Programming Humanoid Robot in Python

2. Joint Control

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Outline

1. Single Joint Control
2. Keyframe Based Whole Body Control
3. Posture Recognition
4. Exercise
Joint Servo

- DC Motor
- Gear box
- Magnetic Rotary Encoders

NAO’s Ankle
DC Motor Control

Plus Width Modulation Control
Feedback Control

\[ r \rightarrow e \rightarrow u \rightarrow d \rightarrow P \rightarrow y \rightarrow n \]

- **P** plant
- **C** controller
- **d** plant disturbance
- **n** sensor noise
- **r** reference or command
- **y** output, controller output
- **e** tracking error
- **u** control signal
- delay in plant and sensor
PID Control

Discretized:

\[ u(t_k) = u(t_{k-1}) + (K_p + K_i \Delta t + \frac{K_d}{\Delta t})e(t_k) - (K_p + \frac{2K_d}{\Delta t})e(t_{k-1}) + \frac{K_d}{\Delta t}e(t_{k-2}) \]
Feedback Control with Prediction

\[ \hat{P} \text{ model of plant} \]

\[ \tilde{y} \text{ prediction without delay} \]

\[ \hat{y} \text{ prediction with delay} \]
Keyframe Based Whole Body Control
Keyframe Interpolation
Linear Interpolation
Splines Interpolation

Cubic Splines \( y_i(t) = a_i t^3 + b_i t^2 + c_i t + d_i \)
where \( i \in [0, n], t \in [0, 1], \)
\( \dot{y}_{i-1}(1) = \dot{y}_i(0), \dot{y}_{i-1}(1) = \dot{y}_i(0), \ddot{y}_0(0) = \ddot{y}_{n-1}(1) = 0 \)
Splines Interpolation

Cubic Splines

\[ \dot{y}_0(0) = \dot{y}_{n-1}(1) = 0 \]

\[ \dot{y}_{i-1}(1) = \dot{y}_i(0) = \begin{cases} 0, & \text{if } (y_{i+1} - y_i)(y_i - y_{i-1}) < 0. \\ (y_{i+1} - 2y_i + y_{i-1})/2, & \text{otherwise.} \end{cases} \]
Bézier Interpolation

Cubic Bézier \[ B(t) = (1 - t)^3 P_0 + 3(1 - t)^2 t P_1 + 3(1 - t)t^2 P_2 + t^3 P_3 \]
where \( t \in [0, 1] \)
Posture Recognition
Classification
Basic Steps of Applying Machine Learning

1. Data collection.
2. Data preprocessing.
3. Build a model on training data.
4. Evaluate the model on the test data.
5. If the performance is satisfying, deploy to the real system.
Lesson Learned

- Single Joint Control
- Keyframe Based Whole Body Control
- Posture Recognition

⇒ Make the robot standing up when it falls.
Exercise

https://github.com/DAInamite/
programming-humanoid-robot-in-python
More Information

- Online course: Control of Mobile Robots
  https://www.coursera.org/course/conrob
- Online course: Stanford Machine Learning by Andrew Ng
  https://class.coursera.org/ml-007
- http://scikit-learn.org/