Credit Task 2.2: Identify Research Trends

1. LiDAR Applications in Gait Analysis

1.1 Synthesis of Paper 1: Development and Validation of 2D-LiDAR-Based Gait Analysis Algorithm

The paper introduces a novel gait analysis tool using compact 2D-LiDAR technology. The methodology involves an object-tracking algorithm and validation with young, healthy participants, comparing 2D-LiDAR to a stereo camera using motion capture as the gold standard. Results show 2D-LiDAR's notable superiority (mean absolute errors of 46.2 ± 17.8 mm) over the stereo camera. Gait parameters measured by 2D-LiDAR exhibit strong agreement with motion capture ($r = 0.955$ for step length, $r = 0.911$ for cadence), and its ability to simultaneously track multiple targets is highlighted.

Key Takeaways

- The 2D-LiDAR system exhibited superior accuracy compared to a stereo camera.
- Gait parameters from 2D-LiDAR showed strong agreement with motion capture data.
- The system demonstrated the ability to track multiple targets simultaneously.
- The tool holds promise for practical use in clinical settings, especially for older adults in constrained environments.

1.2 Synthesis of Paper 2: Gait-Based Person Identification using 3D LiDAR and Long Short-Term Memory Deep Networks

This paper introduces a novel approach for gait recognition using a real-time multi-line 3D LiDAR system coupled with a Long Short-Term Memory (LSTM) based method. Addressing challenges in gait identification, the study generates a Point Cloud Gait dataset from 30 participants using an omnidirectional 3D LiDAR (HDL-32E). The integration of a 2D CNN and LSTM model, with four layers each, forms the core methodology. Comparative experiments with a 3D CNN and GEINet highlight challenges in LiDAR data, specifically in Gait Energy Image (GEI) resolution. Despite these challenges, the LSTM-based method surpasses the 3D CNN, achieving a commendable 60% accuracy in gait recognition.

Key Takeaways

- The study reveals that the lower spatial resolution and time density of LiDAR data, when contrasted with standard camera images, lead to a coarse appearance of Gait Energy Image (GEI), posing challenges for effective identification.
- Identification of the proposed LSTM-based method as better suited for gait recognition compared to 3D CNN.
- Demonstration of robust classification performance with an accuracy level of around 60%.

1.3 Synthesis of Paper 3: Biometric Recognition Through Gait Analysis

This paper introduces BRITTANY, a biometric recognition tool employing gait analysis through Laser Imaging Detection and Ranging (LiDAR) and a Convolutional Neural Network (CNN). The aim is to present an innovative approach to biometric identification leveraging LiDAR technology. The chosen LiDAR sensor is notable for its low computational requirements and privacy features. The methodology involves processing LiDAR readings using People Tracking (PeTra) to create occupational maps that distinguish individual points. These maps are further aggregated to construct a comprehensive gait image. A Convolutional Neural Network (CNN) model is then employed to process the aggregated occupancy maps, producing a user identifier for individuals within the robot's view. Noteworthy architectures, LeNet and AlexNet, are also integrated into the model.

Key Takeaways

- The assessment of various setting schemas, aggregating ten segmented occupancy maps, resulted in an impressive 88% accuracy in biometric recognition.
- The study utilizes gait analysis for person re-identification, employing silhouettes derived from projecting a person's 3D point cloud onto a 2D image.
- Leveraging a 2D LiDAR sensor, the paper highlights more manageable data processing due to the substantially smaller number of values compared to a 3D LiDAR system.

2. Smart Sensor Systems for Seated Environments

2.1 Synthesis of Paper 4: Developing a Mixed Sensor Smart Chair System for Real-Time Posture Classification

This study aims to pioneer a sensor-embedded smart chair system designed to monitor and classify workers' sitting postures in real time. The smart chair employs a mixed sensor configuration, integrating six pressure sensors in the seat cushion and six infrared reflective distance sensors in the seatback. Using a k-Nearest Neighbour algorithm, the system classifies postures based on an ergonomic literature analysis.

Key Findings

- In comparison to benchmark systems utilizing single sensor types, the mixed sensor system exhibited significantly superior classification performance.
- The mixed sensor system achieved an overall posture classification accuracy of 0.92, surpassing individual systems using only pressure sensors (0.59) and distance sensors (0.82).
- F1 scores ranging from 0.83 to 0.97 further emphasize the system's accuracy and reliability in classifying various sitting postures in real time.

2.2 Synthesis of Paper 5: Designing a Testing Device for Athletes Assessing Trunk Control in Seated Environments

This study aims to design a testing device evaluating athletes' responses to propulsion determinants, particularly assessing trunk control in a seated environment. The device features a seat within a sensor-equipped aluminium frame, incorporating two force sensors on the frame and two integrated into ropes for assessing propulsion. Trunk control is evaluated using an electrically driven sledge capable of inducing unpredictable balance perturbations. The conducted tests, including simulated bench press, simulated pulling, and unpredictable balance perturbations, revealed increased trunk Range of Motion (ROM) and angular velocity with perturbation stimuli acceleration.

Key Findings

- Increased trunk Range of Motion (ROM) and angular velocity with perturbation stimuli acceleration.
- Balance control test results proved no significant differences between anterior and posterior directions and could serve as an index of the seated athlete's trunk control.
- The ratio of anterior forces in simulated bench presses can objectively compare core muscle strength among athletes with varying impairment levels.

3. Role of Machine Learning in Gait Analysis

3.1 Synthesis of Paper 6: Review of ML Techniques for Gait Analysis and Rehabilitation

This study aims to conduct a comprehensive review of the implementation of machine learning (ML) techniques in gait analysis and rehabilitation. The methodology involved an extensive literature survey covering research articles from 1980 to 2019, resulting in the inclusion of 43 studies for in-depth analysis. Key findings indicate that supervised ML techniques achieved accuracies exceeding 90% in gait analysis.

Key Findings

- Supervised ML techniques achieved accuracies exceeding 90% in gait analysis.
- SVM was identified as the most effective classifier with a mean score of 0.87 ± 0.07.
- Reinforcement learning and (deep) neural networks are beneficial for control strategies in gait rehabilitation.

3.2 Synthesis of Paper 7: Computer Vision and ML-Based Gait Pattern Recognition for Fall Prediction

This study focuses on utilizing computer vision techniques to identify the most effective machine learning algorithm for classifying gait patterns, specifically in predicting falls on flat ground. The Kinect Motion system recorded spatiotemporal gait data from seven healthy participants in three walking trials. Four classification methods, including convolutional neural network (CNN), support vector machine (SVM), K-nearest neighbours (KNN), and long short-term memory (LSTM) neural networks, were employed to categorize different gait patterns. SVM and KNN exhibited superior accuracy compared to CNN and LSTM, with SVM achieving the highest accuracy at 94.9 ± 3.36%.

Key Findings

- SVM achieved the highest accuracy in gait pattern classification at 94.9 ± 3.36%.
- Proposed AI ML techniques show potential for designing gait biometric systems and machine vision for recognizing gait patterns.
- A promising application for remotely assessing elderly patients and aiding clinicians in decision-making.

4. Clinical Correlations of Gait Patterns in Neurological Disorders

4.1 Synthesis of Paper 8: Gait Analysis and Clinical Correlations in Early Parkinson’s Disease

This study aims to assess spatiotemporal and kinematic gait parameters in individuals with early-stage Parkinson’s disease (PD) using 3D gait analysis. The methodology involved comparing 44 early PD patients with a control group in a laboratory setting, utilizing a dynamometric platform with piezoelectric sensors for three-dimensional data capture. Temporal parameters such as cadence, stride duration, and stance duration, along with spatial parameters like step length, limb and swing velocities, and average velocity, were analysed.

Key Findings

- Distinctions in cadence and stride duration between PD patients and healthy subjects.
- Significant differences in swing phase, swing duration, and spatial parameters.
- Statistically distinct velocities in PD patients compared to healthy subjects.

4.2 Synthesis of Paper 9: Early Signs of Gait Deviation in Duchenne Muscular Dystrophy

This study focuses on identifying early changes in gait analysis features in Duchenne muscular dystrophy (DMD) patients and conducting a quantitative assessment of gait abnormalities. Motion analysis in the Gait Analysis Laboratory utilized a six-camera motion capture system, and participants walked barefoot along a 10-meter walkway with a force platform measuring foot-ground reaction forces. Retroreflective markers and force signals were used to derive joint moments and joint powers, with anthropometric parameters measured for estimating inertial characteristics.

Key Findings

- No reduction in range of motion or walking velocity in DMD patients.
- Significant differences in pelvis orientation and range of pelvis tilt.
- Various significant differences in joint motion at the hip, knee, and ankle joints.

5. Advancements in Gait Analysis Using Wearable Sensors in Real-World Outdoor Environments.

5.1 Synthesis of Paper 10: Analyzing Gait in the Real World Using Wearable Movement Sensors

This study aims to bridge the gap between controlled laboratory studies and the natural behaviour observed in field-based studies by developing a methodology using traditional wearables in outdoor environments. The researchers utilize a foot-mounted inertial sensor, a GPS receiver, and a barometric altitude sensor to track subjects' paths and detailed foot movements both indoors and outdoors. Through strap-down navigation and sensor fusion algorithms, data is collected over days, and movement paths are clustered based on location.

Key Findings

- Identification of four frequently repeated walking paths with significant differences in foot clearance, stride length, and stride width.
- Methodology enables detailed comparisons in semi-controlled data sets.
- Potential applications in evaluating interventions for gait-related conditions.

5.2 Synthesis of Paper 11: Gait Phase Estimation of Unsupervised Outdoors Walking Using IMUs and a Linear Regression Model

This study introduces an experimental protocol to estimate gait phases in unsupervised outdoor environments using body-worn inertial measurement units (IMUs). The methodology involves establishing gait patterns through the integration of a force plate and a motion capture system. After defining gait patterns, human subjects undergo outdoor walking sessions to train and test a PCA-based linear regression model.

Key Findings

- Minimum normalized gait phase estimation error of 1.81%, maximum of 2.48%, and average of 2.21 ± 0.258%.
- Potential for precise control of human-assistive devices, rehabilitation devices, and clinical gait analysis.
- Elimination of the need for fixed thresholds and sensor-embedded insoles in outdoor gait analysis.

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