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Design and functionalities of Decision Support System regarding the risk of Epidemic threats on a sea-going Vessel

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Abstract: In the global crisis of the COVID-19 pandemic, the maritime sector once again drew attention to the issue of epidemic threats on seagoing ships. As an isolated unit, the ship may be a potential source of an epidemic. In addition to COVID-19, there are several other threats, such as Legionnaires' disease, cholera, tuberculosis, infections related to the digestive system, dengue and many others. It should be noted that there is no specialized infectious disease ward or appropriate team of doctors on a seagoing ship (Wiliams et al 2018). There is a need to implement other tools - many of them are described, for example, by IMO and other organizations at global and local levels (Brown & Johnson 2019).. The consortium led by the Maritime University of Szczecin (Poland) set itself the goal of developing and implementing a decision support system in the event of an epidemic on a seagoing ship. The tool being developed is intended to assist captains, medical officers, etc., to assess the situation and take appropriate actions quickly. The system, tentatively named DESSEV (the acronym of the project implemented under the Erasmus+ program), operates based on a knowledge base prepared by medicine and maritime personnel specialists. It is a completely autonomous system, operating online and offline. Much attention was paid to its availability and describing functional and non-functional requirements so that its use was intuitive and did not require specialized training or documentation. The main functional requirements are: entering identified symptoms into the application, processing the received information based on the knowledge base, disease classification based on the probability of belonging to a given class. The Knowledge Base as the primary dataset was obtained from different available sources, including medical and nautical data repositories. Three algorithms were applied to solve the problem: random forest, decision tree and naïve Bayes. The best performance was in the case of random forest algorithm, what is presented in the paper. After developing the knowledge base and validating the algorithms of prediction, a web application was designed and is available online at www.dessevproject.eu/app, intended to serve as a user interface for the DESSEV decision support system. As a further step, a mobile application will be coded on the basis of the development of the web application, serving completely offline.

This article describes the DESSEV decision support system, defines the requirements, and summarizes conclusions based on a series of simulations using the system. DESSEV enhances the control on vessels by accurately recognizing diseases and providing mitigating actions throughout the risk management process. It offers independent and reliable support in maritime pandemic control. Nevertheless, it should be noted at the outset that further activities in this area, including interdisciplinary ones, are worth conducting. The DESSEV system is also intended to become the basis for further solutions of this type, especially given the emergence of further serious health crisis.

Keywords: outbreak, epidemic, seagoing vessel, COVID-19, decision support system

1. Introduction

Merchant ships have been and continue to be a fundamental uniting element on our planet. In addition to transporting people, today, more than 90% of our planet's raw and processed materials are transported by trucks.

Furthermore, maritime transport, key to globalisation, not only moves goods and people but also transports diseases that spread and, in many cases, can result in epidemics. Infectious diseases are transmitted by different routes and forms, and their incubation time varies. If detected on board, they cause a restriction on the entry and disembarkation of crew members or passengers, leaving them in quarantine until the risk of infection has passed. This can cause the disease to act with all its might, leading to a large number of deaths. Merchant ships have never had a medical service on board that could detect any contagious disease that affected a crew member. If a crew member was infected with such a disease, probably, by the time they realised it, the entire crew would be infected.

The COVID-19 pandemic that we have suffered in recent years not only affected maritime transport but all countries in the world. Without experts in contagious diseases, society could not provide a quick response and effective way to stop the pandemic. Only two measures were used: isolation of the entire population and, later, vaccination.

Covid-19 has shown that countries are unprepared to respond quickly to a pandemic. The ship's crew members are even less prepared if the countries with the best resources are not ready. It is important to remember that these are small vessels with limited crews and without adequate medical knowledge that travel to and from all world countries, making them potential disease carriers.

These reasons, as well as the aim of being able to identify in the shortest possible time the type of disease from which a crew member has fallen ill on board a ship and to prevent it from spreading, encouraged members of the Maritime University of Szczecin (MUS), the Polytechnic University of Cataluña (UPC), Satakunnan ammattikorkeakoulu (SAMK), The Maria Skłodowska-Curie Medical School (MU MSC), Spinaker, Idec and the Centre for Factories of the Future (C4ff) to carry out a 2-year project DESSEV – Decision Support System regarding the risk of Epidemic threats on a sea-going Vessel, Erasmus+ program co-funding.

The key objective of the project is to develop a Decision-Support System that enhances maritime safety by providing comprehensive risk assessments and mitigation strategies for the spread of infectious diseases on seagoing vessels. By leveraging a robust data repository and extensive knowledge base, this system aims to facilitate informed decision-making for maritime professionals, thereby reducing the risk of epidemic outbreaks aboard ships and ensuring the health and safety of crew members and passengers. The project identifies objectives:

- repository of data on epidemic situations;
- the knowledge base in the form of IF... THEN... rules;
- decision support system on the risk of epidemic threats on a maritime vessel,

which will be detailed in the following sections of the article.

2. The Repository of Infectious Diseases

A pivotal milestone was the development of the online repository, marked by creating a user-friendly interface. This phase was not just about aggregating information but also about enhancing its accessibility and usability for a wide range of users (Bodus-Olkowska et al, 2024). The repository was designed to be intuitive, ensuring that users could easily navigate the information available.

Until now, the repository contains 102 items of literature and includes:

- IMO (International Maritime Organization) and WHO (World Health Organization) and recommendations (IMO 2022; WHO 2006, WHO 2021);
- Centers for Disease Control and Prevention guidelines (CDC 2023, CDC 2024);
- specific case reports, and
- several scientific medical articles, primarily related to the most recent COVID-19 outbreak (Stamatakis et al. 2010; Wilson et al. 2021; Schlaich et al. 2009).

All types of papers collected in the repository are available online on the project website: www.dessevproject.eu. The gathered literature is divided into two categories: manuals for vessel crews and medical directives. The manuals for crew members gathered IMO and WHO recommendations or other institutions related to maritime transport; for example: "*Joint statement in support of keeping ships moving, ports open and cross-border trade flowing during the covid-19 pandemic*" published by IMO or "*Guide to the ship sanitation, 3rd edition*" published by WHO. It also contains several recommendations and duties governed by specific coasts or ports. The second category, the medical section, is related mainly to travel medicine.

Many articles in the repository refer to the Covid-19 pandemic as the latest case of globally prevailing disease. The outbreak of this coronavirus pandemic forced humanity to pay special attention to the principles of pre-infection prevention, education to avoid the spread of the disease and steps towards recovery. The individual documents have also been ranked very important, important and less important. The very important class includes all IMO manuals, WHO recommendations, and medically relevant scientific articles describing the most serious diseases. The important class includes port regulations and advice from port authorities when a communicable disease is detected on board. The remaining category includes popular science articles describing individual disease cases on board.

The repository, which includes abstracts and titles of individual publications, and the entire project website, which includes all results, will be translated into the languages of the project partners: Polish, Slovenian, Swedish, Finnish, Greek, and Spanish.

3. Knowledge Base and Prediction Algorithm Used in DESSEV Support System

The project's second aim was to develop a knowledge base and inference algorithms. The knowledge base is a NoSQL database containing a list of infectious diseases with the symptoms describing them, grouped into categories. Numerically, the knowledge base presents itself:

- 19 diseases;
- 8 symptom groups;
- 36 signs of a disease.

The prediction algorithm uses three AI models: random forest, decision tree and naive Bayes. These models are used to predict a disease directly based on the symptoms given.

3.1. Knowledge Base

During the project's initial phase, our team's goal was to identify and prioritise for analysis the most prevalent infectious diseases that could potentially pose threats to maritime operations. To establish a robust diagnostic foundation, our team conducted an exhaustive review of scientific literature, statistics, and guidelines from leading health organisations such as the World Health Organization, Centers for Disease Control and Prevention, and European Centre for Disease Prevention and Control.

The selection was based on the diseases' substantial influence on worldwide health, their widespread occurrence, and patterns identified in recent data. This way, we identified 19 diseases for further analysis.

During the first step, diagnostic criteria for each infectious disease were identified based on peer-reviewed articles, editorials, books, and university press releases. The most prevalent symptoms for each disease were then selected and systematically categorised into a table by the frequency of occurrence (in %).

In-depth research was then repeated using Google Scholar, PubMed, Embase, Medline, ScienceDirect articles, and local government publications to complete the database. During this phase, acquiring accurate percentages for the occurrence of symptoms associated with different diseases proved challenging, indicating a potential gap in the detailed reporting of symptom frequencies within the existing literature.

Additionally, the research team engaged in targeted interviews with medical experts. These interviews aimed to elucidate the crucial elements in diagnosing infectious diseases and their interconnectedness with clinical decision-making parameters. The outcome was a comprehensive knowledge base intended for integration into a decision support system for maritime operations.

3.2. Prediction algorithm

The prediction algorithm aims to give the possible infectious disease/s a patient may have based on her/his symptoms. The prediction algorithm has to be trained, and we trained it with the knowledge base of symptoms and infectious diseases.

The knowledge base of symptoms and infectious diseases was expressed in percentages, i.e. how many patients out of 100 would express a specific symptom when infected by a specific infectious disease. Based on these data, we randomly generated hundreds of artificial patients with specific symptoms so that we reached the exact percentages from the knowledge base for the whole group of artificial patients. We used this approach of randomly generating artificial patients to take into account that every human being is unique, so the symptoms appearing after infection are slightly different for each person.

We used these randomly generated data to train our prediction algorithm. In our prediction algorithm we were testing three AI models to be able to compare them and select the most accurate one: random forest, decision tree, and naive Bayes. These models are all used to predict a disease directly based on given symptoms.

The naive bayes model (Hand, 2001) is a classifier which assumes that the symptoms are conditionally independent, given the target disease. This assumption's strength (naivety) gives the classifier its name.

The decision tree model (Rokach, 2013) is a tree-like model of symptoms and possible diseases, including chance event outcomes, resource costs, and utility. Each branch represents the test's outcome (whether a symptom is present or not), and each leaf node represents a disease.

The random forest model (Breiman, 2001) is based on the decision tree model. Still, in the random forest model, a forest (a big number) of decision trees is generated considering only some symptoms for each decision tree. The output of the random forest is the disease selected by most decision trees.

The authors used Orange data mining software to build all three models. As it is a free, widely used software from which the generated models can be exported and then used outside the software just by using an Orange python library (Demsar J. et al. 2013). This allows to easily integrate the prediction algorithm into the website or phone app and make it publicly available

When tested on training data, the classification accuracy of all three models reaches nearly 100%, but the most important is the classification accuracy on test data. We collected a small number of real patients (1 per disease) and used their symptoms/disease combinations as the test data. It should be stressed that the test data was not used during the training process (while building these models). The classification accuracy of all three models, when tested on test data, was as follows:

- random forest: 100%
- decision tree: 57%
- naive Bayes: 86%

In the prediction algorithm, the random forest model outperforms other models in most similar medical applications (Sumwiza et al., 2023). These results confirm that the random forest model is the best model for disease prediction in medicine. Naturally, a limited amount of measurement data must be taken into account. A classification result of 100% is unrealistic in practical applications, but it indicates the correctness of the algorithm selection.

4. Functional Concept of the DESSEV Decision Support System

This part of the DESSEV project goal aims to delve into the importance of system design and the essential requirements of a system, emphasising the importance of user-friendliness, accuracy, simplicity, completeness, a concrete overview, and a quick conclusion for effective guidance.

A Decision Support System (DSS) is a computer-based information system that supports decision-making activities within an organisation or enterprise. It provides users with tools, data, and models to analyse complex problems and make informed decisions. Understanding and defining the requirements is crucial for the success of any system development process.

Several conditions exist for developing a user-friendly DSS, and the system design is decisive for how the DSS will be used. It involves conceptualising, planning, and detailing how components interact to efficiently achieve specific objectives.

The user interface serves as the primary point of interaction between users and the DSS. UI is crucial in apps and online platforms as a bridge between users and the system or application. It provides intuitive tools and visualisation techniques to ease use and facilitate analysis and decision-making. For this to be possible, the platform in question must be easy to use, navigate, and understand. The end user of this project's DSS will rarely be medically trained staff, which underlines the importance of easy understanding. Every cluster of symptoms that cannot be found in everyday language gets a more detailed explanation, this to avoid the user getting confused if the terminology is too medical especially when in a stressful situation.

A user interface that is easy to use and understand increases the chances of actual usage. This means that users can quickly learn to navigate the application or platform without having to go through extensive learning processes. This reduces user frustration and increases the likelihood that they will continue to use the product or service (Lunds University, 2012).

By using colour schemes, typography, and visual elements that are in line with the tone of the shipping industry, recognition and reassurance are provided. Continuous studies are done around interface and userfriendliness, and important information about fonts and colours has guided the development of this DSS.

A responsive user interface is essential to ensure the application or platform works smoothly on different devices and screen sizes, including smartphones, tablets and computers. Within the shipping industry, mobile devices will generally make up the largest use; therefore, the app must be adapted to mobile devices. In summary, the project's main goals for system design have been the following:

- *User-friendly* logical system: the user must quickly and easily understand how DSS works, even when using it for the first time.
- *Simplicity*: It is easy to navigate and understand within DSS.
- *Accuracy*: This is an important aspect since the situations in which DSS is used can be urgent or vulnerable.
- *Concrete overview*: all potential aspects must be covered.

This is the most challenging point as it is incredibly difficult to guard against all eventualities, DSS also does not claim to be able to cover all potential eventualities. Finally, DSS should provide quick conclusions and effective guidance for further steps.

5. On-line application

Considering all the above-mentioned aspects, developing an on-line application intended to serve as a user interface for the DESSEV decision support system was initiated. This web application operates on a clientserver communication model via the HTTP protocol. Here, the application sends a request along with specific parameters to the server, and the prediction system receives, analyses, and sends a response back to the user application. The primary aim was to smoothly guide the user through a simple web form, where they would provide personal data, travel-related information, and any symptoms observed or suspected to be indicative of infectious diseases. It is important to note that the DESSEV system is predictive and is not intended to assess the patient's health status or provide diagnoses fully. A disclaimer was included on the application page, clearly specifying the purpose of the system and the expected outcomes of its operation.

At the early stage of application development, it was decided that the application would primarily collect information from the user and, depending on the type of user (e.g., a seafarer, their superior, or another person acting on behalf of the symptomatic individual) and the purpose of its use, transmit the provided data and system results to a specified email address. Due to the sensitivity of the data (personal and health information), it was stipulated that the collected data should not be stored, shared, or processed by any third parties (including other databases or systems). Additionally, the decision was made to focus on the simplicity of application usability and minimise unnecessary content while still ensuring the provision of accessible options for users to access various information related to the DESSEV project, disease database, or detailed symptom descriptions from within the application interface. The final aspect considered during the preliminary design of the web application was the visual order and aesthetics, ensuring compliance with the previously agreed colour scheme and typographic design of the DESSEV project. An initial graphical design of the webpage was prepared using the Wix online software for website design and management.

After the initial analysis of the application project, significant changes were made. Considering that the application primarily serves for prediction based on observed symptoms and should not give the user a false impression of providing a complete medical diagnosis, the collection of personal information (demographics, travel history, or medical history) was abandoned. Moreover, users might feel discouraged or concerned by questions about sensitive data instead of quickly providing answers regarding predicting a potential infectious disease. Thus, the application's functionality was limited to collecting user input, which was strictly necessary for the prediction system.

The application form was divided into eight categories, each representing a group of symptoms, in the following order:

- General/systemic
- Respiratory
- Musculoskeletal
- Neurological
- Hematological
- Gastric
- Dermatological or associated
- Other

Users can select any number of observed symptoms from a given category (min. four) using checkboxes. For each symptom, there is an information field, which, upon clicking, provides expanded information about the respective symptom—a detailed description accessible in non-medical language. After going through all categories, the user submits the selected symptoms to the prediction system, which responds with the most probable disease for the given symptoms. Additionally, after obtaining information from the prediction system, the application allows the user to send information to a specified email address. If chosen, the user only provides basic personal data (name, age) and information about the person for whom the prediction was made, along with the prediction information and their comment, which can be sent to a doctor, supervisor, or ship captain. The data provided by the user in the application and the prediction information are not stored, retained, or utilised in any way. It disappears once the user finishes using the application.

The application is available in seven languages (English and the native languages of all parties involved in the DESSEV project). Additionally, at any time, the user can access the main page of the application, where its principles, information about its creators, the entire DESSEV project, contact information, and access to a repository containing useful resources such as articles, recommendations, and health procedures for maritime personnel during epidemic situations are available for reference.

6. Conclusions

This article presented the DESSEV online decision support system with a proven potential to add value in pandemic control onboard vessels engaged in international trade. The online tool has an onboard role in a chain of events that may impact the vessel. In an ideal situation, the mechanisms in the logistic chain surrounding the vessel prevent the pandemic from accessing the vessel altogether. We need to elaborate on the maritime logistic chain to understand better the possible routes for a pandemic to the vessel.

Crew transportation consists of multiple means of transportation in variable geographical regions. The opportunities for exposure to a pandemic are practically endless. Congested vehicles such as aeroplanes make it impossible to protect against airborne viruses, for example. When the travelling takes less than 24 hours, the symptoms rarely surface before joining the vessel.

Vessel supplies and maintenance activities during port calls cannot be avoided, and vessel crews are exposed to the local spread of viruses. However strict controls may be, the spread of viruses can only be partially avoided. Therefore, it is justified that high gravity in pandemic risk management should be placed on the onboard control actions.

The onboard environment is multicultural and highly congested. The crew members' language skills and social habits vary between nationalities and cultural backgrounds. The online tool is publicly available, and the use of it requires no medical expertise or clinical background. However, promising the initial results of using the online system are, it is merely a supporting mechanism for decision-making. DESSEV online decisionmaking support is not a substitute for a medical professional. With this in mind, regardless of the outcome of using online tools, shore-based medical professionals should be consulted, when possible, before making critical decisions. From a risk management perspective, the user needs to understand better the role of the online tool and the accumulation of decision-making support.

DESSEV online tool provides a holistic risk management tool for pandemic control on board ocean-going ships. In testing the tool, the system reached theoretically 100% accuracy in classifying a disease from a group of up to 21 options. However, this result should be viewed in light of the limited sample size and the controlled conditions of the test. In practical applications, symptom data is often incomplete and uncertain, making perfect classification unlikely. This accuracy is critical as the results are accumulating. If false supportive advice is given in the state of recognising the disease, the later support with the associated actions will likely not have the desired outcome. Therefore, as handling the patient proceeds further, the risk of a false supporting action becomes lower. The main strength of the DESSEV online decision support system lies in its ability to manage risks.

The initial step in risk management is generally known to be recognising hazards. A risk level associated with a hazard can be evaluated upon recognising a hazard. When the risk level is known, the mitigating actions help manage the risk and lower the risk to a tolerable level. The DESSEV online decision support system assists in recognising the hazard precisely and provides mitigating actions to manage the situation further.

DESSEV's online decision support system is strongly present in every step of the risk management process in a safety-critical environment. The online tool provides an independent and reliable option to fill a recognised gap in maritime pandemic control. The future of the DESSEV online decision support system is conditional on the successful implementation of the novel tool in a conventional safety management environment.

It should also be mentioned that DESSEV is a decision support system. A potential decision-maker should rely mainly on his or her experience. However, using tools of this type makes this work more effective.

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