MilliPose: Facilitating Full Body Silhouette Imaging from Millimeter-Wave Device

**Objective and Challenges**

**Objective**
- To facilitate **full human body silhouette imaging** and 3D pose estimation from 5G millimeter-wave (mmWave) devices.

**Motivation**
- How to enable through-occlusion imaging that is not privacy-invasive and can perform well under low visibility and the low light condition?

**Challenges**
- The **image resolution is extremely poor** due to the mmWave frequency and limited bandwidth.
- **Specular reflectivity** and nature of human body create an imperceptible output image.

**Bio-RNN for Silhouette Quality Improvement**

**Predicting pose by incorporating rules of human biomechanics**
- Bio-RNN predicts the **next pose** from the pose estimated by cGAN and skeleton joint estimator in the previous frame.
- Bio-RNN uses **Gated Recurrent Unit (GRU)** and **Structured Prediction Layer (SPL)** with custom loss function to train the network.
- Bio-RNN **feedbacks cGAN** to recover missing parts and high spatial frequency information and assists cGAN during the training process.

**cGAN for Silhouette Generation**

**Improving image resolution using cGAN**
- Conditional Generative Adversarial Network (cGAN) learns the association between 3D mmWave images to the 2D ground truth (Kinect Depth) images.
- cGAN trains **Generator** and **Discriminator** with custom loss function.

**Preliminary Results and Conclusion**

**Pose prediction**
- Bio-RNN predicts 3D joint location with a **median error of 2.1 cm** for diverse poses.

**Conclusion**
- **Millipose** combines machine-learning and knowledge about human bio-mechanics.
- Bio-RNN module in **Millipose** can predict joint location accurately.
- Post training, cGAN can take 3D mmWave images and generates 2D silhouette.

**Future works**
- Design and prototype cGAN network and jointly train it with Bio-RNN.
- Experiment with multiple volunteers in both home and office settings to evaluate **Millipose** end-to-end.