Maritime Industry 4.0 Sustainability Challenge and Resolving Through Universal Accessibility Design

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ABSTRACT

Maritime industry 4.0 could be characterized as technical solutions through Artificial intelligence thru Neural network, Big data thru Internet connectivity and Industrial internet of things thru Data velocity in real time.

Sustainability challenges in maritime industry could be summarized as acute shortage of qualified human resources, energy efficiency to achieve net zero emission target and decision efficiency through improved data management and communication.

While developed economies are unable to attract their citizens to join seafaring jobs by sacrificing family-friends and city life, now trying to replace or reduce seafarers by means of investing more in industry 4.0 technologies, which in turn multiplying pressure on existing under developed state of industry 4.0 infrastructure in maritime sector.

Here we propose to resolve this maritime industry 4.0 constrain by using universal accessibility design (UAD) model, which incorporates sustainability parameters of maritime industry and limitations of new technologies in covering oceans in cost effective manner.

In the context of newer complexities in achieving sustainability for maritime industry through application of industry 4.0 technologies, utilization of universal accessibility design for bigdata management in remoteness of vessels at seas from the ports and companies in cities, could bring operational flexibility in decision making by local Learning modules and corresponding resolve strategy development and knowledge building issues in remote server by Cognition process. Further iteration, comparison and validation of knowledge for future maritime industry development uses could be done through public access to those bigdata in a cloud base.

KEYWORDS

Maritime Industry 4.0; Sustainability Challenge; Universal Accessibility Design

1. Introduction

Maritime industries integrate Internet of Things (IoT) to assemble sensors into internet connectivity that perform data analysis and are used for real-time decision-making applications. Industrial IoT connects industrial objects with internet infrastructure to support smart industrial automation services. A smart IoT infrastructure is monitored and controlled effectively and improves productivity, security, and sustainability.

The complex IoT Cyber-Physical Systems (CPS) integrate all networking objects with individual identity (IP) to manage all IoT components. Nowadays, 5G facilities accelerate industrial automation, called industry revolution 4.0. Maritime 4.0, shipping 4.0 and shipyard 4.0 are among divisions of industry 4.0 in maritime industry [1]. The performance of a shipping system depends on the navigation system, autopilot system, security system and sensing system, which of these can be improved by IoT embedded networking system [2]. This paper proposes a model that can enhance sustainability features of IoT enabled maritime industry system.

2. Sustainability Challenges and Industry 4.0 Technologies in Maritime Operations

Maritime industries enhance automation by using IoT infrastructure that continuously generates real-time unstructured data called big data. Within maritime industry these could include management of Ports, ships or companies, ranging from legal-compliance, safety-security and economic-commercial perspectives. Each perspective has several mega functional procedures, where each mega functional procedure has many more components and devices to integrate, monitor, data storing, real-time communication, comparison against set values of different level for decision making purpose. For example, for a successful voyage besides other perspectives a vessel need to perform mega functional procedures like cargo operation, machinery operation, navigation and weather routing operations.

Navigation alone may include data from many devices like echo sounder, Velocity meter or speedometer both in water tracking and ground tracking mode, GPS or equivalent positioning data, RADAR and ARPA data, AIS data, Safety Communication data from VHF-MF-HF or Satellite, Navtex, SART, EPIRB, ECDIS, Hygrometer, thermometer, Wind direction and velocity data, Course recorder, Auto pilot, Main engine propulsion data, weather forecast, cargo-stability and hydrostatic information etc. are required on real-time to ensure voyage efficiency and fuel efficiency of the vessel during entire passage while she is travelling all over the world in very remote distances at oceans. Hence any attempt of automation in maritime industry would cause large volume and large variety of data to be transferred in real-time mode to very remote locations, this bigdata management is very difficult to achieve in cost effective manner within existing technology and global maritime industry infrastructure state.

Figure 1: Management of Ports, ships or companies, ranging from legal-compliance, safety-security and economic-commercial perspectives

Sustainability in maritime industry like any other industry has three major dimensions of people, environment and economy. In brief the current sustainability challenges of maritime industry are acute shortage of qualified human resources, fuel efficiency for achieving net zero emission target and efficient management decision making for competitive and profitable business. Now to resolve each challenge investors and ship owners continuously focusing more and more on new technologies of industry 4.0 era.

Maritime industries distribute their functionality via edge computing, fog computing, and cloud computing to minimize complexity [3]. IoT devices are low power-consuming equipment and IoT infrastructure is implemented to improve sustainability practice besides industrial automation [4] but IoT devices have till now been difficult to recycle or reuse due to lack of standardization [5]. IoT frameworks use machine learning applications to collect, process, and share data efficiently. Resource constraint IoT devices face difficulty in executing high complexity cryptography algorithms and light-weight cryptographic algorithms are proposed to improve sustainability [6]. To improve the sustainability of a maritime industry we should select sustainable i) hardware technology for IoT devices like FPGA [7], ii) Sustainable solutions (algorithms) like lightweight cryptography [8], and iii) sustainable model like SQ-framework [9]. This article proposed a new sustainable model called universal accessibility design for the maritime industry 4.0 (UAD MI 4.0).

3. Paradox of Sustainability solutions by using industry 4.0 technologies

The Industrial IoT of shipping companies generates a huge amount of real time data that is nearly impossible to handle by traditional database management systems and it becomes more critical when the number of data sources is increased [10]. Maritime industries are one of the most important big data generating sources with IoT infrastructure in this 4.0 era. Data-driven applications implement artificial intelligence [11] to improve efficiency and sustainability to handle high-volume, high-variant, and high-velocity data. Maritime industries face major barriers with limited bandwidth, asynchronous solutions, as well as complex and risky information systems [12] during ship-to-shore data transfer.

The IoT framework of maritime industries assimilates robotics and sensors with advanced machine learning or deep learning intelligence systems [13]. The common big data generating sources are navigation parameters, engine monitoring measures, environmental indicators, voyage records, crew morale, safety, and cargo information of a ship [14]. A ship generates continuously heterogeneous data which is being processed for decision making. The paradox of using more AI and ML technologies for resolving sustainability challenges of maritime industry 4.0 is that, much more data being produced which has multiple complexity restricting the ability to bigdata communication with existing state of maritime ICT infrastructure globally.

4. Universal Accessibility Design to Resolve Existing Challenges

Continuous data collection, processing, and sharing of edge, fog, and cloud require huge amounts of energy. This research proposed a model that could contribute to reducing energy utilization.

The data source environment of the maritime industry is complicated with physical conditions of land, sea, and sky that increases communication and real-time processing challenges. A three-layer architecture (edge, fog, and cloud) [3] is popular for reducing complexity and improving efficiency. This mode definitely improves sustainability because of a lower number of data transactions but it [3] does not concentrate on sustainability factors.

This article develops a model to focus on the sustainability parameters. A maritime infrastructure can improve sustainability practice by implementing sustainable processes for

- Big data collection, processing and sharing
- Consensus algorithms and protocols
- IoT device management (activation/deactivation time)
- Edge, fog, and cloud computing

An efficient big data handling tool performing real-time analysis, visualization, storing and sharing at the minimum cost (processing time) can enhance quality of service as well as the sustainability of the maritime industry [15]. A ship can be monitored by a tracking system that is enabled by a satellite navigation system. Weather forecasting, road monitoring and vehicle path optimization can reduce the cost of a shipping system and enhance sustainability, but when the same effective solution is found with less energy consumption, then sustainability is further enhanced.

IoT devices need to communicate among themselves to make a decision based on the voting system of a distributed IoT environment. An effective consensus algorithm supports an agreed minimum cost and time. Maritime industry should implement an effective consensus algorithm like Practical Byzantine Fault Tolerant (PBFT) [16]. Protocols that run 24 hours to the IoT devices that need a significant amount of energy. An energy efficient protocol contributes to the low amount of energy consumption and finally energy efficiency of entire smart system improves by total energy saving [17].

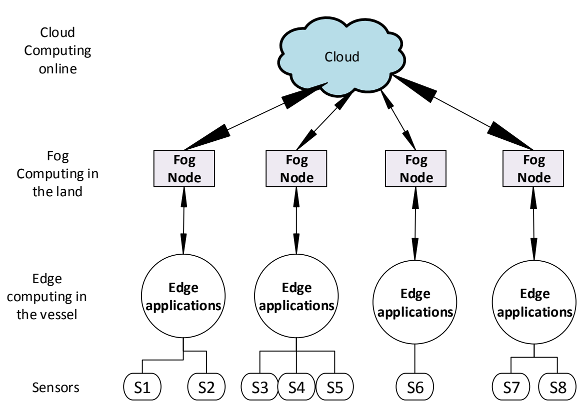

Figure 2: 3 layers computing [3]

Maritime industries are practicing three layers computing architecture (figure 1) to simplify their functionalities and increase efficiency. We also prefer same model to improve sustainability of maritime industries. A ship generates sensitive and real-time data always during its voyage time, which should be processed faster and implement decisions accordingly for safety and efficiency. If the processing system is not inside the ship, it may create the worst situation for a late decision. There is more possibility of data loss or cyberattack when data sharing happens frequently from a ship to a land-station. When an organization wants to compare the findings of multiple ships, then they need to process data for strategic development but not need for real-time decisions. So, an industry prefers to process inside the organization rather than on ship or sharing on the cloud. The task distribution system of a three-layer architecture increases sustainability by reducing complexity, minimizing risk, and deducting computations. The computing systems are as follows:

- Edge Computing: IoT sensors are the main sources of big data, having a variety of units, types, and formats, such as images, text, Boolean, numeric, sound, and graph. It increases data complexity to collect, filter, process, and generate knowledge. The ship is the main part of edge computing that needs to process data immediately for real-time decision and shared with the landing station called fog.

- Fog Computing: Each industry prefers a centralized processing system and a land station with its own storage facilities. This is a local data center to maintain individuals' security. It collects summarized information from the edges and develops regular reports that can improve the decision support system of the organization. It communicates with the cloud only for information sharing, which is common for shipping corporations.

- Cloud Computing: This is a shared infrastructure of the maritime industries under a corporation which is used for data sharing. All organizations share their experience and utilize the information for safety voyages and business improvement goals. This is a common platform for data sharing, processing, and knowledge generation.

5. Sustainability test for UAD MI 4.0 model

Table I maps the KarlsKrona sustainability principles for the implementation of the maritime industries as like software industries [22]. It incorporates 9 distinguished criteria, like longevity, flexibility, and energy saving.

Table I KarlsKrona Principle compliance of Universal Accessibility Design phases in Maritime industry 4.0 context

Karlskrona principle	*Description*	*Phase 1 Edge computing*	*Phase 2 Fog computing*	*Phase 3 Cloud computing*
Kp 1	Meeting future needs without compromising current demand	Current demand	Current demand	Future needs
Kp 2	Long term and continuous practice	Continuous practice	Continuous mutual practice	Long term practice
Kp 3	Systematic approach	Local level Learning and decision making	Regional Cognition process forstrategy development	National and international level knowledge building thru cognition
Kp 4, Kp 5	Multiple dimensions, Multiple disciplines/ Perspectives	Energy saving, Time saving	Cost saving, Environment protecting	Knowledge building, Industry development
Kp 6, Kp 7	Independent of the purpose of the system, Accommodate a wider context	Localization of decision making to accommodate further integration	Mid level collaboration to accommodate different tier integration	Global collaboration for maritime industry 4.0 sustainability
Kp 8, Kp 9	Precondition to system design, More flexible with better alternatives	Local learning modules in design have many alternatives and higher flexibility	This stage allows time and data velocity flexibility	Ensures iterations and validation for long term industrial knowledge base development

6. Conclusion

A ship may consist of thousands of sensors [18] which explain the current status of the engine, fuel, speed, motion, temperature, position, vibration, water level, weather condition, security posture and so on, conditions that continuously generate data. This data is processed and analyzed to predict the safety of a voyage, effectiveness of resource utilization, and commercial purposes [19]. Numerical, textual, Boolean, image, audio, video records of a ship's system are generated in asynchronous mode and increase more complexity when the subject of an information is associated with a correlation of two or more records. Moreover, autopilot systems, radar charts, and navigation equipment generate complex data [20]. A special situation or position of a ship during the voyage is analyzed by anomaly analysis technique [21] that may use Sequential Probability Ratio Test (SPRT) and Associative Kernel Regression (AKR). The implementation of AI applications improves sustainability practices in the maritime industry by enhancing security prediction, cargo systems, port management systems, and ship building industries of industry 4.0 era [19].

This study informs the creation of applications for the marine sector that must deal with big data concerns in IIoT infrastructure. Many distinct independent units of applications are interconnected to execute the task, which poses integration, data processing, and sharing issues. We created a four-layer architecture (sensor layer, edge layer, fog layer, and cloud layer) and used divide-and-conquer strategies to reduce the complexity of big data generated throughout the complete eco system of maritime industry 4.0. Edge computing will give the ship an immediate solution (faster and privately for the ship); fog computing will give the company strategic planning (private and long-term for the organization); and cloud computing will share information among the ships of the same administration and beyond.

In brief, a ship station would do learning for instant decision making, whilst a land station would perform cognition to develop knowledge for future use, and cloud information might assist the entire maritime industry 4.0 community in learning more and progressing. Performance of this architecture also depends on the quality of the applications and appropriate requirement analysis. This architecture maintains redundancy in data storage, processing, and visualization yet safeguards privacy and the integrity of business strategy. The company should adhere to its data manipulation storage plan. The majority of the complicated information processing and knowledge extraction is done at the land station. The cloud architecture is advised to make information available to stakeholders and the community, allowing the whole marine sector to accomplish a shared job via the internet.

In addition to hardware interface with FPGA and sensors, the researchers may focus on process reduction, effective memory management, transition control, and individual computing (edge, fog, and cloud). Last but not least, there is continuing study on the three computing dimensions (edge, fog, and cloud) and associated technologies.

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