# FIBO

*A Cradle of Future Leaders in Robotics*

# Neuro-Fuzzy System for Motion Control of a Humanoid robot

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# Outline

- Humanoid Robot on FIBO (HRF)

- Control Algorithm of HRF

- Foot Force Placement

- Relation between Leg trajectories and Foot force based on Neuro-Fuzzy Modeling

- Problem on Foot Force Placement
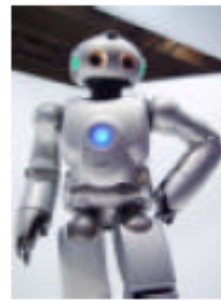
- Further Work

# Research Overview : Some Humanoid robot

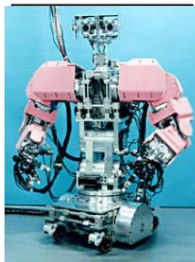

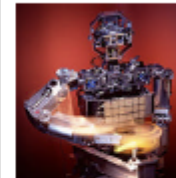| ASIMO | HRP-1S | HRP-2 | SONY 4DX-I/II | HOAP (1&2) | PINO | H7 |

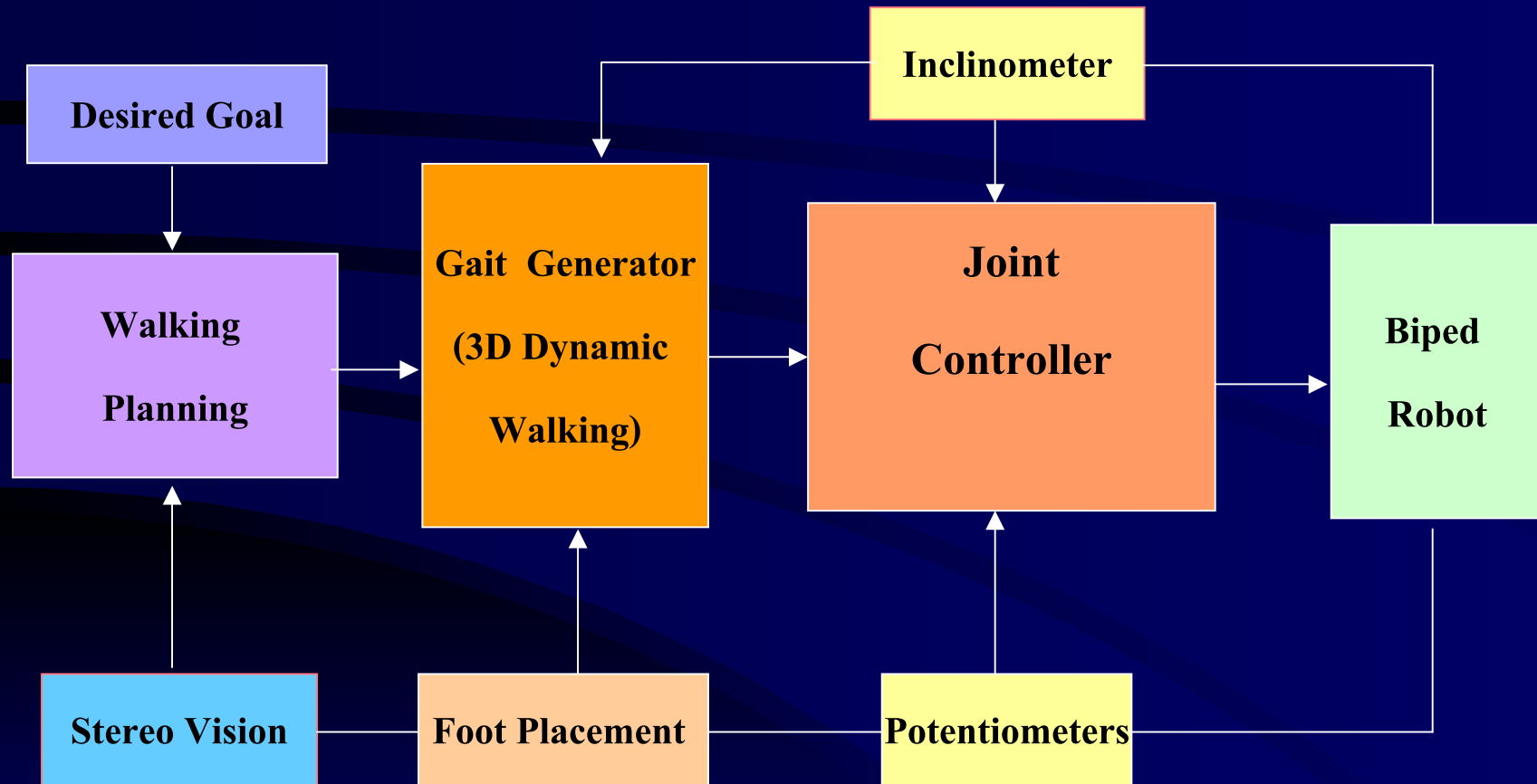| WABIAN RIII | WENDY | JOHNNIE | ELVIS | ROBONAUT (NASA) | MIT-COG | DR ROBOT | SHADOW Project | BHR-1 |

# Humanoid Intelligence

- Neural Network to gait generation

- Fuzzy logic to gait generation

- Genetic to gait generation

- Neural - fuzzy to gait generation

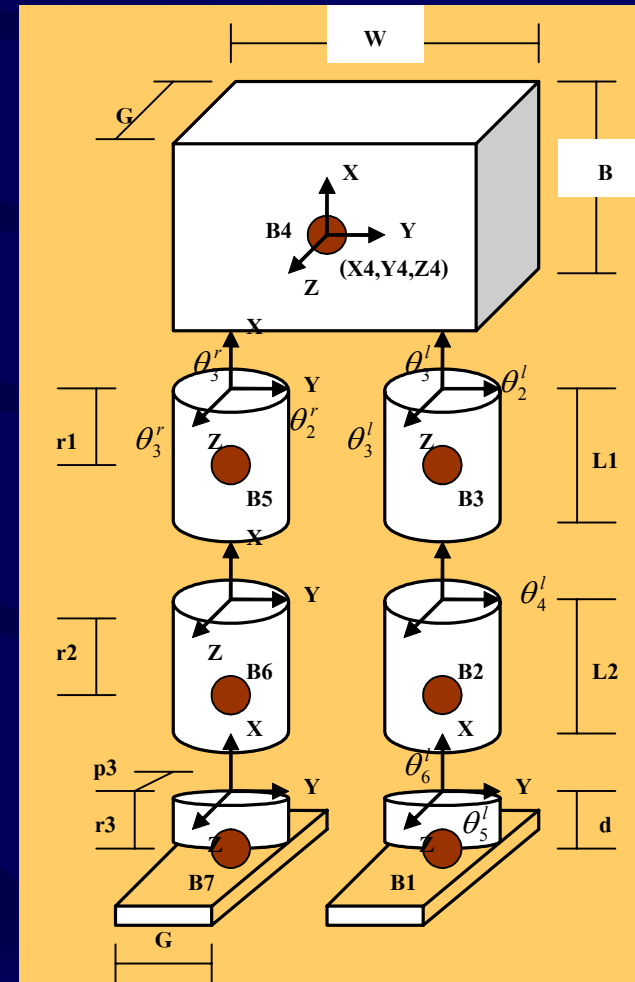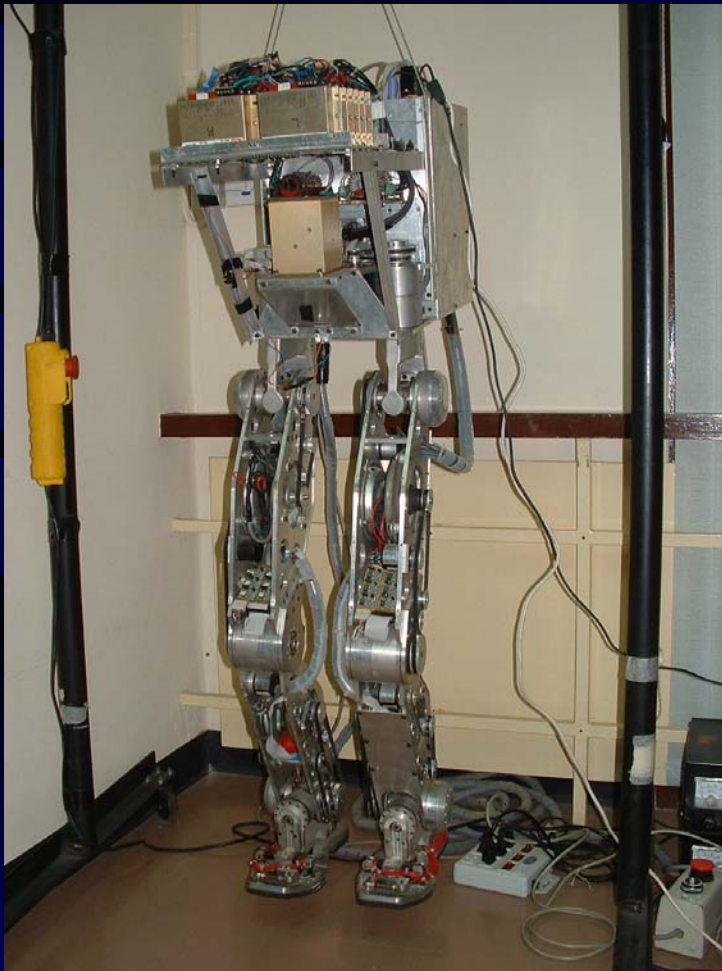# Computational Intelligence - Gait Generator for dynamic walking of a humanoid robot

Three aspects :

1. Extending a soft-computing technique concept into a theoretical framework and further designing a learning controller for dynamic bipedal walking robots.

2. Exploring such a soft computing technique to generate and sustain gait stability in order to achieve global dynamic stability for bipeds.

3. Investigating adaptation in different ways i.e. dynamic level, smooth surface, slop surface, rough terrain.
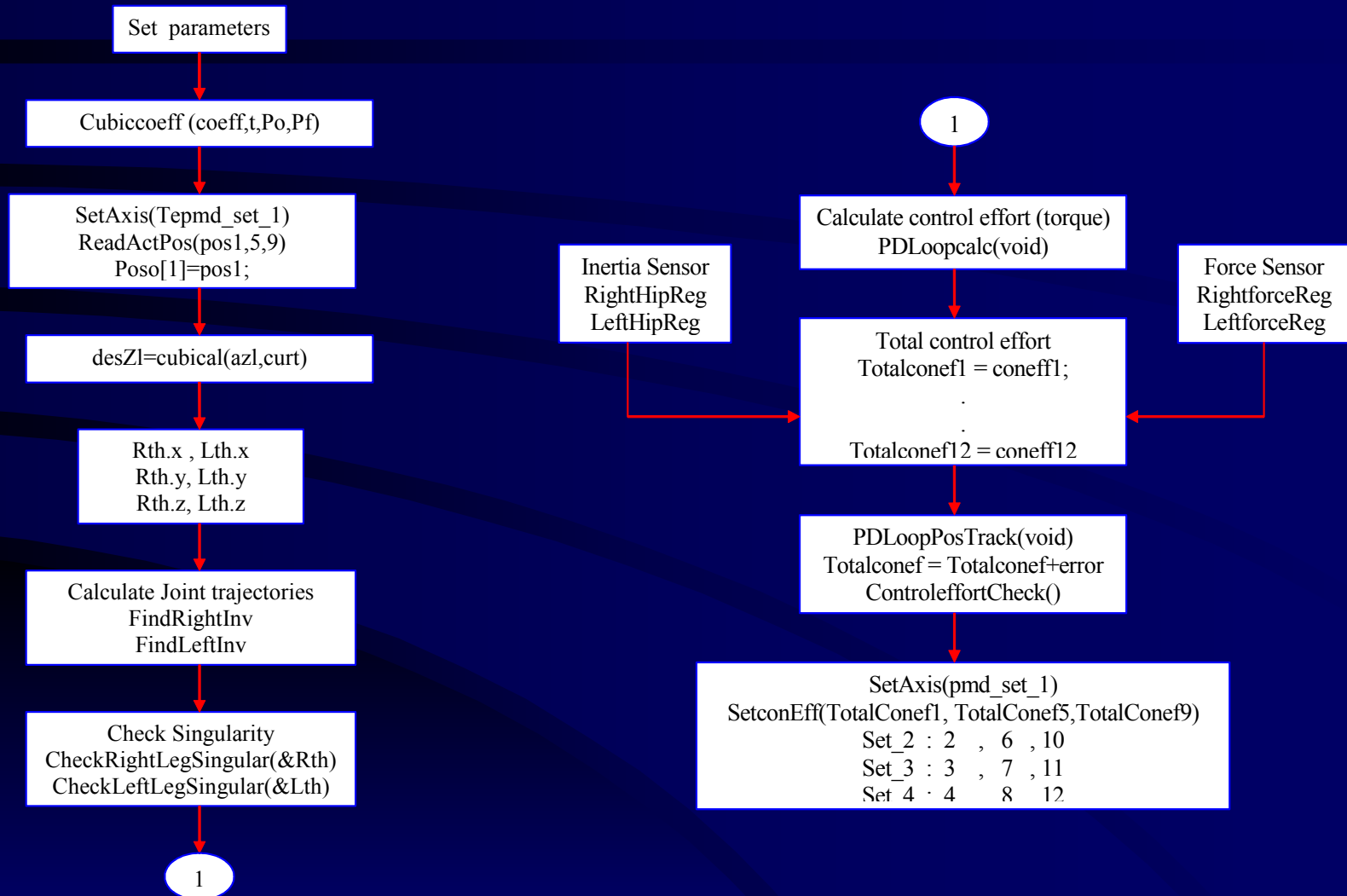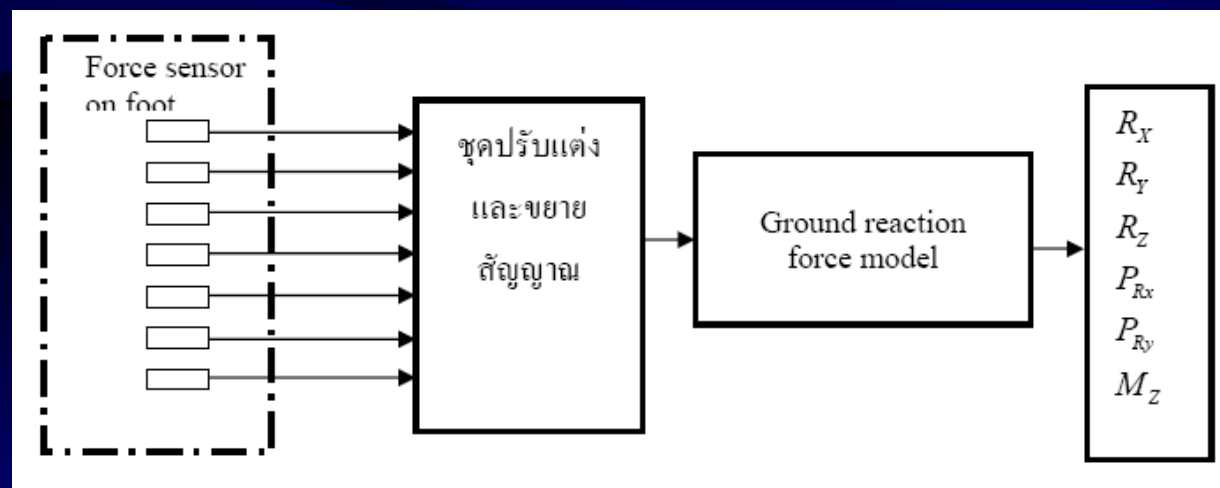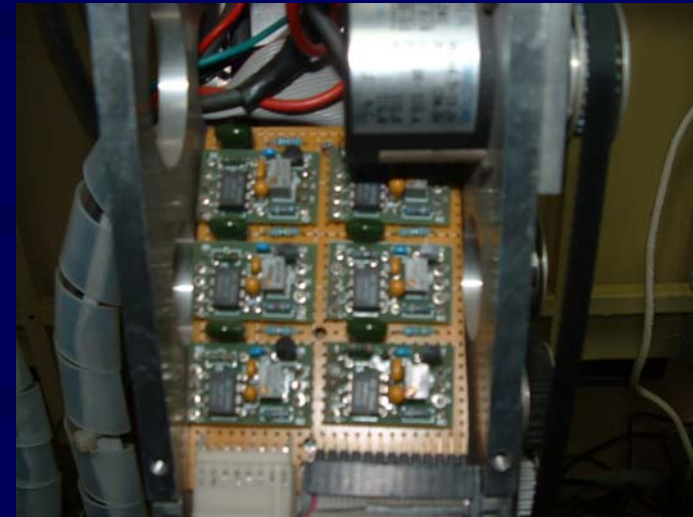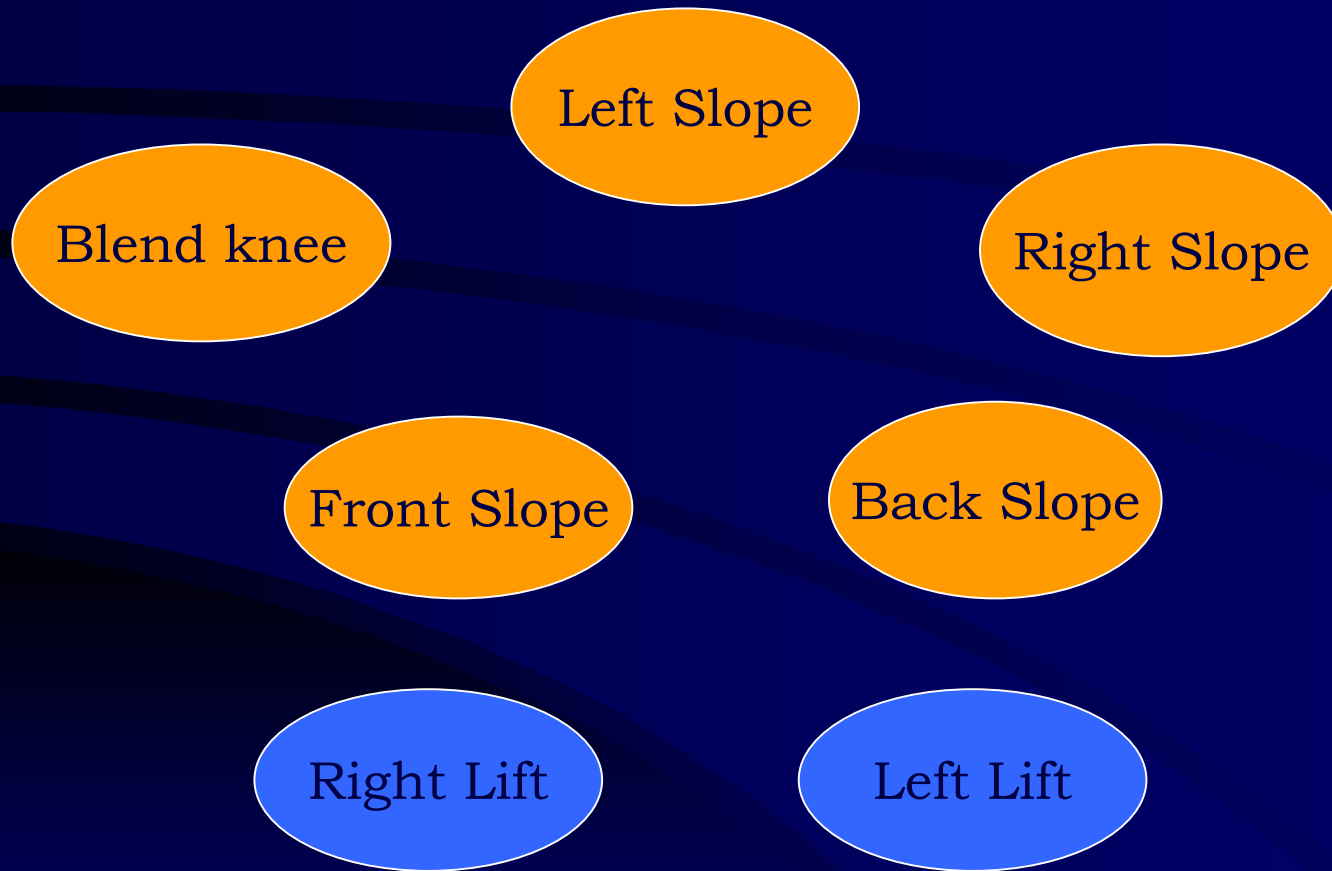
# Control system of the biped robot
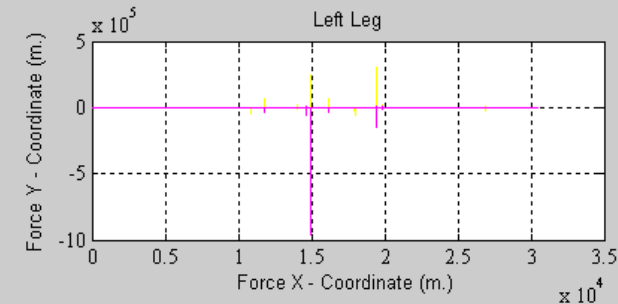
# Humanoid Robot on FIBO (HRF)

# Control Algorithm on HRF

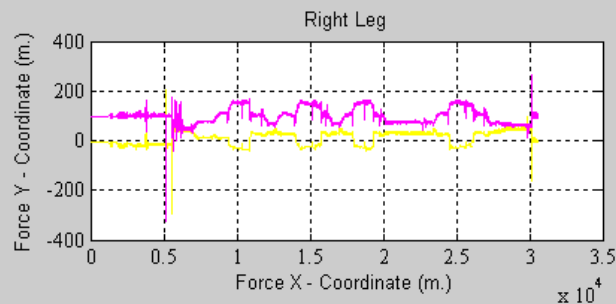Set parameters

↓

Cubiccoeff (coeff,t,Po,Pf)

↓

SetAxis(Tepmd_set_1)
ReadActPos(pos1,5,9)
Poso[1]=pos1;

↓

desZl=cubical(azl,curt)

↓

Rth.x , Lth.x
Rth.y, Lth.y
Rth.z, Lth.z

↓

Calculate Joint trajectories
FindRightInv
FindLeftInv

↓

Check Singularity
CheckRightLegSingular(&Rth)
CheckLeftLegSingular(&Lth)

↓

1

---

1

↓

Calculate control effort (torque)
PDLoopcalc(void)

Inertia Sensor
RightHipReg
LeftHipReg

Force Sensor
RightforceReg
LeftforceReg

↓

Total control effort
Totalconef1 = coneff1;
.
.
Totalconef12 = coneff12

↓

PDLoopPosTrack(void)
Totalconef = Totalconef+error
ControleffortCheck()

↓

SetAxis(pmd_set_1)
SetconEff(TotalConef1, TotalConef5,TotalConef9)
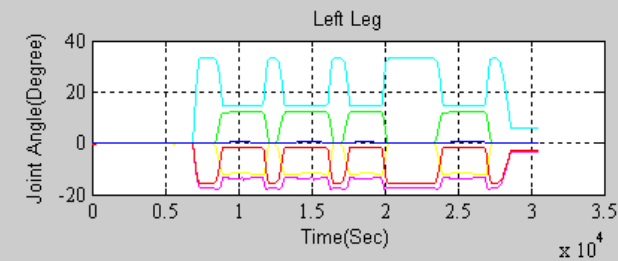Set_2 : 2   , 6  ,10
Set_3 : 3   , 7  ,11
Set_4 : 4      8    12

# Foot Force Placement

# Foot Force Placement

Left Slope

Blend knee

Right Slope

Front Slope

Back Slope

Right Lift
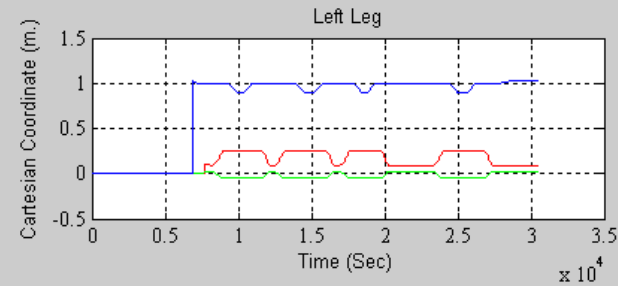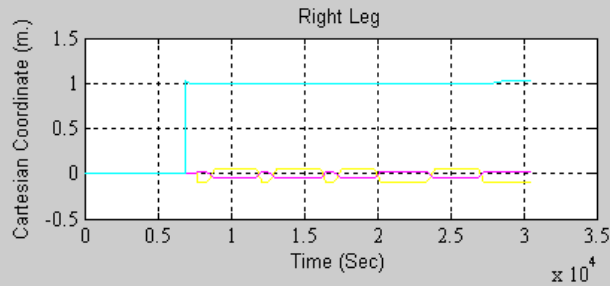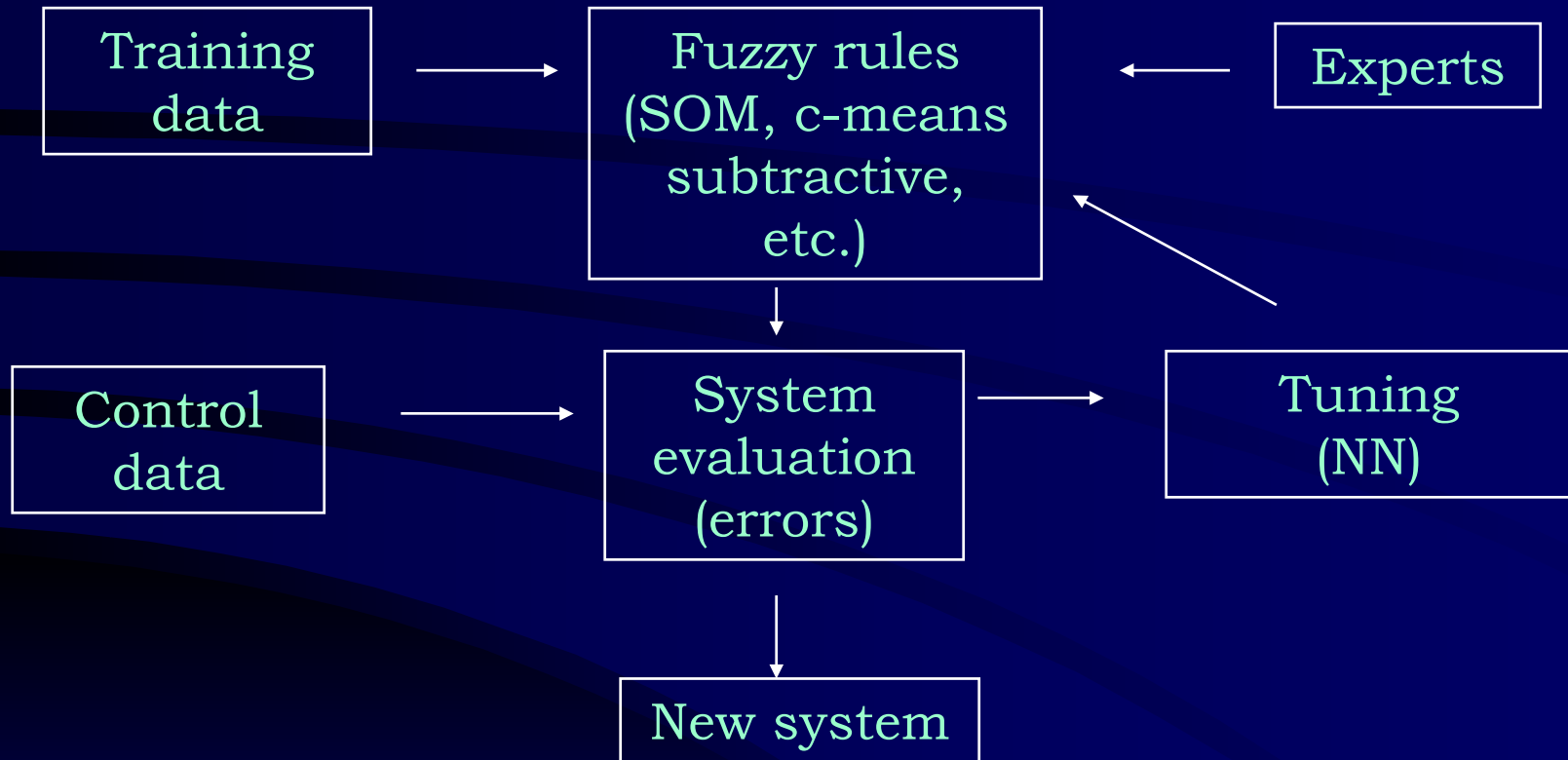
Left Lift

# Foot Force Placement
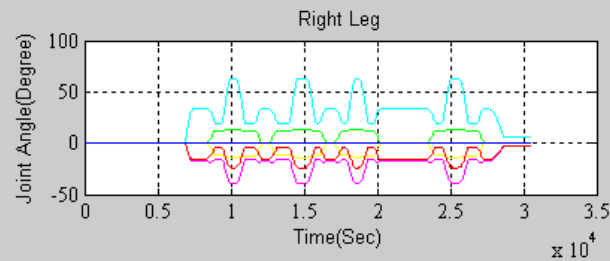


Right slope → Left Lift → Left Down, Front Slope

# Neuro-fuzzy system construction

# Takagi-Sugeno model generation

- Step 1 : Structure identification
  - Methods of fuzzy clustering
- Step 2 : Identification of parameters of the consequent part of the rule adaptation of parameters of the consequent part of the rules
  - Least square method, Reclusive LSE
- Step 3 : Self growing and pruning Rule of Neuro-fuzzy system

# Fuzzy Subtracting Clustering

- A technique for automatically generating fuzzy interference systems by detecting clusters in input-output training data

- One-pass algorithm foe estimating the number of clusters and the cluster centers in a set of data
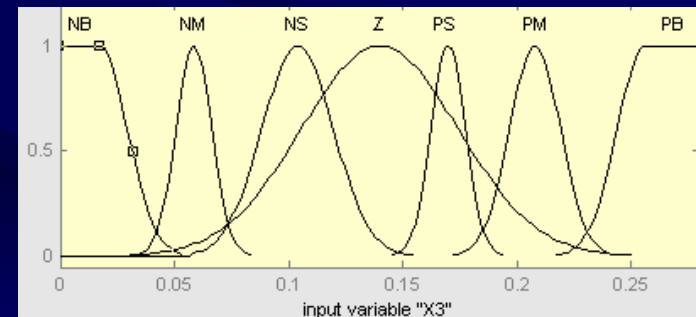
- Density measure at the data point

$$D_i = \sum_{j=1}^{n} \exp\left(-\frac{\|x_i - x_j\|}{(r_a/2)^2}\right)$$

$$D_i = D_i - D_{c1} * \exp\left(\frac{-\|x_i - x_{c1}\|^2}{(r_b/2)^2}\right),$$

# Constructing gait synthesis membership function and rule base
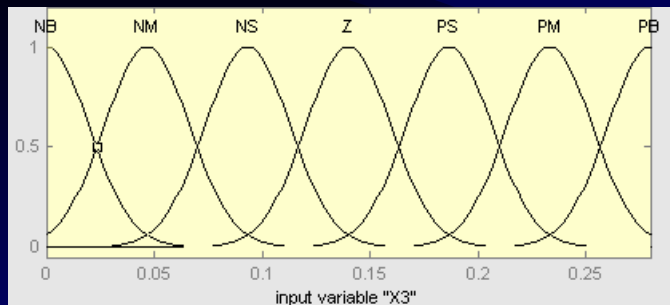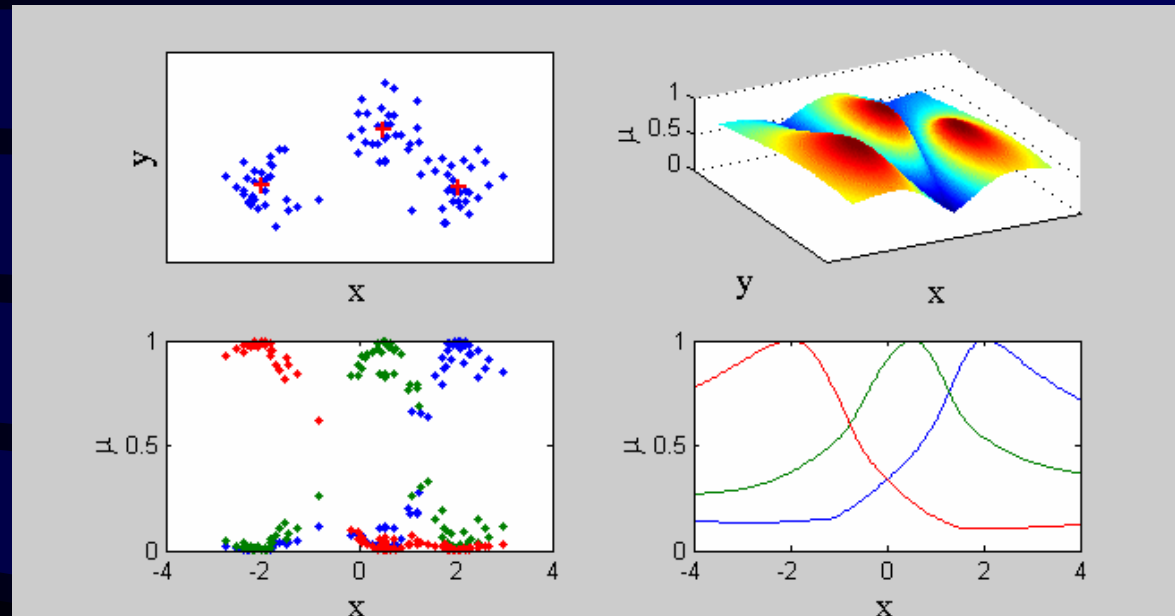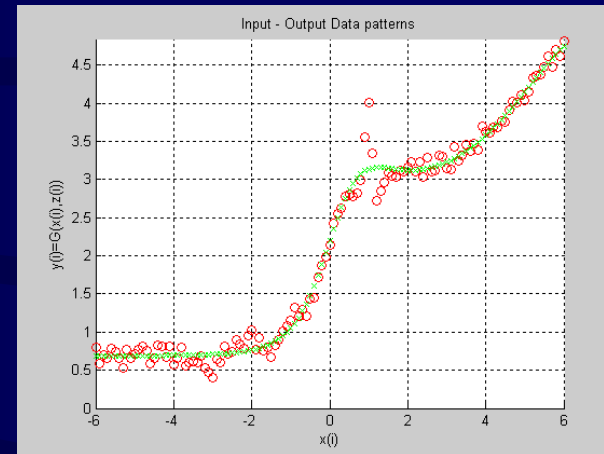


(a) Before Training          (b) After training
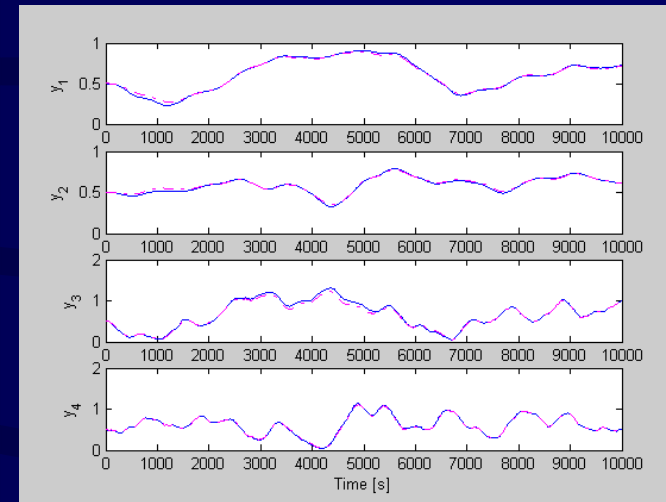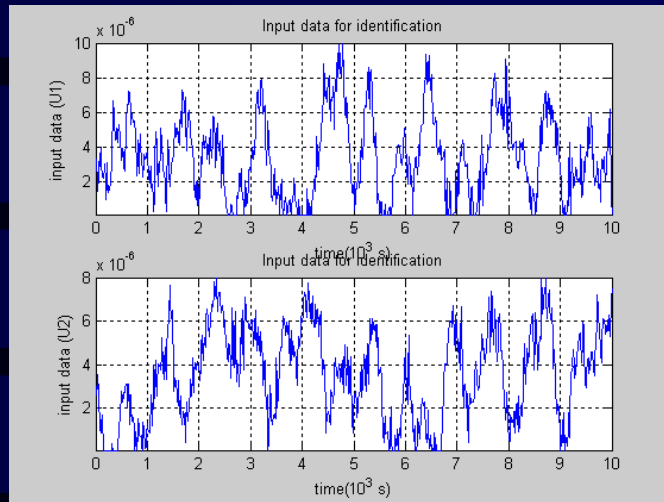
# Subtractive Clustering

- **Fuzzy Approximating unknown function by using Subtractive Clustering**
  trnRmse = 5.8376e-004

  After ANFIS (50 Epochs) :
  trnRmse2 = 5.0199e-004
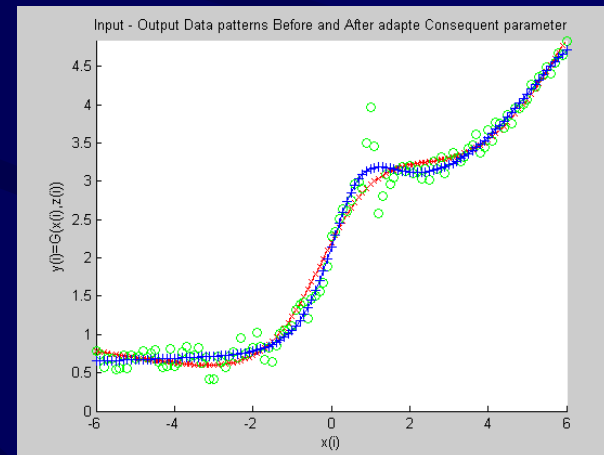
# MIMO identification



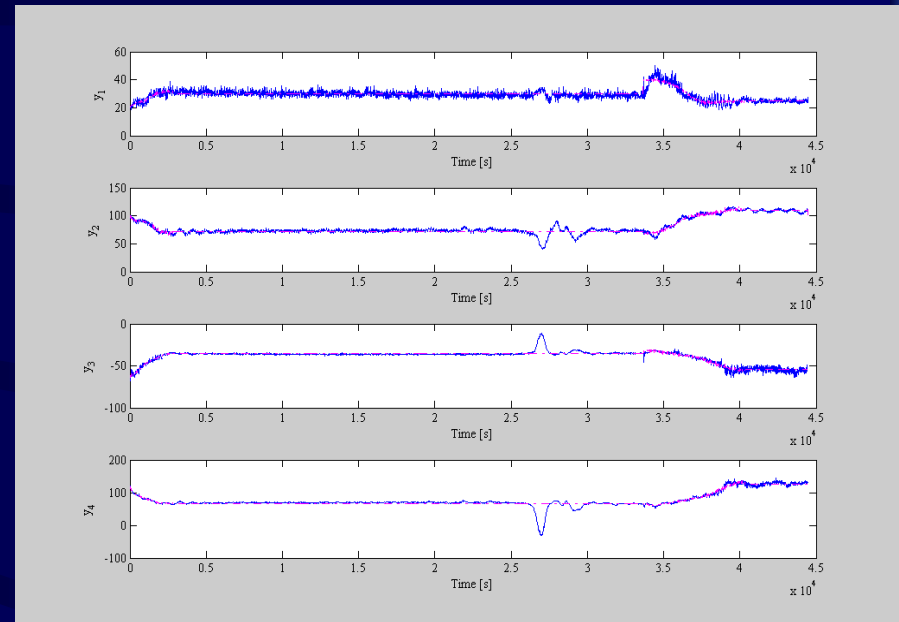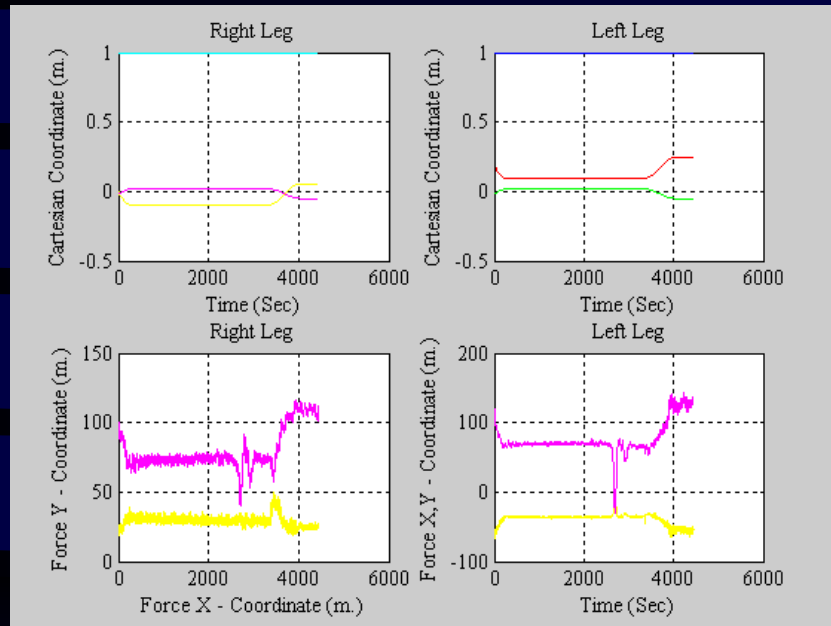$$VAF = 100\% * [1 - \frac{\mathrm{var}(y_d - y_f)}{\mathrm{var}(y_d)}]$$

VAF =

99.4162
98.6394
98.9997
99.7205

# Leg trajectories and Foot force Placement

- Relation between Leg trajectories and Foot force based on Neuro-Fuzzy Modeling
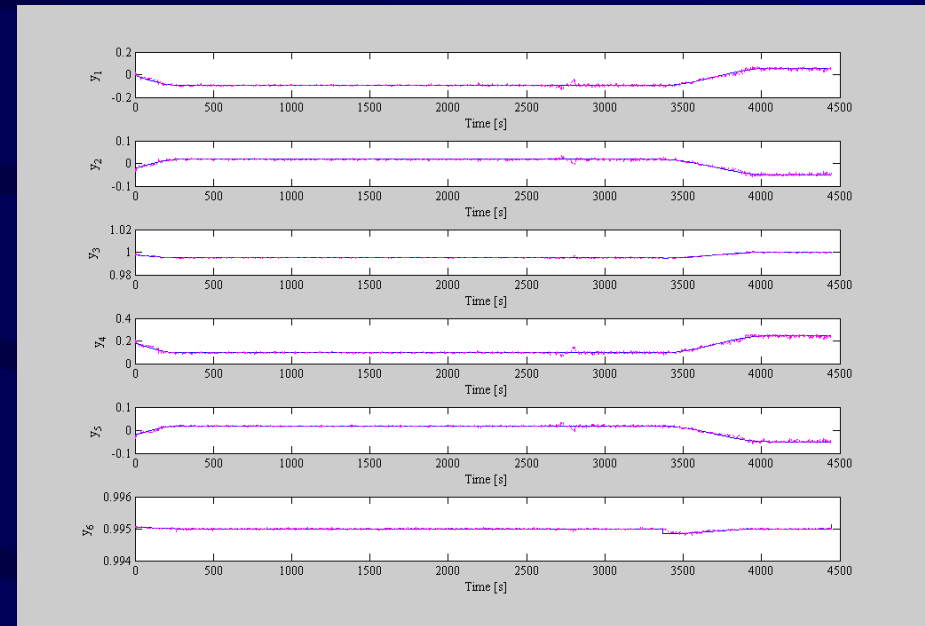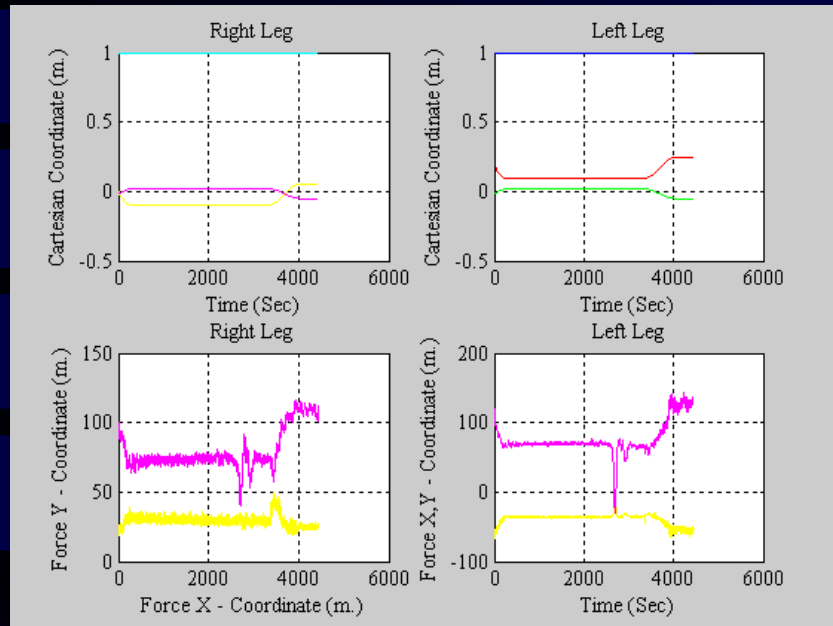
- Takagi-Sugeno, 5 Clustering MF

# Leg trajectories and Foot force Placement



- Input : Desired Right, Left Foot
- Output : Foot Force Placement

VAF = 69.0012
90.0257
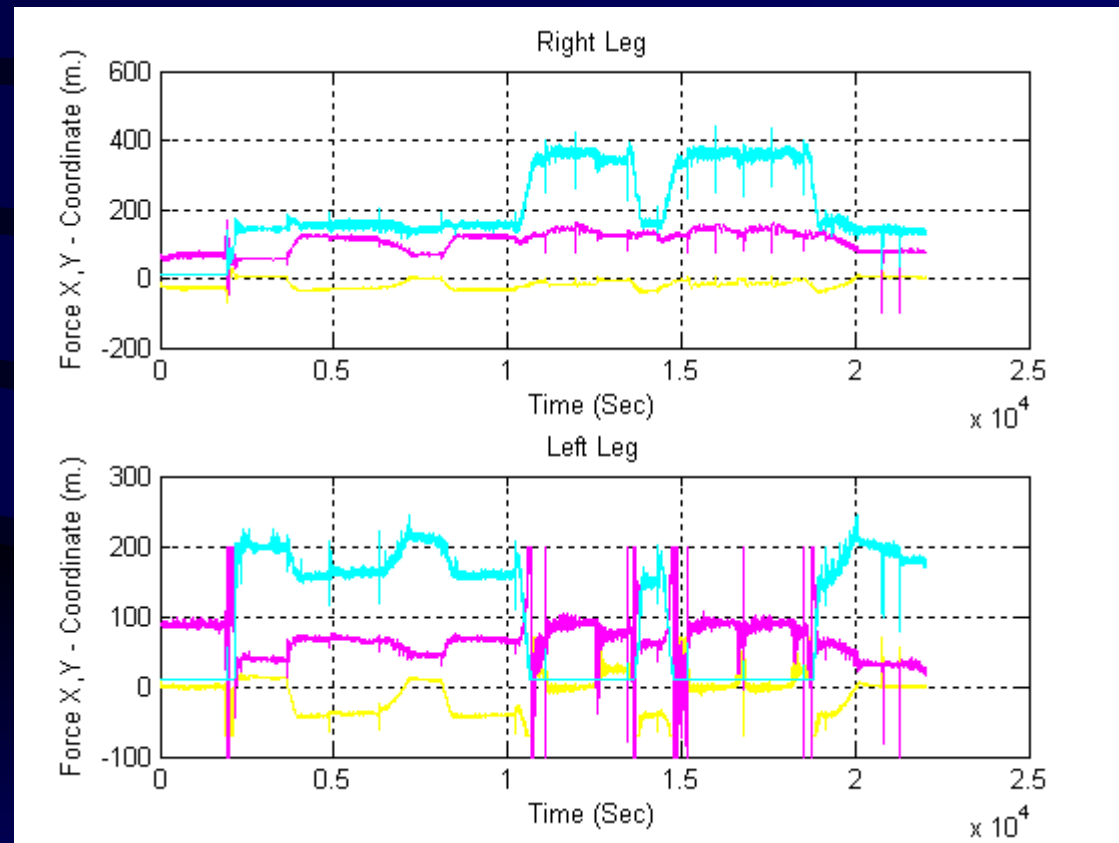87.1980
79.4755

# Leg trajectories and Foot force Placement



• Input : Foot Force Placement

• Output : Desired Right,Left Foot

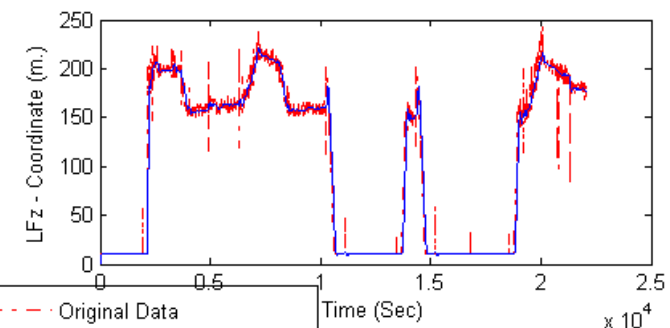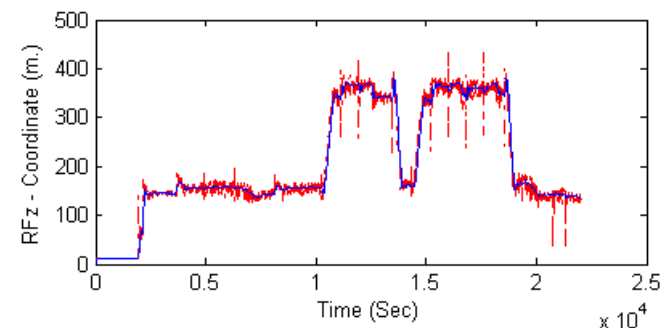VAF =

98.0101

97.9989
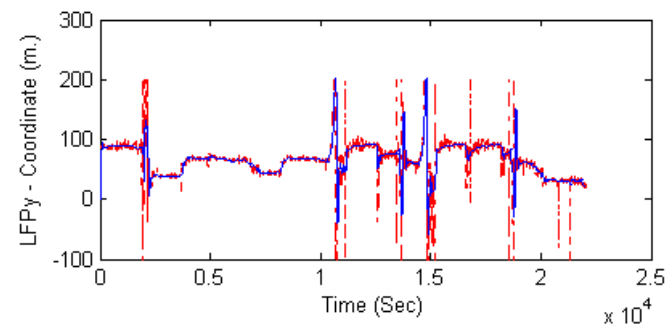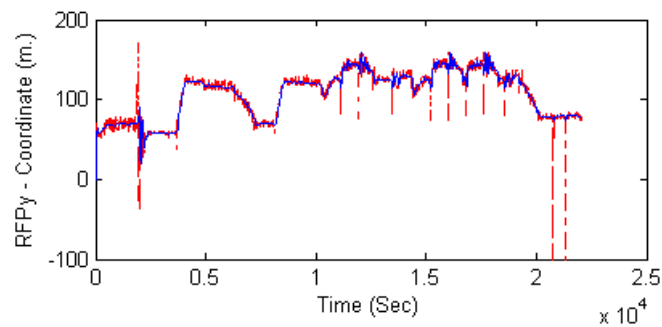
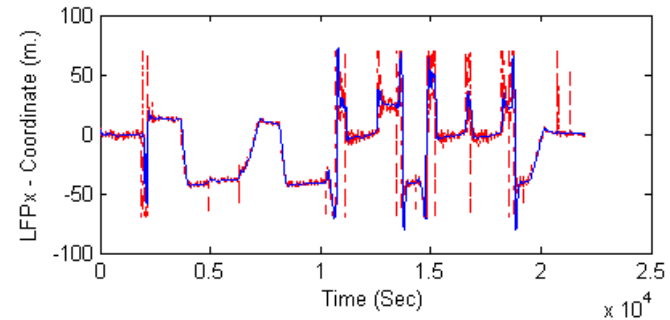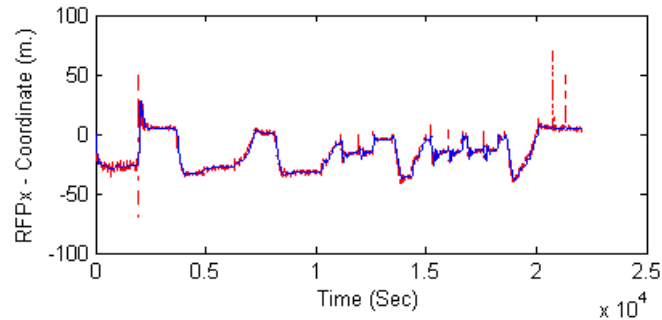97.9921

98.0120

97.9911

73.0810

# Problem on Foot Force Placement

1. Impact Force during foot contact floor

2. Noise or Miscalculating force from force  sensor

3. Bandwidth

# Force Measuring Data

# Filtering Force Data by Matlab
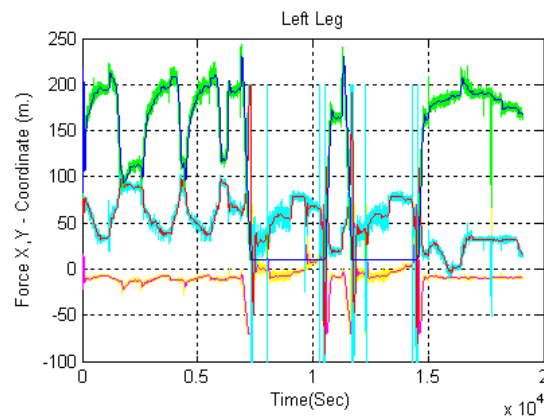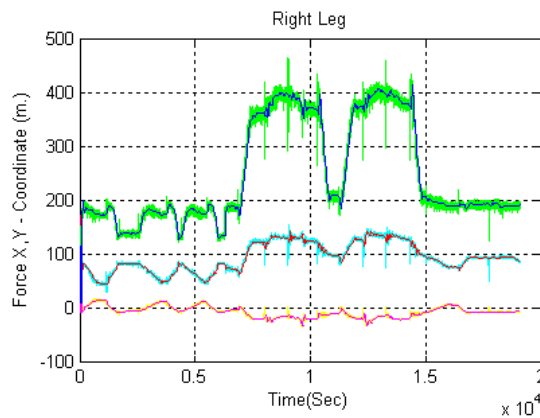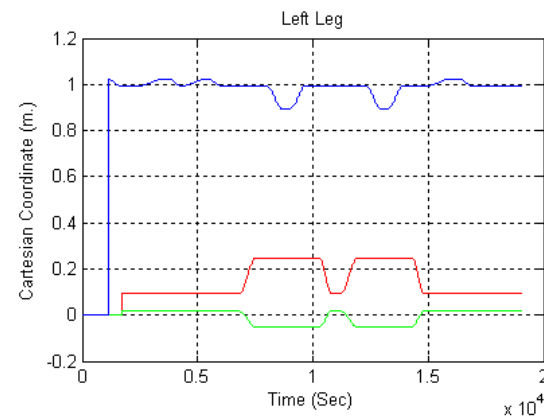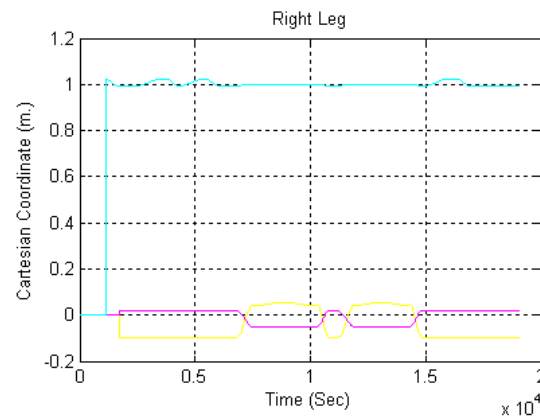
# Neuro-Fuzzy Modeling after filter

- Relation between Leg trajectories and Foot force based on Neuro-Fuzzy Modeling

$$VAF_2 = \begin{bmatrix} 93.21 \\ 77.97 \\ 50.90 \\ 90.35 \\ 78.02 \\ 50.47 \end{bmatrix}$$

$$VAF_{2,Filter} = \begin{bmatrix} 94.73 \\ 88.88 \\ 70.75 \\ 94.92 \\ 88.49 \\ 70.07 \end{bmatrix}$$

# Filtering Force Data on Humanoid Robot

- Use Butterworth 3$^{rd}$ order FIR Filter by software

# Further Work

1. New Algorithm for Force during foot contact floor

2. New algorithm for Foot Force Placement for dynamic walking

3. Adding inertial sensor to control loop

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