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An IoT system based on open APIs and geolocation for human health data analysis

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Abstract. Development of applications based on open API is becoming increasingly popular today. Innovative projects using these technologies provide new opportunities for real-time human health monitoring. Such opportunities are also implemented using Internet of Things (IoT), artificial intelligence (AI) and cloud computing technologies. In the study, we developed an application based on open APIs using smart gadgets and meteorological geographic information system in the process of generating a message about the dangers to human health associated with: the presence of pollen in the air (grass pollen, birch pollen and olive pollen) indicating the level of its concentration in the air; problems with air quality, if the air quality indicator exceeds the permissible standards. The addition of such functions expands the possibilities to provide timely information about potential risks and threats and, accordingly, is an "anthropo-geo-sensor-digital" prerequisite for effective decision-making, prevailing. The implementation of this IoT system has significant methodological and technological potential that can be used to improve the efficiency of Healthcare, both in extreme conditions and in conditions of sustainable existence. First of all, this is relevant during and after the COVID-19 pandemic. The system we have developed can also be seen as one of the ways to innovate in Healthcare, in the educational process in institutions of higher education and in further scientific research on this topic. Further research in this area may be related to data processing in Healthcare systems based on machine learning, deep learning.

Keywords: IoT, open API, smart gadget, smartphone, Meteorological Geographic Information System, cloud services, cloud computing, eHealth, human health, healthcare

1. Introduction

At this stage of the development of Internet of Things (IoT) technologies, more and more attention is paid to the development of health care applications in IoT systems, as they provide an opportunity to remotely monitor the state of human health in real time.

The demand for professional use of IoT systems for real-time health monitoring in relation to environmental conditions, including environmental risks, is present in many fields of activity, science and education [10, 14, 21, 22, 30].

In this aspect, the presence of relationships between the specified technologies and the field of health care is decisive. This is being realized thanks to the proliferation of medical and other

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wearable devices, which have rapidly gained significant popularity over the past few years. Numerous studies in this field show that such systems are effective and that their use does not cause significant discomfort to patients. Another aspect that researchers are paying attention to is the seamless operation of the IoT and the protection of patient data. Also, in modern conditions, the development of IoT systems is carried out by combining the technologies of the Internet of Things (IoT), artificial intelligence (AI), cloud computing, etc.

Currently, there is a need to minimize risks to life and health and optimize the training process by taking into account physiological indicators and environmental data in the work of a coach, instructor, physical culture teacher by using IoT systems for monitoring the state of health in real time.

There is also a need to use these systems in rehabilitation to implement differentiated and individualized rehabilitation. For clinical medicine, including remote diagnostics and treatment, these applications are particularly important, defining new opportunities for the objectification and technologization of medical practices, which is especially important during the COVID-19 pandemic [32].

The use of these systems in ecology opens up new perspectives for considering the environment systemically, holistically, technologically oriented consideration of the environment related to human activity. This gives ecology an anthropological and humanistic orientation, and determines the possibilities of developing digital anthropo-socio-ecological technologies.

The concept of IoT, which allows "smart objects" to "communicate" with each other or with the user [2, 7, 11], is becoming more and more popular. Thanks to IoT, we can get much more information more easily than ever before and manage objects much more efficiently [27]. The concept of IoT can be applied in many fields, including measurement, traffic control, smart homes, etc. [10, 27]. Sensors, smartphones, fitness bracelets, household appliances, counters and other similar devices can be used as such objects.

Remote monitoring of patients has become a popular area of research in recent years [3–5, 8, 12, 17, 20, 27, 31]. Remote monitoring based on personal medical devices is quite often used in healthcare areas that use the IoT concept. Personal medical devices (PMDs) are portable electronic medical devices that perceive and measure users' biomedical signals [27]. To date, many personal medical devices have been developed that can be used for this purpose: activity monitors, drug dispensers, pulse oximeters, ECG monitors, blood pressure monitors, fall detectors, etc. [6, 17, 23–26]. PMDs can be objects in IoT systems for healthcare, and healthcare professionals can take advantage of most of the advantages of the IoT system by monitoring patients remotely using IoT systems. There is an urgent need to develop and implement such IoT systems that would expand the possibilities of air monitoring for the presence of allergens in the environment and, accordingly, present data on the level of their concentration in representative and user-friendly formats. Monitoring of allergens of plant origin, which are represented by the pollen of some plants, is important in this regard.

Also important is the analysis of big data in the field of health care, obtained with the help of the Internet of Things (IoT), which today is used to detect and prevent the development of various diseases. This direction has gained particular importance over the past three years in connection with the COVID-19 pandemic. One of the possibilities of integration of these technologies is their use to collect sensor data in real time by monitoring individuals, for example, with the help of smart watches and other gadgets.

The relevance of this study lies in the need to integrate the above technologies in order to preserve human health. Currently, although the healthcare industry is actively implementing applications based on IoT, cloud computing and the use of open APIs, the issue of using applications that analyze sensor data and meteorological data for the purpose of timely detection of threats to human health and their prevention remains relevant.

Thus, the *aim* of the study is to design and implement an IoT system based on open APIs and geolocation for human health data analysis.

2. Related work

We consider the combination of Internet of Things (IoT), artificial intelligence (AI) and cloud services technologies as an innovation that opens up new opportunities for real-time monitoring of human health. We analyzed the works of scientists for five years from 2018 to 2022 according to the joint use of the terms "Internet of Things" and "human health" in them (figure 1). According to the results, scientists investigated the possibilities of using Internet of Things (IoT) technologies to preserve human health in the areas of telemedicine, disease diagnosis, sensor monitoring networks, biometric monitoring, sports fitness management, smart city, cloud storage, Arduino hardware and software, etc. In this aspect, the existence of a relationship between the specified technologies and the field of health care is decisive. This is being realized thanks to the proliferation of medical and other wearable devices, which have rapidly gained significant popularity over the past few years. Also important is the analysis of big data in the field of health care, obtained with the help of the Internet of Things, which today is used to detect and prevent the development of various diseases.

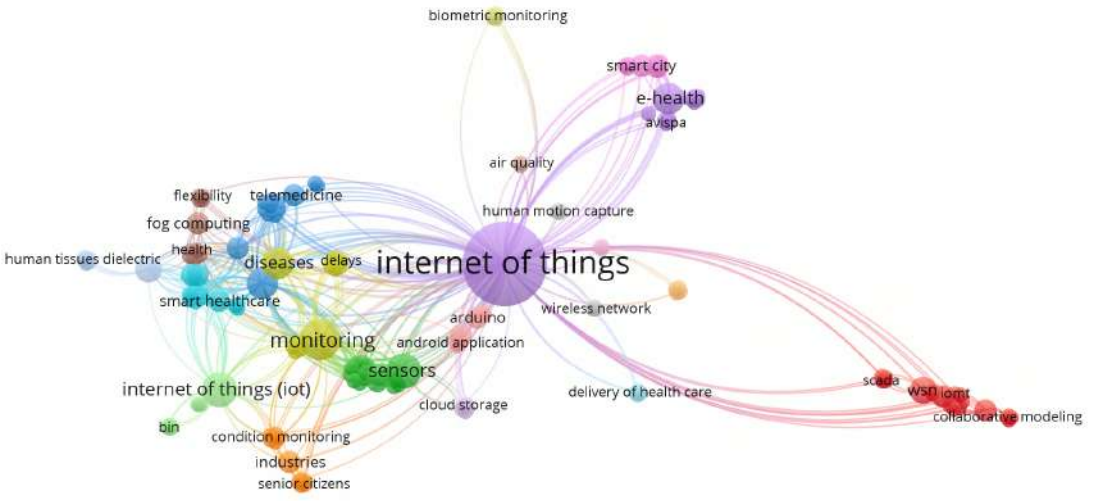

Figure 1: Map of the subject categories of scientists' research for five years from 2018 to 2022 according to the joint use of the terms "Internet of Things" and "human health" [1].

This direction has gained particular importance over the past three years in connection with

the COVID-19 pandemic. One of the IoT's capabilities is the ability to use it to collect real-time sensor data by monitoring individuals, such as through smart watches and other gadgets.

Various aspects of the presented topic are studied by many foreign and domestic scientists, in particular: the use of machine learning, big data and IoT from the point of view of medical informatics [31]; application of IoT technologies and artificial intelligence in health care during the COVID-19 pandemic [3, 31]; use of smart devices with IoT support in healthcare [3–5, 8, 12, 17, 20]; analysis of security threats, data corruption in the network and information security issues in health care related to IoT devices [29, 31]; the issues of real-time data monitoring based on IoT, notifications software with geolocation, data analysis were investigated by Konduru and Naga Surya [12], Kotelianets [13].

Chaouchi [2] conducted research to evaluate and apply clustering algorithms in healthcare based on cloud services and Open API for data mining. Such models are essential for effective decision-making in various healthcare domains, for providers and for patients. Data clustering can help in disease prediction through early disease diagnosis and timely treatment.

The issue of using machine learning, big data and IoT from the point of view of medical informatics was considered by Tawhid, Teotia and Elmiligi [31]. Scientists also focus on the issues of preserving the confidentiality of medical data.

The use of IoT technologies and artificial intelligence in health care during the COVID-19 pandemic was investigated by Chatterjee et al. [3]. The researchers reviewed the main aspects of eHealth services during COVID-19 and modern tools and solutions. In particular, they investigated the possibilities of using mobile applications for the purpose of conducting virtual consultations.

Mitchell [20] also reviewed the possibilities of online patient engagement for the treatment of COVID-19 using IoT-enabled smart devices, healthcare body sensor networks, and online patient engagement for the prevention, screening and treatment of COVID-19. He analyzed the data, determining the curve of the infection of COVID-19.

A feature of the research by Liu et al. [16] is the use of geodata to monitor social and structural determinants of human health, especially during the COVID-19 pandemic, to find strategies to improve health care. The authors proposed a geospatial and ML-based approach (GMLTrace) for finding indicators of differences in the health status of patients and analyzing them taking into account various determinants, for example, the elderly age of patients, racial and ethnic affiliation of patients, etc.

Also, the use of smart devices with IoT support in the field of health care from the point of view of information security of health care organizations was investigated by Graham [5]. The study considered approaches to identify any new patterns and external threats associated with the use of IoT devices, both technical and behavioral. One of the important aspects of the research is new questions related to not knowing how IoT devices work and the consequences of trusting IoT providers, ways to reduce these risks.

Analysis of security threats, data corruption in the network and information security issues in health care related to IoT devices were investigated by Höller et al. [7], Park, Park and Lee [27], Tawhid, Teotia and Elmiligi [31].

The issue of real-time data monitoring based on IoT, geolocation notification system, data analysis was investigated by Konduru and Naga Surya [12]. They proposed a remote pulse monitoring system. Their proposed engineering solution involves collecting information from

the sensor through a microcontroller and transferring it to databases, where it is further processed for consideration. The authors note that in this way medical workers can track changes in the patient's health indicators.

Despite the significant interest of scientists in the issue of using human health monitoring systems based on applications that work using an IoT-based application, cloud computing, open APIs, the issue of developing and using applications based on open APIs using Smart gadgets and Meteorological Geographic Information System (MGIS) for preserving human health has not been studied enough.

3. Selection of methods and diagnostics

In the process of work, research methods were used: analysis, synthesis, method of system analysis, methods of communication theory (development of a system that supports Internet of Things (IoT) technologies), modeling using the unified modeling language UML (in particular, to build a UML diagram of precedents), mathematical modeling, computer modeling (monitoring and data analysis).

In the process of solving the tasks, the method of system analysis was used in order to develop a system that supports the technologies of the Internet of Things (IoT), artificial intelligence (AI), cloud computing, open API, wireless access.

A method of combining devices based on open APIs using smart gadgets and meteorological geographic information system, a smartphone with wireless technologies was proposed. It has been used to track and analyze data related to human health, anywhere and anytime, interfacing with meteorological data to provide operational data (warnings) in real time about the likely presence of threats for human health.

The study considered two main groups of environmental factors as elements of the environmental system that influence the human body [33]:

1) abiotic (temperature, humidity, solar radiation, atmospheric pressure, chemical air pollution, etc.)
2) biotic (pollen).

For the purpose of data analysis, sensor data and indicators about the state of human health, as well as the state of the surrounding environment, were used:

- btotalDistance – total distance covered;
- btotalSteps – total number of steps;
- blastThousandSteps – the number of steps taken in the last 1000 m;
- baverageHeartRate – average heart rate;
- btemperature now – air temperature;
- bwind Speed now – wind speed;
- rainspot – rain spot area;
- pollen_birch – pollen birch;
- pollen_grass – pollen grass;
- pollen_olive – pollen olive;

- airqualityindex – air quality index.

Meteorological GIS Meteoblue [19] was used to quantify environmental factors using open APIs (figure 2).

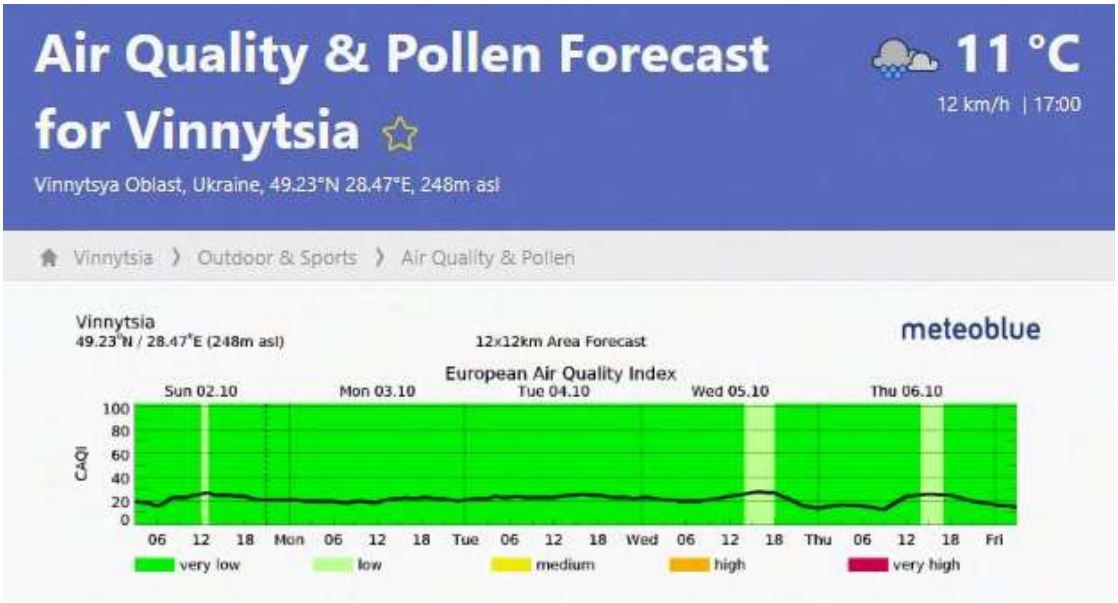

Figure 2: MGIS Meteoblue [19].

4. Designing an IoT system based on open APIs and geolocation

In accordance with the research goal, the task was set to develop and implement a new "anthropo-digital" system for preserving human health by building an IoT system based on open APIs for monitoring and analyzing data related to human health, with taking into account geolocation. For this purpose, it was planned to use smart gadgets (fitness bracelet and smartphone) and meteorological geographic information system.

The software application based on open API provides:

- collection and analysis of sensor data using Smart gadgets;
- real-time data processing – analysis of environmental factors in order to identify threats to human health;
- generation of a warning message to the user's mobile phone.

This system implements a warning about the threat of a person being in an environment with polluted air. Such notification is necessary for the timely prevention of the development of various diseases, determination of the influence of environmental factors on the working capacity and life expectancy of a person [9, 15].

Let's build a specialized UML diagram of precedents for implementing the process of modeling a wireless IoT system based on open APIs for monitoring and analyzing data related to human

health, taking into account geolocation (figure 3). The UML diagram of precedents describes the IoT system at the conceptual level and presents a scheme of relations between the Actor and the precedents that characterize the capabilities of the IoT system (figure 3):

1. Relative indication of heart rate, number of steps and distance covered.
2. Obtaining data on the state of the external environment.
3. Monitoring of geolocation sensor data.
4. Processing and analysis of the state of the external environment based on geolocation data in order to detect threats to human health.
5. Receiving warning signals about threats to human health.
6. Receiving a notification about taking actions aimed at preserving health.

Thus, the architecture of the IoT system proposed by us is a network model (figure 4). It is assumed that the following are integrated in this model:

1) smart gadget (fitness tracker/smart watch). We used the Apple Watch 4 fitness tracker as a smart gadget;
2) smartphone;
3) scale-independent integrated meteorological geoinformation system;
4) cloud services used to host a software application for monitoring and data analysis.

5. Results and discussion

In accordance with the goal of developing an IoT system based on open APIs and geolocation for human health data analysis, meteorological data was monitored and analyzed.

Data monitoring can be carried out anywhere and at any time by establishing a relationship with a fitness tracker and a person's smartphone, provided they are connected to a communication channel (Wi-Fi network, mobile network, etc.). Also, for meteorological data monitoring and analysis, we have developed a software application based on open APIs, which parses the data of the meteorological geoinformation system. Data analysis is carried out to provide real-time operational warnings about the probable presence of threats to human health.

The quantitative assessment of environmental factors is carried out automatically online, taking into account human geolocation data and data on the state of the surrounding environment, which can be obtained using open APIs of the geoinformation system (figure 2).

A software application based on open APIs that analyzes sensor data and geolocation data of smart gadget and MGIS, analyzes them and generates messages about possible threats to human health, developed in the Python programming language [28] (figure 5).

In order to evaluate performance, we conducted functional testing of the IoT system. Performance of the IoT system was tested on various test data: geographic coordinates; state of air pollution; concentration of pollen in the air.

As a result of the test, it was assessed whether the IoT system returns the expected result in response to the specified entered parameters.

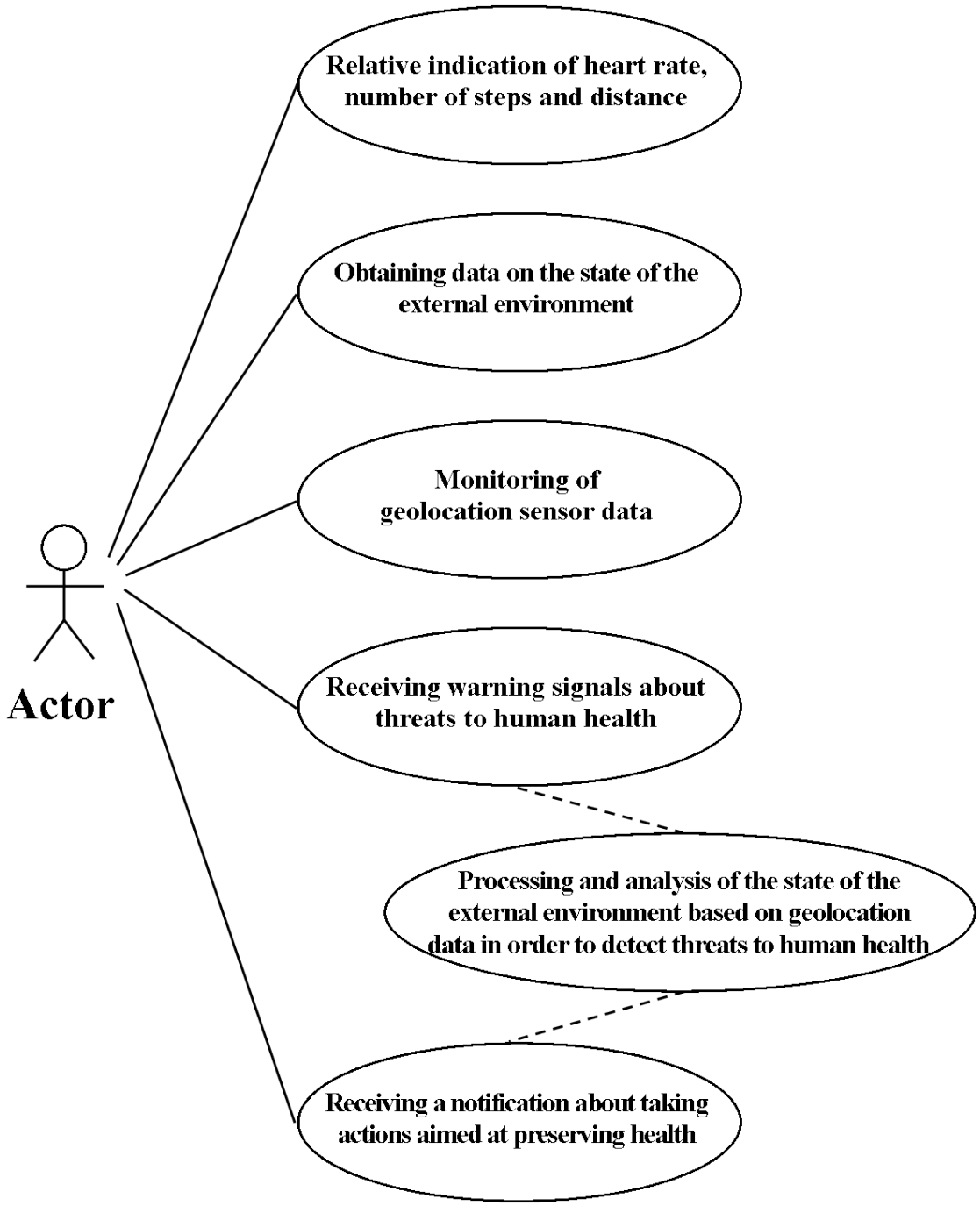

Figure 3: UML diagram of precedents, which reflects the relationship between the Actor and precedents in the IoT system.

The system showed a high efficiency of 100% on the specified test geographic data, various parameters of the air pollution state, including the limit parameters.

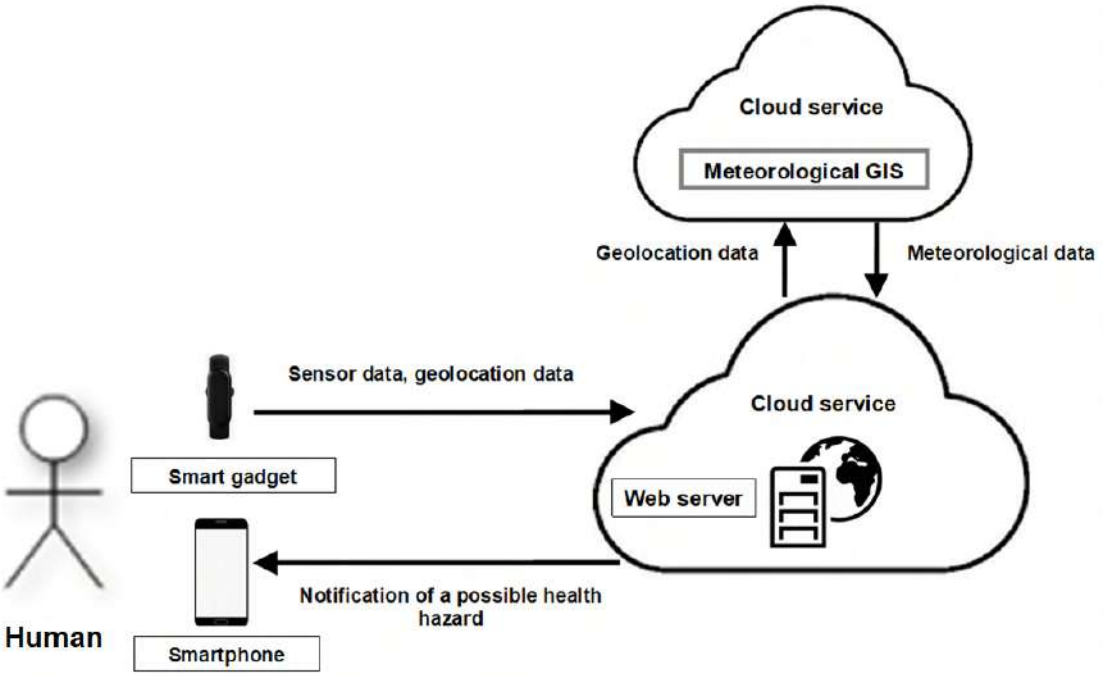

Figure 4: Architecture of a wireless IoT system based on open APIs and geolocation.

```
# calculate distance between two coordinates
def distanceBTP(latitude1, longitude1, latitude2, longi-
tude2):
   R = 6378.137 * 1000  # meters
   f1 = latitude1 * math.pi / 180
   f2 = latitude2 * math.pi / 180
   delf = (latitude2 - latitude1) * math.pi / 180
   dell = (longitude2 - longitude1) * math.pi / 180
   a = math.sin(delf / 2) * math.sin(delf / 2) + math.cos(f1) *
     math.cos(f2) * math.sin(dell / 2) * math.sin(dell / 2)
   c = 2 * math.atan2(math.sqrt(a), math.sqrt(1 - a))
   d = R * c  # in metres
```

Figure 5: Application software based on open APIs.

As a result of testing the IoT system according to the air quality index, it was determined that the MGIS Meteoblue [19] system shows only an hourly "background" index [18]. This IoT system does not define a "roadside" or "traffic" index [18]. Therefore, as a result of its testing near highways, it was found that the system is not effective in use.

For the purpose of testing the system, data obtained previously from a similar Apple Watch 4 fitness tracker, which determines a person's geolocation, was used (figure 6).

If there is pollen in the air (pollen grass, pollen birch, pollen olive), the system issues a message about this danger, indicating the level of pollen concentration in the air. The concentration of

```
<trkpt lat="38.4340980" lon="-122.7151630">
 <ele>48.0</ele>
 <time>2016-08-28T13:03:35Z</time>
 <extensions>
  <gpxtpx:TrackPointExtension>
   <gpxtpx:hr>112</gpxtpx:hr>
   <gpxtpx:cad>92</gpxtpx:cad>
  </gpxtpx:TrackPointExtension>
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  <gpxtpx:TrackPointExtension>
   <gpxtpx:hr>112</gpxtpx:hr>
   <gpxtpx:cad>92</gpxtpx:cad>
  </gpxtpx:TrackPointExtension>
```

Figure 6: Data obtained from the fitness tracker Apple watch 4, which determines the geolocation of a person.

pollen in the air can be increased by the wind. Also, the pollen becomes more allergenic if the air is polluted.

The use of the developed IoT system can have preventive, and in certain cases, therapeutic value (as prevention of disease exacerbations). This is necessary for the prevention of pathologies related to the state of the external environment, in particular, the presence and level of concentration of substances that can be allergens (substances that cause allergies). It is important to use the developed IoT system for the prevention of allergic diseases, including, first of all, pollinosis (diseases caused by plant pollen), as well as other pathologies in which an allergic component is present. Among such disorders with an allergic component, we single out bronchial asthma. It is important to prevent its attacks and exacerbations (the active phase of the disease that manifests itself against the background of relative well-being). Thus, bronchial asthma is presented not only as a medical, but also as an ecological problem, the important preventive aspect of which can be solved by the developed IoT system.

The recommended scales of the air quality index (dimensionless) and the European Common Air Quality Index (CAQI) were used to generate the messages [18] (table 1).

According to the value of the air quality index, the system issues a message about a threat to human health and recommendation for actions in this situation (figure 7).

6. Conclusion

The IoT human health data monitoring system was designed and developed to provide real-time operational alerts anywhere, taking into account meteorological data on likely threats to human health, as well as generating notifications about human sensory data (total distance, total

Table 1
The message that the user of the IoT system can receive on a smartphone according to the air quality index value [18].

Air quality index	Air pollution	Warning signal about threats to human health
0 to 50	Excellent	Neutral, without threats or health consequences.
51 to 100	Good	In the case of existing weather sensitivity, it is necessary to limit outdoor physical activity.
101 to 150	Lightly polluted	Slight irritations may occur, people with pathologies of the respiratory and cardiovascular systems should minimize outdoor physical activity.
151 to 200	Moderately polluted	Some irritations may occur, people with pathologies of the respiratory and cardiovascular systems should minimize outdoor physical activity.
201 to 300	Heavily polluted	In healthy people, the risk of developing diseases increases significantly. In people with diseases of the respiratory and cardiovascular systems, endurance in conditions of activity will decrease. It is recommended that individuals and elders stay indoors and minimize physical activity.
over 300	Severely polluted	A decrease in endurance for motor activity is determined in healthy people. Signs of irritation may appear and the risk of various diseases may increase. Sick and elderly people should minimize physical activity and avoid being outdoors. Healthy people need to minimize physical activity outdoors.

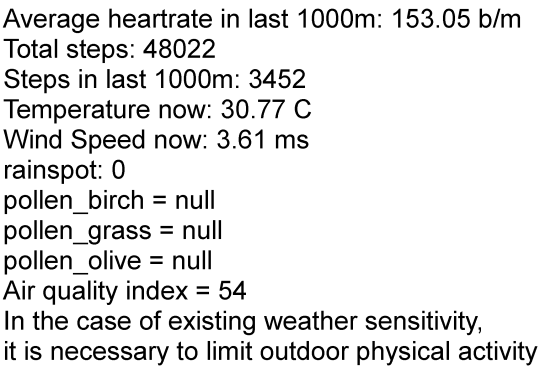

Figure 7: Notifications received on a person's smartphone in the event of an air pollution hazard.

steps, last thousand steps, average heart rate) and the state of the surrounding environment (temperature now, wind speed now, rain spot). The developed application based on open APIs using smart gadgets and meteorological GIS in the process of work generates a message about the danger to human health related to: the presence of pollen in the air (pollen grass, pollen birch, pollen olive), indicating its level concentrations in the air; the presence of air quality

problems, if the air quality indicator exceeds the permissible standards.

Functional testing of the IoT system was conducted on various test data: geographical coordinates; state of air pollution; concentration of pollen in the air. Based on the given test geographic data, various parameters of the state of air pollution, including the limit parameters, the system showed high efficiency. However, as a result of testing the IoT system according to the Air quality index, it was determined that the MGIS Meteoblue system shows a "background" index, therefore, the system is not effective in use along with roads.

Further goals towards which the development of this application is planned are of great importance for scaling in many other possible use cases. The IoT system for tracking data related to human health is aimed at prevention – preventing the problems of negative effects of environmental factors on human health, which is implemented by generating warning signals about possible threats and reminders to take actions aimed at preserving health. The addition of such functions expands the possibilities of timely provision of concise and clear information about probable risks and threats and, accordingly, represents an "anthropo-geo-sensory-digital" prerequisite for making effective decisions in the current situation.

The implementation of this IoT system has significant methodological and technological potential, which can be used to improve the effectiveness of health care, both in extreme conditions and in conditions of sustainable existence. First of all, it is relevant during and after the COVID-19 pandemic. This development is significant for improving the quality of life. The system developed by us can also be considered as one of the ways of introducing innovations in the field of health care.

Further research in this direction may be related to data processing in healthcare systems based on machine learning and deep learning.

The novelty of the obtained results is that: the architecture of the IoT system was designed taking into account geolocation for tracking data related to human health; developed and implemented an IoT system, taking into account geolocation, for tracking data related to human health; improved IoT system for monitoring and analyzing data related to human health, based on the use of meteorological geoinformation systems; technologies for the development of IoT systems based on open APIs, taking into account geolocation, gained further development.

The practical significance of the research results is that the developed IoT system based on open APIs for analyzing data related to human health, taking into account geolocation, has significant methodological and technological potential, which can be used to improve the efficiency of the health care system. Both theoretical and practical results, conclusions, proposals and recommendations formulated in the study can be used: to improve and increase the effectiveness of the human health care system (in extreme conditions, in conditions of sustainable existence), for example, during and after the COVID-19 pandemic; in the educational process of training and retraining of teachers of informatics, physical culture, ecology, health basics, doctors, rehabilitators, trainers; in practices and technologies of rehabilitation, medicine, ecology; in scientific research on this topic; as one of the ways of introducing innovations in the IT sphere and the sphere of health care; in everyday life.

References

[1] Centre for Science and Technology Studies, Leiden University, The Netherlands, 2023. VOSviewer - Visualizing scientific landscapes. Available from: https://www.vosviewer.com/.

[2] Chaouchi, H., ed., 2013. *The internet of things: Connecting objects to the web*. John Wiley & Sons. Available from: https://books.google.com.ua/books?id=EGNm4iT8TC8C.

[3] Chatterjee, P., Tesis, A., Cymberknop, L.J. and Armentano, R.L., 2020. Internet of Things and Artificial Intelligence in Healthcare During COVID-19 Pandemic—A South American Perspective. *Frontiers in Public Health*, 8, p.600213. Available from: https://doi.org/10.3389/fpubh.2020.600213.

[4] Evans, J., Papadopoulos, A., Silvers, C.T., Charness, N., Boot, W.R., Schlachta-Fairchild, L., Crump, C., Martinez, M. and Ent, C.B., 2016. Remote Health Monitoring for Older Adults and Those with Heart Failure: Adherence and System Usability. *Telemedicine and e-Health*, 22(6), pp.480–488. Available from: https://doi.org/10.1089/tmj.2015.0140.

[5] Graham, C., 2021. Fear of the unknown with healthcare IoT devices: An exploratory study. *Information Security Journal: A Global Perspective*, 30(2), pp.100–110. Available from: https://doi.org/10.1080/19393555.2020.1810369.

[6] 2008. Health Informatics - Personal Health Device Communication -Part 10404: Device Specialization - Pulse Oximeter. *IEEE Unapproved Draft Std P11073-10404/D08, Aug 2008*. Available from: https://ieeexplore.ieee.org/document/4621346.

[7] Höller, J., Tsiatsis, V., Mulligan, C., Karnouskos, S., Avensand, S. and Boyle, D., 2014. From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence. Available from: https://doi.org/10.1016/C2012-0-03263-2.

[8] Kang, Y., McHugh, M.D., Chittams, J. and Bowles, K.H., 2016. Utilizing Home Healthcare Electronic Health Records for Telehomecare Patients With Heart Failure: A Decision Tree Approach to Detect Associations With Rehospitalizations. *CIN: Computers, Informatics, Nursing*, 34(4), pp.175–182. Available from: https://doi.org/10.1097/CIN.0000000000000223.

[9] Klochko, O., Fedorets, V., Mudrak, O., Troitska, T. and Kaplinskyi, V., 2022. Modeling of ecophobic tendencies of consciousness of higher education students. *SHS Web of Conferences*, 142, p.03006. Available from: https://doi.org/10.1051/shsconf/202214203006.

[10] Klochko, O.V., Fedorets, V.M., Uchitel, A.D. and Hnatyuk, V.V., 2020. Methodological aspects of using augmented reality for improvement of the health preserving competence of a Physical Education teacher. In: O.Y. Burov and A.E. Kiv, eds. *Proceedings of the 3rd International Workshop on Augmented Reality in Education, Kryvyi Rih, Ukraine, May 13, 2020*. CEUR-WS.org, *CEUR Workshop Proceedings*, vol. 2731, pp.108–128. Available from: http://ceur-ws.org/Vol-2731/paper05.pdf.

[11] Klochko, O.V., Gurevych, R.S., Nagayev, V.M., Dudorova, L.Y. and Zuziak, T.P., 2022. Data mining of the healthcare system based on the machine learning model developed in the Microsoft azure machine learning studio. *Journal of Physics: Conference Series*, 2288(1), p.012006. Available from: https://doi.org/10.1088/1742-6596/2288/1/012006.

[12] Konduru, P. and Naga Surya, S., 2020. IoT based Real-Time Pulse Monitoring and Geolocation Alerting System with Data Analysis. *International Journal of Engineering Research & Technology*, 9(9), pp.143–143. Available from: https://doi.org/10.17577/IJERTV9IS090050.

[13] Kotelianets, V., 2019. *Information Technology for Environmental Monitoring Based on Internet of Thing Concept.* Thesis for a Candidate of Technical Science (PhD) degree on specialty 05.13.06 – Information Technology. Cherkasy State Technological University, Cherkasy. Available from: https://er.chdtu.edu.ua/bitstream/ChSTU/67/1/aref.pdf.

[14] Kravtsova, L.V., Zaytseva, T.V., Bezbakh, M., Kravtsov, H.M. and Kaminska, N.H., 2022. The optimum assessment of the information systems of shipboard hardware reliability in cloud services. *CTE Workshop Proceedings*, 9, pp.200–215. Available from: https://doi.org/10.55056/cte.115.

[15] Kundiiev, Y.I., Bardov, V.H., Serdiuk, A.M., Voronenko, V.V., Polka, N.S., Serdiuk, A.M., Bardov, V.H., Kundiiev, Y.I., Yavorovskyi, O.P., Serdiuk, A.M., Los, I.P., Tsypriian, V.I. and Korzun, V.N., 2006. Hihiiena [Hygiene]. In: I.M. Dziuba, A.I. Zhukovskyi, M.H. Zhelezniak et al., eds. *Entsyklopediia Suchasnoi Ukrainy*. Kyiv: Instytut entsyklopedychnykh doslidzhen NAN Ukrainy, vol. 5. Available from: https://esu.com.ua/search_articles.php?id=29475.

[16] Liu, J., Alo, R.A., Parra Bautista, Y.J., Yedjou, C.G. and Theran, C., 2021. A Geospatial and ML-based Approach to Health Disparity Identification and Determinant Tracing for Improving Pandemic Health Care. *2021 Eighth International Conference on Social Network Analysis, Management and Security (SNAMS)*. pp.01–08. Available from: https://doi.org/10.1109/SNAMS53716.2021.9731851.

[17] Liu, L., Stroulia, E., Nikolaidis, I., Miguel-Cruz, A. and Rios Rincon, A., 2016. Smart homes and home health monitoring technologies for older adults: A systematic review. *International Journal of Medical Informatics*, 91, pp.44–59. Available from: https://doi.org/10.1016/j.ijmedinf.2016.04.007.

[18] Meteoblue, 2022. Air quality. Available from: https://content.meteoblue.com/en/research-education/specifications/weather-variables/air-quality.

[19] Meteoblue, 2022. Weather Vinnytsia. Available from: https://www.meteoblue.com/en/weather/week/vinnytsia_ukraine_689558.

[20] Mitchell, K., 2021. Internet of Things-enabled Smart Devices, Healthcare Body Sensor Networks, and Online Patient Engagement in COVID-19 Prevention, Screening, and Treatment. *American Journal of Medical Research*, 8(1), pp.30–39. Available from: https://doi.org/10.22381/ajmr8120213.

[21] Modlo, Y.O., Semerikov, S.O., Bondarevskyi, S.L., Tolmachev, S.T., Markova, O.M. and Nechypurenko, P.P., 2019. Methods of using mobile Internet devices in the formation of the general scientific component of bachelor in electromechanics competency in modeling of technical objects. In: A.E. Kiv and M.P. Shyshkina, eds. *Proceedings of the 2nd International Workshop on Augmented Reality in Education, Kryvyi Rih, Ukraine, March 22, 2019*. CEUR-WS.org, *CEUR Workshop Proceedings*, vol. 2547, pp.217–240. Available from: http://ceur-ws.org/Vol-2547/paper16.pdf.

[22] Nikitchuk, T.M., Vakaliuk, T.A., Chernysh, O.A., Korenivska, O.L., Martseva, L.A. and Osadchyi, V.V., 2021. Architecture for edge devices for diagnostics of students' physical condition. *CEUR Workshop Proceedings*, 2850, pp.45–56. Available from: https://ceur-ws.org/Vol-2850/paper3.pdf.

[23] Pak, J. and Park, K., 2011. A Smart Personal Activity Monitoring System Based on Wireless Device Management Methods. In: J.J. Park, L.T. Yang and C. Lee, eds. *Future Information Technology*. Berlin, Heidelberg: Springer Berlin Heidelberg, *Communications in Computer*

and Information Science, vol. 184, pp.335–342. Available from: https://doi.org/10.1007/978-3-642-22333-4_44.

[24] Pak, J. and Park, K., 2012. UbiMMS: An Ubiquitous Medication Monitoring System Based on Remote Device Management Methods. *Health Information Management Journal*, 41(1), pp.26–30. Available from: https://doi.org/10.1177/183335831204100104.

[25] Pak, J.G. and Park, K.H., 2012. Advanced Pulse Oximetry System for Remote Monitoring and Management. *Journal of Biomedicine and Biotechnology*, 2012, p.930582. Available from: https://doi.org/10.1155/2012/930582.

[26] Park, K. and Lim, S., 2015. A multipurpose smart activity monitoring system for personalized health services. *Information Sciences*, 314, pp.240–254. Available from: https://doi.org/10.1016/j.ins.2014.10.036.

[27] Park, K., Park, J. and Lee, J., 2017. An IoT System for Remote Monitoring of Patients at Home. *Applied Sciences*, 7(3), p.260. Available from: https://doi.org/10.3390/app7030260.

[28] Python Software Foundation, 2023. Welcome to Python.org. Available from: https://www.python.org/.

[29] Sandeep, C.H., S., N.K. and P., P.K., 2018. Security Challenges and Issues of the IoT System. *Indian Journal of Public Health Research & Development*, 9(11), pp.748–753. Available from: https://www.researchgate.net/publication/329481300.

[30] Semerikov, S., Striuk, A., Vakaliuk, T.A. and Morozov, A.V., 2021. Quantum information technology on the Edge. *CEUR Workshop Proceedings*, 2850, pp.1–15. Available from: https://ceur-ws.org/Vol-2850/paper0.pdf.

[31] Tawhid, A., Teotia, T. and Elmiligi, H., 2021. Chapter 13 - Machine learning for optimizing healthcare resources. In: P. Kumar, Y. Kumar and M.A. Tawhid, eds. *Machine Learning, Big Data, and IoT for Medical Informatics*. Academic Press, Intelligent Data-Centric Systems, pp.215–239. Available from: https://doi.org/10.1016/B978-0-12-821777-1.00020-3.

[32] Tkachuk, V., Yechkalo, Y.V., Semerikov, S., Kislova, M. and Hladyr, Y., 2020. Using Mobile ICT for Online Learning During COVID-19 Lockdown. In: A. Bollin, V. Ermolayev, H.C. Mayr, M. Nikitchenko, A. Spivakovsky, M.V. Tkachuk, V. Yakovyna and G. Zholtkevych, eds. *Information and Communication Technologies in Education, Research, and Industrial Applications - 16th International Conference, ICTERI 2020, Kharkiv, Ukraine, October 6-10, 2020, Revised Selected Papers*. Springer, *Communications in Computer and Information Science*, vol. 1308, pp.46–67. Available from: https://doi.org/10.1007/978-3-030-77592-6_3.

[33] Yesyrkenov, Y.E., 2008. Dovkillia [Environment]. In: I.M. Dziuba, A.I. Zhukovskyi, M.H. Zhelezniak and other, eds. *Entsyklopediia Suchasnoi Ukrainy*. Kyiv: Instytut entsyklopedychnykh doslidzhen NAN Ukrainy, vol. 8. Available from: https://esu.com.ua/search_articles.php?id=20479.