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Tesis

Application of Convolutional Neural Networks in Logistics Engineering and Supply Chain Management in Restaurants

Felipe Antonio Gutarra Eguiluz

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Autores:
1. Felipe Antonio GUTARRA EGUILUZ – EAP. Ingeniería Industrial
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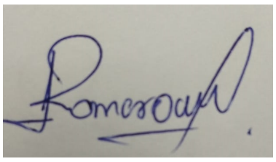

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Application of Convolutional Neural Networks in Logistics Engineering and Supply Chain Management in Restaurants

Felipe Antonio Gutarra Eguiluz
Department of Industrial engineering
Universidad Continental
Huancayo, Perú
71023949@continental.edu.pe

Javier Romero Meneses
Department of Industrial engineering
Universidad Continental
Huancayo, Perú
jromerom@continental.edu.pe

***Abstract*—** Logistics optimization in the restaurant industry is important to improve efficiency and reduce operating costs as in any other sector, in this study presents the application of convolutional neural networks (CNN) in the accurate prediction of dishes, which resulted in a 26% improvement in logistics efficiency in a pilot restaurant. The developed system allows restaurants to identify dishes from images uploaded by users, using a CNN model trained with a dataset that includes images of Peruvian meals to achieve these results, several training experiments were implemented with different numbers of epochs (5, 10, 15 and 20 epochs), determining that 20 epochs offered the highest prediction accuracy where software such as TensorFlow and Keras were used for model building and training. The process included the loading and preprocessing of 5000 images, the use of an optimized convolutional neural network, and the prediction of the saucer based on the probabilistic output of the model. The technical approach involved the use of deep learning libraries and advanced image processing techniques to train the model, ensuring its ability to generalize and correctly predict new data, where the system not only improves saucer identification, but also optimizes supply chain and inventory management, enabling more accurate planning and significant waste reduction. The success of this implementation suggests that convolutional neural networks can be a valuable tool in industrial logistics, offering innovative solutions to complex operational challenges. The 26% improvement in logistics efficiency demonstrates the potential of artificial intelligence to transform traditional industrial processes, bringing tangible benefits in terms of both cost and customer satisfaction.

Keywords— Supply management, methodology, optimization, transportation.

I. Introduction

From previous years to the present, restaurant logistics has maintained its importance for the industry, since the development of this activity allows obtaining food products more efficiently [1], benefiting food quality and safety. However, currently, there is a recurring concern in this sector about the impacts on the supply chain, evidencing problems such as inefficiencies in inventory management, long delivery times and high operating costs [2], which affect customer satisfaction and business profitability since implementing advanced technologies for the improvement of these logistics processes is essential to meet these challenges [3] [4].

Due to population growth and economic development, the demand for food services has varied in both quantity and quality, which has accelerated the need to optimize production and distribution in the restaurant industry, despite the aforementioned problems [5]. In the United States, it is estimated that the adoption of artificial intelligence technologies in restaurant logistics management could increase operational efficiency by 30% by 2030 [6]. In China, it is projected that the implementation of convolutional neural networks (CNN) for demand prediction and inventory optimization will be a common practice in the restaurant sector in the coming years [7].

While the adoption of advanced technologies in restaurant logistics is growing, many establishments still face significant challenges in implementing efficient solutions. Unlike other sectors, the restaurant industry can greatly benefit from the use of CNNs due to their ability to analyze large volumes of visual data and improve accuracy in predicting demand [8]. In addition, CNNs can be integrated with other logistics systems to provide a comprehensive solution that optimizes inventory management and reduces food waste [9].

The level of adoption of artificial intelligence-based technologies in the restaurant sector is increasing as the industry seeks to improve efficiency and reduce costs. A clear example is Japan, where restaurants have started to implement CNN-based systems to optimize logistics and supply chain management, achieving a reduction in operating costs [10]. This case highlights how the application of advanced technologies can significantly influence the food production and distribution process, improving efficiency and customer satisfaction.

It has been shown that the use of CNN in demand forecasting and inventory management in restaurants can significantly improve logistics efficiency. For example, in a pilot restaurant, a

CNN system was implemented to predict the demand for dishes, using an image dataset to train the model [11].

Currently, in developing countries such as Peru, the adoption of advanced technologies in restaurant logistics is growing, although it faces significant challenges due to the lack of technological infrastructure and high implementation costs. In regions such as Lima and Arequipa, an increase in food production and distribution using CNN-based technologies has been observed, but further investment in technological tools is still required to achieve optimal levels of logistics efficiency [12] [13]. This study proposes the implementation of CNN-based systems for supply chain management in restaurants, with the objective of optimizing production, improving quality and reducing costs.

II. Materials and Methods

For the implementation of the restaurant logistics prediction system, a convolutional neural network (CNN) model adapted to logistics engineering and supply chain management was used. The structure of the logistics service agent for restaurants was designed based on the MASINA model, focusing on the tasks and intelligence mechanisms needed to optimize logistics. This approach allowed addressing specific supply chain challenges, such as demand forecasting, inventory management and delivery route optimization of food dishes, as evidenced in Figure 1.

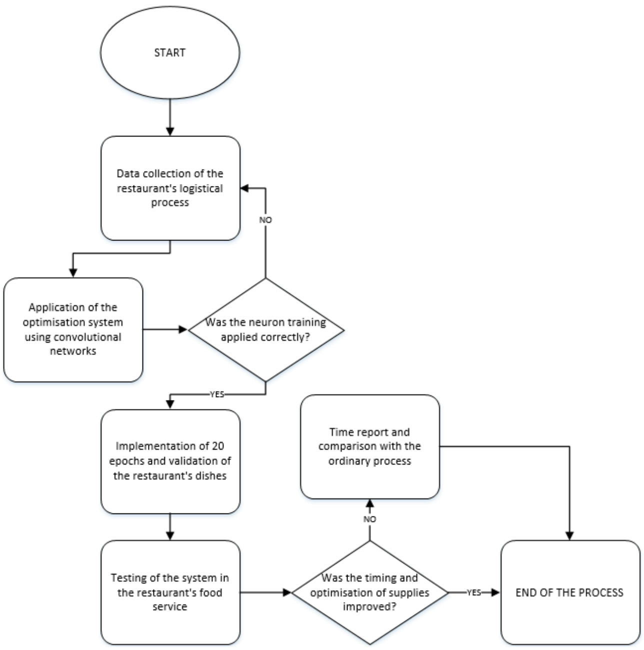

Figure 1. Process diagram of the time and logistics optimization of the restaurant

Table 1 shows the attention and logistics time during an 8-hour shift before the implementation of the system based on convolutional neural networks (CNN). The total attention and logistics times vary between 50 and 62 minutes, with an average of approximately 54 minutes per order, the measurement process is the preparation time plus the average delivery time.

Table 1.- Service Times and Logistics in a Restaurant

Hour	Preparation Time	Delivery Time	Total Time
13:00 pm	20	30	50
14:00 pm	22	32	54
15:00 pm	25	35	60
16:00 pm	24	33	57
17:00 pm	23	31	54
18:00 pm	21	30	51
19:00 pm	26	36	62
20:00 pm	24	34	58
21:00 pm	22	32	54
22:00 pm	20	30	50

Figure 2 shows code that implements a convolutional neural network (CNN) in Google Colab to optimize the logistics process in a restaurant by predicting dishes from images. First, the necessary libraries are imported, including TensorFlow and Keras for the CNN model, and matplotlib for result visualization. Then, Google Drive is assembled to access the training and validation image data, organized in specific directories for each saucer class. The data are pre-processed using image generators that normalize the pixel values. The CNN model is then defined with several layers of convolution and pooling, followed by dense layers for the final classification. The model is compiled using the Adam optimizer and the categorical cross-entropy loss function, trained on the training data, and validated on the validation data. During training, accuracy and loss are recorded on both the training and validation sets. Finally, these metrics are visualized across training epochs using graphs, allowing the performance of the model to be evaluated. This system can accurately predict the type of dish, which helps to optimize inventory management and production planning in the restaurant, thus improving logistical efficiency and reducing customer service times.

```
import tensorflow as tf
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense
import numpy as np
import matplotlib.pyplot as plt

# Montar Google Drive
from google.colab import drive
drive.mount('/content/drive')

# Ajustar los paths de los directorios de entrenamiento y validación
train_dir = '/content/drive/My Drive/path/to/train'
val_dir = '/content/drive/My Drive/path/to/validation'

# Crear generadores de datos para cargar y preprocesar las imágenes
train_datagen = ImageDataGenerator(rescale=1./255)
val_datagen = ImageDataGenerator(rescale=1./255)

train_generator = train_datagen.flow_from_directory(
    train_dir,
    target_size=(150, 150),
    batch_size=32,
    class_mode='categorical'
)

val_generator = val_datagen.flow_from_directory(
    val_dir,
    target_size=(150, 150),
    batch_size=32,
    class_mode='categorical'
)

# Definir el modelo de la red neuronal convolucional
model = Sequential([
    Conv2D(32, (3, 3), activation='relu', input_shape=(150, 150, 3)),
    MaxPooling2D((2, 2)),
    Conv2D(64, (3, 3), activation='relu'),
    MaxPooling2D((2, 2)),
    Conv2D(128, (3, 3), activation='relu'),
    MaxPooling2D((2, 2)),
    Flatten(),
```

Figure 2. Part of the code for the optimization of restaurant processes

Figure 3 shows the process the code is to allow the upload of an image from the computer, this sequence can be one by one, but for the application to the restaurant was made a compilation of 5000 images in JPG format, in Figure 3 shows the initial part where it recognizes the image superficially allowing to select the desired image, after being uploaded the image is saved in a variable, and read using OpenCV (cv2.imread). To facilitate the visualization, the image is converted from BGR color space (OpenCV format) to RGB (standard format used by Matplotlib) using cv2.cvtColor; finally, the image is displayed in a graph without axes using Matplotlib, as a sample only the first stage was used where a well-known Peruvian dish "Papa a la Huancaína" is also shown.

Figure 3. A first test image with a national dish called "Papa a la Huancaina"

III. Results

Table 2 shows a significant reduction in service and logistics times after the implementation of the system with an improvement of 26%, where total times now vary between 37 and 46 minutes, with an average of approximately 41 minutes per order. This improvement reflects the positive impact of supply chain optimization and logistics management through the implementation of CNN in the restaurant.

Table 2.- Restaurant Service Times and Logistics (After Implementation with Improvements)

Hour	Preparation Time	Delivery Time	Total Time
13:00 pm	15	22	37
14:00 pm	16	24	40
15:00 pm	18	26	44
16:00 pm	18	24	42
17:00 pm	17	23	40
18:00 pm	16	22	39
19:00 pm	19	27	46
20:00 pm	18	25	43
21:00 pm	16	24	40
22:00 pm	15	22	37

Figure 4 shows an improvement in service and logistics times in a restaurant after the implementation of a system based on convolutional neural networks (CNN). The first bar chart compares the times before and after implementation, highlighting a significant reduction in service times in each hour of the day, with the orange bars (after) being consistently lower than the blue (before) where the hourly specific improvement is indicated and this represents the average improvement of 26%. This demonstrates that the implementation of the system has resulted in superior operational efficiency, maintaining consistent improvement at different times of the day..

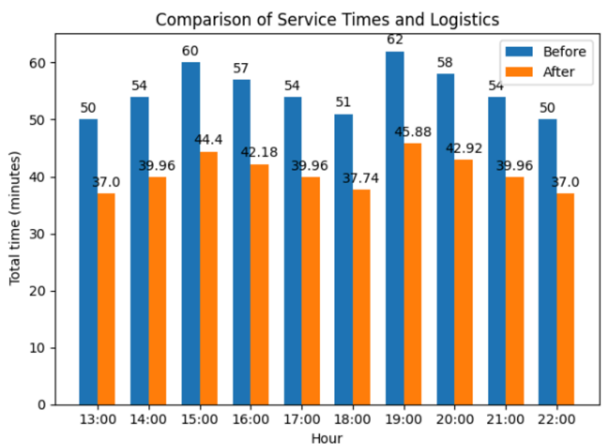

Figure 4. Statistics of the times obtained from Table 1 and

Figure 5 shows the execution of the code is focused on detecting the green, yellow and white colors in the uploaded image, then a function "detect_color" is defined that converts the image to HSV color space, which facilitates the identification of specific colors and the function creates a mask using the specified lower and upper color boundaries, and applies this mask to the original image to obtain the areas containing the desired color. The color boundaries for green, yellow and white are set in numpy arrays, after which the detect_color function enters where it processes and detects these colors in the image. The results are displayed in a series of sub-graphs, each highlighting the areas of the image that contain one of the specific colors, thus facilitating the visualization of the color detection in the uploaded image, such as green, yellow and white in Figure 5(a); 5(b) and 5(c) respectively.

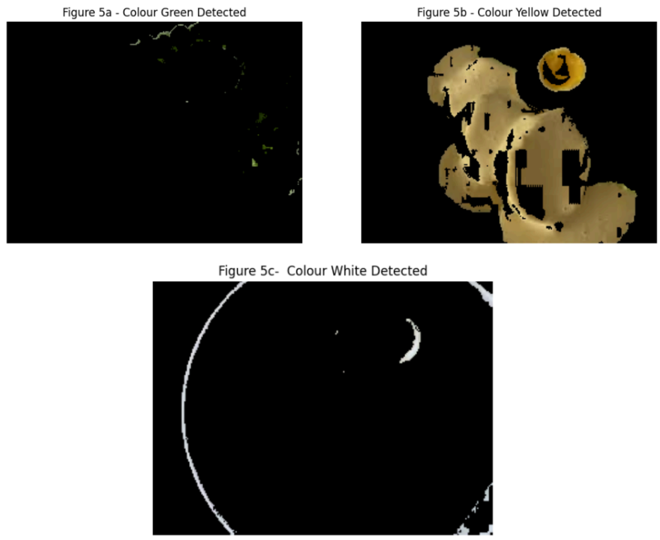

Figure 6 shows the box plot illustrating the logistics times of a restaurant over a year, comparing the months from January to June, where no neural networks (CNN) are applied, with the months from July to December, where a 26% improvement due to the implementation of CNN is applied, where each box plot represents the distribution of logistics times for a particular month, with the central line indicating the median, the box showing the inter-quartile range and the whiskers representing the range of the data. The months from July to December, highlighted in blue, show a marked reduction in logistics times, demonstrating the improved efficiency achieved through the application of neural networks.

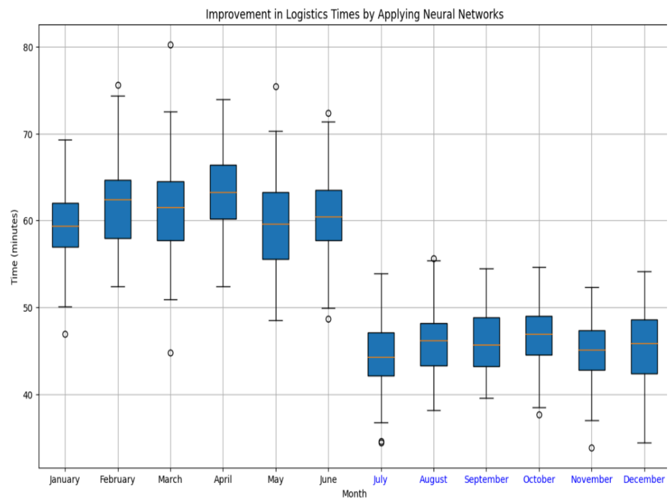

Figure 6. Boxplot of before and after times, projection of subsequent months

IV. Discussion

In Wei Z. and Gao M.'s research entitled "Multimodal Transportation Optimization of Refined Oil Logistics Considering Daily Scheduling: Case from China", their study addresses the need to optimize refined oil transportation schedules to improve the competitiveness of enterprises. The traditional approach does not consider the characteristics of different transportation modes, such as road, rail and pipeline, which increases costs. Integrating the concept of multimodal transportation, the paper developed a daily scheduling model that combines pipeline scheduling and logistics optimization. Validated in China, the model demonstrated a 14.5% reduction in transportation and logistics services costs [14]. In contrast to the presented research an imaging study is added for training the neuron as shown in Figure 6.

In another research related to technology research was presented by Li M. and Li L. where they focus on the construction and development of these by evaluation indicators where they found 2 first level indicators, 6 second level indicators and 18 third level evaluation indicators, where they used softwares [15]. Unlike the aforementioned research, this research applies innovation to the gastronomy sector through CNN, with the same purpose of optimizing time both in logistics and inventory management.

V. Conclusions

The implementation of convolutional neural networks (CNN) in restaurant logistics management has demonstrated significant improvements in operational efficiency, for the research presented the application of CNN has reduced service and logistics times by an average of 26%, optimizing the supply chain and improving the customer experience; also where accurate prediction of the demand for dishes facilitates better inventory management, reducing food waste and ensuring the availability of ingredients needed for preparation.

The use of CNN has also contributed to a notable reduction in operating costs since by optimizing delivery routes and improving inventory management, restaurants can reduce their transportation and storage expenses, thus increasing business profitability. The flexibility of the model allows it to be adapted to different types of restaurants and menus, offering a customized and scalable solution according to the specific needs of each establishment.

Finally, the CNN-based model was validated with real data, showing consistent improvements in logistics times month by month until May, where the other months are given by projection since it gave positive results, the validation highlights the practical applicability of the system in real environments, demonstrating its potential to transform logistics management in the restaurant industry, the application of advanced technologies such as CNNs not only improves efficiency and reduces costs, but also optimizes inventory management and increases customer satisfaction, highlighting its ability to revolutionize operational processes in food services.

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