Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 224 (2023) 572–579

Procedia Computer Science

www.elsevier.com/locate/procedia

2nd International Workshop on Mobile4Medicine: Mobile Systems and Pervasive Computing for Personalized Medicine
August 14-16, 2023, Halifax, Nova Scotia, Canada

Internet of Things-based care monitoring for the elderly and those with special needs

António Godinho[a,*], Filipe Cardoso[b,c], Paulo Jorge Coelho[c,d], Ivan Miguel Pires[b,e]

[a]*Polytechnic Institute of Coimbra, Coimbra Institute of Engineering, Rua Pedro Nunes - Quinta da Nora, 3030-199 Coimbra, Portugal*
[b]*Escola Superior de Gestão e Tecnologia, Politécnico de Santarém, Complexo Andaluz, Apartado 295, 2001-904 Santarém, Portugal*
[c]*Institute for Systems Engineering and Computers at Coimbra (INESC Coimbra), DEEC, Pólo II, 3030-290 Coimbra, Portugal*
[d]*Polytechnic of Leiria, R. Gen. Norton de Matos, 2411-901 Leiria, Portuga*
[e]*Instituto de Telecomunicações, Universidade da Beira Interior, 6200-001 Covilhã, Portugal*

Abstract

As a society, we should provide support and care for individuals who are advanced in age or have special needs. We must offer them the opportunity to lead a safe and comfortable life. Sometimes, addressing simple things can mitigate critical problems. For instance, an improperly functioning heating system can put the users' lives at risk, and a gas leak can prove fatal if not detected in time. Hence, this study aims to identify solutions that can help prevent accidents in such vulnerable populations. To achieve this, a safety device equipped with essential sensors continuously monitors the living environment of people with special needs. If there are any anomalies, the system will immediately alert the concerned family members and competent security authorities, ensuring a quick and efficient response to potential emergencies. The proposed safety device aims to provide extra protection and peace of mind for special care individuals. By implementing such safety measures, we can make significant strides in promoting the well-being and safety of vulnerable populations.

Keywords: IoT Sensors; Monitoring; Surveillance; Security; Special needs; Elderly; Quality of life

1. Introduction

Over the last century, life expectancy at birth has steadily increased everywhere [6]. A country's population health and economic development can be significantly assessed by its life expectancy. A well-established relationship exists between life expectancy and the number of older adults in a population [7]. As life expectancy increases, so does the

* Corresponding author. Tel.: +351-239790200
E-mail address: to@isec.pt

1877-0509
10.1016/j.procs.2023.09.083

number of people who live long enough to become elderly. People are living longer and healthier lives due to advances in medicine, nutrition, and public health [8]. It becomes more than necessary to combat the problems associated with old age or even those related to people with special needs, and for that, there is a need to try by all means to alleviate them. But, unfortunately, there is not always the possibility of someone caring for our loved ones. Since human presence is not infallible, we must look to technology for the means we can use to offer greater security and protection to those who need it most [9].

In recent years, there has been significant development in single-board computers, such as Arduino, Raspberry Pi, and other similar devices. These devices offer low power consumption, with enough processing power and memory capacity, making them ideal for a wide range of applications [1]. Additionally, sensors and other components that can be connected to these devices have become widely available and affordable, making it easier for developers to create complex projects with these devices [2, 3]. It has led to many projects and applications, from home automation to robotics. Another significant advantage of using these devices is the broad support for open-source software for IoT applications [4]. Finally, advancing these devices and components creates possibilities to devise healthcare solutions, particularly emphasizing the needs of the most susceptible and their houses [5].

Housing was how our ancestors found shelter from ferocious animals and adverse weather conditions. With the evolution of man and civilization, housing became where the family lives and coexists. Several amenities were introduced, and with them, naturally, some dangers arose. One of the most common examples of accidents that are often fatal is cold weather. In addition, many homes use heating that produces high concentrations of carbon monoxide, a gas that can lead to death and, unfortunately, is not easy detection [10, 11, 12]. Also, the gas commonly used in household kitchens is another highly hazardous gas that results in many annual fatalities. This gas can be butane, propane, or methane [13].

The proposed monitoring system, equipped with sensors that remain on high alert, is designed to detect unsafe readings and alert users, family members, or authorities. It is primarily intended for older adults or individuals with special needs, and careful analysis is required to determine its optimal placement within the house. The system is powered by electricity, but an internal battery with a 24-hour charge is also included, and it automatically notifies contacts on the user's list and emits a sound signal if it switches to battery power.

2. Related Works

IoT monitoring devices for older people have been a growing area of research in the last decade. Numerous academic papers explore the development and implementation of such devices.

In 2018, A. K. M. M. Hossain et al. [14] proposed an intelligent system for elderly care that integrates IoT and mobile technologies. The design aims to monitor the older person's daily activities, health status, and environmental conditions and provide remote maintenance and support to promote their safety, health, and well-being. The authors also evaluate the feasibility and usability of the proposed system using a user study with elderly participants and caregivers.

Another system for older people was designed by Hu et al. [15], which can monitor their daily activities and vital signs, detect abnormal conditions, and alert caregivers or family members in emergencies. The proposed system utilizes various sensors and devices, such as wearable sensors, environmental sensors, and a Raspberry Pi-based gateway, to collect data and transmit it to a cloud-based platform for processing and analysis.

In 2021, Sumathy et al. [16] developed a wearable health monitoring system for older people using IoT technology to continuously monitor vital health parameters such as body temperature, heart rate, blood pressure, and oxygen saturation levels. The system aims to provide an early warning of health deterioration, which can lead to prompt intervention and prevention of severe health conditions.

In 2022, Deepika et al. [17] presented a monitoring system based on Internet of Things (IoT) technology that can continuously monitor older people and alert their caregivers in emergencies. The system includes various sensors and devices that can track the older person's vital signs, activities, and movements. The data the system collects is transmitted wirelessly to a cloud-based server and can be accessed by authorized caregivers through a web or mobile application.

These studies explore different IoT devices and systems that cater to the elderly population, such as intelligent home systems, wearables, and health monitoring systems. However, the focus of the device presented in this paper is distinct. It evaluates the potential risks in the environment where elderly or vulnerable individuals reside and generates alerts to authorities, caregivers, and emergency contacts.

3. Threats and monitoring features

For the proposed system to be practical and functional, it must analyze data that could endanger the users' lives to whom we suggest to provide a better quality of life. As previously mentioned, there are many victims annually due to the inhalation of carbon monoxide. Although this gas is imperceptible to humans, in high amounts, it can lead to the same losing senses and eventually dying due to its toxicity, dying from poisoning [11]. If death does not occur, this gas can leave irreversible consequences for humans or animals, such as heart problems or neurological problems [18]. This gas, in concentrations up to 400 ppm, causes headaches, chest pains, dizziness, confusion, and weakness. Concentrations above this value lead to the death of humans and animals. Another dangerous gas that can be found in most homes is the well-known cooking gas, that is, the gas that is used by stoves, ovens, water heaters, and boilers. This gas could be classified as butane, propane, or methane. Unlike carbon monoxide gas, these gases have a typical smell, commonly known as "gas smell" as an odor is added to identify it in the event of a leak. Due to this fact, the number of victims is lower, but unfortunately, it is not zero [19]. In addition, these gases, due to their high ease of combustion, in the event of an accident, cause burns that can range from first-degree to third-degree. However, a correlation exists between aging and the deterioration of the sense of smell, which renders older people more susceptible to these types of gases [20]. As the elements referred to above are called gases, they can quickly spread throughout the house, meaning that none of the rooms are safe. Moreover, due to the ease of combustion of these gases, they can fast go from a situation of gas leakage to a fire, putting at risk not only material goods but also human or animal lives. In the case of kitchen gases, if the concentration of these is not sufficient for the human being to feel their presence, they easily combust with a simple light switch due to the tiny spark produced in the button of the lamp in question [21, 22].

Between 2017 and 2022, the National Institute of Legal Medicine and Forensic Sciences collected data on fatalities caused by carbon monoxide inhalation poisoning in Portugal. During this period, there were 171 deaths, with 85 occurring in the north, 37 in the center, 44 in the south, and 5 on the islands.

Compared to countries with larger populations, these numbers are relatively small. For example, the United States Carbon monoxide (CO) poisoning affects 50,000 people annually. The clinical presentation runs a spectrum, ranging from headache and dizziness to coma and death, with a mortality rate ranging from 1 to 3%. In addition, many patients who survive CO poisoning suffer from long-term neurological and affective sequelae [23]. Water is another element found in housing, and sometimes, the dangers that may arise from it are neglected. As is known, a water leak can cause severe damage to a home. Moreover, if this leak comes into contact with electricity, there may be a risk of electrocution. Once again, this considerably impacts a country with a significant population. For instance, in India, where there is a vast population, over 2.2% of deaths occur every year due to electrocution [24]. As such, the proposed solution is equipped with a water sensor. Suppose it detects its presence in an area that would not be expected. In that case, an alert is automatically sent to the competent authorities and the priority contacts previously registered in the equipment.

In addition to reading data related to the environment in which it is inserted, the proposed monitoring system will check if there is movement inside the house in areas of typical passage. By verifying the existence of activity, it is possible to prove the existence of life inside the dwelling. The lack of movement during a specific time may indicate the opposite. This function differs from the previous ones in that it can be turned off, which allows you to leave your home for a long time without activating the physical inactivity alarm.

Due to its concept and modular architecture, the proposed device can easily be expanded. Equipping the device with new sensors to read new data or elements in special needs cases is possible. For example, one of the possibilities is to include a cardiac monitoring system, acting as the devices referenced in section . Furthermore, the system automatically triggers events if an abnormality is detected during the reading. An alarm can be heard inside the house so that, if someone is nearby, they can simultaneously carry out the first rescue maneuvers. Furthermore, the system warns the competent authorities. It informs them was the situation that triggered the request for help, as well as notifies the priority contacts of the internal list in the device.

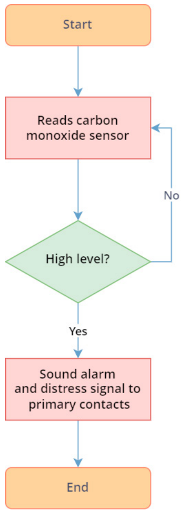

Fig. 1. Carbon monoxide reading flowchart

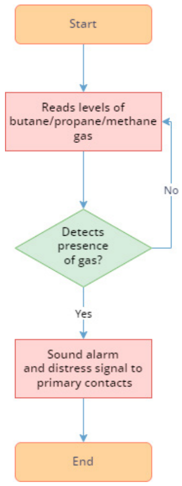

Fig. 2. Gas sensor reading flowchart

4. The functioning of the device

This section details the operational logic of the monitoring system, its interaction with the operating environment, and the actions it takes when predefined safety parameters are exceeded. It also includes flowcharts illustrating the operations of different modules or sensors.

The monitoring system operates in a continuous state of alertness. Its array of sensors continuously monitors the surrounding environment. In contrast to humans who may make errors or become fatigued when performing repetitive tasks over time, this system, controlled by a micro-controller, carries out its duties tirelessly and without errors resulting from task repetition.

4.1. Flowcharts

Each module or sensor is explained separately better to understand the function and interconnection between the various components.

The flowchart in figure 1 explains how carbon monoxide level monitoring works. As you can see in illustration 3, the system is constantly receiving data from the carbon monoxide sensor. If the value received by the system is not within the parameters considered adequate by us, then the carbon monoxide presence alarm will be activated. Carbon above safe amounts. With this, a message is automatically sent to the list of priority contacts, and the competent authorities are also automatically informed to help people residing in the house. Figure 2 demonstrate how the system works if gas is detected. Gas can be butane, propane, or methane. As presented, if the presence of gas is detected, the system triggers the entire process of notifying the competent authorities and informing all contacts in the priority contact list.

Figure 3 shows how the system works if a water level higher than reasonable is detected inside the house. For example, a water level greater than zero centimeters was considered because the house's floors could be washed, leading the system to issue an alert without a real danger situation being present.

It should be noted that all the previously presented flowcharts are isolated. That is, they are excerpts from the system and only portray the functioning of the sensors in question. Subsequently, the whole system in its entirety will be presented. Then, the functioning of the alert system itself is presented, that is, how the system notifies the competent authorities, as well as the list of priority contacts. As seen in Figure 4, as soon as the central system receives an alert from one or more of its sensors, it initiates the audible and visual warning process. At the same time, it starts all the necessary procedures to get in touch with the competent authorities and the list of priority contacts to notify.

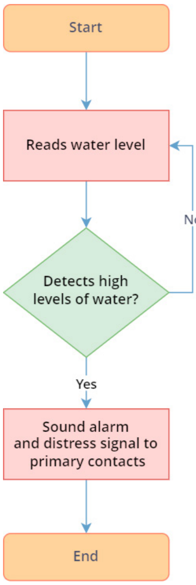

Fig. 3. Water level sensor reading flowchart

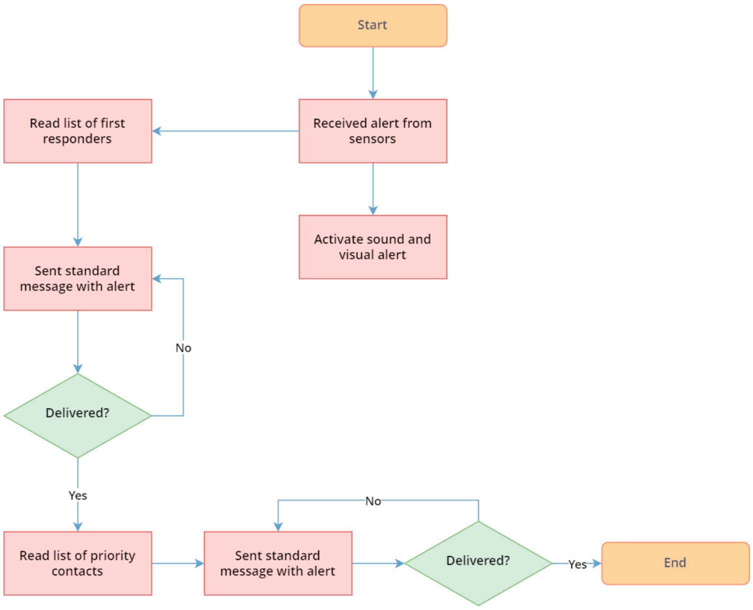

Fig. 4. Alert system flowchart

If the contact attempt has not been successfully made, a new contact attempt is started again. This process is repeated as often as necessary until the contact is established. However, the house residents knew what happened through the sound and visual alarm system, so they could leave the house or even try to solve the problem.

5. Design and implementation of devices for older people

There are various applications for a functional device across different areas, particularly for populations that are more vulnerable and have special needs, such as older people. Therefore, two devices were created with distinct configurations: the first one employs a basic set of components that enable all main features. In contrast, the second device integrates extra functionalities, requiring more parts and a higher cost.

5.0.1. Elderly Device Standard

The stand device contains all the basic functions, such as all gas sensors, the automatic contact of the authorities, and contacts. It also includes a panic button and alarm. The device includes the following functionaries:

- Check if there is movement at home in the time to be defined (it can be according to the customer's wishes);
- Check if your home is issued:
  - Carbon monoxide
  - Butane, Propane, and Methane gas
- Check if there is any flooding in the house;
- Check if there are lights turned on for a certain time;
- Panic button for sending SMS to numbers to be defined;
- GSM module for sending alerts.

5.0.2. Elderly Device Plus

This product should be considered a premium version of the standard device. It includes all the options of the standard versions but adds, for example, a GPS location. The device includes the following functionaries:

- All of the above options, plus:

  – Establish voice call
  – Send SMS to numbers to be defined
  – Send GPS coordinates with the location to facilitate medical emergency services
- Bracelet that monitors heart activity and alerts you in case of problems.

5.0.3. Expansion Kit

It is possible to expand both modules so that the temperature in the room is monitored where it is necessary to control central heating or air conditioning.

5.0.4. Material required

It was essential to confirm the necessary components and ensure their availability. This step enabled the creation of a precise budget, the development of a project timeline, the allocation of resources, and the effective management of risks. There are a variety of components that can be combined to construct the device, including Arduino Uno, Wemos D1 Mini, MQ-2 Methane Gas Sensor, MQ-2 Butane Gas Sensor, MQ-6 Propane Gas Sensor, Light sensor module, MQ-7 Carbon Monoxide CO Gas Detector Sensor, Time clock, Panic Button, SIM800 GSM/GPRS Module, Sim900 GSM/GPRS Module, Sim900 GSM/GPRS Module with sound IN/OUT, GPS NEO-6M/NEO-7M Satellite Positioning Module, Speaker, and Micro High sensitive for Arduino. Two types of devices can be developed: the Elderly Device Standard system and the Elderly Device Plus. The Elderly Device Standard system utilizes Arduino boards, sensors, and other components. The Elderly Device Plus is an enhanced version of the standard system, offering several additional features. Based on the current market rates of various components available on popular online platforms, the standard version of the Elderly Device is priced at approximately 45€. At the same time, the Elderly Device Plus costs 75€.

6. Device prototype

Developing the prototype device was a two-part process that involved creating the hardware and software components. The hardware layout consisted of designing a circuit PCB diagram that included all the necessary sensors, while the software was specifically designed for the Arduino to interact with these components. The first step was to design a comprehensive circuit PCB diagram to create a prototype incorporating all the required sensors. It allowed for testing the board in a real-world environment, where any issues or potential flaws could be identified and addressed, ensuring the board functioned as intended. The PCB design, which includes all the sensors, is illustrated in Figure 5.

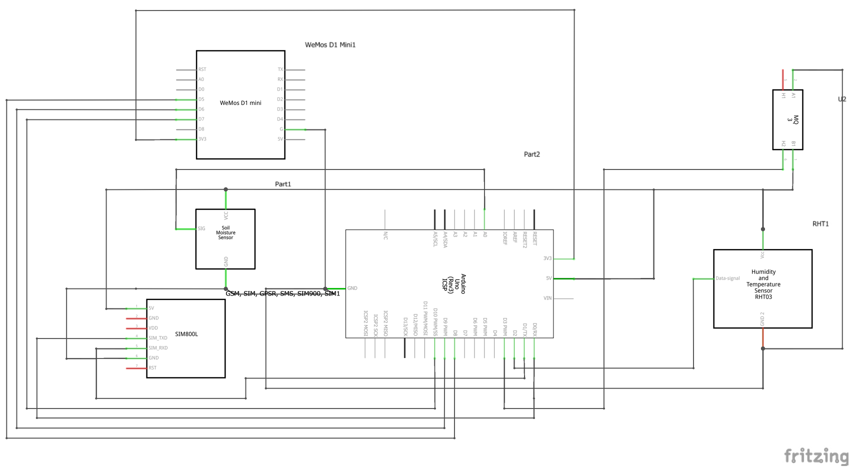

Fig. 5. Schematics with sensors

After the PCB design was finalized, the next step in the development process involved connecting the Arduino board to all the necessary sensors. A breadboard was utilized to position and connect the various components. The software development process involved writing and testing code enabling the Arduino to communicate with the sensors and operate the system as intended. With the hardware and software components in place, extensive testing was conducted to ensure the prototype device was fully functional and met the required specifications. The testing used the operational device depicted in Figure 6.

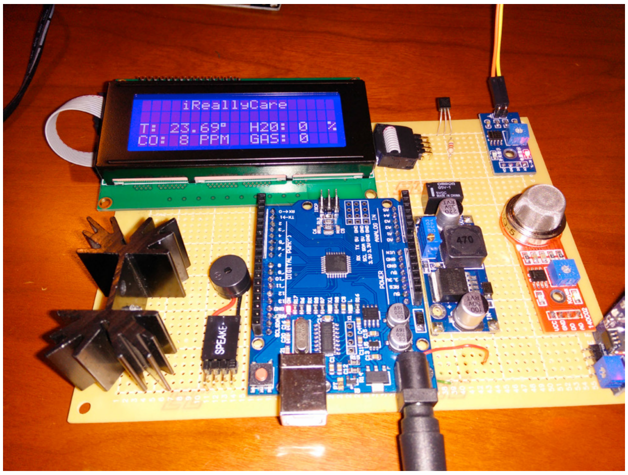

Fig. 6. prototype with all sensors

7. Discussion and Conclusions

A monitoring system with gas sensors, fire and smoke detectors is crucial for elderly and disabled people. It detects life-threatening emergencies early and triggers an alarm for quicker response times. Vulnerability due to mobility issues or lack of smell sensitivity makes monitoring systems a crucial safety measure. The system's sensors offer an added layer of protection, enabling individuals to maintain independence while still receiving assistance if needed. Future development should focus on testing the monitoring system in various environments to assess its reliability and functionality.

Using Arduino boards, sensors, and modules has several advantages, including their wide availability from multiple manufacturers and various models available. The first device designs utilized the Arduino Uno board. However, testing other compatible boards, such as the Wemus D1 Mini, is essential. This board is more powerful than the Arduino Uno and adds Wi-Fi connectivity. Additionally, it is smaller, which is an advantage for portable devices.

By utilizing Arduino boards and other components that are widely available and cost-effective, the Elderly Devices represent an innovative and cost-efficient solution to the challenges faced by elderly individuals. Its low production cost makes it accessible to individuals from all walks of life. In addition, its reliable performance and ease of use make it an ideal choice for anyone looking to enhance their quality of life as they age. Overall, the proposed device with gas sensors, fire, and smoke detectors is essential for ensuring the safety and well-being of elderly and disabled people, allowing them to live independently and with greater peace of mind. Future work must involve conducting extensive testing in multiple homes of elderly individuals. It will allow to evaluate the performance of the device in different environments and under a range of conditions, providing valuable insights into its functionality and reliability.

To ensure that the device is effective in real-world scenarios, conducting a field test with the intended population is crucial, even if the prototype has performed well in all previous tests. This testing is necessary before approval for use can be granted. The automatic notification feature is a critical component of the device, as it enables timely responses and provides reassurance to all parties involved. Moreover, the feedback obtained from the healthcare community during the field test can offer valuable insights into additional features that should be included in the final version of the device.

Acknowledgements

This work is funded by FCT/MEC through national funds and co-funded by FEDER – PT2020 partnership agreement under the project **UIDB/50008/2020**. This work is also funded by FCT/MEC through national funds and co-funded by FEDER – PT2020 partnership agreement under the project **UIDB/00308/2020**. This article is based upon work from COST Action CA19104 - advancing Social inclusion through Technology and EmPowerment (a-STEP). and COST Action CA21122 - PROmoting GeRiAtric Medicine IN countries where it is still eMerGing (PROGRAMMING), supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Our Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. It boosts their research, career, and innovation. More information in www.cost.eu.

References

[1] Jolles, J.W., 2021. Broad-scale applications of the Raspberry Pi: A review and guide for biologists. Methods in Ecology and Evolution, 12(9), pp.1562-1579.

[2] Johnston, S.J., Apetroaie-Cristea, M., Scott, M. and Cox, S.J., 2016, December. Applicability of commodity, low-cost, single-board computers for Internet of Things devices. In 2016 IEEE 3rd World Forum on Internet of Things (WF-IoT) (pp. 141-146). IEEE.

[3] Ferdoush, S. and Li, X., 2014. Wireless sensor network system design using Raspberry Pi and Arduino for environmental monitoring applications. Procedia Computer Science, 34, pp.103-110.

[4] Costa, D.G. and Duran-Faundez, C., 2018. Open-source electronics platforms as enabling technologies for smart cities: Recent developments and perspectives. Electronics, 7(12), p.404.

[5] Islam, S.R., Kwak, D., Kabir, M.H., Hossain, M. and Kwak, K.S., 2015. The Internet of things for health care: a comprehensive survey. IEEE Access, 3, pp.678-708.

[6] Cutler, D.M. and McClellan, M., 2001. Is technological change in medicine worth it?. Health affairs, 20(5), pp.11-29.

[7] Robine, J.M., Saito, Y. and Jagger, C., 2009. The relationship between longevity and healthy life expectancy. Quality in Ageing and Older Adults.

[8] Wang, X.Q., Song, G., Yang, Z., Chen, R.J., Zheng, Y.L., Hu, H.Y., Su, X. and Chen, P.J., 2020. Association between ageing population, median age, life expectancy and mortality in coronavirus disease (COVID-19). Aging (Albany NY), 12(24), p.24570.

[9] Coles-Kemp, L., Robinson, N. and Heath, C.P., 2022. Protecting The Vulnerable: Dimensions of Assisted Digital Access. Proceedings of the ACM on Human-Computer Interaction, 6(CSCW2), pp.1-26.

[10] Byard, R.W., 2019. Carbon monoxide–the silent killer. Forensic Science, Medicine and Pathology, 15(1), pp.1-2.

[11] Blumenthal, I., 2001. Carbon monoxide poisoning. Journal of the royal society of medicine, 94(6), pp.270-272.

[12] Fisher, D.S., Leonardi, G. and Flanagan, R.J., 2014. Fatal unintentional non-fire-related carbon monoxide poisoning: England and Wales, 1979–2012. Clinical toxicology, 52(3), pp.166-170.

[13] Harrison, C. and Popke, J., 2011. "Because you got to have heat": the networked assemblage of energy poverty in eastern North Carolina. Annals of the Association of American Geographers, 101(4), pp.949-961.

[14] Saraubon, K., Anurugsa, K. and Kongsakpaibul, A., 2018, December. A smart system for elderly care using iot and mobile technologies. In Proceedings of the 2018 2nd International Conference on Software and e-Business (pp. 59-63).

[15] B. David Chung Hu, H. Fahmi, L. Yuhao, C. C. Kiong and A. Harun, "Internet of Things (IOT) Monitoring System for Elderly," 2018 International Conference on Intelligent and Advanced System (ICIAS), Kuala Lumpur, Malaysia, 2018, pp. 1-6, doi: 10.1109/ICIAS.2018.8540567.

[16] Sumathy, B., Kavimullai, S., Shushmithaa, S. and Anusha, S.S., 2021. Wearable Non-invasive Health Monitoring Device for Elderly using IOT. In IOP Conference Series: Materials Science and Engineering (Vol. 1012, No. 1, p. 012011). IOP Publishing.

[17] Deepika, S. and Vijayakumar, K.P., 2022, April. IoT based Elderly Monitoring System. In 2022 6th International Conference on Trends in Electronics and Informatics (ICOEI) (pp. 573-579). IEEE.

[18] Guzman, J.A., 2012. Carbon monoxide poisoning. Critical care clinics, 28(4), pp.537-548.

[19] Kim, E.S., Shim, J.H., Kim, J.P. and Park, N.K., 2016. The Study on Evaluation of Human Body Injury by Explosion of Portable Butane Gas Range. Journal of the Korean Society of Safety, 31(3), pp.60-67.

[20] Stevens, J.C., Cain, W.S., Weinstein, D.E. and Pierce, J.B., 1987. Aging impairs the ability to detect gas odor. Fire Technology, 23, pp.198-204.

[21] Demirbas, A., 2002. Fuel properties of hydrogen, liquefied petroleum gas (LPG), and compressed natural gas (CNG) for transportation. Energy Sources, 24(7), pp.601-610.

[22] Feng, H., 2005. The progress of the technology of geophysical survey to preventing gas accident occurring in the colliery in China. Progress in Geophysics, 20(4), pp.1171-1175.

[23] Rose, J.J., Wang, L., Xu, Q., McTiernan, C.F., Shiva, S., Tejero, J. and Gladwin, M.T., 2017. Carbon monoxide poisoning: pathogenesis, management, and future directions of therapy. American Journal of respiratory and critical care medicine, 195(5), pp.596-606.

[24] Gupta, B., Chaudhary, A., Sindhwani, N. and Rana, A., 2021, September. Smart Shoe for Detection of Electrocution Using Internet of Things (IoT). In 2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions)(ICRITO) (pp. 1-3). IEEE.