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Real-time Face Tracking for Service-Robot

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Abstract

Real-time human face tracking is suggested in this paper for use while interacting with robots. The system consists of two main parts, the first works to discover the human face, determine its location in relation to the original image, and find the dimensions of the face to be used in the second part of this system. The second part receives the location and dimension of the face and tracks it by controlling the movement of the camera according to the offset between the interval. In order to detect human faces for the earlier job, the Haar cascade method is used, whereas the Kanade-Lucas-Tomasi (KLT) algorithm is used for face tracking under various circumstances. As a trace output from the prior stage, the camera is offset by its offset between image frames. The findings of the experiments demonstrate that real-time tracking of human faces was successful even when the participants were donning glasses, hats, or face-side positions. At a maximum frame rate of 26 fps, experiments were conducted.

INTRODUCTION

In the present and the future, Human-Robot Interaction (HRI) will be a prominent area of robotics. The primary purpose of robots in this domain is to serve as helpful assistants that can effectively aid humans in performing various tasks. For this, robots must be able to interact and communicate well with people.In this context, the ability to track human faces becomes a primary requirement for the robot's vision system. Applications for face-tracking systems dealing with forward-oriented faces are numerous. The Kanade-Lucas-Tomasi (KLT) method can be used to address this issue in real-time by utilizing several face modes. Based on various facial traits, this system enables precise face tracking. The process involves extracting, selecting, and tracking the most relevant features for monitoring human faces.

LITERATURE SURVEY

In [1], Liu, A.-L., & Chu, W.-T. (2020). A posture evaluation system for fitness videos based on recurrent neural network. In Proceedings of the 2020 International Symposium on Computer, Consumer and Control (IS3C) (pp. 1-6). IEEE.

In [2] We and Wang (2017) introduced a robust face detection and recognition system for home service robots using end-to-end deep neural networks. Their approach focused on accurately detecting and recognizing faces under various lighting conditions and occlusions, which significantly enhances human-robot interaction.

In Paper [3], Tao et al. (2017) proposed a method for fast and robust occluded face detection aimed at ATM surveillance systems. Their technique focuses on handling partial occlusions and complex backgrounds, improving the robustness of face detection systems.

In Reference [4], Machaca Arceda et al. (2016) presented a novel approach for fast face detection in violent video scenes. Their system aims at real-time detection, providing high accuracy even under challenging conditions involving rapid movements and poor lighting.

In article [5], Paul and Michael (2004) developed a real-time face detection system with robustness against various facial orientations and occlusions. Their technique emphasizes quick detection with high accuracy, applicable to various real-world scenarios.

In paper [6], Aditya et al. (2016) discussed the issue of detecting faces with various angular positions [6]. Their approach highlights the challenges of detecting faces that are not front-facing, focusing on improving detection accuracy for different angles.

COMPARATIVE ANALYSIS

Study	Methodology	Key Features	Efficiency Improvement
[1] Liu, A.-L., & Chu	Capturing human movement through 2D skeleton detection.	2D Human Skeleton Detection, Automated Posture Evaluation	Automating the feedback process. Providing consistent and objective evaluations. Increasing accessibility to expert-level feedback.
[2] We and Wang (2017)	End-to-end deep neural networks	- Robust face detection and recognition. - Handles various lighting conditions and occlusions. - Enhances human-robot interaction.	- Improved accuracy in face detection and recognition for home service robots.
[3] Tao et al. (2017)	Focused on handling partial occlusions and complex backgrounds	partial occlusions and complex backgrounds- Fast and robust occluded face detection. - Designed for ATM surveillance systems.	- Increased robustness in face detection under occlusions and complex backgrounds.
[4] Machaca Arceda et al. (2016)	Novel approach for real-time face detection	- Fast face detection in violent video scenes. - High accuracy under challenging conditions (rapid movements, poor lighting).	- Real-time detection with high accuracy in dynamic and challenging environments.
[5] Paul and Michael (200	Real-time face detection system	- Robustness against various facial orientations and occlusions. - Quick detection with high accuracy.	- Improved speed and accuracy in face detection for various real-world scenarios
[6] Aditya et al. (2016)	Focused on detecting faces with various angular positions	- Addresses challenges of non-front-facing face detection. - Improves detection accuracy for different angles.	- Enhanced accuracy in detecting faces at different angular positions.

PROBLEM STATEMENT

The increasing demand for service robots that can effectively interact with humans has made robust and real-time face tracking a critical requirement. Existing systems often struggle with maintaining accurate tracking under challenging conditions such as varying facial orientations, changes in lighting, partial occlusions, and the use of accessories like glasses and hats. While the Haar cascade algorithm offers reliable face detection, its performance is limited when essential facial features are not fully visible. Additionally, conventional tracking algorithms lack robustness in scenarios where faces deviate from frontal poses. Therefore, there is a need to develop a more efficient and resilient face tracking system that ensures continuous monitoring of human faces in real-time, even under suboptimal conditions.

In the present and future, human-robot interaction (HRI) is a prominent area of robotics aimed at creating robots capable of effectively interacting and communicating with humans. Real-time face tracking plays a crucial role in enhancing the robot's vision system, enabling it to maintain continuous engagement with the human user. The proposed system utilizes the Haar cascade algorithm for face detection and the Kanade-Lucas-Tomasi (KLT) algorithm for tracking, which is particularly effective in challenging conditions such as varying facial orientations and the use of accessories.

OBJECTIVE

The objective of this system is to develop a real-time face tracking framework capable of accurately detecting and tracking human faces for effective human-robot interaction. The system aims to achieve the following specific goals:

1. **Accurate Face Detection:** Implement the Haar cascade algorithm to detect human faces by identifying key facial features such as eyes, nose, cheeks, and jawline. The algorithm should accurately distinguish faces from the background even under varying lighting conditions and diverse facial orientations.
2. **Real-Time Face Tracking and Analysis:** Utilize the Kanade-Lucas-Tomasi (KLT) algorithm to continuously track detected faces in real-time, ensuring robust performance when the user is wearing glasses, hats, or partially turning their face away from the camera.
3. **Improved Optical Flow-Based Tracking:** Apply optical flow calculations to enhance the system's ability to monitor facial movements over time, ensuring stability and consistency in tracking despite partial occlusions or changes in facial expressions.
4. **Integration with Servo Motor Control System:** Develop a control mechanism where servo motors adjust the camera orientation based on face position, ensuring the face remains centered in the frame for uninterrupted interaction.
5. **Evaluation and Optimization:** Test the system's performance under various conditions, assess limitations, and improve detection and tracking accuracy by refining the algorithms and optimizing hardware integration.

PROPOSED WORK

The proposed system aims to develop a real-time face tracking framework that utilizes computer vision algorithms to accurately detect and track human faces during human-robot interactions. By integrating the Haar cascade algorithm for face detection and the Kanade-Lucas-Tomasi (KLT) algorithm for continuous face tracking, the system intends to enhance robustness and accuracy under various conditions. This proposed system will be able to:

1. **Capture Live Video Streams for Face Detection and Tracking:** The system will process real-time video input from a camera to detect and track human faces. The live feed will be continuously monitored to ensure consistent face tracking even under varying conditions.
2. **Implement Haar Cascade Algorithm for Face Detection:** The Haar cascade algorithm will be used to detect facial features such as eyes, nose, cheeks, and jawline by analyzing edge and line detection patterns. This method will provide initial face detection before the tracking process begins.
3. **Utilize KLT Algorithm for Continuous Face Tracking:** The KLT algorithm will be applied to track detected facial features based on optimal point selection and optical flow calculations. This ensures reliable tracking even when the user wears accessories like glasses or hats or partially turns their face away from the camera.
4. **Integrate Servo Motor Control System:** The proposed system will include a control mechanism where servo motors adjust the camera orientation based on the face's position. This ensures that the detected face remains centered in the frame, allowing smooth and uninterrupted interaction.
5. **Provide Real-Time Feedback and Adjustment:** The system will continuously monitor the face's position and adjust the camera's orientation using feedback from the tracking algorithm. This feature ensures stable tracking performance under various conditions.
6. **Evaluate Performance and Optimize Algorithms:** Testing will be conducted on different hardware configurations to assess the system's accuracy, speed, and robustness. Improvements will be made based on experimental results to enhance the overall performance.

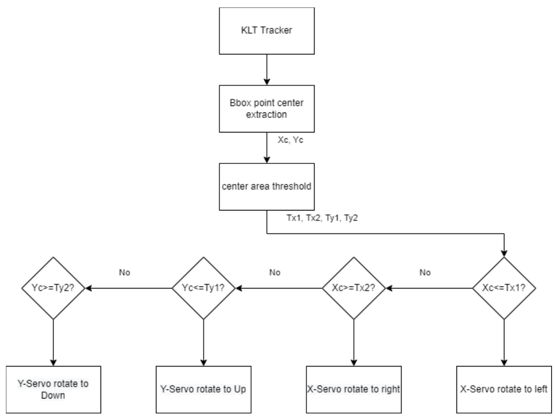

Figure1. Flowchart of Tracking System

METHODOLOGY

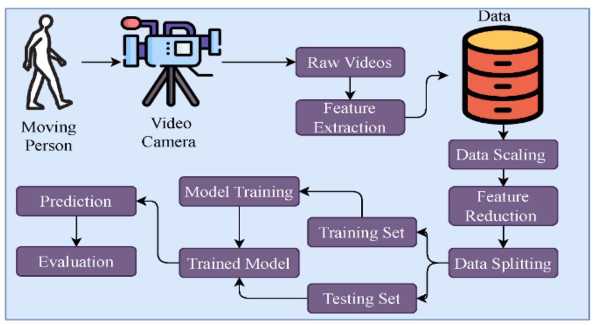

Figure2. Diagram showing the proposed methodology for exercise classification.

1. **Data Collection:** Capture video data using a webcam. Organize the data into files labeled by the type of exercise for easier processing.
2. **Feature Extraction:** Use PoseNet to extract key features from the collected video data, focusing on anatomical landmarks like joints and body posture.
3. **Data Standardization:** Implement standardization procedures to ensure consistency and compatibility for further processing.
4. **Data Splitting:** Divide the standardized features into training and testing sets to facilitate the machine learning (ML) and deep learning (DL) processes.
5. **Model Training & Classification:** Train ML and DL classifiers to identify complex patterns within the data. Fine-tune and optimize the models using training data to improve detection accuracy.
6. **Performance Evaluation:** Test the classifiers using the test set and evaluate their performance using metrics such as accuracy, precision, recall, and F1 score. Assess the models' effectiveness in correctly classifying different types of exercises.
7. **Continuous Monitoring:** Enable real-time analysis and continuous monitoring of the system's performance to ensure robustness and reliability.

Conclusion

This research presents a robust real-time face tracking system aimed at enhancing human-robot interaction by accurately detecting and tracking faces under various conditions. The proposed approach combines the Haar cascade algorithm for face detection and the KLT algorithm for continuous tracking, ensuring reliable performance even when users wear accessories or partially turn their faces. While the system effectively maintains faces within the frame's central region, its performance is limited when essential facial features are occluded or inadequately detected. Future work will focus on improving detection accuracy under harsh conditions and extending the system to support simultaneous tracking of multiple faces using advanced detection algorithms.

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