Triple Pi Sensing to Limit Spread of Infectious Diseases at Workplace

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Abstract: Interactions among employees at a workplace facilitate spread of infectious diseases. This paper proposes to integrate traditional IoT sensor data, wastewater analysis and data from organizational information systems for timely identification of threats and adjustment of work activities. The overall approach combining predictive, preventive and prescriptive capabilities is described as well as the overall technical solution is presented. The proposed approach allows tailoring of work activities depending on macro and micro monitoring results in a non-intrusive manner.

1 INTRODUCTION

There are many different types of interactions among employees at a workplace making it one of the most frequent places for spread of infectious diseases such as flue or Covid-19 (WHO, 2019; Koh, 2020). The organizational structure and processes cause emergence of localized bubbles either promoting or limiting the spread of diseases (Shaw et al., 2020). The Covid-19 pandemic has sparked frantic search for solutions to ensure safe working environment (Dong and Yao, 2021). Many of the solutions relay on massive testing, wearable devices and other intrusive methods or do not provide timely identification of threats and response (Margherita and Heikkilä, 2021;Al-Humairi, 2021; Healthline, 2022). The cost of safety measures is also significant, and their cost efficient should be optimized (Patrizi, 2021).

This paper proposes to combine various sensing technologies to achieve timely and non-intrusive detection of infection threats and to enact suitable response mechanisms. These sensing technologies provide predictive, preventive and prescriptive capabilities referred as to Triple Pi. These technologies are deployed in organizational context, and organizational structure as well as composition of project teams are taken into account to assess and to limited threats.

The objective of the paper is to propose the Triple Pi approach and to elaborate interactions among the sensing technologies. The approach is intended for companies to provide safe working environment and business continuity during outbreaks on infectious diseases if remote work is not a suitable option. The sensing technologies include traditional IoT devices such as air sensors and cameras as well as wastewater monitoring. Data from organizational information system are also solicitated. The paper describes the overall approach and introduces early results from the ongoing project on Covid-19 safe working environment.

The rest of the paper is organized as follows. Section 2 discusses related work. Section 3 introduced the Triple Pi sensing process. Preliminary results are reported in Section 5. The technical solution is presented in Section 4. Section 6 concludes.

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2 RELATED WORK

IoT technologies were among the first to be deployed to tackle Covid-19 challenges. Gradually they were merged with data from other sources to form integrated solutions.

Wearable devices, face recognition and thermal scanning have been used to identify employees with Covid-19 symptoms to prevent spreading of the infection (Otoom et al., 2020; Petrovic and Kocić, 2020; Bashir et al. 2020). An integrated solution processes real-time information from sensors and provides compliance measures in dashboard, which can be used to monitor and assist in Covid-19 standard operating procedure application across organization (Bashir et al. 2020). Al-Humairi (2021) proposes an IoT based smart infrastructure monitoring system for suspected infection cases real-time identifying and tracking. The system performs real-time symptom data collection via thermal scanning algorithm, it includes facial recognition algorithm and data are analyzed using artificial intelligence algorithms. Alternatively, monitoring methods can be used to monitor compliance with masks usage requirements (Wang et al., 2020; Meenpal et al., 2020; Shinde et al., 2022) or CO_2 level control (Eykelbosh, 2021; Peladarinos et al. 2021). The integrated solutions also deploy intelligent algorithms to enact containment measures. These methods include customer rerouting (Yang et al., 2022), access control based on number (Andrade et al., 2022) and air quality prediction (Mumtaz et al., 2021). Data integration serves as an enabler of intelligent data analysis (Duda et al., 2021).

The early detection is a paramount to limiting the spread of infectious diseases. The current methods often rely on intrusive methods not always suitable in environments with elevated privacy requirements. Additionally, few methods fully exploit the organizational context enabling to improve tailoring of mitigation measures.

3 TRIPLE PI SENSING

The objectives of the Triple Pi sensing approach are to identify threats of infectious diseases as quickly as possible and to enact measures limiting their spread and impact in an efficient and non-intrusive manner. Predictive monitoring is performed to provide early detection (Figure 1). It is based on wastewater analysis, which is a non-intrusive method (Zhu et al., 2021) The macro and micro predictive monitoring is distinguished because the wastewater analysis relatively expensive and time consuming. The macro level monitoring is performed at a regional level and it triggers the micro level monitoring for a company (building) if an infection is detected. The infection detection events trigger prevention activities. The infection detection at the micro level also triggers adjustments in company's work organization as suggested by suitable algorithms. Depending on size of the country and national policies, the macro level could be the whole country, state, region or municipality. For example, the population size in regions in Latvia varies from approximately 50 000 to 700 000.

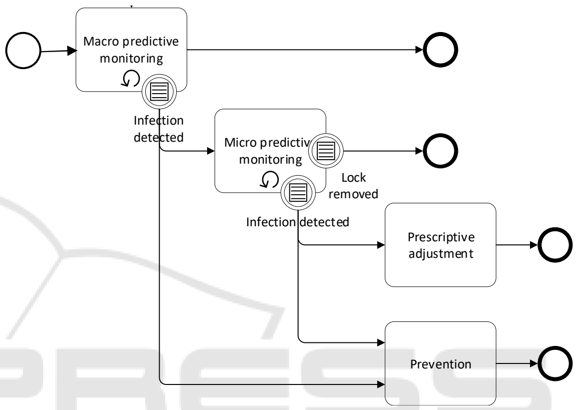

Figure 1: Sensing activities in a safe workplace depicted using BPMN.

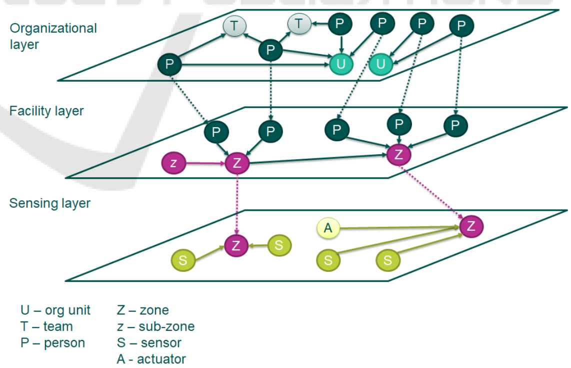

Figure 2: Organizational context.

The Triple Pi sensing is deployed in an organizational context to account for the impact of organizational structure and processes on spread of diseases. The organizational context is defined as a three-layer graph (Figure 2). The organizational layer associates employees (or persons) with organizational units and project team. The organizational units represent permanent arrangement of employees while the teams are dynamic. The facility layer associates the employees with a physical workplace or zone. A zone can consist of multiple sub-zone. The sensing layer defines sensors available in specific zones.

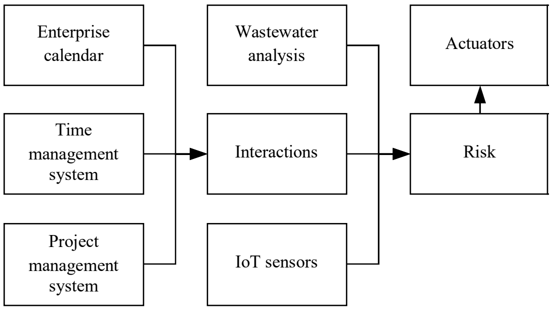

Figure 3: Integrated risk-based decision-making.

Data provided by various sensors, organizational information systems and wastewater analysis are combined to estimate an infectious diseases risk level, which in turn triggers actuators (Figure 3). The Time management system manages data about the organizational units and the zones, the Project management system manages information about dynamic project teams and the Enterprise calendar provides contains scheduled events and their participants. Jointly these information sources characterize expected dynamic interactions among the employees. The intensity and type of interactions is combined with IoT sensor measurements and wastewater analysis results to evaluate the risk. The risk is either predicted or its current value is evaluated. For example, ventilation can be adjusted with regards to expected number of the employees in a room and current air quality measurement or events can be rescheduled if the wastewater analysis warning has been triggered.

4 TECHNICAL SOLUTION

The Triple Pi approach is supported by a safe workplace platform combining interoperable and reusable services to ensure business continuity and to reduce risks of Covid-19 spread at organization's

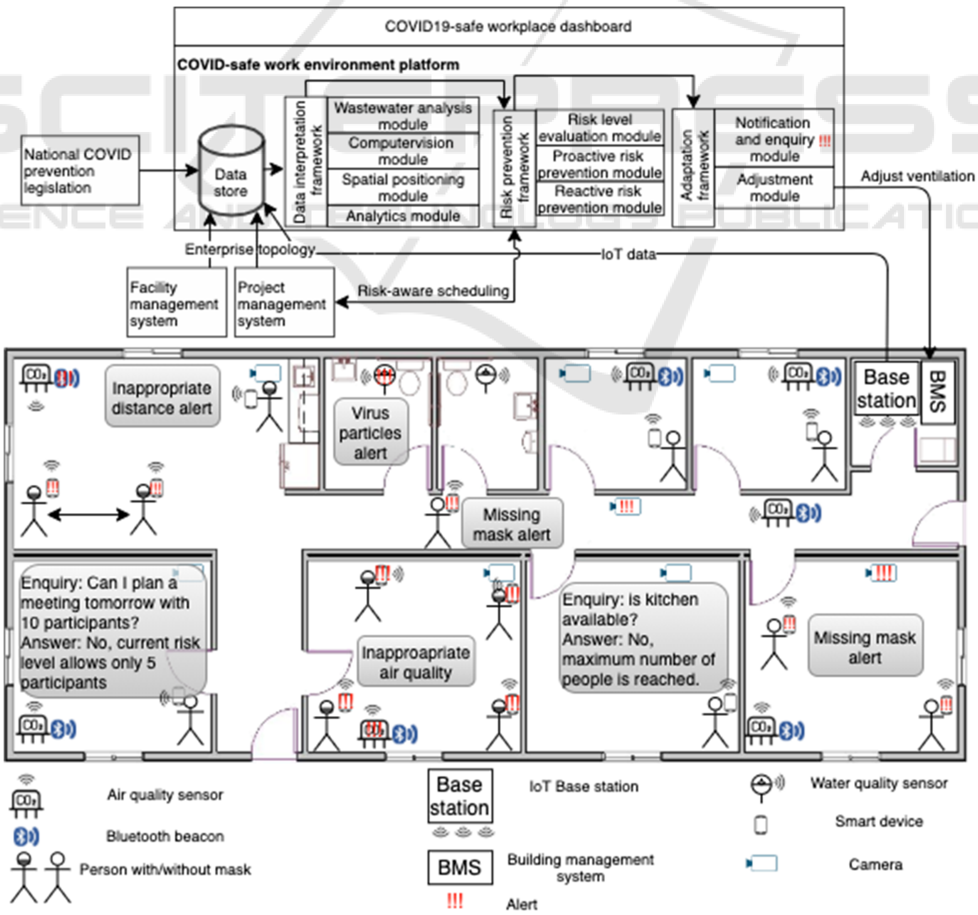

Figure 4: Components of the technical solution.

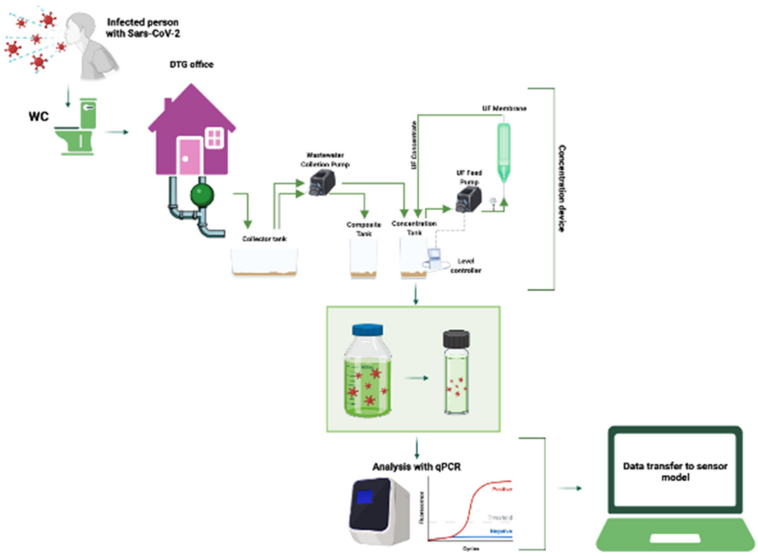

Figure 5: Micro level wastewater analysis.

premises (Figure 4). The platform uses data from the official regulations, Time management system, Project management system and real-time IoT data from the Base station installed on premises. The Base station is used for wirelessly collecting locally gathered sensor data (air quality, water quality, spatial positioning). The platform provides notifications and enquiries for smart devices as well as adjustments in the Building management system. Internally, the platform consists of the Data store (integrates and stores data of external origin), Data interpretation framework, Risk prevention framework and Adaptation framework. The Data interpretation framework contains the Wastewater analysis module (processes data about virus particles in the wastewater), Computervision module (ensures distancing and waring face masks when necessary), Spatial positioning module (more accurate distancing measurement, logging social encounter events among employees), and Analytics module (descriptive and predictive analysis of air quality). The Risk prevention framework contains the Risk level evaluation module, Proactive risk prevention module (provides guidance for Covid-19 safe corporate event planning), Reactive risk prevention module (low latency risk prevention measures based on real-time data). The adaptation framework contains the Notification and enquiry module (notifications and enquires for the personnel) and Adjustment module (interaction with the Building management system for reducing Covid-19 related risks). Various Key Performance Indicators (KPI) are made visible in the platform's dashboard.

At the macro level, the wastewater samples are taken and monitored at wastewater treatment plants (WWTPs). However, the data that are obtained from WWTPs give an overall information about situation in the selected region. At the micro level, the wastewater samples are taken directly from the workplace water distribution network what gives direct information about possible local SARS-CoV-2 virus outbreaks (Figure 5). The wastewater samples are taken directly from the collector tank using an automatic 24 h sampler and later concentrated with a concentration device. The samples are transferred to the laboratory and used for direct RNA purification followed by PCR-based analysis. The data received are analyzed in relation to other sensory measurements. The main components of the concentration device are: feed pump, pressure gauge, ultrafiltration membrane, flow meters with controllers, concentration tank and permeate tank.

5 PRELIMINARY RESULTS

The platform implementing the Triple Pi approach is currently under development and preliminary data are gathered to evaluate feasibility of the approach. Figure 6. shows macro level monitoring for the whole Latvia. It highlights that there are several cities with level of Covid-19 particles in wastewater. That triggers an alert to the micro level that micro level monitoring as well as prevention measures should be put in place.

The micro level wastewater results data are yet to be processed while the air quality is continuously measured (Figure 7). The ventilation flow is increased to provide even higher level of air quality. However, there are several spikes in the number of CO_2 parts (ppm) in the air what increases the risk of spread of infectious diseases.

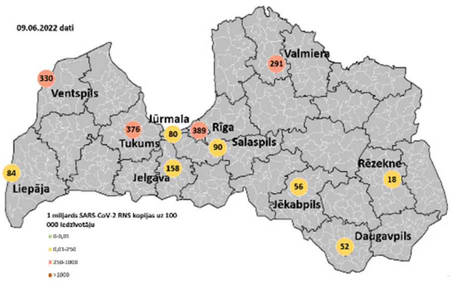

Figure 6: The macro level monitoring in Latvia (https://bior.lv/lv/par-mums/jaunumi/notekudenu-monitorings-covid-19-izplatibas-noteiksanai).

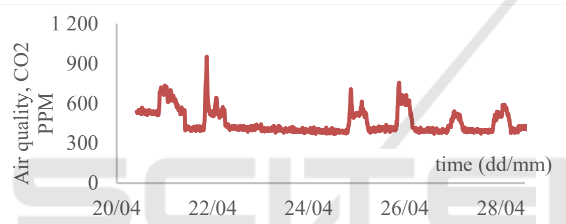

Figure 7: ONSET HOBO MX CO_2 logger air quality monitoring data.

Therefore, prescriptive adjustments are invoked. In this case, rescheduling of planned events is performed for the particular room (zone). Table 1 and Table 2 shows original and adjusted schedules April 27th, respectively. The prescriptive rescheduling model suggests reducing the number of employees gathering for the meeting. That results in reduction of the concentration of CO_2 in air. The intensity of interactions is also reduced by limiting cross-team interactions.

Table 1: The original schedule.

Event	Time	Employees	Duration, min
Customer visit	9:00-10:00	{E1,E3,E4,E5,V1,V2}	60
Team meeting	10:00-11:00	{E3,E4,E5,E6,E8}	60
Team meeting	12:00-12:30	{E4,E5,E6,E8,E9,E13, E2}	30

E – employee, V – visitor

Table 2: The adjusted schedule.

Event	Time	Employees	Duration, min
Customer visit	9:00-10:00	{E1,E3,E4,V1,V2}	60
Team meeting	10:15-11:00	{E3,E4,E5,E6,E8}	45
Team meeting	12:00-12:30	{E5,E6,E8,E9,E13, E2}	30

6 CONCLUSION

The proposed approach and platform advance the state of the art by integrating IoT sensing technologies and wastewater analysis to provide predictive, preventive and prescriptive capabilities for limiting the spread of infectious diseases in non-intrusive manner. The adjustment recommendations are provided in the organizational context taking into account interactions among employees as determined from organizational information systems. The current research focuses on Covid-19 though the model can be adapted to different infectious diseases. The technological foundations of the approach have been established and data analysis will be carried out in on-going activities of the research project.

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