

A Comprehensive Approach to Improving Enterprise Management Processes Through Applying Deep Learning Algorithms: A Case Study

Mikaël Ange Mousse



Abstract: *This paper addresses the critical need to enhance the management of pension payments at Benin's National Social Security Fund (NSSF), highlighting the pivotal role of deep learning methodologies in achieving optimization. As a key institution responsible for safeguarding the financial well-being of the population through social security programs, the NSSF faces unique challenges in managing the large volume of regular pension payments. This study introduces an innovative deep learning-based approach specifically tailored to the complexities of pension payment management at the NSSF in Benin. By leveraging advanced neural network architectures, our methodology aims to streamline and optimize the processes involved in pension disbursements, focusing on improving accuracy, efficiency, and overall operational effectiveness. Key components of this approach include analyzing historical pension payment data, demographic trends, and relevant socioeconomic indicators to develop predictive models. These models help forecast and adapt to changing patterns, ensuring timely and accurate pension payments. Through a detailed case study on the NSSF of Benin, we demonstrate the practical application of deep learning in addressing the specific challenges faced by public entities managing pension payments.*

Keywords: *Deep Learning, Pension Payment Management, National Social Security Fund, Optimization.*

I. INTRODUCTION

The National Social Security Fund (NSSF) of Benin stands as a cornerstone in the nation's commitment to ensuring the financial well-being and security of its citizens through comprehensive social security programs. Among the many responsibilities shouldered by the NSSF, the management of pension payments stands out as a critical and complex task, involving the disbursement of funds to a diverse and growing population at regular intervals. Given this complexity, applying advanced technologies is imperative to streamline processes, enhance efficiency, and ensure the sustainability of pension systems.

This paper embarks on a pioneering exploration into the use of deep learning as a catalyst for optimizing pension payment management, with a particular focus on the context of the National Social Security Fund of Benin.

By introducing a deep learning-based approach, we aim to address the unique challenges inherent in managing a substantial volume of periodic pension payments while navigating the dynamic landscape of demographic shifts, economic fluctuations, and regulatory changes.

The importance of efficient pension payment management cannot be overstated, considering its direct impact on the livelihoods of retirees who depend on these funds for financial stability. The intersection of technological innovation and public financial management presents an opportunity not only to streamline processes but also to enhance the accuracy and reliability of pension disbursements. Various authors propose the use of machine learning to predict financial crises. Liu et al [1], Marhwal et al. [2] and Jain et al. [3]. suggest that machine learning methods should be used when establishing early warning systems to predict financial crises in the future. Katib et al [4]., propose a hybrid hunter-prey optimization with the deep learning-based FCP (HHPODL-FCP) technique which uses the HHPO algorithm for the feature subset selection process. Their objective is to predict financial crises in financial technology. Wang and Zong [5] demonstrate that machine learning outperforms canonical models in alarming crises. They also prove that private sectors can benefit from ML-based EWS in the short term. Casabianca et al [6]. used a machine learning approach, namely AdaBoost, to rank the determinants of banking crises over time and across countries. Their work covers a total of 100 countries, advanced and emerging, over the years from 1970 to 2017. Several research works also have been made to incorporate machine learning. In this direction, Samitas et al. suggested using neural networks [7]. A global literature review was presented by Henrique et al [8]. The use of deep learning as a machine learning method continues to advance [9,10]. Shinde and Shah [11] present a review of machine learning and deep learning applications.

In this paper, we propose a deep learning-based approach to managing a public entity. The major contribution of this article lies in the introduction and application of deep learning to optimize pension payment management at the National Social Security Fund (NSSF) of Benin.

The key contributions are summarized as follows:

1. **Innovative Methodology:** The paper introduces a pioneering methodology that leverages deep learning techniques, specifically advanced neural network models, to analyze historical pension payment data, demographic trends, and socioeconomic indicators.

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*Correspondence Author(s)

Dr. Mikaël A. Mousse*, Institut Universitaire de Technologies, Université de Parakou, Parakou, Benin. Email ID: mikael.mousse@univ-parakou.bj, ORCID ID: [0000-0002-3326-6396](https://orcid.org/0000-0002-3326-6396)

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This innovative approach goes beyond traditional methods, offering a data-driven and adaptive solution to the complex challenges associated with managing a significant volume of periodic pension disbursements.

2. **Improved Accuracy and Efficiency:** By applying deep learning algorithms, the study aims to enhance the accuracy and efficiency of pension payment processes. The developed models can learn and adapt to evolving patterns, resulting in more precise predictions of future pension payment requirements. This contributes to reducing errors, delays, and uncertainties in the disbursement process, ultimately benefiting retirees and ensuring a more reliable financial support system.
3. **Risk Identification and Mitigation:** The integration of deep learning algorithms for risk assessment represents a critical contribution to the financial stability of the NSSF. The paper addresses the identification and mitigation of potential risks associated with pension payment management, providing a proactive approach to safeguarding the fund against adverse economic conditions, regulatory changes, or other factors that may impact the reliability of pension disbursements.
4. **Practical Application in a Real-world Setting:** The case study on the National Social Security Fund of Benin serves as a tangible demonstration of the proposed methodology. The practical application of deep learning in a public entity managing pension payments provides valuable insights for policymakers, fund administrators, and stakeholders. It illustrates the feasibility and benefits of incorporating advanced technologies into the financial management of social security institutions.
5. **Contribution to the Intersection of Technology and Public Financial Management:** This research contributes to the broader discourse on the intersection of technology, particularly deep learning, and public financial management. By addressing the specific challenges faced by social security institutions in managing pension payments, the paper opens avenues for further exploration and discussion on the role of artificial intelligence in optimizing financial systems within the public sector.

The rest of our article is organized as follows. The second section presents the materials. The third section presents the methods. In the fourth section, we present our results. Finally, we end the paper with a conclusion.

II. MATERIALS

A. Dataset

As with all machine learning problems, the training and evaluation of a model are conducted using a set of examples or observations referred to as a dataset. Data plays a crucial role in achieving the objectives of this work. To this end, we opted to extract data from the pension database of the National Social Security Fund (NSSF) [12]. Specifically, we extracted and anonymized the data of deceased pensioners to create a test dataset. Initially, we obtained just under 30,000 records. It was then necessary to extract data from the pension holders and cross-reference them with pension payments to accurately determine the last payment date. In the end, we finalized a test dataset containing 25,835 records.

For each record, we have the following information:

- **type_pens:** pension category (normal pension, early pension, disability);
 - **country code:** country of the pensioner;
 - **pension:** the pension amount;
 - **withholding:** withholding from the pension;
 - **retirement cnss:** type of pensioner;
 - **nb_enf:** number of minor children.
- Nominal type attributes (pension category, pensioner type) have been transformed into numeric type.

B. Development Environment

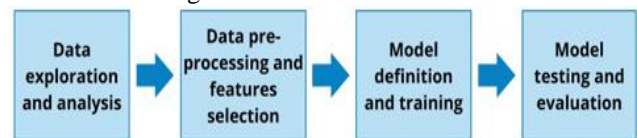
All our experiments were carried out on a computer with the following characteristics:

- Operating system: Windows 10
- Architecture: 64 bits
- Processor: Intel(R) Pentium(R) CPU 4415U @ 2.30GHz 2.30 GHz
- RAM: 8.00 GB

The algorithms were implemented using Python with the Scikit-learn library.

III. METHOD

In our work, we propose the prediction (quantification) of the duration of pension payments to a pensioner. The methodology we used in our study is similar to that employed in classic classification and regression problems. The process is illustrated in Figure 1.



[Fig.1: Steps of our Methodology]

A. Data Exploration and Analysis

This is the first step of our method. It involves exploring and analyzing the data to gain a thorough understanding and make observations that can guide the actions to be taken in the subsequent steps. Thus, we get to know the size of the dataset, the different characteristics of the data, their types, and their missing values. The objective of data exploration and analysis in machine learning is to gain a deep understanding of the dataset before building and training a model. This phase is crucial for making informed decisions regarding data preprocessing, feature engineering, and selecting an appropriate machine learning algorithm.

B. Data Pre-Processing and Feature Selection

The objective of this step is to transform the dataset to put it in an optimized format conducive to machine learning algorithms. This is the step that has the greatest impact on model performance. So, we have undertaken certain actions which are in particular:

- **Handling Missing Values:** Most deep learning algorithms require that all data be present and digital. We differentiate the missing values by the values entered by replacing them with -1 (which is a value different from all values in our dataset).

This method works better than the replacement of missing values by the value zero for the numerical (quantitative) variables and by the fashion for categorical variables (qualitative) because these missing values have a different meaning rent of present values.

▪ **Encoding of Categorical (Qualitative) Variables:** This involves transforming the values of categorical variables into values digital.

Normalization of Variables: It's about putting the values on the same scale. This is important because in some deep learning algorithms, the objective functions will not work correctly and the gradient descent will not converge quickly without normalization. We use the standard normalization defined by the equation where x is the value to transform, \bar{x} the mean of the variable, σ its standard deviation, and x' the

new value:
$$x' = \frac{x - \bar{x}}{\sigma}$$

C. Model Definition and Training

Once the data is preprocessed and optimized, it can be used to train different classification and regression models. We used the Scikit-learn library to split our dataset into training data and testing data. This is necessary so that we can use part of the pensioners' data to train the model and another part to test its performance. Splitting a dataset in this way is a common practice when building deep learning models. It is important to implement this split in the dataset so that the model we create does not have access to the test data during the training process. This ensures that the model learns only from the training data, and we can then test its performance with the test data. If we expose our model to test data during the training process, it will remember the expected results. Therefore, it would not give accurate predictions on data it has not seen. For the creation of our learning model, we specified four layers:

- an input layer to which we transmitted the entities of our dataset;
- two (02) hidden layers which were used to carry out the treatments;
- an output layer that gives the results after training our model

D. Model Testing and Evaluation

Once the model was designed, we carried out the tests using the data. We used 24252 for training and 1583 for testing. The importance of this part is to be able to verify the robustness of the designed model.

IV. RESULTS AND DISCUSSIONS

Our test dataset consists of 1583 samples of pension payments aggregated by year. Each sample is described by seven (07) basic characteristics in addition to the variable to be predicted which is "duration" which designates the number of years during which the National Social Security Fund of Benin will continue to pay the pension to the insured. Figure 2 presents the description of the test dataset whereas Figure 3 shows the definition and training of our model. The model, once it is established, allows us to carry out tests and compare the values obtained to the target values. This manipulation aims to check whether the designed model allows reliable values to be obtained.

The results are presented in Figure 4. We notice that our model manages to capture general trends but sometimes gives results that are far from the real values. We notice that our model manages to capture general trends but sometimes gives results that are far from the real values.

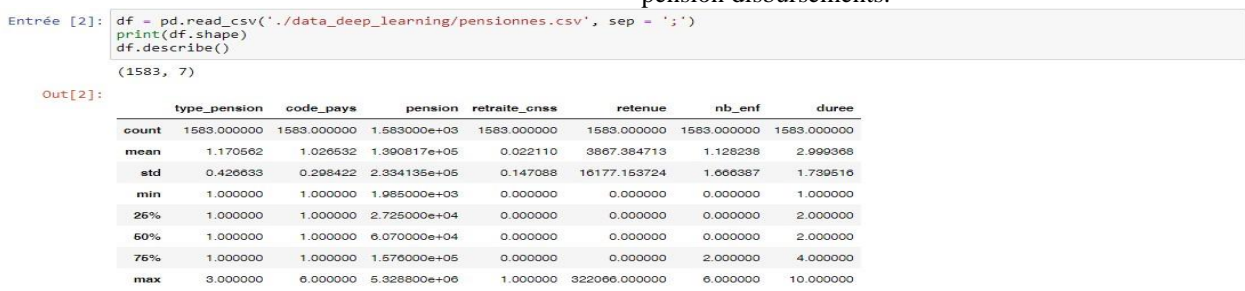
We finally proceeded to evaluate our model. The metric used for the evaluation is the square root of the mean square error. It is the square root of the mean of the squared differences between the forecast and the actual observation. It allows you to evaluate the overall error of a prediction. The calculation is given by the formula:

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (y_i - \hat{y})^2}{n}}$$

In this formula, n represents the size of the sample on which the prediction is made, y_i is the real value for the i -th element in the sample and \hat{y} is the predicted value for this element. The performance results (RMSE) of our model are presented in Figure 5.

V. CONCLUSION

This paper has explored the potential of deep learning as a transformative tool for optimizing the management of pension payments at the National Social Security Fund of Benin. The unique challenges associated with handling a significant volume of periodic pension disbursements demand innovative solutions, and our deep learning-based approach provides a promising avenue for improvement. Through the application of advanced neural network models, we have demonstrated the capacity to analyze historical pension payment data, demographic trends, and socioeconomic indicators. This analysis enables the development of accurate predictive models that enhance the fund's ability to forecast and adapt to evolving patterns in pension disbursements.



[Fig. 2: Description of the Test Dataset]



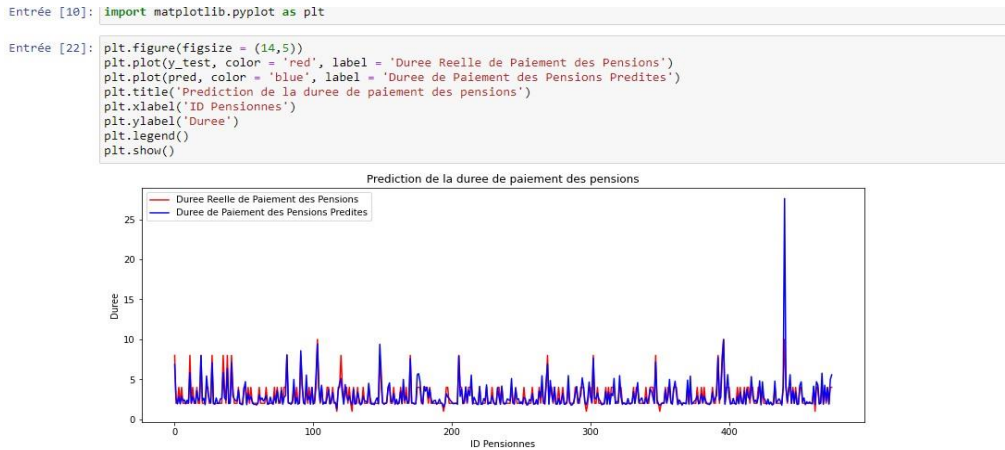
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```
# Define model
model = Sequential()
model.add(Dense(500, input_dim=6, activation= "relu"))
model.add(Dense(100, activation= "relu"))
model.add(Dense(50, activation= "relu"))
model.add(Dense(1))
#model.summary() #Print model Summary

model.compile(loss= "mean_squared_error" , optimizer="adam", metrics=["mean_squared_error"])
model.fit(X_train, y_train, epochs=20)

Epoch 1/20
35/35 [=====] - 0s 5ms/step - loss: 5.8400 - mean_squared_error: 5.8400
Epoch 2/20
35/35 [=====] - 0s 5ms/step - loss: 2.7577 - mean_squared_error: 2.7577
Epoch 3/20
35/35 [=====] - 0s 4ms/step - loss: 2.1440 - mean_squared_error: 2.1440
Epoch 4/20
35/35 [=====] - 0s 4ms/step - loss: 1.2925 - mean_squared_error: 1.2925
Epoch 5/20
35/35 [=====] - 0s 4ms/step - loss: 0.6763 - mean_squared_error: 0.6763
Epoch 6/20
35/35 [=====] - 0s 4ms/step - loss: 0.6016 - mean_squared_error: 0.6016
Epoch 7/20
35/35 [=====] - 0s 4ms/step - loss: 0.5669 - mean_squared_error: 0.5669
Epoch 8/20
35/35 [=====] - 0s 5ms/step - loss: 0.5541 - mean_squared_error: 0.5541
Epoch 9/20
35/35 [=====] - 0s 5ms/step - loss: 0.5145 - mean_squared_error: 0.5145
Epoch 10/20
35/35 [=====] - 0s 4ms/step - loss: 0.5129 - mean_squared_error: 0.5129
Epoch 11/20
35/35 [=====] - 0s 4ms/step - loss: 0.5154 - mean_squared_error: 0.5154
```

[Fig. 3: Model Definition and Training]



[Fig. 4: Comparison Between Actual Data and Predicted Data]

```
Entrée [7]: pred_train= model.predict(X_train)
print(np.sqrt(mean_squared_error(y_train,pred_train)))

pred= model.predict(X_test)
print(np.sqrt(mean_squared_error(y_test,pred)))

0.5904387998022878
1.0165532925148308

Entrée [8]: pred_train

Out[8]: array([[2.154405 ],
 [1.86942 ],
 [1.9645435],
 ...,
 [1.8278302],
 [2.534382 ],
 [4.148806 ]], dtype=float32)
```

[Fig. 5: Performance Evaluation]

The integration of deep learning algorithms for risk identification and mitigation further contributes to the financial stability and reliability of the pension payment system.

The case study on the NSSF of Benin serves as a practical illustration of the benefits and feasibility of implementing deep learning in the context of public entities managing

pension payments. The positive impact on accuracy, efficiency, and operational effectiveness is evident, highlighting the potential for broader applications within the field of financial management for social security institutions.

In conclusion, this research contributes to the growing body of knowledge on the

intersection of deep learning and public financial management, offering insights that can guide future advancements in optimizing pension payment systems. The outcomes of this study underscore the importance of embracing technological innovations to address the evolving needs of social security institutions, ultimately contributing to the financial well-being and security of the population in Benin and beyond.

DECLARATION STATEMENT

I must verify the accuracy of the following information as the article's author.

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AUTHOR PROFILE



Dr. Mikael A. Mousse, has been a faculty member at the University of Parakou since December 2018, where he serves as a lecturer and researcher. His research interests are focused on cutting-edge technologies such as computer vision, multimedia information retrieval, cryptography, blockchain, and artificial learning systems. Our work aims to propose computer models to solve the problems facing society.

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