Project Proposal – Intelligent System for Exercise Classification and Evaluation

Project Repository:
https://github.com/Nicolas-CM/PoseTrack_AI_ADN.git

MMFit Dataset – Official Website and Repository:
https://mmfit.github.io
https://github.com/KDMStromback/mm-fit

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1. Introduction and General Objective

This project aims to develop an intelligent system capable of classifying physical exercises and evaluating whether they are being performed correctly, using real-time pose analysis.

The system will be developed **iteratively**, with continuous adjustments based on data understanding, model performance, and feasibility. Eventually, the system will focus on **three selected exercises**, chosen according to performance, clarity of metrics, and relevance in physiotherapy and fitness contexts.

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2. Main Research Question

How can we develop an intelligent system that accurately classifies physical exercises and determines whether they are being performed correctly, using real-time pose estimation?

Subquestions:

- What joint-based metrics (e.g., angles of knees, hips, wrists) are most relevant for evaluating exercise correctness?
- How can the system provide real-time feedback on posture during exercises?
- How can this system be applied in physiotherapy and fitness to monitor users' progress?

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3. Problem Type

This is a **supervised classification problem** within the domain of artificial intelligence applied to computer vision, focusing on:

- **Human activity recognition** (HAR) from video and sensor data.
- **Pose-based movement analysis** for form evaluation.
- **Multi-modal signal processing** (video + wearable sensors).

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4. Methodology (CRISP-DM Framework)

We follow the CRISP-DM (Cross-Industry Standard Process for Data Mining) methodology, adapted to an experimental and evolving project scope:

1. Business Understanding

- Purpose: Analyze and assess exercise performance in real time to provide corrective feedback.
- Potential applications: personalized training, rehabilitation, home physiotherapy.

2. Data Understanding

- **MMFit Dataset** (GitHub, Web)
  Includes labeled videos and synchronized sensor data for 10 physical exercises.

3. Data Preparation

- Pose extraction using MediaPipe (2D) and MMFit-provided data (3D).
- Feature engineering: joint angles, trunk inclination, joint velocity.
- Data normalization, segmentation, and augmentation if needed.

4. Modeling

- Initial classifiers: SVM, Random Forest, XGBoost.
- Hyperparameter tuning and cross-validation to improve generalization.

5. Evaluation

- Standard metrics: Accuracy, Recall, F1-Score.
- Pose-specific metrics: joint angle error, trunk alignment deviation.

6. Deployment

- Development of a real-time interface with pose visualization and corrective feedback.

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5. Dataset: MMFit

Exercise Types (only 3 will be selected for final system):

- Squats, Lunges, Bicep Curls, Sit-ups, Push-ups, Tricep Extensions, Dumbbell Rows, Jumping Jacks, Dumbbell Shoulder Press, Lateral Shoulder Raises.

Modalities and Sensors:

- **Pose Data**:
    - 2D: 18 keypoints (COCO format)
    - 3D: 17 keypoints (Human3.6M format)
- **Sensors**:
    - Accelerometers, gyroscopes, magnetometers, heart rate monitors
    - RGB and Depth Cameras

Labels:

- Activity class
- Repetition count
- Execution quality (correct/incorrect)

- Start/end of each set

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6. Evaluation Metrics

- **Accuracy**: Correctly classified exercise instances over total.
- **Recall**: Model's ability to detect correct execution.
- **F1-Score**: Balance between precision and recall.
- **Inference time**: Speed of real-time classification.

Pose-specific metrics:

- Joint angle error: Difference between measured vs ideal angles (e.g., 90° in a squat).
- Trunk inclination: Based on the relative position of head, shoulders, and hips.
- Symmetry metrics: Comparison between left and right limbs.

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7. Data Expansion Strategies

If more data is needed to improve performance or generalization, we may:

- **Capture additional videos** from volunteers performing exercises at different speeds and viewpoints.
- **Generate synthetic movements** using simulation tools or pose generators.
- **Use annotation tools** such as LabelStudio or CVAT to label new data.
- **Collaborate with fitness professionals or physiotherapists** to gather real-world data.

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8. Ethical Considerations

- **Informed consent**: Required for all participants whose movements are recorded.
- **Privacy & data protection**: Videos and personal data will be anonymized and securely stored.
- **Inclusivity**: The system should avoid bias and be adaptable to users of different body types, ages, and abilities.

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9. Next Steps

- Complete exploratory data analysis.
- Train initial models and evaluate performance on a subset of exercises.
- Begin development of the real-time interface.
- Iterate on the system design based on feedback and results.
- Select 3 final exercises to focus on for deployment.
