Handling variability of maritime IT solutions

Umut Kandemir[1] and Marite Kirikova[1]

[1] *Department of Artificial Intelligence and Systems Engineering, Riga Technical University, 6A Kipsalas Street, Riga, LV-1048, Latvia*

Abstract

The maritime industry requires complex information technology solutions and a considerable variety of these is reported. For having an overview of the existing solutions this paper proposes an ArchiMate and knowledge graph based method for the representation of models of existing solutions and their analysis. This study examines sources for learning about maritime informatics and seeks an effective way to amalgamate acquired knowledge for further use.

Keywords

Maritime Informatics, Knowledge Graphs, ArchiMate

1. Introduction

The maritime industry recognizes the need for new possibilities in the use of maritime informatics [1], a discipline created to improve operations and meet client expectations through information technology (IT) solutions. In this paper, to provide an overview of the existing IT solutions in the maritime industry, an ArchiMate language [2] and knowledge graph based [3] method is proposed. The method has been created by, first, identifying various IT solutions used in the maritime domain; second, these solutions are modeled as knowledge chunks in the ArchiMate language. Each knowledge chunk, expressed in ArchiMate language, represents a separate information technology solution by describing its purpose, features, and potential applications. Then, third, the knowledge map is created by determining the interdependencies and relations between the knowledge chunks. Fourth, the transfer from an ArchiMate based representation to a Graph Database is established to arrive at the knowledge graph of maritime information technology solutions. The resulting knowledge graph serves as a valuable resource for users who want to navigate the broad field of information technology solutions in the maritime domain.

The paper is organized as follows. Section 2 briefly overviews the spectrum of IT solutions in the maritime domain on a high level of abstraction. Section 3 describes the notion of knowledge chunk and how the chunks, representing maritime IT solutions, were recorded in ArchiMate language [2] to form a knowledge map. Section 4 discusses the transfer of the knowledge map created in ArchiMate language to the graph database for further use as a knowledge graph. The brief conclusions are available in Section 5.

2. Brief overview of maritime IT solutions

The Fourth Industrial Revolution (Industry 4.0) has brought significant changes to the maritime sector, driven by advancements in technology such as robots, artificial intelligence (AI), autonomous vehicles, and the Internet of Things (IoT) [4]. These advancements have led to the emergence of smart shipping, enabled by the integration of Big Data, AI, and IoT. The maritime industry has seen improvements in areas such as autonomous ships, e-navigation, and smart

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Umut.Kandemir_1@edu.rtu.lv (U. Kandemir); marite.kirikova@rtu.lv (M. Kirikova)
0009-0001-8377-2756 (U. Kandemir); 0000-0002-1678-9523 (M. Kirikova)

ports [5]. These technologies have found applications in areas such as real-time connections between sea and land, data analysis for navigation systems, energy consumption optimization, safety improvements, and automation of ship operations [6].

The use of AI and robotics in the maritime industry has led to advancements in autonomous shipping, crewless ships, and underwater vehicles for scientific research and commercial purposes [7]. Cloud computing has facilitated various aspects of the maritime field, such as marine weather detection, data processing, and ship navigation [8]. 3D modeling, simulation, and virtual/augmented reality technologies have opened opportunities for maritime simulators [9].

Cyber security has become extremely important in the maritime industry due to the integration of information and communications technology and the necessity to protect ships, crew, cargo, and the marine environment from cyber threats and attacks [10]. Blockchain technology has been seen as having the potential to revolutionize the shipping and maritime industry by improving transaction efficiency, security, and visibility. It, also, might enhance supply chain operations, port operations, and tracking of ships and containers [11].

These technologies continue to evolve and shape the future of the maritime sector providing a variety of solutions which have their similarities and differences and the potential to be combined, replaced, and co-used. To have an overview of these IT solutions and the possibility to create a repository of knowledge about them, a common model of IT solution representation is necessary. In the next section, such a model is proposed and used. The proposed model is not the only possible way to represent an IT solution, however, to demonstrate the idea of the repository of solutions, it suits well to the purpose as it gives an opportunity to show not only the technical details but also the use and purpose of the technology.

3. IT solution as a knowledge chunk in ArchiMate and Archi

The ArchiMate modeling language [2] and Archi tool [12] were utilized for modeling an information technology solution. Archi is a free and publicly available software application used for enterprise architecture modeling. The tool enables the creation and management of enterprise architecture models in ArchiMate language through a graphical user interface. It also offers the ability to import and export data from other programs.

The use of the ArchiMate is preferred due to its ability to visually represent complex ideas and relationships in a clear and standardized manner. Archi, in turn, facilitates the graphical display of links between researchers and their provided IT solutions. The “Visualizer” feature of the Archi tool allows for the visualization of connections between the models of the IT solutions. Additionally, the tool can be customized to meet specific modeling requirements. Also, the fact that Archi is a free and open tool supports the further use of amalgamated knowledge.

3.1. IT solution as a knowledge chunk

The main principle followed when representing the IT solutions was that a knowledge chunk describes an IT solution so that the source, where it has been reported, could be traced back through the name of the paper’s author(s). So, the knowledge chunk consists of a container (the model that represents the IT solution) related to the author’s name. The following elements were chosen for the representation of an IT solution and the paper’s author(s) in the ArchiMate language.

Business Actor: In ArchiMate this element is described as the person who exhibits behavior in a job. In this work, it is the name of the author/researcher who has proposed or described a maritime IT solution.

Goal: The goal identifies the reason/purpose of the use of the IT solution.

Business Function: The business function shows the business function, which uses the IT solution.

Application component: An application component refers to a particular technology implementation or system that performs a particular function within the technologies.

Application service: An application service refers to a service that is received by a business function from the IT solution.

Equipment: Equipment includes all devices and hardware used regarding the IT solution.

To see how these IT solutions relate together as a knowledge map, the chunks should be related and access to the generated knowledge chunks should be provided. It is possible to establish these relationships and to provide access in Archi tool [12], however, the visualization and querying possibilities are limited. Therefore, the related chunks have been transferred into a graph database to be processed with tools appropriate for knowledge graphs [3]. To facilitate the availability of the represented knowledge, all the findings presented in this paper, together with the guidelines for the use of the knowledge map in ArchiMate language and knowledge graph in the graph database, were saved in a GitHub repository [13].

3.2. Examples of the knowledge chunks

The example of knowledge chunks is given in Figure 1. The container of the IT technology is an ArchiMate grouping with the name that characterizes the solution. Each solution is related to the author(s) who have proposed it.

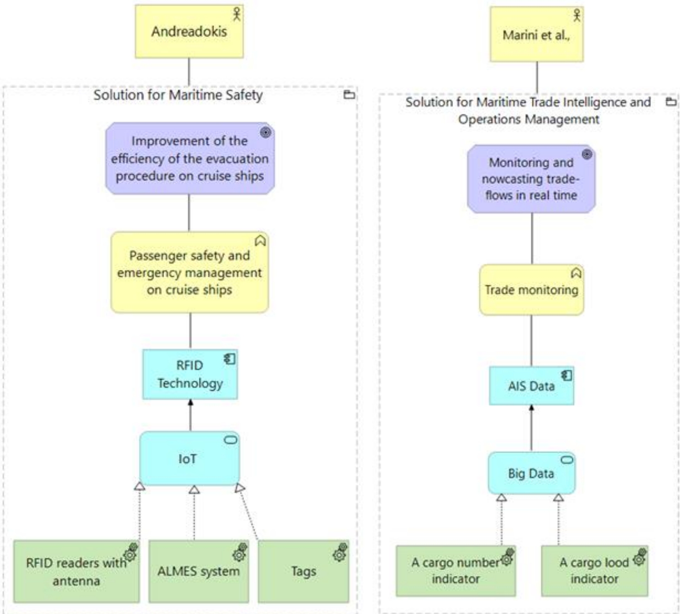

Figure 1: Left: solution for maritime safety; right: maritime trade intelligence and operations management

In Figure 1 (left), the chunk representing the IT solution for the maritime informatics domain offered by the author "Andreadakis" [14] is shown. It suggests using RFID technologies to determine the movement and direction of cruise ships. The author even mentioned that RFID technologies can be included in Life Saving instruments (LSAs) and used in observing the evacuation times of ships. The proposed solution involves the use of radio frequency identification and near-field communication to automate the passenger manifest during the embarkation process. This could help enhance the efficiency of the evacuation procedure [14]. In Figure 1 (right), the IT solution proposed by the author named "Marini" [15] is represented. It is the solution for maritime trade intelligence and operations management. Marini et al. [15] covered in their study the use of vessel data as a big data source to track the movement of products, and the study suggests a two-step method for forecasting trade flows in real time. A filter is created to identify cargo ships involved in trade activity in port call data, and two indicators are created based on the filtered ships: a "cargo number" indicator that counts the number of ships visiting ports and a "cargo load" indicator that combines information from Automatic Identification System (AIS) about the size of the vessel and changes in its cargo load to derive a trade volume index. AIS, which is used to track and observe vessel movements, employs big data technology [15].

3.3. Integrated representation of the chunks as a knowledge map in ArchiMate

Prepared knowledge chunks are not only the representations of IT solutions on their own but also serve as a knowledge map when they are joined together. This subsection demonstrates how technologies can work together to achieve a common goal and demonstrates that there is no one answer to every maritime informatics problem. The same technologies can address many issues. Figure 2 shows the similarity between the maritime IT solutions presented by two different authors. The authors of [14] and [16], have independently presented solutions that serve a very similar purpose using common technology. Ortega's proposal is an IT solution that provides real-time tracking of passengers and personnel on the ship [16]. On the other hand, Andreadakis proposes an IT solution for the improvement of the efficiency of the evacuation procedure on cruise ships [14]. Both solutions are intended for maritime safety purposes as depicted by the name of the containers of the chunks.

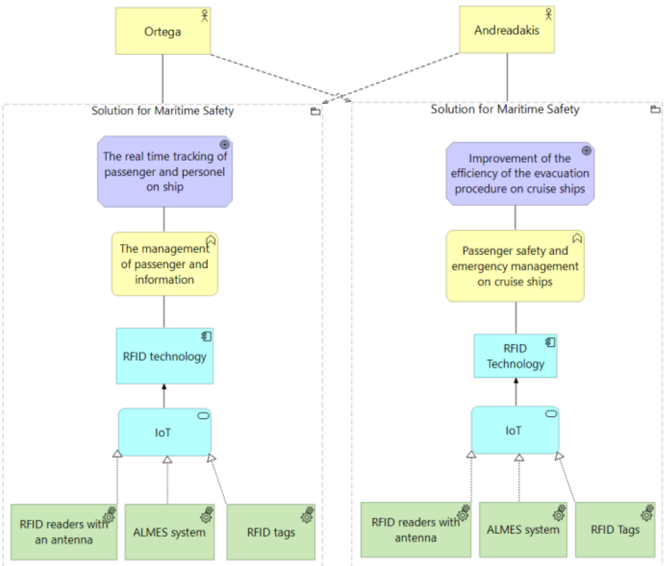

Figure 2: Two Different Solutions for Maritime Security

4. Transfer from Archi to graph database

This section will discuss how related knowledge chunks created with the Archi tool can be transferred to the Neo4j graph database. For users to use the developed knowledge map as a knowledge graph, they must first complete the process of successfully transferring the prepared chunks from the Archi tool to Neo4j. Neo4J was chosen as it has its free version and does provide the most straightforward transfer options compared to other most popular graphical databases. However, the knowledge map in ArchiMate can be transferred also to other graph databases from the Archi tool [16]. If Neo4J is chosen, in the transfer procedure, special attention should be paid to the unique ArchiMate relationship types to ensure the correct transfer.

There are various options regarding the use of amalgamated knowledge. First, the user may choose to stay with the Archi tool, if the capabilities of a Visualizer associated with Archi are sufficient for their knowledge needs. Second, the knowledge map can be transferred to the graph database and all further activities, including adding new knowledge chunks can be done through the graph database. Third, the Archi tool and the graph database can be synchronized so that the changes in the Archi tool are simultaneously reflected in the graph database, too. When the alternatives of transfer options are examined, it is suggested to focus on that option which enables users to use the knowledge map most comfortably. Further in this paper, we consider the third case that is tailored to users for whom synchronizing the Archi tool with Neo4j would be the most practical way to maintain and use the knowledge map.

4.1. Knowledge retrieval from the Archi and NeoJ4

After successfully importing the knowledge map into Neo4j, data discovery can be started to be observed (Figure 3). Using the Neo4j database, fast access is possible with the help of queries. Users can use the knowledge graph in the graph database for two purposes. Firstly, they can use queries to get the information they seek and, secondly, by adding new solutions to the knowledge map, they can ensure that the knowledge graph is regularly expanded and kept up to date. In this section, some potential results that can be reached by simple queries will be displayed and analyzed. More advanced use of the graph database is beyond the scope of this paper.

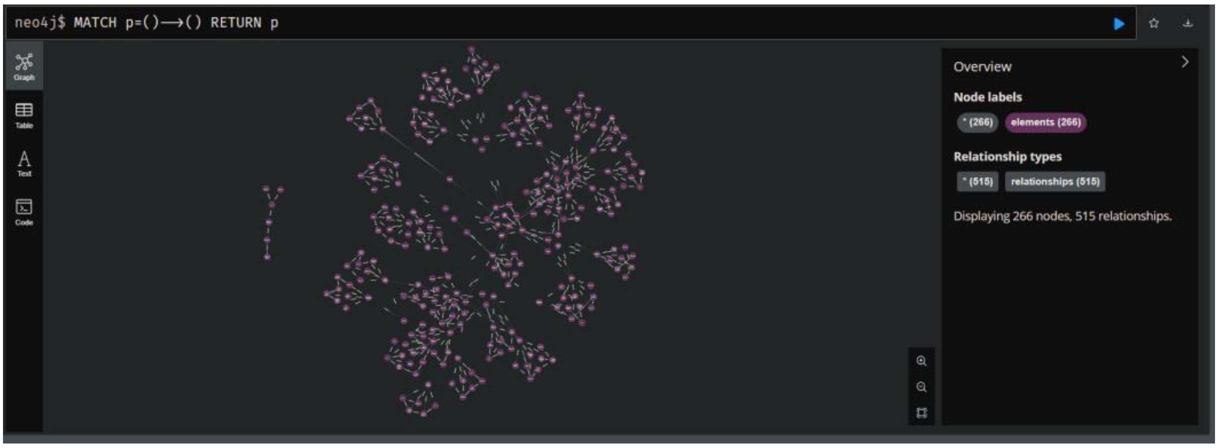

Figure 3: Overall view of the database schema

The data that can be retrieved varies depending on the user's search criteria. While some users would want to examine the purposes of existing solutions, another user might want to know the technologies used in these solutions. In addition, the created Neo4j graph database can be beneficial for users who wish to track which authors are discussing which solutions and to which solutions they are making references.

Here are some examples of the use of the created knowledge graph:

- Before accessing specific data, the user may want to see the entire database schema. The database used as an illustration in this paper consists of more than 25 knowledge chunks (IT solution models) 250 nodes, and 500 relations. The following query written in the query execution line will retrieve the overall database schema:

  match p=()-->() return p.

- Users may want to observe solutions offered by a specific author. In this instance, there are two distinct relationships between the author and the solutions that they make:
  - Association Relationship: It represents a link showing the author's solution directly.
  - Influence Relationship: Represents a link to other solutions that have the same intent as the solution provided by the author.

The following query written in the query execution line will show all the solutions the author is linked with. Node properties can be seen from the node and when the expand button written under "Han et al." is pressed, all the solutions that the author is related to will be seen [7] (Figure 4):

match (n: elements) where n.name contains 'Han et al' return n.

The following query written in the query execution line will show the author's all linked solutions including his/her own generated solutions and other solutions with the same intent as the solution he/she provided (association and Influence relationships together):

match (n:elements)-[r]-(m) where n.name contains 'Han et al' and m.class='Grouping' return n,m,r.

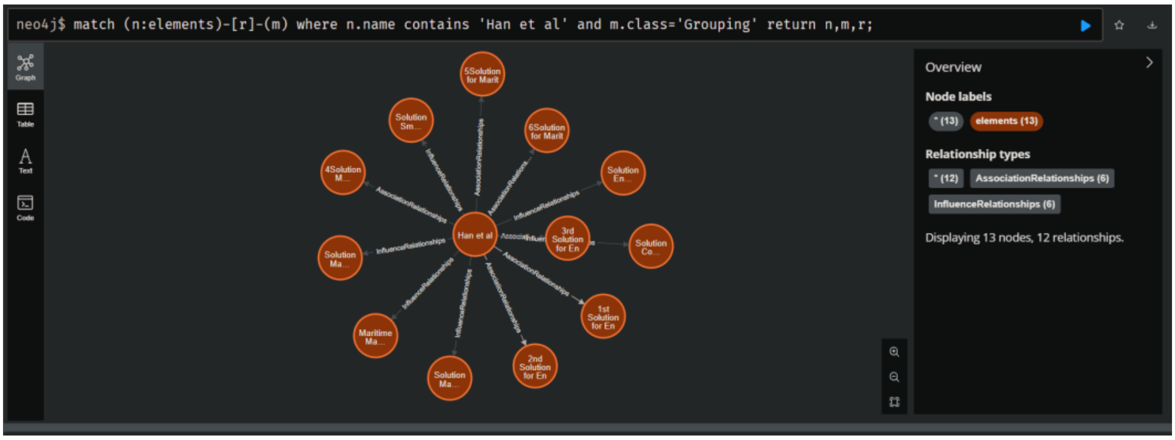

Figure 4: All solutions linked to the author

4.2. Extendibility of the knowledge graph

So far, the knowledge map's characteristics, its transfer to Neo4j, and samples of data that can be accessed using the graph database have been covered. For the created knowledge map to be kept up to date, its modification opportunities should be offered to users. This section will focus on how to expand the knowledge map.

After knowledge chunks created in the Archi tool are transferred to Neo4j, possibilities appear to add knowledge to the map. Providing synchronization between Archi and Neo4j is an important support for users in terms of practicality. The synchronization ensures that a change in the models in the Archi tool is directly reflected in the Neo4j graph database.

Further examples will be seen showing that this synchronization is working successfully. To show the extendibility of the knowledge map, two new chunks will be added to the map in the Archi tool and the change will be observed.

The following query, written in the query execution line, shows how many solutions exist in the knowledge map before adding new chunks to it (as is seen in Figure 5, 28 knowledge solutions exist in Neo4j):

match (a:elements) where a.class="Grouping" return a.name.

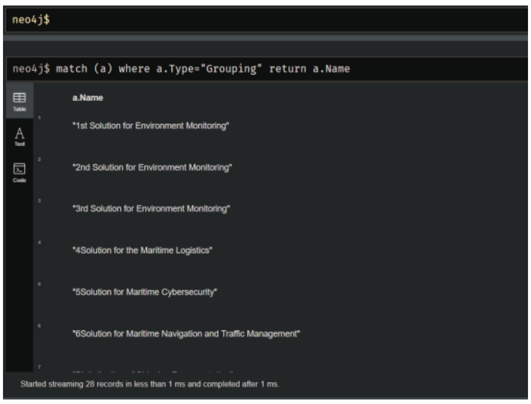

Figure 5: Available solutions before adding new chunks to the knowledge map

Now, two new chunks will be added to the knowledge map via the Archi tool and the change on Neo4j will be seen. One of the added chunks is a solution for maritime operations and safety, and another added chunk provides a solution for environmental monitoring. The newly added knowledge chunks in Archi are shown in Figure 6.

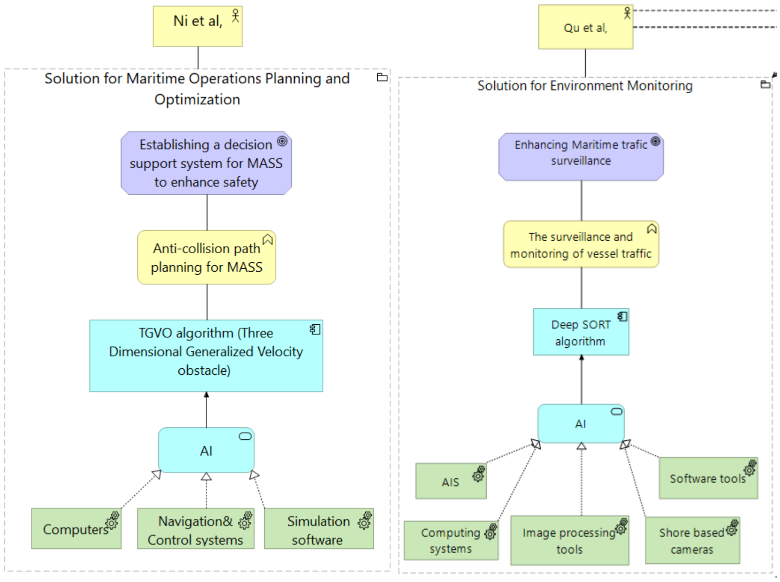

Figure 6: Newly added knowledge chunks

After creating knowledge chunks in Archi, the knowledge should be exported to Neo4j.

The following query, written in the query execution line, shows how many solutions exist in the knowledge graph after adding new chunks to it (as shown in Figure 7, the knowledge graph is successfully extended to 30 records which means 30 solutions exist in the database):

match (a:elements) where a.class="Grouping" return a.name.

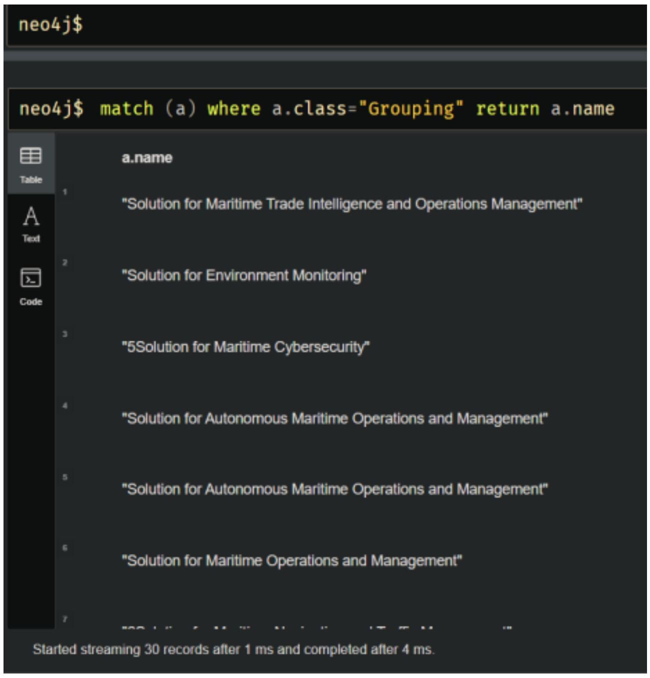

Figure 7: Available solutions after adding new chunks to the knowledge map

Figure 8 displays the chunks added to Neo4j. The new business actors/authors [17], [18], injected recently, can be seen with the following query in Neo4j:

match (n:elements)-[r:AssociationRelationships]-(m) where n.name contains 'Qu et al' or n.name contains 'Ni et al' and m.class='Grouping' return n,m,r.

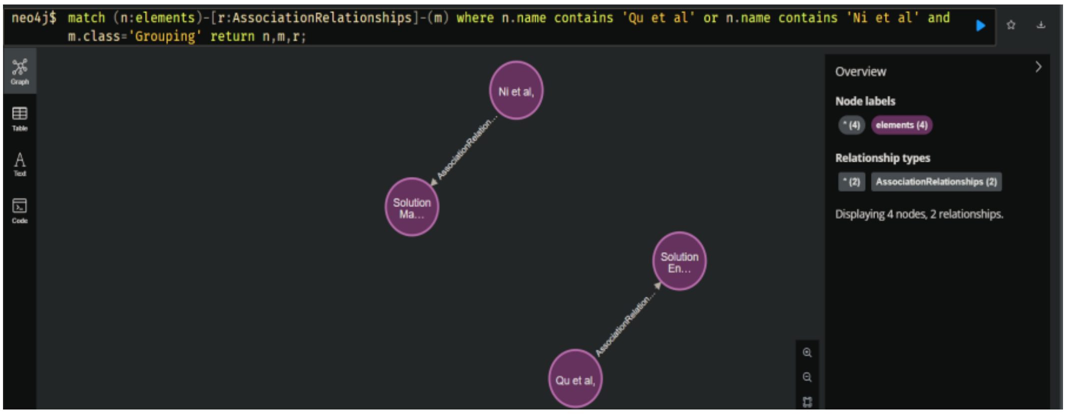

Figure 8: Newly added authors

5. Conclusion

This study aimed to recognize the use of IT solutions in the maritime sector and to develop a comprehensive knowledge map in the form of a knowledge graph.

The identified maritime IT solutions were analyzed and represented with "knowledge chunks" using the ArchiMate language and the Archi tool. The chunks, each illustrating a specific IT solution, were associated with each other to create the knowledge map. The knowledge created with the Archi tool was transferred to Neo4j graph database and Archi-Neo4j synchronization was provided for ease of use. Transferred knowledge was demonstrated on Neo4j with several queries. The knowledge map developed with provided Archi-Neo4j synchronization and querying was tested. With this knowledge map and its representation as a knowledge graph, it is possible to examine IT solutions used in the maritime industry and expand the knowledge map and the knowledge graph when necessary.

Further research is aimed at the possibility of having multi-level chunks and possibilities to automatically expand and maintain the knowledge map and the knowledge graph as well as to establish such IT solution repositories in other domains.

References

[1] M. Lind, M. Michaelides, R. Ward, R. T. Watson (Eds.), Maritime Informatics, Springer, 2020.

[2] The Open Group. ArchiMate® 3.1 Specification (2019). URL: https://pubs.opengroup.org/architecture/archimate3-doc/toc.html.

[3] IEEE Standard for Framework of Knowledge Graphs, IEEE Std 2807-2022, pp.1–52, 2022. URL: https://standards.ieee.org/ieee/2807/7525/.

[4] I. Wrage, CBA, Risk and Legal Assessment – MUNIN D9.3 released. Munin. 2015. URL: http://www.unmanned-ship.org/munin/cba-risk-and-legal-assessment-munin-d9-3-released/, last acceded 2023/01/12.

[5] M. Issa, A. Ilinca, H. Ibrahim, P. Rizk, Maritime Autonomous Surface Ships: Problems and challenges facing the regulatory process. Sustainability, 14(23), 15630 (2022). doi:10.3390/su142315630.

[6] I. de la Peña Zarzuelo, M. J. Freire Soeane, B. López Bermúdez, Industry 4.0 in the port and Maritime Industry: A Literature Review. Journal of Industrial Information Integration, 20, 100173 (2020). doi:10.1016/j.jii.2020.100173.

[7] H. Han, Z. Liu, X. Wang, S. Li, Research of the relations among cloud computing, internet of things, Big Data, artificial intelligence, blockchain, and their application in the Maritime Field. Journal of Physics: Conference Series, 1927(1), 012026 (2021).

[8] M. Sancricca, What value can cloud computing deliver to the maritime industry? AWS Blog Home, 2020 URL: https://aws.amazon.com/tr/blogs/industries/what-value-can-cloud-computing-deliver-to-the-maritime-industry/.

[9] S. C. Mallam, S. Nazir, S. K. Renganayagalu, Rethinking Maritime Education, Training, and Operations in the Digital Era: Applications for Emerging Immersive Technologies. Journal of Marine Science and Engineering, 7(12) 428 (2019). doi:10.3390/jmse7120428.

[10] G. Kavallieratos, S. Katsikas, V. Gkioulos, Cyber-attacks against the Autonomous Ship. In: Computer Security. SECPRE CyberICPS 2018, Lecture Notes in Computer Science, vol. 11387, Springer, Cham. pp. 20–36 (2018). doi:10.1007/978-3-030-12786-2_2.

[11] L. Li, H. Zhou, A survey of blockchain with applications in maritime and Shipping Industry. Information Systems and e-Business Management, 19(3), 789–807 (2020). doi:10.1007/s10257-020-00480-6.

[12] Archi – Open Source ArchiMate Modelling. URL: https://www.archimatetool.com/

[13] GitHub. Created Models. URL: https://github.com/UmutKandemir/Archimate_Models.

[14] A. Andreadakis, T. F. Sloane, D. Dalaklis, An automated lifeboat manifesting embarkation system (ALMES): optimizing evacuation and passenger manifestation via RFID/NFC. TransNav: International Journal on Marine Navigation and Safety of Sea Transportation, 15(1), 215–221 (2021). doi:10.12716/1001.15.01.23.

[15] A. Ortega Piris, E. Diaz Ruiz, C. Pérez Labajos, A. Navarro Morales, Implementation of a RFID system on ships for passenger and crew location. In: Maritime Transport VIII: Proceedings of the 8th International Conference on Maritime Transport: Technology, Innovation and Research: Maritime Transport'20, Universitat Politècnica de Catalunya. Departament de Ciència i Enginyeria Nàutiques. pp. 311–329 (2020).

[16] GitHub repositories for Archi. URL: https://github.com/archi-contribs.

[17] J. Qu, R. W. Liu, Y. Guo, Y. Lu, J. Su, P. Li, Improving maritime traffic surveillance in inland waterways using the robust fusion of AIS and visual data. Ocean Engineering, 275, 114198 (2023). doi:10.1016/j.oceaneng.2023.114198.

[18] S. Ni, N. Wang, Z. Qin, X. Yang, Z. Liu, H. Li, A distributed coordinated path planning algorithm for maritime autonomous surface ship. Ocean Engineering, 271, 113759 (2023). doi:10.1016/j.oceaneng.2023.113759.