IMPROVING EYE CARE WITH PREDICTIVE MODELING: MACHINE LEARNING APPROACH TO CONTACT LENS FITTING

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ABSTRACT

The fitting of Contact Lens is a complex process that traditionally relies on the Clinicans Expertise and patient feedback. Incorrect fitting can lead to discomfort vision problems and eye health issues. However, the variability in individual eye characteristics and patient responses often results in trial-and-error approach leading based on decision support system for contact lens fitting. Leverage predictive modelling to enhance eye care. The system aims to assist eye care professionals in informed decision, reducing errors and improving patient outcomes. By leveraging extensive datasets containing patient demographic, ocular measurements and historical fitting outcomes, the system predicts the most suitable contact lens for each patient. The machine learning model is Support Vector Classifier (SVC) where this model trained and validated to enhance the accuracy and reliability of the fitting process. The results of this SVC model demonstrate a significant improvement in fit accuracy, reduced fitting time and increases the patient satisfaction compared to traditional methods. The implementation of this technology not only simplified the contact lens fitting process but also represents a crucial step towards personalized eye care, offering practitioners as a powerful tool to enhance decision-making and satisfies the patient outcomes.

Key words: Contact Lens Fitting, Eye Care, Healthcare Analytics, Patient Vision Assessment, Kernel Methods, Medical Decision Support.

INTRODUCTION

Pediatric appendicitis is a prevalent cause of acute abdominal pain in children, with approximately 70,000 cases annually in the United States. The highest incidence occurs among children aged 10 to 14 years, with a slightly higher prevalence in boys. Despite advancements in diagnostic and management techniques, delays in diagnosis continue to pose a significant challenge, leading to complications such as perforation in 20-30% of cases. The high negative appendectomy rate, ranging from 15% to 20%, highlights the need for more accurate diagnostic tools. Additionally, concerns over ionizing radiation from CT scans and rising healthcare costs underscore the necessity for machine learning models that can enhance diagnostic precision and optimize patient management. The diagnostic process for pediatric appendicitis is complicated by the non-specific nature of symptoms that overlap with other conditions, leading to potential misdiagnosis and delays in treatment. This issue is exacerbated in younger children who present with atypical symptoms. Traditional diagnostic methods relying on clinical judgment alone are challenged by variability in symptom presentation and the need for extensive expertise.

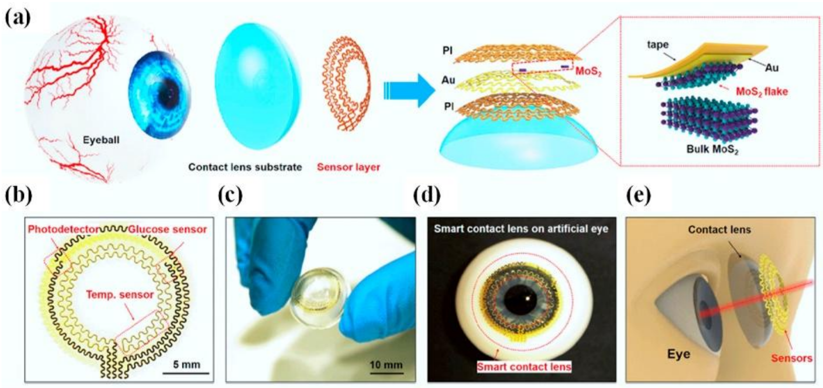

Figure 1. Smart Contact lens

A machine learning system could provide a valuable solution by integrating and analyzing clinical data to offer real-time, evidence-based diagnostic support, thereby reducing errors, unnecessary surgeries, and associated costs. Manual diagnosis of pediatric appendicitis is constrained by cognitive biases and variability in symptom presentation. The process, which relies on physical exams, lab tests, and imaging studies, is both time-consuming and subject to subjective interpretation. For example, interpreting ultrasound images requires significant skill and not always yield conclusive results, especially in atypical cases. Automation through machine learning can efficiently process large volumes of data, identify hidden patterns, and offer consistent, objective diagnostic support. This approach promises to speed up the diagnostic process, reduce errors, and improve patient outcomes by facilitating quicker intervention.

2. LITERATURE SURVEY

Holden et al. [1] conducted a global prevalence study on myopia and high myopia, published in *Ophthalmology* in 2016. Their research provided a comprehensive analysis of myopia and high myopia, examining trends from 2000 through 2050. The study highlighted a significant increase in the prevalence of these conditions globally. Their projections indicated that the prevalence of high myopia would become a major public health concern by mid-century. The research underscored the need for global intervention strategies and preventive measures to manage and reduce the increasing burden of myopia. This study was instrumental in drawing attention to the global implications of myopia and advocating for action to mitigate its impact. Zhao et al. [2] performed a refractive error study in children from Shunyi District, China, published in *Ophthalmology* in 2000. Their study provided a detailed analysis of the prevalence and types of refractive errors among children in this region. It revealed significant insights into pediatric eye health, identifying common refractive errors and their distribution. The findings emphasized the necessity for early screening and intervention to address these issues effectively. This research contributed valuable data for understanding the refractive error landscape in China and highlighted the importance of targeted eye care programs for children. Naidoo et al. [3] explored the potential lost productivity resulting from the global burden of myopia, as detailed in their 2019 publication in *Ophthalmology*. The study assessed the economic impact of myopia on productivity, revealing the substantial costs associated with this visual impairment. Their analysis demonstrated how myopia affects workforce productivity globally and stressed the economic burden it imposes on society. The research advocated for preventive measures and effective management strategies to alleviate these economic impacts. This study was critical in highlighting the need for economic considerations in myopia management. Wong et al. [4] reviewed the epidemiology and disease burden of pathologic myopia and myopic choroidal neovascularization, published in *Am J Ophthalmol* in 2014. Their systematic review provided a thorough examination of the prevalence and impact of severe forms of myopia. The study highlighted the significant health burden associated with pathologic myopia and its complications, including myopic choroidal neovascularization. The findings underscored the need for improved treatment options and preventive measures to address these severe conditions. This review was essential in understanding the broader impact of advanced myopia. Li et al. [5] investigated the expression of the SARS-CoV-2 receptor ACE2 in human conjunctival tissue, published in *Ocul Surf* in 2021. Their study focused on how ACE2 is expressed in healthy and diseased conjunctival tissues, providing insights into the potential ocular implications of COVID-19. The research suggested that SARS-CoV-2 could significantly affect conjunctival tissues, which have implications for ocular health. Their findings highlighted the importance of monitoring and addressing ocular manifestations of the virus during the pandemic.

Fan et al. [6] evaluated a machine learning-based strategy for selecting lens parameters for corneal refractive therapy in Chinese adolescents, published in *Contact Lens Anterior Eye* in 2021. Their study compared machine learning methods with traditional approaches in optimizing lens parameters for corneal refractive therapy. The research demonstrated the superiority of machine learning techniques in improving the accuracy and effectiveness of lens fitting. This study emphasized the potential of advanced algorithms to enhance therapeutic outcomes for myopic adolescents and improve clinical practices. Zhang et al. [7] proposed a novel fitting algorithm for alignment curve radius estimation using corneal elevation data, published in *Contact Lens Anterior Eye* in 2017. Their research introduced an innovative approach to estimating the alignment curve radius in orthokeratology lens trials. The novel algorithm improved the precision of lens fitting, which is crucial for optimizing orthokeratology treatments. The study highlighted the significance of accurate fitting algorithms in achieving better outcomes in corneal refractive therapy. Harvey et al. [8] addressed the testing of equality of prediction mean squared errors, as detailed in their 1997 publication in *Int J Forecast*. Their study focused on statistical methods for comparing prediction errors across different models. The research provided valuable insights into the reliability and accuracy of forecasting models. Their work underscored the importance of rigorous error analysis in developing robust predictive models and enhancing forecasting accuracy. Wen et al. [9] assessed the prevalence of myopia, hyperopia, and astigmatism in non-Hispanic white and Asian children, published in *Ophthalmology* in 2013. Their multi-ethnic pediatric eye disease study offered a comparative analysis of refractive errors among different ethnic groups. The findings contributed to a better understanding of the global distribution of refractive errors and highlighted the need for culturally tailored eye care interventions. The research emphasized the diversity in refractive error patterns across different populations. Sankaridurg et al. [10] reviewed optical and pharmaceutical strategies for controlling myopia progression, published in *Asia Pac J Ophthalmol (Phila)* in 2018. Their study explored various approaches to managing myopia progression, including optical and pharmacological interventions. The research evaluated the effectiveness of different strategies in slowing myopia progression and improving visual outcomes. Their findings provided valuable insights into current and emerging methods for managing myopia and preventing its advancement.

Waleed et al. [11] investigated the antimicrobial susceptibility of bacterial isolates from the conjunctiva, storage cases, and mobile phones of contact lens users, published in *Contact Lens Anterior Eye* in 2021. Their research focused on bacterial contamination risks associated with contact lens use. The study provided insights into the effectiveness of antimicrobial measures and highlighted the importance of hygiene practices. Their findings emphasized the need for improved hygiene protocols to prevent infections among contact lens users. He et al. [12] examined refractive error and visual impairment in urban children in southern China, published in Invest Ophthalmol Vis Sci in 2004. Their study highlighted the prevalence of refractive errors and visual impairment in this urban population. The research provided valuable data for public health initiatives aimed at improving pediatric eye health in urban areas. The findings underscored the need for comprehensive eye care programs to address refractive errors and visual impairment among children. Kleinstein et al. [13] explored refractive error and ethnicity in children, as detailed in their 2003 publication in *Arch Ophthalmol*. The study provided insights into how refractive errors vary among different ethnic groups. Their research contributed to understanding the genetic and environmental factors influencing refractive errors. The findings highlighted the importance of ethnicity-specific approaches in managing and addressing refractive errors effectively. Li et al. [14] conducted a study on peripheral refraction in children in central China, published in *Br Ophthalmol* in 2015. Their research focused on changes in peripheral refraction with age and its implications for myopia development. The study emphasized the role of peripheral refraction in understanding and managing myopia progression. Their findings contributed to developing strategies for myopia control and informed clinical practices. Dolgin [15] discussed the myopia boom in his 2015 article published in *Nature*. The article provided an overview of the global increase in myopia prevalence and its public health implications. Dolgin's review highlighted the urgent need for strategies to address the myopia epidemic and mitigate its impact. The article underscored the growing concern over myopia and the necessity for comprehensive efforts to manage and prevent its spread.

3. PROPOSED SYSTEM

The proposed algorithm for improving contact lens fitting decisions using a predictive modeling approach. The research utilizes a dataset specifically designed to capture various factors influencing contact lens prescriptions. A detailed block diagram illustrates the workflow, including data collection, preprocessing, model training, and evaluation. The methodology begins with acquiring the contact lens dataset containing patient demographics, eye measurements, and visual acuity information, which forms the basis for analysis and model development. The dataset undergoes preprocessing to handle null values through imputation or removal and to convert categorical fields into usable numerical formats. Label Encoding is then applied to transform categorical variables into integer values suitable for machine learning algorithms. The existing model used in this research is the Perceptron classifier, which adjusts feature weights iteratively based on classification errors and is primarily suited for linear, binary classification tasks. To improve performance, the proposed model employs Support Vector Classification (SVC), which identifies the optimal hyperplane separating different classes and utilizes kernel functions to manage non-linear patterns commonly found in contact lens fitting data. A performance comparison between the Perceptron and SVC models is conducted using metrics such as accuracy, precision, recall, and F1-score to determine the more effective classifier. Finally, the trained SVC model is used to predict outputs on a separate test dataset, enabling evaluation of its generalization ability and accuracy in classifying new contact lens fitting cases.

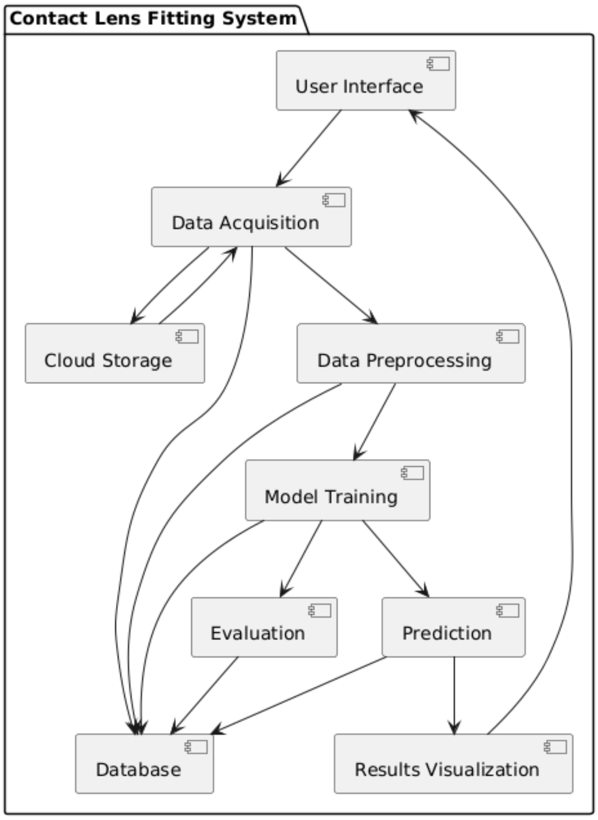

Figure 2. Architectural block diagram

Support Vector Classification (SVC) is an advanced machine learning algorithm based on support vector machines that extends the Perceptron by forming more complex decision boundaries. It works by identifying the optimal hyperplane that maximizes the margin between classes and uses kernel functions to transform non-linear data into higher-dimensional spaces where a linear separator can be applied. Its architecture consists of an input layer, a kernel transformation layer, and an output layer that performs the final classification. SVC offers key advantages such as effectively handling non-linear relationships, providing robustness against overfitting even in high-dimensional spaces, and delivering strong performance on complex datasets, making it highly suitable for classification tasks where data may not be linearly separable.

4. RESULTS AND DESCRIPTION

	age	spectacle-prescrip	astigmatism	tear-prod-rate	contact-lenses
0	young	myope	no	reduced	none
1	young	myope	no	normal	soft
2	young	myope	yes	reduced	none
3	young	myope	yes	normal	hard
4	young	hypermetrope	no	reduced	none

Figure 3. Reading Dataset as head

The dataset has the information on individuals characterized by age, spectacle prescription, astigmatism presence, tear production rate, and contact lens type. It includes examples of young individuals with myopia, both with and without astigmatism, and varying tear production rates. Those with normal tear production rates are more likely to use contact lenses, with types varying between soft and hard. In contrast, individuals with reduced tear production, regardless of myopia or astigmatism status, tend not to use contact lenses. Additionally, young hypermetropic individuals with reduced tear production are not using contact lenses. This data suggests a correlation between tear production rates and the likelihood of contact lens use among individuals with different refractive conditions.

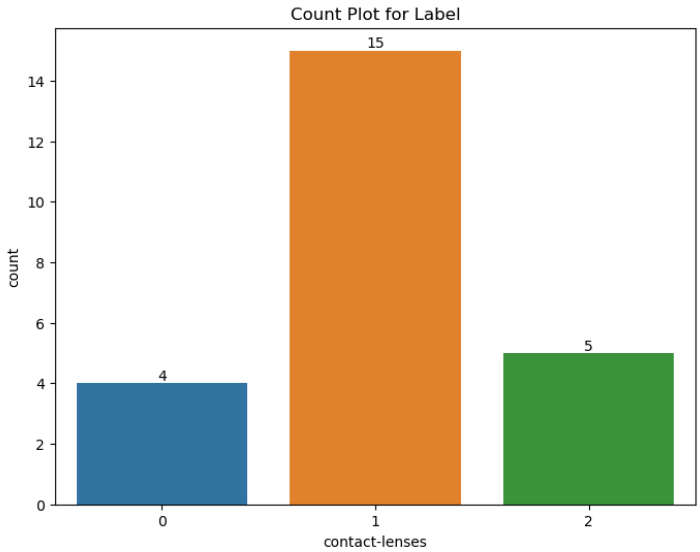

Figure 4. Presents the count plot of target

The research creates a count plot using the Seaborn library to visualize the distribution of the 'contact-lenses' column in the DataFrame `df`. The plot is displayed with a figure size of 8 by 6 inches. The `sns.countplot` function is used to generate the count plot, with the x-axis representing the categories of the 'contact-lenses' column. A loop iterates over each bar (patch) in the plot to annotate it with the corresponding count value. The `ax.annotate` function positions the count annotations at the center-top of each bar, offset slightly upward for better visibility. Finally, the plot is given a title 'Count Plot for Label' and displayed using `plt.show()`.

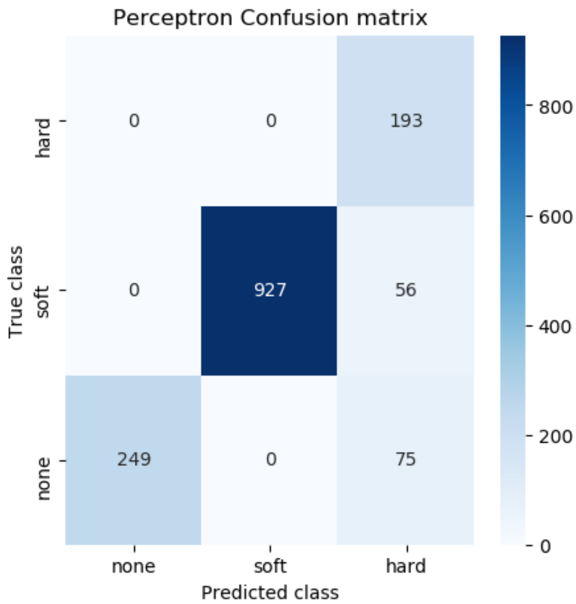

Figure 5. Presents the confusion matrix for perception

The logic first checks if the file 'model/Perceptron.pkl' exists. If it does, it loads the trained Perceptron model using `joblib.load`, prints a success message, and uses the model to predict on `X_test`, followed by calculating metrics with `calculateMetrics("Perceptron", predict, y_test)`. If the file does not exist, it trains a new Perceptron model using `pep.fit(X_train, y_train)`, saves the trained model to 'model/Perceptron.pkl' using `joblib.dump`, prints a success message, and then performs predictions and metric calculations on `X_test` similarly.

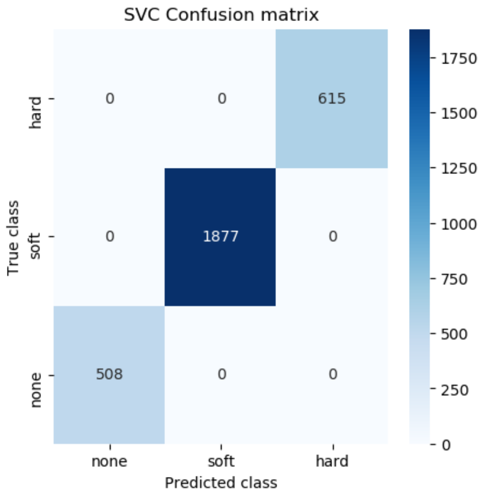

Fig 6. Presents the confusion matrix of SVC

The code snippet checks if the file `'model/SVC.pkl'` exists. If it does, it loads the trained SVC model from the file, prints a success message, makes predictions on `X_test`, and calculates metrics using the `calculateMetrics` function. If the file doesn't exist, it trains a new SVC model using `X_train` and `y_train`, saves the model to `'model/SVC.pkl'`, prints a success message, makes predictions on `X_test`, and calculates metrics using the `calculateMetrics` function.

5. CONCLUSION

The application of machine learning techniques in contact lens fitting presents a significant advancement in optimizing visual performance and patient comfort. This study successfully developed predictive models that utilize a diverse dataset of patient characteristics, leading to enhanced fitting decisions. By identifying critical factors such as corneal curvature, eye shape, and tear film quality, the models provide actionable insights that empower eye care practitioners to make informed recommendations. The incorporation of SHAP values ensures the interpretability of the models, allowing clinicians to understand the influence of individual features on fitting outcomes. The decision-support tool developed as part of this study demonstrates the practical utility of these predictive models, showcasing their ability to improve patient experiences through personalized fitting solutions.

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