An Information System Prototype for Monitoring and Modeling the Spread of Viral Infections

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Abstract. The paper is devoted to the construction of an information system designed to monitor and model possible variants of coronary virus infection situations. Some of its prototypes are being built. The peculiarities of building promising information systems was analyzed, the purpose of which is to identify, localize the spread and complete elimination of source of viral infections with the active use of methods, tools and techniques inherent in modern information technology. A prototype of the model-monitoring complex system information-technological platform has been formed, which is designed to effectively implement the functions of identification, monitoring, modelling and forecasting of the spread of viral infections in society. The basic characteristic by which the authors propose to identify the infected is thehuman body temperature. The paper deals with the construction of an effective temperature screening module, which is based on remote mobile temperature measuring devices, which are installed on unmanned aerial vehicles or installed in the equipment of law enforcement officers (helmets, goggles, etc.). The authors formed a prototype of the hardware of the complex, which in a systematic combination can effectively implement the functions of identification and monitoring of large groups of people who may be carriers, distributors and potentially infected in large crowds, in particular, during various concerts, festivals, rallies, mass festivities, demonstrations, religious ceremonies, sports competitions, etc. The authors developed and tested this model-prognostic complex on real data, which is based on ensembles of mathematical models belonging to the molecular dynamics category. New original results have been obtained, which can be used for further expansion of the functionality proposed by the authors of the innovative class of information systems, which in the future should acquire the status of systems and means of daily use by various target groups, in particular, such as health care workers law and order and power structures.

A set of works on approbation of the proposed design and model solutions in the conditions of the pandemic COVID-19 infection was performed. The situation in the Chernivtsi region of Ukraine during religious ceremonies on the occasion of Orthodox holidays - Palm Sunday and Easter - was studied as a model object.

Keywords: Prototype, Information System, Monitoring, Modeling, Viral Infections

1 Introduction

The emergence of coronavirus infection is one of the greatest challenges to humanity. The lack of reliable universal tools of fixing of the disease source in the early stages leads to the growth small scape, into a global pandemic. The issue of the population anti-epidemiological protection remains open and needs to be studied in detail, and the available information technologies do not fully address the issue of early detection of source of viral infection and need to be improved.

This issue is acute in the context of the spread of viral infections in spring and autumn, in particular in places where is the maximum recreational load - in suburban forests, reserves, during ethnographic, folk or song festivals that held in nature, concerts, football matches, religious and public holidays. The program of activities always includes requirements and systemic restrictions in order to minimize the spread of diseases in these conditions for personal and public safety.

The spread of the coronavirus pandemic in the world indicates its high intensity due to its volatility, rapid spread and deteriorating health.

The main measures are usually aimed to identifying of the virus carriers as soon as possible, clearly defining the procedures for self-isolation and quarantine of infected suspects, providing emergency medical care, and clearly identifying trajectories movements infected peoples and communication to identify sources of potential infection. John Hopkins University [1] is actively conducting research in this direction. Center for Global Analysis of Infectious Diseases MRC (mrc-global-infeentist-disease-analysis) is consolidating information on epidemiological analysis and modeling of infectious diseases [2].

2 Identification of the Disease

Tools and methods of infected persons identification, which in turn are the main spreaders of infection, become especially relevant in a pandemic. The signs of the disease coincide with some signs of the common grippe, such as dry cough, general weakness, fever at the initial stage of coronavirus infection. Diagnosis of coronavirus infection solely on the basis of the clinical picture is almost impossible, because the symptoms of coronavirus are completely or largely identical to the symptoms of other

respiratory infections. Operative testing procedures facilitate the operative determination of the coronavirus presence in the body.
At the same time, there is an urgent need in a pandemic to identify patients by a number of characteristics, which can be fixed in several ways. One of them is to identify the infected patient by the nature of the cough.

Researchers from Embedded Systems Laboratory [3] have created an original mobile application to identify a patient with coronavirus by the results of the tone and strength of cough. The accuracy of this method of identification is 70%.

Another method involves identifying infected people by fever. We will investigate on this direction of identification in more detail.

3 Measurement of Human Body Temperature

3.1 Stationary tools for temperature measurement

Information on body temperature and trajectory collection and processing are important elements in building effective systems for monitoring and modeling of the disease spread. Thermometry generally uses a large number of modern methods and tools, the choice of which is related to several factors: the measured parameter; metrological and operational requirements for different ranges of measured temperatures; a variety of objects and conditions for measuring their temperature; physical and mechanical characteristics of thermometric properties and working substances used in specific temperature measuring instruments.

Implementation of the correct temperature measurement process for each case requires a detailed analysis of the object-thermometer system thermal interaction conditions [4, 5].

Improving the efficiency of the public health identification, monitoring and modeling based on body temperature is based on the use of modern information technology. The problem of the participants cases fever determining for any mass event is relevant in many countries around the world and helps to prevent the rapid spread of infectious diseases. It is characteristic of both underdeveloped countries and countries with a high level of technological development.

One of the priorities in modern research is to conduct a comprehensive monitoring of participants temperature in the mass event or certain crowds places and to identify ways to minimize the consequences of the disease spread to prevent epidemics. At the same time, modern information systems and technologies that allow effective monitoring of crowded places are becoming very important.

The temperature monitoring technology of participants in mass events is based on the tools of early detection of the disease sources. The effectiveness of their functioning is the key to rapid response, which prevent the rapid spread of the disease.

Tools of human body temperature mass monitoring can be both stationary and mobile.

Stationary thermal imaging systems for tracking body temperature have been widely used in recent years. Thermal imagers are installed at the entrance to supermarkets, cinemas, government offices, stadiums, subways and others. This technology involves the processing of large amounts of video and photographic materials, dynamic input signals in order to track the trajectories of people.

The use of these systems provides, in particular, regular temperature monitoring in crowds.

A special place is occupied by the technology of video recording in the thermal range in the study and application of methods for remote monitoring of body temperature of visitors.

We will analyze the methods of temperature measurement in order to select the best of them for implementation in the developed system. It should be borne in mind that the methods of measuring temperature are divided into contact and non-contact, each class has its advantages and disadvantages.

Contact methods of temperature measurement change the temperature field of the object under study due to the contact of the primary transducer and the object of measurement.

Non-contact (pyrometric) methods do not have this disadvantage. However, the tools of pyrometry is characterized by a methodological error due to the fact that the fundamental physical laws that underlie their principle of operation are fulfilled only for a completely black body[6]. Pyrometric instruments, calibrated with a completely black body, will show a temperature with an error different from its real thermodynamic when measuring the temperature of a real object.

The method of thermal imaging of the thermal field of objects by infrared radiation is the one of the non-contact methods[7]. This method does not determine the true value of the temperature, but allows you to select the warmest parts of the object in real time. Each of the methods has its own scope and is used in various subject areas of medicine.

Modern thermal detectors allow to determine the temperature gradient up to tenths of a degree, form the image of the measurement results in the television standard [8], present it in the infrared range of the emitting material in the form of a thermogram. Each individual temperature indicator corresponds to a certain color on the this thermogram. Anomalies in temperature measurements serve as indicators for the identification of potential patients, and the magnitude of temperature signals and their change over time are the basis for quantitative estimates of certain parameters of the object of study.

Based on the generalization of data on metrological characteristics of thermal sensors from global and domestic manufacturers (IRay Technology Co., CEM, Testo AG, Wuhan Guide Infrared Co., Fluke, IPI, Irisys, IRtek, Chauvin Arnoux, SAT Infrared Technology, etc.) and a number of articles [9] modern models of such devices can be characterized as measuring instruments operating: in the middle part of the spectrum, thermal infrared part of the spectrum, wide temperature range.

The main task of thermal imagers is the formation of thermograms that will provide a qualitative (search for "hot" and "cold" areas) and quantitative (determining the temperature and temperature difference of the test and sample areas) evaluation of research results, despite such a variety of devices.

Thermal sensors are quite easy to install in key places of infrastructure (supermarkets, etc.) and get a thermographic picture in real time.

The analysis showed that infrared sounding is best used in the first stage to quickly identify potentially COVID-19 patients, and contact temperature measurement methods should be used in the next step to more accurately analyze health status. Fig. 1 shows a block diagram of a system for identifying a potential patient in the flow of people. All obtained data can be accumulated and stored on a server or in the cloud for further analysis of the increase or decrease in the number of identified persons.

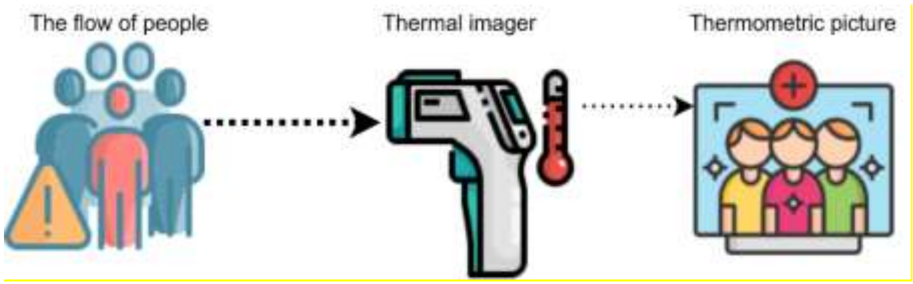

Fig. 1. Block diagram of the looking for potentially "sick" in the flow of people rapid system analysis

Selection of "Suspicious" people for specification of the results received from the thermal imager is carried out on the basis of indicators of the device selection. Compact thermal imagers have been widely used in the conditions of quarantine, which by their mass and dimensions allow them to be installed on a quadcopter, which contributes to a more detailed assessment and identification of potentially sick persons. As thermal sensors give only the general indicators of the person temperature without exact definition of indicators, there is a necessity to clarify of indicators of persons temperature in places of mass concentration of people. Therefore, there is a need to develop an information system based on contact methods that provides prompt verification of temperature indicators. Figure 2 shows a schematic diagram of the clarifying temperature measurement system.

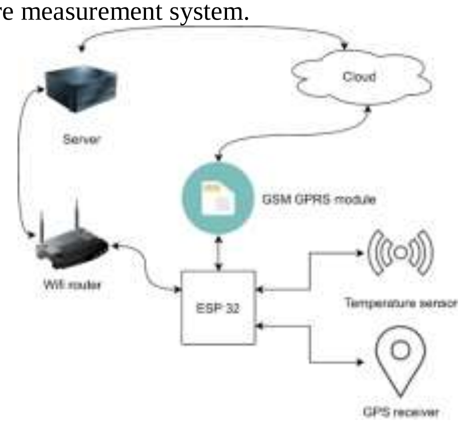

Fig. 2. Schematic diagram of the system for clarifying the temperature of potentially "sick" people

The functionality of the information system is based on chips and microcontrollers ESP32 ESP-WROOM-32. The PT 100 sensor was chosen to measure the temperature, which is based on the thermoelectric effect, namely: in a closed circuit of two dissimilar semiconductors or conductors, an electric current is generated if the fusion sites are at different temperatures. Thus, the output voltage of the thermocouple depends on the temperature difference of its rages (working rage and rage comparison). This sensor allows you to measure the temperature with an accuracy of ± 0.2 C. The data received from the sensor goes to ESP32, where information is accumulated, and GPS data on the location of the device via the GSM module is transmitted to the cloud, where data is processed, and in the presence of WiFi accumulated on the local server. Data from the server is configured at regular intervals with data in the cloud.

This information system will allow to identify potentially sick people with a high probability, track them, as well as on the basis of the obtained data to predict the behavior of the disease.

3.2 Mobile thermal imagers

It is advisable to use temperature sensing methods that are using mobile systems, which are based on infrared thermal imaging cameras, in the construction of systems for identification and monitoring of the spread of viral infection, which are usually accompanied by a rise in human body temperature. The authors made a design decision to use a thermal imaging system, forming a prototype of this class of information system, by installing it on an unmanned aerial vehicle, which at the same time allowed a number of other monitoring types on this platform.

The use of thermal imaging cameras equipped UAVs is one of the promising methods for detecting source of viral infection. Today, more and more companies are emerging that specialize in creating thermal imaging systems for UAVs. Equipping a UAV by the a thermal imaging camera significantly expands the range of possibilities for using thermal imaging systems. The using of UAVs for monitoring studies in the context of the spread of viral infections is considered optimal due to the high efficiency, mobility, high controllability, stability, cost-effectiveness . Usually, thermal imaging equipment is not perfect in the conditions of early monitoring of sources of infection, because its work is significantly affected by extraneous infrared radiation, which can distort the information about the presence of a small source with high temperature characteristics. Fog can also adversely affect the operation of infrared sensors, as water droplets significantly prevent the penetration of infrared radiation.

The capabilities of modern UAVs are analysed in a number of thorough professional studies, which provide, in particular, the main areas of their application and highlight their fundamental advantages [10-13]. One of the main advantages of UAVs is the ability to perform tasks autonomously, which does not require certain professional skills like the direct presence of the performer and the ability to conduct monitoring. Additional advantages of UAVs compared to traditional imaging technologies, including thermal imaging are:

- low shooting height - up to 10 meters to obtain a high resolution (units and tenths of a centimeter) on the ground;
- accuracy - the ability to take detailed pictures of small objects and small areas where it is not cost-effective or technically impossible to do in other ways, for example, in urban areas;
- mobility - no specially prepared runways are required, UAVs are easily transported, there is no complicated procedure for flight permits;
- high efficiency - the whole cycle from system deployment to results can take from 10 minutes to several hours;
- ecological cleanliness of flights - low-power petrol or silent electric motors are used, the minimum loading on environment is provided.

Temperature screening and personal identification of patients among visitors to mass events, such as football matches, concerts, festivals, rallies, religious ceremonies, etc. is one of the current situations of operational remote monitoring of human body temperature.

Involvement of visitors UAVs in the monitoring of mass events is one of the tasks of the viral infection source early detection information system. In this case, the further data transmission chain can be focused on interaction with the systems of mobile operators in order to identify and record the phone numbers of people with high body temperature in order to further track the trajectories of their movement.

Bispectral video surveillance cameras with a thermal imaging sensor that are installed on the UAV allows to identify and monitor the visitors human body temperature in automatic mode for such events.

The UAV informs the dispatcher about the detected sources with elevated temperature through open communication channels.

The integration of UAVs into monitoring systems, in particular the identification of people with fever, does not require cumbersome and expensive technological solutions. The developed by us prototype of the human body temperature mobile monitoring information system can serve as an effective tool, as our previous research has shown.

4 Recording and processing of monitoring results

Messages from the UAV are received by the dispatcher in case of detection of fever in pedastrians or participants of mass events.

These messages contain the original digital image of the suspicious object (group of objects) and its GPS coordinates. This allows the operator to assess the risk of a disease outbreak.

At this time, the control point of the security service sends an alarm signal to those present in the area of the UAV and law enforcement officers in order to verify the validity of the suspicion on the spot. If the information is confirmed, they provide a set of measures to identify, locate and monitor the movement of such persons.

Detection of carriers of viral infection allows you to localize the virus without wasting valuable time and without using powerful technical and material means. Consolidation of this type of data in the central control points of the health and viral infection services increases the level of control over the epidemiological situation. Background signal processing is possible if UAV remote controls are equipped with multi-core processors, the free cores of which are used for background calculations, and GSM communication modules for data transmission via mobile Internet.

Such a mobile information technology service based on UAVs with a bispectral video surveillance camera with a thermal imaging sensor allows to form an effective system of identification and monitoring of the situation by increasing the speed of detecting sources of infection and prompt information about the dangers of relevant services.

5 Modeling the infection processes of large people crowds

The presence of infected people in the area of various activities usually leads to a high probability of infection spread. Therefore, it is advisable to simulate a variety of scenarios when planning mass events. In this context, it is important to develop a model and conduct computer experiments that would allow real-time representation of the development of various critical situations. This, in turn, makes it possible to prepare the necessary measures to localize and stop the spread of infection, or in certain cases to make a reasoned decision on the impossibility of holding a mass event. In this regard, in the plans of mass events it is advisable to conduct predictive modeling of situations in the context of the preparation and operation of specialized security sectors, as was implemented in particular in modeling complexes developed in the context of analysis of possible situations and necessary security measures. matches of the European Football Championship "Euro-2012" and at the stadium "Lviv-Arena". Crowds at events and the danger of mass viral infection were not taken into account in a number of situations, which in relation to the spread of the virus can be described as a "viral bomb explosion". In particular, such a situation took place in Italy [14], when the "virus bomb explosion" took place during a football match between the leaders of the national championship and a mass "public celebration" to celebrate its results. This event concentrated on a relatively small area a large number of fans, who were in constant fairly close contact with each other for a long time (4-8 hours). The result of such interaction did not take long time. A similar situation occurred in Spain [15], when a "viral bomb" occurred during mass events in many Spanish cities during the festivities and demonstrations in early April 2020, which took place on the occasion of the religious holiday of Catholic Easter. In both of the above cases, their consequences may not have been so severe. Underestimation of the possibility of prognostic modeling of possible results of mass concentration of people in the conditions of viral infections spread and development on their basis of a safety set measures had fatal consequences. Such situations can be attributed to the class of problems of modeling the behavior of large crowds of people in order to make centralized decisions, as well as multi-agent optimization. It is advisable to use simplified models of epidemics (SIR-model) to model the consequences of such mass events. These models assume that agents (in our case, participants) can take three states: S - susceptible to disease, I - infected, R - recovered. It should be noted that in a relatively short period of interaction a person can pick up the disease from an infected person, in other words change his condition from S to I. However, a person can not change his condition from I to R. On the other hand, each group will contain a percentage of those already recovered before or have immunity and people still susceptible to the sickness. There are at least 2 approaches to modeling the following situations:

- Analytical, which involves solving systems of differential equations. The advantage of the approach is the speed of obtaining solutions (provided that the appropriate software is available). The disadvantage is that the result is usually presented in the form of statistics on the dynamics of infection and is not convenient for the spatial representation of trends in the spread of infection and it is quite difficult to carry out procedures to improve the model.
- Digital, based on the use of approaches based on the theory of agent systems. It can be implemented using by cellular automata or molecular dynamics. Cellular automata allow to adequately model the propagation of such spatial processes as fires, floods, etc. and allow to obtain the result relatively quickly. However, they do not allow modeling the movement of individual agents. Molecular dynamics approaches assume that each individual person is a specific agent that moves within a fixed area and interacts with other agents according to certain rules. This method is one of the most adequate and demonstrates the best results both in the visualization of the spread of infection and in the quality of individual statistical characteristics. However, this method of modeling is quite slow. Also a significant disadvantage is the dependence of the result on the random number generator, which leads to different simulation results under the same initial conditions. Therefore, it would be advisable to use ensembles of models, which allows you to parallelize the simulation processes on different processor cores or computers. The advantage of such ensembles of models is in particular quite convenient and easy adaptability and suitability for improvement of the modeling system without significant modifications of the corresponding scripts.

Modern computer tools allow you to quickly model the system [16,17], which contain several thousand agents, by the molecular dynamics. Therefore the last of the analyzed approaches is perhaps the most adequate for solving our problem. As can be seen from the list above - the values of S and N - can be obtained from the relevant maps and information that are formed before the start of the action, or from the analysis of data obtained directly from the UAV. The values of d, p and P_R can be obtained as a result of the analysis of medical statistics, which for most sickness are a priori known. The initial coordinates of the agents and the average speed of their movement can be obtained both directly from the UAV and from calculations that can be performed on the mobile operators data. Some virtual area is created, which is identical in shape to the real one to analyze the processes of infection spread on the basis of models formed using molecular dynamics approaches. Next, agents are inicialized within this area according to the values of (L). The next step is to simulate the process of moving objects. The specified coordinates of the agents are supplemented by the initial values of the velocities of the objects $L = l_{i=1,N}(x, y, v_x, v_y))$. It seems impossible to get instantaneous values of the speeds of individual agents (people) in a real situation.

However, it is possible to estimate the average speed v¯of human movement within a certain action based on data obtained from UAVs, and generate some initial values, using a random number generator with a normal distribution. The next step is to simulate the movement processes of people. To do this, the iteration time during which the person moves the distance determine $s = (x + v_x dt, y + v_y dt)$. It should be noted that this time should be short enough for a person not to be able to cover a distance greater than the distance at which infection can occur d: $dt << d/\bar{v}$. The shorter the corresponding period of time is – the longer the calculation process will be. After calculating the position of the agents in the next step of the iteration, the following situations are possible (Table 1):

Table 1. The following data is required for modeling

Variable	Mark	Measured
Area and shape of the territory	S	Maps
Number of agents	N	UAV
Average speed	$\bar{v}$	UAV
Initial positions of infected and uninfected agents	$L = l_{i=1,N}(x, y)$	UAV
Distance necesssary for infec-tion	d	Medical statistics
Probability of infection if a healthy person comes close to an infected person	p	Medical statistics
Percentage of people who have immunity to the illnes or was recovered	PR	Medical statistics

1. The agent is near or has already crossed the line of action. In this case, it is possible to either simulate the specular reflection (change the sign of one of the velocity components to the opposite), or direct the movement of the agent in the opposite direction (change the signs of both velocity components to the opposite)
2. The uninfected agent has entered the dangerous area of the infected agent. The following two situations are possible in this case:

- No action is taken to the agent if it has the status R.
- If the agent has the status S, the value z is determined by the generator of random numbers $z = [0,1]$. If $< p$, then the person is marked infected and is assigned the status I.

3. People collided approaching at a dangerous distance. In this case, it seems most logical to ignore such a situation and allow the passage person through a person. Because, a person is more likely to avoid a collision and continue his movement in the previously planned direction in real life. At the same time, it is possible to simulate an "elastic collision", when velocity vectors change their signs to the opposite. This situation is possible with a large crowd of people, like near the stage or tribune.

4. In the case of large crowds, people usually try to maintain a certain distance from each other. To simulate this, it is sufficient to add factor, such as the "repulsive force" similar to the Coulomb's law.

$$F = k\frac{q_1 q_2}{r^2}$$

In this case, by charges we mean the degree of unwillingness of an individual to stand near each another, k – repulsion coefficient (determined empirically), r – distance between peoples. It is necessary to calculate the total force acting on the agent by all other agents to account for this force.: $\vec{F_i}(F_x, F_y) = \sum_{j=1, j\neq i}^{N} \vec{F}_{ij}$. Next you need to calculate the acceleration:

$$\vec{a}(a_x, a_y) = \frac{\vec{F}}{m}$$

In this case, mass means the empirical inertia of a person. The displacement of the agent is defined as:

$$s = (x + v_x dt - \frac{1}{2}a_x dt, y + v_y dt - \frac{1}{2}a_x dt)$$

After determining the displacement, the new coordinates of the agents are calculated and the iterative process is repeated.

This model will work until all agents are infected, or the time of the action is over. It is possible to simulate different types of situations. For example:

The desired direction

By this we mean the presence of a certain center of attraction, such as a food point, stage, etc. It is enough to enter into the system an additional fixed agent with zero velocity components and initial coordinates that correspond to the location of such object to simulate this. A large negative value is chosen as the charge value q for simulation of attraction, which is determined empirically.

Imitation of the exit queue

This case should be considered when simulating the end of the action, or when there is a threat of "panic" when the infected agent seeks to withdraw from the recreation area. The simulation of such a situation is similar to the behavior of the crowd near the stage. That is, a fixed agent "exit" is created, which attracts other agents, which are removed from the calculation when reaching the exit.

Identification of potentially infected people

This is the case when an uninfected person get into the area of potential infection of the infected person, the distance between them satisfies the condition $r < d$. It is possible to clearly indicate whether or not an infection has occurred In a computer simulation. However, it is almost impossible to clearly define in real situations because there is a long period of so-called incubation period of the disease, which can often last up to several weeks. Therefore, all potentially infected people are marked in the simulation system with a special IP status. Than potential infection from IP people are simulated according to similar rules to I peoples in parallel with the main simulation. As a result, we get a spatial diagram, which ilustrate people who are either really sick or are potentially infected. It is possible to decide on the extent of the necessary isolation, or the absolute isolation of such persons based on such information.

Simulation of locking and isolation of the object

The infected agent is isolated (removed) from the simulation area after a certain number of iterations in this case. Here are some possible options:

- The agent is simply removed from further simulation procedures.
- An "Exit" agent is created that acts only on the infected agent. This leads to the fact that the components of the agent velocity vectors at each iteration step is directed to the exit. Thus, he is "given the opportunity" to infect other agents who will meet him along the way. The infected agent is subsequently removed from the simulation process upon reaching the exit.

Increasing the distance between people

This situation simulate the announcement on the radio about the need to maintain a safe distance between agents. This means a simple increase of the attraction coefficient k.

Thus, the modeling complex (ensemble of models) allows you to model different situations and make scientifically based decisions to minimize the number of infected and allows you to make a real link between computer and real time.

The generalized functional scheme of the software-algorithmic complex, which allows to make reasonable decisions, is given in Figure 3.

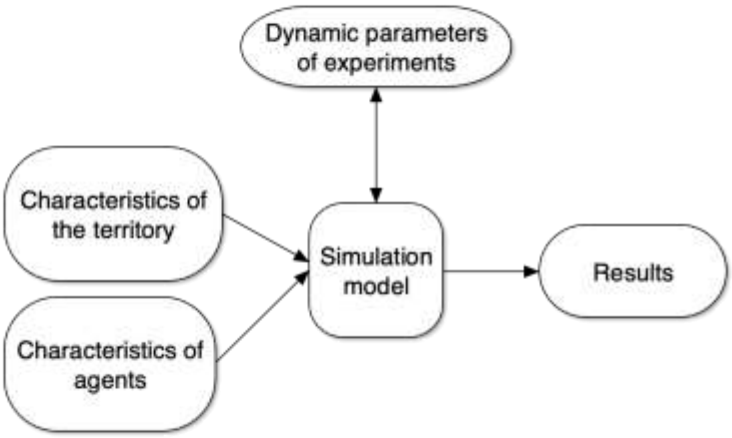

Fig. 3. Functional diagram of a virus spread simulation model

The input variables are divided into 2 types: characteristics of the territory (area, shape, number of agents) and characteristics of agents - a set of agents with unique characteristics. You can dynamically influence the characteristics of existing agents, enter new ones or remove agents in real time when conducting a simulation experiment. This allows you to simulate and analyze in real time the effectiveness of certain actions. Statistics on the number of infected agents and the rate of infection are the starting point. In the case of modeling the spread of infection in large cities, districts, regions, regions, countries - the initial data will additionally be the number of healthy, recovered, as well as the total parameters of fatalities, as well as other possible additional characteristics. Figure 4 shows the results of the spread of the COVID-19 virus in the Chernivtsi region during the Christian Easter holidays prognostic modeling. As is known at this time, the Church of the Moscow Patriarchate urged the faithful to attend churches, despite on the pandemic and government quarantine restrictions. A simulation of 2 scenarios was performed (simulation of 5 events for each scenario) to assess the consequences of such actions:

- Scenario 1: complete restrict on church attendance
- Scenario 2: mass church attendance on Palm Sunday and Easter (real scenario)

It was assumed that according to official data estimates, about 12,500 parishioners of the region visited the church on Palm Sunday in Chernivtsi region, and 8,500 on Easter (Table 2). The models take into account:

- Population of Chernivtsi and all districts of the region
- Population density of the regional center and districts
- Social distance between people
- Duration of illness
- Incubation period
- The probability of the sickness in human contact
- Mortality rate
- Availability of crowded places (churches, supermarkets, pharmacies, markets, construction sites)
- The percentage of people who carry the disease asymptomatically
- The presence of the procedure of isolation of sick people
- Ability to move a person from the district to the regional center and back
- Observance of necessary distance by people

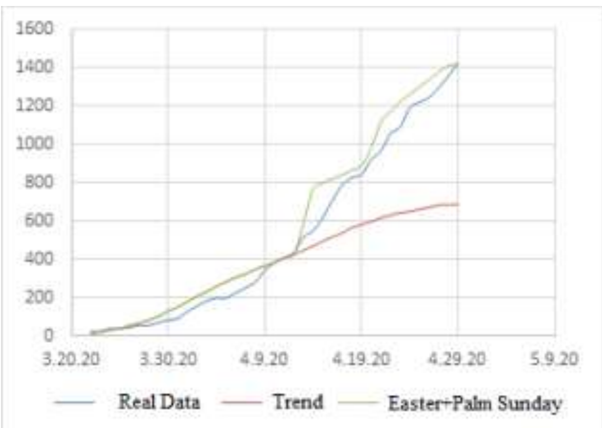

Fig.4. The result of mass church attendance on Easter and Palm Sunday compared to real data

Table 2. Statistics of modeling of scenarios of attendance of churches of MP on Palm Sunday and Easter in comparison with real data

Data	Real data	Scenario 1	Scenario 2	Data	Real data	Scenario 1	Scenario 2
22.03.2020	24	13	13	11.04.2020	403	410	410
23.03.2020	24	19	19	12.04.2020	434	425	425
24.03.2020	39	32	32	13.04.2020	515	447	589
25.03.2020	40	37	37	14.04.2020	548	468	765
26.03.2020	44	55	55	15.04.2020	619	495	798
27.03.2020	55	66	66	16.04.2020	710	516	820
28.03.2020	55	83	83	17.04.2020	786	536	839
29.03.2020	70	101	101	18.04.2020	827	565	865
30.03.2020	83	129	129	19.04.2020	841	580	887
31.03.2020	92	151	151	20.04.2020	919	597	981
01.04.2020	128	179	179	21.04.2020	965	615	1114
02.04.2020	156	207	207	22.04.2020	1055	630	1170
03.04.2020	183	230	230	23.04.2020	1090	642	1220
04.04.2020	198	259	259	24.04.2020	1190	649	1259
05.04.2020	198	282	282	25.04.2020	1219	661	1300
06.04.2020	225	306	306	26.04 2020	1244	671	1336
07.04.2020	251	322	322	27.04.2020	1295	682	1378
08.04.2020	280	348	348	28.04.2020	1356	683	1409
09.04.2020	342	365	365	29.04.2020	1422	686	1418
10.04.2020	382	384	384				

As can be seen from the figures, the dynamics of morbidity would gradually begin to saturate in the absence of church attendance. The massive involvement of people in church attendance, consequently the non-observance of safe social distance and the sharp weakening of hygienic norms that parishioners should follow these days, has led to a rapid "catastrophic" increase in the number of infected people. Thus, the chart clearly shows the sharp jumps in the number of new infections directly on holidays. The total number of people infected due to non-compliance with quarantine restrictions as of April 29, 2020 has doubled (from 686 to 1,418 people) compared to the situation when the conditions of quarantine were not violated on holidays.

Conclusions

Special importance is given to tools that can quickly identify infected people in a pandemic period. The identification of such individuals can take place in several ways, among which a method based on temperature measurement is important. It should be borne in mind that measurements can be performed by stationary or mobile means. Mobile devices can be located both on the helmets of law enforcement officers and installed on board the UAV. The results of thermal screening and identification of people with fever are recorded and processed in real time. This allows monitoring and operational scenario modeling based on mathematical models.

The paper proposes to form ensembles of models that would adequately reflect the spread of viral infections in large crowds. There are classes of tasks of identification, monitoring, modeling and situational forecasting, the complex solution of which allows to form plans and programs for effective counteraction to the spread of viral infection. Basic groups of possible model situations that can take place in the process of holding mass events, such as football matches, concerts, rallies, demonstrations, festivals, etc., have been formed.

Mathematical modeling - building a model, its formalization, testing (verification) and interpretation of the results, performed on the basis of a coordinated approach based on the use of simulation tools and a group of models of epidemics using formalisms of molecular dynamics methods.

A computer experiment conducted using real data on the spread of the COVID-19 virus in the Chernivtsi region during the Easter holidays showed that the mass involvement of people in church attendance, and hence the lack of safe distances and a sharp weakening of hygiene standards that people should follow , these days has led to a catastrophic increase in morbidity.

The process of spreading a viral infection in cases of mass gatherings of people during concerts, sports competitions, demonstrations, etc. is the object of modeling. The information system performs the functions of collecting and analyzing data on infected people with fever and provides tracking of real trajectories of their movement. This function is implemented both during mass events and after their completion in cases of potential contact with infected persons. This is the basis for modeling possible scenarios for the situation and the implementation of procedures for forecasting and preventive measures.

In further research, we plan to provide information on modeling treatment procedures. It is envisaged to take into account not only the quantitative characteristics of contacts, but also the quantitative characteristics of groups of people who have recovered.

References

1. Covid-19 information. https://hub.jhu.edu/novel-coronavirus-information/
2. MRC Centre for Global Infectious Disease Analysis. https://www.imperial.ac.uk/mrc-global-infeentist-disease-analysis/
3. A new app can help detect the coronavirus, https://www.epfl.ch/labs/esl/coughvid-launch/
4. Schuster, G., Hechtfischer, B., Fellmuth, B.: Rep. Prog. Phys. (1994).
5. Lutsyk, Y., Guk, O., Lakh, O., Stadnyk, B.: Temperature measurement: theory and practice. Beskid Bit, Lviv (2006).
6. Brao, I.: Analysis of issues and promising areas of contactless thermometry. Measuring equipment and metrology 75, 40-44 (2014).
7. Nilanjan, Dey, Amira S., Ashour: Thermal Imaging in Medical Science Recent Advances in Applied Thermal Imaging for Industrial Applications, https://www.researchgate.net/publication/312222298.
8. Kumar, Bhartee1, Kartik, Manas, Srivastava, Tanuj Sharma: Object Identification using Thermal Image Processing Ajeet, http://ijesc.org/upload/
9. Minkina, W., Dudzik, S.: Infrared Thermography – Errors and Uncertainties. Chichester: John Wiley & Sons Ltd (2009).
10. Lavrovsky, M., Tour, N.: The use of unmanned aerial vehicles for monitoring emergencies in forest areas. Collection of scientific and technical works. Scientific Bulletin of NLTU of Ukraine 25.8, 353–359 (2015).
11. Chuan, Li, George, D., Skidmore, C. J., Han.: DRS uncooled VOx infrared detector development. Optical Engineering 50 (50) (2010).
12. Alekseev, O., Bondarev, D.: Prospects for the development of unmanned and municipal aviation in Ukraine. Information processing systems 8, 10–16 (2016).
13. Efremov, P., Popov, K., Kapitonova, T., Struchkova, G.: Processing and analysis of drone data for monitoring of linear objects operated in the north. International Journal of Experimental Education 10-2, 238–239 (2016).
14. Gori (alcalde de Bérgamo): "El Atalanta-Valencia fue una bomba biológica", https://www.marca.com/futbol/valencia/2020/03/25/5e7b106c22601d35238b4595.html.
15. How did Spain get its coronavirus response so wrong?. https://www.theguardian.com/world/2020/mar/26/spain-coronavirus-response-analysis.
16. Kazarian, A., Kunanets, N., Pasichnyk, V., Veretennikova, N., Rzheuskyi, A., Leheza, A., Kunanets, O.: Complex information e-science system architecture based on cloud computing model. CEUR Workshop Proceedings 2362, 366–377 (2019).
17. Tomashevskyi, V., Yatsyshyn, A., Pasichnyk, V., Kunanets, N., Rzheuskyi A.: Data warhouses of hybrid type: features of construction. Advances in Intelligent Systems and Computing II (AISC) 938, 325–334 (2019).