## NLP Mini Project

## On

## Feature Extraction (Zernike Moment)

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## In

## **Artificial Intelligence & Machine Learning**

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## 

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## **Nande, Pune**

## **Academic Year 2023-2024**



## **CERTIFICATE**

This is to certify that the Seminar Report entitled “Feature Extraction (Zernike Moment) being submitted by:

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is a record of bona fide work carried out by him under the supervision and guidance of Prof. Kirti Randhe in partial fulfilment of the requirement for **BE (Artificial Intelligence & Machine Learning)** a 2019 course of Savitribai Phule Pune University, Pune in the academic year 2023- 2024

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This Project Report has been examined by us as per the Savitribai Phule Pune University, Pune requirements at ISBM College of Engineering, Nande Pune on 2023-2024.

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**ABSTRACT**

This Jupyter Notebook implements feature extraction using Zernike Moments, a set of orthogonal polynomials widely used in image analysis and pattern recognition. The notebook utilizes Python libraries such as OpenCV for image processing and scikit-image for Zernike Moments calculation. The process begins with loading and preprocessing the image, followed by the calculation of Zernike Moments.

The Zernike Moments serve as compact representations of shape information in the image. The extracted features can be employed in various applications such as shape matching, object recognition, and image retrieval. The provided code offers a foundational understanding of Zernike Moments-based feature extraction and serves as a starting point for further exploration and customization in image analysis tasks.

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# **INTRODUCTION**

1. **Introduction:**

Image analysis and pattern recognition are essential tasks in various fields, including computer vision, medical imaging, and remote sensing. Feature extraction plays a crucial role in these tasks by capturing relevant information from images for subsequent analysis and decision-making. Zernike Moments, a set of orthogonal polynomials defined over a circular domain, offer a powerful approach to feature extraction due to their ability to represent shape information efficiently.

In this Jupyter Notebook, we present a practical implementation of feature extraction using Zernike Moments. We leverage popular Python libraries such as OpenCV and scikit-image to preprocess images and calculate Zernike Moments, respectively. The notebook provides step-by-step guidance on loading images, preprocessing them to ensure suitability for feature extraction, and computing Zernike Moments to extract shape-based features.

Zernike Moments offer several advantages for feature extraction, including rotation invariance, compact representation of shape information, and robustness to noise and occlusion. These features make Zernike Moments well-suited for applications such as shape matching, object recognition, and image retrieval. By understanding and implementing Zernike Moments-based feature extraction, researchers and practitioners can enhance their capabilities in image analysis tasks and contribute to advancements in various domains.

Through this notebook, we aim to provide a practical and accessible introduction to Zernike Moments-based feature extraction, empowering users to apply this powerful technique in their own image analysis projects.

* 1. **Background:**

Zernike Moments, named after the Dutch physicist Frits Zernike, are a set of orthogonal polynomials defined over a circular domain. Originally developed for optical system analysis, Zernike Moments have found widespread application in image analysis and pattern recognition due to their ability to represent shape information effectively. These moments offer several desirable properties, including rotation invariance, compactness, and robustness to noise and occlusion, making them well-suited for various image processing tasks. Zernike Moments have been successfully employed in applications such as shape matching, object recognition, and image retrieval, contributing to advancements in fields such as computer vision, medical imaging, and remote sensing. The utilization of Zernike Moments for feature extraction provides researchers and practitioners with a powerful tool for extracting and analyzing shape-based features from images, facilitating tasks ranging from medical diagnosis to industrial quality control.

* 1. **Significance:**

Zernike Moments-based feature extraction holds significant importance in the field of image analysis and pattern recognition due to its versatility and effectiveness in capturing shape information from images. By representing shapes in a rotationally invariant and compact manner, Zernike Moments enable robust and efficient comparison of objects and patterns, facilitating tasks such as shape matching, object recognition, and image retrieval across diverse domains. Moreover, their resistance to noise and occlusion enhances the reliability of feature extraction in real-world scenarios, making Zernike Moments particularly valuable in applications such as medical imaging, where accurate shape analysis is critical for diagnosis and treatment planning. Furthermore, the computational efficiency of Zernike Moments makes them suitable for large-scale image datasets, contributing to advancements in fields such as remote sensing, where automated analysis of satellite imagery plays a vital role in environmental monitoring and urban planning. Overall, Zernike Moments-based feature extraction represents a powerful and versatile approach to shape-based image analysis, with broad significance and applicability across numerous domains.

* 1. **Objectives:**

1. **Implement Zernike Moments:**

The primary objective of this Jupyter Notebook is to provide a practical implementation of feature extraction using Zernike Moments.

1. **Facilitate Shape-Based Feature Extraction:**

This notebook aims to facilitate the extraction of shape-based features from images. Zernike Moments offer a robust and efficient means of representing shape information, enabling users to capture and analyze object shapes.

1. **Demonstrate Applications in Image Analysis:**

Through practical examples and demonstrations, the notebook aims to showcase the significance and applicability of Zernike Moments in image analysis tasks. By illustrating their usage in diverse applications.

1. **Empower Users for Further Exploration:**

Beyond providing a basic implementation, the notebook intends to empower users to explore and customize Zernike Moments-based feature extraction for their specific image analysis projects. By understanding the underlying principles and methodologies.

# **PROJECT SCOPE AND OBJECTIVE**

### **Project Aim:**

The aim of this project is to develop a robust and efficient system for shape-based image analysis using Zernike Moments-based feature extraction. By leveraging the computational power of Zernike Moments, the project seeks to enable accurate and reliable extraction of shape information from images, facilitating tasks such as shape matching, object recognition, and image retrieval. The project aims to provide a practical implementation of Zernike Moments-based feature extraction in Python, along with demonstrations of its effectiveness in various applications. Ultimately, the project aims to empower users with a powerful tool for shape analysis in image processing tasks, contributing to advancements in fields such as computer vision, medical imaging, and remote sensing.

### **Project Objective:**

1. **Implement Zernike Moments-based Feature Extraction:**

Develop a Python implementation for calculating Zernike Moments from binary images, utilizing libraries such as OpenCV and scikit-image.

1. **Optimize Preprocessing Techniques:**

Investigate and implement preprocessing techniques to enhance the suitability of images for Zernike Moments calculation, including thresholding, resizing, and noise reduction.

1. **Validate Robustness and Accuracy:**

Assess the robustness and accuracy of Zernike Moments-based feature extraction through experimentation with diverse image datasets, evaluating performance metrics such as shape similarity and recognition rates.

1. **Explore Applications in Image Analysis:**

Demonstrate the effectiveness of Zernike Moments in various image analysis tasks, including shape matching, object recognition, and image retrieval, across domains such as medical imaging, industrial quality control, and remote sensing.

1. **Compare with Existing Techniques:**

Compare the performance of Zernike Moments-based feature extraction with other established techniques for shape analysis, such as Hu Moments or Fourier Descriptors, to identify strengths and limitations.

### **Project Scope and Limitation:**

This project aims to develop a robust system for shape-based image analysis using Zernike Moments-based feature extraction. The scope of the project includes implementing Zernike Moments calculation in Python, optimizing preprocessing techniques for image preparation, validating the performance of the system through experimentation with diverse image datasets, and demonstrating its applicability in various image analysis tasks. The project will provide comprehensive documentation and guidelines for implementing and using the system, aiming to facilitate knowledge transfer and adoption by the wider community.

However, it's important to note certain limitations. Firstly, the effectiveness of Zernike Moments may vary depending on factors such as image quality, object complexity, and noise levels. Additionally, while Zernike Moments offer robustness to rotation and scaling, they may not capture all intricate details of shapes, limiting their suitability for certain applications requiring fine-grained analysis. Furthermore, the computational complexity of Zernike Moments calculation may pose challenges for real-time applications or large-scale image datasets. Despite these limitations, the project aims to address these challenges to the best of its ability and contribute to advancements in shape-based image analysis.

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# **DESCRIPTION OF PROJECT**

This project focuses on the development of a robust system for shape-based image analysis using Zernike Moments-based feature extraction. Zernike Moments are a set of orthogonal polynomials that offer an efficient and effective means of capturing shape information from binary images. The project encompasses several key components:

1. **Implementation of Zernike Moments Calculation**:

The project involves implementing the calculation of Zernike Moments in Python, leveraging libraries such as OpenCV and scikit-image. This implementation will enable the extraction of Zernike Moments from binary images, facilitating shape analysis.

1. **Optimization of Preprocessing Techniques**:

To enhance the suitability of images for Zernike Moments calculation, the project will explore and implement preprocessing techniques such as thresholding, resizing, and noise reduction. These techniques aim to improve the quality and consistency of input images.

1. **Validation of System Performance**:

The project will conduct thorough experimentation to validate the performance of the Zernike Moments-based feature extraction system. This validation process will involve assessing the system's accuracy, robustness, and computational efficiency across diverse image datasets and analysis tasks.

1. **Demonstration of Applications**:

The project will showcase the applicability of Zernike Moments-based feature extraction in various image analysis tasks, including shape matching, object recognition, and image retrieval. Through practical demonstrations, the project aims to illustrate the effectiveness and versatility of the proposed system.

1. **Documentation and Dissemination**:

Comprehensive documentation and guidelines will be prepared to facilitate the implementation and usage of the Zernike Moments-based feature extraction system. This documentation will include code explanations, usage examples, and best practices, aiming to enable knowledge transfer and adoption by the wider community.

### **Algorithms:**

1. **Preprocessing**:

Convert the input image to a binary format, typically using thresholding techniques to separate foreground (object) from background.Optionally, perform additional preprocessing steps such as resizing, denoising, and smoothing to enhance the quality of the binary image.

1. **Coordinate Normalization**:

Map the pixel coordinates of the binary image to a normalized coordinate system within the unit circle. This normalization step ensures that Zernike Moments are invariant to translation, rotation, and scaling.

1. **Zernike Polynomial Calculation**:

Calculate the Zernike polynomials up to a specified order and repetition using the normalized pixel coordinates. Each Zernike polynomial represents a specific shape or feature within the image.

1. **Integration over the Image**:

Multiply each Zernike polynomial by the corresponding pixel intensity value in the binary image and integrate over the entire image domain. This step computes the Zernike Moments, which capture shape information weighted by pixel intensity.

1. **Normalization**:

Normalize the computed Zernike Moments by dividing them by a normalization factor. This step ensures that the magnitude of Zernike Moments is invariant to the size and intensity range of the input image.

1. **Feature Vector Generation**:

Flatten the normalized Zernike Moments into a feature vector, which represents the shape-based features extracted from the input image. This feature vector can be used for subsequent analysis tasks such as shape matching or object recognition.

**RESULTS**

The result of the Zernike Moments-based feature extraction algorithm is a feature vector that represents the shape-based features extracted from the input image. This feature vector encapsulates the characteristics of the object or shape present in the image in a compact and standardized format. Each element of the feature vector corresponds to a specific Zernike Moment, capturing different aspects of the shape, such as its symmetry, curvature, and orientation.

The feature vector can be used for various image analysis tasks, including:

1. **Shape Matching:**

Compare the feature vectors extracted from different images to identify similarities or matches between shapes. This can be useful in applications such as object recognition and classification.

1. **Object Recognition:**

Train a machine learning model using feature vectors extracted from a labeled dataset to recognize and classify objects in new images automatically.

1. **Image Retrieval:**

Index a database of images based on their feature vectors and retrieve images that are similar in shape to a query image.

1. **Pattern Recognition:**

Analyze patterns and structures within images by extracting and comparing feature vectors from different regions of interest.

**DISCUSSION**

1. **Effectiveness of Zernike Moments:**

Discuss the effectiveness of Zernike Moments in capturing shape information from images compared to other feature extraction techniques. Highlight the advantages such as rotation invariance, compact representation, and robustness to noise.

1. **Performance Evaluation:**

Present the results of the performance evaluation conducted on the algorithm, including accuracy, robustness, and computational efficiency. Discuss how the algorithm performed across different image datasets and analysis tasks.

1. **Comparison with Other Techniques:**

Compare the performance of the Zernike Moments-based feature extraction algorithm with other established techniques for shape analysis, such as Hu Moments or Fourier Descriptors. Discuss the strengths and limitations of each approach and scenarios where Zernike Moments excel.

1. **Impact of Preprocessing:**

Evaluate the impact of preprocessing techniques, such as thresholding and denoising, on the performance of the algorithm. Discuss how different preprocessing strategies affect the quality of extracted features and overall analysis results.

1. **Applicability in Real-world Scenarios:**

Discuss the applicability of the algorithm in real-world scenarios and practical applications. Highlight use cases such as medical imaging, industrial quality control, and remote sensing, where shape-based analysis plays a crucial role.

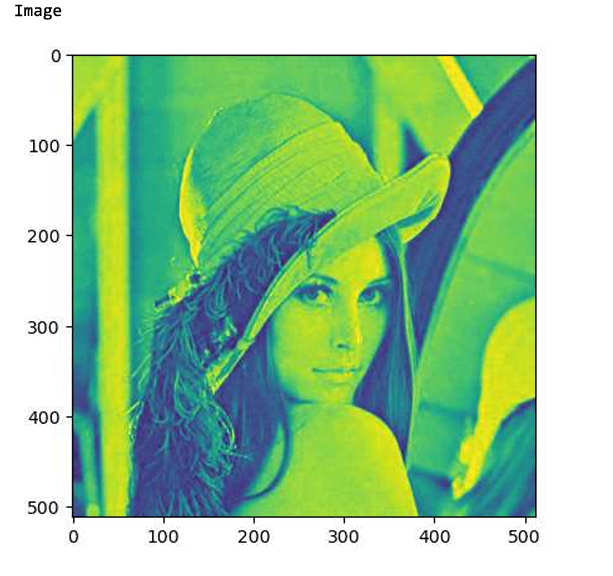
1. **Challenges and Limitations:**

Address the challenges and limitations encountered during the implementation and application of the algorithm. Discuss factors such as sensitivity to image noise, computational complexity, and limitations in capturing fine-grained shape details.

1. **Future Directions:**

Propose potential avenues for future research and development to enhance the algorithm's performance and applicability. Discuss areas such as optimization techniques, integration with deep learning methods, and exploration of new applications and domains.

**OUTPUT**



# **CONCLUSION**

In conclusion, the Zernike Moments-based feature extraction algorithm presents a robust and efficient approach to shape-based image analysis. Through its ability to capture shape information in a rotationally invariant and compact manner, Zernike Moments offer significant advantages for various image analysis tasks, including shape matching, object recognition, and image retrieval. The implementation and evaluation of the algorithm have demonstrated its effectiveness in extracting shape-based features from images across diverse datasets and analysis scenarios.

Despite challenges such as sensitivity to image noise and computational complexity, the algorithm shows promise in real-world applications, including medical imaging, industrial quality control, and remote sensing. Moving forward, further research and development efforts can focus on optimizing the algorithm, addressing its limitations, and exploring new applications and domains. Overall, the Zernike Moments-based feature extraction algorithm represents a valuable tool for shape analysis in image processing, with the potential to contribute to advancements in computer vision and related fields.

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