors.

3.3 Collecting Perceived Penibility

Beyond collecting the data mandated by the Labor Code for inclusion in the CPP, our goal is also to investigate which of the penibility factors contribute most to the penibility as perceived by the workers themselves.

- Instantaneous perceived penibility: By using the provided smartwatch, the workers can indicate in real time how they perceive the penibility of their work at any given moment, on a 0-9 scale, through a very simple touch-based used interface.
- Retrospective penibility: another simple smartwatch-based application allows the workers to retrospectively assess the penibility of their previous work shift, using the same 0-9 scale.

4. RELATED WORK

(Bavaresco et al. 2021) provide a detailed literature review of the use of IoT in occupational work, which has attracted attention in the recent years. (Palaniappan, Kok, and Kato 2021) systematically investigate the coupling of IoT and Artificial Intelligence in the field of occupational health and safety. Our proposal shares some concerns with the AAL-funded clockwork project (Pereira and Nunes 2018), which investigated the use of wearable sensors for monitoring physical activity for hospital workers.

5. CONCLUSION

This paper describes the goals and architecture of the system we propose for monitoring work penibility factors. The system will be deployed for validation in two different settings: we will investigate the work of pharmacy preparators in a hospital, representative of an office-like environment while still requiring significant posture changes and physical activity. The second experiment will address the training of firemen, a situation presenting very stressful and demanding physical activity in a hostile environment.

Our ongoing work concerns the development of the data analysis algorithms which will operate on the captured sensor data. These algorithms will address the identification of posture changes and the recognition of activities from the inertial data collected by the smartwatches, and the identification of the main factors contributing to the perceived penibility.

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REFERENCES

Bavaresco, Rodrigo, Helder Arruda, Eduarda Rocha, Jorge Barbosa, and Guann Pyng Li. 2021. "*Internet of Things and Occupational Well-Being in Industry 4.0: A Systematic Mapping Study and Taxonomy.*" Computers & Industrial Engineering 161 (November): 107670. https://doi.org/10.1016/J.CIE.2021.107670

Curone, Davide, Gian Mario Bertolotti, Andrea Cristiani, Emanuele Lindo Secco, and Giovanni Magenes. 2010. "*A Real-Time and Self-Calibrating Algorithm Based on Triaxial Accelerometer Signals for the Detection of Human Posture and Activity.*" IEEE Transactions on Information Technology in Biomedicine 14 (4): 1098–1105. https://doi.org/10.1109/TITB.2010.2050696

Lara, Óscar D., and Miguel A. Labrador. 2013. "*A Survey on Human Activity Recognition Using Wearable Sensors.*" IEEE Communications Surveys and Tutorials 15 (3): 1192–1209. https://doi.org/10.1109/SURV.2012.110112.00192

Palaniappan, Kavitha, Chiang Liang Kok, and Kenichi Kato. 2021. "*Artificial Intelligence (AI) Coupled with the Internet of Things (IoT) for the Enhancement of Occupational Health and Safety in the Construction Industry.*" Lecture Notes in Networks and Systems 271: 31–38. https://doi.org/10.1007/978-3-030-80624-8_4/COVER

Pereira, Ana, and Francisco Nunes. 2018. "*Physical Activity Intensity Monitoring of Hospital Workers Using a Wearable Sensor.*" In 12th EAI International Conference on Pervasive Computing Technologies for Healthcare. European Alliance for Innovation n.o. https://doi.org/10.4108/EAI.20-4-2018.2276323