CS481/SE481
E-COMMERCE
(3 Credits)

General Information

People

- Instructor
  - Ting Lan
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  - Tel: 3017

- Please check your course moodle regularly.
  - http://moodle.must.edu.mo/
  - Students Login: *Students should login with their MUST E-mail Account.*
  - **Student ID**:**1234567A-BC89-0123**

    Username: 1234567abc89012

    Password: <Student's e-Mail Password>

Course Description

The course introduces the concepts of e-commerce, the different models of e-commerce, the architecture of the e-commerce system. Through the lectures, the students will experience and study different e-commerce systems, such as e-government, e-procurement, and online auction.

Course Objective

- Gain an understanding of basic concepts, theories, and business models underlying e-commerce.
- Apply e-commerce theory and concepts to what e-marketers are doing in “the real world”.
- Improve familiarity with current challenges and issues in e-commerce.
- Demonstrate an understanding of the foundations and importance of e-commerce.
- Describe Internet trading relationships including Business to Consumer, Business-to-Business, Intra-organizational.
- Describe the infrastructure for e-commerce.
- Describe the key features of Internet, Intranets, and Extranets and explain how they relate to each other.
- Discuss legal issues and privacy in e-commerce.
- Assess electronic payment systems.

Course Assessment

- Class Participation ~ 10%
- Assignments ~ 10%
- Project (Presentation and Report) ~ 30%
- Final Exam ~ 50%

Total ~ 100%

Class Participation

- Hope everyone of you attend each class.
- In general, I will not call the roll in the class. Instead, I will check your attendance by looking at your activities in Wemust.

Assignments

- There are some assignments. You should attend each class and submit your assignments on time.

Project

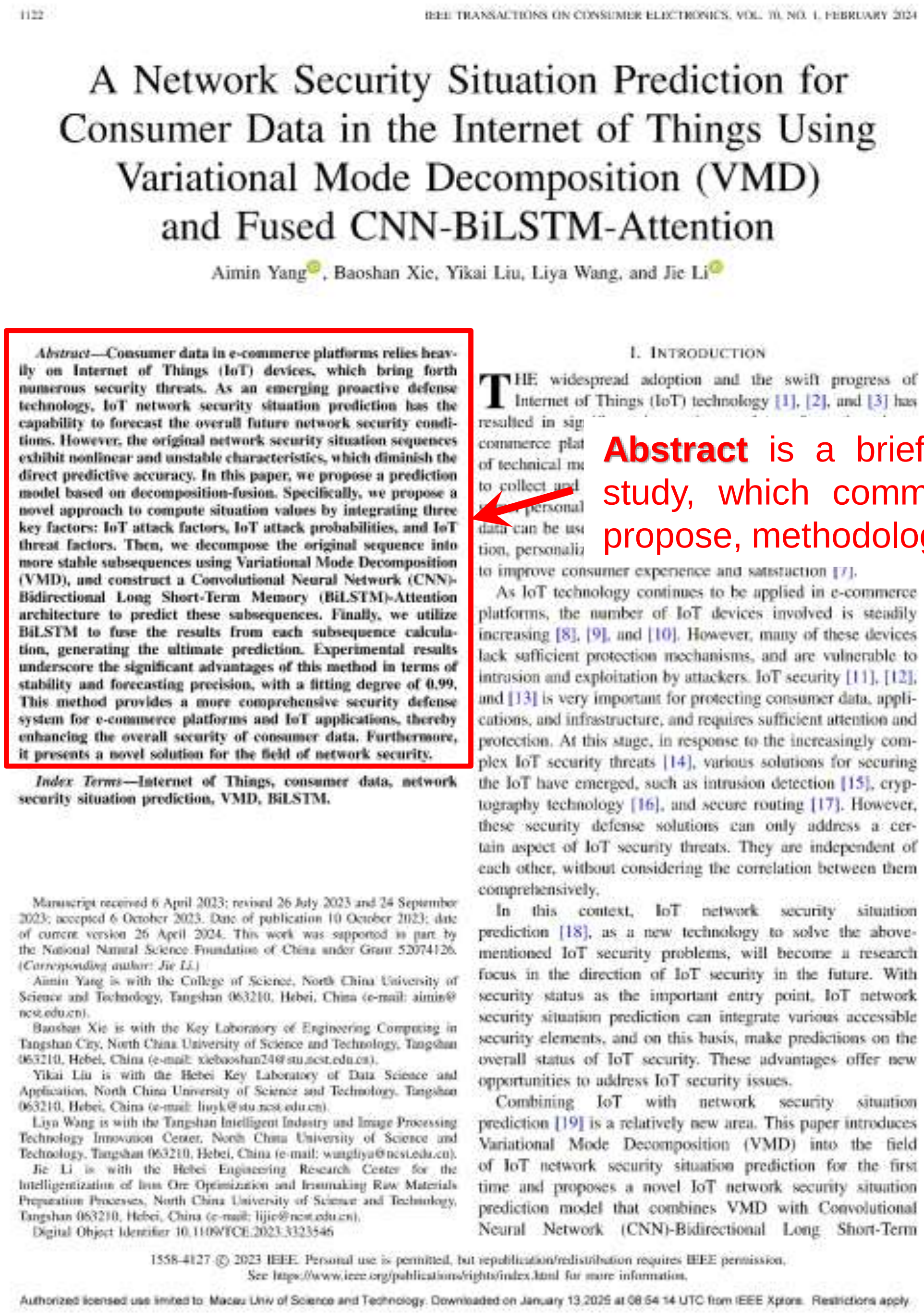
- Each group (three students) should find a SCI-indexed journal paper about e-commerce.
- Each group (three students) should make a paper presentation (about 10 mins).
- Each group (three students) should write a SUMMARY REPORT (more than 2000 words excluding references and appendices) about the paper.

Project

- A ***research paper*** is based on original research, which presents original findings or results from a study.
- A ***review paper*** is based on other published articles, which generally analyzes and summarizes existing literature on a particular topic.

A good research paper addresses a specific research problem. The paper will give the problem, then solve it. The basic structure of a typical research paper is the sequence of Introduction, Methods, Results, and Discussion.

Research Paper



A Network Security Situation Prediction for Consumer Data in the Internet of Things Using Variational Mode Decomposition (VMD) and Fused CNN-BiLSTM-Attention

Aimin Yang, Baoshan Xie, Yikai Liu, Liya Wang, and Jie Li

Abstract—**Consumer data in e-commerce platforms relies heavily on Internet of Things (IoT) devices, which bring forth numerous security threats. As an emerging proactive defense technology, IoT network security situation prediction has the capability to forecast the overall future network security conditions. However, the original network security situation sequences exhibit nonlinear and unstable characteristics, which diminish the direct predictive accuracy. In this paper, we propose a prediction model based on decomposition-fusion. Specifically, we propose a novel approach to compute situation values by integrating three key factors: IoT attack factors, IoT attack probabilities, and IoT threat factors. Then, we decompose the original sequence into more stable subsequences using Variational Mode Decomposition (VMD), and construct a Convolutional Neural Network (CNN)-Bidirectional Long Short-Term Memory (BiLSTM)-Attention architecture to predict these subsequences. Finally, we utilize BiLSTM to fuse the results from each subsequence calculation, generating the ultimate prediction. Experimental results underscore the significant advantages of this method in terms of stability and forecasting precision, with a fitting degree of 0.99. This method provides a more comprehensive security defense system for e-commerce platforms and IoT applications, thereby enhancing the overall security of consumer data. Furthermore, it presents a novel solution for the field of network security.**

Index Terms—**Internet of Things, consumer data, network security situation prediction, VMD, BiLSTM.**

I. Introduction

THE widespread adoption and the swift progress of Internet of Things (IoT) technology [1], [2], and [3] has resulted in sig
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to improve consumer experience and satisfaction [7].

As IoT technology continues to be applied in e-commerce platforms, the number of IoT devices involved is steadily increasing [8], [9], and [10]. However, many of these devices lack sufficient protection mechanisms, and are vulnerable to intrusion and exploitation by attackers. IoT security [11], [12], and [13] is very important for protecting consumer data, applications, and infrastructure, and requires sufficient attention and protection. At this stage, in response to the increasingly complex IoT security threats [14], various solutions for securing the IoT have emerged, such as intrusion detection [15], cryptography technology [16], and secure routing [17]. However, these security defense solutions can only address a certain aspect of IoT security threats. They are independent of each other, without considering the correlation between them comprehensively.

In this context, IoT network security situation prediction [18], as a new technology to solve the above-mentioned IoT security problems, will become a research focus in the direction of IoT security in the future. With security status as the important entry point, IoT network security situation prediction can integrate various accessible security elements, and on this basis, make predictions on the overall status of IoT security. These advantages offer new opportunities to address IoT security issues.

Combining IoT with network security situation prediction [19] is a relatively new area. This paper introduces Variational Mode Decomposition (VMD) into the field of IoT network security situation prediction for the first time and proposes a novel IoT network security situation prediction model that combines VMD with Convolutional Neural Network (CNN)-Bidirectional Long Short-Term

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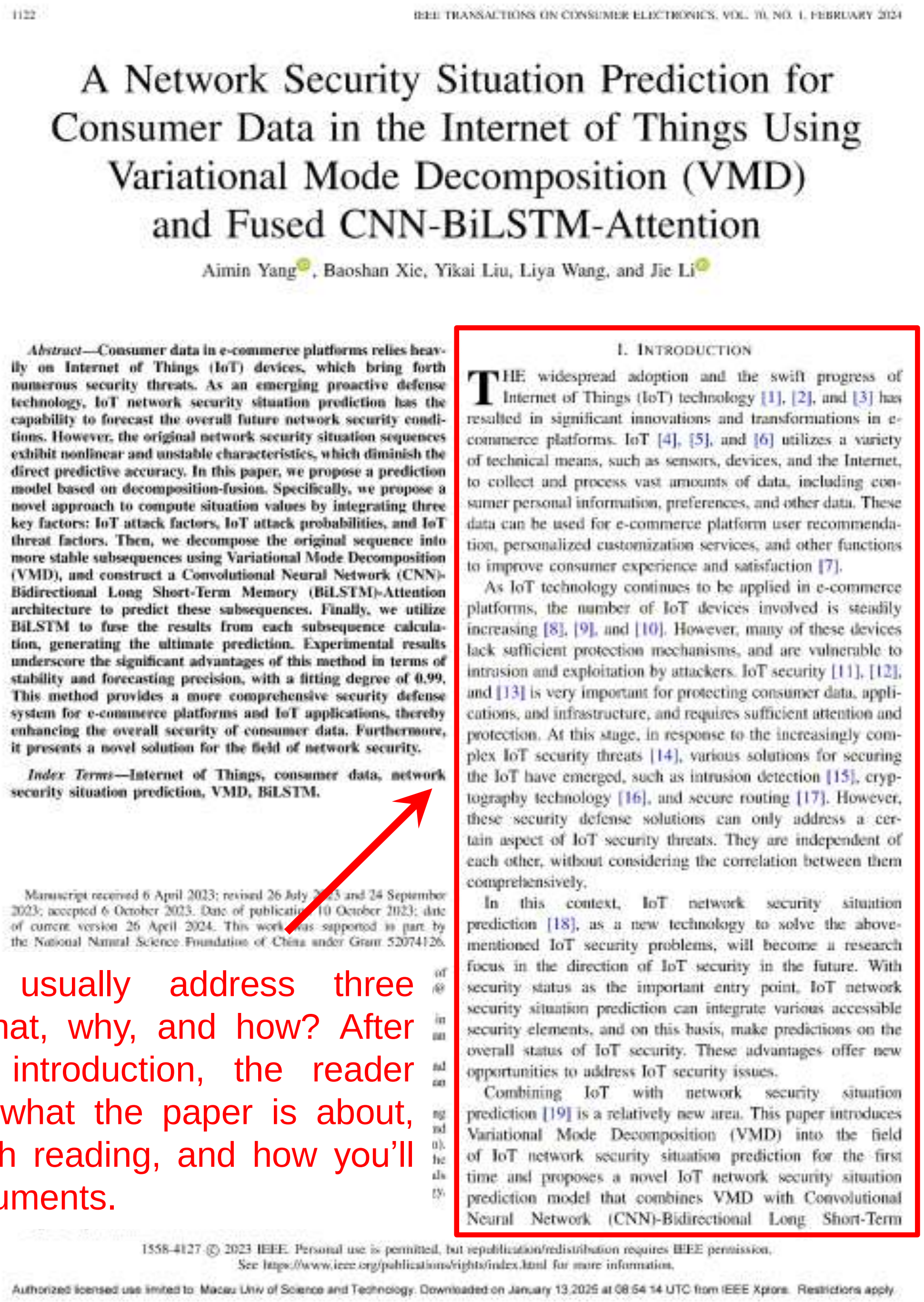
Abstract is a brief overview of the study, which commonly includes its propose, methodology, and findings.

Research Paper



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Index Terms—Internet of Things, consumer data, network security situation prediction, VMD, BiLSTM.

I. Introduction

THE widespread adoption and the swift progress of Internet of Things (IoT) technology [1], [2], and [3] has resulted in significant innovations and transformations in e-commerce platforms. IoT [4], [5], and [6] utilizes a variety of technical means, such as sensors, devices, and the Internet, to collect and process vast amounts of data, including consumer personal information, preferences, and other data. These data can be used for e-commerce platform user recommendation, personalized customization services, and other functions to improve consumer experience and satisfaction [7].

As IoT technology continues to be applied in e-commerce platforms, the number of IoT devices involved is steadily increasing [8], [9], and [10]. However, many of these devices lack sufficient protection mechanisms, and are vulnerable to intrusion and exploitation by attackers. IoT security [11], [12], and [13] is very important for protecting consumer data, applications, and infrastructure, and requires sufficient attention and protection. At this stage, in response to the increasingly complex IoT security threats [14], various solutions for securing the IoT have emerged, such as intrusion detection [15], cryptography technology [16], and secure routing [17]. However, these security defense solutions can only address a certain aspect of IoT security threats. They are independent of each other, without considering the correlation between them comprehensively.

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Introduction usually address three questions: What, why, and how? After finishing the introduction, the reader should know what the paper is about, why it is worth reading, and how you'll build your arguments.

Research Paper

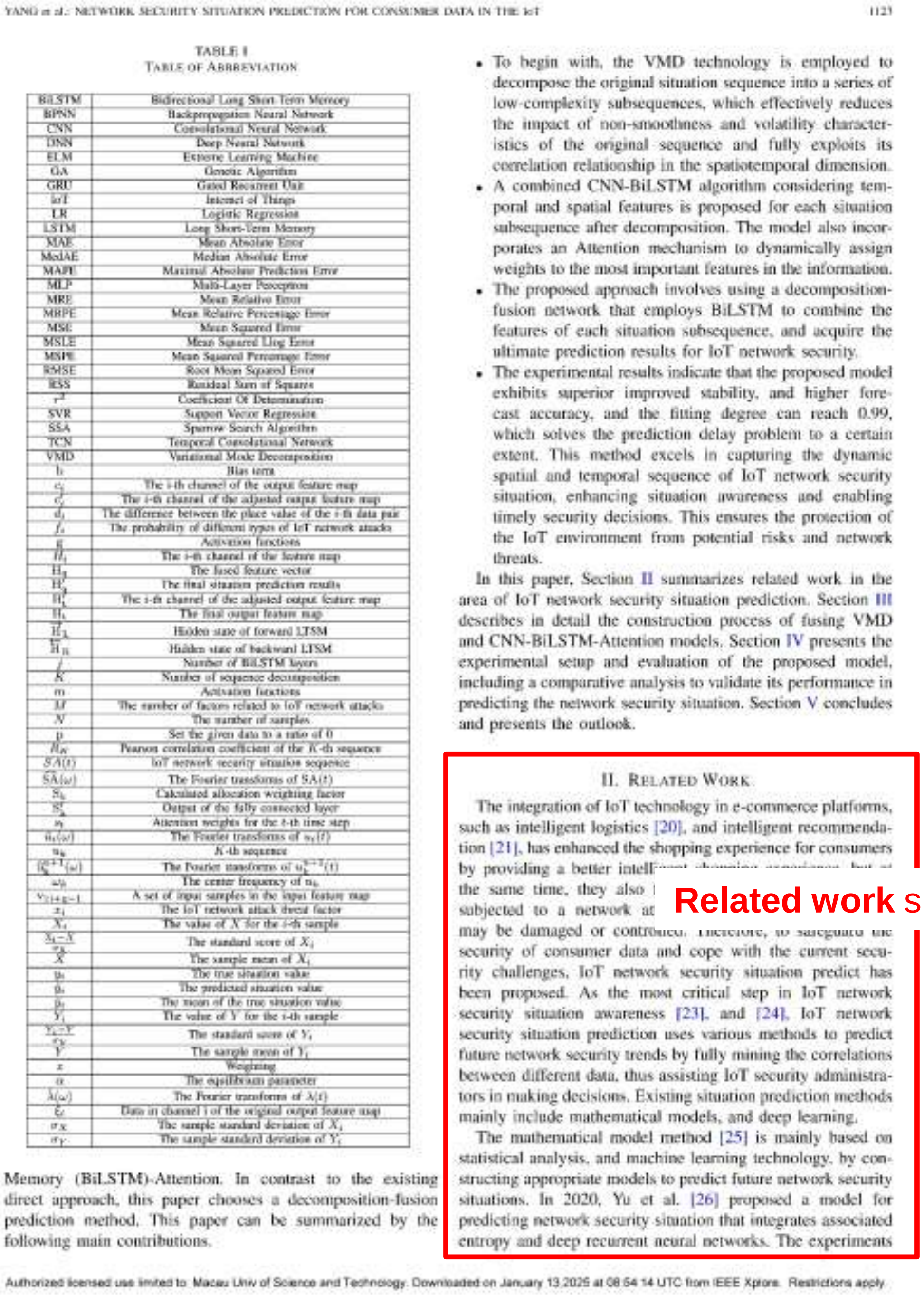


TABLE I
TABLE OF ABBREVIATION

BiLSTM	Bidirectional Long Short-Term Memory
BPNN	Backpropagation Neural Network
CNN	Convolutional Neural Network
DNN	Deep Neural Network
ELM	Extreme Learning Machine
GA	Genetic Algorithm
GRU	Gated Recurrent Unit
IoT	Internet of Things
LR	Logistic Regression
LSTM	Long Short-Term Memory
MAE	Mean Absolute Error
MedAE	Median Absolute Error
MAPE	Maximal Absolute Prediction Error
MLP	Multi-Layer Perceptron
MRE	Mean Relative Error
MRPE	Mean Relative Percentage Error
MSE	Mean Squared Error
MSLE	Mean Squared Log Error
MSPE	Mean Squared Percentage Error
RMSE	Root Mean Squared Error
RSS	Residual Sum of Squares
r^2	Coefficient Of Determination
SVR	Support Vector Regression
SSA	Sparrow Search Algorithm
TCN	Temporal Convolutional Network
VMD	Variational Mode Decomposition
b	Bias term
c_i	The i-th channel of the output feature map
c_i'	The i-th channel of the adjusted output feature map
d_i	The difference between the place value of the i-th data pair
f_i	The probability of different types of IoT network attacks
g	Activation functions
H_i	The i-th channel of the feature map
H_3	The fused feature vector
H_3'	The final situation prediction results
H_i'	The i-th channel of the adjusted output feature map
H_i	The final output feature map
$\overrightarrow{H}_L$	Hidden state of forward LTSM
$\overleftarrow{H}_R$	Hidden state of backward LTSM
l	Number of BiLSTM layers
K	Number of sequence decomposition
m	Activation functions
M	The number of factors related to IoT network attacks
N	The number of samples
p	Set the given data to a ratio of 0
R_K	Pearson correlation coefficient of the K-th sequence
$SA(t)$	IoT network security situation sequence
$\widehat{SA}(\omega)$	The Fourier transforms of $SA(t)$
S_k	Calculated allocation weighting factor
S_k'	Output of the fully connected layer
w_t	Attention weights for the t-th time step
$\hat{u}_k(\omega)$	The Fourier transforms of $u_k(t)$
u_k	K-th sequence
$\hat{u}_k^{n+1}(\omega)$	The Fourier transforms of $u_k^{n+1}(t)$
ω_k	The center frequency of u_k
$v_{j:j+g-1}$	A set of input samples in the input feature map
x_i	The IoT network attack threat factor
X_i	The value of X for the i-th sample
$\frac{X_i-\bar{X}}{\sigma_X}$	The standard score of X_i
$\bar{X}$	The sample mean of X_i
y_t	The true situation value
$\hat{y}_t$	The predicted situation value
$\bar{y}_t$	The mean of the true situation value
Y_i	The value of Y for the i-th sample
$\frac{Y_i-\bar{Y}}{\sigma_Y}$	The standard score of Y_i
$\bar{Y}$	The sample mean of Y_i
z	Weighting
α	The equilibrium parameter
$\hat{\lambda}(\omega)$	The Fourier transforms of $\lambda(t)$
ξ_i	Data in channel i of the original output feature map
σ_X	The sample standard deviation of X_i
σ_Y	The sample standard deviation of Y_i

Memory (BiLSTM)-Attention. In contrast to the existing direct approach, this paper chooses a decomposition-fusion prediction method. This paper can be summarized by the following main contributions.

- To begin with, the VMD technology is employed to decompose the original situation sequence into a series of low-complexity subsequences, which effectively reduces the impact of non-smoothness and volatility characteristics of the original sequence and fully exploits its correlation relationship in the spatiotemporal dimension.
- A combined CNN-BiLSTM algorithm considering temporal and spatial features is proposed for each situation subsequence after decomposition. The model also incorporates an Attention mechanism to dynamically assign weights to the most important features in the information.
- The proposed approach involves using a decomposition-fusion network that employs BiLSTM to combine the features of each situation subsequence, and acquire the ultimate prediction results for IoT network security.
- The experimental results indicate that the proposed model exhibits superior improved stability, and higher forecast accuracy, and the fitting degree can reach 0.99, which solves the prediction delay problem to a certain extent. This method excels in capturing the dynamic spatial and temporal sequence of IoT network security situation, enhancing situation awareness and enabling timely security decisions. This ensures the protection of the IoT environment from potential risks and network threats.

In this paper, Section II summarizes related work in the area of IoT network security situation prediction. Section III describes in detail the construction process of fusing VMD and CNN-BiLSTM-Attention models. Section IV presents the experimental setup and evaluation of the proposed model, including a comparative analysis to validate its performance in predicting the network security situation. Section V concludes and presents the outlook.

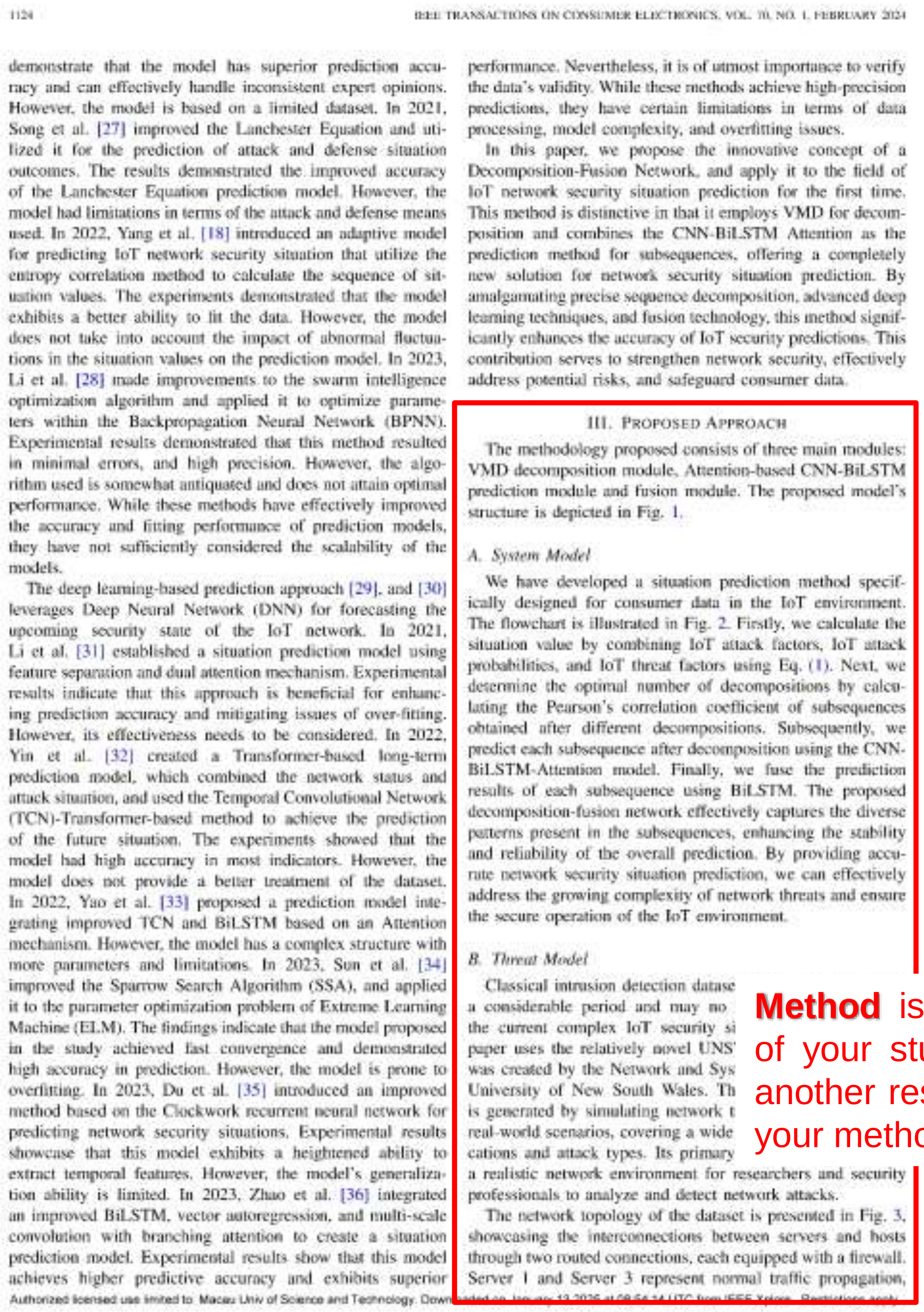
II. RELATED WORK

The integration of IoT technology in e-commerce platforms, such as intelligent logistics [20], and intelligent recommendation [21], has enhanced the shopping experience for consumers by providing a better intelligent shopping experience, but at the same time, they also [illegible] subjected to a network at[illegible] may be damaged or controlled. Therefore, to safeguard the security of consumer data and cope with the current security challenges, IoT network security situation predict has been proposed. As the most critical step in IoT network security situation awareness [23], and [24], IoT network security situation prediction uses various methods to predict future network security trends by fully mining the correlations between different data, thus assisting IoT security administrators in making decisions. Existing situation prediction methods mainly include mathematical models, and deep learning.

The mathematical model method [25] is mainly based on statistical analysis, and machine learning technology, by constructing appropriate models to predict future network security situations. In 2020, Yu et al. [26] proposed a model for predicting network security situation that integrates associated entropy and deep recurrent neural networks. The experiments

Related work shows literature review.

Research Paper



demonstrate that the model has superior prediction accuracy and can effectively handle inconsistent expert opinions. However, the model is based on a limited dataset. In 2021, Song et al. [27] improved the Lanchester Equation and utilized it for the prediction of attack and defense situation outcomes. The results demonstrated the improved accuracy of the Lanchester Equation prediction model. However, the model had limitations in terms of the attack and defense means used. In 2022, Yang et al. [18] introduced an adaptive model for predicting IoT network security situation that utilize the entropy correlation method to calculate the sequence of situation values. The experiments demonstrated that the model exhibits a better ability to fit the data. However, the model does not take into account the impact of abnormal fluctuations in the situation values on the prediction model. In 2023, Li et al. [28] made improvements to the swarm intelligence optimization algorithm and applied it to optimize parameters within the Backpropagation Neural Network (BPNN). Experimental results demonstrated that this method resulted in minimal errors, and high precision. However, the algorithm used is somewhat antiquated and does not attain optimal performance. While these methods have effectively improved the accuracy and fitting performance of prediction models, they have not sufficiently considered the scalability of the models.

The deep learning-based prediction approach [29], and [30] leverages Deep Neural Network (DNN) for forecasting the upcoming security state of the IoT network. In 2021, Li et al. [31] established a situation prediction model using feature separation and dual attention mechanism. Experimental results indicate that this approach is beneficial for enhancing prediction accuracy and mitigating issues of over-fitting. However, its effectiveness needs to be considered. In 2022, Yin et al. [32] created a Transformer-based long-term prediction model, which combined the network status and attack situation, and used the Temporal Convolutional Network (TCN)-Transformer-based method to achieve the prediction of the future situation. The experiments showed that the model had high accuracy in most indicators. However, the model does not provide a better treatment of the dataset. In 2022, Yao et al. [33] proposed a prediction model integrating improved TCN and BiLSTM based on an Attention mechanism. However, the model has a complex structure with more parameters and limitations. In 2023, Sun et al. [34] improved the Sparrow Search Algorithm (SSA), and applied it to the parameter optimization problem of Extreme Learning Machine (ELM). The findings indicate that the model proposed in the study achieved fast convergence and demonstrated high accuracy in prediction. However, the model is prone to overfitting. In 2023, Du et al. [35] introduced an improved method based on the Clockwork recurrent neural network for predicting network security situations. Experimental results showcase that this model exhibits a heightened ability to extract temporal features. However, the model's generalization ability is limited. In 2023, Zhao et al. [36] integrated an improved BiLSTM, vector autoregression, and multi-scale convolution with branching attention to create a situation prediction model. Experimental results show that this model achieves higher predictive accuracy and exhibits superior performance. Nevertheless, it is of utmost importance to verify the data's validity. While these methods achieve high-precision predictions, they have certain limitations in terms of data processing, model complexity, and overfitting issues.

In this paper, we propose the innovative concept of a Decomposition-Fusion Network, and apply it to the field of IoT network security situation prediction for the first time. This method is distinctive in that it employs VMD for decomposition and combines the CNN-BiLSTM Attention as the prediction method for subsequences, offering a completely new solution for network security situation prediction. By amalgamating precise sequence decomposition, advanced deep learning techniques, and fusion technology, this method significantly enhances the accuracy of IoT security predictions. This contribution serves to strengthen network security, effectively address potential risks, and safeguard consumer data.

III. Proposed Approach

The methodology proposed consists of three main modules: VMD decomposition module, Attention-based CNN-BiLSTM prediction module and fusion module. The proposed model's structure is depicted in Fig. 1.

A. System Model

We have developed a situation prediction method specifically designed for consumer data in the IoT environment. The flowchart is illustrated in Fig. 2. Firstly, we calculate the situation value by combining IoT attack factors, IoT attack probabilities, and IoT threat factors using Eq. (1). Next, we determine the optimal number of decompositions by calculating the Pearson's correlation coefficient of subsequences obtained after different decompositions. Subsequently, we predict each subsequence after decomposition using the CNN-BiLSTM-Attention model. Finally, we fuse the prediction results of each subsequence using BiLSTM. The proposed decomposition-fusion network effectively captures the diverse patterns present in the subsequences, enhancing the stability and reliability of the overall prediction. By providing accurate network security situation prediction, we can effectively address the growing complexity of network threats and ensure the secure operation of the IoT environment.

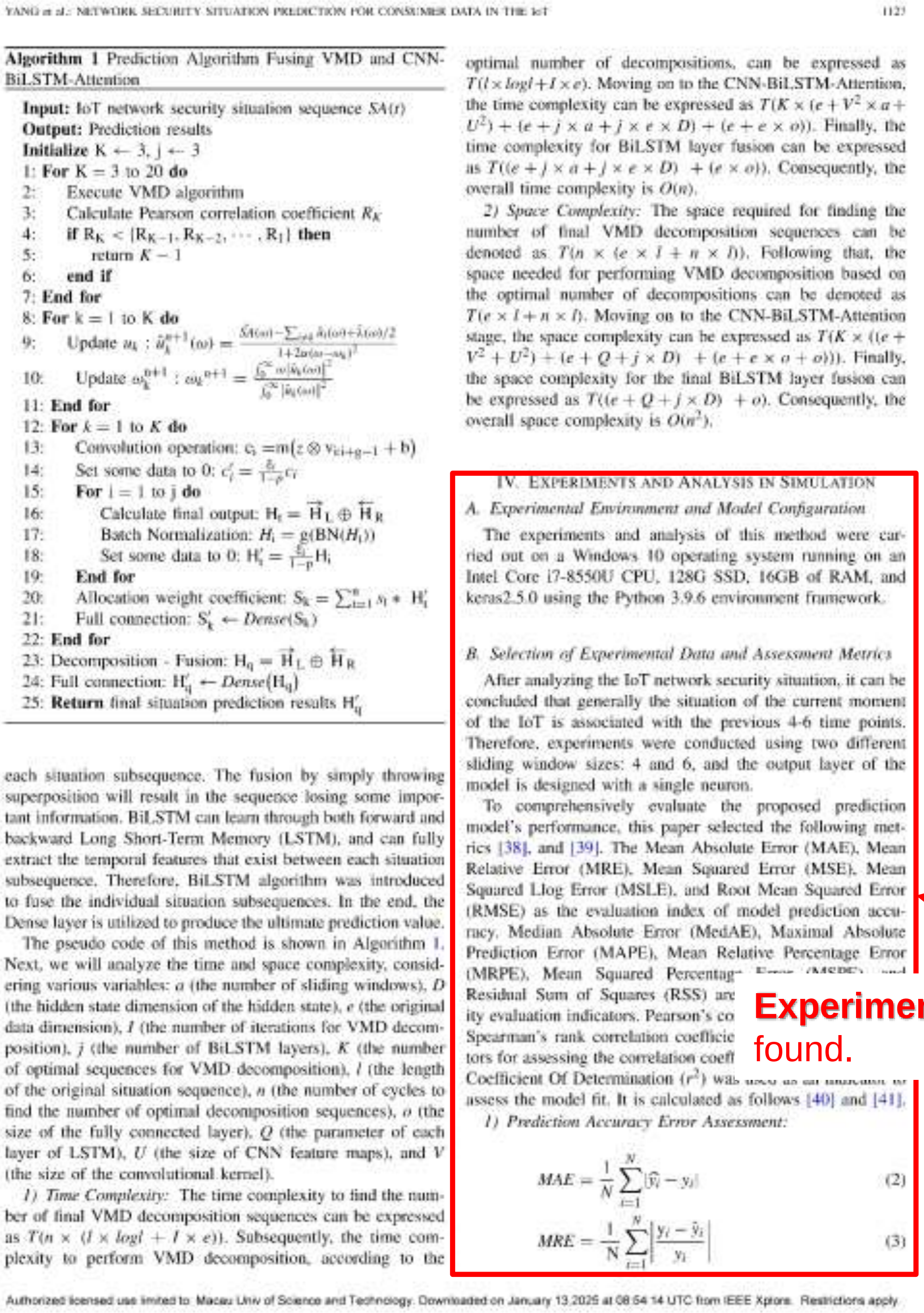
B. Threat Model

Classical intrusion detection datase
a considerable period and may no
the current complex IoT security si
paper uses the relatively novel UNS
was created by the Network and Sys
University of New South Wales. Th
is generated by simulating network t
real-world scenarios, covering a wide
cations and attack types. Its primary
a realistic network environment for researchers and security professionals to analyze and detect network attacks.

The network topology of the dataset is presented in Fig. 3, showcasing the interconnections between servers and hosts through two routed connections, each equipped with a firewall. Server 1 and Server 3 represent normal traffic propagation,

Method is to describe the details of your study in such a way that another researcher could duplicate your methods exactly.

Research Paper



Algorithm 1 Prediction Algorithm Fusing VMD and CNN-BiLSTM-Attention

```
Input: IoT network security situation sequence $SA(t)$
Output: Prediction results
Initialize $K \leftarrow 3, j \leftarrow 3$
For $K = 3$ to 20 do
    Execute VMD algorithm
    Calculate Pearson correlation coefficient $R_K$
    if $R_K < \{R_{K-1}, R_{K-2}, \cdots, R_1\}$ then
        return $K - 1$
    end if
End for
For $k = 1$ to $K$ do
    Update $u_k$ : $\hat{u}_k^{n+1}(\omega) = \frac{\hat{SA}(\omega) - \sum_{i \neq k} \hat{u}_i(\omega) + \hat{\lambda}(\omega)/2}{1 + 2\alpha(\omega - \omega_k)^2}$
     Update $\omega_k^{n+1}$ : $\omega_k{}^{n+1} = \frac{\int_0^{\infty} \omega |\hat{u}_k(\omega)|^2}{\int_0^{\infty} |\hat{u}_k(\omega)|^2}$
End for
For $k = 1$ to $K$ do
    Convolution operation: $c_i = m(z \otimes v_{i:i+g-1} + b)$
    Set some data to 0: $c_i' = \frac{\delta_i}{1-\rho} c_i$
    For $i = 1$ to $j$ do
        Calculate final output: $H_t = \overrightarrow{H}_L \oplus \overleftarrow{H}_R$
        Batch Normalization: $H_i = g(BN(H_t))$
        Set some data to 0: $H_i' = \frac{\delta_i}{1-p} H_i$
    End for
    Allocation weight coefficient: $S_k = \sum_{i=1}^{n} s_i * H_i'$
    Full connection: $S_k' \leftarrow Dense(S_k)$
End for
Decomposition - Fusion: $H_q = \overrightarrow{H}_L \oplus \overleftarrow{H}_R$
Full connection: $H_q' \leftarrow Dense(H_q)$
Return final situation prediction results $H_q'$
```

each situation subsequence. The fusion by simply throwing superposition will result in the sequence losing some important information. BiLSTM can learn through both forward and backward Long Short-Term Memory (LSTM), and can fully extract the temporal features that exist between each situation subsequence. Therefore, BiLSTM algorithm was introduced to fuse the individual situation subsequences. In the end, the Dense layer is utilized to produce the ultimate prediction value.

The pseudo code of this method is shown in Algorithm 1. Next, we will analyze the time and space complexity, considering various variables: a (the number of sliding windows), D (the hidden state dimension of the hidden state), e (the original data dimension), I (the number of iterations for VMD decomposition), j (the number of BiLSTM layers), K (the number of optimal sequences for VMD decomposition), l (the length of the original situation sequence), n (the number of cycles to find the number of optimal decomposition sequences), o (the size of the fully connected layer), Q (the parameter of each layer of LSTM), U (the size of CNN feature maps), and V (the size of the convolutional kernel).

1) Time Complexity: The time complexity to find the number of final VMD decomposition sequences can be expressed as $T(n \times (l \times logl + I \times e))$. Subsequently, the time complexity to perform VMD decomposition, according to the optimal number of decompositions, can be expressed as $T(l \times logl + I \times e)$. Moving on to the CNN-BiLSTM-Attention, the time complexity can be expressed as $T(K \times (e + V^2 \times a + U^2) + (e + j \times a + j \times e \times D) + (e + e \times o))$. Finally, the time complexity for BiLSTM layer fusion can be expressed as $T((e + j \times a + j \times e \times D) + (e \times o))$. Consequently, the overall time complexity is $O(n)$.

2) Space Complexity: The space required for finding the number of final VMD decomposition sequences can be denoted as $T(n \times (e \times I + n \times l))$. Following that, the space needed for performing VMD decomposition based on the optimal number of decompositions can be denoted as $T(e \times I + n \times l)$. Moving on to the CNN-BiLSTM-Attention stage, the space complexity can be expressed as $T(K \times ((e + V^2 + U^2) + (e + Q + j \times D) + (e + e \times o + o)))$. Finally, the space complexity for the final BiLSTM layer fusion can be expressed as $T((e + Q + j \times D) + o)$. Consequently, the overall space complexity is $O(n^2)$.

IV. Experiments and Analysis in Simulation

A. Experimental Environment and Model Configuration

The experiments and analysis of this method were carried out on a Windows 10 operating system running on an Intel Core i7-8550U CPU, 128G SSD, 16GB of RAM, and keras2.5.0 using the Python 3.9.6 environment framework.

B. Selection of Experimental Data and Assessment Metrics

After analyzing the IoT network security situation, it can be concluded that generally the situation of the current moment of the IoT is associated with the previous 4-6 time points. Therefore, experiments were conducted using two different sliding window sizes: 4 and 6, and the output layer of the model is designed with a single neuron.

To comprehensively evaluate the proposed prediction model's performance, this paper selected the following metrics [38], and [39]. The Mean Absolute Error (MAE), Mean Relative Error (MRE), Mean Squared Error (MSE), Mean Squared Llog Error (MSLE), and Root Mean Squared Error (RMSE) as the evaluation index of model prediction accuracy. Median Absolute Error (MedAE), Maximal Absolute Prediction Error (MAPE), Mean Relative Percentage Error (MRPE), Mean Squared Percentag Error (MSPE), and Residual Sum of Squares (RSS) are ity evaluation indicators. Pearson's co Spearman's rank correlation coefficie tors for assessing the correlation coeff Coefficient Of Determination (r^2) was used as an indicator to assess the model fit. It is calculated as follows [40] and [41].

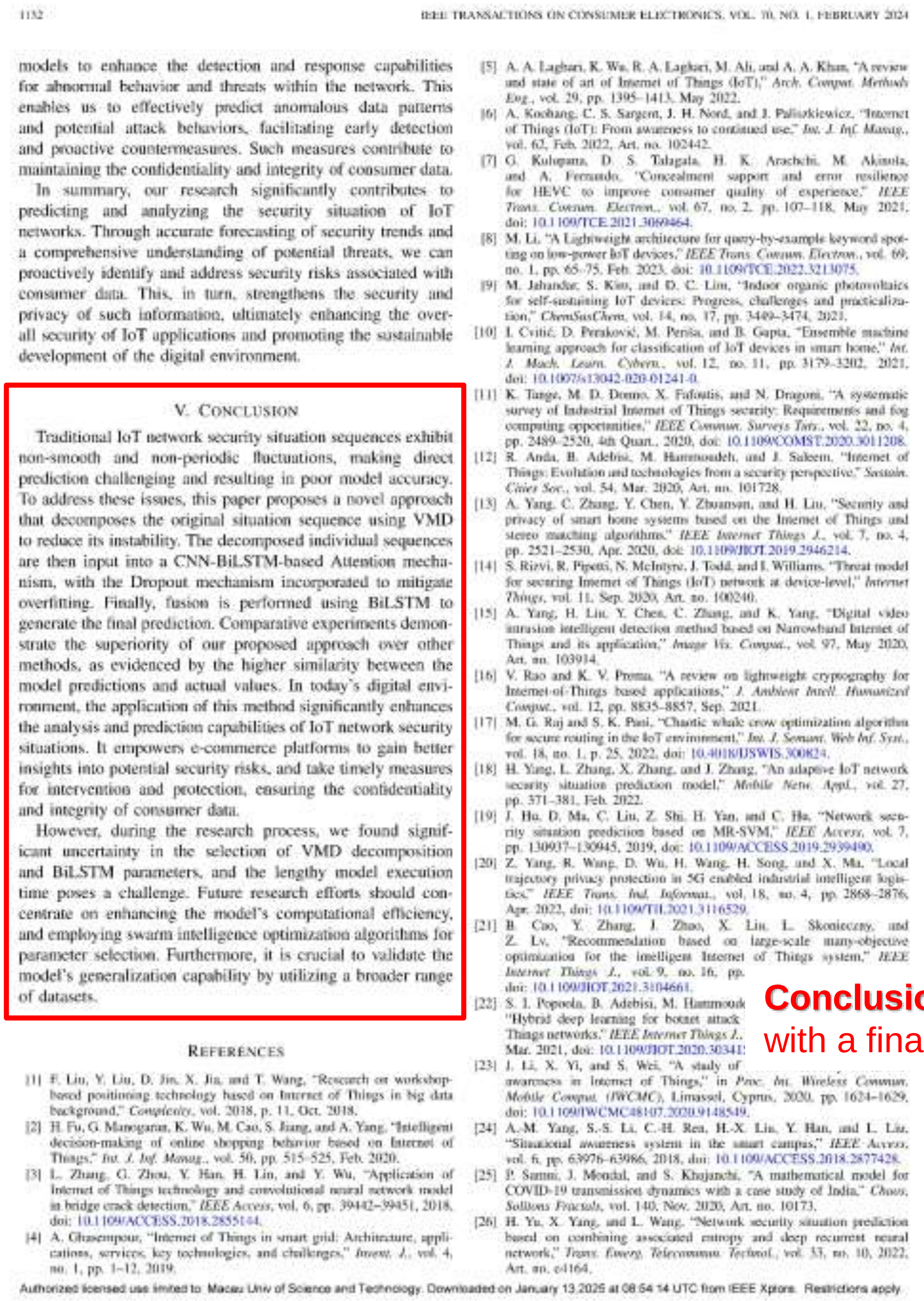
1) Prediction Accuracy Error Assessment:

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|\hat{y}_i - y_i| \tag{2}$$

$$MRE = \frac{1}{N}\sum_{i=1}^{N}\left|\frac{y_i - \hat{y}_i}{y_i}\right| \tag{3}$$

Experiments describe what you found.

Research Paper



models to enhance the detection and response capabilities for abnormal behavior and threats within the network. This enables us to effectively predict anomalous data patterns and potential attack behaviors, facilitating early detection and proactive countermeasures. Such measures contribute to maintaining the confidentiality and integrity of consumer data.

In summary, our research significantly contributes to predicting and analyzing the security situation of IoT networks. Through accurate forecasting of security trends and a comprehensive understanding of potential threats, we can proactively identify and address security risks associated with consumer data. This, in turn, strengthens the security and privacy of such information, ultimately enhancing the overall security of IoT applications and promoting the sustainable development of the digital environment.

V. Conclusion

Traditional IoT network security situation sequences exhibit non-smooth and non-periodic fluctuations, making direct prediction challenging and resulting in poor model accuracy. To address these issues, this paper proposes a novel approach that decomposes the original situation sequence using VMD to reduce its instability. The decomposed individual sequences are then input into a CNN-BiLSTM-based Attention mechanism, with the Dropout mechanism incorporated to mitigate overfitting. Finally, fusion is performed using BiLSTM to generate the final prediction. Comparative experiments demonstrate the superiority of our proposed approach over other methods, as evidenced by the higher similarity between the model predictions and actual values. In today's digital environment, the application of this method significantly enhances the analysis and prediction capabilities of IoT network security situations. It empowers e-commerce platforms to gain better insights into potential security risks, and take timely measures for intervention and protection, ensuring the confidentiality and integrity of consumer data.

However, during the research process, we found significant uncertainty in the selection of VMD decomposition and BiLSTM parameters, and the lengthy model execution time poses a challenge. Future research efforts should concentrate on enhancing the model's computational efficiency, and employing swarm intelligence optimization algorithms for parameter selection. Furthermore, it is crucial to validate the model's generalization capability by utilizing a broader range of datasets.

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Conclusion sums up the paper with a final concluding statement.

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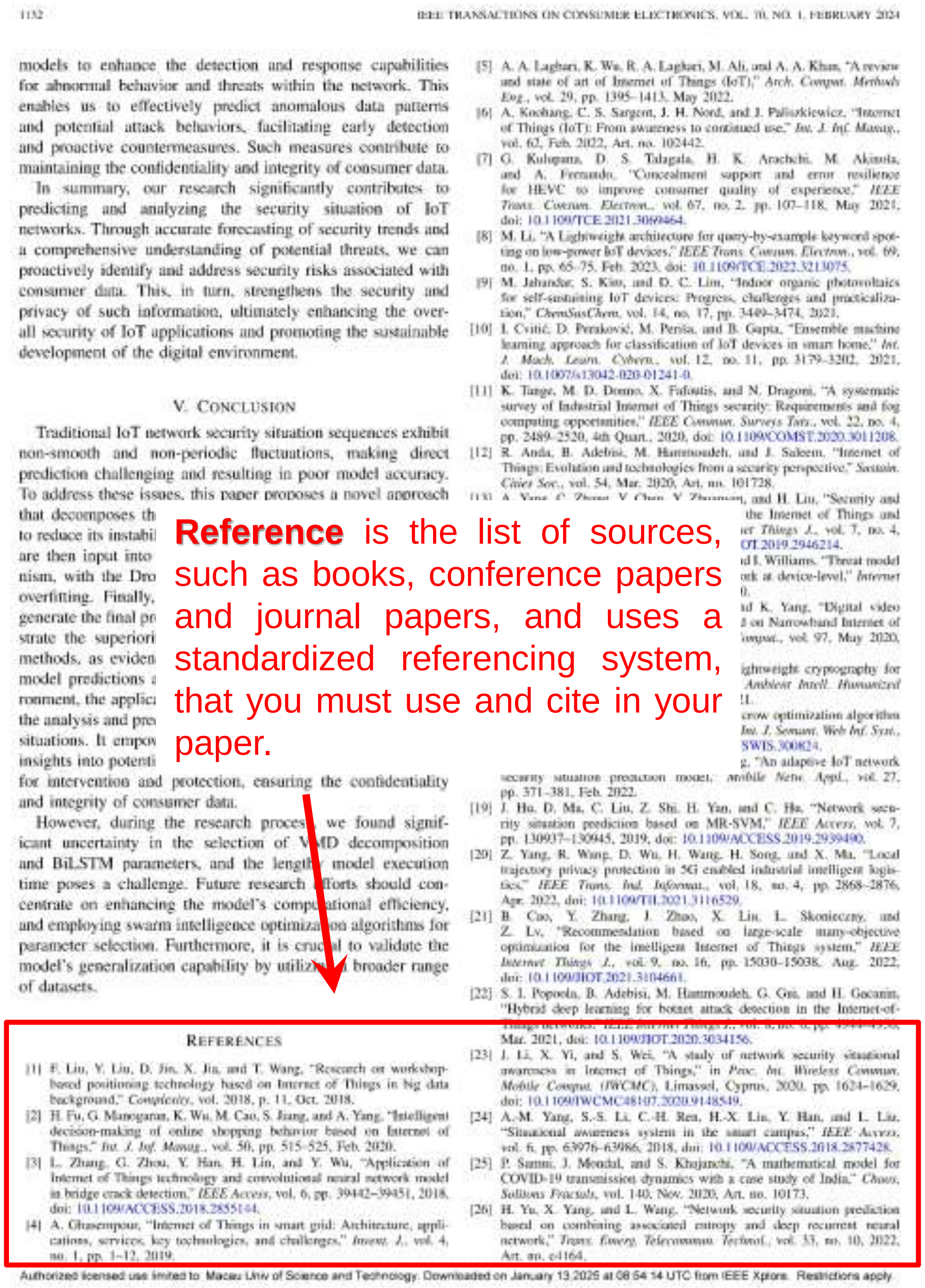

models to enhance the detection and response capabilities for abnormal behavior and threats within the network. This enables us to effectively predict anomalous data patterns and potential attack behaviors, facilitating early detection and proactive countermeasures. Such measures contribute to maintaining the confidentiality and integrity of consumer data.

In summary, our research significantly contributes to predicting and analyzing the security situation of IoT networks. Through accurate forecasting of security trends and a comprehensive understanding of potential threats, we can proactively identify and address security risks associated with consumer data. This, in turn, strengthens the security and privacy of such information, ultimately enhancing the overall security of IoT applications and promoting the sustainable development of the digital environment.

V. Conclusion

Traditional IoT network security situation sequences exhibit non-smooth and non-periodic fluctuations, making direct prediction challenging and resulting in poor model accuracy. To address these issues, this paper proposes a novel approach that decomposes th
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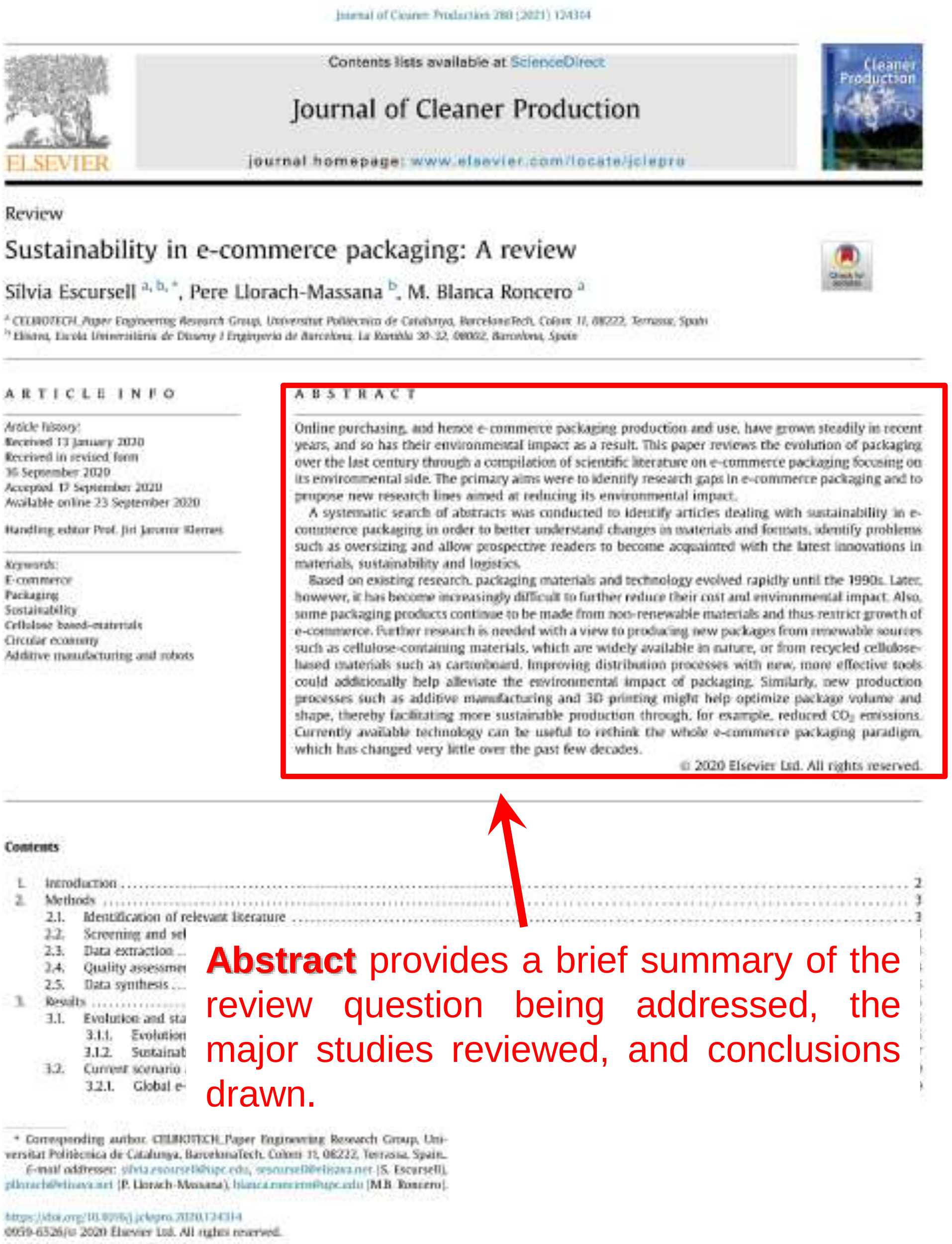

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Review

Sustainability in e-commerce packaging: A review

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ABSTRACT

Online purchasing, and hence e-commerce packaging production and use, have grown steadily in recent years, and so has their environmental impact as a result. This paper reviews the evolution of packaging over the last century through a compilation of scientific literature on e-commerce packaging focusing on its environmental side. The primary aims were to identify research gaps in e-commerce packaging and to propose new research lines aimed at reducing its environmental impact.

A systematic search of abstracts was conducted to identify articles dealing with sustainability in e-commerce packaging in order to better understand changes in materials and formats, identify problems such as oversizing and allow prospective readers to become acquainted with the latest innovations in materials, sustainability and logistics.

Based on existing research, packaging materials and technology evolved rapidly until the 1990s. Later, however, it has become increasingly difficult to further reduce their cost and environmental impact. Also, some packaging products continue to be made from non-renewable materials and thus restrict growth of e-commerce. Further research is needed with a view to producing new packages from renewable sources such as cellulose-containing materials, which are widely available in nature, or from recycled cellulose-based materials such as cartonboard. Improving distribution processes with new, more effective tools could additionally help alleviate the environmental impact of packaging. Similarly, new production processes such as additive manufacturing and 3D printing might help optimize package volume and shape, thereby facilitating more sustainable production through, for example, reduced CO_2 emissions. Currently available technology can be useful to rethink the whole e-commerce packaging paradigm, which has changed very little over the past few decades.

Contents

Abstract provides a brief summary of the review question being addressed, the major studies reviewed, and conclusions drawn.

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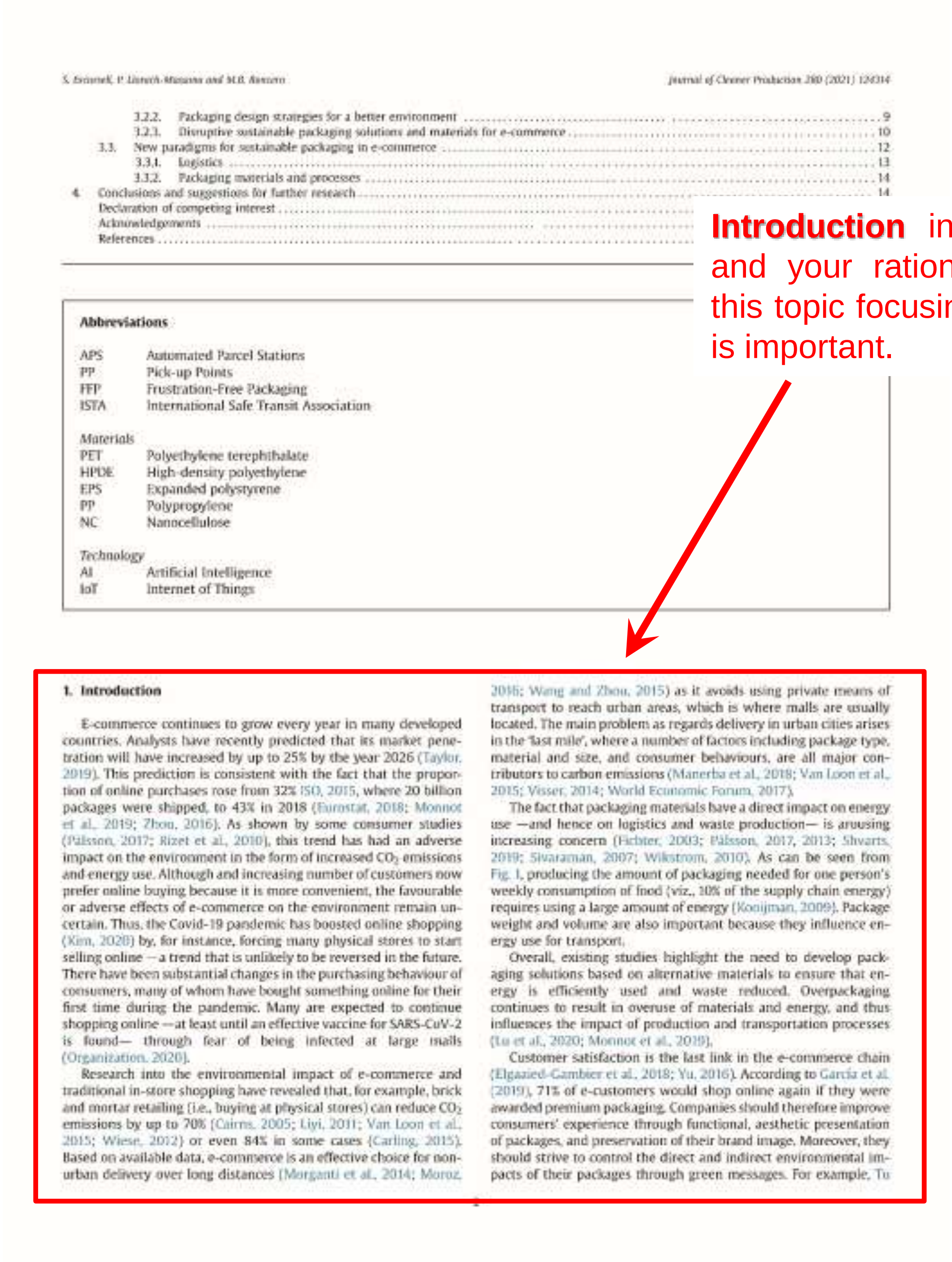

Abbreviations

APS	Automated Parcel Stations
PP	Pick-up Points
FFP	Frustration-Free Packaging
ISTA	International Safe Transit Association
Materials	
PET	Polyethylene terephthalate
HPDE	High-density polyethylene
EPS	Expanded polystyrene
PP	Polypropylene
NC	Nanocellulose
Technology	
AI	Artificial Intelligence
IoT	Internet of Things

1. Introduction

E-commerce continues to grow every year in many developed countries. Analysts have recently predicted that its market penetration will have increased by up to 25% by the year 2026 (Taylor, 2019). This prediction is consistent with the fact that the proportion of online purchases rose from 32% ISO, 2015, where 20 billion packages were shipped, to 43% in 2018 (Eurostat, 2018; Monnot et al., 2019; Zhou, 2016). As shown by some consumer studies (Pålsson, 2017; Rizet et al., 2010), this trend has had an adverse impact on the environment in the form of increased CO_2 emissions and energy use. Although and increasing number of customers now prefer online buying because it is more convenient, the favourable or adverse effects of e-commerce on the environment remain uncertain. Thus, the Covid-19 pandemic has boosted online shopping (Kim, 2020) by, for instance, forcing many physical stores to start selling online — a trend that is unlikely to be reversed in the future. There have been substantial changes in the purchasing behaviour of consumers, many of whom have bought something online for their first time during the pandemic. Many are expected to continue shopping online —at least until an effective vaccine for SARS-CuV-2 is found— through fear of being infected at large malls (Organization, 2020).

Research into the environmental impact of e-commerce and traditional in-store shopping have revealed that, for example, brick and mortar retailing (i.e., buying at physical stores) can reduce CO_2 emissions by up to 70% (Cairns, 2005; Liyi, 2011; Van Loon et al., 2015; Wiese, 2012) or even 84% in some cases (Carling, 2015). Based on available data, e-commerce is an effective choice for non-urban delivery over long distances (Morganti et al., 2014; Moroz, 2016; Wang and Zhou, 2015) as it avoids using private means of transport to reach urban areas, which is where malls are usually located. The main problem as regards delivery in urban cities arises in the 'last mile', where a number of factors including package type, material and size, and consumer behaviours, are all major contributors to carbon emissions (Manerba et al., 2018; Van Loon et al., 2015; Visser, 2014; World Economic Forum, 2017).

The fact that packaging materials have a direct impact on energy use —and hence on logistics and waste production— is arousing increasing concern (Fichter, 2003; Pålsson, 2017, 2013; Shvarts, 2019; Sivaraman, 2007; Wikstrom, 2010). As can be seen from Fig. 1, producing the amount of packaging needed for one person's weekly consumption of food (viz., 10% of the supply chain energy) requires using a large amount of energy (Koonijman, 2009). Package weight and volume are also important because they influence energy use for transport.

Overall, existing studies highlight the need to develop packaging solutions based on alternative materials to ensure that energy is efficiently used and waste reduced. Overpackaging continues to result in overuse of materials and energy, and thus influences the impact of production and transportation processes (Lu et al., 2020; Monnot et al., 2019).

Customer satisfaction is the last link in the e-commerce chain (Elgaaied-Gambier et al., 2018; Yu, 2016). According to García et al. (2019), 71% of e-customers would shop online again if they were awarded premium packaging. Companies should therefore improve consumers' experience through functional, aesthetic presentation of packages, and preservation of their brand image. Moreover, they should strive to control the direct and indirect environmental impacts of their packages through green messages. For example, Tu

Introduction introduces the topic and your rationale for addressing this topic focusing on why this topic is important.

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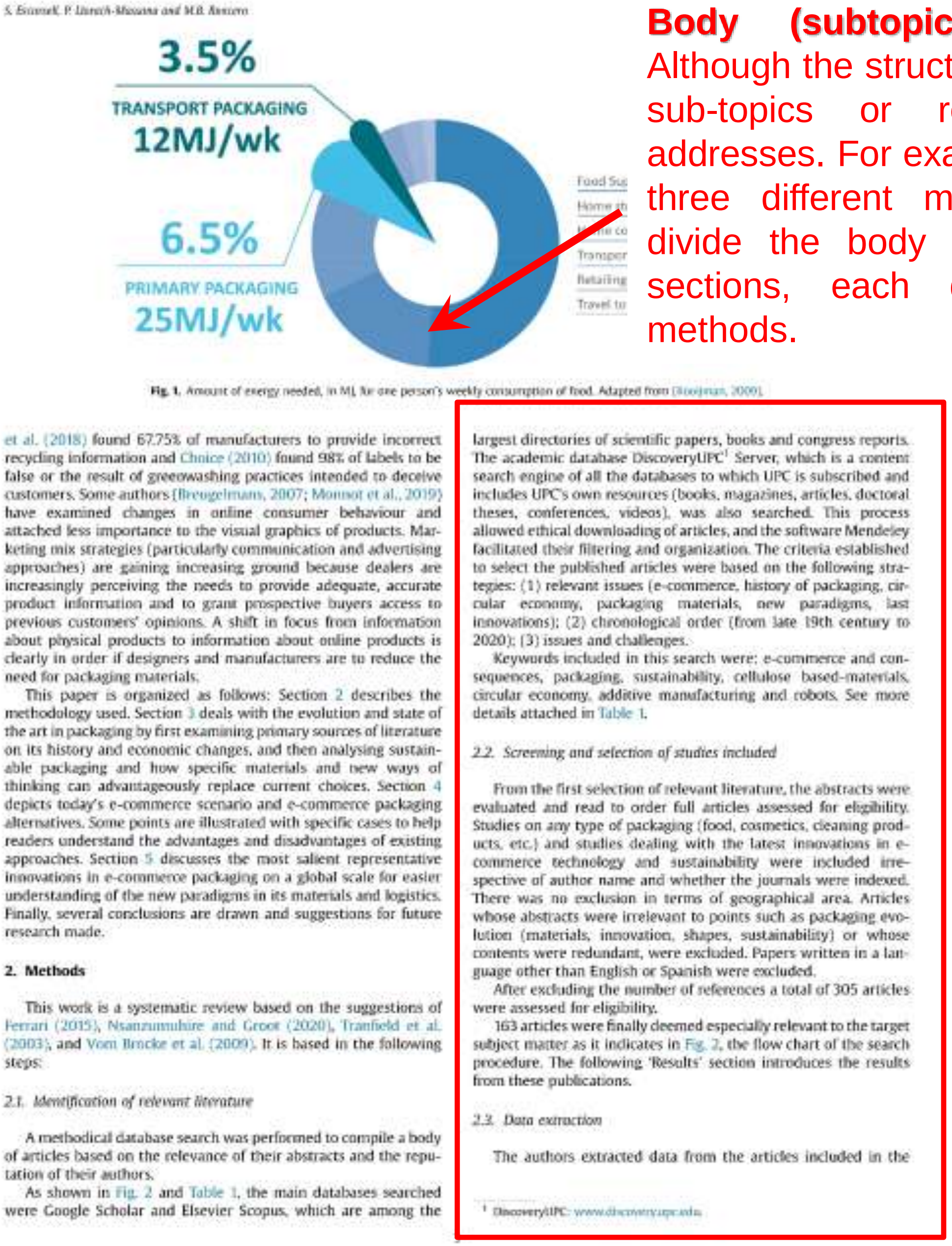
Body (subtopics being addressed): Although the structure may vary based in the sub-topics or review questions being addresses. For example, if you are reviewing three different methodologies, you might divide the body of the article into three sections, each discussing one of the methods.



S. Escursell, P. Llorach-Massana and M.B. Roncero

Fig. 1. Amount of energy needed, in MJ, for one person's weekly consumption of food. Adapted from (Rooijman, 2009).

et al. (2018) found 67.75% of manufacturers to provide incorrect recycling information and Choice (2010) found 98% of labels to be false or the result of greenwashing practices intended to deceive customers. Some authors (Breugelmans, 2007; Monnot et al., 2019) have examined changes in online consumer behaviour and attached less importance to the visual graphics of products. Marketing mix strategies (particularly communication and advertising approaches) are gaining increasing ground because dealers are increasingly perceiving the needs to provide adequate, accurate product information and to grant prospective buyers access to previous customers' opinions. A shift in focus from information about physical products to information about online products is clearly in order if designers and manufacturers are to reduce the need for packaging materials.

This paper is organized as follows: Section 2 describes the methodology used. Section 3 deals with the evolution and state of the art in packaging by first examining primary sources of literature on its history and economic changes, and then analysing sustainable packaging and how specific materials and new ways of thinking can advantageously replace current choices. Section 4 depicts today's e-commerce scenario and e-commerce packaging alternatives. Some points are illustrated with specific cases to help readers understand the advantages and disadvantages of existing approaches. Section 5 discusses the most salient representative innovations in e-commerce packaging on a global scale for easier understanding of the new paradigms in its materials and logistics. Finally, several conclusions are drawn and suggestions for future research made.

2. Methods

This work is a systematic review based on the suggestions of Ferrari (2015), Nsanzumuhire and Groot (2020), Tranfield et al. (2003), and Vom Brocke et al. (2009). It is based in the following steps:

2.1. *Identification of relevant literature*

A methodical database search was performed to compile a body of articles based on the relevance of their abstracts and the reputation of their authors.

As shown in Fig. 2 and Table 1, the main databases searched were Google Scholar and Elsevier Scopus, which are among the largest directories of scientific papers, books and congress reports. The academic database DiscoveryUPC[1] Server, which is a content search engine of all the databases to which UPC is subscribed and includes UPC's own resources (books, magazines, articles, doctoral theses, conferences, videos), was also searched. This process allowed ethical downloading of articles, and the software Mendeley facilitated their filtering and organization. The criteria established to select the published articles were based on the following strategies: (1) relevant issues (e-commerce, history of packaging, circular economy, packaging materials, new paradigms, last innovations); (2) chronological order (from late 19th century to 2020); (3) issues and challenges.

Keywords included in this search were: e-commerce and consequences, packaging, sustainability, cellulose based-materials, circular economy, additive manufacturing and robots. See more details attached in Table 1.

2.2. *Screening and selection of studies included*

From the first selection of relevant literature, the abstracts were evaluated and read to order full articles assessed for eligibility. Studies on any type of packaging (food, cosmetics, cleaning products, etc.) and studies dealing with the latest innovations in e-commerce technology and sustainability were included irrespective of author name and whether the journals were indexed. There was no exclusion in terms of geographical area. Articles whose abstracts were irrelevant to points such as packaging evolution (materials, innovation, shapes, sustainability) or whose contents were redundant, were excluded. Papers written in a language other than English or Spanish were excluded.

After excluding the number of references a total of 305 articles were assessed for eligibility.

163 articles were finally deemed especially relevant to the target subject matter as it indicates in Fig. 2, the flow chart of the search procedure. The following 'Results' section introduces the results from these publications.

2.3. *Data extraction*

The authors extracted data from the articles included in the

[1] DiscoveryUPC: www.discovery.upc.edu

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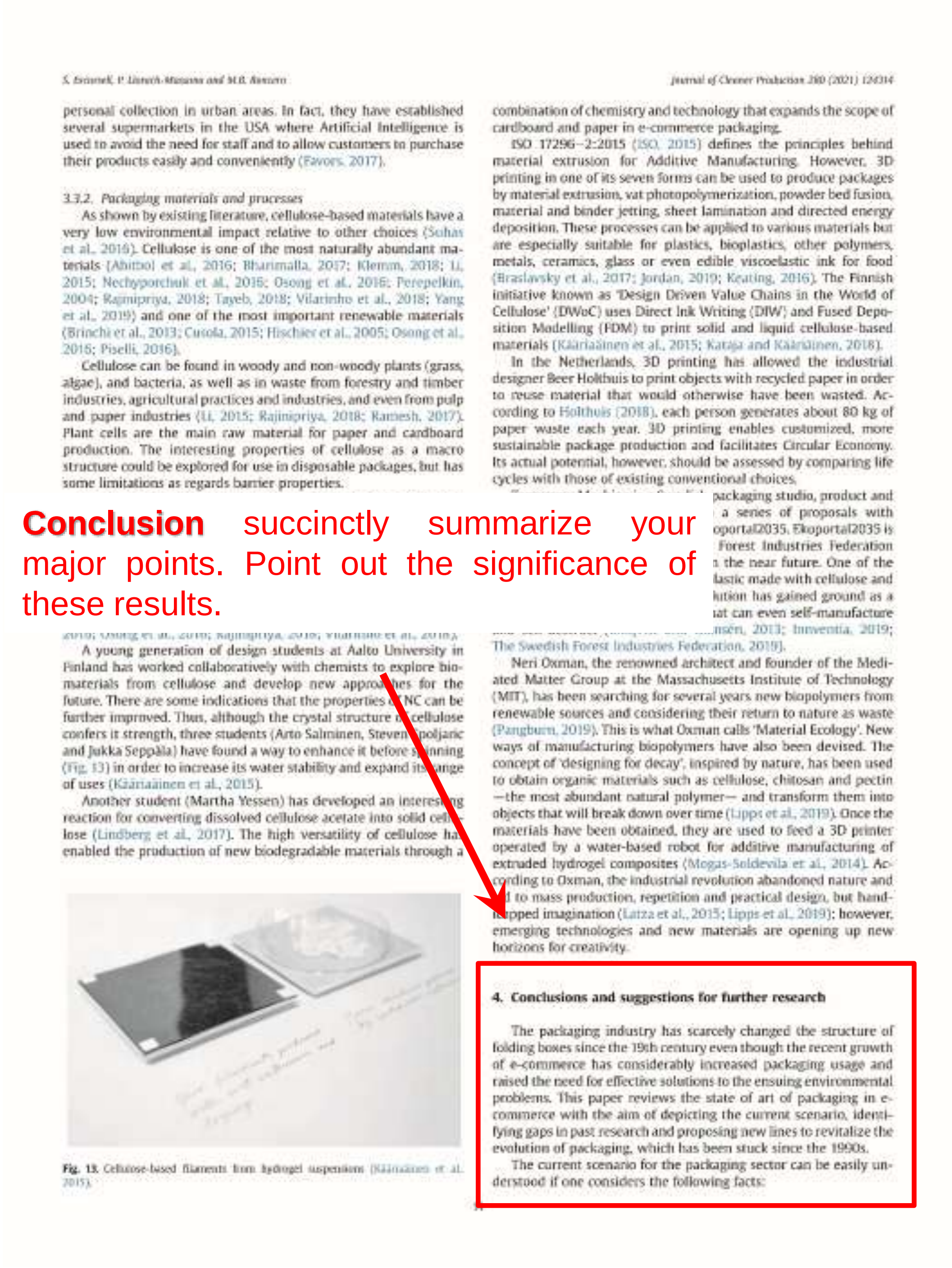

personal collection in urban areas. In fact, they have established several supermarkets in the USA where Artificial Intelligence is used to avoid the need for staff and to allow customers to purchase their products easily and conveniently (Favors, 2017).

3.3.2. *Packaging materials and processes*

As shown by existing literature, cellulose-based materials have a very low environmental impact relative to other choices (Suhas et al., 2016). Cellulose is one of the most naturally abundant materials (Abitbol et al., 2016; Bharimalla, 2017; Klemm, 2018; Li, 2015; Nechyporchuk et al., 2016; Osong et al., 2016; Perepelkin, 2004; Rajinipriya, 2018; Tayeb, 2018; Vilarinho et al., 2018; Yang et al., 2019) and one of the most important renewable materials (Brinchi et al., 2013; Cusola, 2015; Hischier et al., 2005; Osong et al., 2016; Piselli, 2016).

Cellulose can be found in woody and non-woody plants (grass, algae), and bacteria, as well as in waste from forestry and timber industries, agricultural practices and industries, and even from pulp and paper industries (Li, 2015; Rajinipriya, 2018; Ramesh, 2017). Plant cells are the main raw material for paper and cardboard production. The interesting properties of cellulose as a macro structure could be explored for use in disposable packages, but has some limitations as regards barrier properties.

2016; Osong et al., 2016; Rajinipriya, 2018; Vilarinho et al., 2018).

A young generation of design students at Aalto University in Finland has worked collaboratively with chemists to explore biomaterials from cellulose and develop new approaches for the future. There are some indications that the properties of NC can be further improved. Thus, although the crystal structure of cellulose confers it strength, three students (Arto Salminen, Steven Spoljaric and Jukka Seppäla) have found a way to enhance it before spinning (Fig. 13) in order to increase its water stability and expand its range of uses (Kääriaäinen et al., 2015).

Another student (Martha Yessen) has developed an interesting reaction for converting dissolved cellulose acetate into solid cellulose (Lindberg et al., 2017). The high versatility of cellulose has enabled the production of new biodegradable materials through a combination of chemistry and technology that expands the scope of cardboard and paper in e-commerce packaging.

Fig. 13. Cellulose-based filaments from hydrogel suspensions (Kääriäinen et al., 2015).

ISO 17296−2:2015 (ISO, 2015) defines the principles behind material extrusion for Additive Manufacturing. However, 3D printing in one of its seven forms can be used to produce packages by material extrusion, vat photopolymerization, powder bed fusion, material and binder jetting, sheet lamination and directed energy deposition. These processes can be applied to various materials but are especially suitable for plastics, bioplastics, other polymers, metals, ceramics, glass or even edible viscoelastic ink for food (Braslavsky et al., 2017; Jordan, 2019; Keating, 2016). The Finnish initiative known as 'Design Driven Value Chains in the World of Cellulose' (DWoC) uses Direct Ink Writing (DIW) and Fused Deposition Modelling (FDM) to print solid and liquid cellulose-based materials (Kääriaäinen et al., 2015; Kataja and Kääriäinen, 2018).

In the Netherlands, 3D printing has allowed the industrial designer Beer Holthuis to print objects with recycled paper in order to reuse material that would otherwise have been wasted. According to Holthuis (2018), each person generates about 80 kg of paper waste each year. 3D printing enables customized, more sustainable package production and facilitates Circular Economy. Its actual potential, however, should be assessed by comparing life cycles with those of existing conventional choices.

packaging studio, product and
a series of proposals with
oportal2035. Ekoportal2035 is
Forest Industries Federation
the near future. One of the
lastic made with cellulose and
lution has gained ground as a
at can even self-manufacture
nsén, 2013; Inventia, 2019;
The Swedish Forest Industries Federation, 2019).

Neri Oxman, the renowned architect and founder of the Mediated Matter Group at the Massachusetts Institute of Technology (MIT), has been searching for several years new biopolymers from renewable sources and considering their return to nature as waste (Pangburn, 2019). This is what Oxman calls 'Material Ecology'. New ways of manufacturing biopolymers have also been devised. The concept of 'designing for decay', inspired by nature, has been used to obtain organic materials such as cellulose, chitosan and pectin —the most abundant natural polymer— and transform them into objects that will break down over time (Lipps et al., 2019). Once the materials have been obtained, they are used to feed a 3D printer operated by a water-based robot for additive manufacturing of extruded hydrogel composites (Mogas-Soldevila et al., 2014). According to Oxman, the industrial revolution abandoned nature and led to mass production, repetition and practical design, but handicapped imagination (Latza et al., 2015; Lipps et al., 2019); however, emerging technologies and new materials are opening up new horizons for creativity.

4. Conclusions and suggestions for further research

The packaging industry has scarcely changed the structure of folding boxes since the 19th century even though the recent growth of e-commerce has considerably increased packaging usage and raised the need for effective solutions to the ensuing environmental problems. This paper reviews the state of art of packaging in e-commerce with the aim of depicting the current scenario, identifying gaps in past research and proposing new lines to revitalize the evolution of packaging, which has been stuck since the 1990s.

The current scenario for the packaging sector can be easily understood if one considers the following facts:

Conclusion succinctly summarize your major points. Point out the significance of these results.

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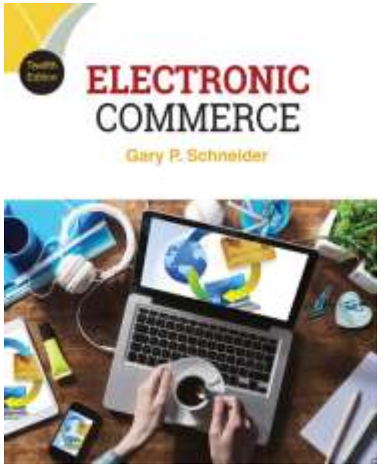

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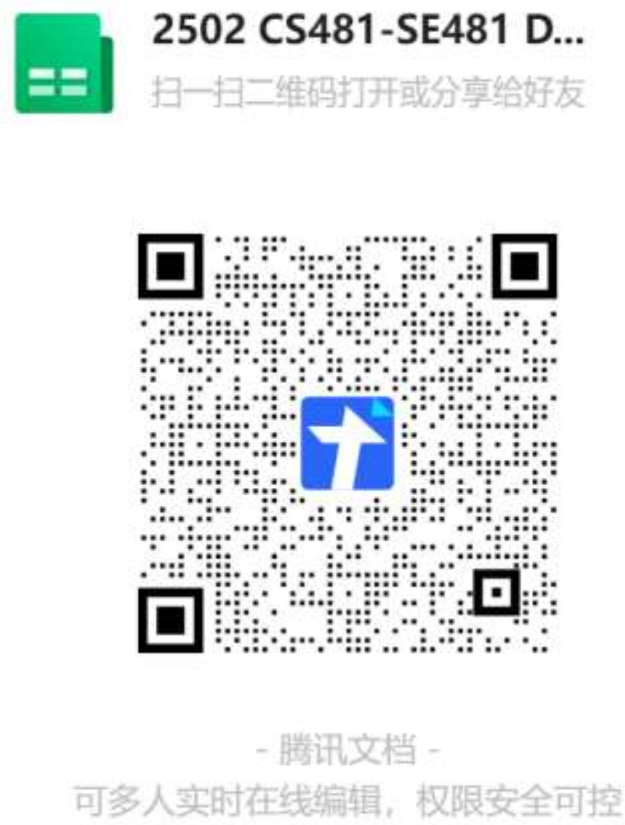

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