ISSN: 2764-5886
e-ISSN: 2764-622X

Volume 5· N° 2 · June 2022

Journal of Bioengineering, Technologies and Health

An Official Publication of
SENAI CIMATEC

ISSN: 2764-5886 / e-ISSN 2764-622X

Volume 5 • Number 2 • June 2022

JOURNAL OF BIOENGINEERING TECHNOLOGIES AND HEALTH

An Official Publication of SENAI CIMATEC

PUBLISHED BY SENAI CIMATEC

Sistema FIEB | SENAI CIMATEC
PELO FUTURO DA INOVAÇÃO

June 2022
Printed in Brazil

JOURNAL OF BIOENGINEERING, TECHNOLOGIES AND HEALTH

An Official Publication of SENAI CIMATEC

JOURNAL OF BIOENGINEERING AND TECHNOLOGY APPLIED TO HEALTH

Volume 5 • Number 2 *June 2022*

SUMMARY

The Journal of Bioengineering, Technologies and Health (JBTH) is an official publication of the SENAI CIMATEC (Serviço Nacional de Aprendizagem Industrial - Centro Integrado de Manufatura e Tecnologia). It is published quarterly (March - June - September - December) in English by SENAI CIMATEC – Avenida Orlando Gomes, 1845, Piatã, Zip Code: 41650-010, Salvador-Bahia-Brazil; phone: (55 71) 3879-5501. The editorial offices are at SENAI CIMATEC.

Editorial Office

Correspondence concerning subscriptions, advertisements, claims for missing issues, changes of address, and communications to the editors should be addressed to the Deputy Editor, Dr. Roberto Badaró, SENAI CIMATEC (Journal of Bioengineering, Technologies and Health – JBTH) – Avenida Orlando Gomes, 1845, Piatã, Zip code: 41650-010, Salvador-Bahia-Brazil; phone: (55 71) 3879-5501; or sent by e-mail: jbth@fieb.org.br / jbth.cimatec@gmail.com.

Permissions

Postmaster

Send address changes to JBTH, Avenida Orlando Gomes, 1845, Piatã, Zip Code: 41650-010, Salvador-Bahia-Brazil.

Information by JBTH-SENAI CIMATEC

Address: Avenida Orlando Gomes, 1845, Piatã, Zip Code: 41650-010, Salvador-Bahia-Brazil
Home-page: www.jbth.com.br
E-mail: jbth@fieb.org.br / jbth.cimatec@gmail.com
Phone: (55 71) 3879-5501 / 3879-5500 / 3879-9500

DOI:10.34178/jbth.v5i2

Copyright

COVER: Application for Holographic Pyramids in Exhibition Spaces: An Expansion of the Teaching Mode.Figure 4. Quadruple video example for holographic pyramids. Júlia Maria Nascimento Ribeiro. J Bioeng. Tech. Health 2022;5(2): 149.

Dunaliella salina Biorefinary: An Evaluation of the State-of-the-Art

Stephanie de Melo Santana[1*], Ana Lucia Barbosa de Souza[1], Fernando Luiz Pellegrini Pessoa[1]
[1]SENAI CIMATEC University Center; Salvador, Bahia, Brazil

Biorefinery is an important concept that can be applied to improve the industrial processes, making them more sustainable, and reducing waste, and costs of operation. Algal biomass is too onerous to be exploited, and only a few microalgae have products that are feasible to commercialize. Combining this concept and other ones, such as intensification and integration procedures, can also help reduce the costs and become more attractive to industries. *Dunaliella salina* is one of the most critical microalgae studied nowadays. Currently, its process exploits only 10% of its compounds in beta-carotene production. Studies show that different compounds can be exploited and the processes can be combined in a biorefinery approach.
Keywords: *Dunaliella salina* **Biorefinery. Beta-Carotene Production. Microalgal. Biorefinery.**

Introduction

Microalga is a large group of photosynthesizing microorganisms that along with some cyanobacteria have been studied to produce a wide range of compounds. They are considered cell factories because their biomass might be used for various industrial applications as a sustainable raw material. They are also critical players in the future of the blue-bioeconomy, which is about living aquatic resources [1,2]. Some of them have been studied for decades and were the first commercial cultures, mainly in the food and feed industries, like *Arthrospira platensis* (Spirulina), *Chlorella genus*, *Dunaliella salina*, and *Haematococcus pluvialis*. Nowadays, they are also studied and used in the bioenergy, pharmaceutical, and cosmetic industries. Some compounds are lipids or oils such as biofuels, pigments (carotenoids), proteins, polyunsaturated fatty acids (PUFAs), and carbohydrates [1,3].

As the world faces challenges like global climate changes, water scarcity, and increasing global population, there is a need for sustainable production chains. Microalgal biomass has been widely studied to be a sustainable alternative in industry, and one of the main topics of the current research is the bioenergy industry. It is very promising as a source of bioenergy, because it doesn't compete with food supplies, doesn't require large amounts of land or freshwater to be cultivated, and doesn't require complex treatment methods as the lignocellulosic-enriched biomass does for producing biofuels, for example [1,3,4]. Despite it, the algal biomass production is onerous, and some steps of the downstream processing can be energy-intensive, which are barriers to an industrial scale [1-3].

Techno-economic-analysis works indicate that it is necessary to make multiple products in a single cycle to reduce the costs, which is a biorefinery concept. It can also be a way to valorize the other components of the microalgal biomass and reduce waste. Sustainability can be obtained by combining the biorefinery concept with integration and intensification of the processes, technical-economic evaluation, and life-cycle assessment [1-4].

The existing commercial cultures are feasible because they are focused on some bioactive food compounds, like single-cell protein (dried biomass) supplements and carotenoids (main beta-carotene from *Dunaliella salina* and astaxanthin from *Haematococcus pluvialis*). Jacob-Lopes and colleagues (2019) discuss them in a review of bioactive food compounds from microalgae and say that they are less competitive but are economically attractive because they are more effective than synthetic molecules. The natural

Received on 26 February 2022; revised 25 April 2022.
Address for correspondence: Stephanie de Melo Santana. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA- Brazil. Zipcode: 41650-010. E-mail: sms.teca@gmail.com. DOI 10.34178/jbth.v5i2.205.

J Bioeng. Tech. Health 2022;5(2):96-99.

sources are better absorbed by the human body, and some of these compounds are hard to synthesize, like the isomers that comprise the mixture of the natural form of beta-carotene [5,6].

Even though this microalga can produce many compounds, the existing industrial processes are made for specific applications. A biorefinery approach should also produce other compounds. Thus, this work aims to investigate the state-of-the-art biorefinery concept applied to *Dunaliella salina*. Among the microorganisms cited, it can be highlighted as a potential raw material to be explored in a biorefinery, for being a marine microalga that is highly resistant to different stress conditions and is rich in carotenoids (high-value components) and also in oil content for biofuels (medium/low-value) [1,5,7].

Material and Methods

For an initial comprehension, Science Direct was the scientific database chosen to explore the review articles about microalgae biorefinery. The keyword searched was "microalgae-based biorefinery", sorting articles between 2019 and 2021 by relevance order. The articles chosen were the ones that presented the current highlighted species, discussion about the different routes that a microalgal biorefinery can have, the different products that can be obtained, the bottlenecks, and techno-economic assessments. Then, other keywords were explored with the same filters to understand how much these species are being explored by researchers (Table 1).

We decided to investigate the *Dunaliella salina* potential in a biorefinery for being able to tolerate different stress conditions, having a consolidated commercial production of a high-value compound, and its potential to produce various other products and energy. Scholar Google was also used, sorting articles between 2016 and 2021 by relevance order. From the articles considered the most relevant, some references were consulted for better understanding, and different keywords were chosen to find information using the Scholar Google database to show all works between 2016 and 2021 by relevance order. The other keywords were "beta-carotene production", "*Dunaliella salina* products", and "biorefinery of *Dunaliella salina*". The literature research consisted in finding information about the processes involved, the compounds of interest, characteristics of the microalgae, and biorefinery perspectives.

Table 1. Quantity of scientific reviews.

Keywords	Quantity
Arthrospira platensis biorefinery	264
Chlorella genus biorefinery	982
Dunaliella salina biorefinery	298
Haematococcus pluvialis biorefinery	230
Spirulina platensis biorefinery	512

Results and Discussion

Dunaliella salina is a unicellular flagellated green microalga that occurs in hypersaline environments [1,8]. It can produce carotenoids to protect the cell from harsh conditions, such as high salinity, high light intensity, alkaline environment, lack of nutrients, and/or extreme temperatures, resulting in an orange-ochre color [6,8].

Carotenoids are colored lipid-soluble pigments naturally found in plants, macro and microalgae, bacteria, and fungi, presenting yellow, orange, and red coloration [1,8,9]. The principal carotenoid accumulated in *D. salina* cell is beta-carotene, which can constitute up to 10% of its dry mass [6,8,9].

Microalgal Beta-Carotene Commercial Production

Carotenoids are known as Vitamin A precursors (pro-vitamin A) and are largely used in industry as food and feed colorant. Synthetic beta-carotene is mainly produced by Roche and BASF that transforms beta-ionone into beta-carotene. Most of the beta-carotene produced worldwide is

synthetic, and the main source of its natural form is the microalga *Dunaliella salina* [1,8,10].

Remahnji's (2021) work shows information about the global market size of beta-carotene from Polaris Market Research's report, in which it is valued at USD 439 million with a forecasted growth of 3,8% CAGR (compound annual growth rate) in 2017 with an expectation to continue to grow. Ribeiro's (2011) work showed that the global market size of beta-carotene is valued at circa USD 245 million. The 10-Year Bibliometric Review, comprising works between 2009 and 2019, confirms that it's a market that is still growing [6,10,11].

The basic process steps consist of microalgae cultivation, harvesting, dewatering, and extraction. *Dunaliella salina* is industrially cultivated in shallow open tanks in Israel and Australia. Warm and arid environments are ideal for it. We presented the conditions for the cultivation of *Dunaliella salina* for beta-carotene in Table 2 [7, 8,10].

The central nutrients that are limited are Nitrogen and Phosphorus. Pourkarimi (2020) presents that although nitrogen depletion can increase beta-carotene production, its long-time limitation can lead to a high rate of cell death. Salinity can also be affected by reducing cell growth. The article showed a two-stage strategy: in the first stage, the cells grow in a nutrient-rich environment (NaCl 18%) and then transfer to a poor medium in nutrients with 27% of NaCl (high salinity) to improve the carotenoids production by the cells [7,8,10]. Even though natural and synthetic forms of beta-carotene have the same structure, the natural form comprises several other carotenoids, including isomers as 9-cis-beta-carotene, and only 10% of the *Dunaliella salina* biomass extracts it [10].

Table 2. Conditions for cultivation of *Dunaliella salina* for beta-carotene.

Factor	Range
Low concentration of nutrients	0.05–0.1 g/L
The concentration of NaCl	2-5M
Temperature	20-40°C
Light intensity 50-800µmol photons	m^{-2} s^{-1}
pH	6-9

Other Bioactive Compounds

Dunaliella salina biomass is also rich in other compounds, such as glycerol and fatty acids. Glycerol is a carbohydrate commonly used in food and pharmaceutical production, and fatty acids are lipids that can be exploited as nutritional supplements or as raw material for biofuel production by transesterification. Pirwitz (2016) shows that carbohydrates can be converted into glucose by hydrothermal liquefaction (HTL) and used as a carbon source by *Chlorella vulgaris*, E*scherichia coli*, and *Saccharomyces cerevisiae* [8,12].

Biorefinery Approach

Nowadays, a microalgal biorefinery that focuses on bioenergy is not feasible. Techno-economic assessments show that it is necessary to reduce the costs, focus on high-value products, or both [1,2,7]. A biorefinery approach aiming to produce different chemicals is a way to reduce the cost and also valorize the other compounds [3,4,9]. *Dunaliella salina* is a promising raw material that already has a scaled-up process in the industry with a product with high commercial interest, and some studies show that the unused biomass can be exploited.

Conclusion

A biorefinery approach reduces operational costs and valorizate the other components of microalgae biomass. *Dunaliella salina* is already exploited, but only 10% of its biomass is used in beta-carotene production. The unused biomass which goes to waste has critical compounds that should be exploited. Integrating the principal

process with the processes that can obtain these other compounds should be done. These processes are the HTL conversion of glycerol, the transesterification of the fatty acids, and energy conversion with the remaining biomass. Defining the routes, intensification, and optimization should also be applied, resulting in a circular and sustainable economy.

Acknowledgments

We thank SENAI CIMATEC and the EIPQB (Engineering for Intensification of Chemical and Biochemical Processes) Group.

References

1. Jacobs E et al. Handbook of microalgae-based processes and products. London: Academic Press, 2020.
2. Gufini I et al. Current bottlenecks and challenges of the microalgal biorefinery. Trends Biotechnology 2019;37:242-252.
3. Bhattacharya M, Goswami S. Microalgae – A green multi-product biorefinery for future industrial prospects. Biocatalysis and Agricultural Biotechnology 2020;25(101580).
4. Wu W, Chang J-S. Integrated algal biorefineries from process systems engineering aspects: A review. Bioresource Technology 2020;291(121939).
5. Jacob-Lopes E et al. Bioactive food compounds from microalgae: An innovative framework on industrial biorefineries. Current Opinion in Food Science 2019;25:1-7.
6. Silva SC et al. Microalgae-derived pigments: A 10-year bibliometric review and industry and market trend analysis. Molecules 2020;25(3406).
7. Pourkarimi S et al. Factors affecting production of beta-carotene from *Dunaliella salina* microalgae. Biocatalysis and Agricultural Biotechnology 2020;29(101771).
8. Ben-Amotz A et al. The alga *Dunaliella*: biodiversity, physiology, genomics and biotechnology. Science Publishers, E.U.A., 2009.
9. Espada JJ et al. Environmental and techno-economic evaluation of β-carotene production from *Dunaliella salina*. A biorefinery approach. Biofuels, Bioproducts and Biorefining 2020;14(1):43-54.
10. Ribeiro BD, Barreto DW, Coelho MAZ. Technological aspects of β-carotene production. Food and Bioprocess Technology 2011;4:693-701.
11. Rehmanji M et al. Chapter 26 - microalgal cell factories, a platform for high-value-added biorenewables to improve the economics of the biorefinery. Microbial and Natural Macromolecules - Syntesis and Applications 2021:689-731.
12. Pirwitz K, Rihko-Struchmann L. Sundmacher K. Valorization of the aqueous phase obtained from hydrothermally treated *Dunaliella salina* remnant biomass. Bioresource Technology 2016;219:64-71.

Computational Model for Electrical Motors Condition Analysis and Monitoring

Álvaro Souza de Melo[1*], Oberdan Pinheiro Rocha[1], Alex Álisson Bandeira Santos[1]
[1]SENAI CIMATEC University Center; Salvador, Bahia Brazil

Predictive maintenance uses several methods to monitor the conditions of electric motors applied in industrial plants. Among these methods, vibration analysis stands out as a widely used method due to the possibility of identifying a wide chance of failures. This work presents the development of a computational model endowed with a classifying algorithm to receive vibration readings from electric motors and determine if the machine has a fault behavior and, if so, which fault. For the algorithm to detect which type of failure, a dataset with readings from several engines in different failure conditions should be developed for training the model.
Keywords: Vibration Analysis. Condition-Based Monitoring. Feature Extraction. Classifier Agent.

Introduction

Maintenance is a critical and constantly evolving point in industries. Even with many technological advances, it is still a challenge to predict failures before happen. Predictive maintenance is essential, especially in the industrial environment, where the failure of some equipment that results in the need for corrective maintenance can cause the partial or total stoppage of the production plant, which causes inconvenience and losses for the company.

Vibration analysis in electric motors mitigates the possibility of failure. This method is an important tool for diagnosing operating conditions. Many engine problems reflect directly on their vibration due to several factors: misalignment, cavitation, and clearance, among others. Each component of a motor has a signature at a different frequency. It is possible to detect the type of fault present in the machine from the analysis of the behavior of the vibration profile of the equipment. Current studies show classification algorithms specialized in a specific failure, which does not allow their implementation in an industrial environment to obtain indications of several failures, since an electric motor can induce defects in different components of this equipment. This research project aims to develop a classifier algorithm that will determine the current condition of an electric motor based on a dataset containing readings from different equipment. To this research is considered feasible, the dataset was obtained in a laboratory with industrial vibration analysis equipment.

Different classification methods were also evaluated to obtain what brings greater precision and accuracy to detect the failure in the shortest execution time. After training the network using the model that best fits the problem solving, the technical feasibility of the proposed model was analyzed based on laboratory tests.

Materal and Methods

Classifier Algorithms

Classifier algorithms aim to predict the class of a new piece of data based on learning about similar data. They are a subcategory of supervised learning algorithms, where the objective is to predict the category of new data based on past observations [1]. We evaluated the performance, accuracy, and precision by three classification algorithms: Support Vector Machine (SVM), K-Nearest Neighbor (KNN), and Artificial Neural Networks (ANN).

SVM

Support Vector Machine (SVM) is a classification and regression tool that uses machine

Received on 16 January 2021; revised 20 April 2022.
Address for correspondence: Álvaro Souza de Araújo. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA- Brazil. Zipcode: 41650-010. E-mail: alvarosouza00@gmail.com.
DOI 10.34178/jbth.v5i2.206.

J Bioeng. Tech. Health 2022;5(2):100-105.

learning theory to maximize prediction accuracy, while automatically avoiding overfitting the network [2]. This algorithm performs the learning by assigning annotations to the data [3]. Also, according to Noble (2006), SVM can be used in several applications, from fraudulent credit card transactions and detection of handwriting patterns, through images, to applications in biology to recognize anomalies in DNA.

SVM algorithms are well known for their excellent performance in statistical classification. Still, the high computational cost due to the complexity of the cubic runtime is problematic for big data sets: training the SVM classifier requires solving a quadratic optimization problem [4].

Given an N number of training data for, where (x_i, y_i) is the input data and corresponds to its target value, the algorithm tries to find the hyperplane in a manner that the margin (distance perpendicular to the hyperplane) between support vectors is maximized [5]. If the data are linearly separable, there is a hyperplane, which can be expressed in the equation (1), considering the weight parameter.

$$f(x) = w^T x + b = \sum_{i=1}^{N} w_i x_i + b = 0 \qquad (1)$$

The regularization parameter C and kernel parameter y influence the performance of SVM [6]. The C is used to control the trade-off between maximizing the margin and minimizing the training error. For a given problem, if C is too large, SVM may store many support vectors, and it may be overfitting. If C is too small, SVM may again not fit properly, or it is underfitting [6].

RNA

Artificial Neural Networks can be defined as machines designed to model the working principle of a brain to perform a task [7]. The essential elements of this algorithm are the input connections, where each one has a weight to be determined, subsequent layers of neurons, an accumulator element to concentrate the signals, and, finally, an activation function, which can take different formats, to then, present the output value. One of the difficulties in neural networks is choosing the best architecture since this process is experimental and requires a great deal of execution time [8]. Thus, this technique requires extensive tests with different configurations to obtain the model best adapted to the problem.

Neural networks are similar to the human brain in two main aspects: the network acquires knowledge from its environment through the learning process, and connection forces between neurons (synaptic weights) are used to store the acquired knowledge [9]. At the output of each neuron, the generated signal goes through an activation function, which is responsible for weighing the effect of each output on the subsequent layer.

KNN

For pattern recognition, the KNN algorithm is a method to classify objects based on training examples that are closer in space [10]. This model was proposed by Fukunaga and Narendra (1975) and is a simple to implement classifier that can get very accurate results depending on the application [11].

This algorithm sorts data in a dataset based on proximity to already sorted data. Thus, the number of neighbors that must be considered for the classification of later data is determined as a parameter. This rule retains the entire training set during learning and assigns each query a class represented by the label of most of its closest neighbors in the training set [10].

The KNN classification method also has good accuracy and precision compared to the previously mentioned methods. The algorithm consists of estimating the distance between data to determine classification limits. It is important to emphasize that it is possible to graphically represent the data separation limits represented by up to three dimensions. With higher dimensions, the method can obtain the classification, however, the representation of more dimensions does not make physical sense.

To determine the degree of similarity of an entry with its closest neighbors, there are different methods for calculating the distance between the data, including the Euclidean distance, Hamming distance, and Manhattan distance, the first being the most used with input variables of the same type.

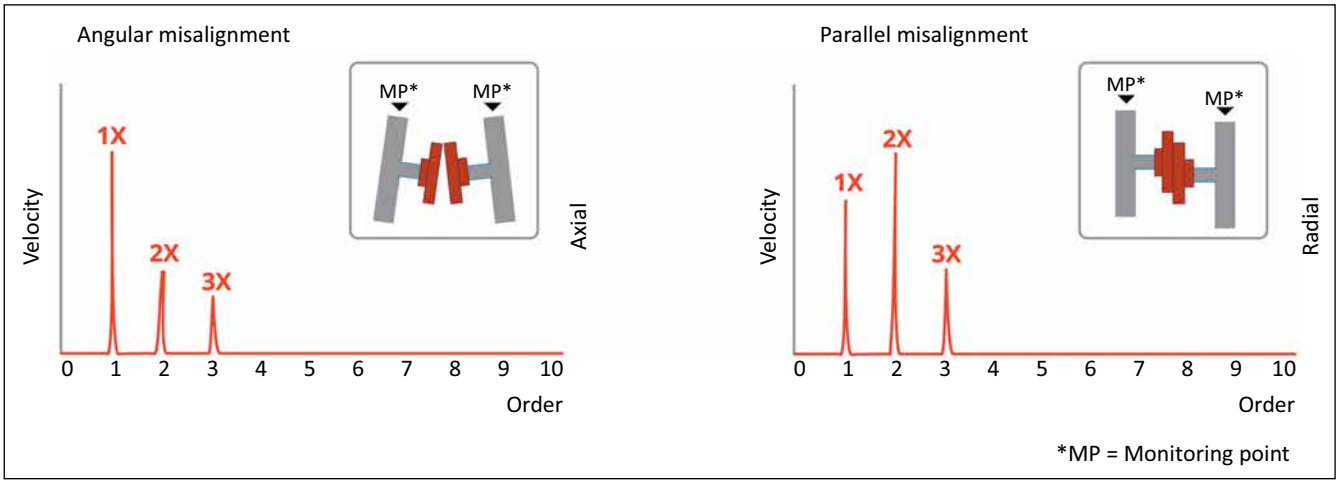
Vibration Analysis

Every machine has noise and vibration due to its operation and external excitations. However, a portion of the vibration is due to minor defects that compromise the performance of the equipment [12]. In this way, each failure behavior has a different frequency spectrum, which allows the distinction of the type of failure and knowing the specifications of the machine operation and the degree of severity. For the detection of failures of mechanical origin, vibration analysis is used, where, using the equipment equipped with an accelerometer sensor, a vibration signal in acceleration, velocity or displacement is measured, to then observe these data in the spectrum of time or frequency. In Figure 1, it is possible to visualize the behavior in the frequency spectrum of two faults: the angular and parallel misalignment, where 1x represents the dominant operating frequency of the motor. If it is powered directly from a 60 Hz electrical grid, which means that this is its dominant frequency.

Dataset

A dataset MaFaulDa [13] was selected to implement and train this model, which contains 1,951 multivariable series containing vibration sensor readings. This dataset covers the following equipment conditions: normal operation, unbalance, axial and radial misalignment, and internal and external bearing failures. Each reading is composed of three single-axis accelerometers, model IMI 601A01, in this dataset, each positioned on the radial, axial, and tangential axes, a triaxial accelerometer, model IMI 604B31, an analog tachometer, model MT-190, and a microphone Shure SM81 model. The dataset contains data referring to multiple rotation frequencies, ranging from 737 to 3,686 rpm. The first sensor, the uniaxial accelerometer, has a sensitivity of 100 mV/g, which can measure accelerations between -50 g and +50 g, and with a frequency spectrum from 0.27 Hz to 10,000 Hz. The operating principle of this equipment is a piezoelectric sensor, where a mass is in direct contact with the piezoelectric element and, when subjected to an acceleration, this mass exerts a mechanical force on the load that can be converted

Figure 1. Angular and parallel misalignment and the frequency behaviors.



into an electrical signal, thus being readable through a converter analog to digitally connected to a controller. This type of sensor is suitable for industrial applications that require high-frequency responses while maintaining stable responses in varying temperature environments. The triaxial accelerometer is the second sensor, which also has the same sensitivity as the previous one (100 mV/g) and the same measurement range (-50 g to +50g). However, its frequency response varies between 0.5 and 5,000 Hz. It has a ceramic sensor element, which results in low interference from external noise, suffering minimal reading variations when subjected to different temperatures.

Proposed Model

The first step to the entire dataset is to perform the Fast Fourier Transform in all signals to extract the frequency spectrum. Then, the preprocessing algorithm will retrieve statistic features, such as standard deviation, kurtosis, mean, skewness, and variance. ARFF file stores all this information that can train the classifiers. With Weka machine learning software [14], the next step performs an analysis to determine which features are relevant to the models. Therefore, another ARFF file is generated, including the most relevant features. Then, the filtered dataset is used to train classifiers using KNN, SVM, and RNA algorithms. The RNA algorithm was configured with a 0.3 learning rate, using one hidden layer containing 23 neurons, as described in equation (2). Furthermore, the classifier was limited to 500 epochs as stopping criteria.

$$n_{neurons} = \frac{(classes + attributes)}{2} \qquad (2)$$

Since the KNN classifier is a simpler type of classifier, it has fewer parameters to adjust. The model used 5 nearest neighbors, with the Euclidian distance. At last, the SVM model used the polynomial kernel, with the C parameter set to 0.1.

Results and Discussion

After evaluating the accuracy of all three models, the SVM presented the best accuracy for the dataset, as per Table 1. It is important to note that the time required to train the dataset using this classifier is comparable to the RNA, but considerably larger than KNN, due to the nature of the algorithm, which demands higher computational power as the number of neurons and layers increases.

Table 1. Accuracy of the classifier algorithms.

Algorithm	Accuracy
SVM	95.6433%
RNA	94.0031%
KNN	91.3378%

Comparing the results, it is possible to note that the SVM algorithm performed the best, considering the accuracy. Furthermore, in the confusion matrix, the entries, in general, were classified with minimal error, with the class IMBALANCE reporting the lowest score of 93.09% of correct classifications. Other classes such as UNDERHANG_BEARING_CAGE_FAULT and NORMAL contained, respectively, 93.61% and 93.09% of accuracy, which slightly decreased the overall accuracy of the model, to 95.64%. However, the other classes were correctly classified with over 96% of certainty (Figure 2).

The RNA classifier provided the second most accurate result. In its confusion matrix, it showed that the algorithm obtained 55.11% of correct classifications for the class NORMAL, and it negatively impacted the lower global accuracy of the model. However, the other classes presented over 91% accuracy, as shown on the confusion matrix for this algorithm (Figure 3).

At last, the KNN classifier presented the lowest accuracy of the three but was close to the previous RNA values. Differently from the prior results, this model could classify 42.89% of the entries from the NORMAL class correctly. However, this fact still indicates that this model encounters difficulty distinguishing NORMAL and other categories,

Figure 2. Confusion matrix from the results of the SVM classifier.

```
  a   b   c   d   e   f   g   h   i   j   <-- classified as
 46   1   1   0   1   0   0   0   0   0 |   a = NORMAL
  5 187   1   0   2   0   0   2   0   0 |   b = HORIZONTAL_MISALIGNMENT
  0  10 285   0   6   0   0   0   0   0 |   c = VERTICAL_MISALIGNMENT
  1   6   7 310   8   0   0   1   0   0 |   d = IMBALANCE
  4   4   0   1 176   1   0   1   1   0 |   e = UNDERHANG_BEARING_CAGE_FAULT
  2   0   0   0   0 182   0   0   0   0 |   f = UNDERHANG_BEARING_OUTER_RACE
  1   0   0   0   0   0 185   0   0   0 |   g = UNDERHANG_BEARING_BALL_FAULT
  4   1   0   0   0   0   0 178   5   0 |   h = OVERHANG_BEARING_CAGE_FAULT
  1   1   0   0   2   0   0   4 180   0 |   i = OVERHANG_BEARING_OUTER_RACE
  0   0   0   0   0   0   0   0   0 137 |   j = OVERHANG_BEARING_BALL_FAULT
```

Figure 3. Confusion matrix from the results of the RNA classifier.

```
  a   b   c   d   e   f   g   h   i   j   <-- classified as
 27   7   3   6   5   0   0   0   1   0 |   a = NORMAL
  4 175  11   0   2   1   0   2   1   1 |   b = HORIZONTAL_MISALIGNMENT
  0   4 286   1   4   0   3   2   0   1 |   c = VERTICAL_MISALIGNMENT
  0   3   1 323   1   0   2   1   1   1 |   d = IMBALANCE
  1   3   5   6 167   1   0   4   1   0 |   e = UNDERHANG_BEARING_CAGE_FAULT
  0   0   0   0   0 184   0   0   0   0 |   f = UNDERHANG_BEARING_OUTER_RACE
  0   0   0   0   0   0 186   0   0   0 |   g = UNDERHANG_BEARING_BALL_FAULT
  0   1   7   2   3   2   0 172   1   0 |   h = OVERHANG_BEARING_CAGE_FAULT
  1   1   1   0   2   0   0   6 177   0 |   i = OVERHANG_BEARING_OUTER_RACE
  0   0   0   0   0   0   0   0   0 137 |   j = OVERHANG_BEARING_BALL_FAULT
```

such as HORIZONTAL_MISALIGNMENT, with 78.71% accuracy. The other classes presented over 89% of accuracy, as shown in Figure 4.

Conclusion

The proposed model could correctly identify different mechanical faults on electrical motors using the vibration analysis readings. To obtain the result, an initial processing step is required to transform the signals to the frequency spectrum, extract relevant statistical features, and filter the amount of data provided to train the classifiers.

We trained the model to detect faults in multiple rotational speeds on the motor to provide better accuracy in a real-world

Figure 4. Confusion matrix from the results of the KNN classifier.

```
  a   b   c   d   e   f   g   h   i   j   <-- classified as
 21  11   6   0  11   0   0   0   0   0 |   a = NORMAL
  9 155  20   2   5   0   0   4   2   0 |   b = HORIZONTAL_MISALIGNMENT
  0   8 288   3   0   0   1   1   0   0 |   c = VERTICAL_MISALIGNMENT
  0   2  14 313   2   0   0   1   1   0 |   d = IMBALANCE
  3  10   1   7 160   1   0   3   3   0 |   e = UNDERHANG_BEARING_CAGE_FAULT
  0   0   0   0   0 183   0   1   0   0 |   f = UNDERHANG_BEARING_OUTER_RACE
  0   0   0   0   0   0 186   0   0   0 |   g = UNDERHANG_BEARING_BALL_FAULT
  0   7   0   0   2   1   0 169   9   0 |   h = OVERHANG_BEARING_CAGE_FAULT
  1   2   0   1   1   0   0  13 170   0 |   i = OVERHANG_BEARING_OUTER_RACE
  0   0   0   0   0   0   0   0   0 137 |   j = OVERHANG_BEARING_BALL_FAULT
```

scenario, since, in many applications, the frequency inverters control equipment's speed. Furthermore, the classifier was tested under three different algorithms to evaluate which one provides a better result: SVM, KNN, and RNA. Tests were done to determine the best parameters for all three classifiers. From the results, it is possible to note that the SVM algorithm is better suited for classifying this dataset and detecting with better accuracy which failure a vibration signal contains, despite the higher computational requirements, especially since the other algorithms such as KNN and RNA presented a lower accuracy with some classes that are relevant to the failure detection.

References

1. Raschka S. Python machine learning. Packt publishing ltd, 2015.
2. Jakkula V. Tutorial on support vector machine (svm). School of EECS, Washington State University 2006;37.
3. Noble WS. What is a support vector machine? Nature Biotechnology 2006;24(12):1565-1567.
4. Chapelle O et al. Choosing multiple parameters for support vector machines. Machine Learning 2002;46(1):131-159.
5. Kumar A, Kumar R. Time-frequency analysis and support vector machine in automatic detection of defect from vibration signal of centrifugal pump. Measurement 2017;108:119-133.
6. Chang C-C, Lin C-J. LIBSVM: a library for support vector machines. ACM transactions on intelligent systems and technology (TIST) 2011;2(3):1-27.
7. Jr, Ribeiro RF, De Almeida FA, Gomes GF. Fault classification in three-phase motors based on vibration signal analysis and artificial neural networks. Neural Computing and Applications 2020;32(18):15171-15189.
8. Haykin SS, Van Veen B. Sinais e sistemas. Bookman, 2001.
9. Fleck L et al. Redes neurais artificiais: Princípios básicos. Revista Eletrônica Científica Inovação e Tecnologia 2016;1(13):47-57.
10. Imandoust SB, Bolandraftar M. Application of k-nearest neighbor (knn) approach for predicting economic events: Theoretical background. International Journal of Engineering Research and Applications 2013;3(5):605-610.
11. Fukunaga K, Narendra PM. A branch and bound algorithm for computing k-nearest neighbors. IEEE Transactions on Computers 1975;100(7):750-753.
12. Da Silva LEB et al. Desenvolvimento de um Sistema de Detecção de Defeitos Precoces em Motores de Indução.
13. Ribeiro FML et al. Rotating machinery fault diagnosis using similarity-based models, 2017.
14. Frank E et al. The WEKA Workbench. Online Appendix for Data Mining: Practical Machine Learning Tools and Techniques, Morgan Kaufmann, Fourth Edition, 2016.

Influence of the Driver Profile on the Autonomy of Electric Vehicles

Cleovano Gonçalves Batista[1*], Thomaz Barros de Carvalho Prado[1], Júlio César Chaves Câmara[1], Lilian Lefol Nani Guarieiro[1]

1SENAI CIATEC University Center; Salvador, Bahia, Brazil

In response to the growing pressure from civil society on the automotive industry and governments regarding the sustainability and reduction of environmental impacts of vehicular fleets, there has been a substantial increase in the application and development of technologies applied to vehicular electrification. Among the efforts to massify electric vehicles there are aspects of their reduced autonomy compared to combustion vehicles. The studies concerning vehicle aspects that influence vehicle autonomy become imperative so that the best driving practices and energy management strategies are mapped and known. This work aimed to evaluate the influence of the driver profile on the autonomy of electric vehicles. Data were obtained through a device connected to the OBDII port and collected significant information for vehicle parameters evaluation such as speed, battery level, distance covered, autonomy, and so on. The results obtained, albeit preliminary, indicate that the profile of the driver influences the autonomy of electric vehicles.

Keywords: Vehicle Autonomy. Electric Vehicles. Driver Profile.

Introduction

The way of driving an electric vehicle influences the vehicle's autonomy considering some habits that contribute to the reduction of energy consumption of the electric vehicle as shown in several studies [1-3]. Considering combustion vehicles, the driving behavior has an important effect on fuel consumption, regardless of the type of vehicle driven. Respecting speed limits and optimizing the use of regenerative brakes contribute to battery-charge lower consumption [4].

According to a study by Sofit [5], evaluating the behavior of drivers for companies that employ drivers is vital because it can have a significant impact on companies' financial results and evaluating the profile of drivers requires work based on serious and concrete parameters. The study also mentions that choosing a driver with an adequate profile for the company's goals can even bring savings in fuel consumption. Research developed by E. Ericsson [6] suggests that driving behavior is affected by several factors such as street design, traffic management methods, traffic conditions, weather conditions, and the physical and mental condition of the driver.

In research carried out by Catarina C. Rolim [7], results indicate that the adoption of electric vehicles impacted daily routines in 36% of participants and 73% of drivers observed changes in driving style. In this context, the present work aimed to evaluate the correlation between the driver's profile and the autonomy of electric vehicles.

Material and Methods

We fixed the type of vehicle and the trip route in this study. The variable factor was drivers (e.g, their driving behavior) and traffic conditions. Therefore, all of the data for our experiment was collected using a road route (Figure 1). The total distance of the route segment was 200 km. Data were obtained through a data collector device connected to the vehicle OBDII port, responsible for monitoring and recording vehicle parameters on the Chevrolet Bolt. The device was connected to the OBDII port and collected information for vehicle-parameters evaluation: speed, battery level, distance covered, and autonomy. The vehicles followed a road route between Salvador and Feira de Santana in Bahia. The data was made available on an online platform and updated daily in real-time.

Received on 26 January 2022; revised 22 April 2022.
Address for correspondence: Carlos César Ribeiro Santos. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA- Brazil. Zipcode: 41650-010. E-mail: cleovano@globo.com. DOI 10.34178/jbth.v5i2.207.

J Bioeng. Tech. Health 2022;5(2):106-110

For an analysis of the driver profile impact on the vehicle autonomy, six drivers were evaluated, and the drivers covered a total of 1,200km on the test route of this research.

Results and Discussion

Route of Test

The Figure 1 shows the road route taken from SENAI CIMATEC (Salvador BA) to Amélia Rodrigues-BA, via BR 324. The vehicles travel on a round-trip route totaling an average of 200 km on an asphalt road and predominantly of the flat feature. The average speed estimated by Google Maps for this route is 70km/h [8], considering an ambient temperature of 28ºC on average, an Air conditioning setting at 25ºC, and a maximum allowed speed of 100km/h. The traffic condition on this road is considered moderate, taking into account that the average speed of the route was 57km/h with a maximum allowed speed of 100km/h, which exposes the driver to a large variation in speed parameters.

Battery Level

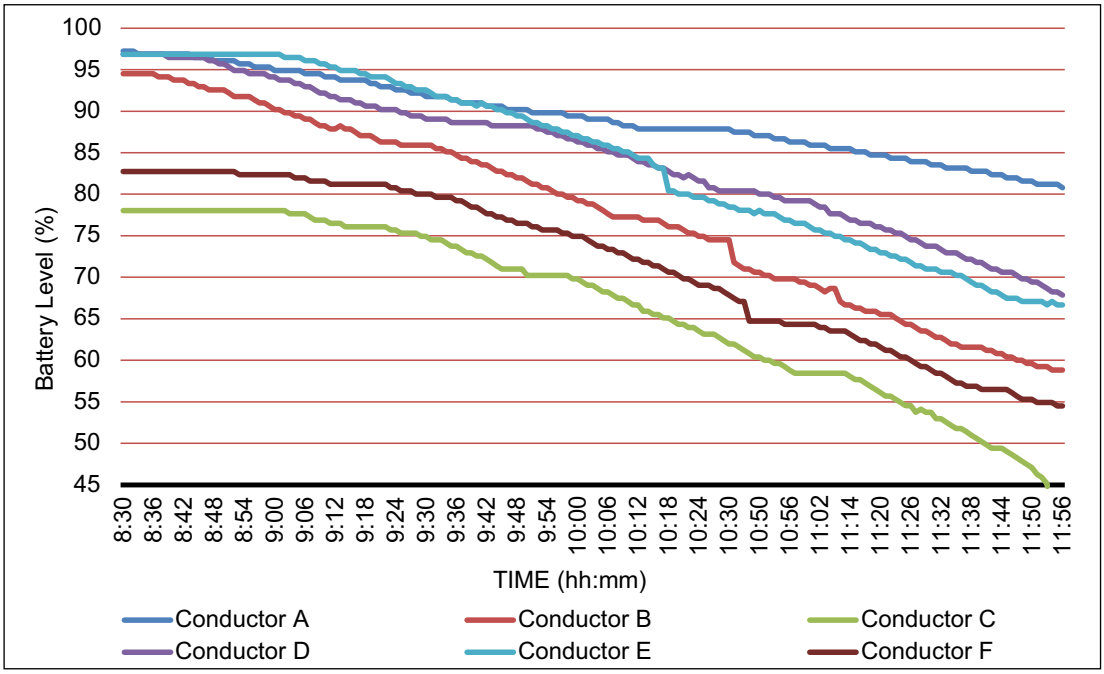
Just as conventional cars have large or small fuel tanks, lithium-ion batteries for electric cars come in different sizes. Instead of liters of fuel, its capacity is measured in kilowatt-hours (kWh). A typical 40kWh battery in a conventional electric car might be enough to power you for 150 miles or more, while Tesla's larger 100kWh battery is good for 375 miles according to the WLTP standard - which is intended to give an estimated Realistic real-world range or fuel economy [9]. We tried to relate the vehicle performance with the battery-charge, to compare the drivers (Figure 2). The battery charge level is reported in percentage and the Battery capacity of the Bolt EV used in the test is 66kWh.

The data in Figure 2 shows the battery charge level at a specific moment and considering a period

Figure 1. Feira de Santana route.

Source by Authors.

Figure 2. Battery level - Feira de Santana route.



Source by Authors.

of execution of the chosen route in which the vehicle starts the test with a charge above 80%. Table 1 shows the battery charge condition at the beginning and end of the test period with each driver and based on the distance traveled and the test vehicle's battery capacity of 66kwh we have the consumption for each driver's kWh/100km.

We can observe that conductors D and E performed better than the others, with conductor C having the worst performance. From the premise that the vehicles were exposed to the same road environment with the same atmospheric conditions, road traffic, and departure time, the difference in consumption/ autonomy in battery charge can be attributed to the direction profile of the conductor. However, we can extend the analysis a little further and check the average speed of each driver to assess whether this item confirms the idea that the profile influenced autonomy. In Figure 3, we see the comparative graph of the average speed of Conductor C (worst performance) and Conductor E (best performance).

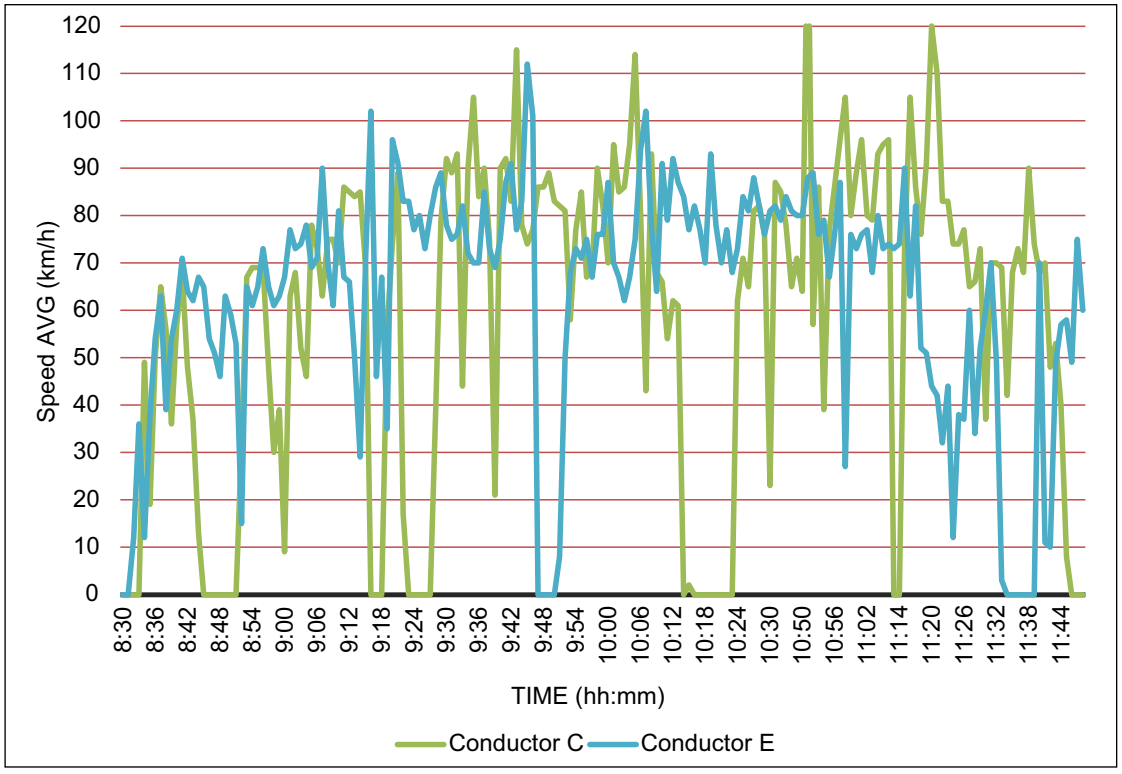
The average speed of Conductor C was 59km/h and Conductor E was 64km/h. The electric vehicles are capable of recovering part of the charge from the batteries through a system that takes advantage of the "running" of the car during decelerations to generate energy with the movement of the wheels [10], and that the engine no longer consumes to generate electricity when the driver takes his foot off the accelerator, activating the so-called regenerative brake. However, driver E had a greater regenerative capacity and lower battery consumption (Figure 4).

Table 1. Autonomy of vehicles on the Feira de Santana route.

X	Start %	End %	Variation %	km	kwh/100km
Conductor A	97	59	38	205	12.2
Conductor B	94	59	35	183	12.6
Conductor C	78	29	49	174	18.6
Conductor D	97	63	34	200	11.2
Conductor E	97	66	31	184	11.1
Conductor F	83	47	36	184	12.9

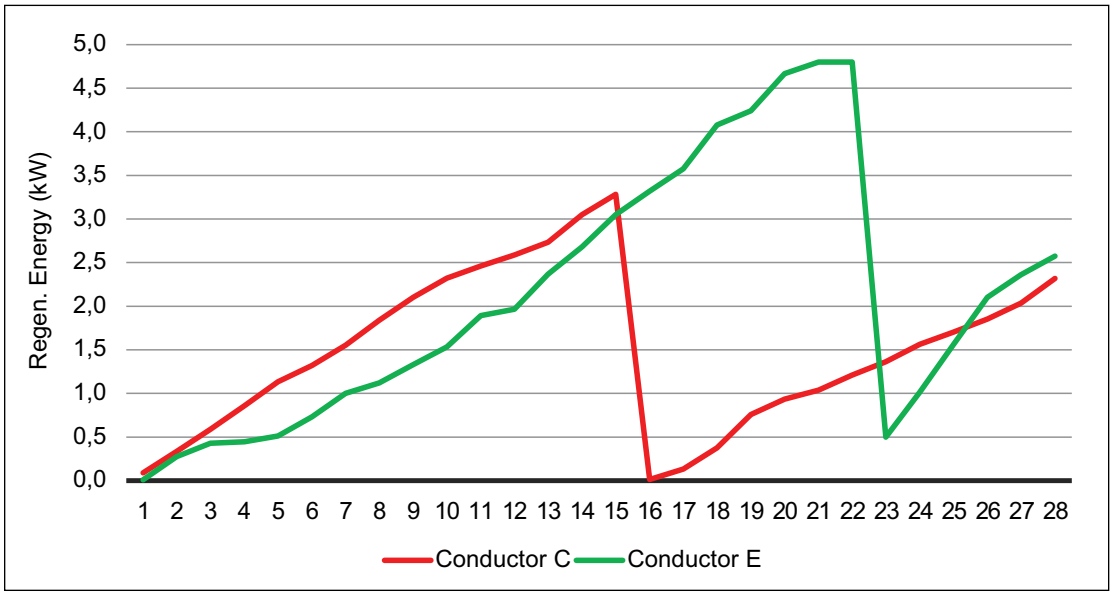
Source by Authors.

Figure 3. The Average speed of conductors C and E.



Source by Authors.

Figure 4. Energy regeneration for conductors C and E.



Source by Authors.

Conclusion

Given the preliminary test data presented, there are the first clarifications on how much the steering profile affects the SOC of electric vehicles when subjected to the same running conditions. From the first results, it is possible to identify the driving characteristics that best meet the need to take advantage of the SOC, which directly impacts the autonomy of pure electric vehicle models, or 100% battery powered. In the second part of the research, vehicle parameters, such as acceleration, pedal position, and use of air conditioning, among others, were better during the study, which consolidate the assessment of the impact of the steering profile on the SOC, leading the influence of these variables on the vehicle dynamics and their influence on the electric vehicle battery, which is solely responsible for the energy supply for the electric motor in this type of vehicle. From the data collected and the results obtained, it is necessary a greater number of drivers and repetitions of the tests on a routing table, as well as the use of other vehicle models to obtain a more accurate investigation.

Acknowledgments

The authors thank the Green Corridor Project team, which has a partnership with NEOENERGIA, ANEEL, SENAI, and others. We also thank the SENAI CIMATEC university center for providing the opportunity to be part of a research project of such great importance for the Northeast and Brazil.

References

1. Peng, Ping & Qin, Wenhu & Xu, Yang & Miyajima, Chiyomi & Takeda, Kazuya. Impact of Driver Behavior on Fuel Consumption: Classification, Evaluation and Prediction Using Machine Learning. IEEE Access. 2019:1-1.10.1109/ACCESS.2019.2920489.
2. Liimatainen H. Utilization of fuel consumption data in an eco-drivingincentive system for heavy-duty vehicle drivers. IEEE Trans. Intell.Transp. Syst. 2011;12(4):1087-1095.
3. Meseguer JE, Calafate CT, Cano JC, Manzoni P. Assessingthe impact of driving behavior on instantaneous fuel consumption. 12th Annual IEEE Consumer Communications and Networking Conference. CCNC 2015:443-448.
4. Enel X. O que determina a autonomia de um carro elétrico. 2021. Disponível em: https://www.enelx.com/br/pt/conteudos/historias/o-que-determina-a-autonomia-deum- carroeletrico#:~: text=Usar%20o%20modo%20econ%C3%B4mico%3A%20os,outras%20medidas%20que%20poupam%20energia. Acessado em: 05/04/2021
5. Sofit. Perfil do condutor: como analisar e determinar o melhor para a sua frota? 2019. Disponível em: https://www.sofit4.com.br/blog/perfil-condutor.
6. Rolim CC, Gonçalves GN, Farias TL, Rodrigues Ó. Impacts of electric vehicle adoption on driver behavior and environmental performance. Procedia - Social and Behavioral Sciences 2012;54:706–715. https://doi.org/10.1016/j.sbspro.2012.09.788.
8. GOOGLE, Maps, 2021. Mapa Rota Rodoviária Salvador-Feira. Disponível em: https://goo.gl/maps/FqPEvLyZvzGkBaju5.
9. EDF 2020. All about electric car batteries. Disponível em: https://www.edfenergy.com/electric-cars/batteries
10. Mobiauto 2021. Carro elétrico: 12 dúvidas muito comuns que todo mundo tem sobre ele. Disponível em: https://www.mobiauto.com.br/revista/carro-eletrico-12-duvidas-muito-comuns-que-todo-mundo-tem-sobre-ele/710.

Technical Feasibility Analysis of the Patent Ondomotric Energy Generations System With Code BR 10 2016 016119 3 A2

Kelson Mascarenhas Cirne[1*], Gabriel Pereira Ugucioni Rocha[2], Alex Álisson Bandeira Santos[1]
[1]SENAI CIMATEC – Campus Integrado de Manufatura e Tecnologias; [2]Núcleo de Pesquisa, Desenvolvimento e Inovação, Lactec; Salvador, Bahia, Brazil

With the industrial expansion arising from the national development process, and the current global trend towards the search for clean and renewable energy sources, the diversification of the energy matrix becomes vital in the process of renovation and strengthening of energy generating sources to meet the SIN (National Interconnected System). This work presents the technical feasibility analysis of the wave power generation prototype with patent code BR 10 2016 016119 3 A2. The simulations carried out in modeling software to evaluate the constructive aspects of the prototype allowed the analysis of data on the mass of the components, gravity centers, and moments of inertia. Finally, the positive and negative aspects and points for improvement of the project were presented, aiming to raise interest in the topic presented and develop new studies for the electricity sector.
Keywords: Ondomotive. Patent. Electric Sector. Energy Matrix.

Introduction

With the changes characterized by the challenging scenario caused by Coronavirus (COVID-19), where social and environmental impacts have brought behavioral changes, such as social isolation, modeling strategies for expansion of the electricity sector, which are directly linked to the country's economic growth projections, have also undergone major changes [1]. The Decennial Plan report presented by the Energy Research Company (EPE) shows that, after the impacts on economic growth in 2020, the percentages of resumption of economic development are on average between 2.9% and 3% per year until 2030.

Brazil presents itself on the world stage as one of the countries that maintain its energy matrix as one of the cleanest, complying with the guidelines of the Paris Agreement with the new Nationally Determined Contribution (NDC) pledging to reduce its gas emissions by 37% greenhouse effect by the year 2025 and 43% of its emissions by the year 2030 [2]. Sustainable growth strategies combined with the vision of strengthening security in meeting energy demand contribute to the expansion of studies in the national electricity sector. The use of natural resources to diversify the energy matrix, as well as boost investments in renewable energy sources, is promising for large companies in the electricity sector, as well as for new investors in this market [3].

Geographical positioning is also one of the factors that contribute to the development of solutions aimed at diversifying the energy matrix, in which the oceans represent 71% of the surface of the globe [4]. One of the greatest renewable energy potentials on the planet is linked to the oceans with the following distribution: Wave Energy, represented by the surface and subsurface movement of the oceans, estimated at up to 80000 TWh/year; Hydrokinetic Energy, which is related to the movement of ocean currents and tides, estimated at 800 TWh/year; Ocean Thermal Energy, which can be obtained by the temperature gradient existing between the surface and the ocean floor, estimated at 2000 TWh/year; Osmotic energy, obtained by the pressure difference between opposite sides of a membrane, containing fresh water on one side and salt water on the other, estimated at 10000 TWh/year [5].

Received on 23 January 2022; revised 27 April 2022.
Address for correspondence: Kelson Mascarenhas Cirne. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA- Brazil. Zipcode: 41650-010. E-mail: kelsoncirne@jsglobal.com.br.
DOI 10.34178/jbth.v5i2.208.

J Bioeng. Tech. Health 2022;5(1):111-117.

Bearing in mind the Brazilian energy scenario and its geographic characteristics, the literary gaps about the application of ondomotive technologies in the national territory, and the studied potential of the oceans, this work proposes to technically evaluate the constructive aspects of the solution designed by the company Hidrobombas of a system of wave power generation, under patent number BR 10 2016 016119 3 A2. The initial prototype presented by the company was modeled in a CAD environment, according to dimensions and original mechanical elements. Based on the CAD model, studies of the functionality of the power take-off mechanism (PTO), the buoyancy of the structure, as well as of the fluid-structure interaction in the presence of typical waves for the Brazilian coast, were elaborated. Thus, it is possible to estimate characteristics such as the range of motion of the articulated elements of the GEO (Ondomotive Energy Generator) and energy generation, as well as its stability against oceanic movement.

Material and Methods

The technical feasibility analysis was performed at Lactec's research, development and innovation center, located in the southern region of Brazil. For the development of this study, a quantitative analysis was carried out with a survey and analysis of experimental data, for the formulation of mathematical models that allow a technical analysis of the chosen technology.

In this article, simulations in System Dynamics software (3D CAD and ANSYS AQWA) are presented to evaluate the behavior of the model with changes in the input and output flows. The analysis of the 3D modeling allowed obtaining physical quantities referring to patent BR 10 2016 016119 3 A2, such as component mass, gravity centers, and moments of inertia. In this way, it is possible to evaluate the stability of the prototype to be developed using the results obtained by computational simulations of fluid-structure iteration.

Results and Discussion

3D Modeling of the Prototype Geometry

The prototype developed by Hidrobombas, which has patent code BR 10 2016 016119 3 A2, contains 22 drums, 12 for the central structure and 1 for the flotation of each of the 10 arms. This nationally developed and patented model resembles the product developed and named Wave Star of multi-body systems that have two prototypes built, the first being located in Nissum Bredning, Denmark [6].

The power take-off system, known as PTO (Power Take OFF), are devices that are part of the sea wave energy converters, among the existing systems, it was adopted directly (Figure 1) [7].

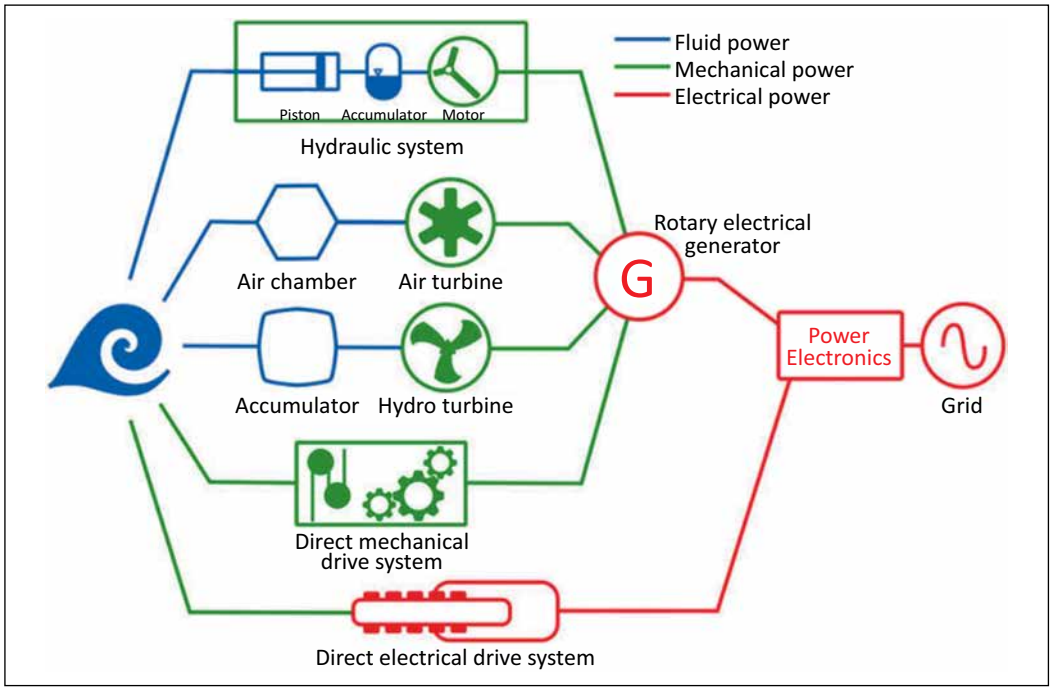
The wave power generation model presented in this research uses a direct conversion system where its force transmission elements are composed of pulleys and gears, aiming to reduce losses from composite processes, thus optimizing the transmission of resulting forces from the oscillation of the waves to the electric generator. Figure 2 below illustrates the modeling of the power take-off system in 3D using CAD software with real dimensions of the patent.

Modeling in Ansys Aqwa Environment

From the initial wave power generation (GEO) model conceived by Hidrobombas, with the dimensioning of the project structures and modeling in a three-dimensional environment of the prototype carried out by LACTEC, it was possible to carry out the analysis of the centers of gravity and moments of inertia of the structure. Figure 3 shows the centers of gravity obtained via Autodesk Inventor® software calculations and Table 1 shows the mass properties and moments of inertia of the structures, concerning the respective centers of gravity.

From the simulations carried out in an Ansys Aqwa environment of the simplified system with fewer components and surfaces, it was possible

Figure 1. PTO models.

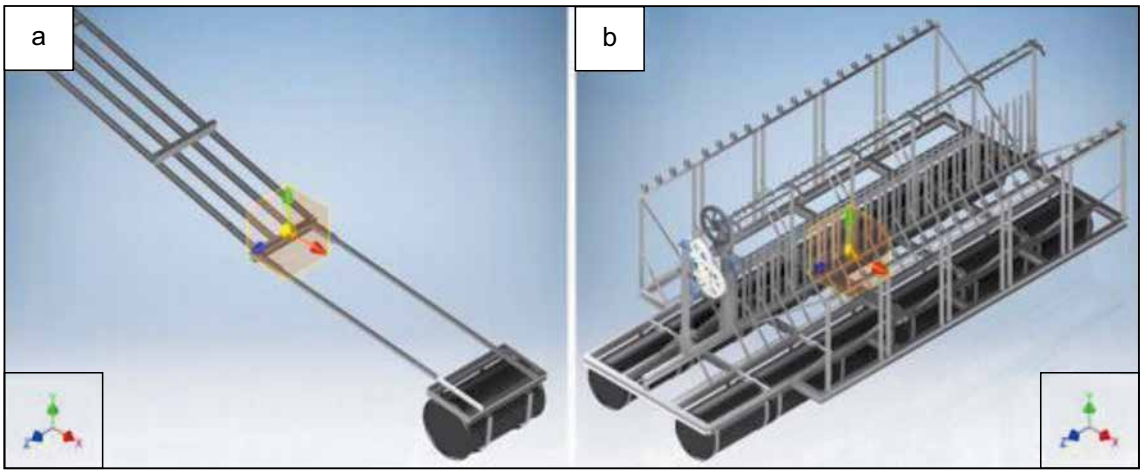


Source: (Amélie Têtu, 2017).

Figure 2. 3D CAD modeling.

Source: Technical Report 2.2 - GEO Project.

Figure 3. Centers of gravity for the structure of the GEO arm (a) and central body (b).



Source: Technical Report 2.2 - GEO Project.

Table 1. Inertial properties of GEO components.

Structure	Mass (kg)	lxx (kg.m^2)	lyy (kg.m^2)	lzz (kg.m^2)
Main Body	1293	4390	4633	1356
Articulated Arm	135	30	446	456

Source: Technical Report 2.2 - GEO Project.

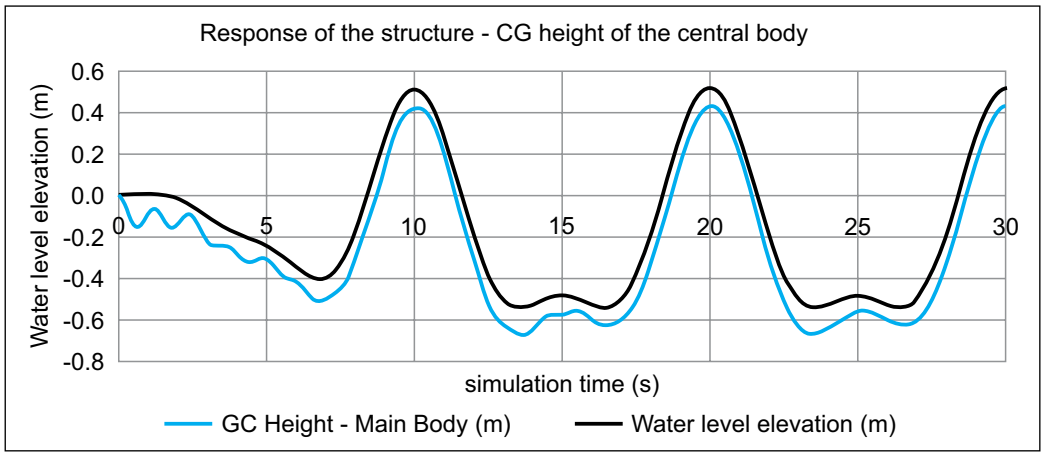
to evaluate the fluid-structure interactions. Thus, the analysis of the behavior of patent BR 10 2016 016119 3 A2 in a near-shore and offshore environment can be studied in compliance with the physical characteristics of the real model. For technical evaluation of the behavior of the structure proposed by the research patent, simulations were carried out in different scenarios of wave directions, enabling the understanding of the dynamics of the system when anchored to a physical structure compared to the free-floating system.

To determine the classical behavior of wave energy and obtain reliable data through simulations, it is necessary to understand the study of mathematical models that address depth variation, as well as the main quantities arising from the energy conversion process (Joaquim & Calejo, 2012). As an example of the results obtained through the simulations carried out, Figure 4 shows the behavior of the structure of the main body when submitted to a regular wave, with 2nd Order Stokes theory (T = 10s, H = 1 meter). To allow the evaluation of only the vertical displacement, the displacement of the structure in the direction of incidence of the waves was prevented.

It is possible to notice that the center of gravity moves along with the wave, and therefore there is little relative movement, which impairs the capture of energy available in the waves. Figure 5 illustrates the general behavior of the floating structures of the ordomotive energy generation system, such as the rotation of the arms around the axis of rotation in which it is fixed.

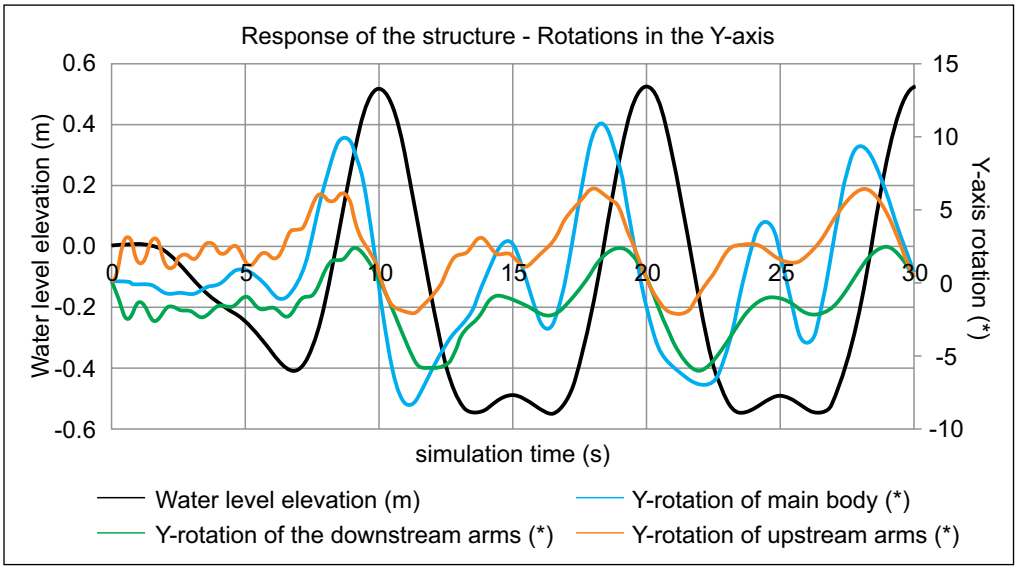
Note that because the structure rotates when following the incident wave, the arms also rotate, which results in low rotation of the downstream arms, and thus, the kinetic energy transferred to the PTO is considerably low.

Figure 4. Idealized Model Response: Z position of the CG of the central body and elevation of the water level in the YZ plane, which contains the CG of the central structure.



Source: Technical Report 2.2 - GEO Project .

Figure 5. Idealized Model Response: rotation of the components around the Y axis and elevation of the water level in the YZ plane, which contains the CG of the central structure.



Source: Technical Report 2.2 - GEO Project.

Strong Points

The identified strengths for GEO Hidrobombas are:

I. Direct generator drive, with mechanical power transmission. The absence of intermediate energy conversion systems makes the system simpler and increases the theoretical efficiency of the energy conversion system.

II. The relationship between the weight of the central body and the thrust resulting from the partial submersion of the floats is such that it gives the structure buoyancy.

III. Hidrobombas' GEO prototype does not generate residues in its operation, thus presenting a low risk of environmental contamination.

IV. As it is floating, the GEO has the advantage of being transportable and not depending

on near-shore structures for rigid fixation of the generator set. In addition, its installation can occupy uninhabitable regions without economic exploitation, making it possible to obtain better use of the physical coastal space.

V. The vast majority of components used in the construction of the prototype are all commercial and easily purchased on the market. The welded structural elements are based on standardized structural steel profiles and the floats are cylinders in commercial dimensions.

Weak Points

I. The take-off (PTO) and power transmission mechanisms feature sets of pulleys, pinions with ratchets, and non-lubricated bearings that can present high friction, adding torque against the main shaft. This can lead to excessive wear of mechanical joints and reduced efficiency.
II. Some components related to system functionality are unsuitable for the marine environment and continuous operation, such as the use of elastic cords and mechanical elements exposed to the corrosiveness of the environment.
III. Human locomotion on the GEO is difficult, which can make its installation, operation, and maintenance difficult.
IV. The GEO does not have inertial reference and/or fixation points (hardpoints) for support and anchoring. Thus, relative movements between the GEO central body and the arms would imply a reduction in the arms' range of motion and, consequently, in the gravitational potential energy available in the arm when at the crest of each wave. Therefore, in addition to the GEO drift, possible efficiency losses are expected due to the absence of inertial references.
V. The absence of inertia flywheels or other kinetic energy accumulation systems of the spindle assembly, or the impossibility of insertion of electronic control systems, due to the GEO direct transmission characteristic, can result in large rotation oscillations of the generator, as well as large accelerations at the beginning of the transfer of power from the articulated arms to the main shaft and large decelerations at the end. Thus, the proper dimensioning of an inertia flywheel would provide the opportunity for a more controlled operation under a permanent wave incidence regime.
VI. Severe difficulty in adjusting the resonant frequency of the mechanical system against the frequency of incidence of waves, due to the direct characteristic of energy transmission.

Improvement Points

I. The articulated arms fixation bearings, which currently consist of screws that traverse through holes in the central structure and arm support, can be replaced by rolling bearings or low friction polymeric materials - considering the difficulty of maintaining lubrication in an environment marine.
II. Elastic cords that maintain the contact tension of roller chains with sprockets can be replaced by mechanical elements designed for fatigue life and weather resistance, such as stainless steel helical springs.
III. Enclosure of lubricated machine elements and subject to seawater corrosiveness, such as the roller and pinion chain assembly, or the main shaft and bearings.
IV. The ondomotive energy source has great temporal and spatial variability. For this reason, the prototype will tend to provide intermittent electrical power generation. To correct this, the Generator must be able to operate an output signal stability. A possible solution to this problem could be the implementation of an electrical control system that stabilizes the output signal to the network. In addition, it is interesting to insert individual sensors for each Generator Arm, among other automation components, for monitoring purposes.

V. It is suggested to optimize the load distribution in the Arm so that an optimal point is reached about the moment performed that will transmit power to the axis (displace the Center of Gravity of the Arm so that it is as far as possible from the axis central) and there is possibly an optimal distance that will depend on inertial factors and wave incidence frequency.

VI. The GEO prototype absorbs ondomotive energy through the gravitational potential energy of the arms, which, when passing wave crests, are positioned above sea level. When in the valley of the wave, the arm returns to its lowest energy position, with the movement being resisted by the power take-off system (PTO), through the set of roller chains and ratchet pinions. Thus, the increase in the system's generating capacity depends on the amplitude of the waves and the total mass in balance. Since the first is a characteristic of the ondomotive potential of the installation site and the second implies an increase in the total dimensions of the system, as well as structural reinforcement for compatibility with self-weight loads, it is proposed to design a system capable of absorbing wave energy in the arm's ascent movement (thrust) and arm's return (gravity).

VII. To provide the GEO with an inertial reference, which limits the displacements of its central structure, and considering that it is a near-shore or offshore installation system, it is proposed that the system be adapted to receive anchoring or support cables.

VIII. Another possibility that will be taken into consideration will be the replacement of the direct transmission system using roller chains and ratchets, with the use of hydraulic systems, keeping the other conceptual geometries of GEO Hidrobombas.

Conclusion

After performing the 3D modeling of the type of wave power generation patent BR 10 2016 016119 3 A2 and simulations in the Ansys Aqwa environment that allowed evaluating the behavior of physical quantities, such as component mass, gravity centers, and moments of inertia, it was possible to verify the technical unfeasibility of the project due to the performance presented from the hydrodynamic simulations, in which both the arms and the central body move along the wave, and also due to its constructive characteristics. However, there are positive points that, linked to the improvements proposed by Lactec's research staff, can enable the construction of the suggested prototype.

References

1. Plano de Expansão de Energia 2030. Empresa de Pesquisa Energética, 2021. Disponível em: <https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-490/PDE%202030_RevisaoPosCP_rv2.pdf>. Acesso em: 03 de Agosto de 2021.
2. Energia nas Construções. Câmara Brasileira da Indústria da Construção, 2017. Disponível em: <https://cbic.org.br/wp-content/uploads/sites/22/2017/11/Publica%C3%A7%C3%A3o-Energias-Renov%C3%A1veis-2017.pdf>. Acesso em: 27 de Julho de 2021.
3. Sachs I. Eco desenvolvimento: crescer sem destruir. São Paulo: Vértice, 1986.
4. Marroni EV. Política internacional dos oceanos, 2013.
5. Soerensen HC, Weinstein A. Ocean Energy: Position paper for IPCC. IPCC Scoping Meeting on Renewable Energy Sources 2008:93–102. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.362.1202&rep=rep1&type=pdf#page=109 tecnundo.
6. Rocha TP. Estudo Numérico de Unidade Flutuante Monocoluna para Conversão de Energia de Ondas do Mar. Universidade de São Paulo. 2017.
7. Amélie Têtu. Handbook of Ocean Wave Energy. Aalborg, 2017.

Comparison of Models for Wind Speed Prediction Through Neural Networks in Lençóis, Bahia

Amanda Santana Lins Bispo[1*], Lian Filipe Santana Nascimento[1], Yuri de Jesus Gomes[1], Flávio Santos Conterato[1]
[1]SENAI CIMATEC University Center; Salvador, Bahia Brazil

This study aims to compare forecasting models using artificial intelligence to conclude which is the best one for the forecasting wind speed for 1 hour in Lençóis, BA, using a data source from the Instituto Nacional de Meteorologia (INMET). Furthermore, an Artificial Neural Network (ANN) was developed using TensorFlow and Keras libraries, it was compared with other forecasting models, which showed to be the most efficient among the options for this purpose. Moreover, the principal metric used to evaluate this study was Mean Absolute Error (MAE), and the auxiliary ones were Mean Squared Error (MSE) and R^2. The RNA obtained the following values for each metric: 0.421 for MAE, 0.389 for MSE, and 0.523 for the R^2 metric.
Keywords: Artificial Intelligence. Machine Learning. Neural Networks. Wind Speed. Wind Speed Forecasting.

Introduction

In the current distribution, Brazil has its energy matrix based on hydroelectric sources, with about 63% of total production. However, there is a considerable presence of other methods of energy production since wind energy is about 9% of the energy participation, for instance [1]. Wind energy still has a possible growing outlook because there is a great potential for generation through this type of renewable energy due to the natural characteristics and the size of the Brazilian territory. Furthermore, the hydroelectric power plants may generate environmental impacts, reducing the local fauna and impacting economic activities [2]. With technological and economic development, the importance of the discussion on the implementation of clean and inexhaustible sources of energy is reinforced. Between 2011 and 2019, Brazil invested approximately R$ 187 billion in the wind energy matrix [3], and it triggered an expansion of the participation of this energy source in the country. Wind energy is a sustainable production process, which transforms the energy of air masses into mechanical energy through the force of the winds. Because a problem arises, the wind will not always be favorable for the implementation and activation of wind turbines, and this factor contributes to this source of energy production being less adhered to, as in certain situations it may have low profitability.

Artificial Intelligence (AI) has been progressively assimilated into the daily routine to optimize time to help, solving problems that often cannot be solved with only human capacity. In most cases, artificial intelligence is applied to two types of problems: classification, and regression. In classification issues, the data are used to define which group another specific data fits into, and the regression aims to predict values. Since the 1940s, with the creation of the first neural networks, the complexity and potential of these networks have expanded at an accelerated pace, allowing an improvement in the efficiency of several processes. In February 2019, DeepMind announced a new artificial intelligence program for forecasting energy production in wind farms, executing a practical application of AI in solving an important problem: the unpredictability of renewable energy. The neural network could make a forecast of up to 36 hours about the amount of energy generated by the parks. This attitude increased the value of wind energy produced in those locations by approximately 20% [4]. This example denotes the importance of comparative studies on the efficiency of different neural networks for predicting this type of variable. Its usefulness is evident in solving this problem, considering the importance of this energy source and its character.

Received on 26 January 2022; revised 22 April 2022.
Address for correspondence: Amanda Santana Lins Bispo. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA- Brazil. Zipcode: 41650-010. E-mail: amabispo08@gmail.com. DOI 10.34178/jbth.v5i2.209.

J Bioeng. Tech. Health 2022;5(2):118-122

The research was focus on the city of Lençóis-BA, Brazil, a city with 1,277 km² and approximately 11 thousand inhabitants [5]. A comparison was made with different regression models [6], to predict the wind speed in one hour, based on meteorological data provided by INMET (National Institute of Meteorology), corresponding from 2017 to 2019. The models used for comparison were trained and tested for parameter improvement.

Material and Methods

The study algorithm was developed in Python programming language using the Scikit-Learn library. The models were the Stochastic Gradient Descent Regressor (SGD Regressor), Linear Regression, K Nearest Neighbors Regressor (KNN Regressor), and Gradient Boosting Regressor. Besides being compared to each other, an Artificial Neural Network (ANN) of the Multilayer Perceptron (MLP) type was created, using the TensorFlow and Keras libraries, contrasting with the other models.

The dataset used provided by INMET for the city of Lençóis, BA, contains records of the time interval between the years 2014 to 2019, about 46 thousand data, but due to lack of data in the middle of the dataset, that generated intervals in the time series. Only 18 thousand data were considered, referring from 2017 to 2019. This dataset also contained 24 variables. For training, 70% of the data were used during the training stage (30% of this 70% was used for validation), and the remaining 30%, of all, for testing.

The variables, except for the target (Wind, Hourly Speed), were normalized between the 0 and 1 interval with the MinMaxScaler, a data normalizer provided by Scikit Learn. MinMaxScaler works by normalizing the data in the range that is passed, keeping the proportion of the data, where the largest value will be transformed into the highest value passed and the smallest, moreover, into the lowest value, the other values are between this range, keeping the original proportion.

$$Data\_std = \frac{(X - X.min(axis=0)}{(X.max(axis=0) - X.min(axis=0)} \quad (1)$$

$$Data\ Scaler = Data\_std * (max - min) + min$$

Source: Scikit-Learn.

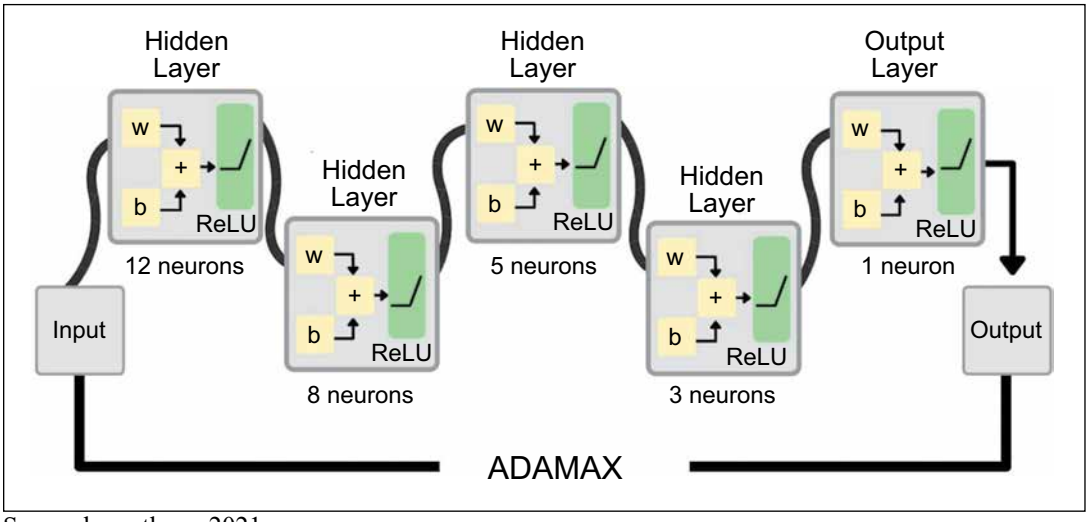
In addition, to determine most of the parameters, the strategy used was to test which combinations of parameters and weights brought improvements to the network, or a reduction in its quality, and with that, the final configurations of the models were found. The neural network (Figure 1) had 5 layers of neurons, including the last layer, the output layer, which contains only 1 neuron, as it is a regression task for a prediction horizon. All layers had the activation function of ReLU (Rectified Linear Unit), which is an activation function widely used in the area of machine learning and was the one that showed the best results. In the output layer, ReLU was also used, because the variable that occurred in the prediction does not contain negative values and this function in the output layer only returns values between 0 and positive infinity. The optimizer used in the network was Adamax, which performed better for this task. During training, 200 epochs were made, and from that, there was no considerable improvement, the batch size used was 100.

The models were also tested to achieve better results than what were seen using their default parameters.

The SGDRegressor (Stochastic Gradient Descent Regressor) had its loss changed from squared loss to squared epsilon insensitive, which presented a better conclusion according to the error metrics. The tool (the stopping criterion) value was reduced by 6 decimal places. So, the model had more training time, and the penalty, also called the regularization term, was changed to l1, and, with that, the model had an improvement in results.

The linear regression model had no parameter changes, as it ended up training better with the pattern, exhibiting lower error values than with customizations.

Figure 1. Structure of the neural network.



Source by authors, 2021.

The KNN Regressor underwent some changes: the number of n_neighbors was changed from 5 to 20, and the weights were defined as distance and metric kept in Minkowski.

The last model, Gradient Boosting Regressor (GradBoost) had its learning rate changed to 0.09. The max depth, which is the maximum depth of the individual estimators, was set to 6 and the number of estimators was changed from 100 to 300, which returned a slight improvement. In your performance.

Thereby, the study tends to compare the efficiency of the models using the following metrics MSE (Mean Squared Error), MAE (Mean Absolute Error), and R^2 score (coefficient of determination), such as metrics were applied by importing tools from the Scikit Learn.

The principal metric used was the mean absolute error, MAE, which calculates the mean between the error module, that is, in its absolute value. Due to its nature of using raw values, this metric is not very efficient in occasions where there is the presence of outliers, which can interfere with the quality of this metric. The smaller the MAE value, the better the model that generated that result was:

$$MAE = \frac{1}{n} \sum_{j=1}^{n} |yj - \hat{y}j| \quad (2)$$

Source: Zucatelli and colleagues, 2018 [8].

The second MSE metric, which represents the root mean square error, is used to check the accuracy of the model. The way to calculate this metric gives greater importance to larger errors, since the values are squared individually, and, only after that, the average between them is calculated, generating higher values for models that present worse results.

$$MSE = \frac{1}{n} \sum_{i=1} |yi - \hat{y}i|^2 \quad (3)$$

Source: Zucatelli and colleagues, 2018 [8].

The last metric that was applied was the R^2 score, from Scikit Learn, a statistical measure of the data distance for the adjusted regression line, the maximum value is 1.0, and it can return values below zero according to the precision of the model, the lower value, the worse the model.

$$R^2 = \frac{\sum_{i=1}^{n} (\hat{y}i - \hat{y})^2}{\sum_{i=1}^{n} (yi - \hat{y})^2} \quad (4)$$

Source: Zucatelli and colleagues, 2018 [8].

Results and Discussion

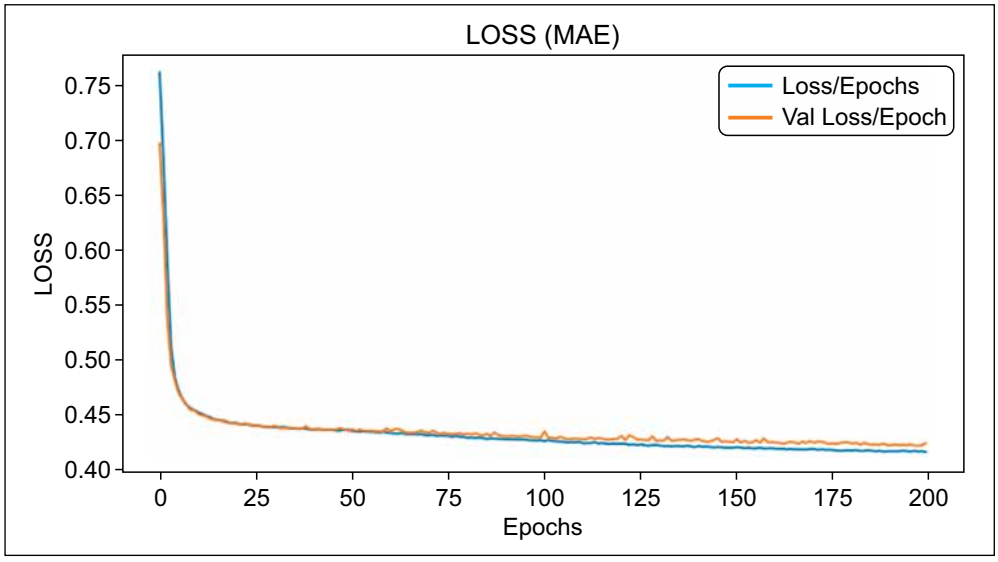
After changes and training, the networks improved their performance for predicting the variable, and the MLP neural network training had a good learning curve, this is represented in the loss graphs (Figure 2). The MAE metric was chosen as a loss metric and MSE (Figure 3), which was the second error metric passed to network training.

The models had similar results, with some distortions in the metrics [7] (Table 1).

Conclusion

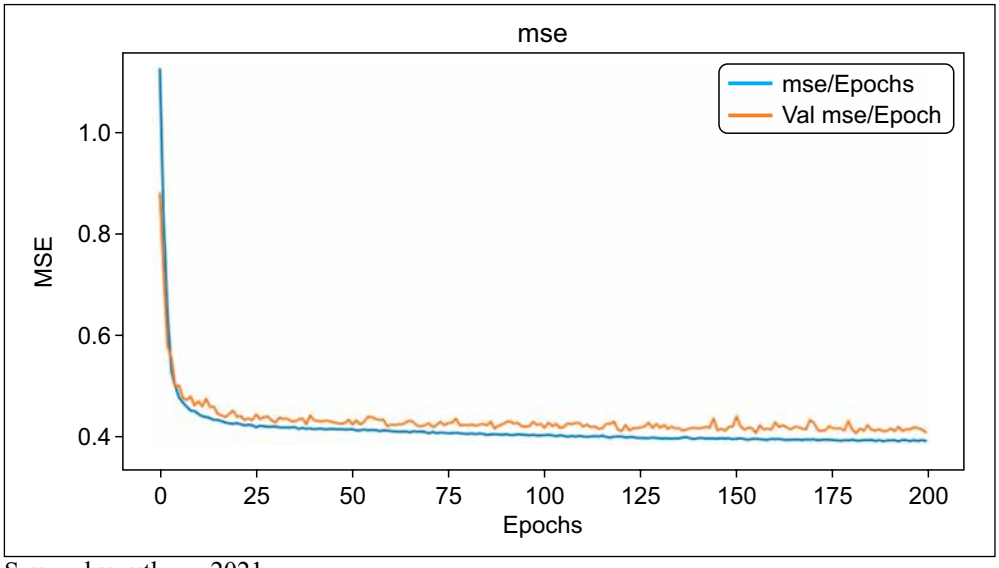
Given the great advances in the technological area and the great need for clean energy and pro-sustainable development are widely disseminated. As aforementioned, a tool capable of predicting

Figure 2. Neural network training loss graph.



Source by authors, 2021.

Figure 3. Neural Network training MSE graph.



Source by authors, 2021.

Table 1. Network results table.

REGRESSION	MAE	MSE	R^2
KNN	0.455	0.378	0.537
MLP	0.421	0.389	0.523
SGD	0.475	0.402	0.507
LINEAR	0.467	0.392	0.555
GRADBOOST	0.439	0.363	0.519

Source by authors, 2021.

wind speed is a great achievement in solving the problem of clean energy sources, becoming essential for reducing the unpredictability of the wind energy matrix, which has great potential, especially in Brazilian territory. Comparing forecasting models and an artificial neural network (ANN). During the process and analyzing the results, the artificial neural network was the most efficient for 1-hour wind speed forecasting, in Lençóis, BA. Considering that the main metric used to contrast the predicting tools was MAE, and on this metric, the ANN showed better results than the other models (0.421) and in other metrics, the results referring to RNA do not differ as much from the others, keeping a result relatively close to the best among the models, having 0.389 of MSE and 0.523 of R^2. Although, for this technology to be used on a large scale and has a more assertive performance, it is expected to get better results from the network with superior computational resources. The potential of this technology can leverage wind energy, making it more widespread worldwide.

Acknowledgments

The authors thank SENAI-CIMATEC and the technical course in Artificial Intelligence, its team of professors, and, in particular, the respective coordination, who encouraged and helped to make the article, and with extreme concern and competence, enabled the development of the research.

References

1. www.gov.br. Fonte de energia renováveis representam 83% da matriz elétrica brasileira. GOV, 2020. Available in: https://www.gov.br/pt-br/noticias/energia-minerais-e-combustiveis/2020/01/fontes-deenergia- renovaveis-representam-83-da-matriz-eletrica-brasileira. Access in: 22 jul. 2021.
2. Lessa C. Especialistas apontam efeitos ambientais negativos de pequenas hidrelétricas. Câmara dos Deputados, 2019. Available in: https://www.camara.leg.br/noticias/606063-especialistas-apontam-efeitos-ambientais-negativos-de-pequenas-hidreletricas/. Access in: 25 jul. 2021.
3. Gomes LH. Investimento na matriz eólica superam R$ 187,1 bi na última década. Folha de São Paulo, 2021. Available in: https://www1.folha.uol.com.br/mpme/2021/07/investimentos-na-matriz-eolica-superam-r-1871-bi-na-ultima-decada.shtml. Access in: 22 jul. 2021.
4. www.deepmind.com. Machine Learning can boost the value of wind energy. DeepMind, 2019. Available in: https://deepmind.com/blog/article/machine-learning-can-boost-value-wind-energy. Access in: 23 jul. 2021.
5. IBGE – Instituto Brasileiro de Geografia e Estatística. Panorama da cidade de Lençóis. Lençóis - BA. 2017, IBGE - Instituto Brasileiro de Geografia e Estatística 2017;4.6.8.
6. Conterato FS. et al. Comparison of short-term temperature forecasting between artificial neural network and machine learning. Blucher, 2020. Available in: http://pdf.blucher.com.br.s3-sa-east-1.amazonaws.com/engineeringproceedings/siint ec2020/comparisonofshort-term.pdf. Access in: 26 jul. 2021.
7. Penteado K. Métricas de avaliação para séries temporais. alura, 2021. Available in: https://www.alura.com.br/artigos/metricas-de-avaliacao-para-series-temporais. Access in: 30 jul. 2021.
8. Zucatelli PJ et al. Short-term wind speed forecasting in Uruguay using computational intelligence, Colonia Eulacio, Soriano Department, Uruguay, v. 5, p. 1-11, may 2019. DOI https://doi.org/10.1016/j.heliyon.2019.

Modeling of an Extreme Flooding Event in the Amazon Basin Using the WRF-Hydro Model

Carolina Sacramento Vieira[1*], José Roberto Dantas da Silva Júnior[1], Daniel Guimarães Silva[1], Filipe Milani de Souza[1], Diogo Nunes da Silva Ramos[1], Yasmin Kaore Lago Kitagawa[1], Davidson Martins Moreira[1]
[1]SENAI CIMATEC Unicersity Center; Salvador, Bahia, Brazil

In the Amazon, the frequency of extreme events has been increasing notably in recent decades. In April, May, and June 2021, the city of Manaus faced the greatest flood in 119 years, and the Rio Negro reached at a level of 29.98 m. Because of this, the present work aims to evaluate the performance of the WRF-Hydro model in simulating precipitation during an extreme flood event in the Amazon Basin. The simulations were performed with 1 km spatial resolution and a 250 m channel network from April 30 to June 5, 2021. Such applications were evaluated using comparisons of the variability of accumulated precipitation with observed data from National Water Agency rainfall stations. The results showed a tendency for the model to underestimate the accumulated precipitation, slightly reproducing some observed precipitation patterns. We concluded that the tool presents a capacity for precipitation estimation, with potential for operational purposes.
Keywords: Amazon. Rio Negro Basin. WRF-Hydro.

Introduction

Floods are among the most common natural disasters related to deaths, destruction, and economic losses in many places. According to the World Water Resources Development Report (2021), during the period 2009-2019, floods caused nearly 55,000 deaths (including 5,110 in 2019 alone), affected another 103 million people (including 31,000 in 2019), and caused $76.8 billion in economic losses ($36.8 billion of which was in 2019 alone). Globally, flooding and extreme precipitation events have increased by more than 50% in the last decade, occurring at a rate four times higher than in 1980 [1].

In the Amazon, the frequency of extreme events has been increasing notably in recent decades. There is growing evidence that the hydrologic cycle of the Amazon basin has intensified since the late 1990s [2]. A prominent feature of the changing hydrology of the Amazon is the occurrence of recent floods that are usually widespread and sometimes severe for those living very close to the rivers, but urban areas are usually more socially affected than rural areas [3].

In April, May, and June 2021, the city of Manaus faced the greatest flood in 119 years, reaching the Rio Negro at a level of 29.98 m. According to Bittencout and Amadio [4], extreme events of drought and flood were quantitatively defined when daily water levels in Manaus fall below 15.8 m or rise above 29 m, respectively, and flood: rise in river level, between 20 and 26 m [2].

The Negro River basin is inserted in the great Amazon Basin, inheriting the same natural characteristics of that region. Despite the differences in the basin size, the water levels of the lower Negro River in Manaus are affected by the main course of the Solimões-Amazonas. During the flood period, the Rio Negro is barred by the Solimões River (backwater effect), causing flooding in the city of Manaus [3].

Hydrological modeling, proposed in this work, using the coupling of Hydrological Models with Numerical Weather Prediction Models (NWP), aims at understanding the hydrological processes of the Earth's surface [5]. The principal model of this type, the Weather Research and Forecasting Model (WRF) - Hydro, is the object of this work. It was originally conceived as a coupled model framework designed to facilitate the coupling of the Weather Research and Forecasting Model (WRF) and land hydrologic model components according

Received on 25 February 2022; revised 24 April 2022.
Address for correspondence: Carolina Sacramento Vieira. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA- Brazil. Zipcode: 41650-010. E-mail: carolinavieira265@gmail.com.
DOI 10.34178/jbth.v5i2.210.

J Bioeng. Tech. Health 2022;5(2):123-129.

De Souza and colleagues an Gochis and colleagues [6,7]. The WRF-Hydro system represents the state-of-the-art for water resources and also enables a better representation of land surface flows and terrestrial hydrologic processes related to the spatial redistribution of surface, subsurface, and channel waters at very high spatial resolution (typically 1 km or less) using a variety of physics-based approaches [6].

The WRF-Hydro modeling system was developed by NCAR (US National Center for Atmospheric Research) in partnership with NASA (National Aeronautics and Space Administration).It was created to simulate flooding, hydrometeorological variables, and the spatial distribution of water resources [1], to provide an enhanced numerical tool to meet worldwide needs for water resources planning, environmental impact assessment, risk prediction, and mitigation. Further details about the numerical and computational structure of the model can be described by Maciel and colleagues [3].

This model has been tested and recognized as a powerful tool in several studies in different watersheds around the globe. Recently, for example, Galanaki and colleagues [8] and Kim and colleagues [9] use WRF-Hydro for operational flood forecasting in the Sarantapotamos basin in Greece and the USA, respectively. White and colleagues [10] estimate the flow of the Brahmaputra River located between India and Bangladesh, verifying good results in model performance. Liu and colleagues [5] simulate typical 24-hour storm events, providing a reference for model application. In Brazil, the works of De Souza and colleagues [6], White and colleagues [11], and Silva and colleagues [12] applied the WRF-Hydro model in Brazilian watersheds. In this context, the main objective of this study is to simulate the precipitation and river level of the Rio Negro in the extreme event of a flash flood in the Rio Negro watershed located in the Amazon from April 30 and June 6, 2021, which caused deluge, flooding, and inundation in the city of Manaus registering the major flood in history since records began in 1902. For this first study, the model precipitation output data was initially analyzed, to later examine the modeled river elevation data in the next steps of this study. In addition, to validate the capability of WRF-Hydro, the simulated data are compared with data collected by ANA (Agência Nacional de Águas) telemetric stations located along the course of the Rio Negro. The study of these events estimates hydrometeorological variables, and was of great importance since there are no data from stations along the entire river bed and such information is considered essential for projects of structures for harnessing water resources, besides providing efficient planning and management of these resources.

Material and Methods

Study Area Description

The Negro river basin in Amazonia has a total surface area of about 696,810 km², occupying areas in four countries: 82.8% in Brazil, 9.9% in Colombia, 5.9% in Venezuela, and 1.5% in Guyana. The Negro River is formed by the confluence of the Uaupés and Içana rivers. From this point, it receives contributions from several tributaries, of which we can highlight: the Cassiquiare river, Demini river, and, mainly, Branco river (tributaries on the left margin). Near Manaus, the confluence of the Negro River and the Solimões River occurs and the Amazon River is formed [13].

The headwaters of the Black River are located in Colombia, where it is called the Guiania River. When it enters Brazil through the North of the State of Amazonas it is called the Black River, and runs for about 1,700 km until its mouth in the Amazon River, having 1,070 km of rivers with favorable conditions for navigation [14].

The Rio Negro Basin has the wettest climate in the Amazon Basin, with average annual rainfall values between 2,000 and 2,200 mm, reaching levels greater than 3,500 mm in the upper Rio Negro region. The river's flood period is from May to August, while the dry period is from December to February [15].

The city of Manaus, located in the lower Rio Negro, is commonly affected by extreme rainfall

events of a damaging nature in recent decades. However, recent floods are not only occurring more frequently but also have become more severe, exceeding a duration of 70 days or a level of 29.7 m [3]. In this regard, the present study aims to simulate the extreme event of flash floods between April 30 and June 05, 2021, causing flash floods and flooding in the city of Manaus and the level of the ruler of the Port of Manaus reached 30 m on 06/05/2021. Then the statistical comparison of the data simulated by the coupled model (WRF-Hydro) with the observed data was performed. Figure 1 illustrates the basin under study and its location.

Simulation Details

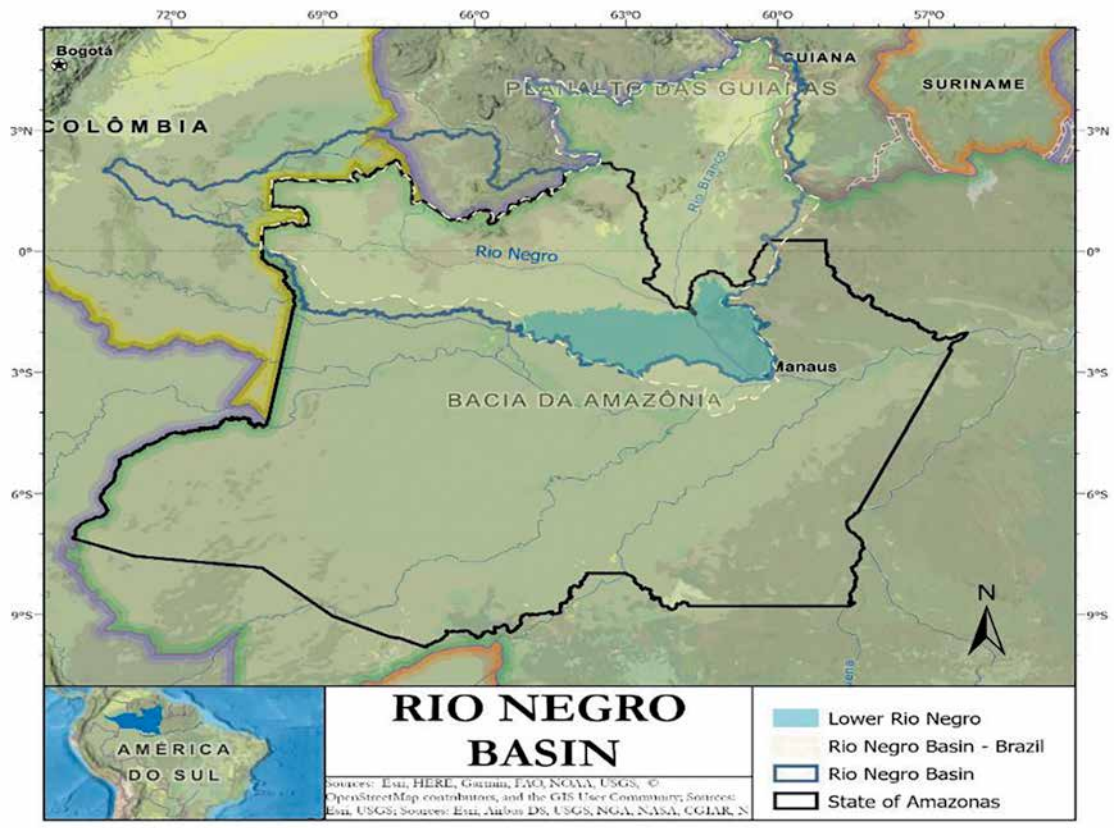
The WRF Model

The Numerical Weather Prediction Model (NWP) WRF produces high-resolution (1-10 km) simulations of meteorological variables such as precipitation [1]. The WRF model (version 3.6) was used to generate initial conditions of soil moisture, soil temperature, soil water content, the temperature of the topmost soil layer, and atmospheric forcing, among other variables for the WRF-Hydro model run over the basin under study, covered by three nested domains of 9, 3 and 1 km resolution (Figure 2).

In Figure 2, the domain of interest (D03) has a horizontal resolution of 1 km and 35 vertical levels with model top pressure set at 50 hPa. Table 1 shows an overview of the spatial configurations.

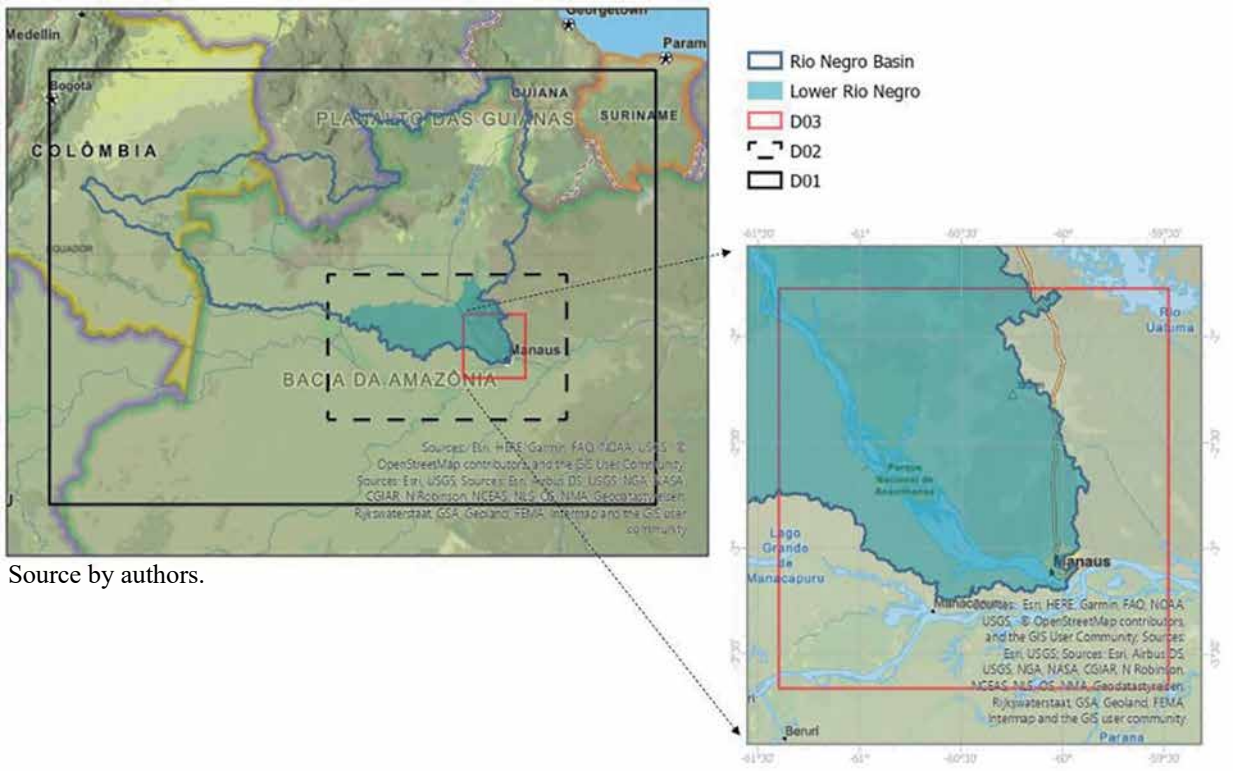
The simulation was started at 0000 UTC on 04/29, extending until 1800 UTC on 06/05. The first 24 hours of simulations were considered as spin-up, which is the model adjustment time, and it was excluded from the evaluation performance. The initial and boundary conditions employed in the simulations come from the NCEP-FNL (National Centers for Environmental Prediction - Final Analysis), with a horizontal resolution of 0.25° x 0.25° and temporal resolution of six hours. The topography

Figure 1. Rio Negro basin.



Source by authors.

Figure 2. Location of the three nested domains in the Rio Negro basin.



Source by authors.

Table 1. Details of the model configuration.

Region	Domain	Horizontal resolution	Cell numbers	Number of levels η
Bacia do Rio Negro	D01	9 km	232x160	35
	D02	3 km	274x160	
	D03	1 km	214x211	

and land use and land cover data are provided by the USGS (United States Geological Survey). The WRF model presents several physical parameterizations that must be chosen according to the local under study and the objective that one wishes to achieve. Based on the existing literature, the physical parameterizations (Table 2).

The WRF-Hydro Model

When generating the input files for the WRF-Hydro model, the file with routing data of the hydrographic channel network with a resolution of 100 m was created, using the pre-processing tool ArcGIS Pro (Geographic Information System – GIS). This tool creates high-resolution fields in routing grids such as flow direction, underground flow, and channel routing processes required to be used as input data in the WRF-Hydro model. WRF-Hydro mainly includes a Land Surface Model (LSM) module and a hydrologic module that provides a framework of multiple land physics options, including surface water and groundwater flow, channel flow, and reservoir or bucket model to account for river base flow. In this study, WRF-Hydro version 5.2.1 was configured in its fully coupled mode for running with WRF. Table 3 shows the main settings of WRF-Hydro.

After the simulations of the WRF-Hydro model data for the period under study, data post-processing was performed. Daily observational data from telemetry stations monitored by ANA were used to validate the simulation.

Results and Discussion

Among the meteorological variables, precipitation is the most difficult to be estimated using numerical models. The spatial and temporal discontinuity of the mechanisms that control the formation of precipitation in each region has different factors, depending on the location and time of year. The extreme precipitation events on a regional scale is a complex task. Figure 4 shows the results of the simulations of the WRF-Hydro model in the simulated values compared to those observed in the ANA rainfall.

As it is possible to verify in Figure 3, this period was marked by a great volume of precipitation that triggered the rise in the level of the Negro River, causing flooding in the city of Manaus.

Analyzing the Figure 3, we can note that WRF-Hydro underestimates the precipitation values on most days. It is also observed that the model can capture some rainfall peaks, reasonably reflecting the rainfall distribution characteristics. The performance of the WRF-Hydro model was evaluated by comparing simulated precipitation data with observed data at the location of interest. The statistical evaluation procedure was used and relied on the following parameters: in the indices written below (Eqs. 1, 2, and 3), *o* and *p* refer to the observed and model-predicted measurements, respectively. The bar indicates the mean and σ the deviation.

NMSE reflects the dispersion of the measured values. The best results are achieved when while for NMSE and MBE are close to zero, and the value of FAC2 was close to one. Table 4 presents the statistical metrics calculated for model performance analysis.

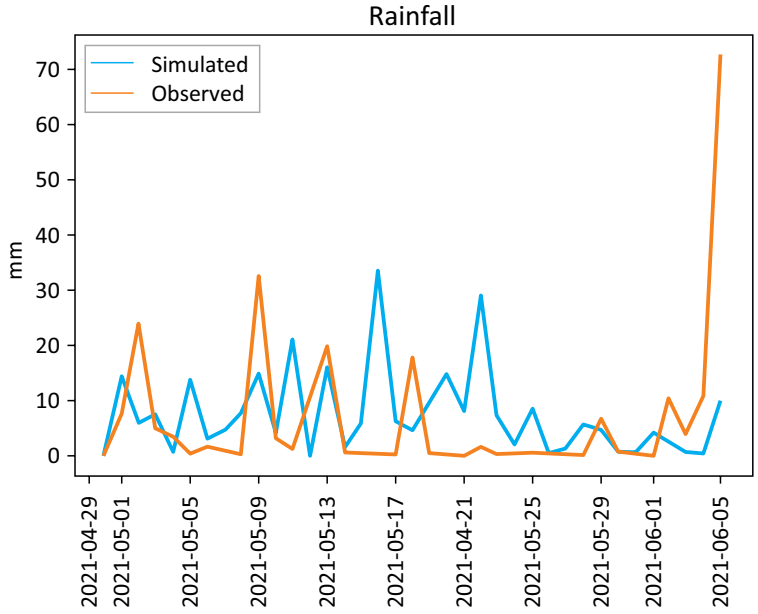
Table 2. Physical parameterizations of the WRF model.

Category	Parameterization Selected
Microphysical processes	WRF Single-Moment 3-class
Cumulus option	Grell-Freitas
Planetary boundary layer	Mellor-Yamada Nakanishi and Niino
Surface Layer	MM5 similarity
Radiation scheme	RRTMG
Land surface model	Noah MP
Projection	Lambert

Table 3. The parameterizations of coupled WRF-Hydro model.

Category	Parameterization Selected
NWP model	WRF model
Land surface model	Noah LSM
Subsurface flow (i.e., Interflow)	Distributed hydrology soil and vegetation model
Overland flow	D8 method
Baseflow	Exponential storage-discharge function
Channel routing	Diffusive wave-gridded

Figure 3. Daily behavior of simulated and observed accumulated precipitation.



$$\text{NMSE (Normalized Quadratic Error)} = \overline{(X_o - X_p)^2} \Big/ \overline{X_p}\ \overline{X_o}\,, \quad (1)$$

$$\text{FAC2 (Factor of two), fraction of data that are between } 0.5 \le (X_p / X_o) \le 2\,, \quad (2)$$

$$\text{MBE (Mean error) } MBE = \frac{1}{n} . \sum_{i=1}^{n} (X_p - X_o). \quad (3)$$

By analyzing the statistical indicators (Table 4), the MBE is negative, indicating a tendency to underestimate the accumulated precipitation. It was below 0.5, suggesting a high deviation between the estimated and observed data. Finally, we recognized that the number of sampling points (rainfall stations) used in this study is small, considering the high spatial variability of precipitation in this region. However, the low density of rainfall stations (active and/or with a consistent data series) is still characteristic of the northern region of the country.

Table 4. Statistical comparison between observed and simulated data.

Station	NMSE	MBE	FAC2
Manaus	2.97	-7.28	0.42

Conclusion

The present work is characterized as an initial study to evaluate the performance of the WRF-Hydro model in simulating precipitation during an extreme flood event in the Amazon region. The presented results show that the simulations obtained values with a low agreement index, underestimating them for most of the period. However, this tendency to underestimate the WRF-Hydro occurs due to a lack of calibration in the model initialization. For the next steps, the simulated river level data will be analyzed, as well as the sensitivity tests of the model in response to different parameterization schemes. Finally, the WRF-Hydro model shows itself to be a computational tool with great potential in water resource management and risk estimation and mitigation.

Acknowledgments

The authors thank the Supercomputing Center for Industrial Innovation of the SENAI CIMATEC for providing the computational infrastructure needed to run the models and the Fundação de Amparo à Pesquisa do Estado da Bahia (FAPESB) for the financial support.

References

1. Sun M et al. Evaluation of flood prediction capability of the WRF-Hydro model based on multiple forcing scenarios. Water 2020;12(3):874.
2. Barichvich J et al. Recent intensification of Amazon flooding extremes driven by strengthened Walker circulation. Science Advances 2018;4(9):7.
3. Maciel JSC et al. Flood forecast in Manaus, Amazonas, brazil. WIT Transactions on The Built Environment 2020;194:63-72.
4. Bittencout MM, Amadio SA. Proposta para identificação rápida dos períodos hidrológicos em áreas de várzea do Rio Solimões-Amazonas nas proximidades de Manaus. Acta Amazônica 2007;37(2):303–308.
5. Liu Y et al. Parameter sensitivity analysis of the WRF-Hydro modeling system for streamflow simulation: A case study in semi-humid and semi-arid catchments of Northern China. Asia-Pacific Journal of Atmospheric Sciences 2020:1-16.
6. De Souza LP et al. Avaliação da previsibilidade do modelo WRF-Hydro em modelagens hidrometeorológicas com diferentes resoluções na Bacia do Taquari-Antas. Revista Brasileira de Geografia Física 209;12(5):1872-1890.
7. Gochis DJ et al. Coupled WRF|WRF-Hydro V5 Test Case User Guide (Version 5.0). Nota Técnica NCAR. 107 ps. 2018.
8. Galanaki E et al. Implementation of WRF-Hydro at two drainage basins in the region of Attica, Greece, for operational flood forecasting. Natural Hazards and Earth System Sciences 2021;21(7):1983-2000.
9. Kim S et al. High-resolution modeling, and prediction of urban floods using WRF-Hydro and data assimilation. Journal of Hydrology 2021;598:126236.
10. Dubey AK et al. Flood modeling of a large transboundary river using WRF-Hydro and microwave remote sensing. Journal of Hydrology 2021;598:126391.
11. White DD et al. Co-producing interdisciplinary knowledge and action for sustainable water governance: Lessons from the development of a water resources decision support system in Pernambuco, Brazil. Glob Challenges, 2019.
12. Silva JRDD et al. Feasibility analysis on the construction of a solution for monitoring and hydrometeorological forecasting. Blucher Engineering Proceedings. Editora Blucher, São Paulo, 2020:585–593.
13. Escarião RD. Modelagem hidrológica da bacia do rio Negro na Amazônia. 2001. Tese de Doutorado. Dissertação de M. Sc., Universidade de Brasília, Brasília, Brasil.
14. Zeidemann VK. O rio das Águas Negras. Florestas do Rio Negro. Companhia das Letras, São Paulo. 344p, p. 62-87, 2001.
15. Neves RR. Caracterização hidrológica das sub bacias hidrográficas do Rio Negro e Rio Solimões. 2017. 109 f. Dissertação (Mestrado). Universidade Federal do Pará, Instituto de Tecnologia. Programa de Pós-Graduação em Engenharia Civil, Belém, 2017.

Precipitation Simulation Using the WRF-Hydro Model in the Matopiba Region

Daniel Guimarães Silva[1*], Diogo Nunes da Silva Ramos[1], Filipe Milani de Souza[1], José Roberto Dantas da Silva Júnior[1], Yasmin Kaore Lago Kitagawa[1,2], Davidson Martins Moreira[1]

[1]Integrated Center for Manufacturing and Technology (SENAI CIMATEC); Salvador, Bahia; [2]Department of Environmental Engineering, Federal University of Espírito Santo (UFES); Vitória, Espírito Santo Brazil

Hydrological modeling is a technique for monitoring a region's water resources. The WRF-Hydro model is a powerful system for this type of study and it is attracting more and more attention from the academic community. Studying the hydrology of a region involves several physical components sensitive to the occurrence of precipitation. Thus, to verify whether a hydrological model effectively simulates parameters such as evapotranspiration, surface runoff, or river flow, it has to be effective in estimating precipitation. Therefore, this work evaluates the performance of the precipitation simulation of the WRF-Hydro system in the Brazilian region named MATOPIBA, located in North and northeast Brazil. The simulation presented a good correlation with the observed data, showing itself as promising.

Keywords: Hydrological Modeling. Numerical Modeling. WRF-Hydro. Matopiba.

Introduction

Water resources are a vital source of economic development in Brazil and worldwide. In Brazil, water sources correspond to more than half the capacity of the Brazilian electricity matrix, enhancing the importance of monitoring this resource. One way to monitor water resources, in terms of quantity and water cycle, is through hydrological modeling, which can help in the management of these resources, and which is associated with economic issues such as agriculture and livestock or extreme weather events like floods. Hydrological modeling effectively carries out forecasts, studies on the effects of climate change and land use, water availability analysis, and other applications to support decisions [1].

The coupled hydrological modeling system WRF-Hydro (Weather Research and Forecasting Hydrological modeling system) is an open-source system developed initially by the NCAR (National Center for Atmospheric Research - USA) in collaboration with other entities. The system has been used extensively for various purposes, such as flood forecasting, water resources management, and seasonal watershed monitoring. The WRF-Hydro combines the atmospheric and hydrological model, which can operate coupled or uncoupled [2]. The coupled mode of these models is advantageous for precipitation in different areas and different seasons, especially during convective summer precipitation [3].

The MATOPIBA region is an area shared between the states of Maranhão, Tocantins, Piauí, and Bahia and it is known as the plain land with the greatest agricultural potential in the world [4]. The cultivation of grains stands out as the main agricultural activity. The region still has many conservation units, indigenous lands, and quilombola areas [5], characteristics that show the importance of hydrological monitoring in this territory.

To carry out this monitoring, verifying whether variables such as evapotranspiration, surface runoff, or river flow reflect the region's reality, the simulated precipitation must also be in agreement with the real data. Any assessment between amounts of water from various hydrological variables only makes sense if the precipitation inputs are equal or at least comparable with the observations. The evaluation of WRF-Hydro starts from the main force of a hydrological model, precipitation [6].

Received on 28 January 2022; revised 22 May 2022.
Address for correspondence: Daniel Guimarães Silva. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA- Brazil. Zipcode: 41650-010. E-mail: guimaraessilvadaniel@gmail.com. DOI 10.34178/jbth.v5i2.211.

J Bioeng. Tech. Health 2022;5(2):130-135

In this context, this work has as main objective to analyze the performance of the precipitation simulation in a period of intense rains, comparing the model results with the observations in two meteorological stations.

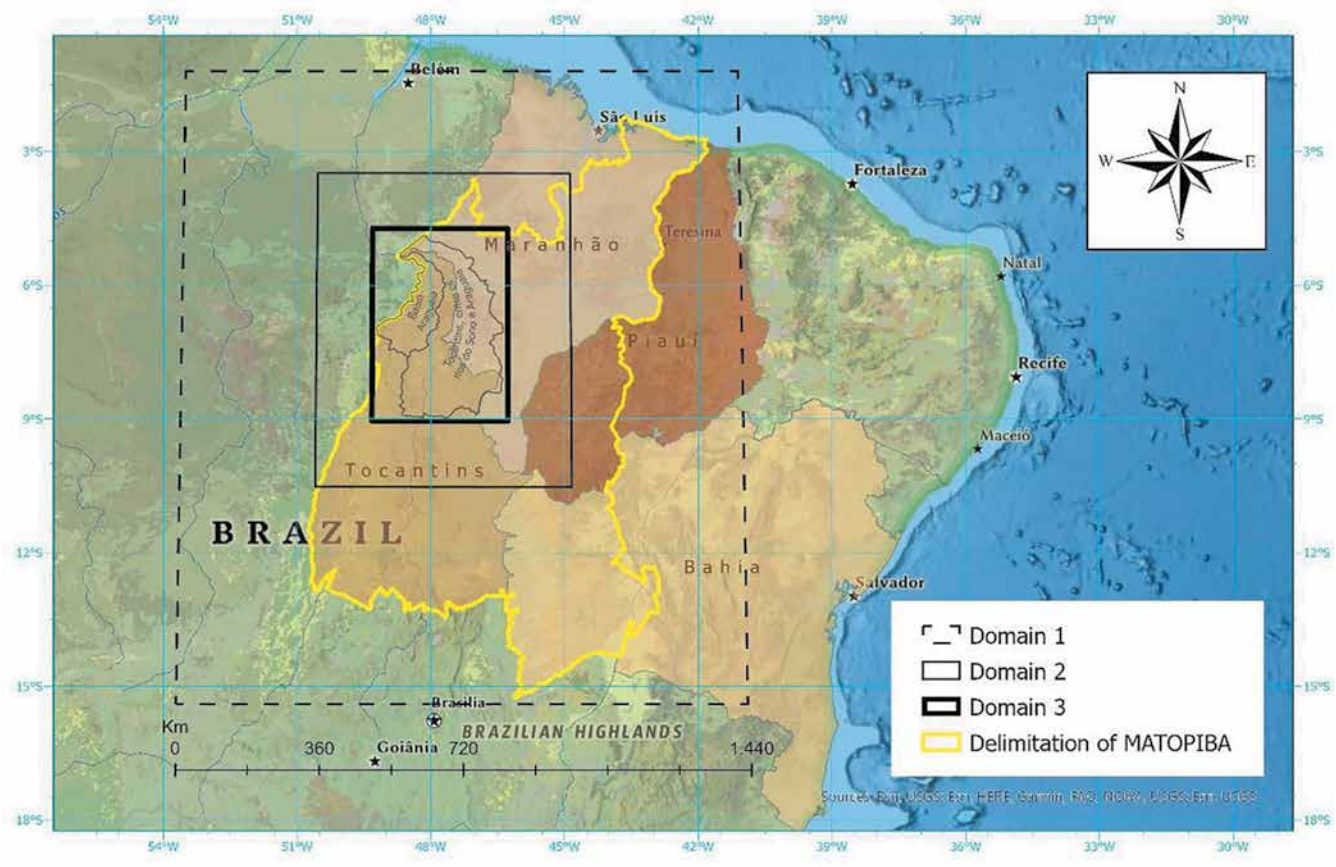
Material and Methods

Study Area

The MATOPIBA region is located in the North/Northeast of Brazil and comprehends 337 municipalities in 31 geographical micro-regions, which add up to approximately 73 million hectares. The predominant biome is the Cerrado, which corresponds to around 91% of the territory, followed by the Amazon and Caatinga, 7.3% and 1.7% of the area, respectively. Three hydrographic basins are part of the region: Tocantins River Basin, occupying 43% of MATOPIBA, Atlantic Basin – North/Northeast Section, with 40%, and São Francisco River Basin, with 17%, each of these hydrographic basins being divided into ten sub-basins [7].

The predominant climate is semi-humid tropical, 78% of the territory, with average temperatures above 18°C all over the year and dry periods between 4 to 5 months in winter. The eastern limit is characterized by a semi-arid climate, with low humidity and precipitation, about six dry months, and high temperatures. Figure 1 shows the three aligned domains used in the simulation of the WRF-Hydro model. Domain 1 covers the entire MATOPIBA region, while domain 3, which is the domain of interest and has the highest spatial resolution, occupies two hydrographic sub-basins, Baixo Araguaia and Tocantins, between the Sono and Araguaia rivers, belonging to regions with higher precipitation indices of MATOPIBA.

Figure 1. Study area.



The WRF-Hydro Model

The modeling system used in this study is the WRF-Hydro, a well-attractive system to the meteorological and hydrological community that is the most used mesoscale numeric time prevision model hydrological module [2].

The model was developed to improve the representation of terrestrial hydrological processes relating to the spatial redistribution of surface, ground, and channel waters across the terrestrial surface. It can be operated in two modes: independent or coupled to an atmospheric model. In the independent mode, meteorological data obtained by grid input time series are used, and, in coupled mode, meteorological data are provided with a frequency dictated by the time interval of the specified terrestrial surface model [8].

In this work, the WRF-Hydro occurred in a fully coupled mode with the WRF meteorological model, which was configured with three nested domains and resolutions of 9, 3, and 1 km, as shown in Table 1.

Geoprocessing tools were used in domain 3, resizing the grid from 1 km to 100 m, aiming to create input data from the WRF-Hydro, related to surface, underground, and channel water flows. These data were obtained through the WRF Hydro GIS Pre-Processing Toolkit, developed by NCAR, to use in the geographic information system application ArcGIS, developed and maintained by the American company ESRI (Environmental Systems Research Institute).

The simulation was carried out in March 2020, a period in which there were records of intense rains in the state of Tocantins. The simulation period was 00 h (UTC) on March 9, 2020, until 18 h (UTC) on March 19, 2020, the first two days being considered as spin-up. The physical parameters used were based on the NCAR Tropical Physics Suite, released by the research center, for real-time forecasts focusing on tropical storms and tropical convection [9].

Model Performance Evaluation

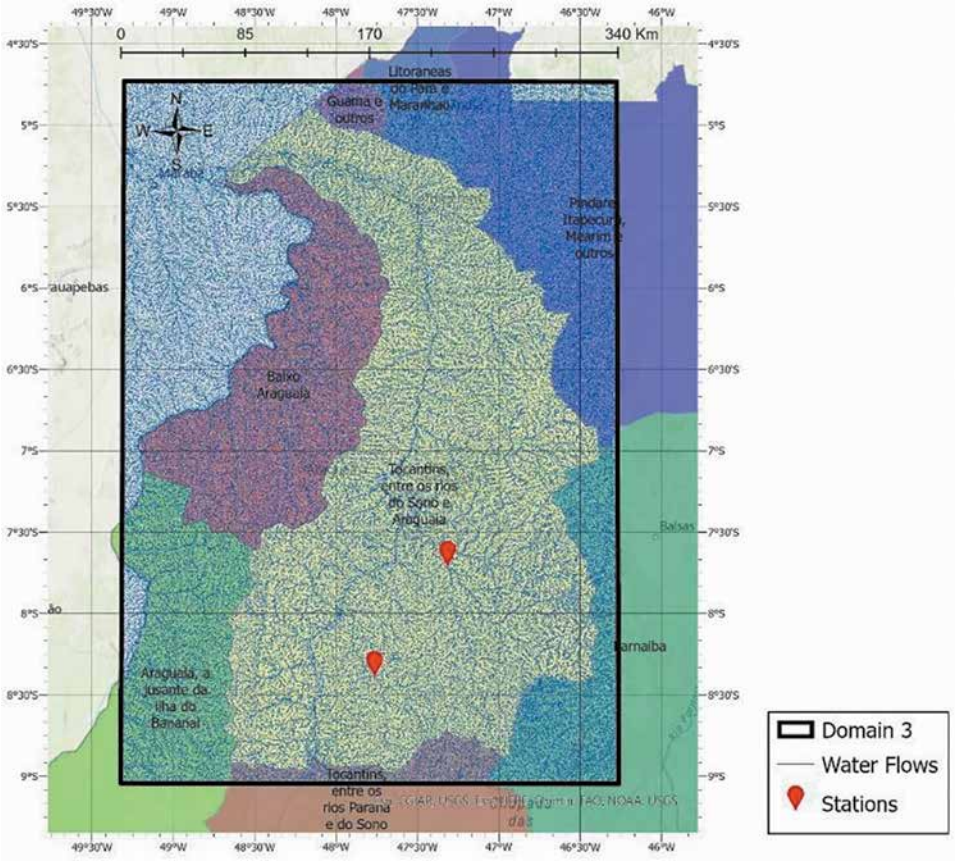
To evaluate the performance of the WRF-Hydro about precipitation data, we compared the daily results at the closest grid points of two meteorological stations of the National Water and Basic Sanitation Agency of Brazil (ANA). The Goiatins stations (7.71° S; 47.32° W and Itacajá (8.39° S; 47.76° W) were chosen, presented in domain 3, within the Tocantins River sub-basin, between the Sono and Araguaia rivers. Figure 2 shows the location of stations with water flows.

We graphically did the analysis from the observed and simulated data with some statistical indices: the correlation coefficient R, the root mean square error (RMSE), and the BIAS estimator, widely used to evaluate forecast models [10]. Pearson's correlation coefficient (R) describes the degree of collinearity between simulated and measured data, ranging from -1 to 1. If R = 0, there is no linear relationship. If R is close to 1 or -1, it indicates a strong positive or negative linear relationship. The RMSE, on the other hand, expresses systematic and random errors, consisting of the square root of the mean squared errors. It is one of the most commonly used error rate statistics. The lower RMSE, the better the model's performance. Finally, BIAS measures the average tendency of simulated values to be larger or smaller than the measured data [10,11].

Table 1. Domain configuration.

	Domain 1	**Domain 2**	**Domain 3**
Horizontal resolution	9 km	3 km	1 km
Number of cells	155 x 177	211 x 262	337 x 481
Domain size	1395 x 1593 km	633 x 786 km	337 x 481 km

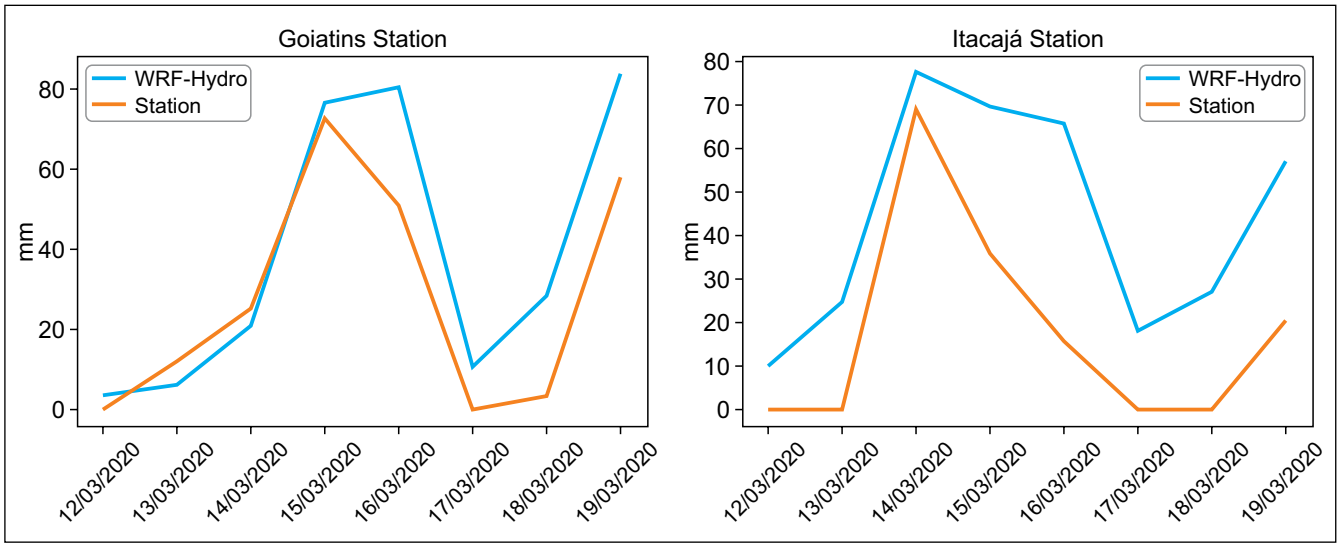
Figure 2. Location of stations with water flows.



Results and Discussion

The month of March 2020 had a high amount of rainfall observed in the study region, reaching a daily total of 72.5 mm at the Goiatins station and 69 mm at Itacajá. Figure 3 shows the time series from 03/12/2020 to 03/19/2020 of the daily rainfall of the data observed in the two ANA stations and the data obtained with the simulation of the WRF-Hydro. In both analyses, the simulated precipitation data overestimated the precipitation values recorded in the mentioned pluviometric stations. However, there is a considerable correlation between the WRF-Hydro and season curves, indicating growth and decrease of data in practically the same intervals. This good correlation is verified through the Pearson correlation coefficient, which obtained a value of 0.92 at the Goiatins station and 0.84 at the Itacajá station. These values corroborate other works presented in the literature that evaluated the performance of precipitation simulations using the WRF model [10,12,13]. The BIAS and RMSE coefficients did not present values as satisfactory as the R correlation. The BIAS proves a greater overestimation of the simulated data concerning those observed at the Itacajá and Goiatins stations, with 26.03 and 10.89, respectively. The RMSE value at Itacajá station was 29.13 and at Goiatins 17.06. Despite being a smaller number, the latter is still not an error considered adequate [14]. However, these simulations are initial and still need further analysis. For example, tests with other parameterizations based on studies carried out

Figure 3. Daily precipitation was simulated at WRF-Hydro and observed at ANA stations.



with the WRF and WRF-Hydro in regions with climatic characteristics similar to MATOPIBA have already started.

Conclusion

The preliminary results of the simulations with the WRF-Hydro model are encouraging. This model represents state-of-art hydrological modeling and is a fundamental step for hydrological assessments, both in the MATOPIBA region and in other regions of Brazil. Despite the differences between the results measured at the stations and those simulated, they can be considered very good given the complexity involved. In this sense, the following steps will explore other parameterizations and a longer simulation time (for example, one year of data), both in the precipitation variable and in the flow of the rivers under analysis.

Acknowledgments

The authors thank the Center for Supercomputational and Industrial Innovation (CIMATEC) for providing the computational infrastructure necessary for the execution of the models .

References

1. Fan FM, Collischonn W. Integração do modelo MGB-IPH com sistema de informação geográfica. Brazilian Journal of Water Resources 2014;19(1): 243-254.
2. Liu Y, Liu J, Yu F, Wang W, Qiu Q. Parameter sensitivity analysis of the WRF-Hydro modeling system for streamflow simulation: a case study in semi-humid and semi-arid catchments of Northern China. Asia-Pacific Journal of Atmospheric Sciences 2020;57:451-466.
3. Givati A, Gochis D, Rummler T, Kunstmann H. Comparing one-way e two-way coupled hydrometeorological forecasting systems for flood forecasting in Mediterranean Region. Hydrology 2016;3.
4. Salomon MMR. Quem Disputa o MATOPIBA? Interesses e Sustentabilidade na Fronteira Agrícola. Thesis (Doctorate in Sustainable Development) - Center for Sustainable Development, University of Brasília, Brasília, 2020.
5. Miranda EE, Magalhães LA, Carvalho CA. Proposta de Delimitacao Territorial do MATOPIBA. Campinas: EMBRAPA, 2014. Available in: <https://www.embrapa.br/gite/publicacoes/NT1_DelimitacaoMatopiba.pdf >. Accessed on: 27 Jul. 2021.
6. Naabil E, Lamptey BL, Arnault J et al.Water resources management using the WRF-Hydro modeling system: Case-study of the Tono dam in West Africa. Journal of Hydrology: Regional Studies 2017;12:196-209.
7. Magalhães LA, Miranda EE. MATOPIBA: Quadro Natural. Campinas: EMBRAPA, 2014. Available in: <https://www.embrapa.br/gite/publicacoes/NT5_Matopiba_Quadro_Natural.pdf>. Accessed on 27 jul. 2021.
8. Gochis DJ, Barlage M, Cabell R et al. The WRF-Hydro modeling system technical description,

(Version 5.1.1). Nota técnica NCAR, 2020. Available in: <https://ral.ucar.edu/sites/default/files/public/WRFHydroV511TechnicalDescription.pdf>. Accessed on: July 23, 2021.

9. Ucar. NCAR Tropical Physics Suite for WRF. Disponível em: <https://www2.mmm.ucar.edu/wrf/users/physics/ncar_tropical_suite.php>. Accessed on: 10 aug. 2021.
10. Mendoza UI, Lugo MDR. Performance of the WRF model with different physical parameterizations in the precipitation simulation of the state of Puebla. Atmosfera 2020;33(4):357-383.
11. Moriasi DN, Arnold JG, Liew MW et al. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the ASABE 2007;50:885-900.
12. Kitagawa Y, Nascimento E, Souza N et al.. Evaluation of the WRF-ARW model during an extreme rainfall event: subtropical storm Guará. Atmosfera 2021.
13. Das MK, Chowdhury M, Das S. Sensitivity study with physical parameterization schemes for the simulation of mesoscale convective systems associated with squall events. International Journal of Earth and Atmospheric Science 2015;2:20–36.
14. Singh J, Knapp H, Demissie M. Hydrologic modeling of the Iroquois River watershed using HSPF and SWAT. J. Am. Water Resour 2005:343-360.

Building Information Modeling Integrated With Life Cycle Analysis in Plumbing Projects: A Preliminary Systematic Review

Diogenes Oliveira Senna[1,2*], Larissa da Silva Paes Cardoso[1], Alex Álisson Bandeira Santos[1]
[1]SENAI CIMATEC University Center; Salvador; [2]State University of Feira de Santana; Feira de Santana, Bahia, Brazil

Many studies point out that the modeling of construction information (BIM) integrated with life cycle analysis (LCA) can be launched as an alternative, to identify and quantify the environmental impact generated by the construction industry. However, most studies are based on architectural and structural projects, there are few works in plumbing installations. The objective of this study was to evaluate, through a systematic literature review (SLR), the scientific contribution from 2015 to 2021 in articles on free access to BIM integrated with LCA in plumbing facilities projects. In the RSL, 128 articles were found, and we selected 5 articles for analysis and extraction of information that identified gaps and potential studies.
Keywords: BIM. LCA. Plumbing Project.

Introduction

The Industry of Architecture, Engineering, and Construction (AEC) accounts for a considerable portion of the Brazilian economy, generating several jobs, moving a considerable economic chain, and consequently consuming a high volume of natural and energy resources, thus generating a great environmental impact.

But in counterpoint, it is perceived that there are joint efforts to minimize and or mitigate this impact, promoted mainly by groups of national and international researchers bringing concepts, methodologies, tools, or directly, solutions that promote sustainability. One of these concepts/ methods is the use of bim integrated life cycle analysis (LCA), which proved to be powerful for the identification and quantification of these generated impacts [1-3].

Several studies have demonstrated in the last 7 years the potential to use the integration of BIM and LCA methodologies to promote sustainability in the various phases of projects and constructions.Santos and colleagues [4] surveyed the state-of-the-art BIM and LCA integration and concluded that while there are currently tools to do this integration, there are still gaps that make it difficult to use their results effectively.

It was perceived by Machado and colleagues [5] that the adoption of mitigating measures facilitated by BIM through the incorporation of solutions in the virtual model, taken from the results of a LCA increases the efficiency of the response to the reduction of environmental impact. In another work, the authors affirm that this integration has the potential for managing the built environment. However, most of these works are limited to methodologies application in architectural design and structural design, and few works on projects of construction systems, precisely, in hydrosanitary projects. The objective of this study is to evaluate through a systematic literature review (RSL) the scientific contribution in the period from 2015 to 2021 of open access articles on BIM integrated with LCA in hydrosanitary facilities projects identifying gaps and potential studies.

Material and Methods

In the present study, the Systematic Literature Review (SLR) was used, according to Dresch and colleagues [6], to map, critically evaluate, consolidate and aggregate the results of relevant primary studies.

Protocol for the Implementation of Systematic Literature Review

Received on 12 December 2021; revised 20 February 2022.
Address for correspondence: Diógenes Oliveira Senna. Campus Universitário UEFS. Av. Transnordestina, S/N - Novo Horizonte, Feira de Santana - BA - Brazil. Zipcode 44036-900. E-mail:dosenna@uefs.br. DOI 10.34178/jbth.v5i2.212.

J Bioeng. Tech. Health 2022;5(2):136-140.

We used StArt, free software on the Windows platform, developed by the Software Engineering Research Laboratory (LaPES) of the Federal University of São Carlos (UFSCar) to facilitate the reference systematizations.

Figure 1 shows the flowchart of the protocol model proposed by Kitchenham and Charters [7] and adopted by the StArt tool to elaborate the RSL.

The following are the steps or phases for conducting the Systematic Literature Review:

(i) Planning - Define the objective and plan the protocol of systematic review;
(ii) Execution - Execute the RSL protocol; Quality Assessment and Data Extraction;
(iii) Summarization - Synthesize the information obtained through graphs and publish the results (report, articles, thesis, dissertation).

Purpose of Systematic Review

The objective of the systematic literature review is directly the objective of the present study. Through a systematic literature review (RSL) the scientific production of the last 7 years on BIM integrated with LCA in plumbing facilities projects.

Research Questions

Can the systematic literature review filter the free access scientific production from 2015 to 2021 on Building Information Modeling (BIM) and Life Cycle Analysis (LCA) in plumbing plant projects?

Search Terms and Search String

For the execution of this work, terms were used for searches in the databases, in the English language and their respective acronyms: ***Building Information Modeling (BIM); Life Cycle of Analysis (LCA); Hydraulic and Sanitary Installations, Plumbing System, Hydraulic Facilities, Drainage Facilities.***

After defining the search terms in the databases, the generic search string was assembled ***("bim") AND ("lca") AND ("project" OR "system") AND ("plumbing" OR "hydraulic" OR "drainage" OR "sanitary")***.

Search Database

For the search for scientific articles, we used the Science Direct platform (www.sciencedirect.com) due to its multi-interdisciplinary character.

Inclusion/Exclusion Criteria

Inclusion/exclusion criteria are necessary to delimit the search of databases related to the subject of the research and to ensure the specificity of the searches, thus reducing the document volume sought.

They include listing as follows:

- Theme - Works that use Building Information;
- Modeling (BIM) and Life Cycle Analysis (LCA) in the design phase and/or construction phase;
- Language - English, and Portuguese;
- Period - 2015 to 2021;
- Scope - National and International;
- Type of Article - Research article (primary study);
- Access to Article - Open access.

The following are the exclusion criteria:

- Document Types - Non-scientific (commercial) journals, SITES;
- Thematic Areas - Works that do not relate to the Architecture, Engineering, and Construction Industry - AEC;
- Theme - Works that do not relate to BIM and LCA;
- Full-text access - No free access to the full text.

Figure 1 . Flowchart of the protocol model adapted from Kitchenham and Charters (2007).

Method for Evaluating the Quality and Extraction of Data from Selected Papers

The RSL uses the expedient of evaluating the quality of the selected scientific articles as a 2nd filtering of them. Table 1 presents the quality criteria for reading prioritization.

By the protocol used, data extraction is the final stage of the execution phase, in which, after the quality selection of the primary studies, we can extract the information desired using extraction criteria elaborated as questions. We proceeded with a dynamic reading of the full text. Table 2 presents the Information Extraction Criteria.

Results and Discussion

The flow chart presents the result of the selected texts in the applied steps of the stArt protocol, and in the search platform (ScienceDirect), visualized in Figure 2.

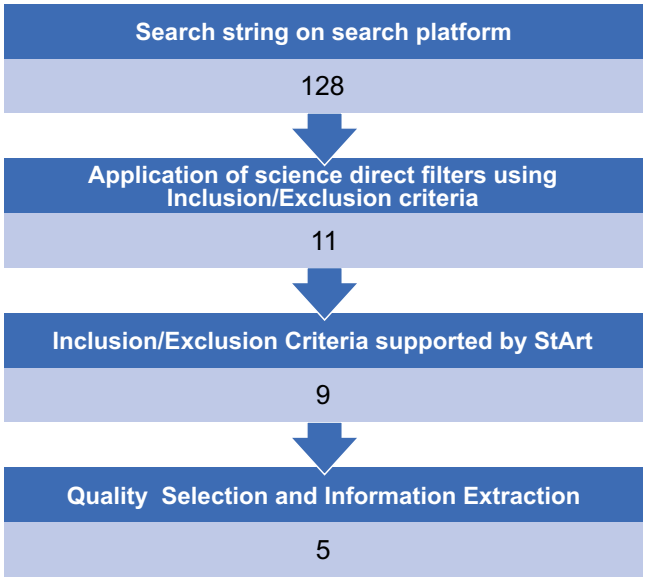
Table 1. Criteria for quality assessment of scientific articles.

Identification	Quality Assessment Criteria
C1	The objectives of the selected article are clear as to how much they use BIM integrated with LCA?={YES, NO}
C2	The methodological procedures are clear?={YES, NO}
C3	Do the descriptors appear in the title, in the abstract, or in the words-keys?={YES, NO}

Table 2. Research questions for analysis and extraction of information.

Identification	Information Extraction Criterion	Selection Field in StArt
CE01	What is the BIM computational tool used in the article? (text)	Text
CE02	What is the computational tool of LCA used in the article? (text)	Text
CE03	What LCA inventory database is used? (text)	Text
CE04	What design disciplines were used in the scientific article (Architectural, Structural, Electrical Installations, Hydrosanitary Installations, Other, Unidentified)	Pick on many
CE05	What is the type of construction (single-family residential, multifamily residential, Commercial, Mixed, Industrial, Unidentified)	Pick on many
CE06	Is the scientific article the kind that automatic data extraction is? (yes or no)	Pick on list
CE07	The article is a proposal for The Development of a Computational Tool that integrates BIM/LCA? (yes or no)	Pick on list
CE08	Does it present a model or framework for the development of the BIM and LCA integration tool? (yes or no)	Pick on list
CE09	The article presented which stage of LCA?(Complete, Cradle - Gate, Tomb Gate, Unidentified)	Pick on list
CE10	Stage/phase of the construction lifecycle={Complete,Planning/ Design,Construction,Use,Post-use,Unidentified}	Pick on list

Figure 2. Flowchart of selection of studies on INTEGRATED ACV BIM in plumbing facilities projects.



The end of the process of selecting the quality of the articles found, recommended in the StArt protocol, resulted in the selection of 5 articles that after a reading of the full text was extracted the information, because of the criteria presented in Table 2, to evaluate the research potential of BIM integrated with LCA in facilities projects. Table 3 shows the consolidation of the result of this work.

In general, the extraction criteria CE04 (plumbing project), CE07, and CE08 were not found, specifically, gathered in the articles evaluated in the RSL strategy, allowing evidence of research gaps and potential studies in BIM integrated to LCA in plumbing projects.

Conclusion

The systematic literature review of the present study sent the identification of possible gaps and

Table 3. Analysis of articles given the criteria for extracting information.

Authors	Analysis of information extraction criteria
Ahmad and colleagues [1]	This paper can highlight the development of a conceptual framework of a Bim/ACV (SimulEIcon)(C07)(C09) interaction tool for decision making taking into account the dimensions of sustainability (economic, social, and environmental).
Ahmed and colleagues [2]	This work is a case study that comems conventional constructions and green constructions with GHG emission and energy incorporated in the design phase and presents an integrated BIM/LCA tool, but does not propose the development of another tool.
Holberg and colleagues [3]	The article aims to build an integrated tool BIM/ACV (C07)(C09) for automatic extraction of material quantity (C06 using Revit/Dynamo (CE01) and the swiss database LCA(C03)/ Ecoinvent V2.2 (C02) in a commercial building (CE05) during the architectural design phase.
Kaspersen and colleagues [8]	The authors made a cradle-gate LCA (CE08) using SIMAPRO (CE02) in the hydrosanitary, electrical, and other (CE04) facilities of a commercial building (CE05), evaluating the influence of height and concluded that in buildings up to 21 floors this impact on GHG generation is negligible. The use of BIM was evidenced, but without identifying the software used, and there was also no proposal to develop a BIM-LCA integration tool.
Sozer and Sozen [9]	The work does not propose to develop a BIM-LCA(C07) integration tool but does ACV (e-QUEST/TUIK)(CE02/C03) of the tomb gate (CE08) in the construction, use, and post-use phases of multifamily residential buildings evaluating effluents and solid waste and demolition. The BIM tool (C01) has not been identified.

potential studies related to the construction of computer tools or integrated BIM-LCA frameworks applied in hydrosanitary projects. As noted, the articles selected in the information extraction process do not present an integrated BIM-LCA constructor specifically applied in projects of medical facilities. It is recommended for future work to expand the RSL using more databases and accepting articles of any kind of access.

References

1. Ahmd T, Aibinu A, Thaheem MJ. BIM-based iterative tool for sustainable building design: A conceptual framework. Procedia Engineering 2017;[s. l.]180,:782–792. Available at: https://doi.org/10.1016/j.proeng.2017.04.239.
2. Ahmed N et al. Impact of sustainable design in the construction sector on climate change. Ain Shams Engineering Journal 2021;[s. l.]12(2):1375–1383, 2021. Available at: https://doi.org/10.1016/j.asej.2020.11.002.
3. Holberg A, Genova G, Habert G. Evaluation of BIM-based LCA results for building design. Automation in Construction 2019;[s. l.]109;May: 102972. Available at: https://doi.org/10.1016/j.autcon.2019.102972.
4. Santos R, Neves E, Silvestre JD, Costa AA. Integração de BIM com Avaliação ACV: Análise do estado da arte e das ferramentas disponíveis. 16º Congresso de Inovação na Construção Sustentável. Available at:www.researchgate.net/publication/309733082_Integracao_de_BIM_com_Avaliação_do_Ciclo_de_Vida_analise_do_estado_da_arte_e_das_ferramentas_disponiveis. accessed Oct 10, 2019.
5. Machado D, Simões CCA, Moreira LCSO. Potencialidades da Iintegração do BIM ao Método de Avaliação do Ciclo de Vida das Edificações. In: 9th Brazilian Symposium on Construction Management and Economics and 6th Latin American Meeting on Construction Management and Economics (Sibragec and Elagec, 2015, São Paulo.
6. Dresch A, Lacerda PL, Anrunes Jr. JAV. Design Science Research: Método de pesquisa para avanço da ciência e tecnologia. Porto Alegre: Bookman, 2015.
7. Kitchenham B, Charters S.. Guidelines for performing systematic literature reviews in software engineering. 2007.
8. Kaspersen B, Lohne J, Bohne RA. Exploring the CO_2-impact for building height; A study on technical building installations. Energy Procedia 2016[s. l.];96 October:5–16. Available at: https://doi.org/10.1016/j.egypro.2016.09.089.
9. Sözer H, Sözen H. Waste capacity and its environmental impact of a residential district during its life cycle. Energy Reports 2020;[s. l.]6:286–296. Available at: https://doi.org/10.1016/j.egyr.2020.01.008.

Theory-Based Studies of Maritime Networks: A Literature Review

Carlos César Ribeiro Santos[1*], Hernane Borges de Barros Pereira[1,2]
[1]SENAI CIMATEC University Center; [2]State University of Bahia (UNEB); Salvador, Bahia, Brazil

This article reviews the literature regarding maritime networks, including identifying the essential articles and authors and suggesting a categorization of associated topics. Network theory in logistics demonstrates strategic information about and competitive advantages of maritime transport between regions. We analyzed 145 technical/scientific studies of maritime networks, including articles, theses, patents, dissertations, and conference proceedings. After defining the inclusion and exclusion criteria, we selected 103 technical and scientific studies, whose analysis allowed us to suggest six categories of interest: Ports, Economy, Containerized Cargo, Maritime Safety, Clusters, and Technological Solutions and Innovations.
Keywords: Network Theory. Maritime Networks. Systematic Review. Category of Analysis. Maritime Systems.

Introduction

The heading of each section should be numbered with Arabic numerals and left-aligned, with uppercase and bold letters. A space should be added between the end of a section and the heading of the next section.

In recent decades, worldwide trade growth has resulted in significant changes in maritime transport and the port system. Maritime transport is responsible for approximately 90% of goods currently transported worldwide. Changes, such as increasing the size of bulk cargo ships, oil tankers, and container ships and the intensification of the use of containers for freight transport have led to significant improvements in the sector, e.g., the emergence of economies of scale stemming from larger ships, applied technology resulting in increased safety and decreased losses in cargo transportation, a decrease in the time ships are at berth, greater operational agility, the emergence of large shipping companies, and the enhancement of intermodal operations with the creation of logistical networks, with ports being the main hubs of that model.

Received on 20 January 2022; revised 28 May 2022.
Address for correspondence: Carlos César Ribeiro Santos. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA- Brazil. Zipcode: 41650-010. E-mail: carlos.santos@fieb.org.br. DOI 10.34178/jbth.v5i2.213.

J Bioeng. Tech. Health 2022;5(2):141-145

Research studies regarding maritime transport and technological applications to waterways have emerged as direct consequences of the importance of maritime navigation to the world economy. The theory of social and complex networks is presented as a strategic tool capable of generating significant competitiveness markers for international maritime transport in these studies.

The available reviews regarding maritime networks still approach the use of network theory superficially. The present article presents a systematic literature review regarding maritime networks. Systematic reviews are useful to impartially gather as much information available about a phenomenon of interest (e.g., a research problem) over a given period, where the current date usually defines the end of the period [1].

The present paper aims to examine the state of research regarding maritime networks between 1957 and 2018; focusing on the following question: what are the analytical-qualitative categories of maritime networks that have been employed by researchers to develop maritime transport worldwide?

The present article is divided into different sections: contextualization of existing work related to maritime networks; a presentation of the research methodology employed in the construction of this systematic review, which enumerates its stages of implementation; a discussion of the results obtained; and finally, presentation of conclusions about the state of the art of this field and future research suggestions.

Maritime Network Reviews

Secondary headings should be left-aligned, and bold, and the first letter of each word should be capitalized. A systematic review of a given subject is a means to evaluate and interpret all available research relevant to a particular scientific question, scientific topic area, or phenomenon of interest [1]. Reviews aim to present an overview of a given research topic using a reliable and auditable methodology. We used the articles about reviews by Kitchenham (2007) [1], Insfram and Fernandez (2008) [2] and Borgati and Foster (2003) [3] as theoretical and methodological guidelines for the present article.

A few studies have developed theories about maritime networks and their applicability to maritime transport. A review article by Ducruet (2012) [4] published in the Journal of Transport Geography focuses on the existing scientific literature about the subject and notes the scarcity and fragmentation of empirical studies. The main reason for this lack of publications stems from the unavailability of detailed maritime traffic information, including vertices (ports), edges (shipping lanes), and flows (traffic). The authors also emphasize four research approaches to the topic: Geographical Coverage of Logistics Operators, Maritime Network Connectivity, Maritime Network Efficiency, and Complex Networks.

Although not the main focus, there are maritime networks that emphasize the economic strategies of logistics operators, such as alliance and integration [5-7] or the performance and competition of a given port within a network [8,9]. There are some relatively limited reviews about these subjects.

Likewise, some geographers have blazed a path for the study of maritime networks by analyzing maritime transport company strategies, considering the spatial extension and expansion of port networks, such as the study about Maersk [10] and those about regional maritime transport networks in Asia [11-14].

Material and Methods

This section presents the stages of constructing a systematic review:

Stage 1: The first stage consists of planning the literature review, where the need for the review is identified and the research questions and literature review protocols are determined. A literature review about the application of network theory in the maritime navigation context is sorely needed because of the lack of effective studies on this subject, in addition to the subject's importance to society, because it can provide social, competitive, and economic benefits to a given country or region.

We considered the following research question: what are the categories of analysis of maritime networks that have been used by researchers in the development of world maritime transport? This research question will enable summarizing the existing knowledge of marine networks and identifying gaps; future research topic areas are suggested.

Data Sources

The principal sources used for the construction of this review of maritime networks consisted of five digital databases and three books: Web of Science (Thomson Reuters); Scopus (Elsevier); Portal Periódicos from Capes/MEC/Brazil; ScienceDirect; Scientific Electronic Library On-Line (all countries). We analyzed publications between 1957 and 2018. In the period 1950-to 1980, marine network studies were scarce. Nevertheless, some works published during this period are seminal and are still used by researchers. Data collection was performed from July 1st, 2014 to April 2nd, 2018.

Stage 2: The second stage consists of (i) determination of scientific research data inclusion and exclusion criteria, (ii) construction of a summary with results of the application of the descriptors to digital databases, and a table that lists the resulting technical and scientific products (i.e., articles, books, patents, theses, and dissertations), and (iii) analysis of the categorization.

Inclusion Criteria

We defined two inclusion criteria for the selection of technical and scientific literature about the subject: (IC1) works that propose and/or describe methods for construction and analysis of maritime networks applied to different regions of the world and (IC2) works that apply network theory as a method theoretical framework to maritime transport.

Exclusion Criteria

The need for filtering the resulting technical and scientific output in digital databases led us to define five exclusion criteria: (EC1) works that did not analyze maritime transport, whether long distance or cabotage; (CE2) works that did not refer to network theory; (EC3) repeated works (appearing more than once in different digital databases); (EC4) full or summarized works published in technical or scientific proceedings of conferences/events; and (CE5) patents.

Descriptor Definitions

Definition of descriptors was necessary to search for technical and scientific publications about the subject. The terms Maritime Network, Network Maritime, Complex Maritime Networks, and Complex Networks were used as descriptors of maritime networks. We found a total of 145 works. A hundred three were from scientific journals (n=96, 93.21%), doctoral theses (n=2, 1.94%), master's theses (n=2, 1.94%), and books (n=3, 2.91%).

Characterization of the Technical and Scientific Output

We built a theoretical matrix to detail the selected technical and scientific output and thus address the need for their characterizations. The following aspects were considered: application of network theory; definition of categories of study, i.e., focused on a theoretical framework or computational modeling (or both); and research method used. Figure 1 represents a framework of the method.

Results and Discussion

This section analyses the main publications on maritime networks, and their authors. We divided this section according to publication typology: Clustering, Containerized Cargo, Ports, Economic Conditions, Technology Solutions, Innovations, and Maritime Safety.

Clusters

The analysis of clustering and its direct influence on the existence of maritime networks is a research field experiencing remarkable growth. Vieredyte (2013) [15] demonstrates the importance of clustering for the competitiveness of maritime businesses in Europe. However, the author does not focus directly on building complex systems to develop competitiveness in that region but rather on the difference between top-down clusters (financed by public organizations) and bottom-up clusters (financed by companies). Vieredyte (2013) [15] also highlights the need to build a European cluster database for the development of new strategies and strengthening maritime organizations in the region.

We realize that research about clusters and maritime networks is still in its infancy compared with other categories. However, the benchmarks presented herein indicate a worldwide growth of Clustering studies, with impacts on international maritime geography. This growth will enable future exploration of the theme with the aid of network theory.

Containerized Cargo

The use of containers for the shipment of goods in international maritime transport has grown substantially during the last decade. For

Figure 1. The framework of Review Method.

example, the handling of containerized cargo grew proportionally 81% more compared with liquid and dry bulk in the last eight years in Brazil alone [16]. In this sense, the number of publications related to containerized cargo utilizing maritime networks marks the relevance of this analysis.

Regional Economic Conditions

Some publications about maritime networks emphasize the importance of economic data in their construction [17]; discussed the influence of the Tehran port and its economic drivers in maintaining maritime networks. Sen (2006) [18] investigated the political history, especially the economic history, in the formation of South Asian maritime networks. The article depicts historical trade relations in Asia and their direct influence on the establishment of maritime networks in South Asia. From the surveyed benchmarks, we found that economic factors are relevant to the formation of maritime networks. However, the importance of this issue in international competitiveness demands a deeper analysis and additional specific research regarding the economy and these network formations.

Port Location

The importance of port location is reinforced in published works concerning maritime networks and their construction. The majority of published methods use ports as vertices and the movement of ships between ports as edges. Thus, most publications about maritime networks focus on the importance of ports to establish an efficient maritime network infrastructure. The number of authors and publications in the international literature regarding maritime networks indicates the growth and importance of ports for determining maritime networks.

Technological Solutions and Innovations

Maritime networks, the focus of the present review, exhibit an important category of scientific research – technology applications in the optimization of movements between ports.

Maritime Safety

Regional and national protection, the development of national safety systems, and the survival of sea operators are directly related to the construction of maritime networks. This finding arises from the ability of complex systems in providing countries with technology that can be used in the fight against terrorism and the increasingly enhanced monitoring of sea movements.

Conclusion

This article presented a systematic review of the maritime networks and their applications between 1957 and April 2018.

The results of this literature review point to a vast field of research regarding maritime networks to be explored by the scientific community, especially the Clustering, Containerized Cargo, Regional Economic Conditions, Port Importance and Location, Technologic Solutions and Innovations for Maritime Navigation, and Maritime Safety, qualitative categories and the possible intersections among them.

The number of categories may be expanded based on the significant number of associated publications; critical topics include dry and gas

cargo handling, oil tankers, insurance in cargo handling (all types), and boarding operations. We emphasize the need to conduct additional research regarding Network Theory use and simulations as logistical support instruments to existing maritime systems. Finally, we believe in the importance of this review article as a summary of recent theoretical benchmarks for those seeking to investigate maritime networks. Academics in general, consultants, researchers, and other interested parties can use this review to more objectively guide their research.

References

1. Kitchenham B. Guidelines for Performing Systematic Literature Reviews in Software Engineering. Version 2.3, EBSE Technical Report, Keele University, UK, 2007.
2. Insfram E, Fernandez Adrian. A Systematic review of usability evaluation in Web development. ISSI Group, Department of Information Systems and Computation Universidad Politécnica de Valencia Camino de Vera, Valencia, Spain, 2008.
3. Borgatti SP, Foster PC. The network paradigm in organizational research: A review and typology. Journal of Management 2003;29(6):991–1013.
4. Ducruet C. Port regions and globalization, in T.E. Notteboom. Ports in proximity: Competition and coordination among adjacent seaports, Aldershot: Ashgate 2012:41-54. Available at < http://www.sciencedirect.com/science/journal/13665545>. Accessed on: 07/08/2021.
5. Bergantino AS, Veenstra AW. Interconnection and coordination: an application of network theory to liner shipping. International Journal of Maritime Economics 2002;4(3):231-248.
6. Bergantino AS, Veenstra AW. Complexity in liner shipping networks. Paper presented at the International Association of Maritime Economists Conference, Athens, Greece, 2007;July:4-6.
7. Parola F, Veenstra AW. The spatial coverage of shipping lines and container terminal operators, Journal of Transport Geography 2007;16(4):292-299.
8. Veenstra AW, Mulder HM, Sels. Analyzing container flows in the Caribbean. Journal of Transport Geography 2005;13(4):295-305.
9. Wilmsmeier G, Hoffmann J. Liner shipping connectivity and port infrastructure as determinants of freight rates in the Caribbean. Maritime Economics and Logistics 2008;10(1-2):130-151.
10. Fremont A. Global maritime networks: the case of Maersk, Journal of Transport Geography 2007;5(6):431-442.
11. Robinson R. Ports as elements in value-driven chain systems: The new paradigm, Maritime Policy, and Management, 2002. Available at < http://www.journals.elsevier.com/computers-and-industrial-engineering>. Accessed on: 06/07/2021.
12. Comtois C, Wang JJ. Géopolitique et transport: nouvelles perspectives stratégiques dans le détroit de Taiwan, Études Internationales 2003;34(2):213-226.
13. Rimmer PJ, Comtois C. China's extra and intra-Asian liner shipping connections 1990-2000, Journal of International Logistics and Trade 2005;3(1):75-97.
14. Ducruet C, Zaid F, Inria B. Maritime constellations: A complex network approach to shipping and ports. Maritime Policy and Management 2012;39(2):51-168. [Special issue on "The Geography of Maritime Transport: Space as a Perspective in Maritime Transport Research"], 2012. Available at < http://www.sciencedirect.com/science/journal/13665545>. Accessed on: 07/08/2021.
15. Viederyte R. Maritime cluster organizations: Enhancing role of maritime industry development. Procedia - Social and Behavioral Sciences 2013;81:624–631.
16. Agência Nacional de Transportes Aquaviários – ANTAQ. Relatórios Técnicos 2006 a 2012. Relatórios de Desempenho Portuário, Brasília, 2013. Available at <http:// www.antaq.gov.br>. Accessed on: 29/06/2021.
17. Knappett C, Evans T, Rivers R. Modelling maritime interaction in the Aegean Bronze Age. Antiquity 2008;82(318):1009-1024.
18. Sen T. The formation of Chinese maritime networks to Southern Asia 1200-1450. Journal of the Economic and Social History of the Orient 2006:421-453.

Application for Holographic Pyramids in Exhibition Spaces: An Expansion of the Teaching Model

Júlia Maria Nascimento Ribeiro[1*]
[1]*SENAI CIMATEC University Center; Salvador, Bahia, Brazil*

Research indicates that Augmented Reality can contribute to the challenges of communicating complex research findings in an accessible language to a broader audience. This research will use the methodology of Design Science Research divided by the following: (1) Characterization of current knowledge on the subject based on an integrative literature review in the Scopus and Web of Science scientific databases; (2) Requirements and architecture of applicable hardware and software.
Keywords: Holographic Pyramids. Augmented Reality. Exhibition Space. Classroom.

Introduction

Augmented reality (AR) is the overlap of virtual elements and reality. This technology got popular in 2016 with the game Pokémon GO, which brought light over the AR, especially for the grate masses. Even though the popularity of AR had achieved extraordinary numbers in 2016, its origin comes from long before. It was created in 1992 by the scientist Thomas P. Caudell to make an easier way of building the Boeing 747. However, the project to build a monitor to guide the installation of the Boeings' parts was not successful. Caudell's monitor did not work, but it does not cancel that he is the father of AR, a technology with much potential. The AR can be used in the making of cars, in surgeries, in education, translation, facial scanners, and many others.

In Brazil, the AR has already been used in museums, as in the National Historical Museum in Rio de Janeiro, which counts with a system of augmented reality. This system has the responsibility of giving museum visitants additional information about the pieces in the exhibition, especially the exhibition of the royal carriages and cars of the empire that has been the principal pieces involved in the system of AR. The museum faces some difficulties, knowing the AR system is available to visitants, the necessity of a good internet signal, due to it is an old building (XVII – XVIII century), and the internet signal is too weak inside the museum, and also the mobile data has some trouble working inside the building [1]. All those difficulties reduce the efficiency of the AR system and reduce the number of people that know and have access to the system and the knowledge that it holds.

The holograms have been used for many years, having started with simple techniques such as the Pepper ghost or Monga effect, which consists of light refraction to create optical illusions and advanced systems such as overhead projectors. Holograms are already widely used in the entertainment world. However, this image display technique has great potential for use in other areas, such as in the world of information display, where holograms can generate expansion of the way a subject is understood and exposed, expanding the absorption of the content and enabling the observation of details that were previously unnoticed. Holographic pyramids are a way more viable option for using holograms, even though it is not a hologram itself, the holographic pyramid has the same effect as a hologram projected to the eye of the same effect as a hologram projected to the eye of the observer, and this technique is very useful in exposing data and projects, and being a resource that is simpler to be handled and cheaper to build than the most advanced equipment for the projection of holograms.

The holographic pyramids belong inside of the world of the augmented reality (AR), which mixes

Received on 12 January 2022; revised 25 April 2022.
Address for correspondence: Júlia Maria Nascimento Ribeiro. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA- Brazil. Zipcode: 41650-010. E-mail: julia.ribeiro@aln.senaicimatec.edu.br. DOI 10.34178/jbth.v5i2.214.

J Bioeng. Tech. Health 2022;5(2):146-149

the real world with the virtual world, bringing a whole new interaction between the virtual world and the user that is being exposed to this technology, AR brings an entire set of possibility to the exhibition world. Inside the AR, the holographic pyramids are a cheaper possibility to exhibit information and data, even thou the holographic pyramids are being more used in entertainment as a playful option to introduce the world of AR to children would be a great way to improve the teaching. For that matter, the use of holographic pyramids has much potential and has been already used in education because it can bring to the students a new way of seeing the subjects taught, which can get a novel experience and improve teaching as it is known, being able to teach subjects that were considered hard to understand more readily.

Material and Methods

The method in this paper follows the technique of literature research, going through similar papers and assimilating the main idea to create a new vision of augmented reality. The principal research has focused on the use of augmented reality in exhibition spaces such as museums, but also the capacity of this technology as a new tool in education, especially in the teaching of science in general. The holographic pyramids have great potential inside the classrooms, and this potential has been explored in multiple papers that bring on this subject, especially the use of holographic pyramids and AR in the school environment. The bibliographic research has focused on papers published from 2016 to 2021, the Google Scholar and the site SCIELO have been the principal sources of research for the articles.

Results and Discussion

After the literature review, the various applications of holographic pyramids, especially in education, were verified, and the holographic pyramids can expose subjects considered by most as difficult in a much more playful and palpable way, which makes the absorption of these subjects much easy. However, this technology in classrooms comes with several variables that can reduce the effectiveness of holographic pyramids use. Among these variables are the issue of building the pyramid, obtaining quadruple videos, and the Know-How to work with the pyramids and get the best of your performance.

The Holographic Pyramid Constructions

There are several models of holographic pyramids. The most common is the basic model composed of four sides with a transparent material (glass, acrylic, among others) and a device to project the images, transformed into holograms. Regarding the position of the projector device, the pyramids are divided into two groups, the inverted pyramids that have the projector device at the bottom and the non-inverted pyramids that have the projector device at the top. Pyramids can also vary in many sides and can have between three (Figure 1) and four sides (Figure 2), the 3-sided pyramid provides more space for projection, or the 4-sided model, which is the most common, in Figure 3 is possible to see a small comparison between the three-sided and the four-sided pyramid.

In addition to the projector positioning issue and the number of pyramid sides, refraction is also a crucial issue for AR. According to Shivani in his article “Holographic pyramids: conceptual errors and didactic potential”, when increasing the size of the monitor, which is responsible for projecting the images inside the pyramids, there is a simple “doubling” image. This duplication is due to the multiple reflection factor mentioned by Shivani. Depending on the angle of incidence, dimensions, and the type of material used in the pyramid built (acrylic, glass, polymers, among others). To ensure the stability of the structure by enlarging the size of the pyramid, it is necessary to build it using materials already mentioned. Therefore, we chose to use 4.0mm thick acrylic sheets, especially because it is lighter and offers less risk of accidents when compared to glass (Shivani, 2017).

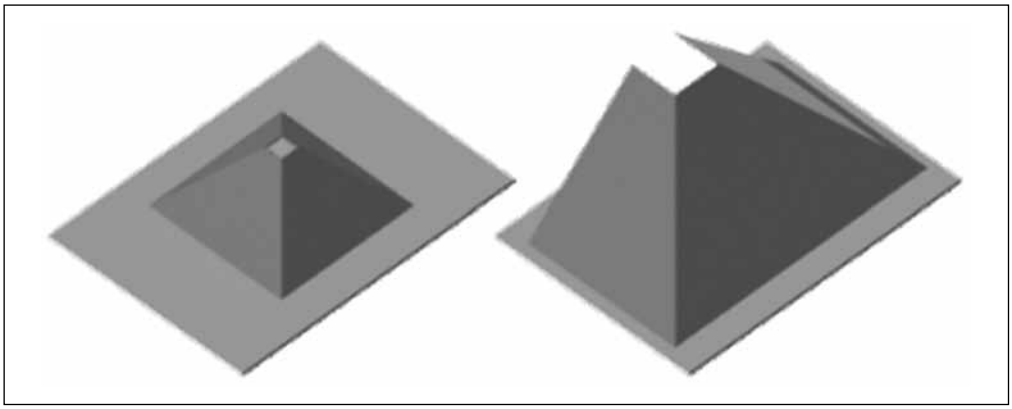
Figure 1. Three-sided holographic pyramid model with the overhead projector.

Source: Blupix.

Figure 2. Four-sided pyramid model with the projector on top.

Source: Four-season electronics.

Figure 3. Comparison of the area of the pyramids with 4 and 3 sides about the projection screen in the top view.



Source: Gabriel Anciuti [2].

According to the Shivani model, some measures are recommended, as follows: the use of 2mm thick acrylic, to reduce the internal reflection of the images, in addition to the Shivani scaling (2018) that has a trapezium with a dimension of 24 cm at the base, 14 cm from height and 4 cm at the top, these being the base measures, and the pyramid can be built at different scales from the multiplication or division of the measures already mentioned, in addition to the measures already mentioned, it is recommended that a triple layer of an automotive film be used, to thus decreasing the reflection rate, thus eliminating the appearance of double images.

Obtaining Quadruple Videos

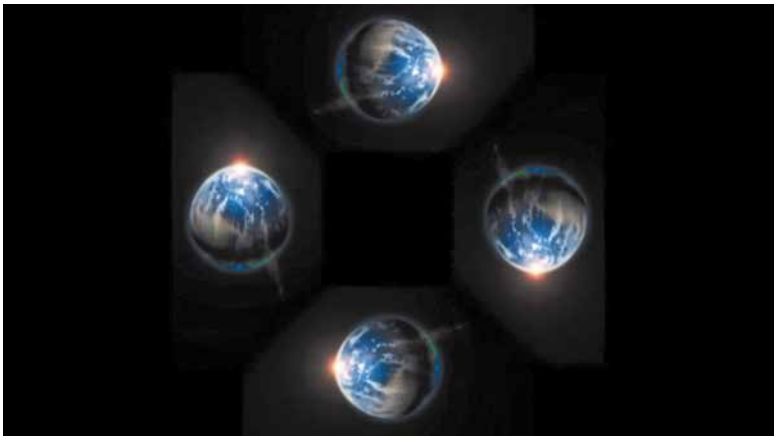
Another issue for holographic pyramids is the manufacture of quadruple video, the type of video necessary for the use of pyramids. It is necessary to manufacture a video in which the image you want to transform into a "hologram" is represented four times (Figure 4). Each image is positioned at one side of the video, all with the same distance from the middle that must remain free. This free medium is where the pyramid should be positioned. The video must be done through some computational method. The Sony Vega is an option because it is free, easy and intuitive handling, which would be recommended for people who are not so familiar with the area of computing and video editing. However, the pyramid user can make the video where he feels most comfortable as long as he uses the information above on how the images can be positioned.

Conclusion

Given the above, augmented reality has many possibilities within exhibition spaces, with even more potential within the scope of education, having the ability to make learning much more playful and efficient by bringing the idea of the third dimension to classrooms, thus creating the possibility of exemplifying subjects considered abstract more efficiently.

Thus, the use of holographic pyramids in classrooms brings, in addition to the possibility of more efficient teaching, difficulties that can be surpassed using the parameters already defined and the correct materials. With the writing of this article, it was possible to visualize the influence of augmented reality in everyday life and the influence of technology on education, showing that technological advances can be of great help in education since scientific advances and education are interconnected.

Figure 4. Quadruple video example for holographic pyramids.



Source: Trendy.

References

1. Marçal AO. A Realidade aumentada como ferramenta de mediação: análise crítica de sua aplicação no Museu Histórico Nacional. Universidade Federal do Estado do Rio de Janeiro, Rio de Janeiro, 2018. Disponível em: http://www.repositorio-bc.unirio.br:8080/xmlui/bitstream/handle/unirio/12713/alessandra_oliveira_mar%C3%A7al.pdf?sequence=1. Acesso: 05 de julho, 2021.

2. Anciuti GAC. Captura de movimento na construção de animações em pirâmides holográficas: Um case do projeto The Rotfather. Universidade Federal de Santa Catarina, Florianópolis, 2019, Disponivel em: https://repositorio.ufsc.br/bitstream/handle/123456789/219973/Projeto_de_Conclusao_de_Curso_-_Captura_de_movimento_na_construcao_de_animacoes_em_piramides_holograficas_Um_case_do_projeto_The_Rotfather_-_Gabriel_Anciuti.pdf?sequence=1&isAllowed=y. Accessed: 05 de Jul, 2021.

Battery Thermal Management System for Electric Vehicles: A Brief Review

Artur Sales Carlos Maia de Amorim[1*], Fernando Luiz Pellegrini Pessoa[1], Ewerton Emmanuel da Silva Calixto[1]
[1]Professional Master in Industrial Management and Technology, University Center SENAI CIMATEC; Salvador, Bahia, Brazil

Battery is the heart of an electric vehicle. The global growth of electrification in the automotive market makes improvements in battery health and longevity a vital aspect to consider to accommodate this growing demand. This paper presents a qualitative literature review on different battery thermal management systems (BTMS) for electrified vehicles. Different works in the literature were examined to determine the types of BTMS to be considered and their main characteristics. As a result, we listed different types of BTMS with their main characteristics. This brief review can support the research about battery thermal management systems as a summary of the state-of-the-art on this topic.
Keywords: Battery Thermal Management. Battery Cooling. BTMS.

Introduction

Lithium-ion batteries have a fundamental role in the acceptance and diffusion of electric vehicles worldwide as they are one of the main components of electric vehicles and, depending on the battery's energy capacity, it can reach 27% of the total cost of the vehicle [1]. Due to this high cost, reducing the degradation and improving the life cycle and safety of lithium-ion batteries are still one of the main challenges for its development and application in electric vehicles [2]. Reviews from the literature showed that the capacity, life cycle, and safety of the battery depend significantly on the temperature, whether it is high (>50 °C) or low (<15 °C) [2-4]. Many temperature ranges are recommended for lithium-ion batteries in the literature, but only a range between 15 °C and 35 °C is desired [5].

Some battery suppliers define four temperature ranges [1-14] as follows: (1) (0–10 °C) decreased battery capacity and pulse performance, (2) (20–30 °C) optimal range, (3) (30–40 °C) faster self-discharge, and (4) (40-60 °C) irreversible reactions, with 60 °C being the upper safety limit under normal operating conditions. Another crucial point is the temperature uniformity between the battery cells in which the temperature difference must be <5 °C [4-8]. Tete and colleagues [4] revealed that at high temperatures, lithium-ion battery cells lost more than 60% of their initial energy after 800 cycles at 50 °C and lost 70% after 500 cycles at 55 °C. In another example, they reported that a lithium-ion battery life cycle at 45 °C is approximately 3323 cycles, and this value is reduced to 1037 cycles at a temperature of 60 °C. Currently, the temperature control of batteries in electric vehicles is done through the use of the battery thermal management system (BTMS).

This system is responsible for ensuring that the battery works in the proper temperature range and keeps the temperature between the cells as homogeneously as possible [1-15].

Based on this context, this paper aims to present a brief literature review on the types and pros & cons of battery thermal management systems for electrified vehicles to drive new researchers on this topic and as a comprehensive data for beginners.

Materials and Methods

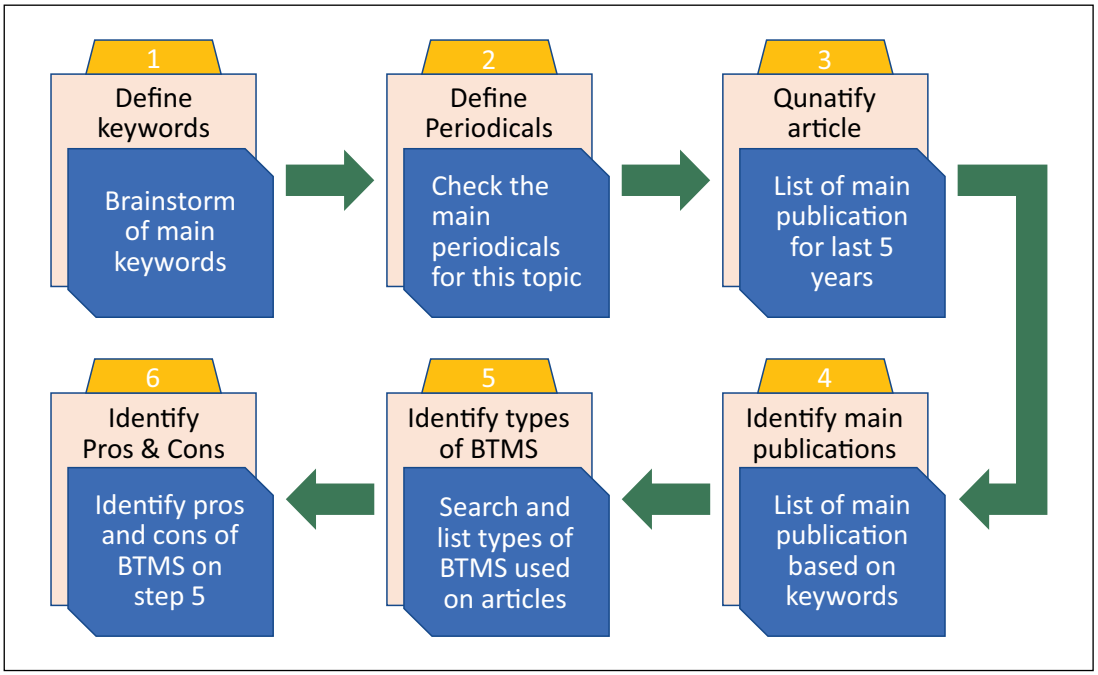
Figure 1 represents the steps and works definition to identify the data used herein.

The first step is the brainstorming session to define the keywords for the initial exploration of battery thermal management system that has as result the following list: "battery cooling", "battery thermal management" and BTMS. The list is intentionally

Received on 20 December 2021; revised 21 February 2022.
Address for correspondence: Artur Sales Varlos Maia de Amorim. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA-Brazil. Zipcode: 41650-010. E-mail: artursales@hotmail.com.
DOI 10.34178/jbth.v5i2.215.

J Bioeng. Tech. Health 2022;5(2):150-154.

Figure 1. Method used in this study on battery thermal management systems for electrified vehicles.



Source by the authors.

simple to optimize the number of returned articles on the exploration performed in the scientific periodicals. Those keywords were used on different scientific databases as follows: Science Direct (www.sciencedirect.com), Scopus (www.scopus.com), MDPI (https://www.mdpi.com), Google Scholar (www.scholar.google.com), SAE (www.sae.org/publications/technical-papers), and CAPES Periodicals (www.periodicos.capes.gov.br), as they are the most recognized databases for engineering field. After a few tryouts, it was noticed that there is a large number of articles for each platform, and to simplify the analysis of the publication titles, only review articles published in the Science Direct and MDPI platform were considered due to results aligned with the aim of this paper. These databases are robust scientific directories, which reason why they were considered in these analyses.

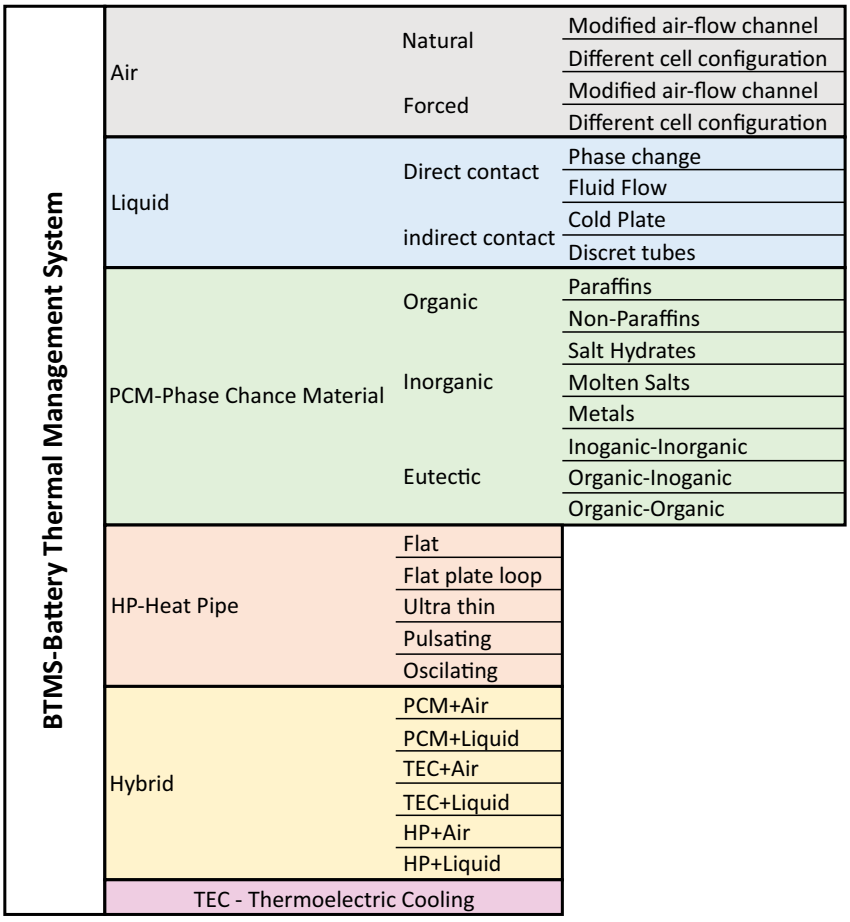
Results and Discussion

In the literature, there are several forms of BTMS classification. Some authors [4-6] classify it by the system's energy consumption as passive and active, and others [2]classify it by functionality as preheating, cooling, and emergency. The most common form of classification is based on the medium used for heat transfer: air, liquid, PCM-phase change material, TEC-thermoelectric modules, HP-heat pipe, and hybrid models. Figure 2 presents the possibility of grouping the types of BTMSinto 6 main sets - the hybrid set is composed of a combination of two or more types of the other BTMS.

Each BTMS system has a specific feature that makes it more suitable for certain applications. Listed below are the main characteristics to be considered when choosing a medium that will exchange heat with the battery components that need to be cooled or heated [4]:

- Thermal conductivity: It is the capability that the medium has to exchange heat with the environment around it, whereas the higher the coefficient efficiency is, the higher is also the battery temperature control and heat transfer.

Figure 2. List of BTMS under study in literature.



Source by the authors.

- Heat capacity: the amount of heat to be supplied to an object to produce a unit change in its temperature. The higher the value, the more the medium can accumulate heat with a low-temperature change.
- Viscosity is the resistance a fluid (air or liquid) has to flow. Medium with high viscosities requires more energy to flow. The lower viscosity is the smaller energy consumed by the system.
- Dielectrics: to avoid electrical short, liquids should be as deionized water, silicon-based oils, or mineral oils.
- Nontoxic: It can't cause damage to the operator or environment.
- Inflammable: In case of leakage, it can't catch fire when exposed to a hot surface.
- Good chemical stability: It can't change properties or composition in long-term usage.

Despite the characteristics of the medium, the BTMS system must have some fundamental characteristics, such as follow: cooling to remove heat from the battery, heating for very low-temperature environments, insulation to prevent sudden changes in battery temperature, ventilation to exhaust the potentially dangerous gases from the battery, as has a low volume as space in vehicles are limited, be light helps the system's efficiency, low

cost, high reliability since the battery is the heart of the electric vehicle, low energy consumption (pump, fans, and heaters), easy maintenance and assembly.

Currently, each OEM has its particularity in the definition of the thermal management system, but, for hybrid and electric vehicles with low power batteries, the most adopted cooling system is air due to its simplicity and low energy consumption. On the other hand, in hybrid vehicles and 100% electric vehicles with high battery power demand, the most widespread system is liquid cooling due to the ability to keep the battery at the ideal temperature even in extreme battery usage and high heat release. In a comparative assessment carried out by Han and colleagues [15], they demonstrated that while the liquid cooling system has a rating of 500 W/K, the air-cooling system is around 70 W/K. Table 1 shows the main characteristics of each BTMS.

Conclusion

This paper highlights the importance of BTMS for electrified vehicles and reveals the current BTMS under study in the literature and their pros and cons. Despite the many varieties of BTMS in the literature and their pros and cons, only air and liquid cooling have been implemented for commercial purposes in electric vehicles and hybrid electric vehicles, whereas other cooling methods are still under research. It indicates a long way to run research and development technics that make the most efficient BTMS feasible to implement and commercialize.

These findings are significant to support new research on this topic and can be used as comprehensive information for beginners on electrified vehicles, giving directions on types of battery cooling and critical points during definition and usage.

Table 1. BTMS pros and cons.

BTMS	Pros	Cons
Air	Simplicity, low weight, electrical safety, easier maintenance, no worries about leaks, and low cost [4-8,15].	Low thermal conductivity, and wind noise, can't be used for high cooling demand [4-8,15].
Liquid	High thermal conductivity, is mostly applied for high cooling demand [2-15].	Complexity, high cost, heavy, must store the fluid, viscosity, potential leaks, additives for anti-freeze & Boiling [2-15].
PCM	Passive BTMS, better thermal management due to its high latent heat, promises effective thermal energy storage [2-13].	Low thermal conductivity, need an additive to improve thermal conductivity, can't be used alone just works with hybrid model [2-13].
HP	Passive BTMS, good thermal conductivity [4].	Can't be used alone just works with the hybrid model, low efficiency, and small contact area [4].
TEC	Using the Peltier effect can heat and cool at the same surface depending on the current direction, and low complexity [4,6,14].	Low thermal conductivity, can't be used alone just works with a hybrid model [4,6,14].
Hybrid	It has the pros of each method that it decides to combine [6].	It has the cons of each method that it decides to combine [6].

References

1. Bernhart W et al. E-Mobility Index 2019; Roland Berger-Automotive Competence Center & fka GmbH: Munich, Germany, 2019.
2. Lin J et al. A review on recent progress, challenges, and perspective of battery thermal management system. International Journal of Heat and Mass Transfer 2021;167.
3. Choudhari VG et al. A review on the effect of heat generation and various thermal management systems for the lithium-ion battery used for the electric vehicle. Journal of Energy Storage 2020;32.
4. Tete PR et al. Developments in battery thermal management systems for electric vehicles: A technical review. Journal of Energy Storage 2021;35.
5. Pesaran A et al. Tools for designing thermal management of batteries in electric drive vehicles (presentation); technical report. National Renewable Energy Lab. (NREL). USA, 2013.
6. Zhao C et al. Hybrid battery thermal management system in electrical vehicles: A review. Energies 2020;13(23).
7. Raza W et al. Induction heater based battery thermal management system for electric vehicles. Energies 2020;13(21).
8. Jeffs J et al. Optimisation of direct battery thermal management for EVs operating in low-temperature climates. Energies 2020;13(22).
9. Jaguemont J, Mierlo JV. A comprehensive review of future thermal management systems for battery electrified vehicles. Journal of Energy Storage 2020;31.
10. Youfu LV et al. Experimental investigation on a novel liquid-cooling strategy by coupling with graphene-modified silica gel for the thermal management of cylindrical battery. Applied Thermal Engineering 2019;159.
11. Weixiong WU et al. A critical review of battery thermal performance and liquid-based battery thermal management. Energy Conversion and Management 2019;182.
12. Ziegler MS, Trancik JE. Re-examining rates of lithium-ion battery technology improvement and cost decline. Energy & Environmental Science 2021;14:1635-1651.
13. Gao M et al. Lithium metal batteries for high energy density: Fundamental electrochemistry and challenges. Journal of Energy Chemistry 202;59:666-687.
14. Shujie WU et al. The state of the art on preheating lithium-ion batteries in cold weather. Journal of Energy Storage 2020;27.
15. Taeyoung HAN et al. Li-ion battery pack thermal management: Liquid versus air cooling. ASME. J. Thermal Sci. Eng. App. 2018;11(2).

Violence Detection on Board of Shared Autonomous Vehicles: A Literature Review

Raufi F. Stella[1*], Camila de Sousa Pereira Guizzo[2], Xisto Lucas Travassos[3]
[1]Product Development, Ford Motor Company; [2]Programa de Modelagem Computacional e Tecnologia Industrial, SENAI CIMATEC University Center; Salvador, Bahia; [3]Federal University of de Santa Catarina; Joinville, Santa Catarina; Brazil

This paper presents proposals for technological solutions to previously detect violence among passengers of a shared autonomous transport mode. By analyzing the Design Science Research method and the conjectural behavior of the population, the problem contextualization about the safety of public transport can be determined in terms of violence. So, a product meant to detect violence is proposed in this study. Product design proposals, based on artificial intelligence, are described within. We concluded that this subject is relevant and demands more attention to support the public acceptance of autonomous vehicles (AVs), and shows there are existing solutions that can be adapted to fulfill the needs of this specific usage.
Keywords: Surveillance. Safety. Shared Autonomous Vehicle. Violence. Detection.

Introduction

Urban areas will concentrate at least 60% of the world population until 2030 [1]. The increase in the urban population will put a strain on the current public transportation system. To prevent this fact and provide sustainable growth, United Nations (UN) has established ambitious targets for the beginning of the next decade. These targets call for valuable transport systems for everybody that will have to be affordable, accessible, safe, and sustainable. This will improve road safety, as well as provide for people who need special attention, such as people in vulnerable situations, people with disabilities, the elderly, women, and even children.

There are several work streams in place to propose solutions for urban mobility in the future. One of them is the race for the development and implementation of autonomous vehicles, which promise to minimize the traffic chaos in big cities [2]. It has been said that urban transportation will face three revolutions in the form of fleet electrification, automation, and ride-sharing [3]. Those will translate to less pollution, less traffic, and better use of the vehicle fleet. The fully self-driven vehicles, with level 5 autonomy [4], will have a highly beneficial impact on the lives of people who are not eligible for driving. It was also demonstrated that when more shared autonomous vehicles are used; more benefits for the population exist. That means by having mobility as a service in place, creates an environment where vehicles don't pollute and are fully shared, as well as integrated into other transportation modes [5]. Incentivizing the population to use shared transport is a key priority for a public administration that aims to improve urban mobility and consequently, some hostile problems must be faced and reduced. Sexual harassment is a reoccurring and worrying issue on public transportation and is typically against women [6]. The integration of various modes of transportation during a unique trip makes the user more exposed to violence when transferring from one mode of transportation to another [7]. Besides that, emerging countries like Brazil are experiencing rising levels of violence in big urban centers [8].

So far, tests with self-driven vehicles have been performed in developed countries only. Although there are still many constraints to be solved, such as legislation, privacy, cybersecurity, vehicle to vehicle, vehicle to infrastructure connection, and others; sooner or later, autonomous vehicles are going to hit the roads, and spread out into the world. The point is that safety issues related to violence are mostly present in emerging countries,

Received on 18 January 2022; revised 28 April 2022.
Address for correspondence: Raufi F. Stella. Via Atlântica, BA 530, Km 2,5. Camaçari- BA- Brazil. Zipcode: 42810-440. E-mail: rstella2@yahoo.com. DOI 10.34178/jbth.v5i2.216.

J Bioeng. Tech. Health 2022;5(2):155-159.

and maybe overseen by the developers of this new disruptive technology.

Problem Contextualization

In a near future, solutions for urban mobility will be at the forefront; therefore, a trend of stakeholders such as academy researchers and car manufacturers will be betting on the shared autonomous vehicle as a strong competitor. The fact is that, beyond congestion problems, the high population density in big cities will worsen safety and security issues for the population. If we compare an autonomous vehicle to a vending machine, we may see that a surveillance safety system should be in place to inhibit the action of criminals. Today's public transportation system is not perfect, but the simple aspect of having more people around may help in terms of law and order, even if it is a single bus driver.

Thus, the pain point is the vulnerability of the passengers of a shared autonomous vehicle transportation service in terms of violence.

Research Question

What is the existing literature regarding violence detection technologies that could contribute to the development of a surveillance system to be implemented on shared autonomous vehicles?

Research Objective

This study aims to identify the state-of-the-art technologies, which are treated as potential features of the proposed artifact and fulfill the requirements to meet the expected function.

Material and Methods

The method used is based on the Design Science Research Model (DSRM), which is a variation of the Design Science Research (DSR), as a means of practicing scientific research through the development of an artifact. DSR may have either the approach of generating technical and scientific knowledge or developing an artifact to solve a problem. DSRM follows the foundation of DSR and states that the development of an artifact has to be grounded on the conjectural behavior of people in terms of how they learn, work, and communicate. This conjectural behavior is then applied to the development of such an artifact, which is meant to solve an existing pain point that may bother those people (Figure 1) [9].

DSR is largely used in the information systems (IS) field, leading to either scientific or technical knowledge or both. The first step in a DSR is the literature revision. In addition, being the artifact novel and useful, thus it contributes to design knowledge [10].

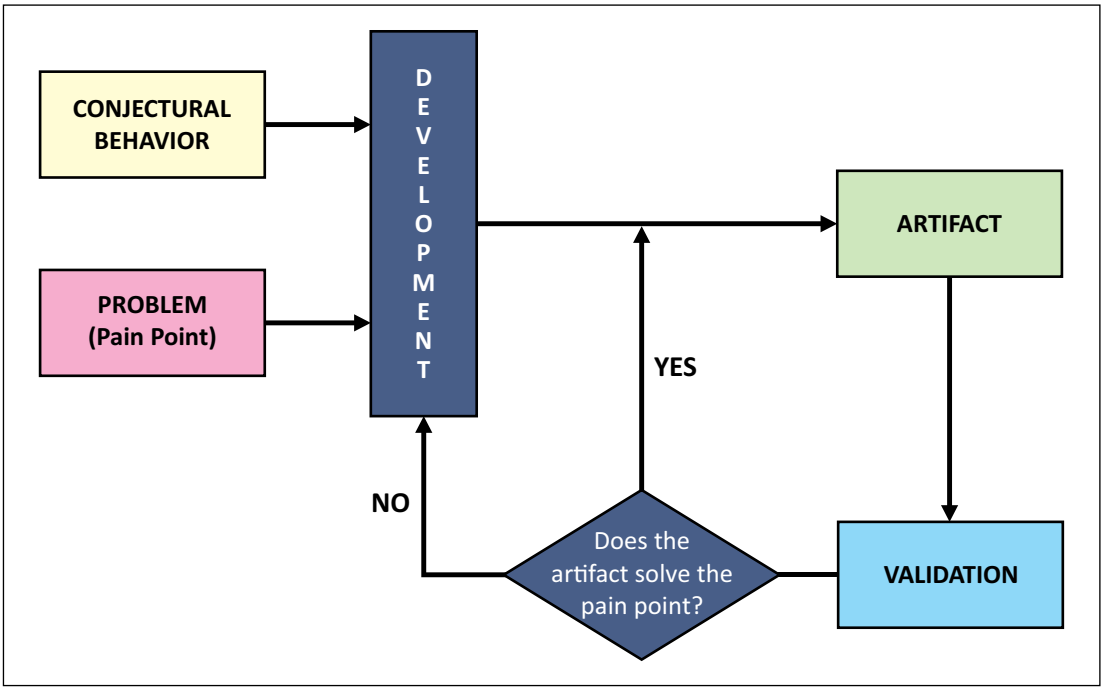
Being a qualitative type study, the present research aims to seek information about a supposed artifact that will minimize the pain point of a group of people by proposing solutions to answer the research question.

Research Parameters

Only recent papers from 2019 to 2021 were selected, according to the following search string applied: (Surveillance), AND ("Violence detection"), AND (Safety), AND ("Shared Autonomous Vehicle") OR ("Autonomous vehicle") OR ("Self-driven vehicle"), AND (Violence) OR (Harassment) OR ("Sexual abuse"). The usage of punctuation such as commas, inverted commas, brackets, and the prepositions AND, OR were necessary to restrict the search of papers related to some kind of violence, which were also related to the new technology of the shared autonomous vehicles, which can also be found with the terminology of self-driven vehicles. The data banks used for information research were:

- Google Scholar (https://scholar.google.com
- Science-Direct Elsevier (https://www.sciencedirect.com)
- IEEE Xplore Access Digital Library (https://ieeexplore.ieee.org).

Figure 1. Design Science Research Model (DSRM).



Source: Adapted from Pimentel and colleagues [9].

The search resulted in only eleven papers, which suggests that the subject violence detection referred to shared autonomous vehicles is still limited. These papers were evaluated, and only two were relevant to autonomous vehicles. This drove the author to search for more information in papers related to violence detection in general, with a focus on recent smart technology studies. As said, a new round of research was conducted, using the same data banks, and at that time eliminating the following terms from the previously used search string: ("Shared Autonomous Vehicle") OR ("Autonomous vehicle") OR ("Self-driven vehicle"). This new search came up with more results, which were sorted by relevance and affinity to the artifact subject of this paper, which allowed the author to get more information about state-of-the-art technologies applied to surveillance systems.

Results and Discussion

Conjectural Behavior

Human aggression may be interpreted following either an evolutionary or a psychological approach and comprehended because of natural selection, or as a consequence of the behavior learned during childhood, respectively. While the function of an aggressive act falls into two categories: resource competition and reaction to danger. Nevertheless, both approaches overlap each other in several ways, and so the motivation for the aggression may be understood under the frustration-aggression hypothesis, where frustrations can create aggressive behaviors [11,12]. The meaning of the term aggression is a subject of many discussions, and one suggestion defines it as, any kind of behavior expressing the goal of harming or injuring another person, who oppositely

is motivated to react back to avoid that [13]. An aggressive action can be translated into violence, which can be expressed physically, verbally, or indirectly. This study explores the first two, while the third is more related to social manipulation. Furthermore, the study illustrates that alcohol and illicit drugs are considered catalyzers of violence [14,15]. The consequential effects can be classified into three categories: visual (facial expression, body language); auditive (linguistic speech, paralinguistic speech); and physiological (skin temperature, respiratory rate, brain activity; heart rate) [16].

Design Concept of the Artifact

An artifact capable of identifying physical and verbal violence among passengers of a shared autonomous vehicle transport system. The artifact was split into two portions, being: hardware and software.

Hardware (sensors)

Thermal cameras are more appropriate to monitor violent movements once they are not dependent on luminosity [17]. These same cameras can also monitor the passengers' temperature. Voice recognition techniques are also abundant, and microphones can be easily adapted to the interior of a vehicle. However, the location of the microphones may have to be tuned. Doppler radars might also be used to can monitor heart rate at distance. The challenge arises in detecting alcohol and illicit drugs are more difficult to be detected in a fast way and without more invasive methods. The behavior of the drug user can express or perhaps suggests the presence of these substances in his body.

Software

Violent activities can be detected using computer vision techniques by analyzing the images of surveillance cameras and then extracting information such as acceleration, flow, appearance, time, etc. The methods used may vary and are in a continuous improvement process in terms of performance, accuracy, and efficiency. Simply put, the steps of the process are:

- Extraction of the data from the images or videos;
- Preprocess of the data;
- Transformation of it into fragments;
- Extraction of the features to be used (motion, speed, acceleration, optical flow, time);
- Transformation of the data into the format to be fed to the Artificial Intelligence (AI);
- Evaluation of the data through the AI;
- Checking the accuracy;
- Presentation of the result.

The AI used can be based on techniques such as Machine Learning, Support Vector Machine, and Deep Learning [18].

Due to privacy restrictions regarding video recording and transferring of data, patches on the images might be needed to avoid the identification of the occupants. Unfortunately, this deteriorates the capacity of the software to detect emotions or other important information. To overcome this issue, techniques for generating facial anonymization have been proposed [19].

Conclusion

Aggressiveness is somehow present in human beings and depending on the person, and the surrounding environment it can turn into violence. The goal is to detect the possibility of an incident, but if it cannot be avoided, it is desirable to collect and provide evidence of a crime. Besides violence detection in terms of the safety of the passengers, it's important to think about a surveillance system also aimed at the security of goods and other products that may be delivered by a transportation system based on autonomous vehicles. As in any other surveillance system, legal terms of the local legislation regarding privacy aspects must be observed and evaluated.

Even though the literature about violence detection onboard autonomous vehicles is still rare, the literature about violence detection itself is very vast, which suggests there are many opportunities about adapting these already known technologies to the AVs.

Acknowledgments

The author would like to thank Ford Motor Company for the opportunity to publish his work.

References

1. ONU. 2021. Available in: <https://www.un.org/en/>. Accessed in: 10 April 2021.
2. Lanhang YE, Yamamoyo T. Evaluating the impact of connected and autonomous vehicles on traffic safety. Physica A: Statistical Mechanics and its Applications 2019;526:121009.
3. Fulton LM. Three revolutions in urban passenger travel. Joule 2018;2(4):575–578.
4. SAE. 2021. Disponível em: <https://www.SAE.org/>. Accessed in: 10 Aug 2021.
5. Agriesti S et al. Impact of driverless vehicles on the urban environment and future mobility. Transportation Research Procedia 2020;49:44-59.
6. Orozco-Fontalvo M et al. Women's perceived risk of sexual harassment in a Bus Rapid Transit (BRT) system: The case of Barranquilla, Colombia. Journal of Transport & Health 2019;14:100598.
7. Caires, FOC, Santos GF. A Geografia do crime e os efeitos do metrô sobre assaltos a ônibus na cidade de Salvador. In: XVII Encontro Nacional da Associação Brasileira de Estudos Regionais e Urbanos. Rio de Janeiro, XVII ENABER, 2019.
8. Cerqueira DRC et al. Atlas da violência 2020.
9. Pimentel M, Filipo D, Santos TM. Design Science Research: pesquisa científica atrelada ao design de artefatos. RE@ D-Revista de Educação a Distância e eLearning 2020;3(1):37-61.
10. Baskerville R et al. Design science research contributions: Finding a balance between artifact and theory. Journal of the Association for Information Systems 2018;19(5):3.
11. Berkowitz L. Frustration-aggression hypothesis: examination and reformulation. Psychological Bulletin 1989;106(1):59.
12. Archer J. The nature of human aggression. International journal of law and psychiatry 2009;32(4):202-208.
13. Baron RA, Richardson DR. Human aggression. Springer Science & Business Media, 2004.
14. Chermack ST, Giancola PR. The relation between alcohol and aggression: An integrated biopsychosocial conceptualization. Clinical Psychology Review 1997;17(6):621-649.
15. Abdalla RR et al. Association between drug use and urban violence: Data from the II Brazilian National Alcohol and Drugs Survey (BNADS). Addictive Behaviors Reports 2018;7:8-13.
16. Osman ALH, Falk TH. Multimodal affect recognition: Current approaches and challenges. Emotion and Attention Recognition Based on Biological Signals and Images 2017:59-86.
17. Zizi TKT et al. Aggressive movement detection using optical flow features based on digital & thermal camera. In: Proceedings of the 6th International Conference on Computing and Informatics. 2017:256-261.
18. Ramzan M et al. A review on state-of-the-art violence detection techniques. IEEE Access 2019;7:107560-107575.
19. Mishra A, Cha J, Kim S. HCI based in-cabin monitoring system for irregular situations with occupants facial anonymization. In: International Conference on Intelligent Human Computer Interaction. Springer, Cham 2020:380-390.

Instructions for Authors

The Authors must indicate in a cover letter the address, telephone number and e-mail of the corresponding author. The corresponding author will be asked to make a statement confirming that the content of the manuscript represents the views of the co-authors, that neither the corresponding author nor the co-authors have submitted duplicate or overlapping manuscripts elsewhere, and that the items indicated as personal communications in the text are supported by the referenced person. Also, the protocol letter with the number should be included in the submission article, as well as the name of sponsors (if applicable).

Manuscripts may be submitted within designated categories of communication, including:

- Original basic or clinical investigation (original articles on topics of broad interest in the field of bioengineering and biotechnology applied to health). We particularly welcome papers that discuss epidemiological aspects of international health, clinical reports, clinical trials and reports of laboratory investigations.
- Case presentation and discussion (case reports must be carefully documented and must be of importance because they illustrate or describe unusual features or have important practice implications).
- Brief reports of new methods or observations (short communications brief reports of unusual or preliminary findings).
- State-of-the-art presentations (reviews on protocols of importance to readers in diverse geographic areas. These should be comprehensive and fully referenced).
- Review articles (reviews on topics of importance with a new approach in the discussion). However, review articles only will be accepted after an invitation of the Editors.
- Letters to the editor or editorials concerning previous publications (correspondence relating to papers recently published in the Journal, or containing brief reports of unusual or preliminary findings).
- Editor's corner, containing ideas, hypotheses and comments (papers that advance a hypothesis or represent an opinion relating to a topic of current interest).
- Innovative medical products (description of new biotechnology and innovative products applied to health).
- Health innovation initiatives articles (innovative articles of technological production in Brazil and worldwide, national policies and directives related to technology applied to health in our country and abroad).

The authors should checklist comparing the text with the template of the Journal.

Supplements to the JBTH include articles under a unifying theme, such as those summarizing presentations of symposia or focusing on a specific subject. These will be added to the regular publication of the Journal as appropriate, and will be peer reviewed in the same manner as submitted manuscripts.

Statement of Editorial Policy

The editors of the Journal reserve the right to edit manuscripts for clarity, grammar and style. Authors will have an opportunity to review these changes prior to creation of galley proofs. Changes in content after galley proofs will be sent for reviewing and could be required charges to the author. The JBTH does not accept articles which duplicate or overlap publications elsewhere.

Peer-Review Process

All manuscripts are assigned to an Associate Editor by the Editor-in-Chief and Deputy Editor, and sent to outside experts for peer review. The Associate Editor, aided by the reviewers' comments, makes a recommendation to the Editor-in-Chief regarding the merits of the manuscript. The Editor-in-Chief makes a final decision to accept, reject, or request revision of the manuscript. A request for revision does not guarantee ultimate acceptance of the revised manuscript.

Manuscripts may also be sent out for statistical review ou *ad hoc* reviewers. The average time from submission to first decision is three weeks.

Revisions

Manuscripts that are sent back to authors for revision must be returned to the editorial office by 15 days after the date of the revision request. Unless the decision letter specifically indicates otherwise, it is important not to increase the text length of the manuscript in responding to the comments. The cover letter must include a point-by-point response to the reviewers and Editors comments, and should indicate any additional changes made. Any alteration in authorship, including a change in order of authors, must be agreed upon by all authors, and a statement signed by all authors must be submitted to the editorial office.

Style

Manuscripts may be submitted only in electronic form by www.jbth.com.br. Each manuscript will be assigned a registration number, and the author notified that the manuscript is complete and appropriate to begin the review process. The submission file is in OpenOffice, Microsoft Word, or RTF document file format for texts and JPG (300dpi) for figures.

Authors must indicate in a cover letter the address, telephone number, fax number, and e-mail of the corresponding author. The corresponding author will be asked to make a statement confirming that the content of the manuscript represents the views of the co-authors, that neither the corresponding author nor the co-authors have submitted duplicate or overlapping manuscripts elsewhere, and that the items indicated as personal communications in the text are supported by the referenced person.

Manuscripts are to be typed as indicated in Guide for Authors, as well as text, tables, references, legends. All pages are to be numbered with the order of presentation as follows: title page, abstract, text, acknowledgements, references, tables, figure legends and figures. A running title of not more than 40 characters should be at the top of each page. References should be listed consecutively in the text and recorded as follows in the reference list, and must follow the format of the National Library of Medicine as in Index Medicus and "Uniform Requirements for Manuscripts Submitted to Biomedical Journals" or in "Vancouver Citation Style". Titles of journals not listed in Index Medicus should be spelled out in full.

Manuscript style will follow accepted standards. Please refer to the JBTH for guidance. The final style will be determined by the Editor-in-Chief as reviewed and accepted by the manuscript's corresponding author.

Approval of the Ethics Committee

The JBTH will only accept articles that are approved by the ethics committees of the respective institutions (protocol number and/or approval certification should be sent after the references). The protocol number should be included in the end of the Introduction section of the article.

Publication Ethics

Authors should observe high standards with respect to publication ethics as set out by the International Committee of Medical Journal Editors (ICMJE). Falsification or fabrication of data, plagiarism, including duplicate publication of the authors' own work without proper citation, and misappropriation of the work are all unacceptable practices. Any cases of ethical misconduct are treated very seriously and will be dealt with in accordance with the JBTH guidelines.

Conflicts of Interest

At the point of submission, each author should reveal any financial interests or connections, direct or indirect, or other situations that might raise the question of bias in the work reported or the conclusions, implications, or opinions stated - including pertinent commercial or other sources of funding for the individual author(s) or for the associated department(s) or organizations(s), and personal relationships. There is a potential conflict of interest when anyone involved in the publication process has a financial or other beneficial interest in

the products or concepts mentioned in a submitted manuscript or in competing products that might bias his or her judgment.

Material Disclaimer

The opinions expressed in JBTH are those of the authors and contributors, and do not necessarily reflect those of the SENAI CIMATEC, the editors, the editorial board, or the organization with which the authors are affiliated.

Privacy Statement

The names and email addresses entered in this Journal site will be used exclusively for the stated purposes of this journal and will not be made available for any other purpose or to any other party.

Brief Policies of Style

Manuscript	Original	Review	Birief Comunication	Case Report	Editorial ; Letter to the Editor; Editor' s Corner	Innovative Medical Products	State-of-the-Art	Health Innovation Initiatives
Font Type	Times or Arial	Times or Arial	Times or Arial	Times or Arial	Times or Arial	Times or Arial	Times or Arial	Times or Arial
Number of Words – Title	120	90	95	85	70	60	120	90
Font Size/Space-Title	12; double space	12; double space	12; double space	12; double space	12; double space	12; double space	12; double space	12; double space
Font Size/Space-Abstracts/Key Words and Abbreviations	10; single space	10; single space	10; single space	10; single space	-	-	10; single space	10; single space
Number of Words – Abstracts/Key Words	300/5	300/5	200/5	250/5	-	-	300/5	300/5
Font Size/Space-Text	12; Double space	12; Double space	12; Double space	12; Double space	12; Double space	12; Double space	12; Double space	12; Double space
Number of Words – Text	5,000 including spaces	5,500 including spaces	2,500 including spaces	1,000 including spaces	1,000 including spaces	550 including spaces	5,000 including spaces	5,500 including spaces
Number of Figures	8 (title font size 12, double space)	3 (title font size 12, double space)	2 (title font size 12, double space)	2 (title font size 12, double space)	-	2 (title font size 12, double space)	8 (title font size 12, double space)	8 (title font size 12, double space)
Number of Tables/Graphic	7 title font size 12, double space	2 title font size 12, double space	2(title font size 12, double space)	1(title font size 12, double space)	-	-	7 title font size 12, double space	4 title font size 12, double space
Number of Authors and Co-authors*	15	10	5	10	3	3	15	10
References	20 (font size 10,single space	30(font size 10,single space	15 (font size 10,single space)	10 (font size 10,single space)	10 (font size 10,single space	5(font size 10,single space	20 (font size 10,single space	20

*First and last name with a sequencing overwritten number. Corresponding author(s) should be identified with an asterisk; Type 10, Times or Arial, single space. Running title of not more than 40 characters should be at the top of each page. References should be listed consecutively in the text. References must be cited on (not above) the line of text and in brackets instead of parentheses, e.g., [7,8]. References must be numbered in the order in which they appear in the text. References not cited in the text cannot appear in the reference section. References only or first cited in a table or figures are numbered according to where the table or figure is cited in the text. For instance, if a table is placed after reference 8, a new reference cited in table 1 would be reference 9.1 would be reference 9.

Checklist for Submitted Manuscripts

❑1. Please provide a cover letter with your submission specifying the corresponding author as well as an address, telephone number and e-mail.

❑2. Submit your paper using our website www.jbth.com.br. Use Word Perfect/Word for Windows, each with a complete set of original illustrations.

❑3. The entire manuscript (including tables and references) must be typed according to the guidelines instructions.

❑4. The order of appearance of material in all manuscripts should be as follows: title page, abstract, text, acknowledgements, references, tables, figures/graphics/diagrams with the respective legends.

❑5. The title page must include a title of not more than three printed lines (please check the guidelines of each specific manuscript), authors (no titles or degrees), institutional affiliations, a running headline of not more than 40 letters with spaces.

❑6. Acknowledgements of persons who assisted the authors should be included on the page preceding the references.

❑7. References must begin on a separate page.

❑8. References must be cited on (not above) the line of text and in brackets instead of parentheses, e.g., [7,8].

❑9. References must be numbered in the order in which they appear in the text. References not cited in the text cannot appear in the reference section. References only or first cited in a table or figures are numbered according to where the table or figure is cited in the text. For instance, if a table is placed after reference 8, a new reference cited in table 1 would be reference 9.

❑10. Reference citations must follow the format established by the "Uniform Requirements for Manuscripts Submitted to Biomedical Journals" or in "Vancouver Citation Style".

❑11. If you reference your own unpublished work (i.e., an "in press" article) in the manuscript that you are submitting, you must attach a file of the "in press" article and an acceptance letter from the journal.

❑12. If you cite unpublished data that are not your own, you must provide a letter of permission from the author of that publication.

❑13. Please provide each figure in high quality (minimum 300 dpi: JPG or TIF). Figure must be on a separate file.

❑14. If the study received a financial support, the name of the sponsors must be included in the cover letter and in the text, after the author's affiliations.

❑15. Provide the number of the Ethics Committees (please check the guidelines for authors).