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Gait recognition system

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Abstract
Gait recognition is a critical biometric approach used for identifying individuals based on their walking patterns. This paper presents an efficient gait recognition framework capable of addressing both known and unknown covariate conditions using Gait Energy Images (GEI). The proposed methodology integrates Convolutional Neural Networks (CNN) for known covariate conditions, where models are trained and tested on similar conditions such as normal walking. For unknown covariate conditions, which involve variations such as clothing, carried items like bags, and altered walking styles, features are extracted using Histogram of Oriented Gradients (HOG), Local Binary Patterns (LBP), and Haralick descriptors. These extracted features are then dimensionally reduced using Fisher Linear Discriminant Analysis (FLDA) and classified using Support Vector Machines (SVM), Multi-Layer Perceptron (MLP), and Random Forest classifiers.

The framework is implemented through a series of well-defined modules: the dataset upload module allows integration of the GAITB dataset; preprocessing ensures normalization and grayscale transformation of images for effective training; CNN is employed to train a model for recognizing person IDs under known covariate conditions; and advanced feature extraction techniques followed by FLDA are used to reduce feature sizes for subsequent training with SVM, MLP, and Random Forest classifiers. Performance metrics such as accuracy, precision, recall, and F1-score are utilized to evaluate the models. An additional comparison graph visually represents the accuracy of these classifiers, highlighting their effectiveness under different covariate conditions.

Keywords: SVM, gait energysystem, CNN, GAITB, MLP

Introduction

Gait is a biometric trait that depicts and measures how people move. Over the decades, gait analysis has been successfully used in different domains, including biometrics and posture analysis for healthcare applications. It has also been used in human psychology where gait analysis using point lights employed for recognition of emotional patterns. The same idea was extended and ultimately resulted in the development of gait signatures through which the identification of individuals can be performed. Borrowing from this, computer vision-based approaches have also used motion analysis and human movement modeling for person identification. In the early days of gait recognition, the focus was to identify and classify the different movement patterns such as walking, jogging, and climbing. Gradually, the focus shifted towards human identification and has become an active area of research. As compared to other biometric traits such as fingerprint and iris, gait recognition can work without the cooperation of a person. Moreover, it can work without interfering with a person's activity. This makes gait more suitable for different real-time applications like surveillance and long distance security. Existing techniques employed for gait analysis are divided into model-based and appearance-based methods. The former requires high-resolution videos whereas the latter can deal with low-resolution imagery. Model- based approaches use the parameters of the body, appearance-based approaches on the other hand employ the features extracted directly from image sequences of gait. The simplicity of appearance-based methods and their robustness against noise make them more suitable for real-world scenarios. Appearance-based methods rely on silhouettes extracted from a gait sequence. Silhouettes contain important information about the stance and shape of the human body. Gait representations used in appearance-based approaches include frequency- domain features, chrono-gait images, features extracted from silhouettes (Gait Energy Image (GEI)), and Gabor GEIsGait is a unique non-invasive biometric form that can be utilized to effectively recognize persons, even when they prove to be uncooperative.

Computer-aided gait recognition systems usually use image sequences without considering covariates like clothing and possessions of carrier bags whilst on the move. Similarly, in gait recognition, there may exist unknown covariate conditions that may affect the training and testing conditions for a given individual. Consequently, common techniques for gait recognition and measurement require a degree of intervention leading to the introduction of unknown covariate conditions, and hence this significantly limits the practical use of the present gait recognition and analysis systems. To overcome these key issues, we propose a method of gait analysis accounting for both known and unknown covariate conditions. For this purpose, we propose two methods, i.e., a Convolutional Neural Network (CNN) based gait recognition and a discriminative features-based classification method for unknown covariate conditions. The feature set utilized here includes Local Binary Patterns (LBP), Histogram of Oriented Gradients (HOG), and Horlick texture features. Furthermore, we utilize the Fisher Linear Discriminant Analysis for dimensionality reduction and selecting the most discriminant features. Three classifiers, namely Random Forest, Support Vector Machine (SVM), and Multilayer Perceptron are used for gait recognition under strict unknown covariate conditions. We evaluated our results using CASIA and OUR-ISIR datasets for both clothing and speed variations. As a result, we report that on average we obtain an accuracy of 90.32% for the CASIA dataset with unknown covariates and similarly performed excellently on the ISIR dataset. Therefore, our proposed method outperforms existing methods for gait recognition under known and unknown covariate conditions

Literature Survey

A survey of behavioral biometric gait recognition

In today digital society, vulnerability to person authentication is a serious issue in real time scenarios like (airport, hospital, metro stations, etc.). This issue has increased the growth of video surveillance security systems. In recent decades behavioural biometric trait gait has emerged as a potential surveillance monitoring system because of its inconspicuous and unperceivable nature. Even more human gait has a benefit that it can be tracked at a distance and under low resolution videos. Finally, it is difficult to impersonate gait features. In this article, we comprehensively investigate the past and current research development in vision-based (VB) gait recognition. We give a brief description of feature selection and classification techniques used in gait recognition. The article extensively investigates feature representation techniques, classified into model-based and model-free. The article also provides a detail description of databases that are available for research purposes classified into two categories: VB and sensor-based. We extensively examine factors that affect gait recognition, and current research was done to cope with these factors. Moreover, this article proposes future perspectives after investigating state-of-art literature that can be more helpful to experts and new comers in gait recognition. In last, we also give a brief description of the proposed workflow..

The reationship between 2d static features and used in gait recognition: In most gait recognition techniques, both static and dynamic features are used to define a subject’s gait signature. In this study, the existence of a relationship between static and dynamic features was investigated. The correlation coefficient was used to analyse the relationship between the features extracted from the “University of Bradford Multi-Modal Gait Database”. This study includes two dimensional dynamic and static features from 19 subjects. The dynamic features were compromised of Phase-Weighted Magnitudes driven by a Fourier Transform of the temporal rotational data of a subject’s joints (knee, thigh, shoulder, and elbow). The results concluded that there are eleven pairs of features that are considered significantly correlated with ($p<0.05$). This result indicates the existence of a statistical relationship between static and dynamics features, which challenges the results of several similar studies. These results bare great potential for further research into the area, and would potentially contribute to the creation of a gait signature using latent data. "IoT: Internet of Threats? A Survey of Practical Security Vulnerabilities in Real IoT Devices."

Gait as Evidence

This study examines what in Denmark may constitute evidence based on forensic anthropological gait analyses, in the sense of pointing to a match (or not) between a perpetrator and a suspect, based on video and photographic imagery. Gait and anthropometric measures can be used when direct facial comparison is not possible because of perpetrators masking their faces. The nature of judicial and natural scientific forms of evidence is discussed, and rulings dealing with the admissibility of video footage and forensic evidence in general are given. Technical issues of video materials are discussed, and the study also discusses how such evidence may be presented, both in written statements and in court.

Gait verification system for criminal investigation

This paper describes the first gait verification system for criminal investigation using footages from surveillance cameras. The system is designed so that the criminal investigators as non-specialists on computer vision-based gait verification can, independently, use it to verify unknown perpetrators as suspects or ex- convicts in criminal investigations. Each step of the gait verification process is proceeded by interactive operation on a graphics-user interface. Eventually, for each pair of compared subjects selected by a user, the system outputs a posterior probability on a verification result, which indicates that compared subjects are the same, with the consideration of various circumstances of the subjects such as the size, frame-rate, observation views, and clothing of subjects. One gait-specialist and ten non-gait-specialists participated in operation tests of the system using five different datasets with various types of scenes, each of which contained two or three verification sets. It was shown that all the non-gait-specialists, as well as the gait-specialist, could obtain reasonable verification results for almost all of the verification sets.

Human gait recognition based on matching of body components

This paper presents a novel approach for gait recognition based on the matching of body components. The human body components are studied separately and are shown to have unequal discrimination power. Several approaches are presented for the combination of the results obtained from different body components into a common distance metric for the evaluation of similarity between gait sequences. A method is also proposed for the determination of the weighting of the various body components based on their contribution to recognition performance. Using the best performing of the proposed methods, improved recognition performance is achieved.

On reducing the effect of covariate factors in gait recognition

Robust human gait recognition is challenging because of the presence of covariate factors such as carrying condition, clothing, walking surface, etc. In this paper, we model the effect of covariates as an unknown partial feature corruption problem. Since the locations of corruptions may differ for different query gaits, relevant features may become irrelevant when walking condition changes. In this case, it is difficult to train one fixed classifier that is robust to a large number of different covariates. To tackle this problem, we propose a classifier ensemble method based on the random subspace Method (RSM) and majority voting (MV). Its theoretical basis suggests it is insensitive to locations of corrupted features, and thus can generalize well to a large number of covariates. We also extend this method by proposing two strategies, i.e, local enhancing (LE) and hybrid decision-level fusion (HDF) to suppress the ratio of false votes to true votes (before MV). The performance of our approach is competitive against the most challenging covariates like clothing, walking surface, and elapsed time.

Related Methodologies

Gait recognition is a promising biometric technology that identifies individuals based on their unique walking patterns. It is non-intrusive and can be performed from a distance, making it suitable for surveillance and security applications.

1. Data Acquisition

This is the initial step where gait data is captured. The choice of capture device depends on the system's objectives and environment. Common methods include:

- **Video Cameras:** Standard video cameras (including infrared) are widely used to capture a person's movement. This is particularly common for remote identification in surveillance settings.
- **Wearable Sensors:** Inertial Measurement Units (IMUs) containing accelerometers and gyroscopes can be attached to various body parts (e.g., ankles, shins, hips) to collect precise motion data.
- **Pressure-Sensing Floors/Insoles:** These systems use sensors embedded in the floor or in shoe insoles to measure ground reaction forces and pressure distribution during walking.

2. Pre-processing

The raw data acquired needs to be processed to isolate the gait information and prepare it for feature extraction.

- **Background Subtraction (for video data):** This step aims to separate the moving human subject from the static background in video frames, resulting in binary silhouettes. This reduces computational complexity by focusing only on the relevant subject.
- **Noise Reduction:** Filtering techniques are applied to remove unwanted noise from the captured data (e.g., sensor noise, environmental fluctuations).
- **Normalization:** Gait data can vary due to factors like walking speed, clothing, or viewing angle. Normalization techniques are applied to minimize these intra-class variations and make the gait features more consistent. This might involve resizing silhouettes, adjusting for different walking speeds, or transforming data to a canonical view.

3. Feature Extraction

This is a crucial stage where distinctive characteristics of a person's gait are extracted from the pre-processed data. Gait features can be broadly categorized into:

- **Gait Energy Image (GEI):** This is a popular technique where a sequence of silhouettes over a full gait cycle is averaged into a single, static image. The GEI captures the average motion and shape information, creating a unique "gait signature."
- **Silhouette Contours:** Analyzing the shape and changes in the outer boundaries of the human silhouette over time.
- **Spatial and Temporal Features:** Metrics like step length, stride length, cadence (steps per minute), walking speed, and variations in body part positions and angles during the gait cycle.

4. Classification and Recognition

In this final stage, the extracted gait features are compared against a database of known gait patterns to identify an individual.

Training Phase: A machine learning model (e.g., Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs) like LSTMs, Support Vector Machines (SVMs), K-Nearest Neighbors (KNN)) is trained on a dataset of labeled gait features. The model learns to associate specific gait patterns with individual identities.

Testing/Recognition Phase**:** When a new, unknown gait sequence is presented, its features are extracted using the same methodology. These features are then fed into the trained classification model, which outputs the most probable identity by comparing the input features to the learned patterns in the database.

Similarity Measurement

Algorithms calculate the similarity or distance between the extracted features of the unknown gait and the stored gait signatures. A high similarity score indicates a match.

Results and Discussions

Gait recognition system results are measured by metrics like accuracy, Rank-1 recognition rate, and Equal Error Rate (EER). In controlled lab settings, deep learning models often achieve 95-99% Rank-1 accuracy. However, "in-the-wild" performance, facing challenges like varying viewpoints, clothing, and occlusions, sees accuracies typically range from 55-85%. Factors like resolution, walking speed, and temporary gait changes also significantly impact results. Continuous advancements in robust feature learning and covariate handling are steadily improving real-world applicability.

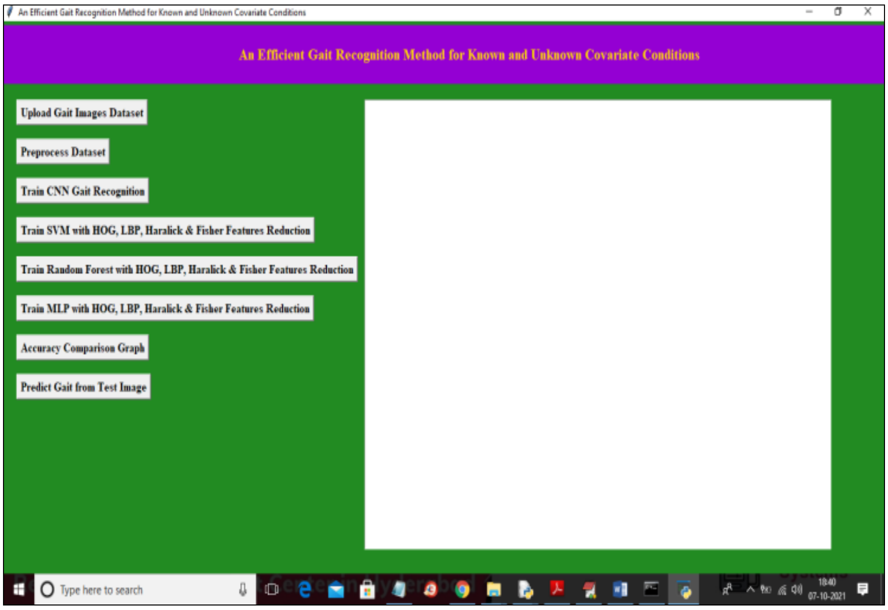

Fig 1: AK interface to upload images

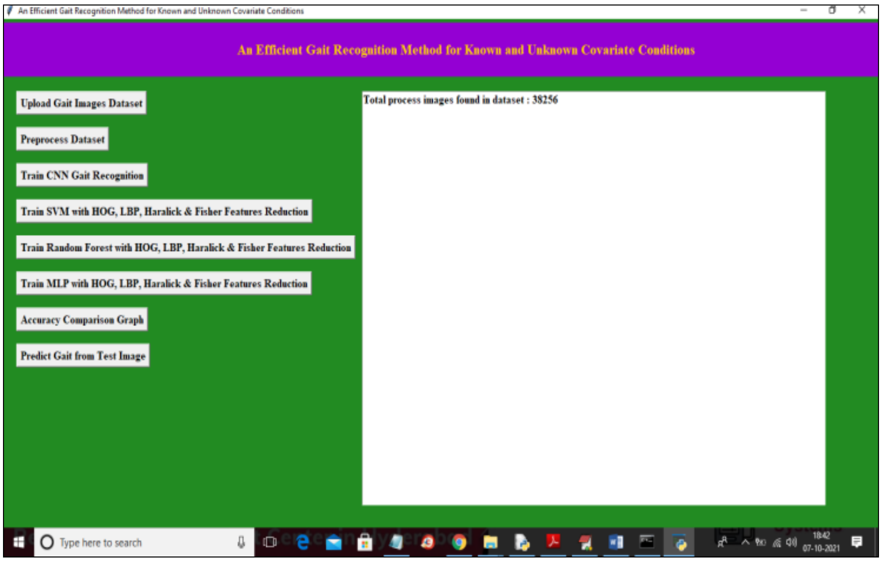

Fig 2: Uploading dataset

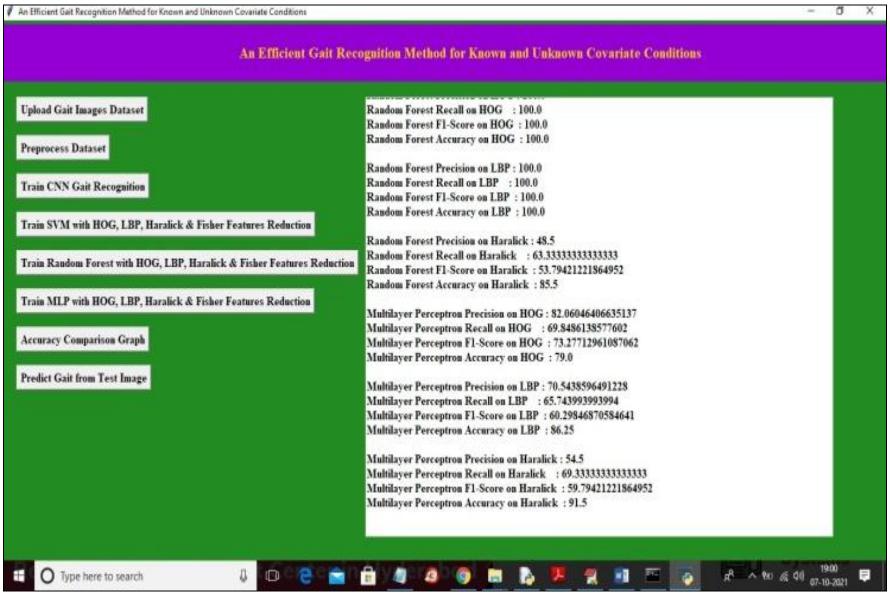

Fig 3: Performing algorithms

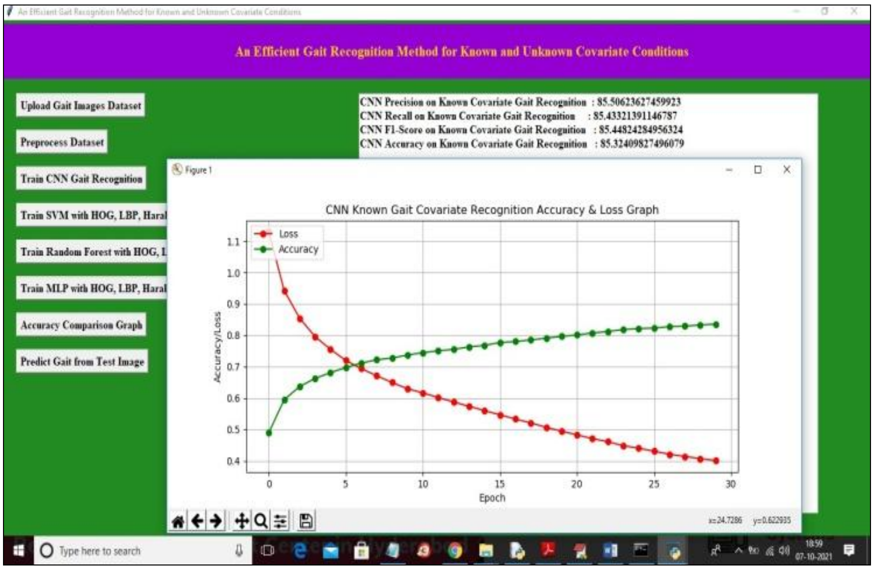

Fig 4: Accuracy & loss graph

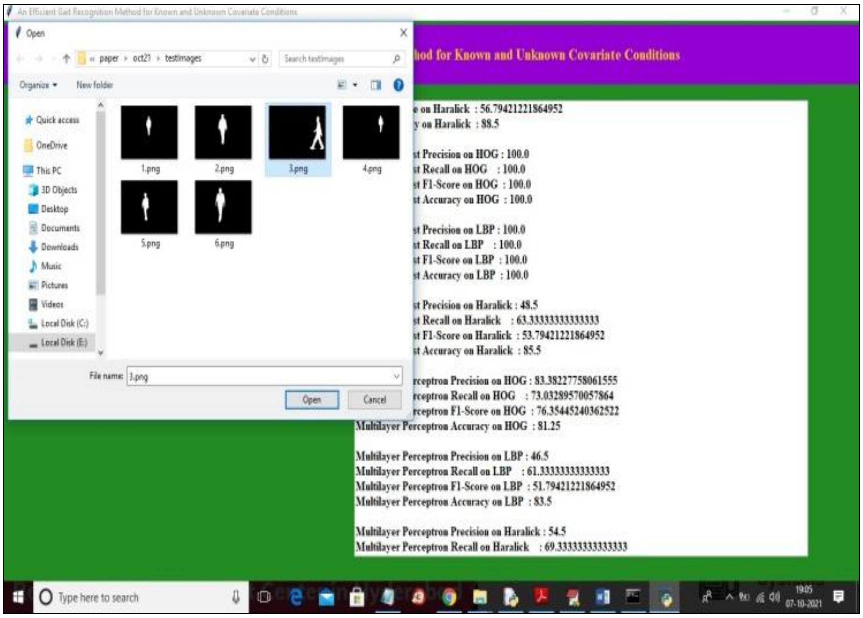

Fig 4: Upload image

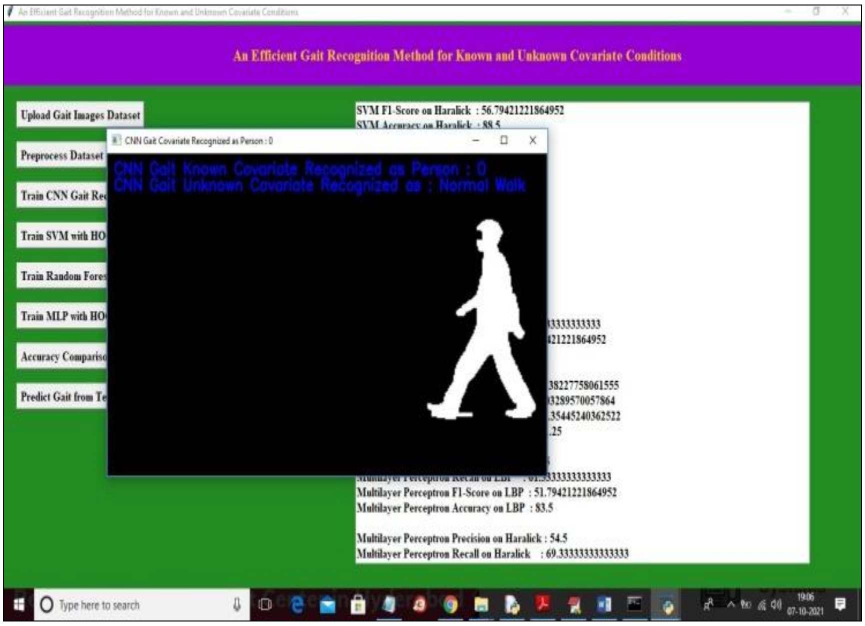

Fig 5: Result 1

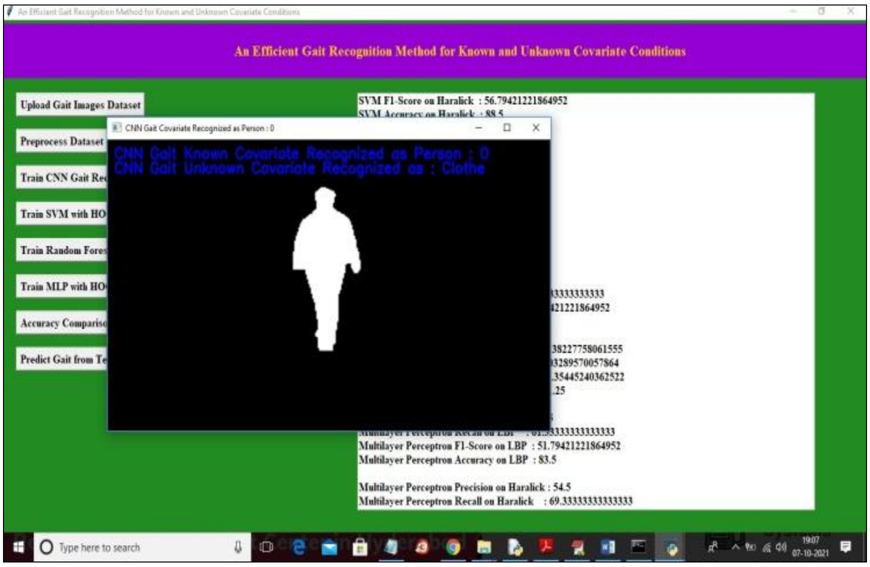

Fig 6: Result 2

Conclusion

Gait recognition without the subject's cooperation remains one of the most challenging research areas in the field.The covariate conditions, including clothing and speed variations,are still difficult to handle inrealistic experimental setups.The existing solutions perform poorly when subject cooperation is not possible,and there are changes in covariate conditions, making them unsuitable to deploy for practical purposes. The emergence of deep learning approaches has made computer vision tasks easier.However,there are certain scenarios where pre-processed data can further improve the performance of these deep learning methods.

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