Development of an Omnidirectional Walking Engine for Full-Sized Lightweight Humanoid Robots

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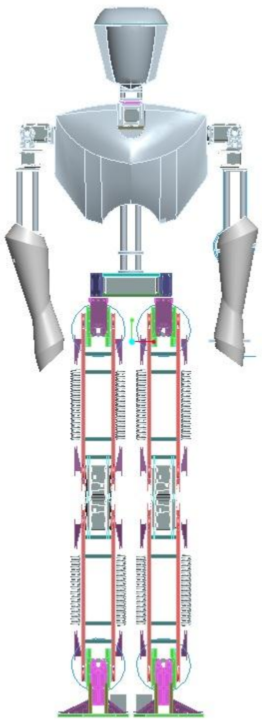
RoMeLa
Robotics & Mechanisms Laboratory

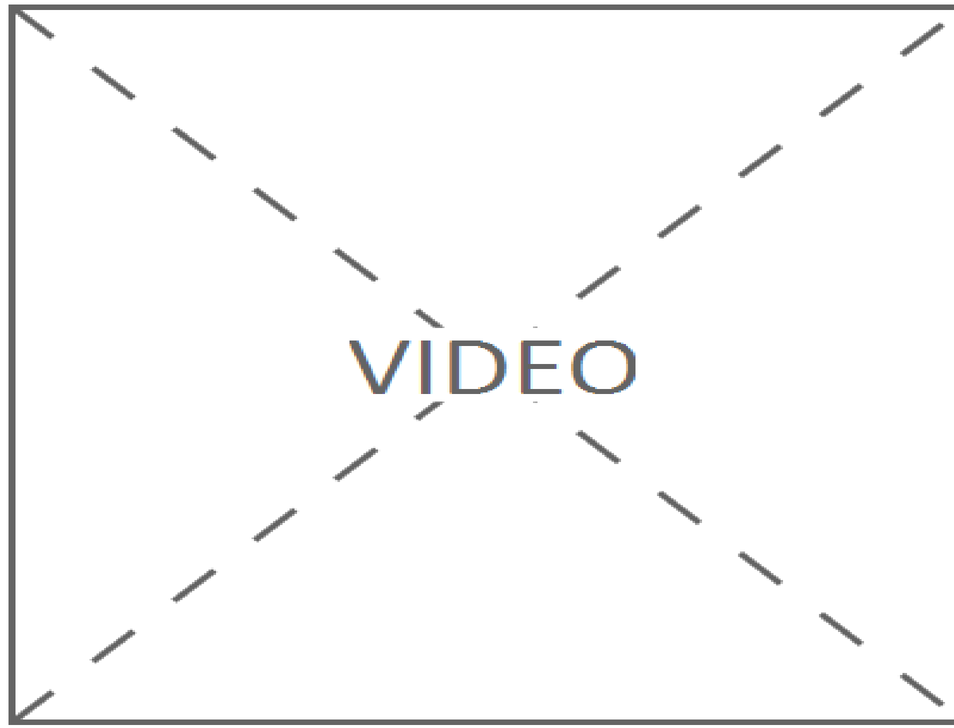
Outline

- CHARLI-L
- ZMP Based Walking
- Walking Engine
- Experimental Results



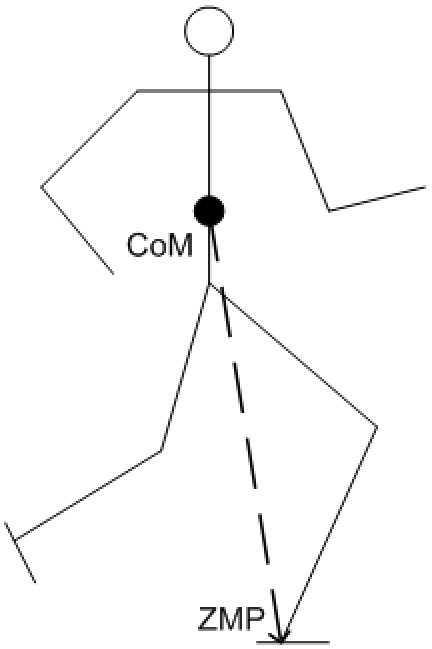
CHARLI-L

- Design concept
  - Stable walking
  - Light weight
  - Proper weight balance
  - Low cost
- Single-board Computer
  - Vision
  - Motion planning
  - Autonomous behaviors
  - Walking engine

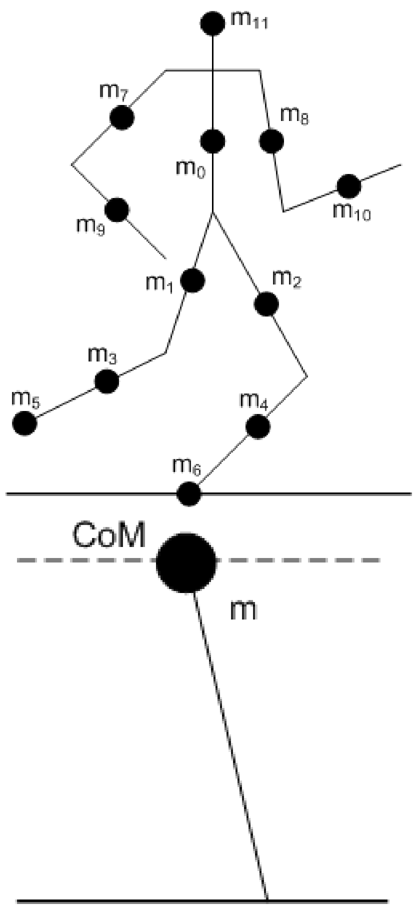


- **Walking engine with low computational load which requires less sensory data**

- CHARLI-L
- **ZMP Based Walking**
- Walking Engine
- Experimental Results



ZMP (Zero Moment Point)



$$p_x = \frac{\sum_i m_i(\ddot{z}_i + g)x_i - \sum_i m_i \ddot{x}_i z_i - \sum_i J_{Y_i} \cdot \ddot{\Omega}_{Y_i}}{\sum_i m_i(\ddot{z}_i + g)}$$

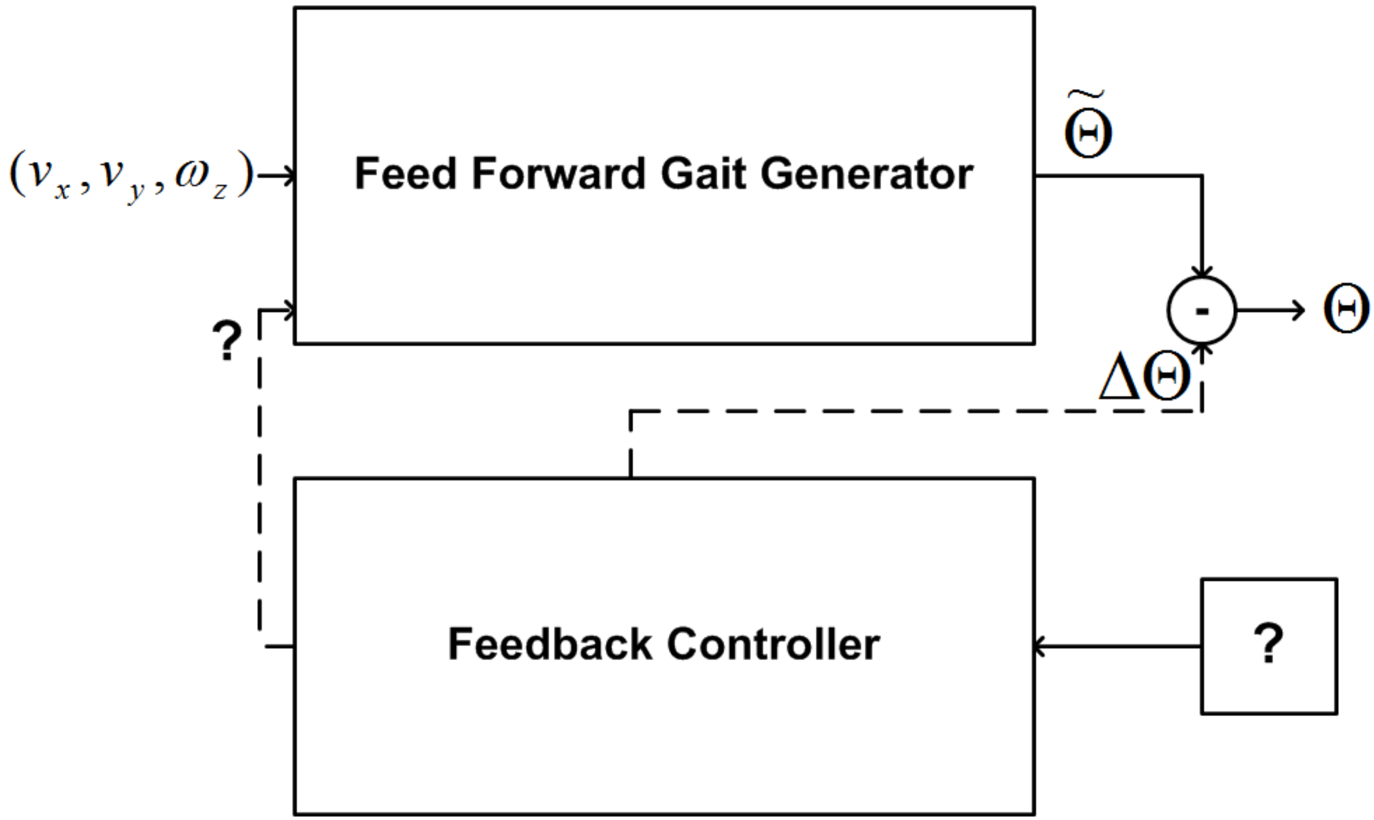
$$p_y = \frac{\sum_i m_i(\ddot{z}_i + g)y_i - \sum_i m_i \ddot{y}_i z_i - \sum_i J_{X_i} \cdot \ddot{\Omega}_{X_i}}{\sum_i m_i(\ddot{z}_i + g)}$$

$$p_x = x_{CoM} - \frac{z_{CoM}}{g}\ddot{x}_{CoM}$$

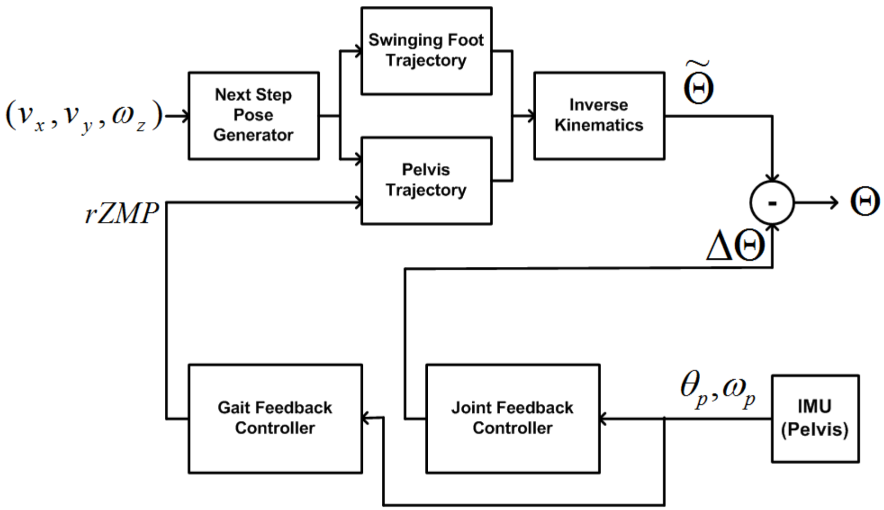
$$p_y = y_{CoM} - \frac{z_{CoM}}{g}\ddot{y}_{CoM}$$

ZMP Based Walking

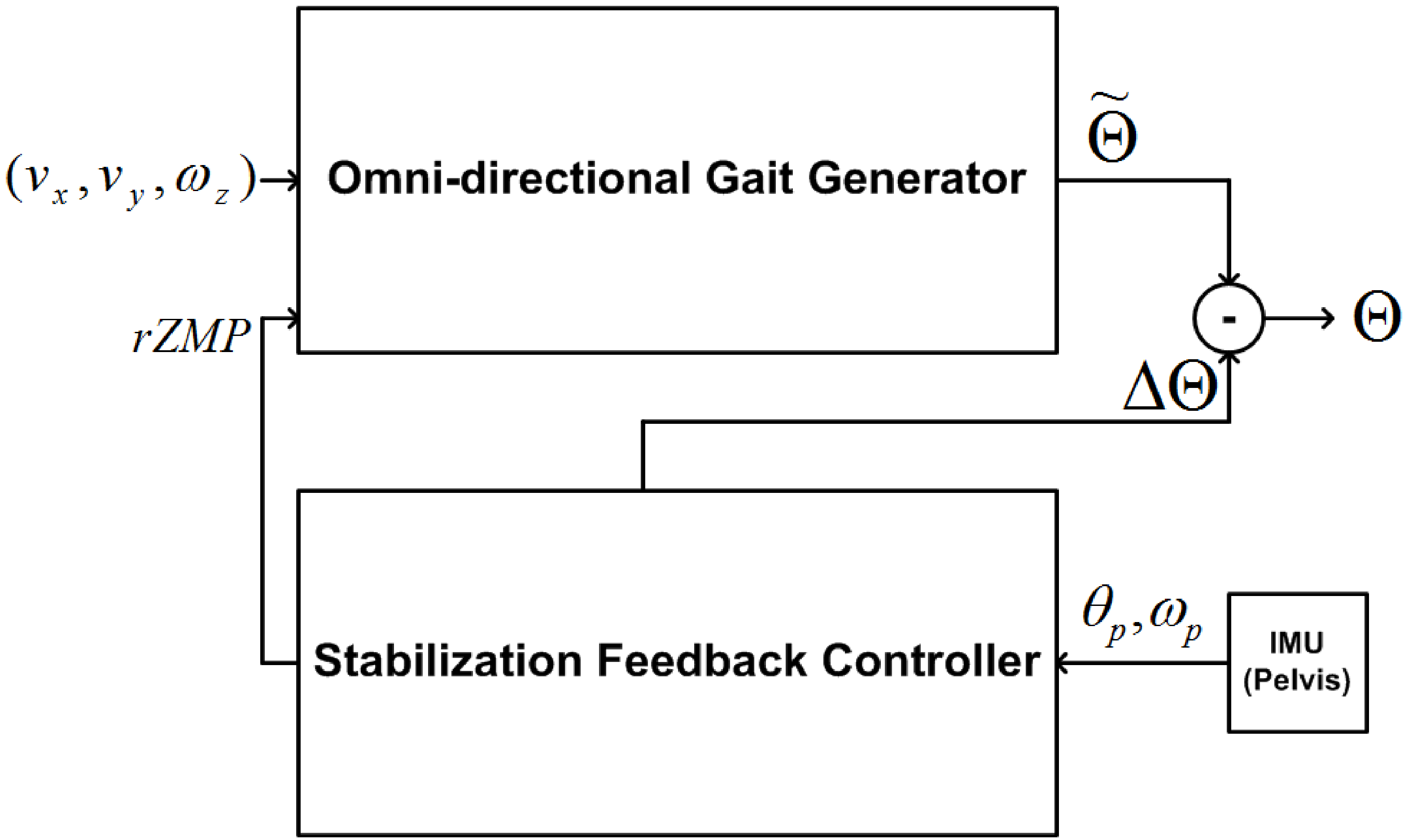
- Joint Position Control



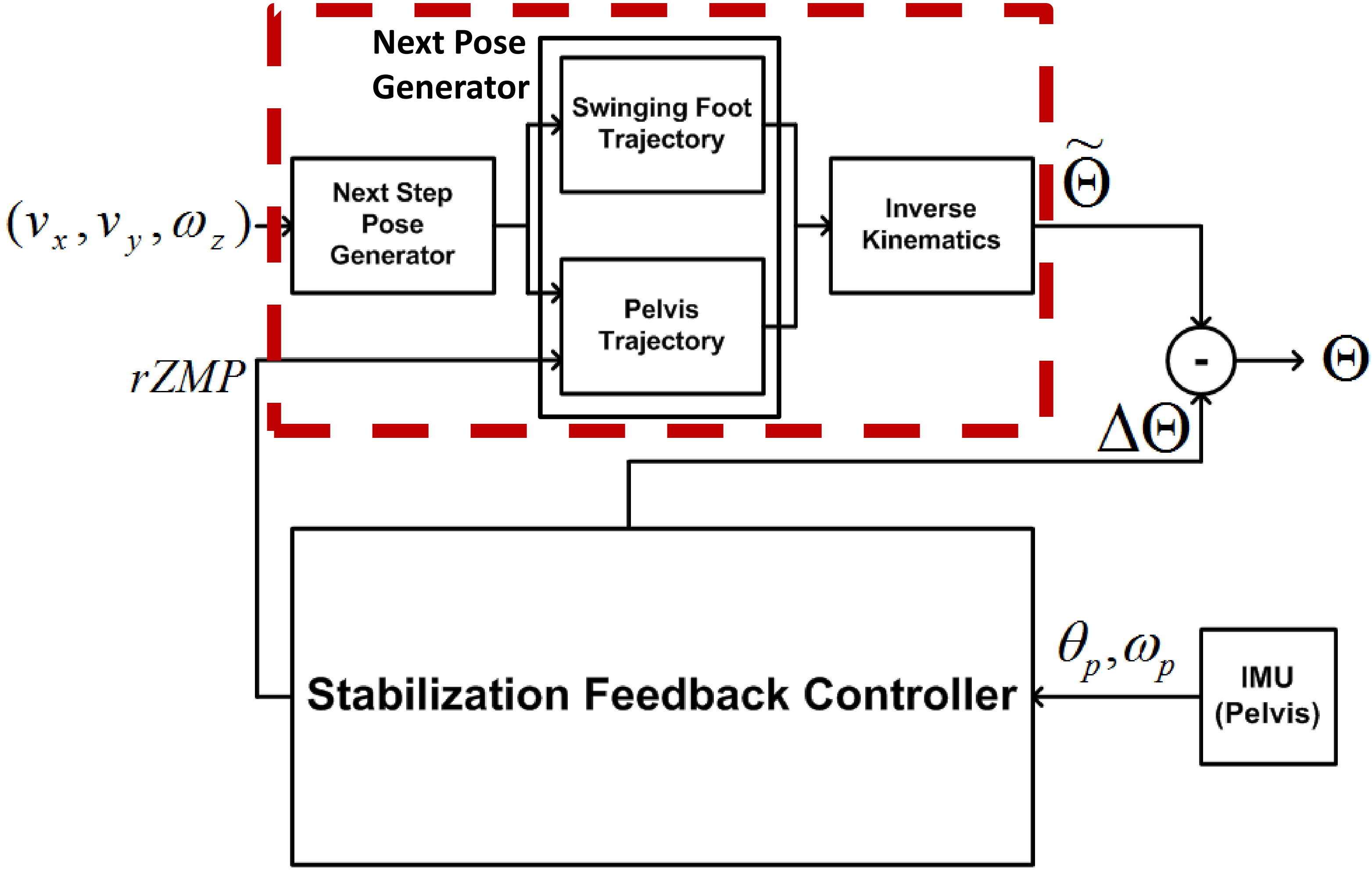
- CHARLI-L
- ZMP Based Walking
- **Walking Engine**
- Experimental Results



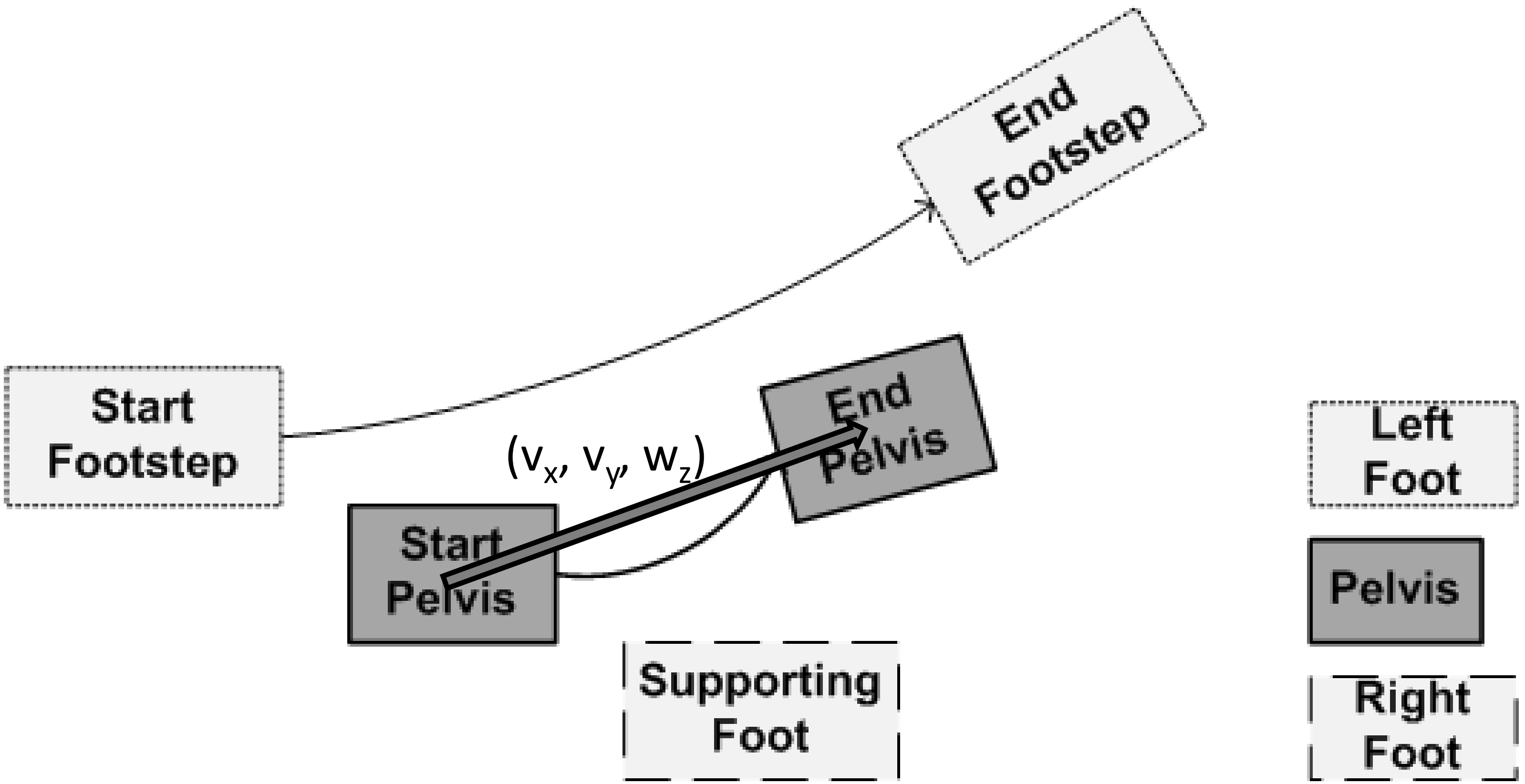
Walking Engine



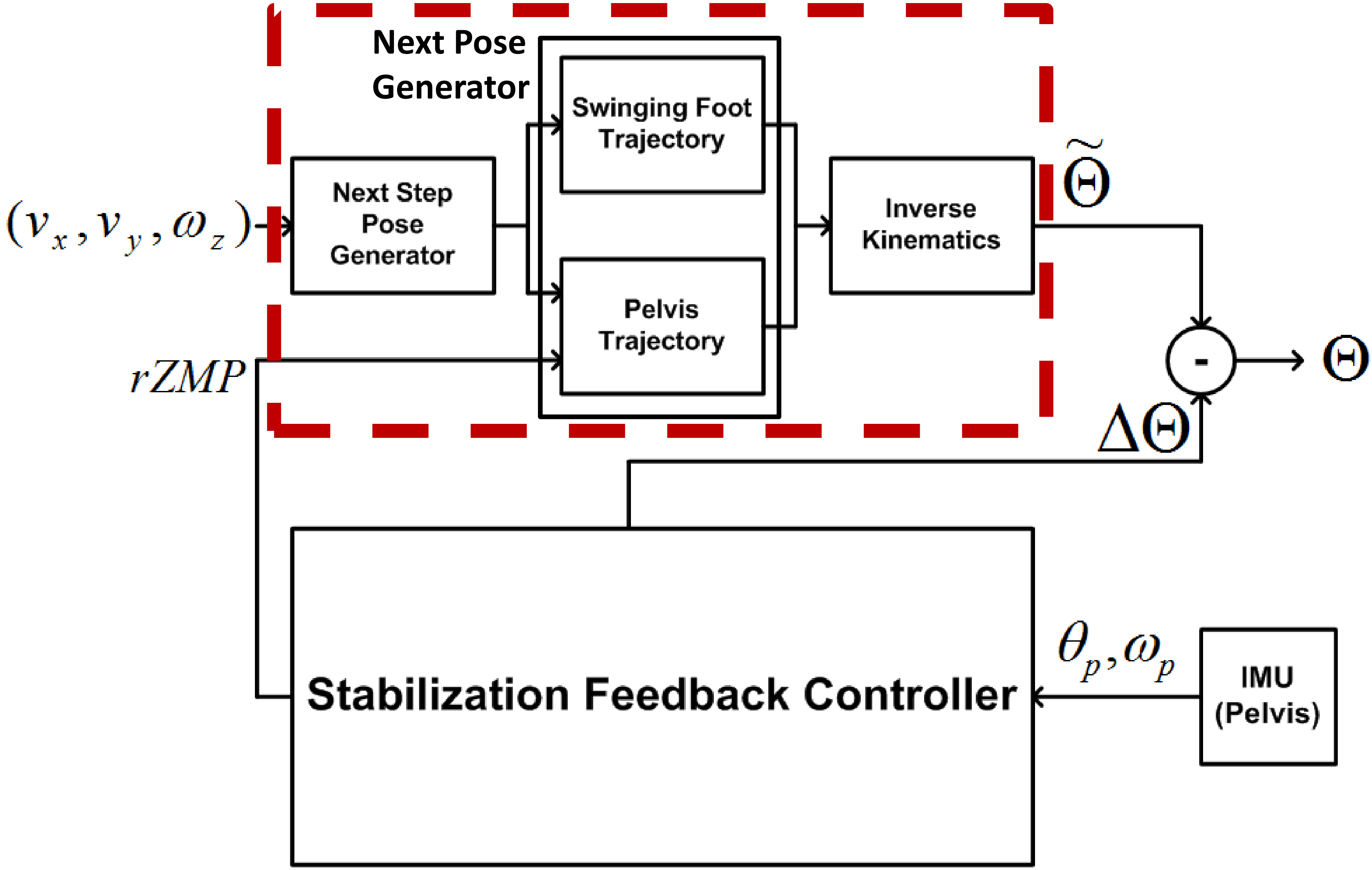
Omnidirectional Gait Generator



Omnidirectional Gait Generator : Next Step Pose



Omnidirectional Gait Generator

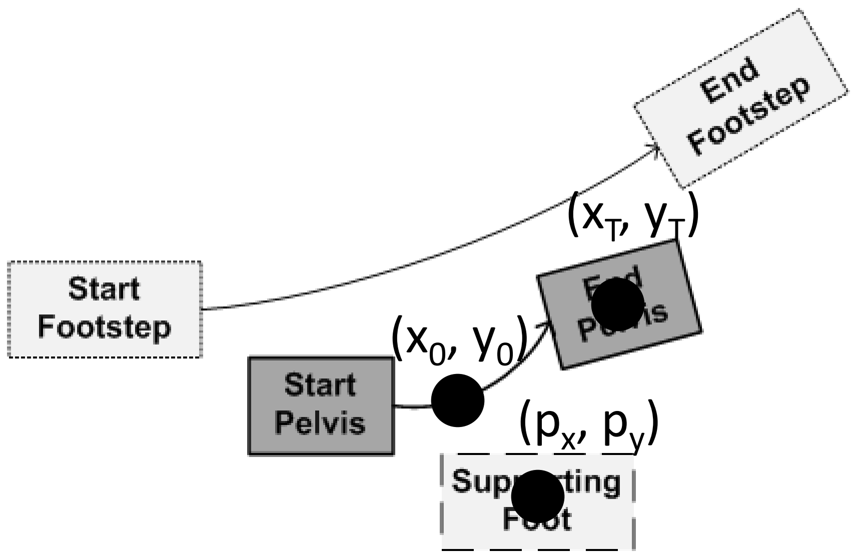


Omnidirectional Gait Generator : Next Pose

$$p_x = x_{CoM} - \frac{z_{CoM}}{g}\ddot{x}_{CoM}$$

$$p_y = y_{CoM} - \frac{z_{CoM}}{g}\ddot{y}_{CoM}$$

- p_x, p_y = 0 (*rZMP*)
- x_0, y_0 = current pelvis position
- x_T, y_T = end pelvis position



Omnidirectional Gait Generator : Next Pose

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- p_x, p_y = 0
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$$x(t) = x_0 * \cosh\left(\sqrt{\frac{g}{z_{CoM}}} \cdot t\right) + \left\{x_T - x_0 \cdot \cosh\left(\sqrt{\frac{g}{z_{CoM}}} \cdot T\right) \cdot\right\} \frac{\sinh\left(\sqrt{\frac{g}{z_{CoM}}} \cdot t\right)}{\sinh\left(\sqrt{\frac{g}{z_{CoM}}} \cdot T\right)}$$

$$y(t) = y_0 * \cosh\left(\sqrt{\frac{g}{z_{CoM}}} \cdot t\right) + \left\{y_T - y_0 \cdot \cosh\left(\sqrt{\frac{g}{z_{CoM}}} \cdot T\right) \cdot\right\} \frac{\sinh\left(\sqrt{\frac{g}{z_{CoM}}} \cdot t\right)}{\sinh\left(\sqrt{\frac{g}{z_{CoM}}} \cdot T\right)}$$

Omnidirectional Gait Generator : Next Pose

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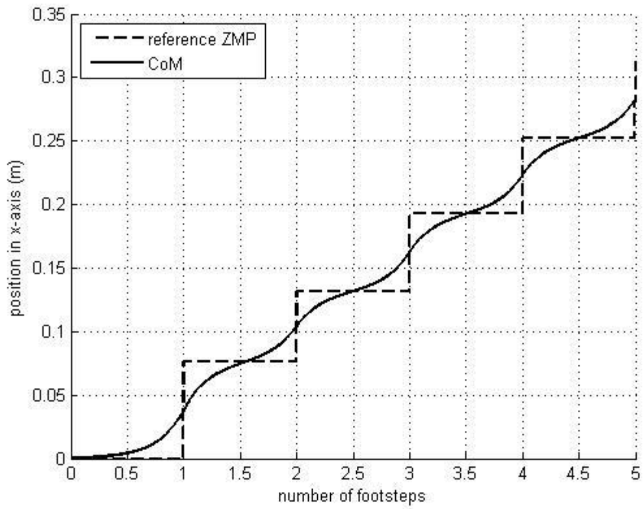
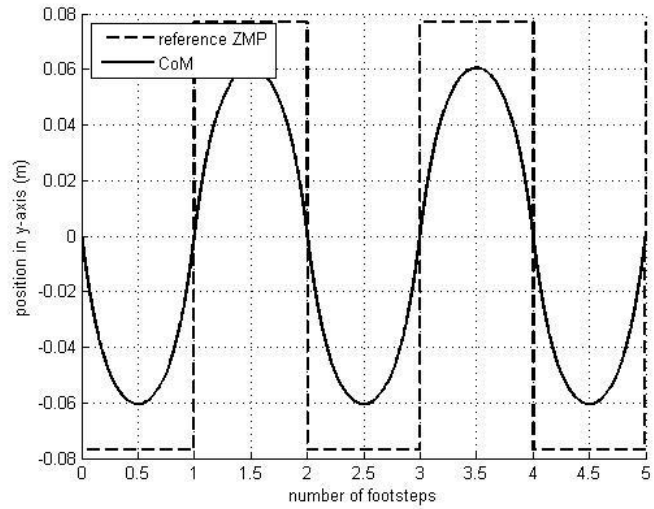


x-axis



y-axis

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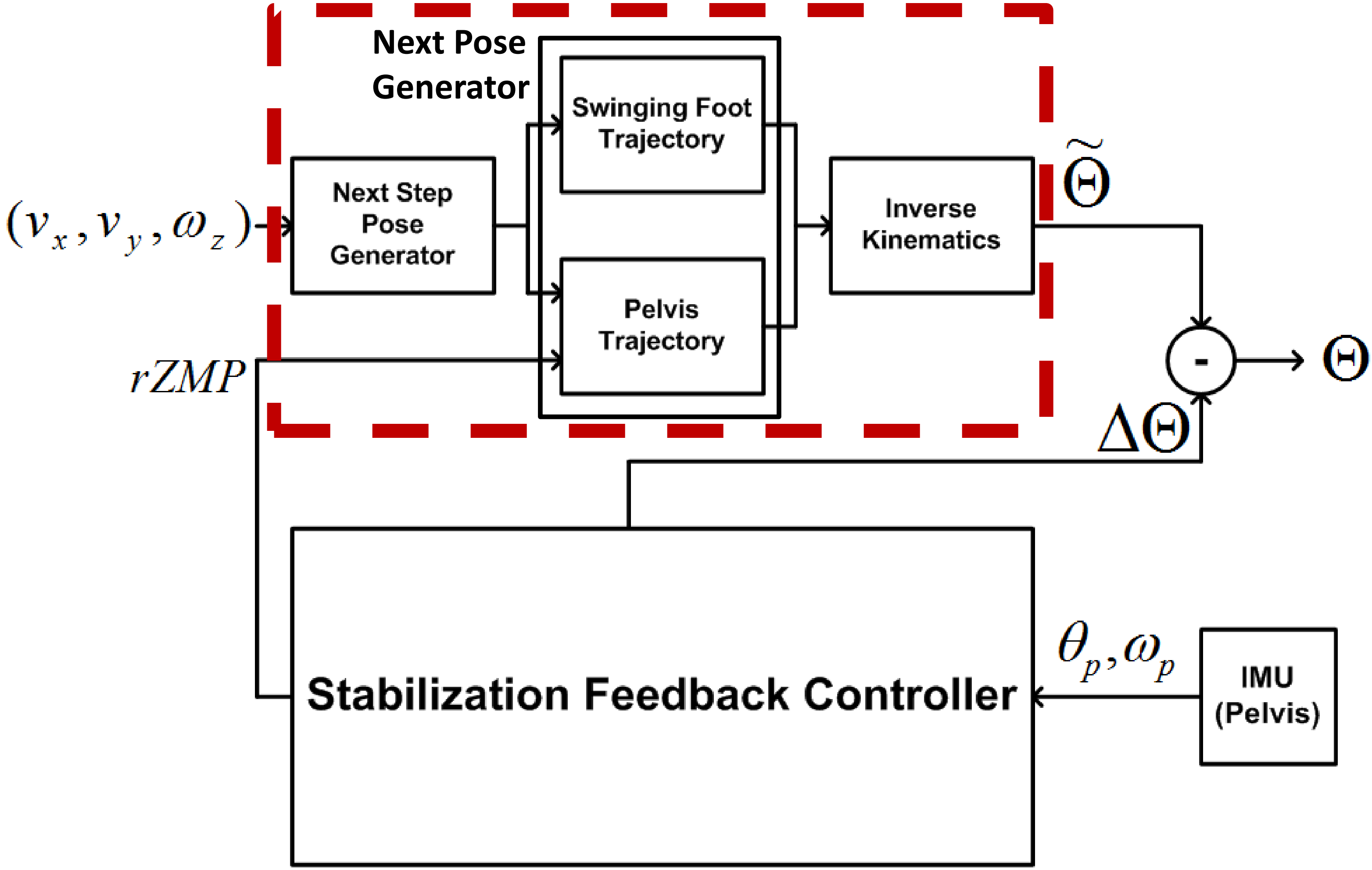
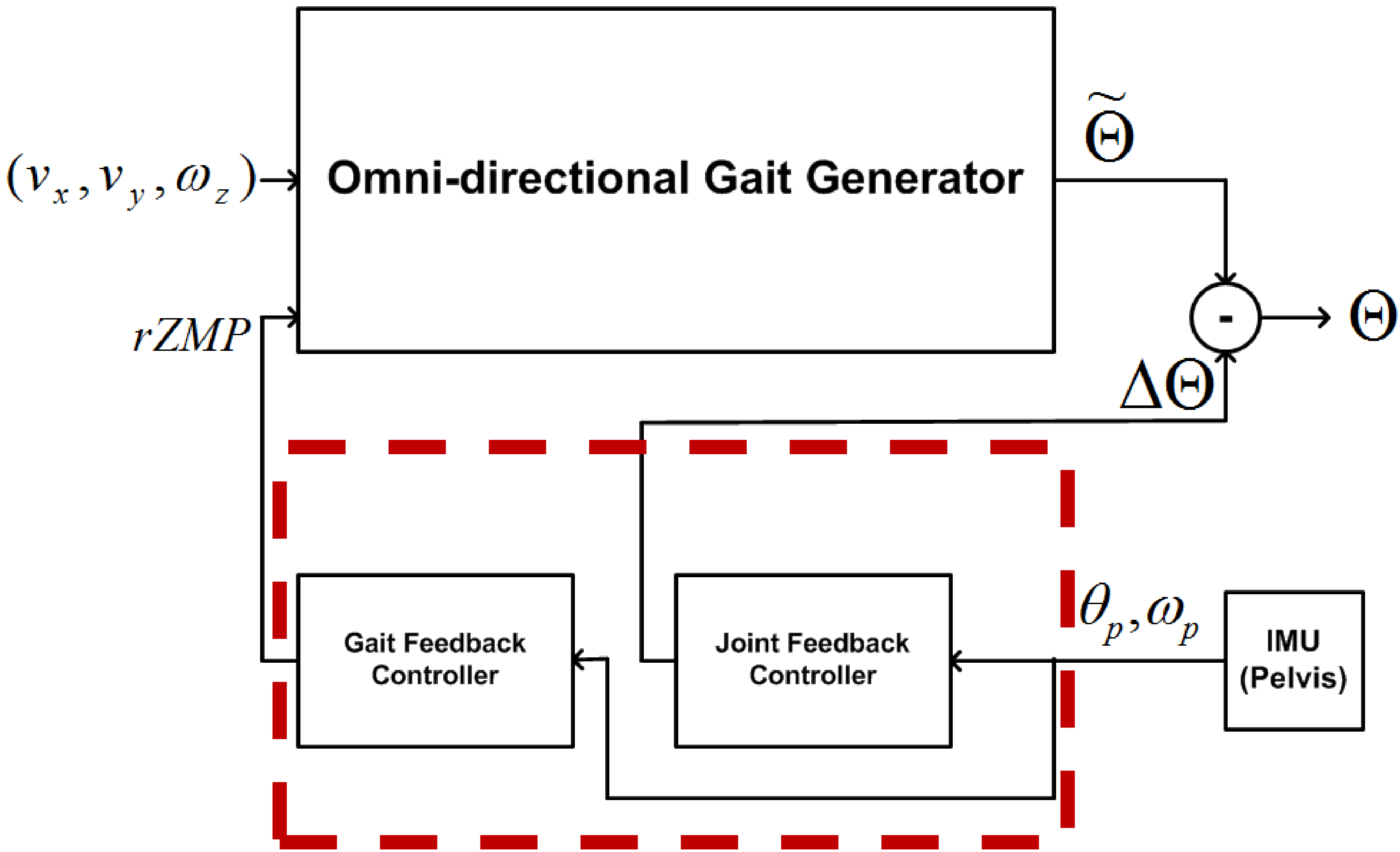
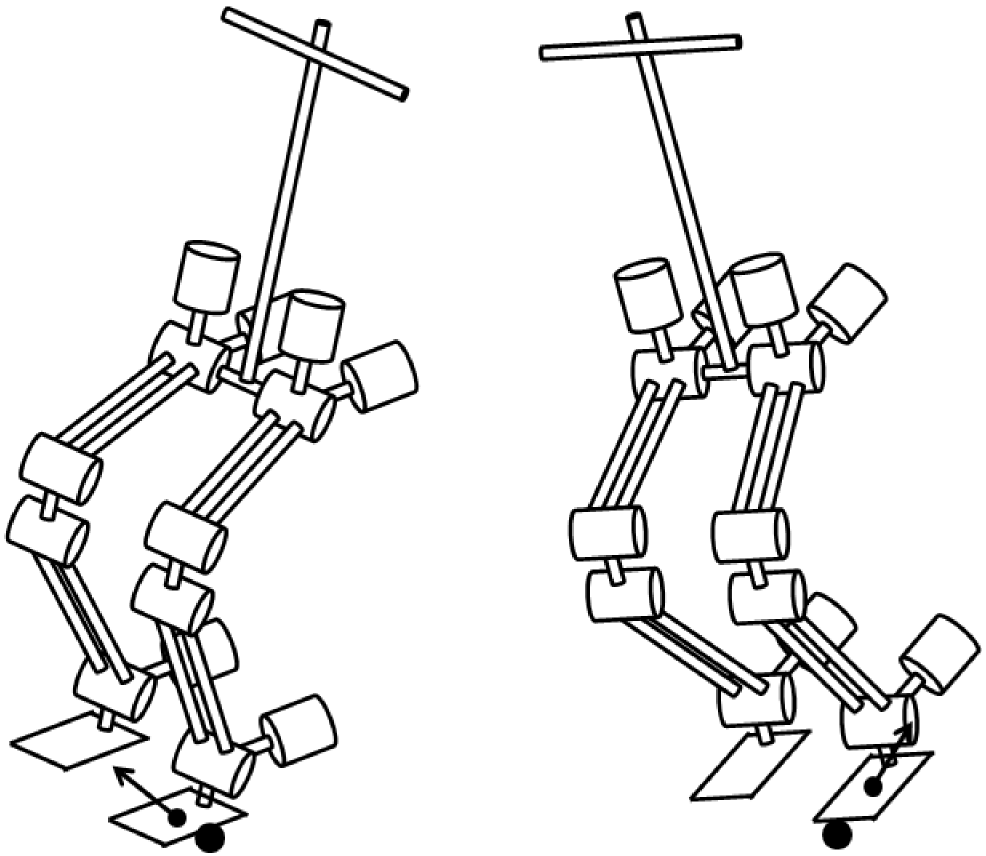
Omnidirectional Gait Generator



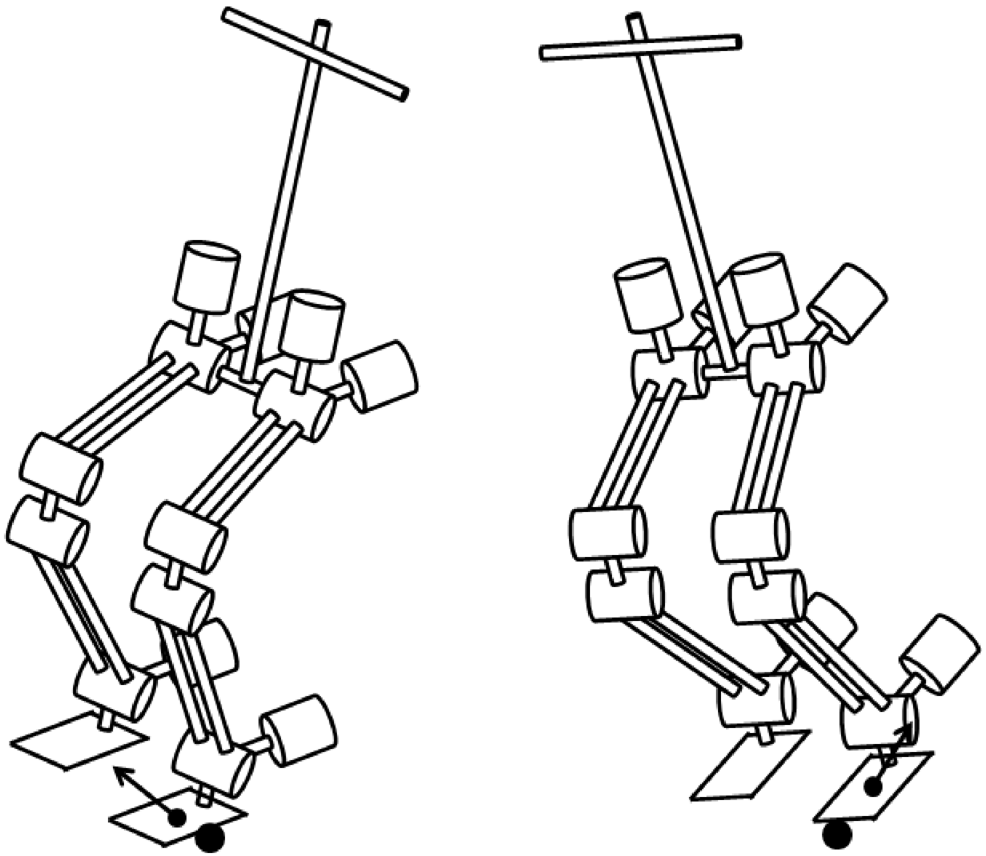
Stability Controller

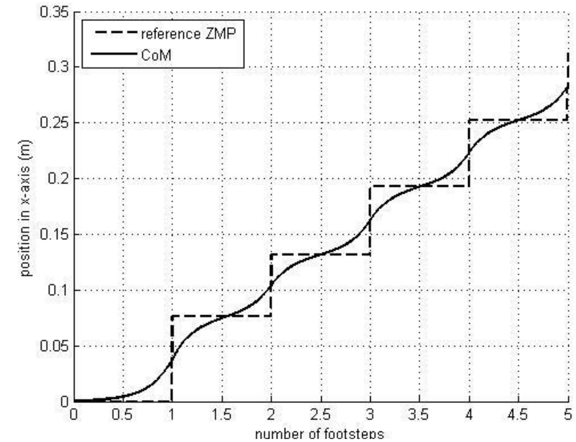


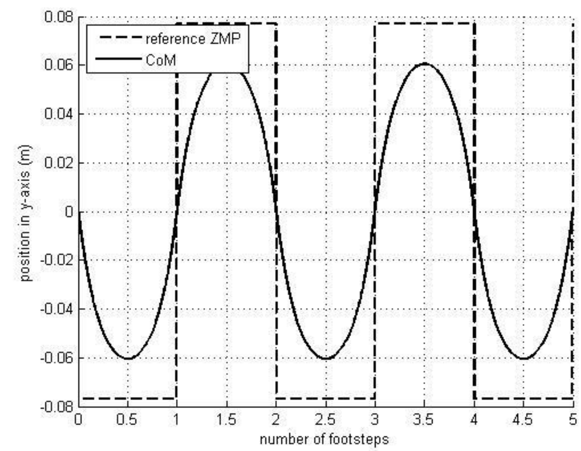
Stability Controller
: Gait Feedback Controller



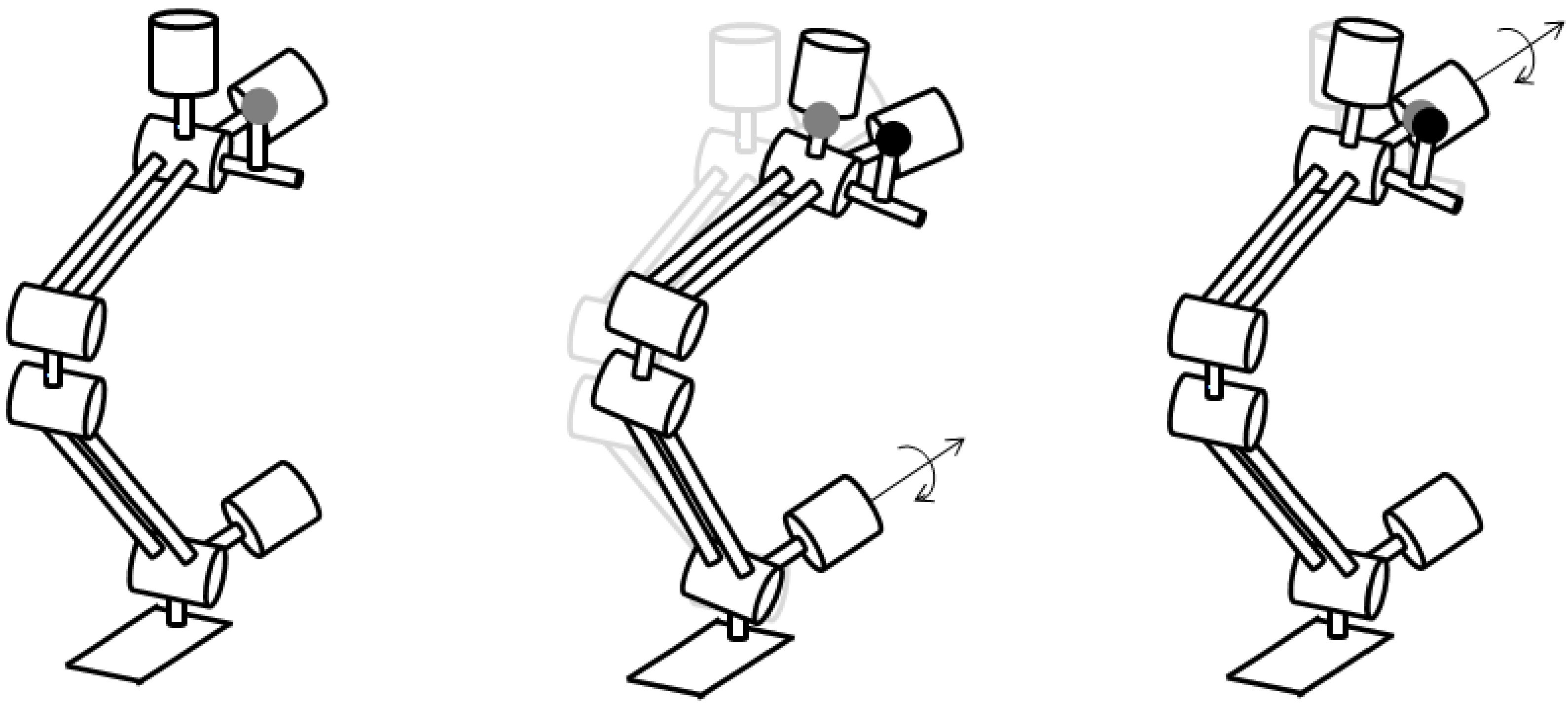
Stability Controller
: Gait Feedback Controller



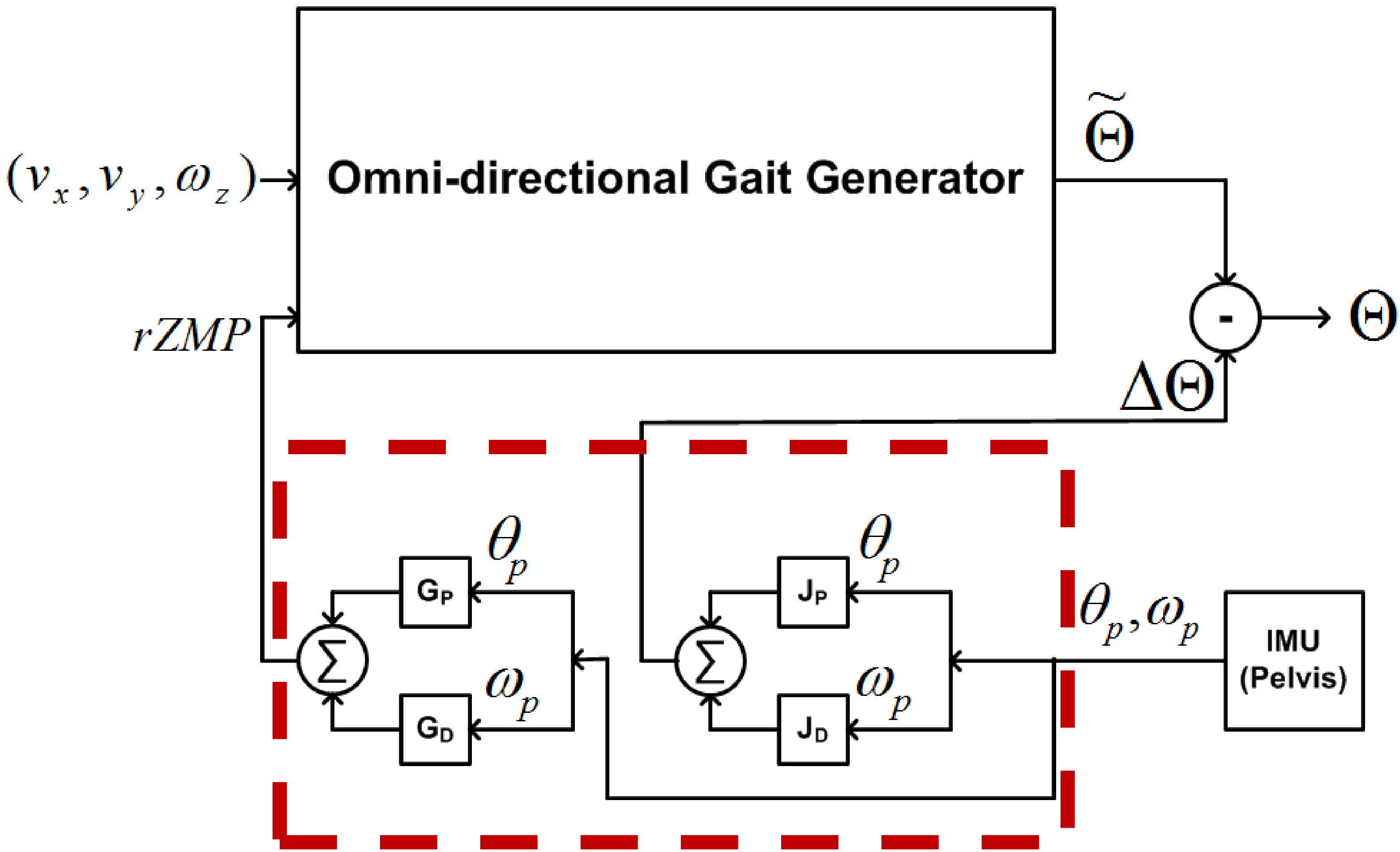




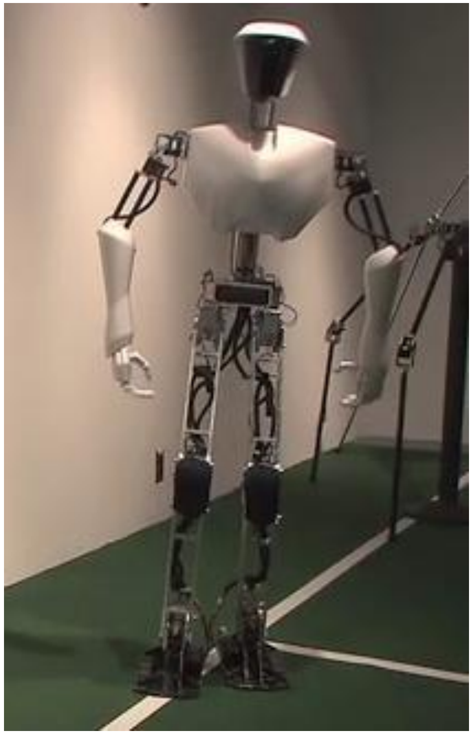
Stability Controller
: Joint Feedback Controller



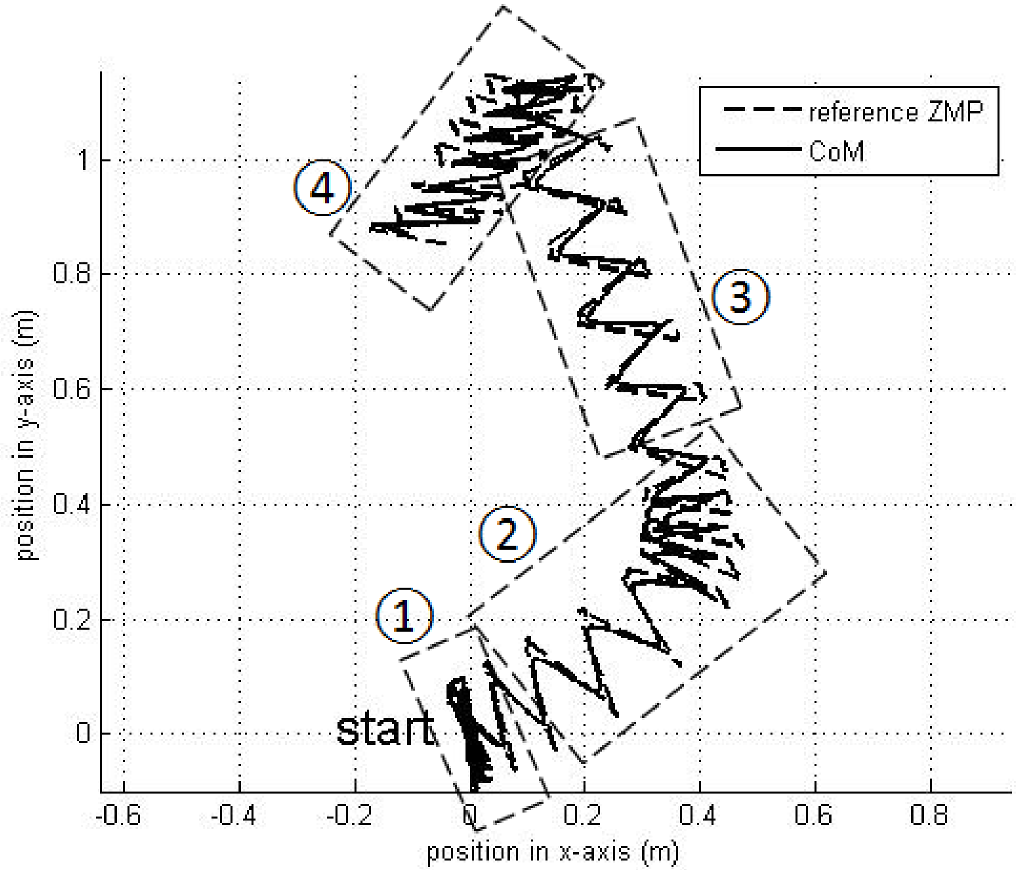
Stability Controller



- CHARLI-L
- ZMP Based Walking
- Walking Engine
- **Experimental Results**
- Discussion



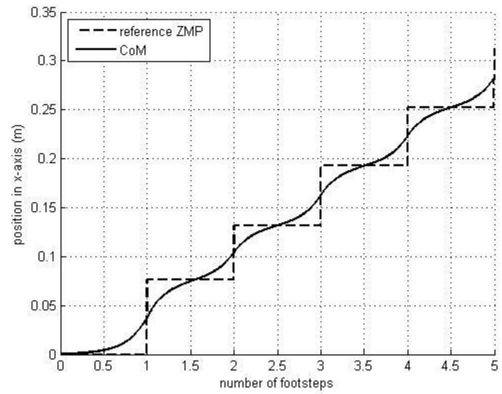
Experimental Results : Omnidirectional

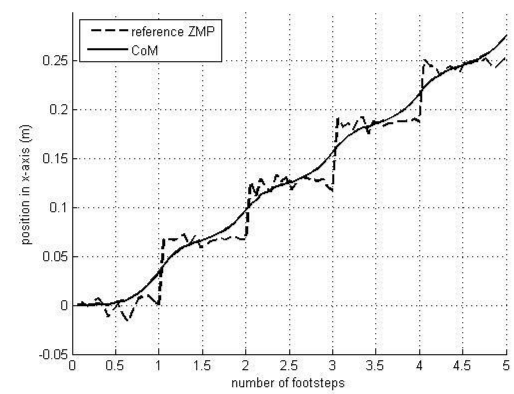


Experimental Results
: Commanded rZMP and CoM

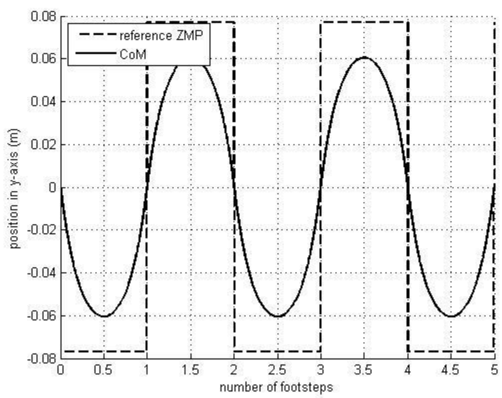
Open-loop | Feedback

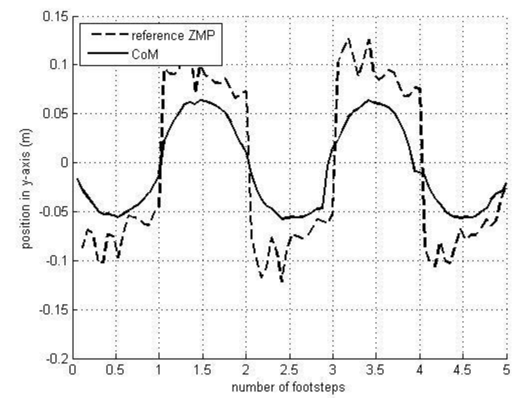
x-axis





y-axis



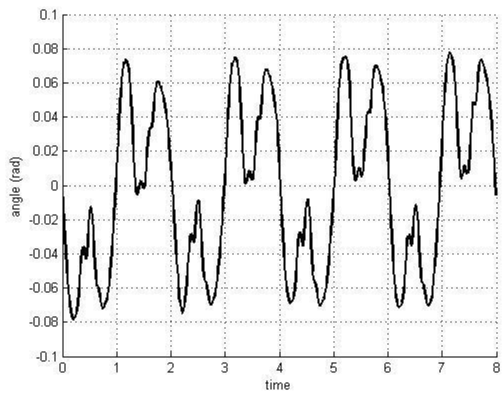


Experimental Results
: Angular Data of the Pelvis

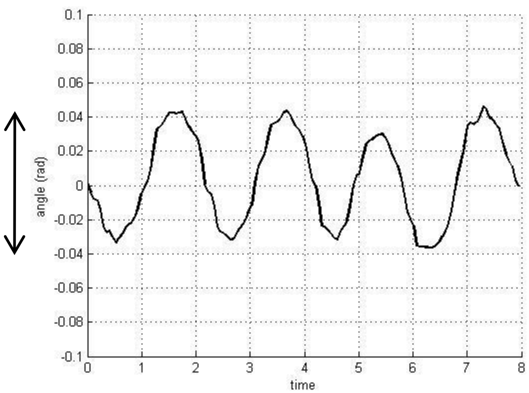
Open-loop | Feedback

Role

10°

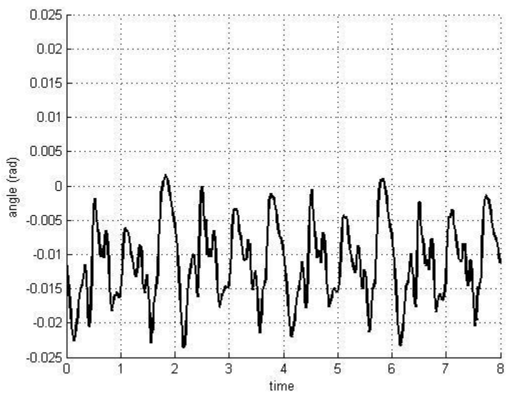


5°

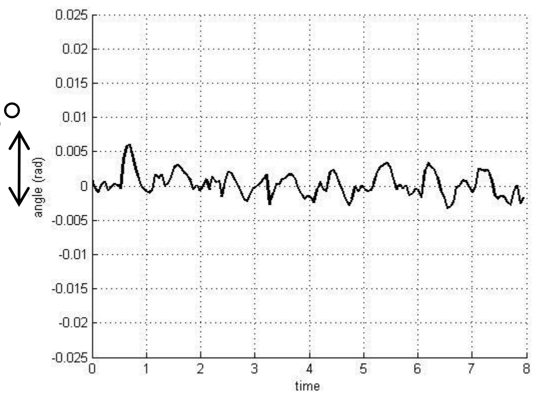


Pitch

2°



0.5°



Summary

- Low computational load with a single IMU
- ZMP based walking
  - ZMP equation
  - Joint Position
- Gait generator
- Feedback controller
- CHALI-L1 walks