Actively Balanced Walking Gaits for Tao-Pie-Pie a small humanoid robot

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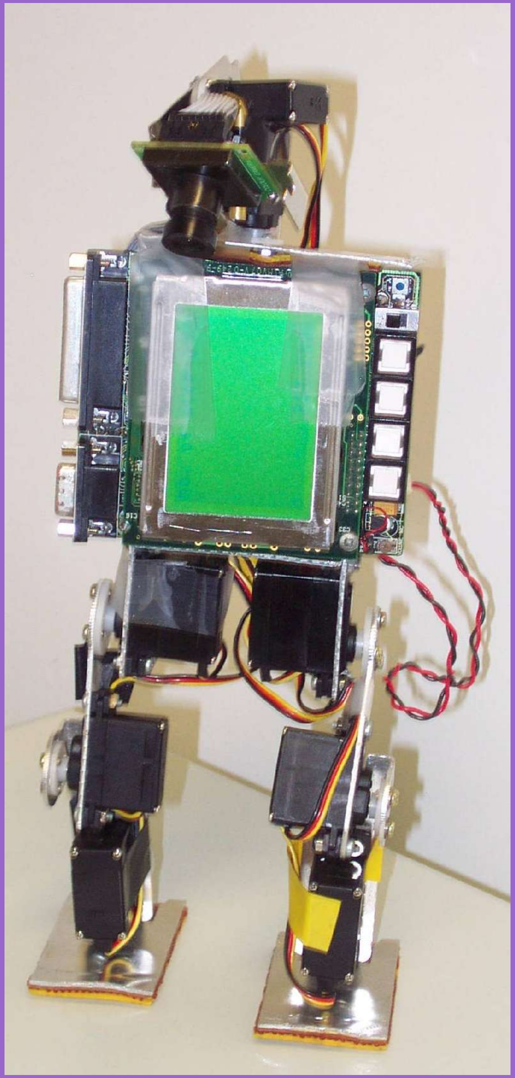
Outline

- Description of Tao-Pie-Pie
- Existing static walking gait
- Design methodology for dynamic walking gait
- Gyroscopic feedback integration
- Conclusions

Tao-Pie-Pie

- 3rd generation of humanoid robot developed by Jacky and students.
- Minimalistic design approach. What is the minimum number of DoF to achieve stable walk
- All processing and sensing on board
- All reasoning on board (Fully autonomous robot)

Tao-Pie-Pie



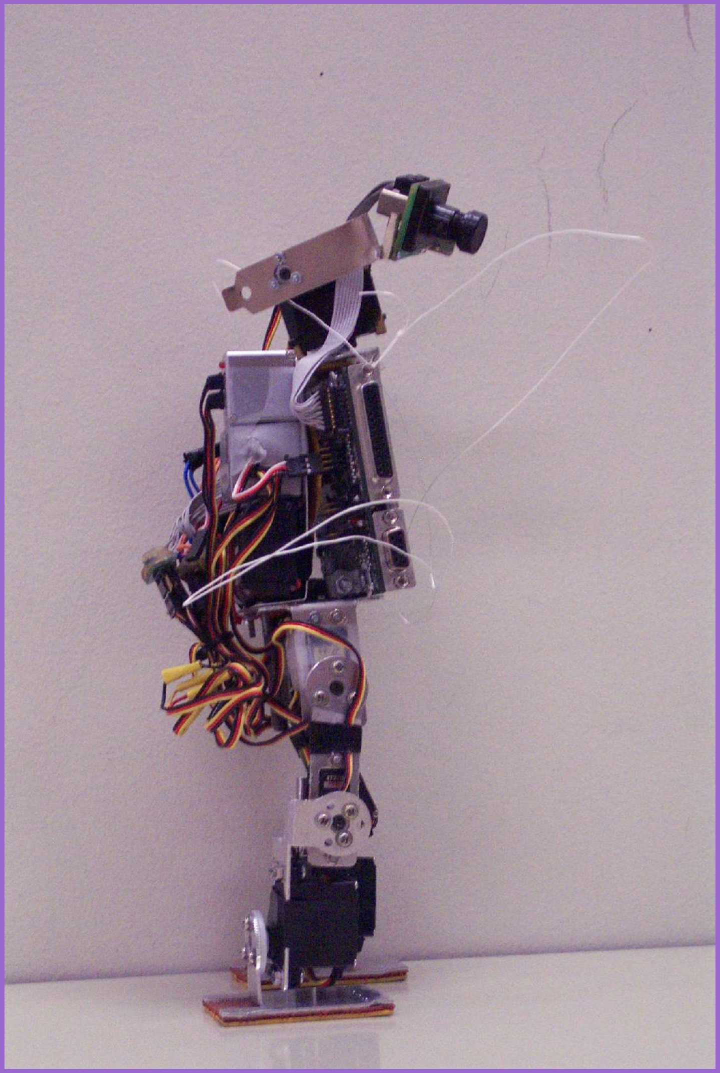
Designed in collaboration with Nadir Ould Kheddal's group at Temasek Politechnic, Singapore

6 DOF for the legs
- Ankle left-right
- Knee forward backward
- Hip forward backward
- RC Servos * 6

Eyebot controller (32 Mhz 68332, 1MB Ram)

Cheap at < $1,000

Tao Pie Pie



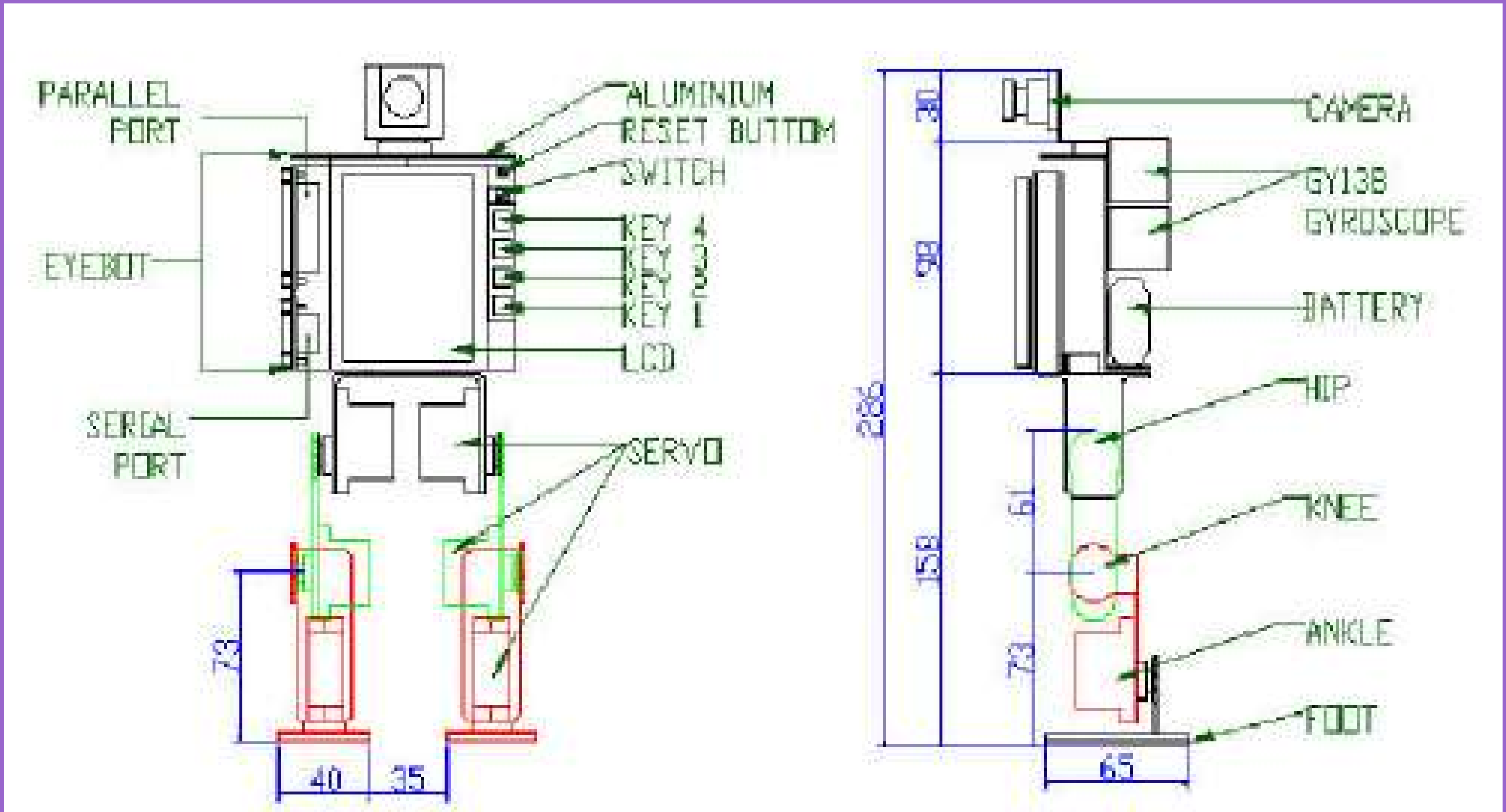
Battery is on-board. 7.2V Li-Ion

Sensors

- 2 gyroscopes (left, forward)
- CMOS camera (80x60 pixels)
  - -pan/tilt assembly

Tao-Pie-Pie

Plans available at http://wwww.cs.umanitoba.ca/~jacky



Existing Walking Gait

- Divide and conquer approach
- Break the cyclical pattern up into six phases
- The phases are symmetric
- A phase is defined as a statically (almost) stable position

Bezier Curves

- Interpolate points path from the start and end points of all phases
- Linear interpolation leads to jerkiness
- Compute smooth control function
  - Cubic splines minimize 2nd derivative (acceleration) of the robot
- Bezier curves
  - Allow for finer grained control
  - Easily calculated

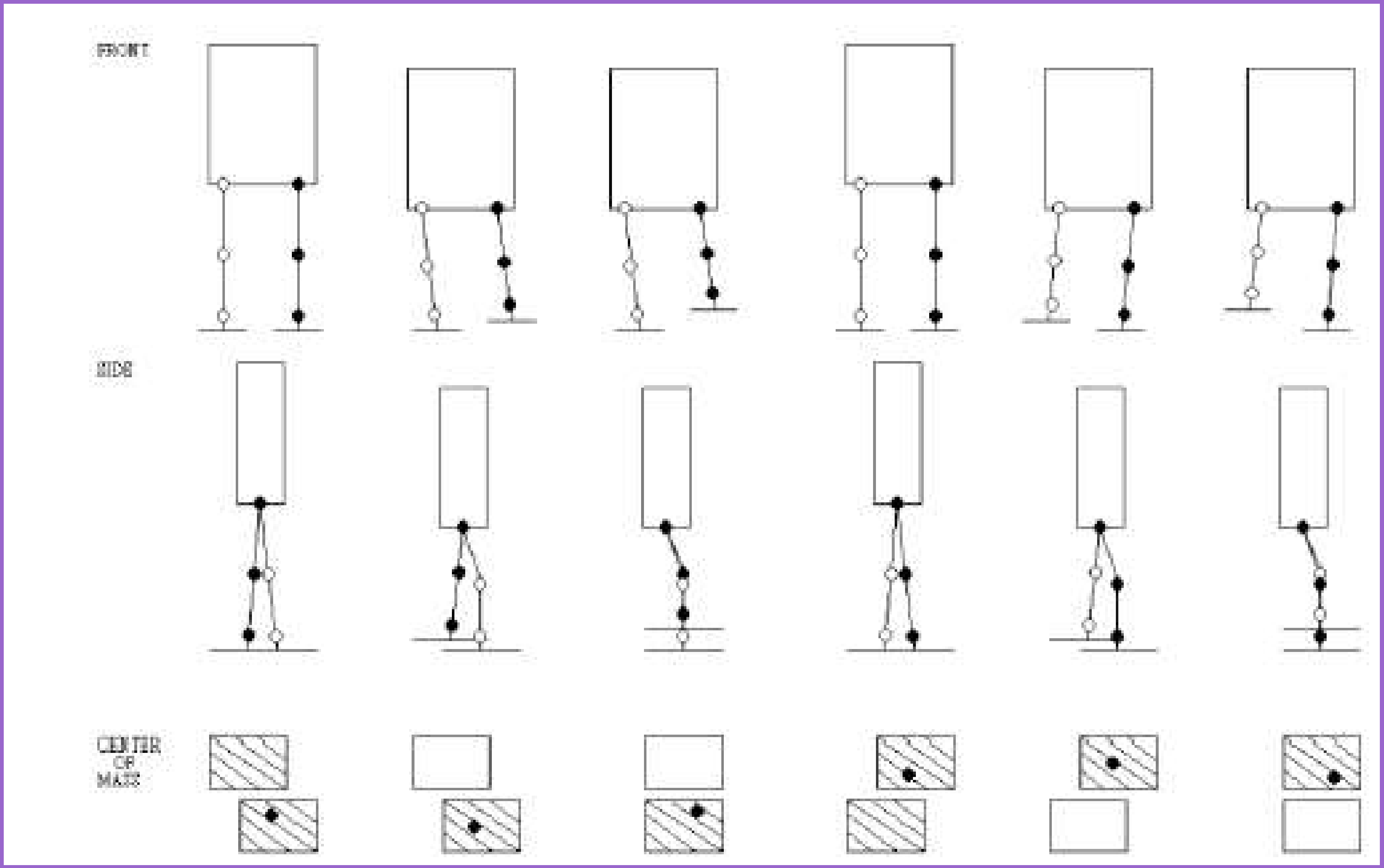
Linear Interpolations

- Linear interpolation leads to jerkiness
  - But only at slow speeds
- Smooth control function approximated linearly
  - Effects of the Bezier curve decrease as walk speeds increase
- Less processing

Walking Pattern

- Phase 1: Two leg stand. Right leg in front. COM in the middle
- Phase 2: Ankle servo generates torque that moves COM to inside edge of right leg. Back left leg lifts off the ground
- Phase 3: Swing free left leg forward and ready for landing. COM moves to tip of right leg
- Phase 4: (Dynamic balance). Right leg extends to move COM forward, Robot falls onto the left leg

Walking Pattern



Revised Walking Pattern

- Multiple control points for each joint
  - 100% to reach full pattern
- Extremely easy to change timing
- Necessary for integrating gyro feedback
  - Interesting points at ends of phases
  - More soon..

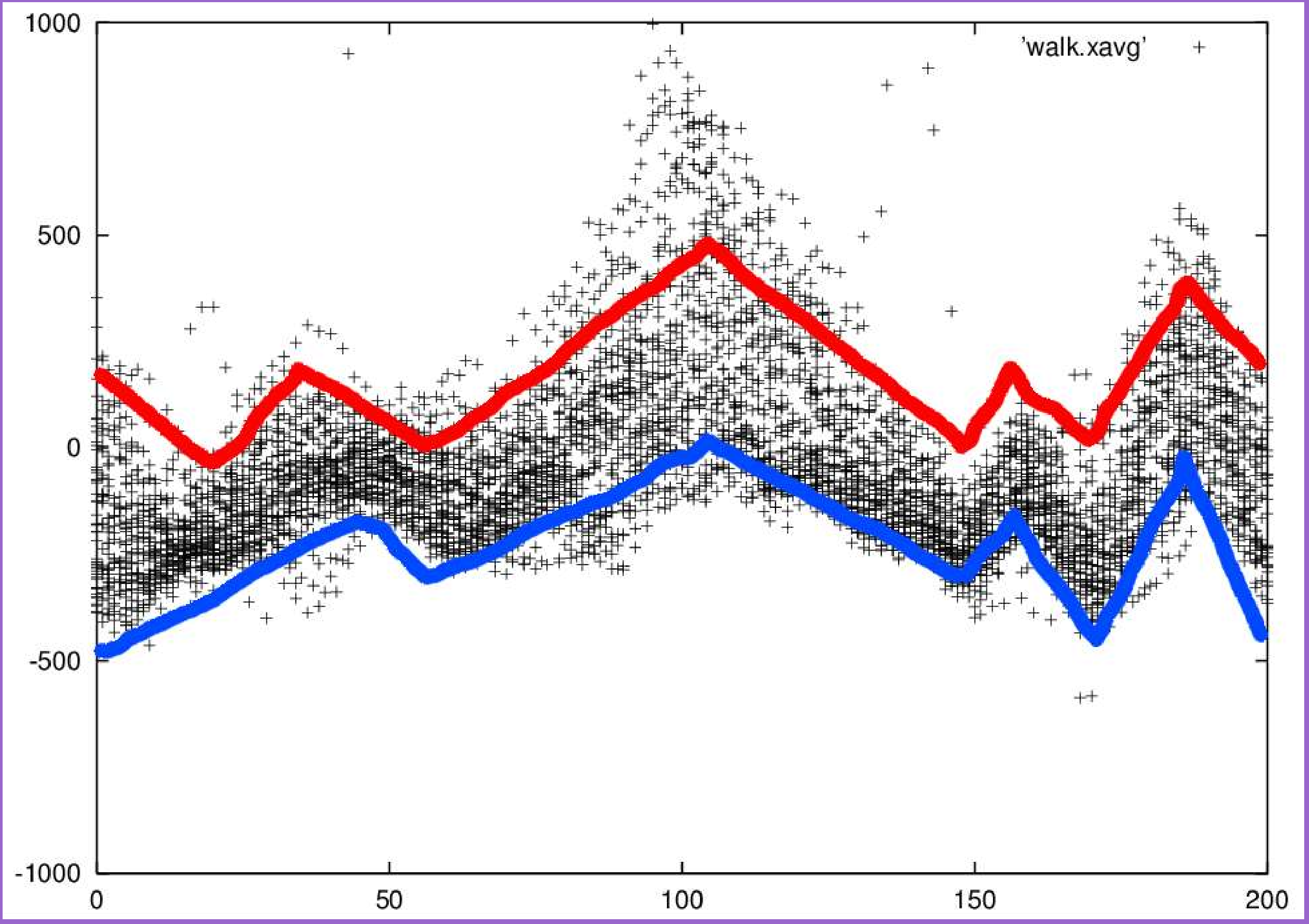
Feedback

- Cheap gyroscopes provide noisy data during transitions
- No traditional feedback control
- Instead, the gyroscope velocities are used to measure successful transition from one phase to the next
- Initial idea: move robot into a two leg stand if transition is not successful

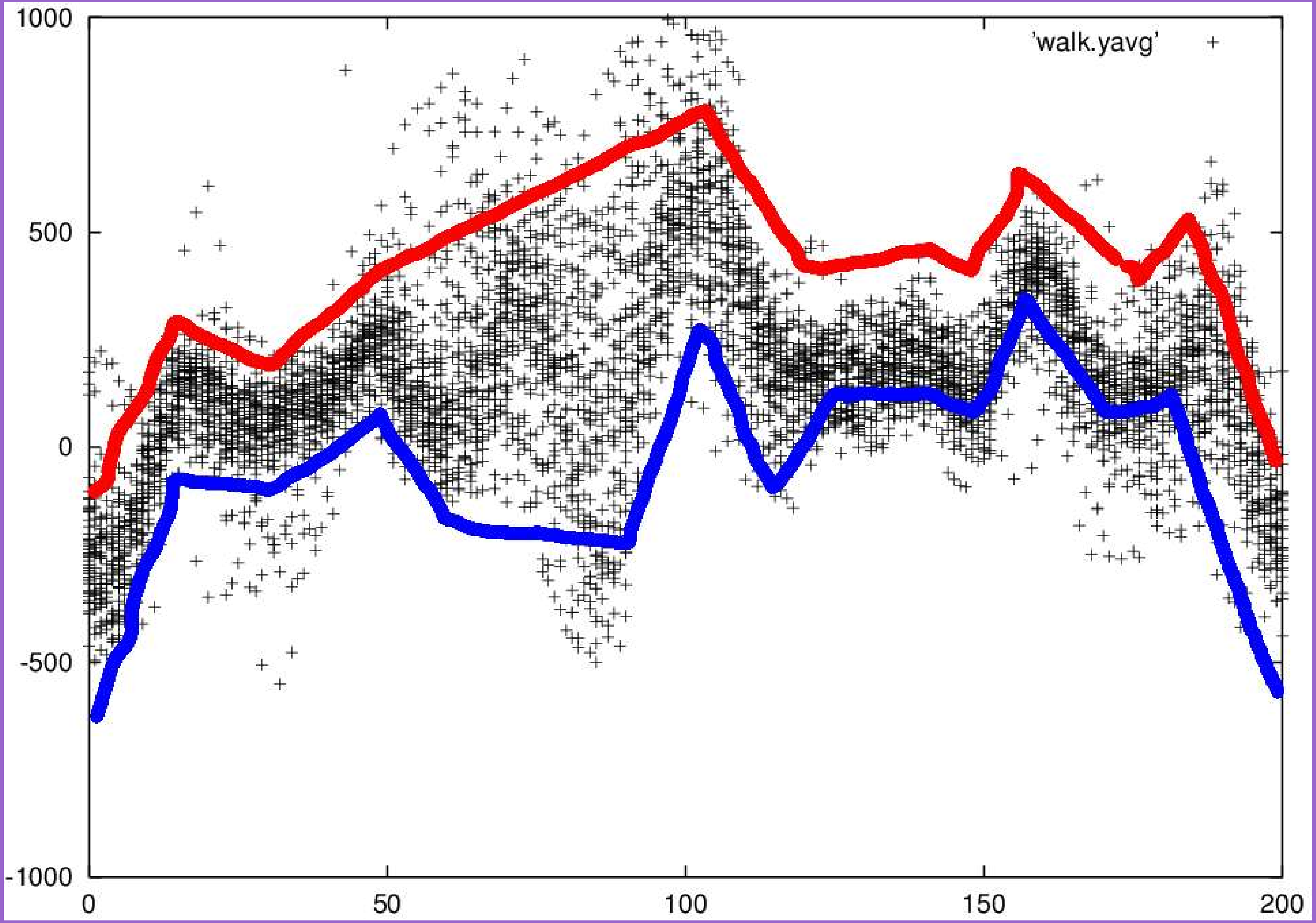
Feedback

- Initial thought: aim for zero velocity
  - Problem!
  - Movement is inherently unstable
- How do you describe a good walk?
  - You've got to have one first
  - Extremely dependent on walk speed
    - Future reseach area?
- What should you correct?

Feedback



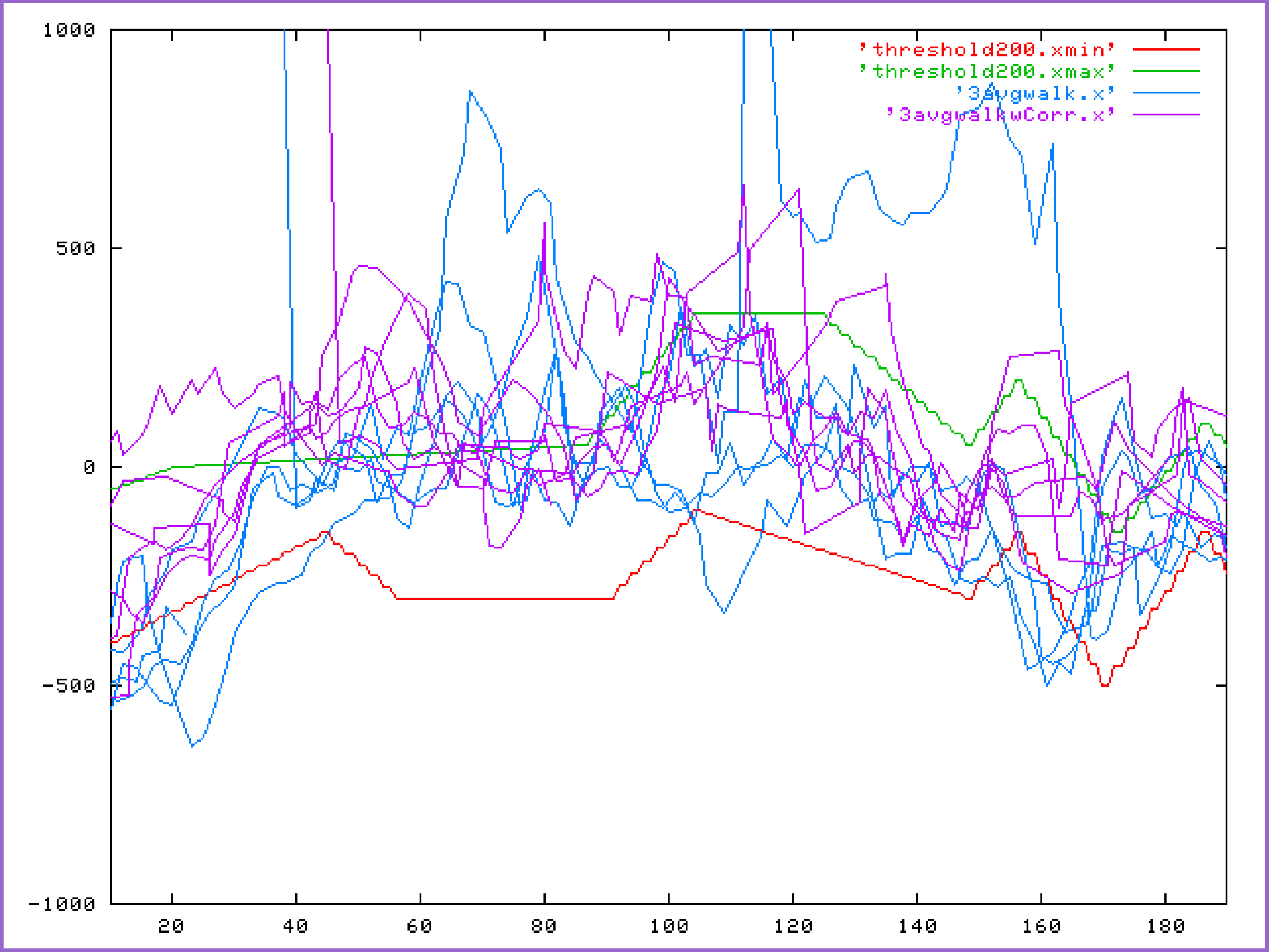
Feedback



Feedback

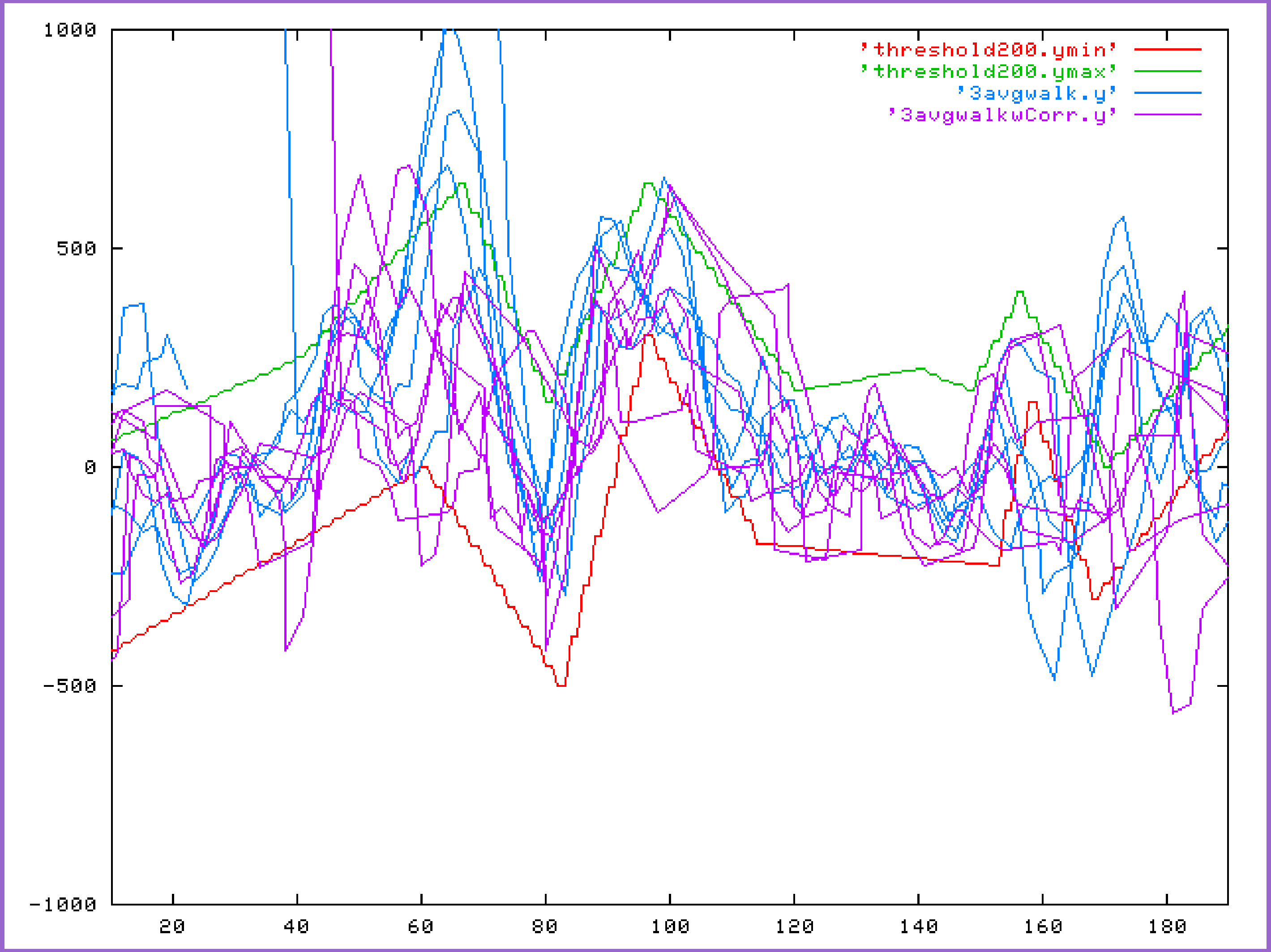
- Correct for appropriate broken threshold
  - Move control point in for high, out for low
- Initially
  - Just corrected for one threshold at a time
  - Used static correction measure
- Currently
  - Correct both x and y simulteanously
  - Correct using proportional controller, with dead bands

Feedback



'threshold200.xmin'
'threshold200.xmax'
'3avgwalk.x'
'3avgwalkwCorr.x'
1000
500
0
-500
-1000
20
40
60
80
100
120
140
160
180

Feedback



'threshold200.ymin'
'threshold200.ymax'
'3avgwalk.y'
'3avgwalkwCorr.y'
1000
500
0
-500
-1000
20
40
60
80
100
120
140
160
180

Conclusions

- Described the design methodology for walking gaits for Tao-Pie-Pie
- Described integrating feedback from gyroscopes
- Successful at competitions
- Velocity based gyroscope feedback used directly in balancing control
- Improves balancing for COM changes

Conclusions

- In 2003 Tao-Pie-Pie walked about twice as fast
- Added pan and tilt camera
- New humanoid robot HIRO
  - Uses more DOFs (6 per leg)
  - Digital servos
  - Dynamic Gait