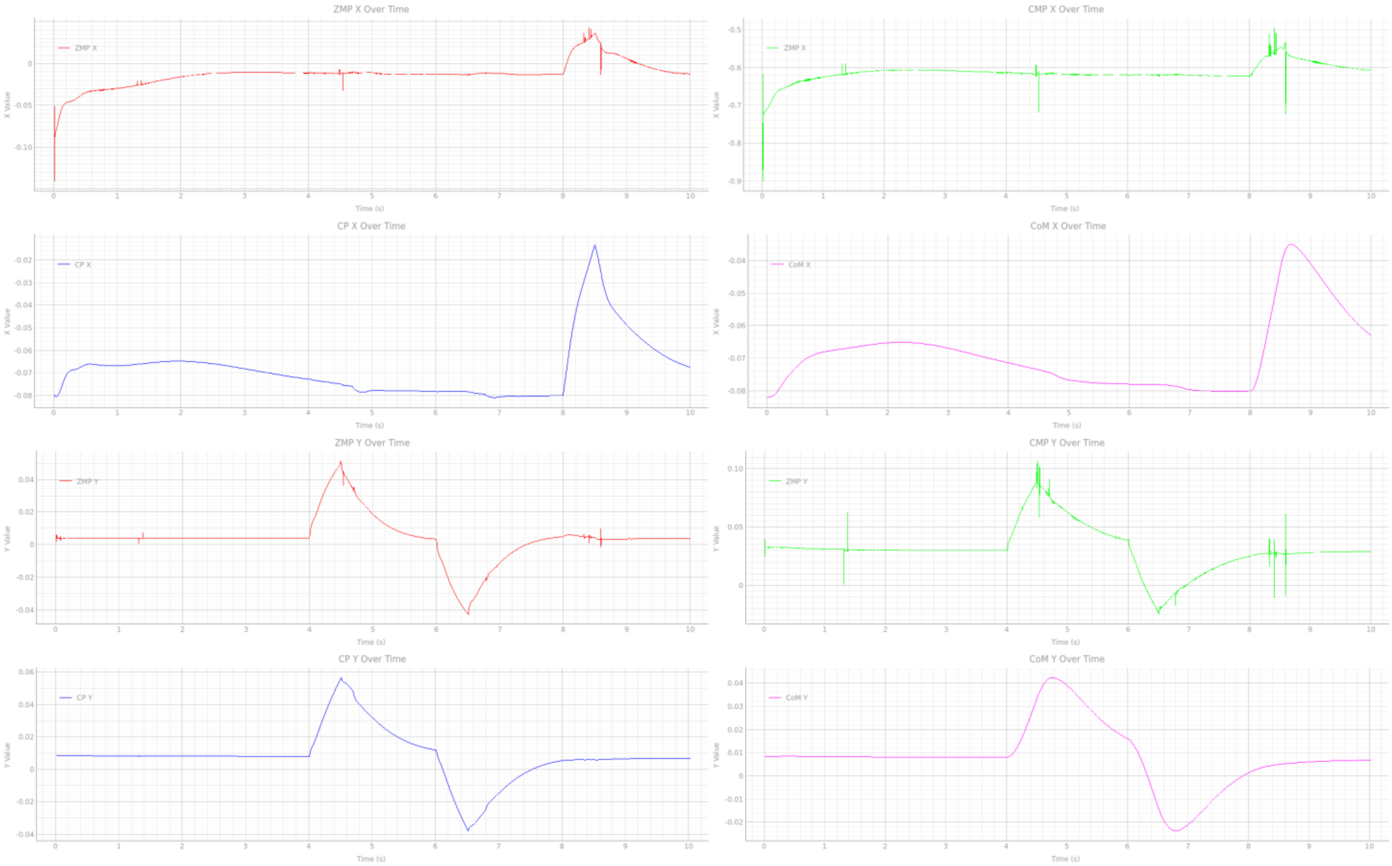
Timo Class, 26.06.2025

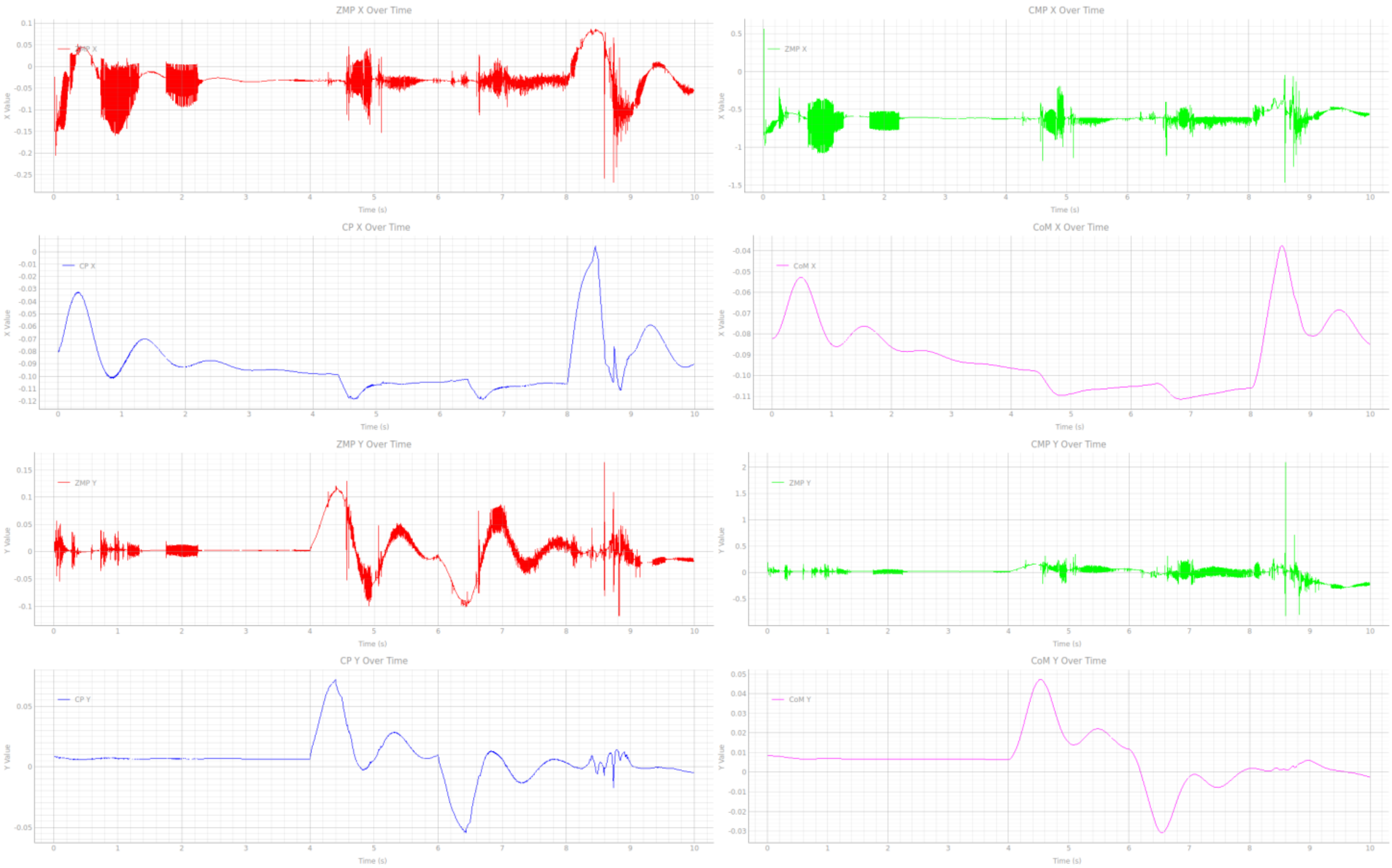
Report & Questions

Plots:

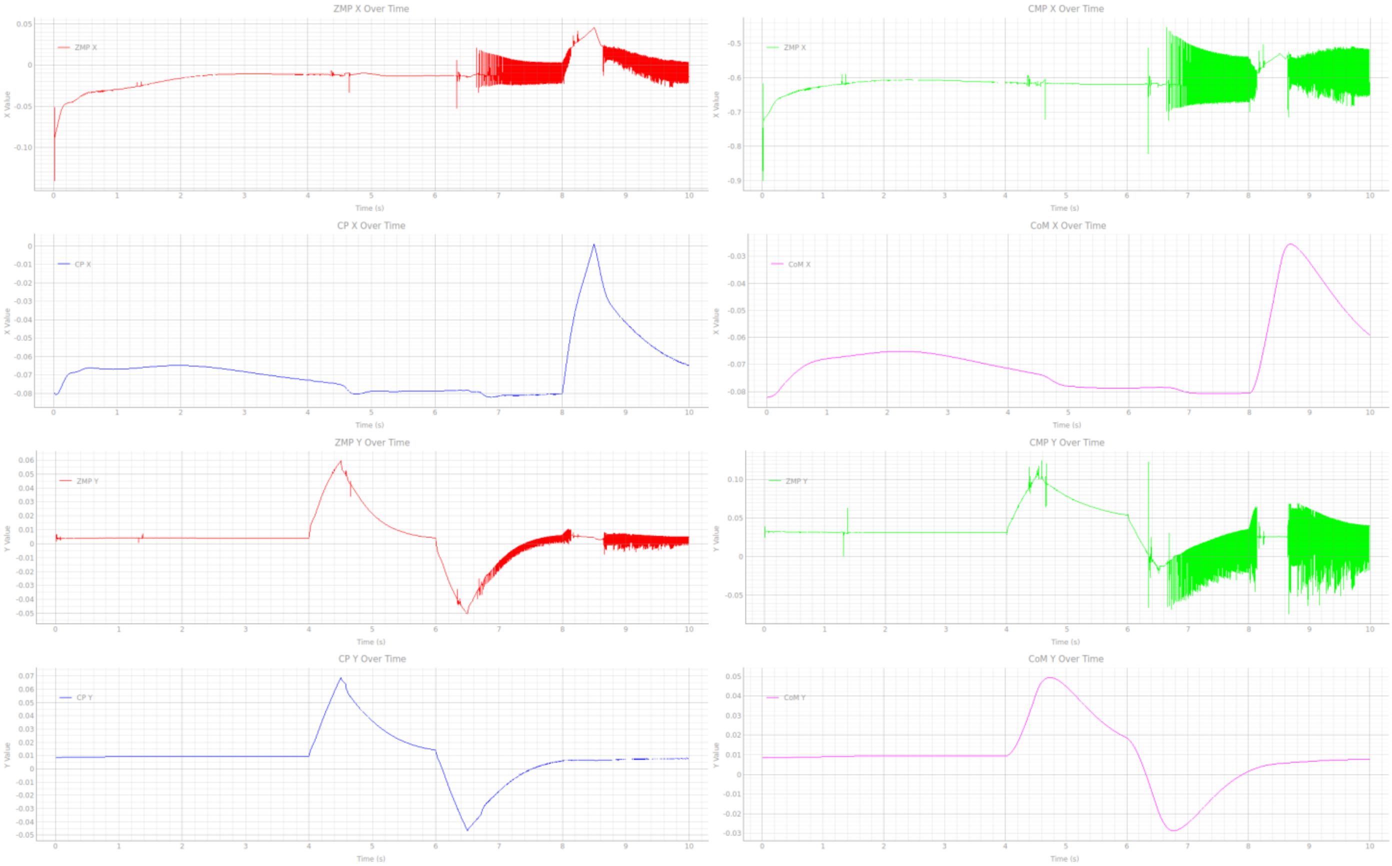
- **T51** - Torque Control: No controllers (external force: 25.0 N)



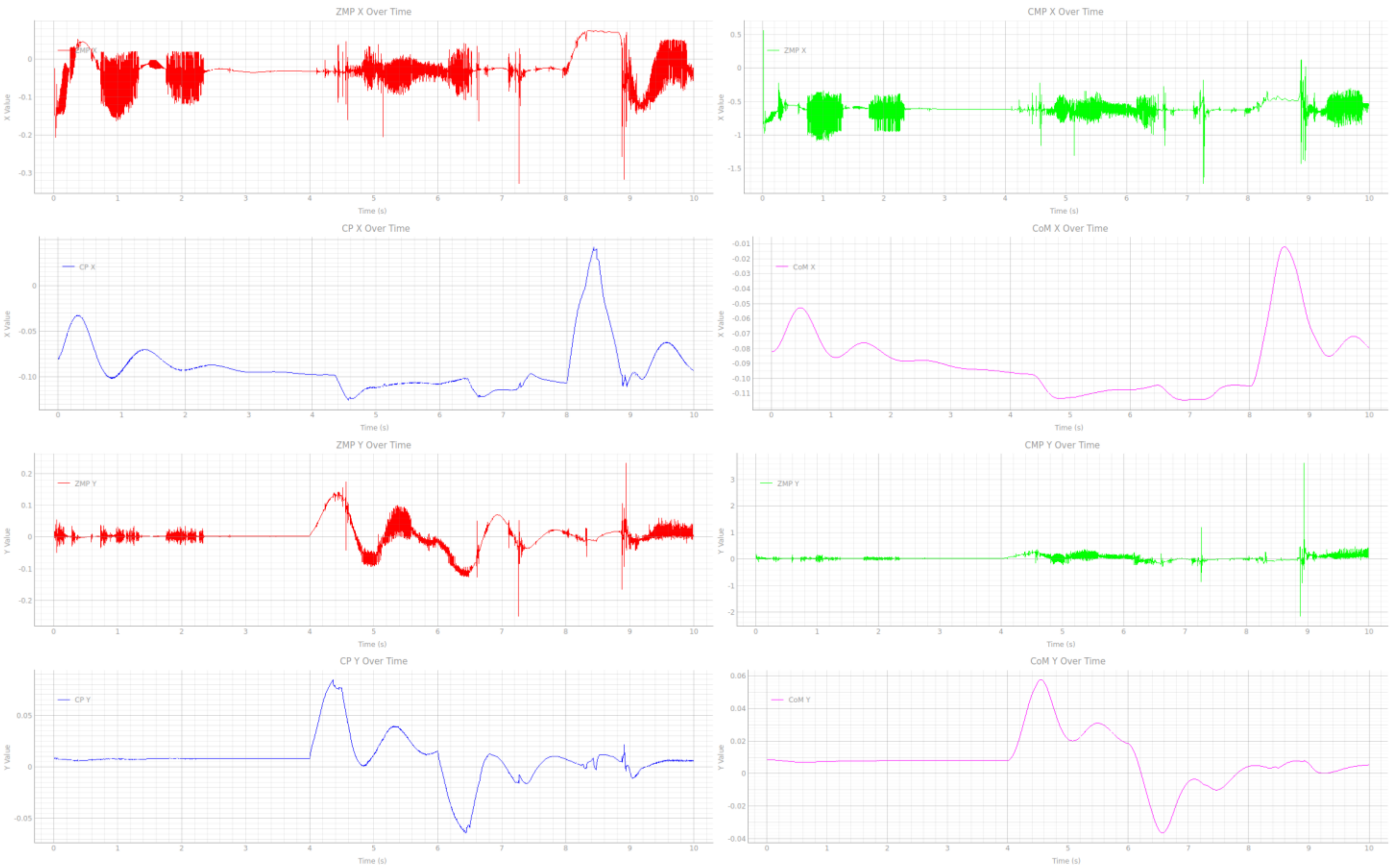
- **T51** - Torque Control: Ankle strategy (external force: 50.0N)



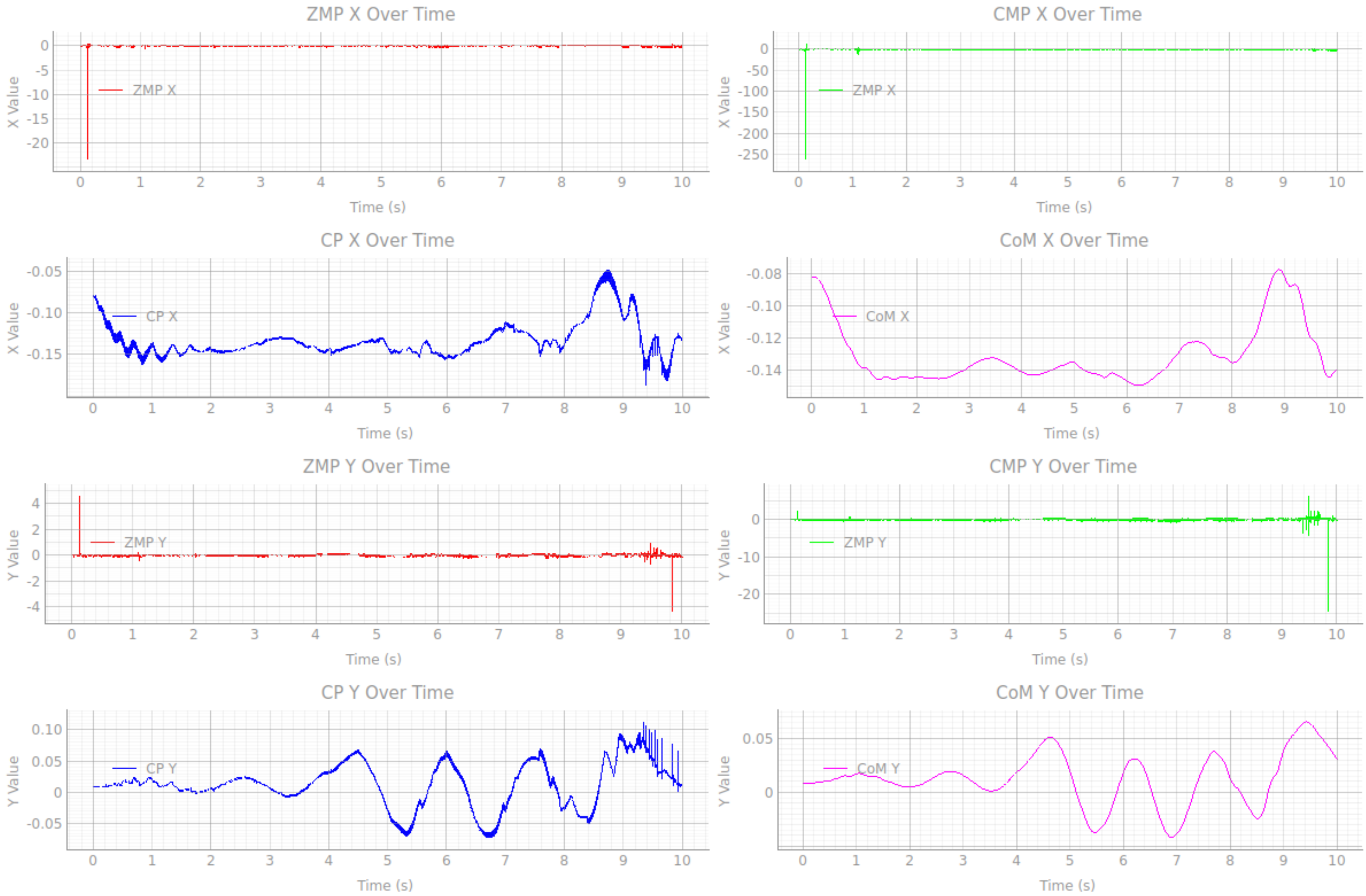
- **T51** - Torque Control: Hip strategy (external force: 30.0N)



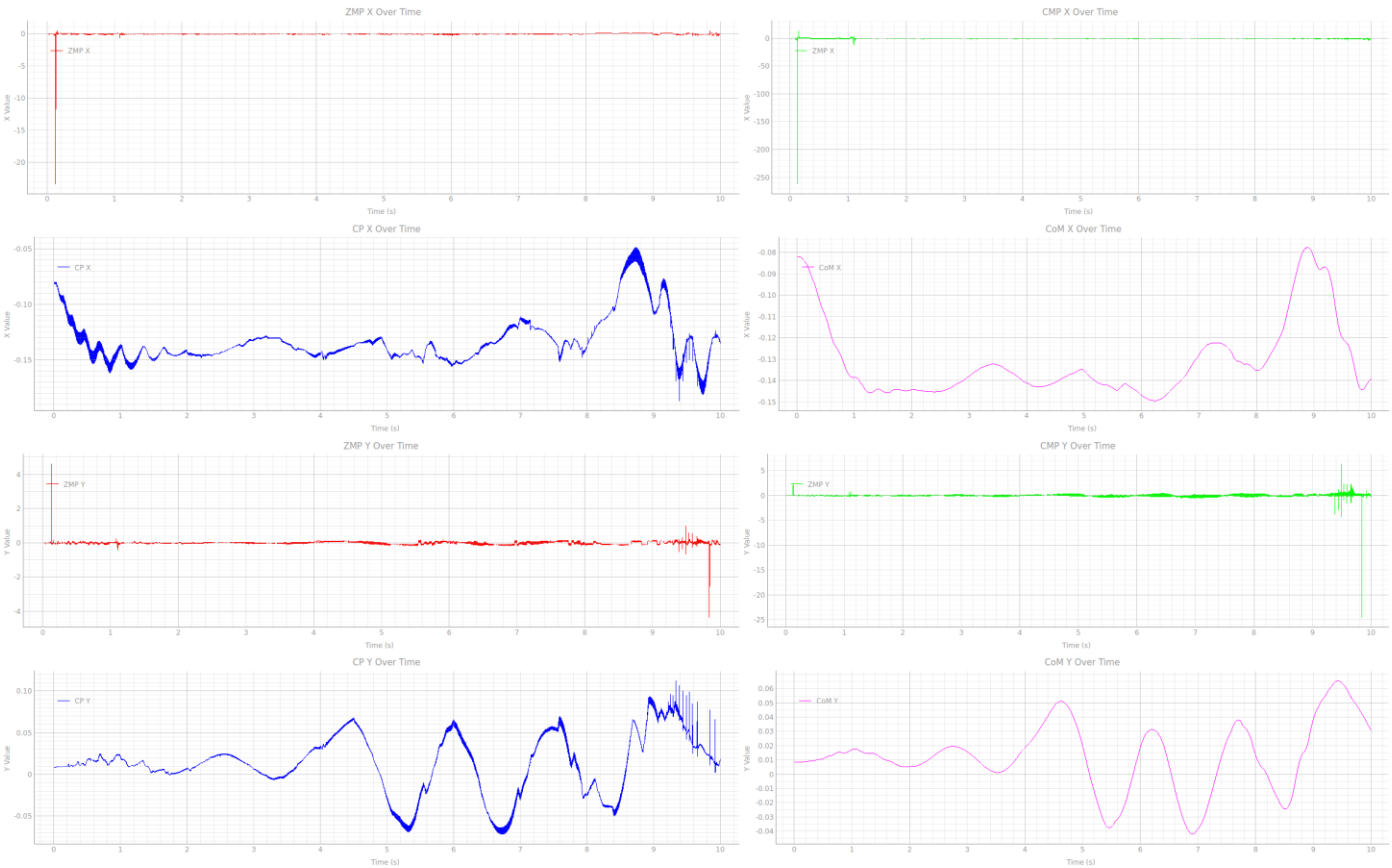
- **T51** - Torque Control: Ankle strategy & Hip strategy (external force: 60.0N)



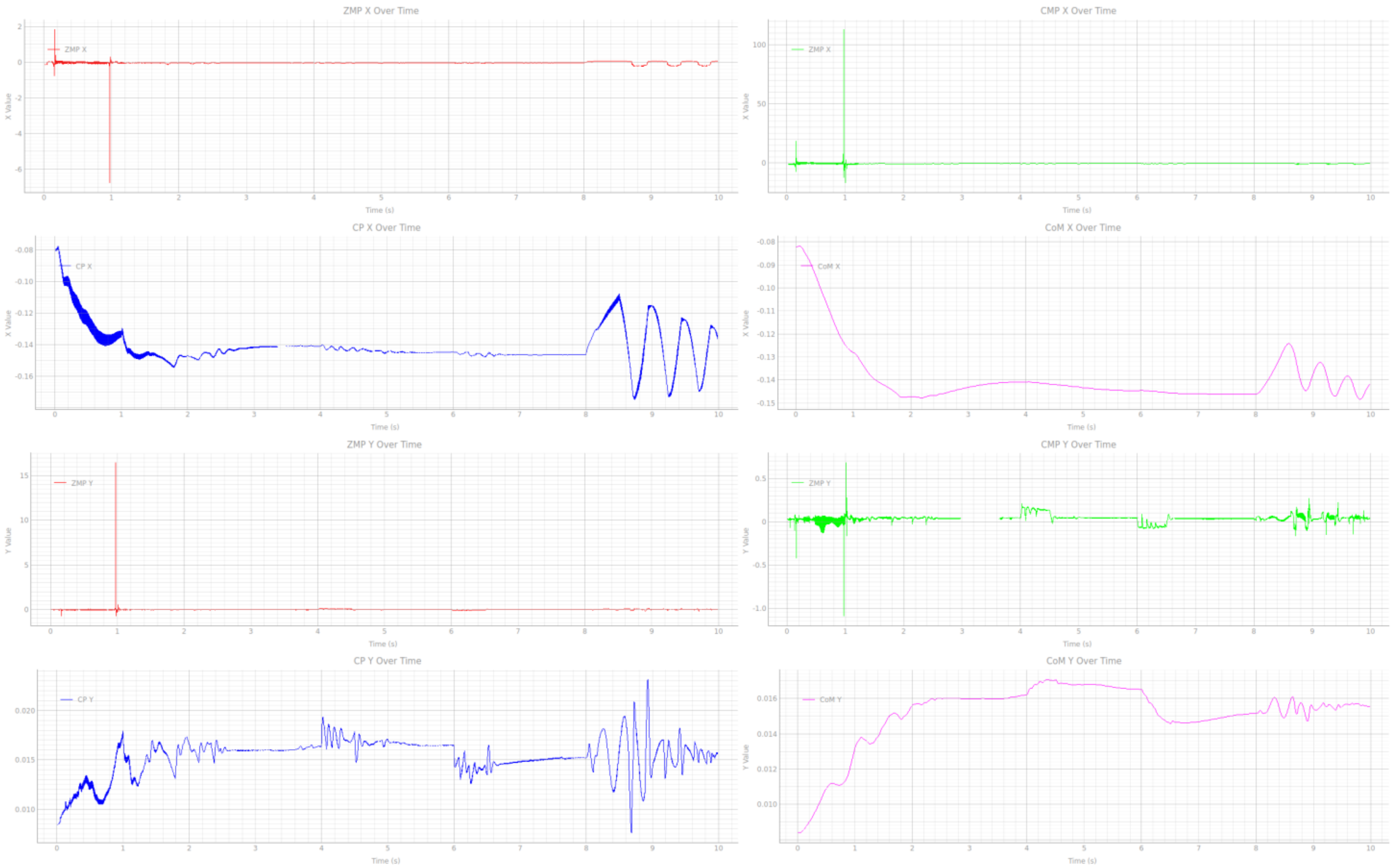
- **T52** - Position Control: No controllers (external force: 70.0 N)



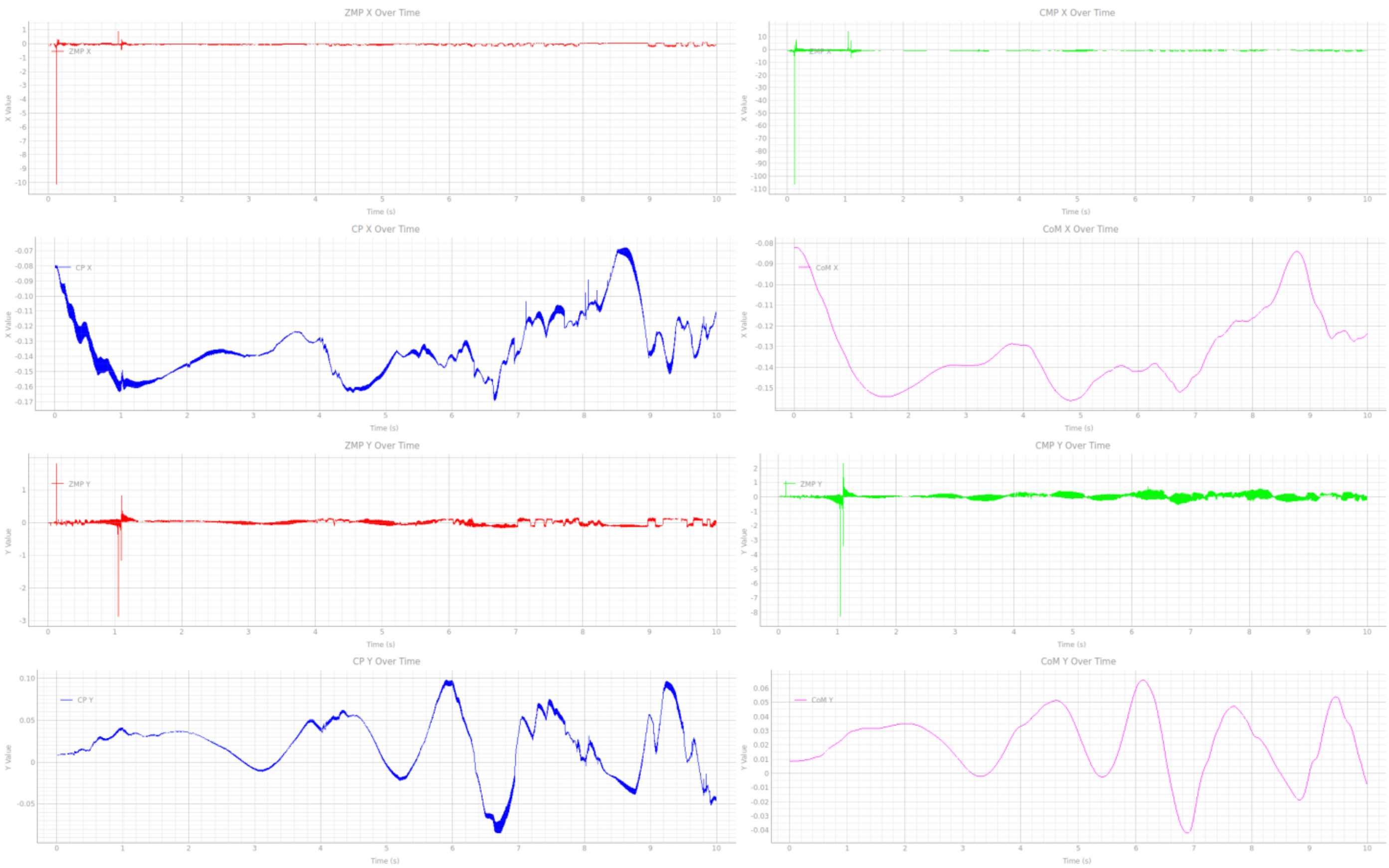
- **T52** - Position Control: Ankle strategy (external force: 70.0 N)



- **T52** - Position Control: Hip strategy (external force: 70.0 N)



- **T52** - Position Control: Ankle strategy & Hip strategy (external force: 70.0 N)



Questions:

- Which ones of the ground reference points can exist outside the supporting polygon?
  Answer:

  The Centroidal Moment Pivot (CMP) and Capture point (CP) can legitimately exist outside the supporting polygon.

  - CMP: The point where a line parallel to the ground reaction force, passing through the CoM, intersects with the external contact surface. I.e. the CMP can lie outside the supporting polygon.
  - CP: Point on the ground where the robot can step to in order to bring itself to a complete stop. I.e. the CP can lie outside the supporting polygon.

  The ZMP, however, is required to stay within the supporting polygon for the robot to remain statically stable. It can temporally move outside the supporting polygon — but this indicates that the system is no longer statically stable, and unless active control mechanisms (like stepping or using angular momentum) are applied, the robot will likely fall.
- Which modality holds higher pushing forces, torque or position hardware interface?
  Answer:

  In this case, position control performs better under high pushing forces because PyBullet adds internal damping and stiffness when using position commands (through implicit PD control), resulting in smoother and more “stable” behaviour via the virtual dynamics approach. In contrast, direct torque control disables these internal controllers, making it more sensitive to tuning the gains. Additionally, due to noisy measures of the forces, insufficient surface contact modeling and the stiffness of the position control, the robot’s feet are “dragged” across the surface — an effect unlikely to occur in real-world scenarios with proper friction and contact constraints.
  However, when the torque controller is properly tuned and the contact model is more realistic — either through an improved simulator or in real-world conditions — torque control can outperform position control in high disturbance scenarios. This is because it enables direct control of joint forces, offering faster and more precise reactions to large, external disturbances. Unlike position control, which only reacts indirectly through simulated motion integration.
- Are the torque and position control modalities equivalent with the proposed method? if not, why?
  Answer:

  No, they are not equivalent. The position-based method only approximates torque control through virtual dynamics and integration, and then relying on internal PD controllers to convert those positions back into motor torques. In contrast, torque control disables these gains/controllers and directly controls the torques.