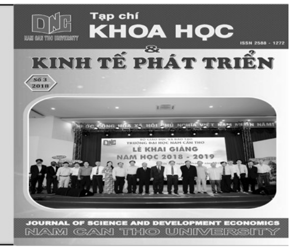
Journal of Science and Development Economics
Nam Can Tho University

Website: jsde.nctu.edu.vn



Development experience of glass classification by Bernoulli Naive Bayes improved the continuous learning method

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Received: November 10, 2023
Revised: November 30, 2023
Accepted: December 5, 2023

Keywords: *advanced machine learning, Bernoulli Naive Bayes, deep learning, glass types*

Từ khóa: *các loại kính, Bernoulli Naive Bayes, học máy nâng cao, học sâu*

ABSTRACT

Artificial intelligence is gradually emerging as a method for optimizing various tasks, offering cost-saving and highly efficient solutions. Nowadays, AI is used as a general term for diverse tasks performed by computers. Fields like machine learning, deep learning, and data science, among others within this scope, are considered part of AI as long as they exhibit the characteristics of artificial intelligence. AI is particularly valuable in predictive analysis, specifically in predicting datasets, and is applied to classification problems. The application of artificial intelligence in solving the glass classification problem aims to categorize and recycle different types of glass. The sliding window method is employed for this classification task as it is the most suitable approach. By classifying glass, this approach can contribute to the recycling and reuse of industrial glass, reducing glass waste for the benefit of humanity and limiting environmental pollution.

TÓM TẮT

Trí tuệ nhân tạo đang dần nổi lên như một phương pháp tối ưu hóa các nhiệm vụ khác nhau, đưa ra các giải pháp tiết kiệm chi phí và hiệu quả cao. Ngày nay, AI được sử dụng như một thuật ngữ chung cho các nhiệm vụ đa dạng được thực hiện bởi máy tính. Các lĩnh vực như học máy, học sâu và khoa học dữ liệu, cùng những lĩnh vực khác trong phạm vi này, được coi là một phần của AI miễn là chúng thể hiện các đặc điểm của trí tuệ nhân tạo. AI đặc biệt có giá trị trong phân tích dự đoán, cụ thể là dự đoán các tập dữ liệu và được áp dụng cho các bài toán phân loại.

Việc ứng dụng trí tuệ nhân tạo vào giải bài toán phân loại kính nhằm mục đích phân loại và tái chế các loại kính khác nhau. Phương pháp cửa sổ trượt được sử dụng cho nhiệm vụ phân loại này vì đây là phương pháp phù hợp nhất. Bằng cách phân loại kính, phương pháp này góp phần tái chế và tái sử dụng kính công nghiệp, giảm thiểu rác thải thủy tinh vì lợi ích của nhân loại và hạn chế ô nhiễm môi trường.

1. INTRODUCTION

With the rapid development of industrialization and modernization, human needs have also increased accordingly. In fields such as construction and aesthetics, glass plays a significant role in fulfilling essential human requirements. Glass appears in various types of structures, ranging from religious edifices like churches to office skyscrapers and the private living spaces of families. The application of glass is diverse and prevalent to the extent that in any modern house, we can observe this material. In modern life, glass is extensively used due to its beauty and quality. Most modern-style houses utilize glass for decoration and construction. The advantages of glass lie in its user-friendliness, ease of cleaning, lightweight nature, and its ability to transmit light. When we fully comprehend the functional aspects of glass and use it appropriately, it enhances its aesthetic value. Presently, the market offers a wide array of glass types, but glass recycling still remains less common. Recognizing the need for classifying and recycling various types of glass is an intriguing subject that contributes to the development of our domestic industry. Hence, the topic "Advancing Machine Learning for the Identification of Glass Types" has been chosen for the reason that if successfully applied and widely developed, it will bring numerous benefits to the glass industry as well as other domains like construction and beauty enhancement. Moreover, it will assist in reducing industrial glass waste, yielding advantages for both humanity and the environment.

Some international articles on the significance and benefits of glass recycling are discussed in, the author emphasizes the best options for large and small-scale recycling, reusing, and repurposing of public glass, highlighting the importance of glass and glass recycling for both human beings and the environment. In Rinkesh et al. (2023) [1], the author elaborates on the glass recycling process and its benefits, as it can be transformed into various products for daily human use. It is an amorphous solid that can have different semiconductor components, but most importantly, it is made from molten silica along with limestone and soda ash,... Another article titled 'Recycling glass is one of the many ways we can help reduce pollution and waste,' discusses how glass recycling contributes to environmental well-being, specifically how recycling glass is one of the ways to help minimize pollution and waste. Every day, tons of waste are discarded, and glass constitutes a significant portion. Instead of allowing landfills to accumulate hazardous glass items that threaten safety and the environment, we can reuse them, emphasizing the benefits of glass recycling for the environment. In Tạp Chí Môi Trường (2023) [2], the author explains the reasons for recycling waste, specifically glass, and its benefits, the author also addresses the issues of the harmful nature of glass, whether broken glass items should be recycled, and the specific methods of recycling broken glass items in the article 'Should broken glass items be recycled?'. An environmental journal article also highlights the reasons for classifying and recycling glass waste in the specific article 'Why glass waste should be classified and recycled' [2].

In Okafor (2023) [3] has outlined the ways of recycling glass that anyone can do on their own. Specifically, the author has identified the types of glass that can be recycled and those that cannot, along with the methods to recycle them. Furthermore, the author has also highlighted the environmental impacts of improper glass disposal, stating that it takes a million years for glass to completely decompose. Despite the numerous benefits of glass recycling, not all types of glass are recyclable. Over the course of many years of decomposition, glass breaks down into small fragments of super-small and nano sizes. Scientists are concerned about the potential hazards of nano glass particles corroding the environment. Nano glass pollution poses a greater environmental threat than pollution from larger glass particles. Glass at the nano scale becomes the end of the food chain, ingested by marine life. Additives and other components used in glass production can harm both terrestrial and aquatic animals when consumed. Additionally, plant roots can absorb these super-small glass elements. Environmental glass pollution can lead to soil degradation, loss of animal habitats, and water contamination [3]. In Cleanipedia (2023) [4], there are 27 ways to recycle old glass bottles into useful home decorations are pointed out, such as recycling glass bottles into flower vases, repurposing glass bottles as water jugs, upcycling glass jars into chandeliers, reusing glass containers as storage items, utilizing glass bottles as plant pots, creating mesmerizing twinkling effects using glass bottles, making alcohol lamps, and crafting oil lamps by recycling glass bottles [4]. Thu Ngân (2022) [5] presented various methods of recycling glass bottles, such as transforming glass bottles into bird food troughs, repurposing glass bottles as wind chimes, simple decoration ideas for glass jars like turning them into oil lamps, repurposing glass bottles as decorative items for weddings [5].

Currently, there are numerous solutions worldwide addressing the issue of glass recycling. In Experts (2022) [6], five pieces of advice are provided for recycling glass, focusing on specific aspects. For instance, shattered glass can indeed be recycled, but it might not return to its original state. In other words, recycling a broken bottle may not result in the glass being remanufactured into a new bottle. Instead, the glass can still find utility as an additive in glass fibers or tiles. However, it's crucial to maintain the integrity of recycled glass as much as possible. Regarding glass handling, not all glass is the same. Glass utilized for windows, mirrors, and similar items undergoes chemical treatment and thus possesses a distinct melting point compared to, for example, glass bottles. Consequently, it's generally advised not to mix non-container glass with container glass during recycling.

Additionally, it's safer to avoid processing shattered glass whenever possible. Many recycling facilities require glass to be cleaned before recycling. If the glass contains residues, such as sugar, for instance, it can become sticky and potentially attract pests. This is also true for other glass containers used for food and beverages. In Momentum Recycling (2023) [7] the steps for glass recycling and the resulting products are highlighted for practical applications. These steps include glass recycling processes, collection, sorting stations, glass breaking, trommel, steam layer drying, filtering and cleaning, crushing, secondary screen size classification, and final product output. The author also presents various products applied after recycling glass, such as glass container production, glass fiber manufacturing, abrasive material, fluxing agent in ceramics and bricks, filler in paint and plastics, glass bead for reflection, adsorbent material, and cation exchange [7].

In Vietnam, the recycling of glass to minimize environmental harm is increasingly receiving positive attention, as highlighted in numerous articles by khoahoc.tv. These articles address questions such as the feasibility of glass recycling and the specific methods involved. Recycling used glass bottles, for instance, proves to be an effective means of safeguarding our planet. With each ton of recycled glass, humanity conserves a significant amount of raw materials necessary for producing new glass, including 590 kg of sand, 186 kg of Sodium Carbonate powder, and 173 kg of limestone. The manufacturing of new glass also consumes substantial energy and contributes to industrial pollution, thus exacerbating the greenhouse effect. This is due to the requirement of heating sand and other substances to temperatures exceeding 1400°C to create glass. Conversely, recycling glass consumes less than 40% of the energy required for producing new glass. The glass is collected and sorted by color—basic hues of white, green, and amber—then cleaned to remove contaminants. During the sorting process, paper labels adhered to glass containers are removed, along with all non-glass elements such as plastic caps, metal lids, and types of glass that cannot be recycled. After the initial sorting, the glass is shattered using crushing machines, followed by passing through machines that separate metal, plastic, and paper. The glass is then ground into small fragments called cullet. The purpose of grinding the glass is to eliminate sharp edges that pose hazards. Subsequently, the fragments are sifted to filter out larger pieces for further grinding, resulting in glass particles of the desired size. Cullet refers to the finely ground glass, free from non-glass materials, which is ready to be fed into mixing machines for crafting new glass (Khoahoctv, 2023) [8].

The following, the author will employ the sliding window approach to address this issue by using Machine learning, through the Glass Types database, across the sections: the theoretical foundation of the issue, the implementation method, and the experimental results of the problem, before moving to the conclusion.

2. MATERIALS AND METHODS

Based on glass categorization, it aids in the recycling and reutilization of various types of industrial glass, contributing to reducing glass waste for humans and limiting environmental pollution. The problem is addressed using the sliding window method as it is the most suitable approach for this problem. The existing database remains static over time, trained using classical methods (performed only once, requiring retraining from scratch with new data). However, in modern reality, data environments change over time, necessitating continuous real-time training and periodic updating of predictive models. Hence, data learning must be carried out within an ever-changing data environment, indicating the practical application of continuous learning in non-stable environments. This problem aligns with scenarios involving evolution within an unstable environment. To address this, the term "Concept drift" has been widely adopted. The concept of drift forms the basis for slow, continuous change and the "forgetfulness" of past situations. Nevertheless, the challenges in an unstable environment stem from the fact that they are contingent on various factors. Developments may sometimes occur rapidly, at other times slowly; sometimes forgetting occurs, and there are even instances where knowledge resurfaces after it has disappeared. It should also be noted that these approaches are not sufficient standards for an "incremental approach." The document lists three different methods proposing solutions to this issue: The Sliding Windows-based approach, considering the evolution of concepts in an environment of recent non-stationary training data, determined by a defined time window (according to a time scale or a data quantity). This approach can reclassify the "group" type (on data selected by the temporary window), or update the model if online learning methods allow. In this case, the "forgetting" (as mentioned above) is automatically managed by this learning method. This type of approach usually consists of 3 steps: 1) detecting concept changes by using statistical tests on different windows; 2) if an observed change exists, select representative and recent data to adjust the models; 3) update the models. The window size is predetermined by the user. The main point of these methods is to determine the window size. Most methods use a fixed-size window configured for each real-world problem. This issue will rely on the aforementioned characteristics and based on the history of research on the methods, the research will employ the “sliding window” method for the upcoming task, specifically using the “sliding window” method on the Bernoulli Naive Bayes algorithm.

During the process of searching for data for the topic, a multitude of datasets were found. However, these datasets lack complete specifications and the highest level of availability. These datasets include: "multi-Classification of Glass Types" by Jay "Glass Types Classification Tensorflow ResMLP” (GeeksforGeeks, 2021) [9] and "Glass Types Predict with SMOTE". The aforementioned datasets are all related to glass detection or classification; however, only one dataset meets the requirements of the topic. Other datasets have various issues that render them unusable for this particular project. For a dataset to be usable in this project, it must be numerical data, exhibit specific class divisions, contain multiple attributes to yield objective outcomes, and have recently updated and relevant data. The "Glass Types" dataset is the only one that fulfills these criteria, utilized for solving this classification problem making it the chosen dataset which is provided by the author Zahra Arabi, a member of the Kaggle website. The most recent update to this dataset was in August 2022, based on the Vietnam local time. The creation of the "Glass Types" dataset aims to address the problem of glass recycling classification, facilitating the classification and reuse of various glass types. The most recent update to the dataset was in August 2022, according to the Vietnam local time.

The raw data must undergo preprocessing before being applied to the software's training process. From the raw data, unnecessary information such as serial numbers and IDs will be removed, as they are not essential during program execution. The dataset must be saved in a ".csv" file format. Each data entry is allowed only in a single cell, where parameters and labels must be separated by a comma "," as stipulated by the system's regulations. According to the system's guidelines, the data parameters must be placed at the front, and the label should be placed at the end. After all the data standardization processes, we will obtain a normalized dataset consisting of 9 features, totaling 215 data entries, including parameters in the following format:

<Label Predictions> 1: <RI> (Refractive Index): In reality, each RI value corresponds to a different size, while factors such as material, color, style, etc. will be completely consistent. The range of RI values can go from 1 to infinity. The size of the glass being predicted is a mandatory input, and the minimum and maximum sizes in the dataset are 1.5115 and 1.53393, respectively.

2: <Na> (Sodium): An elemental component of glass, sodium is a chemical element as well as one of the constituents of glass. The minimum and maximum sodium values in the dataset are 10.73 and 17.38.

3: <Mg> (Magnesium): An elemental component of glass. Magnesium, the 8th most abundant element in Earth's crust, is an alkali metal. The minimum and maximum magnesium values in the dataset are 0 and 4.49.

4: <Al> (Aluminum): An elemental component of glass. Aluminum, the most abundant metal in Earth's crust, constitutes about 17% of Earth's solid outer layer. The minimum and maximum aluminum values in the dataset are 0.29 and 3.5.

5: <Si> (Silicon): An elemental component of glass. Silicon is a very hard element with a dark gray - metallic blue shine. The minimum and maximum silicon values in the dataset are 69.81 and 75.41.

6: <K> (Potassium): An elemental component of glass. Potassium is a soft alkali metal with a silver-white color that easily oxidizes in the air. The minimum and maximum potassium values in the dataset are 0 and 6.21.

7: <Ca> (Calcium): An elemental component of glass. The minimum and maximum calcium values in the dataset are 5.43 and 16.19.

8: <Ba> (Barium): An elemental component of glass. The minimum and maximum barium values in the dataset are 0 and 3.15.

These indices are entirely derived from the above data source and have been validated by experts in the field. Each feature will have values as follows:

− RI (Refractive Index): In reality, each RI value corresponds to a different size, while factors such as material, color, style, etc. will be completely consistent. The range of RI values can go from 1 to infinity. The size of the glass being predicted is a mandatory input, and the minimum and maximum sizes in the dataset are 1.5115 and 1.53393, respectively.

− Na (Sodium): An elemental component of glass, sodium is a chemical element as well as one of the constituents of glass, and the minimum and maximum sodium values in the dataset are 10.73 and 17.38.

− Mg (Magnesium): An elemental component of glass, and the minimum and maximum magnesium values in the dataset are 0 and 4.49.

− Al (Aluminum): An elemental component of glass, and the minimum and maximum aluminum values in the dataset are 0.29 and 3.5.

− Si (Silicon): An elemental component of glass, and the minimum and maximum silicon values in the dataset are 69.81 and 75.41.

− K (Potassium): An elemental component of glass, and the minimum and maximum potassium values in the dataset are 0 and 6.21.

− Ca (Calcium): An elemental component of glass, and the minimum and maximum calcium values in the dataset are 5.43 and 16.19.

− Ba (Barium): An elemental component of glass, and the minimum and maximum barium values in the dataset are 0 and 3.15.

− Fe: an element constituting glass. Iron is a useful element on Earth, forming the outer and inner layers of the Earth's core, and the smallest and largest values of aluminum in the dataset are 0 and 0.51, respectively.

3. RESULTS AND DISCUSSION

The dataset is provisional due to the emergence of various new types of glass, leading to possible changes in the dataset's classification in the future, indicating its instability. Consequently, increasing the dataset's dimensions cannot be applied in classical machine learning algorithms within a static environment, as traditional methods do not allow dimension expansion, necessitating the use of progressive algorithms capable of handling data in dynamic environments. Upon downloading the dataset, the values will not be entirely appropriate, thus requiring normalization. Following this, data will be divided to create proportions for training and testing, with a ratio of seven parts (70%) to three parts (30%). After segmenting the data, it will be saved to the machine, then the proportions will be allocated for the execution of the algorithm. This will be done by selecting a batch size of 70% * n or 70% * n/2, with a training/test ratio of 70%, where n represents the total number of data. All achieved results are based on Balanced Accuracy, a metric used to assess the performance of binary classifiers. It proves particularly useful when dealing with imbalanced classes, meaning one of the two classes is far more frequent than the other. The utilization of Balanced Accuracy is significantly more intricate than conventional Accuracy. Conventional Accuracy simply calculates the percentage ratio of a dataset based on the total available data, which initially functions stably. However, when the data is greatly skewed, the accuracy's reliability diminishes. To address this issue, the formula for Balanced Accuracy can be employed to calculate percentages in the most authentic and optimal manner.

By applying artificial intelligence, specifically algorithms such as Bernoulli Naive Bayes in combination with the sliding window method, this approach achieves the most fairness in terms of data veracity when comparing results from different algorithms. The experimental outcomes of the algorithms are averaged and presented in the chart in Figure 1.

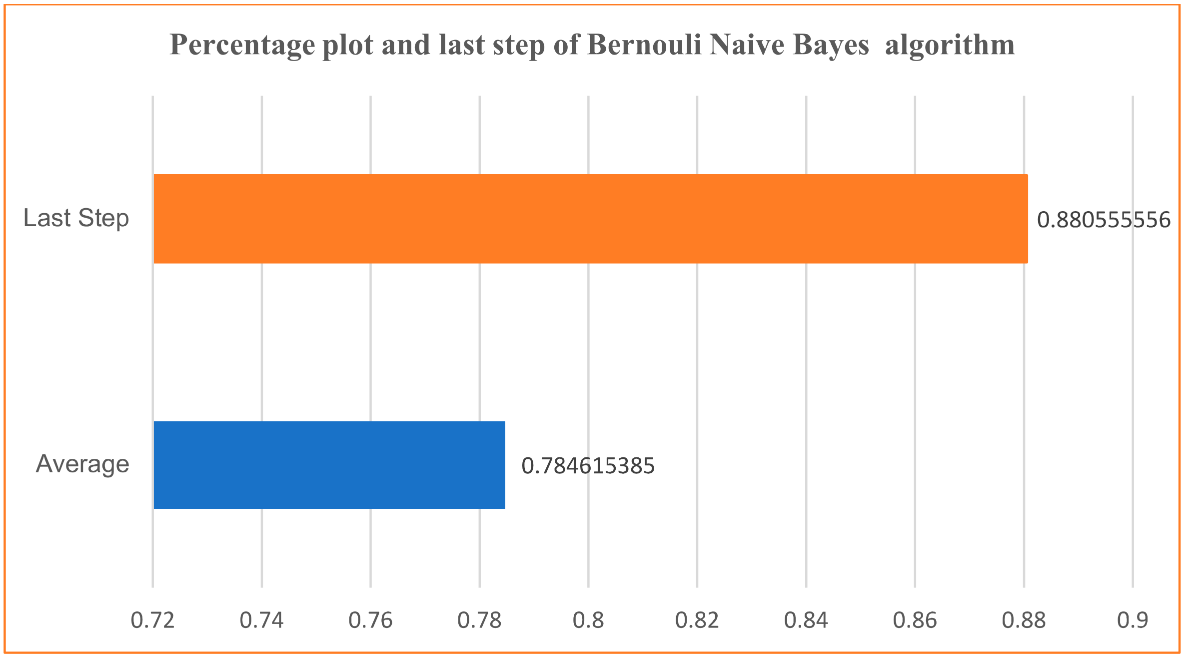

Figure 1. The chart of average percentages of experimental algorithm performance by age (Bernoulli Naive Bayes)

Looking at the data on the chart, we can analyze the average ratio, and the final step has a fairly good ratio of Bernoulli Naive Bayes as follows:

The performance of Bernoulli Naive Bayes is very stable and consistently reaches above 70%. The data demonstrates that Bernoulli Naive Bayes achieves a steady and remarkable performance with an average accuracy of over 70% (precisely 78.61%), and the accuracy in the final stage also surpasses 80% (precisely 88.06%). The performance of the final step and the average, with a relatively narrow gap of 9.45%, indicates a fairly stable algorithmic performance. This is an important advantage, highlighting that Bernoulli Naive Bayes has the ability to provide accurate predictions in various scenarios, making it applicable to this predictive task.

In addition to calculating the algorithm's average results, another approach such as analyzing the experimental model results by age group provides a more comprehensive and detailed perspective. This helps us visually assess and reach the most accurate conclusions regarding the experimental model's results by age group, represented in the chart in Figure 2.

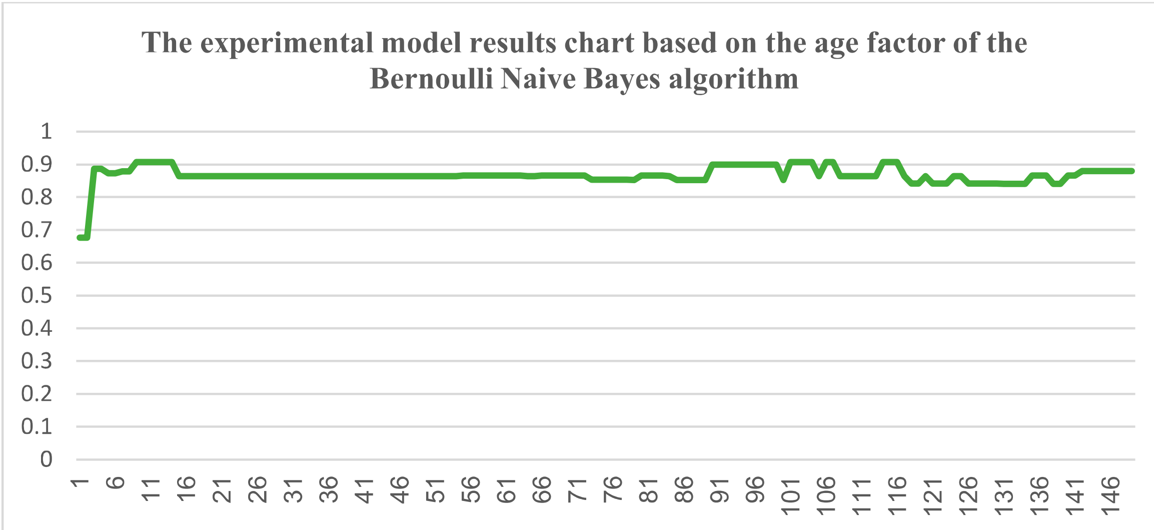

Figure 2. Chart of Experimental Model Results by Age (Bernoulli Naive Bayes)

Examining the chart, we can observe that the Bernoulli Naive Bayes algorithm starts with a relatively stable point at around 67.69%, and then experiences a sharp increase in the subsequent steps, reaching 90.04% from step 2 to step 6. Following this, the algorithm maintains a consistently stable and fairly uniform performance in steps 7 to 16, specifically at 86.40%. From step 17 to step 71, the algorithm demonstrates stability, maintaining a consistently high performance represented by a horizontal line on the graph, specifically at 86.40%. Overall, the Bernoulli Naive Bayes algorithm exhibits a stable and quite high performance across the entire chart, with its peak performance occurring in steps 111 to 121, as shown in the graph in Figure 3.

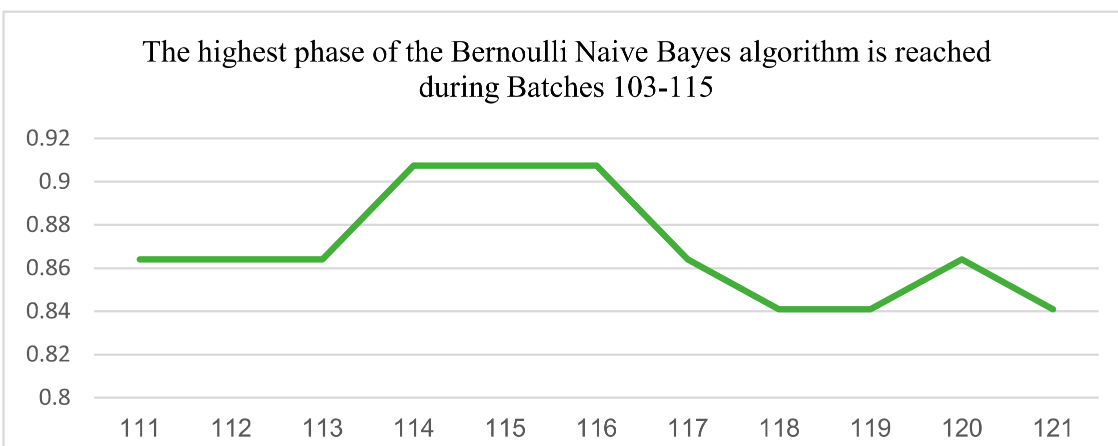

Figure 3. Experimental Model Results by Age (Bernoulli Naive Bayes)

Examining the chart, we clearly observe a consistent upward trend of Bernoulli Naive Bayes's performance across different age groups. The accuracy consistently remains above 80% and nearly reaches the 95% mark. The highest points are observed at steps 114 and 115, reaching an accuracy of 90.74%. This represents a notably high rate compared to other algorithms, as Bernoulli Naive Bayes excels in handling non-continuous and missing value data. This capability significantly reduces the need for preprocessing tasks and allows the algorithm to operate effectively across various data types. Despite instances where the algorithm's results may not be optimal during certain data phases, Bernoulli Naive Bayes consistently maintains a stable and swift performance, as depicted in the chart below (Figure 4).

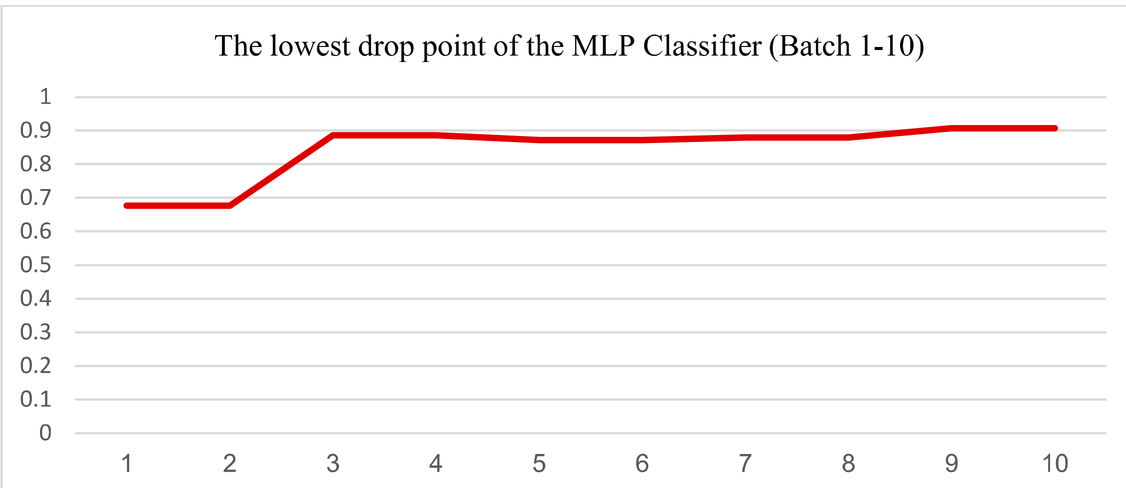

Figure 4. The lowest falling segment of the Decision Tree (Batch 795 - 815)

In steps 1 and 2, the lowest success rate of Bernoulli Naive Bayes achieved is only 67.70%. However, in step 3, this algorithm quickly returns to a stable rate, reaching 88.60% and gradually increasing in the following steps. Despite being the phase with the lowest data accuracy in Decision Trees, it is considered relatively stable as the discrepancies in numbers are not significantly large. For instance, steps 4 to 8 form an almost straight line with fairly similar ratios. Specifically, step 4 has an accuracy of 88.60%, while steps 5, 6, 7, and 8 maintain a rate of 87.29%.

In summary, the Bernoulli Naive Bayes algorithm offers numerous advantages and consistent performance, achieving an accuracy of over 90%, with the highest being 90.74%. This demonstrates that Bernoulli Naive Bayes can be a useful choice for various prediction and classification tasks. However, it's important to note that each algorithm has its own strengths and weaknesses. Selecting the appropriate algorithm also depends on the specific requirements of the task and the characteristics of the data.

Installation of the practical application:

In this topic, the system has been packaged in the form of a .ZIP file and compressed into a file named "GlassType.zip". Once users download and extract it, there will be a folder named "BaoCaoThucTap" ("InternshipReport" in English). Inside this folder, there are files required to run the program. The system has the following computer requirements: a constant internet connection, minimum configuration of Windows 10, 2GB RAM, and 10GB hard drive space. To proceed with the installation, navigate to the "SETUP" directory. Install Python by executing the Python version 3.9.9 (Python-3.9.9-amd64.exe). Install the necessary libraries by running the script "CaiThuVien.bat".

To run the software, your computer needs to have the Node.js environment installed. Once you've opened the folder, press and hold the "Shift" key, then right-click in the empty area of the folder. Select "Open command window here" to display the command line dialogue. In the command prompt, input the command "pip install -r requirements.txt" to install the required packages for the program. After successfully installing the packages, to execute the program, you need to enter the command "py manage.py runserver" to initiate the program. The program will run on the default port "http://127.0.0.1:8000/". While the program can be deployed on a web platform, current circumstances do not permit practical web deployment. This is the default installation process for the program.

The algorithm used in this problem will be the best-performing algorithm, which is the Random Forest algorithm that was ultimately selected. The website includes functionalities such as login and logout features. The homepage functionality will comprise 7 buttons for inputting the following initial parameters: RI, Na, Mg, Al, Si, K, Ca, along with a prediction initiation button to perform diagnoses. The algorithm selection feature allows users to choose the Bernouli Naive Bayes algorithm. In the algorithm interface, users need to input age, batch, text size, number for, and upload a .csv file. The interface for listing models will display the models of the algorithms that were just executed. The prediction configuration interface allows users to input the model file for prediction, select the model for prediction, and upload it.

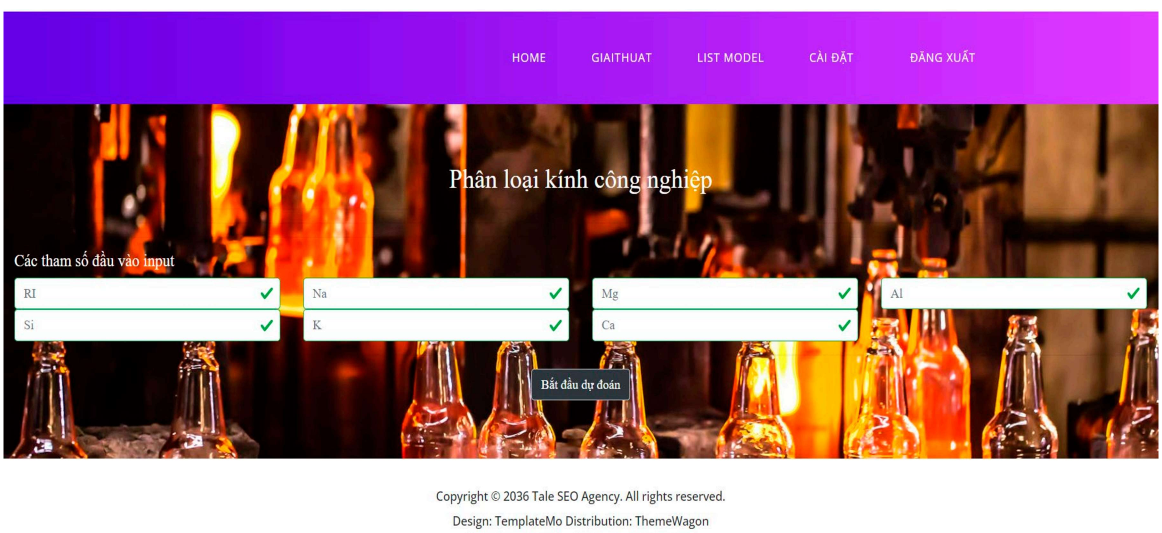

Figure 4. Predictive Configuration Page Interface

Allow users to input the initial parameters including RI, Na, Mg, Al, Si, K, Ca, and a start button for prediction initiation.

5. CONCLUSION

The topic has contributed to classifying different types of glasses based on users' required parameters. This helps minimize the amount of glass waste, bringing economic value to the people of Vietnam through the recycling and utilization of discarded glass, thereby reducing the significant amount of glass waste released into the environment. Enhancing the overall quality of life for the people of Vietnam and the world. This is a much-needed topic in Vietnam because glass recycling and classification are not yet widely practiced, so this topic contributes to approaching the task of classifying the recycling of glass by citizens, helping raise environmental awareness for each citizen, thereby bringing economic benefits to themselves, society, and the nation.

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