QUIRANTE, BLIX, L. (LP CAMPUS) NOVEMBER 9, 2023
CSPE102 BSCS - III MR. CASAS

MIDTERMS SYSTEM ANALYSIS AND DESIGN MAJOR EXAM

Key Point Extraction and Feature Engineering in Human Pose Analysis (single person)

Objective:

The objective of this activity is to understand the process of key point extraction from single-person images or videos and to perform feature engineering by calculating distances between key points using the distance formula and angles at key points using sine law and/or cosine law.

1. Introduction

- Key points in human pose analysis are the representation via line points of the orientation of the various body landmarks of a person. This is a field in computer vision where these key points track a human person's stature or pose, via detecting a set of key point coordinates of a human body's joint like forearms, shoulders, and lower body.
- Discuss the importance of key point extraction in various applications like:
    - **Gesture recognition**
        - For recognizing, interpreting gestures made by humans. Tracking the positions of those key body joints, specifically the arm, hand and finger placement which the system tries to identify the specific gesture.
        - Can be a great example for sign language recognition, these gestures from key points generated can be understood to convey word/phrases to be able to communicate among persons with hearing disability.

- **Human-computer interaction**
  - The trained computer tracks and understands an individual's body movement, allowing for more natural interaction between the human and the computer.
  - One instance is where the human navigates through a user interface, or plays video games that utilize body movements (Virtual Reality) without the requirement of computer peripheral devices such as the keyboard and mouse.
- Affective computing
  - The key points extracted from an individual's face, such as the position of the eyebrows, mouth, and eyes can be recognized and interpreted through various facial expressions including happiness and sadness.

2. Key Point Extraction

- Explain the concept of key point detection algorithms like:
  - **MediaPipe** is an open-source network developed by Google that provides pre-trained models for key point extraction. Models can be used for landmark detection, body post estimation, facial recognition, etc.
  - **OpenPose** is also a popular real-time 2D person pose estimation, based on deep learning where it can identify the positions of the human body's joints such as shoulder, elbow, wrists, knee, hip and ankles. via in a provided media types such as imagery, and videos. Often used in action recognition, and also in sports analysis.
  - **Posterior Network (PoseNet)** is a deep learning Tensorflow model developed by google, where trained as single human, or multi-human pose detection to estimate human poses. Can be used in Augmented Reality tech, and fitness apps, face "filters" that generate effects to a face subject.

- **You Only Look Once (YOLO)** is an object detection algorithm developed in 2015, known for speed and accuracy in real-time object detection tasks. YOLO is wide-ranged beyond key point extraction, including vehicles, surveillance and real-time image/video analysis.

- Using a pre-built key point detection algorithm, extract key points from single-person images or video frames. Discuss challenges and solutions encountered during the extraction process.
  - **Variability in Poses** - various human poses tested have an effect on the used pre-trained model where in situations that cannot distinguish such poses.
  - **Multiple People** - With multiple subjects, the model having a confusion on which of the human subjects to focus into, causing the key point markers to be in unusual places like shoulder of the first, to shoulder of the second person
  - **Lighting** - Having weak light illumination makes the camera unable to properly detect the body, causing the key point to not appear in the subject's body.
  - **Background** - Things in the background such as frames or displays that often the model confuses to that can interfere with the detection.
  - **Real-time Processing** - Trading accuracy of the key point estimation, versus the process speed that computes the best key point position. One solution is to opt for real-time processing algorithms specialized for it, and also with hardware processes like stronger computation power from better CPUs or GPUs
  - **Model drift** - Exhibits positional shift dues to sudden camera or the subject's movement, limiting the consistency of the estimation of key points.

3. Feature Engineering: Distance Calculation

- The **Euclidean distance** formula is a fundamental mathematical concept that plays a role in feature engineering and various data analysis processes. Serves the purpose of calculating the direct, straight-line distance between two points in a multi-dimensional space.
- Euclidean Distance, also referred to as "d," is a mathematical measure used to determine the straight-line distance between two points, denoted as A and B, in an n-dimensional Euclidean space. This distance is calculated by taking the square root of the sum of the squared differences in each dimension. Mathematically, it can be expressed as:
    - $d(A, B) = sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + ... + (z_1 - z_2)^2}$
    - Here, $(x_1, y_1, ..., z_1)$ and $(x_2, y_2, ..., z_2)$ represent the coordinates of points A and B in this n-dimensional space.
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- **Distances between specific key points**
    - **Shoulder-to-Elbow Distance**
        - This distance aids in evaluating arm angle and alignment, with abnormal angles potentially indicating incorrect posture or issues with shoulder or elbow joints.
        - In contexts like physical therapy or fitness training, monitoring SED can facilitate the correction of arm alignment during exercises.
    - **Knee-to-Ankle Distance**
        - Measuring the distance between knee and ankle key points helps track the length of the lower leg segment. Deviations from the normal measurement can suggest leg length discrepancies or improper weight distribution during activities like walking, running, or standing.
        - This measurement is valuable for gait analysis and orthopedic assessments.

- **Hip-to-Knee Distance**
  - This distance aids in evaluating the alignment of the hip and knee joints. Irregularities in this measurement can indicate conditions like knock knees (genu valgum) or bow legs (genu varum).
  - Detecting such issues early is crucial for orthopedic assessments and interventions.
- **Distance Between Feet**
  - Monitoring the distance between the feet offers insights into a person's stance width, which is vital for balance, stability, and performance in sports.
  - Deviations from the norm can impact an athlete's performance, especially in sports like basketball or gymnastics.
- **Hand-to-Foot Distance**
  - Measuring the distance between a hand and a foot is relevant for assessing flexibility and reach. This is particularly useful in physical therapy and fitness training to track improvements in flexibility and reach.
  - For example, in practices like yoga or rehabilitation, changes in this distance can indicate progress.
- **Head-to-Hip Distance**
  - This distance assists in evaluating posture and alignment of the upper body in relation to the lower body.
  - Proper alignment is essential for ergonomic workspace design and preventing musculoskeletal problems in desk jobs.

- **Arm Span**
  - Measuring the distance between extended arms provides an estimate of a person's wingspan.
  - In sports like basketball or swimming, arm span is crucial for assessing reach and determining suitable sports or positions within sports.

4. Feature Engineering: Angle Calculation

- Trigonometric concepts like **the sine and cosine laws** are useful in feature engineering because they can be used to compute angles between important locations like the wrist, elbow, and shoulder, which can provide information about a person's movement patterns and posture.
    - Triangle side lengths and angle sines are related by the sine law, often known as the law of sines. The lengths of two sides and the opposite angle are required in order to use the sine law to obtain an angle.
        - ~~The equation is: **(A - B) - (B - c) = (C - c)**~~
    - The law known as the cosine law, or law of cosines, joins a triangle's angles and sides. An angle can be calculated after the lengths of all three sides are known.
        - ~~The equation is: **$c^2 = 2ab * cos(C) + a^2 + b^2$**~~
- **Discuss how these angles can provide insights into body posture and movement patterns.**
    - Angles calculated using trigonometric principles in feature engineering provide insights into body posture and movement patterns.
    - These angles help assess:
        - **Posture**
        - **Analyze movement**
        - **Monitor health**
        - **Improve ergonomics in various fields, such as sports, therapy, and workspace design.**

5. Group Discussion and Analysis

- **Discuss the variations observed in distances and angles among different poses.**
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- **Analyze how these variations can be used for applications like fitness tracking, sports training, and healthcare.**
  - **Fitness Tracking**: Valuable for monitoring body form and progress in workouts.
  - **Sports Training**: Essential for optimizing technique and enhancing performance.
  - **Healthcare**: Aids in rehabilitation.
  - **Biometrics**: Used for authentication and animation.

6. Conclusion and Future Applications

- **Summarize the key learnings from the activity, emphasizing the importance of key point extraction and feature engineering in human pose analysis.**
    - To sum up, key point extraction and feature engineering are essential for human posture analysis, with applications ranging from affective computing to gesture recognition and human-computer interaction. Main conclusions:
        - Natural human-computer interaction and gesture recognition are made possible by key point extraction.
        - Feature engineering helps with sports, rehabilitation, and healthcare by offering insights into movement patterns and body posture.
- **Discuss potential future applications and advancements in the field of Affective computing.**
    - Future uses for emotional computing encompass:
    - improvements in the recognition of a larger spectrum of moods and emotions.
    - improved interactions between humans and machines, supporting customer service and education.
    - uses in healthcare, ranging from AI-powered therapy to emotional well-being monitoring.
    - As technology advances, there is an increasing focus on data privacy and ethical implications.

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