

NPTEL ONLINE CERTIFICATION COURSES

Course Name: Fuzzy Logic and Neural Networks

Faculty Name: Prof. D. K. Pratihar

Department : Mechanical Engineering

Week 8

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Topic

Lecture 09: Concepts of Soft Computing, Expert Systems

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CONCEPTS COVERED

Concepts Covered:

- Soft Computing
- Expert Systems
- A Few Applications

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Introduction to Soft Computing

Hard Computing

- Coined by Prof. L.A. Zadeh, University of California, USA, in 1996

Steps to be Followed to Solve Engineering Problem:

- Variables are identified and classified into two groups – input/ condition variables (antecedents) and output/action variables (consequents)

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•Input – Output relationships are expressed using mathematical equations (say differential equation)

• Differential equations are solved analytically or using numerical methods

• Control action is decided based on the obtained solutions

• Hard computing is nothing but the steps stated above

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Examples :

1. Stress Analysis using FEM
2. Determination of gain values of PID controller

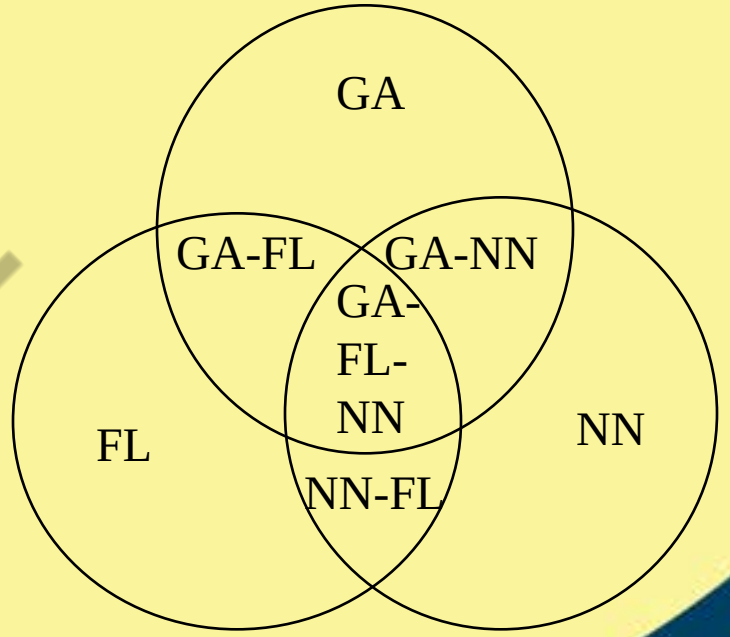
Features of Hard Computing

- Based on pure mathematics
- Yields precise solutions
- Suitable for problems which are easy to model mathematically
- May not be suitable to solve complex real-world problems

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Soft Computing

- Introduced by Prof. Zadeh, in 1992.
- Family consisting of some biologically-inspired techniques, such as Fuzzy Logic (FL), Neural Network (NN), Genetic Algorithm (GA) and their various combined forms, namely GA-FL, GA-NN, NN-FL, GA-FL-NN; in which precision is traded for tractability, robustness, ease of implementation and a low cost solution.



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Features of Soft Computing

- Does not require an extensive mathematical formulation of the problem
- May not be able to yield so much precision as obtained by hard computing
- Functions of the constituent members are complementary in nature
- Control algorithms developed based on Soft Computing may be robust and adaptive in nature

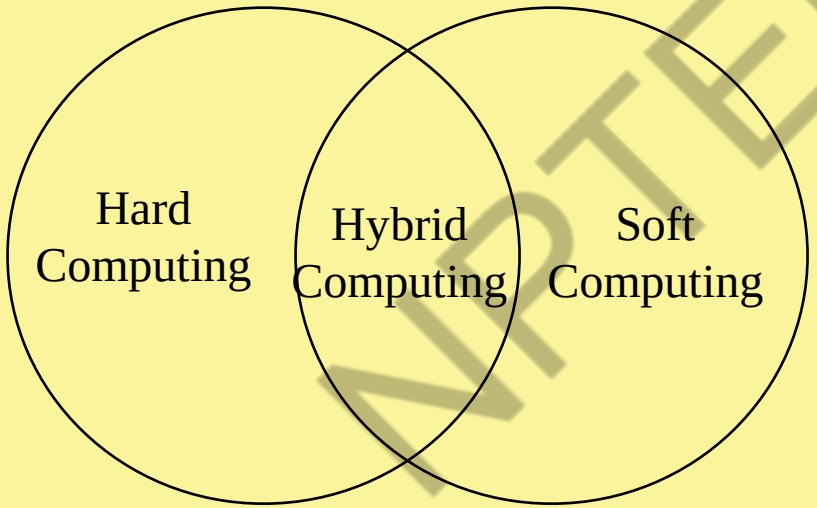
Examples:

- FL- or NN- based motion planners for intelligent and autonomous robots

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Hybrid Computing

- **Combination of the conventional hard computing and emerging soft computing**



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- A part of a complex real-world problem will be solved using hard computing and the remaining part can be tackled utilizing soft computing

- Here, hard computing and soft computing are complementary to each other

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Examples:

- Optimal design of machine elements using FEM and Soft Computing
- PID controller trained by soft computing

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Knowledge–Based/ Expert Systems

- We, human beings, have a natural quest/thirst to know input-output relationships of a process/system.

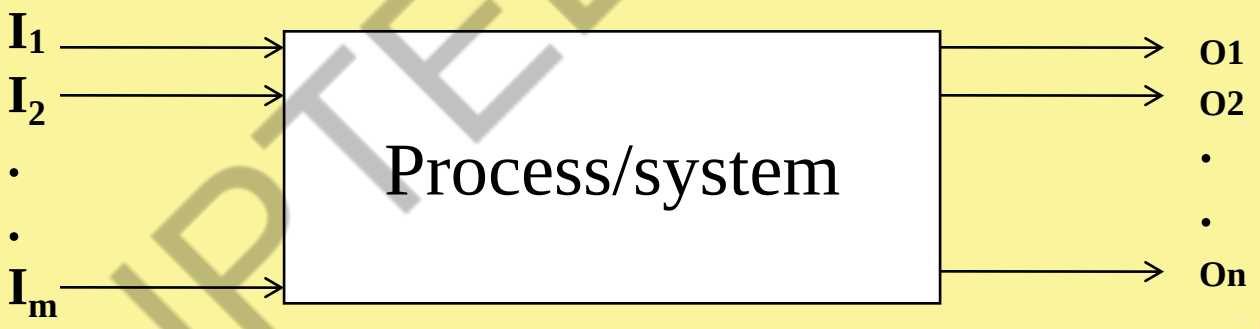
Forward Mapping

$$O = f(I)$$

$$\Rightarrow [O] = [T][I]$$

Reverse Mapping

$$[T]^{-1}[O] = [I]$$



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Methods

1. Physics → Mathematics → Differential Equations → Solutions

2. Real experiments following any statistical DOE → Regression analysis

3. Complex real-world problems → difficult to model mathematically
→ Knowledge-Based Systems/Expert Systems

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What is a Knowledge-Based/an Expert System?

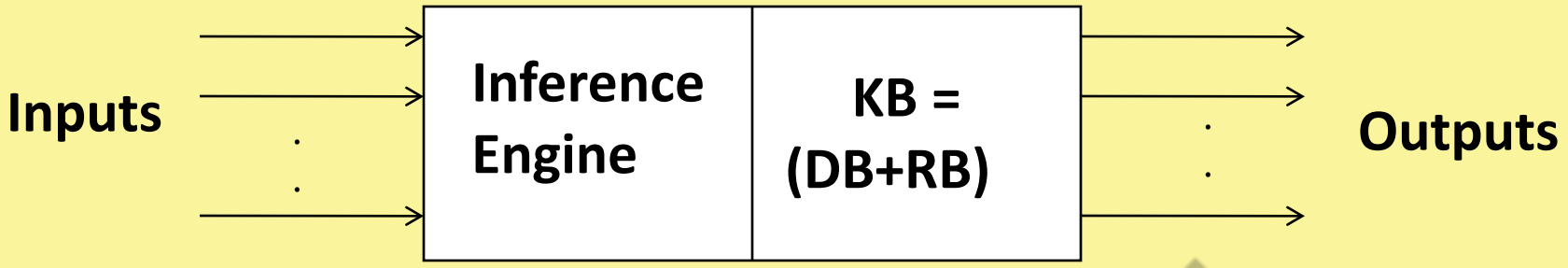
A Knowledge-based system/an expert system is a computer program used to simulate human reasoning for solving a problem

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Notes

- An expert system simulates human reasoning about a problem domain, whereas ordinary computer program simulates the domain itself.
- Solves the problems using heuristic/approximate methods
- Does not use any algorithmic and statistical method
- Consists of a Knowledge Base (KB), an inference engine and some forms of user interface

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- **DB:** A set of numerical values used to represent the physical parameters, which are presented in a particular fashion.

- **RB:** Consists of a number of rules, each of which is used to relate an output to the inputs using the information of DB.

- **Inference Engine:** For a set of inputs, it determines which part of the KB is getting fired (becoming active) to determine the output.

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Why do we need an Expert System?

- To solve complex real-world problems

- If properly developed, it may give some information, which are difficult to foresee beforehand

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Main Task

To design and develop suitable KB to solve a problem

- **We will have to take the help of Soft Computing**

- **Comes under the umbrella of Knowledge Engineering/Applied AI/ Computational Intelligence (CI)**

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Some Examples of Knowledge–Based Systems

- **DENDRAL:** To determine the structure of chemical compounds for the given set of constituent elements.

  It could discover a number of unknown structures.

- **MYCIN:** To diagnose infectious blood diseases and determine a recommended list of therapies for the patient.

- **IBM's Deeper Blue** could defeat the World Chess Champion, Gary Kasparov (1997).

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A Few Applications

- Intelligent and Autonomous Robots
- Intelligent Data Mining

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Intelligent and Autonomous Robots (Contd.)

- **Intelligent Robot**: Should be able to take decision as the situations demand
- **Autonomous Robot**: Should have the permission to act as an intelligent robot
- **Adaptive Motion Planner & Controller** (AI to be merged with Robotics); Ex. Robot Soccer
- **Ultimate Goal of the RoboCup**: "By the mid-21st century, a team of autonomous humanoid robots shall beat the human World Cup champion team under the official regulations of FIFA"

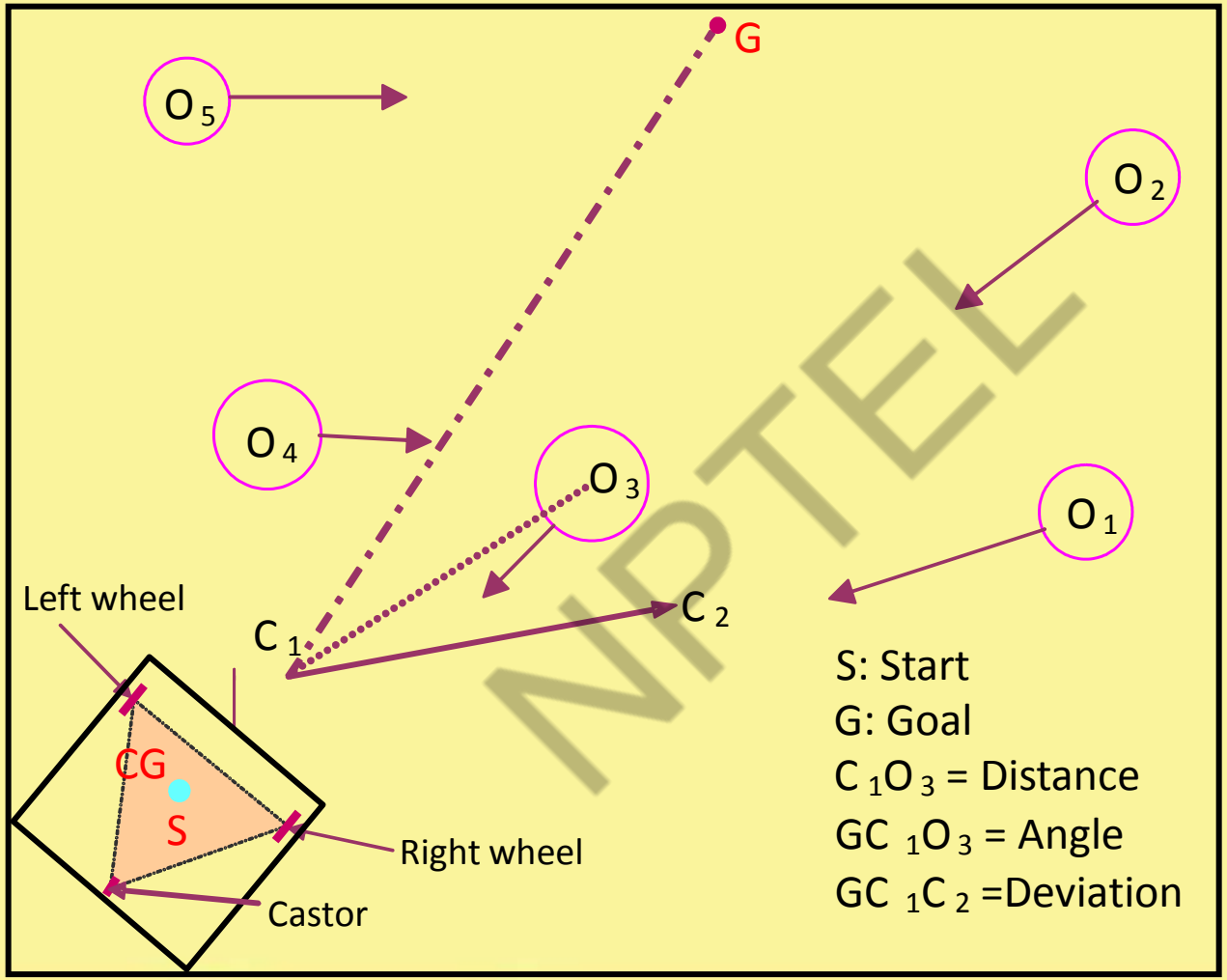
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Role of CI to Develop Intelligent Robots

- Adaptive Motion Planner
- Adaptive Controller
- Robot Vision
- Adaptive Gait Planner

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Adaptive Motion Planner



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Adaptive Motion Planner (Contd.)

Optimization

Minimize

Traveling time

subject to

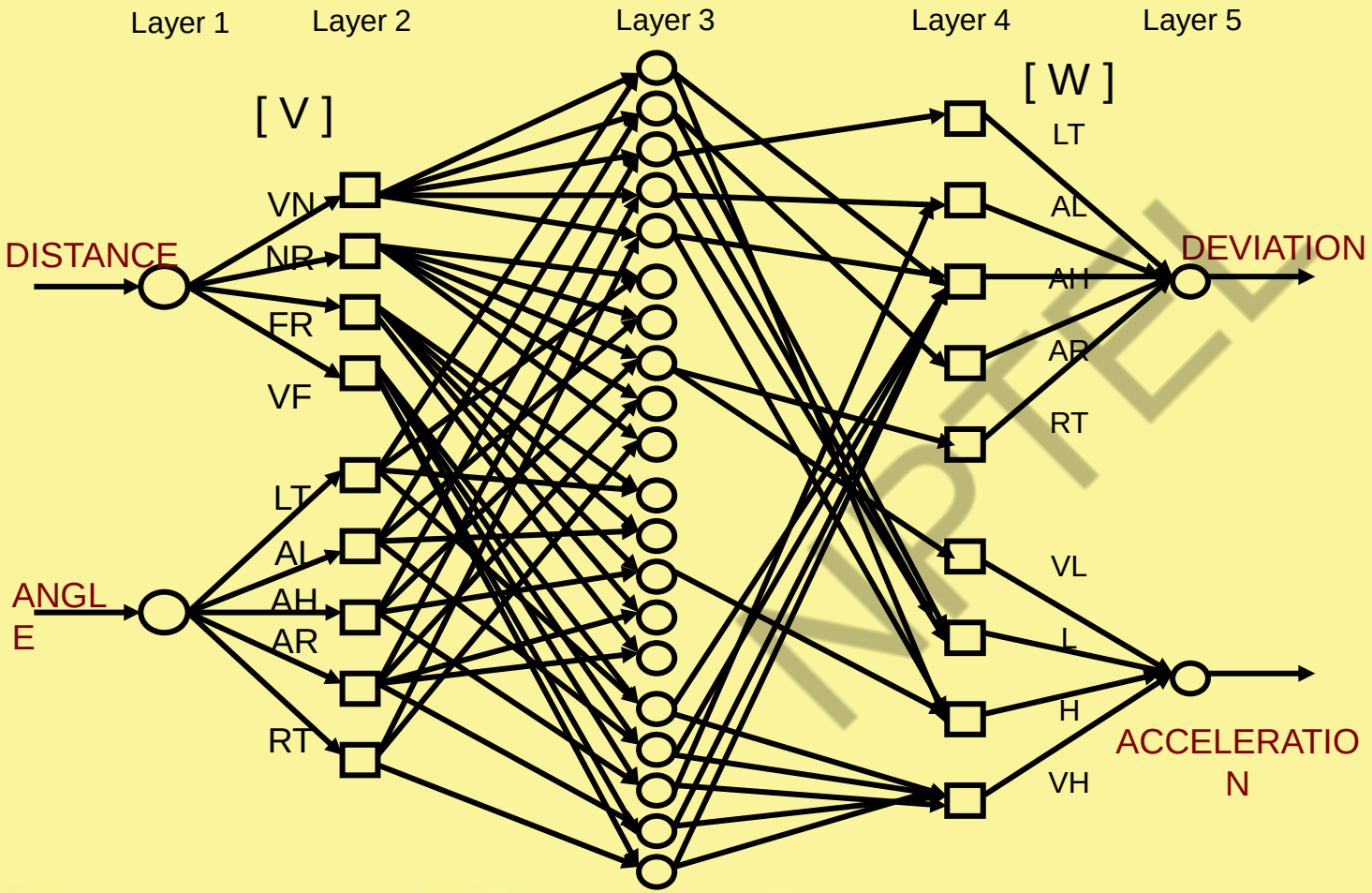
Path is collision-free

Kinematic and Dynamic constraints

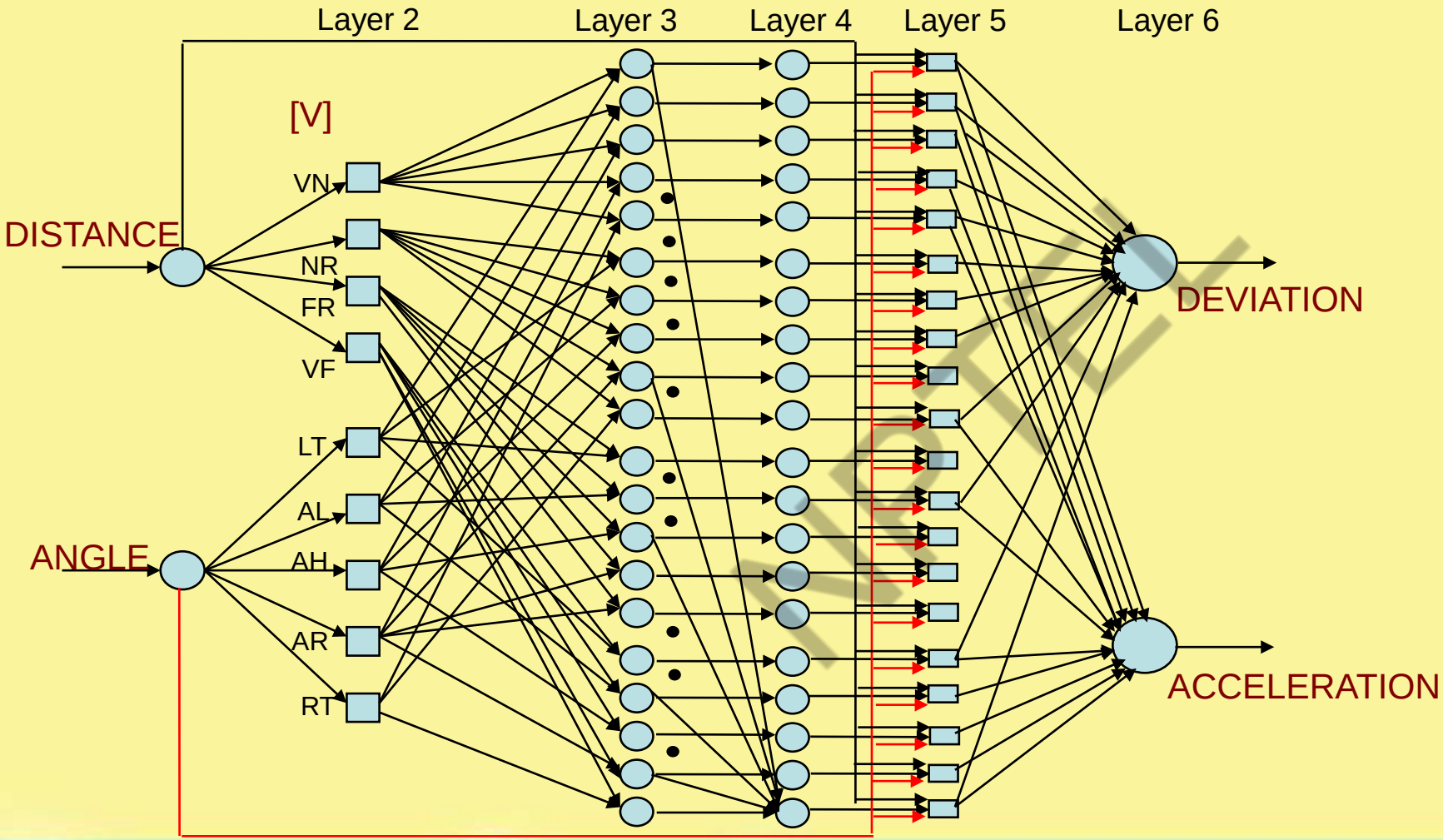
are satisfied

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Adaptive Motion Planner (Contd.) – Neuro-Fuzzy System



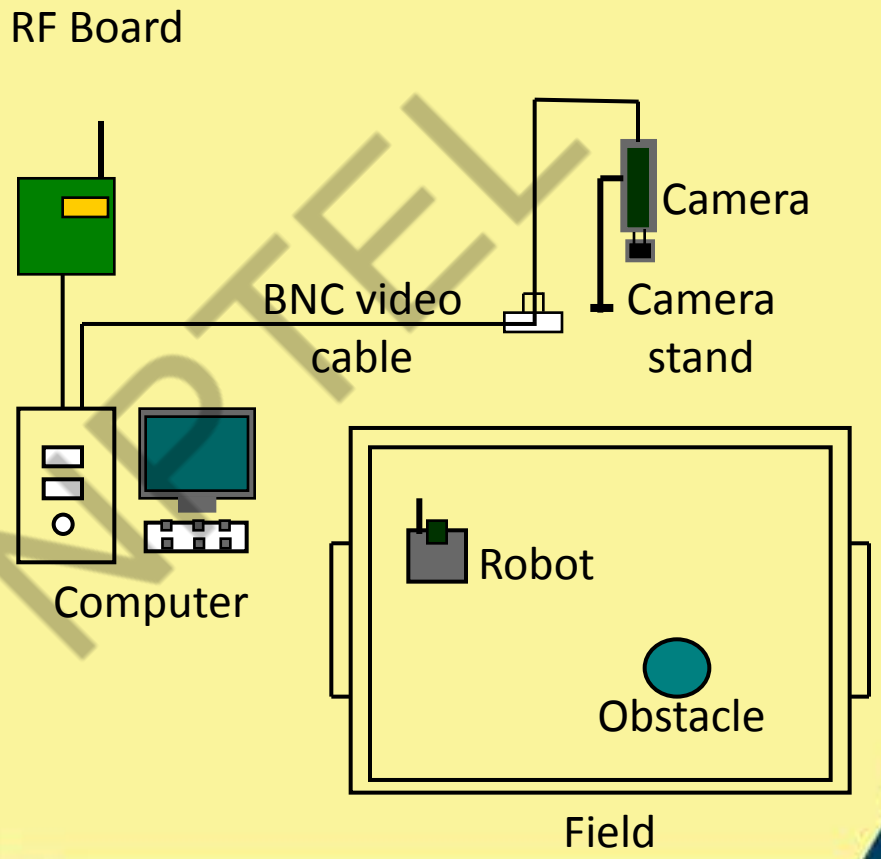
Adaptive Motion Planner (Contd.) – Neuro-Fuzzy System



Experiment on Real Robot



Experimental Set-up



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Adaptive Motion Planner (Contd.)

Research Issues

- On-line learning of the motion planner
- De-Centralized Multi-Agent System

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Adaptive Controller

- Joint torque τ can be represented as follows:

$$\tau = D(\theta)\ddot{\theta} + h(\theta, \dot{\theta}) + C(\theta)$$

where

$D(\theta)$: inertia terms

$h(\theta, \dot{\theta})$: Coriolis and centrifugal terms

$C(\theta)$: gravity terms

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Adaptive Controller (Contd.)

Let us consider Partitioned Control Scheme

$$\tau = \alpha\tau' + \beta$$

where $\alpha = D(\theta)$

$$\beta = h(\theta, \dot{\theta}) + C(\theta) + F(\theta, \dot{\theta})$$

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Adaptive Controller (Contd.)

$$\tau' = \ddot{\theta}_d + K_P E + K_D \dot{E}$$ (for PD control law)

$$\tau' = \ddot{\theta}_d + K_P E + K_I \int E dt + K_D \dot{E}$$ (for PID control law)

where E = error = $\theta_d - \theta$

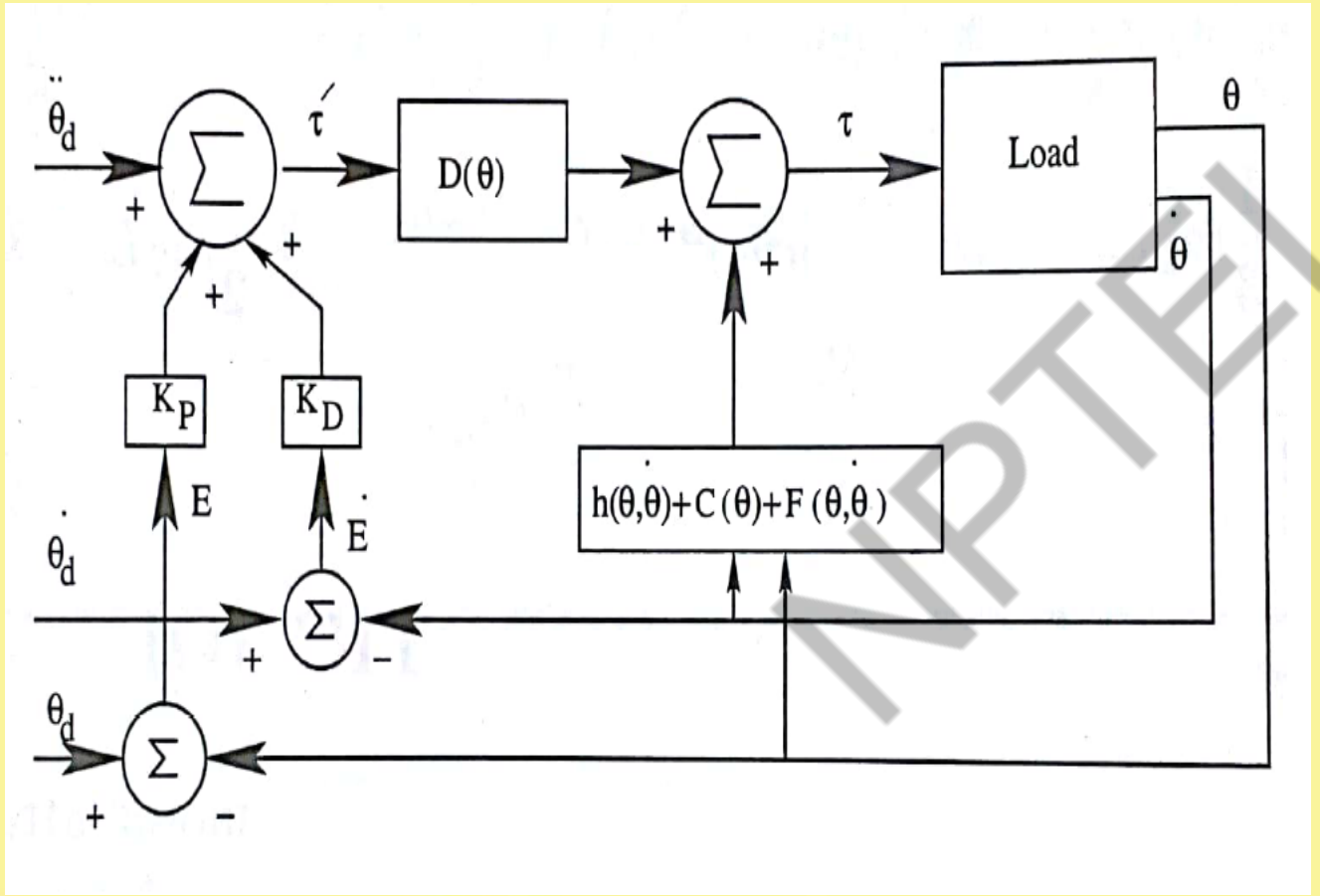
where θ_d : Desired value of θ

θ : Actually obtained value of θ

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Control Architecture



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Adaptive Controller (Contd.)

- Gain values can be determined using Ziegler-Nichols method

- Adaptive values of Gains can be obtained using CI

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Robot Vision

- **Steps of vision**
  - ✓ Image capturing
  - ✓ Sampling – A/D conversion
  - ✓ Frame grabbing
  - ✓ Pre-processing
  - ✓ Thresholding
  - ✓ Edge detection
  - ✓ Boundary descriptors
  - ✓ Identification of objects

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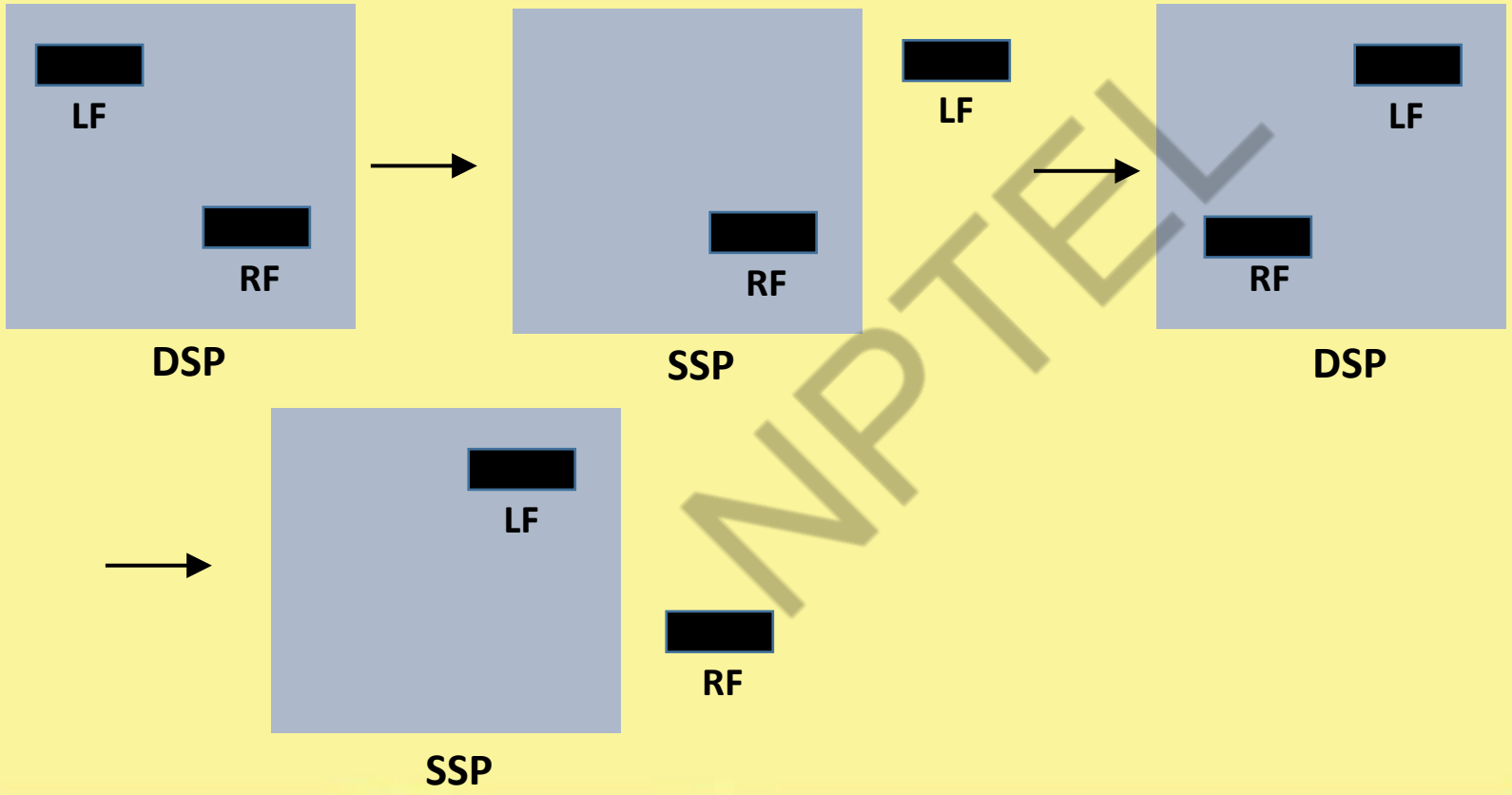
Adaptive Gait Planner

- Gait: sequence of legs' movement synchronized with its body movement during walking

- During walking, a legged robot should be able to develop adaptive gait

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- **Biped Robot: Walking cycle consists of two single-support phases (SSPs) and two double-support phases (DSPs)**



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Adaptive Gait Planner (Contd.)

- Power consumption during walking is to be optimized
- Balance is to be maintained during walking

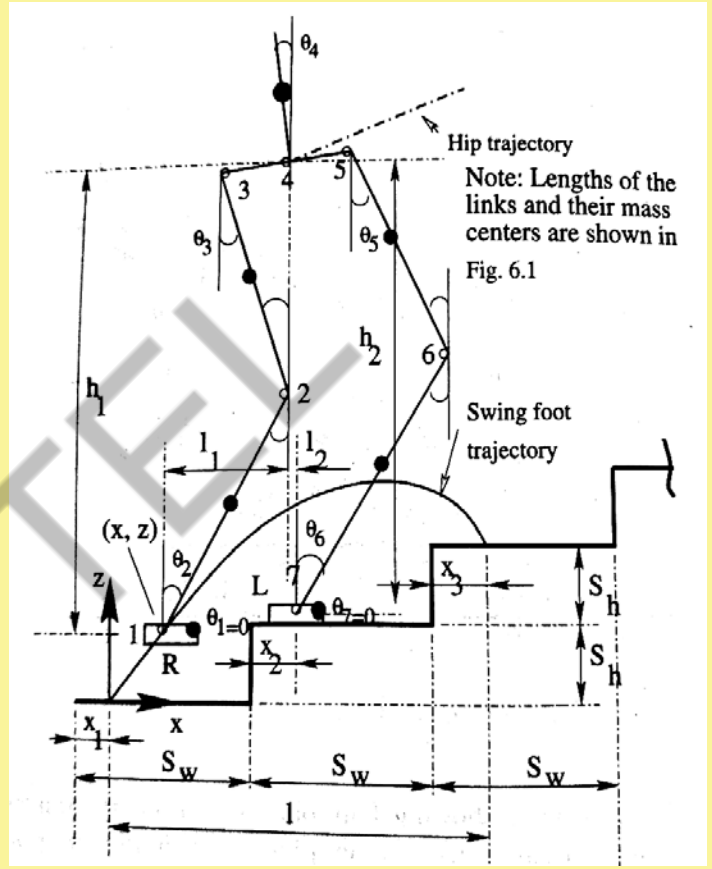
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Staircase Ascending (SSP)

- In the present study, movement has been considered in the sagittal plane only.

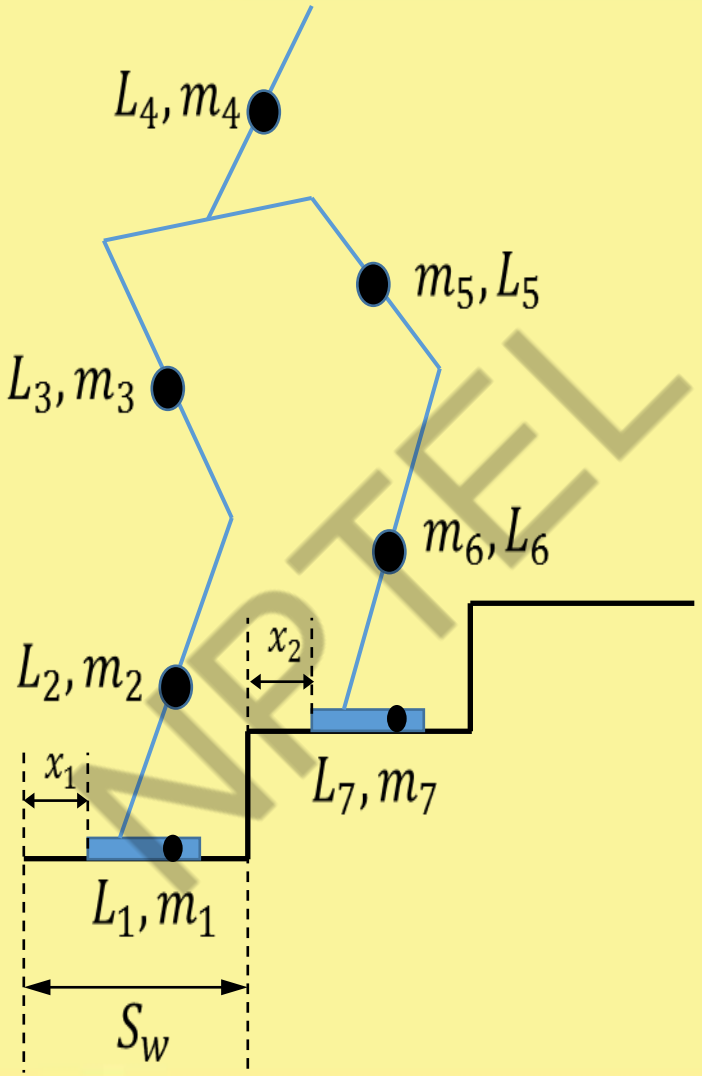
$$step\ length\ l = (2s_w + x_3) - x_1$$

$$hip\ height\ h = L_2 cos\theta_2 + L_3 cos\theta_3$$



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Double support phase



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Genetic-Neural system

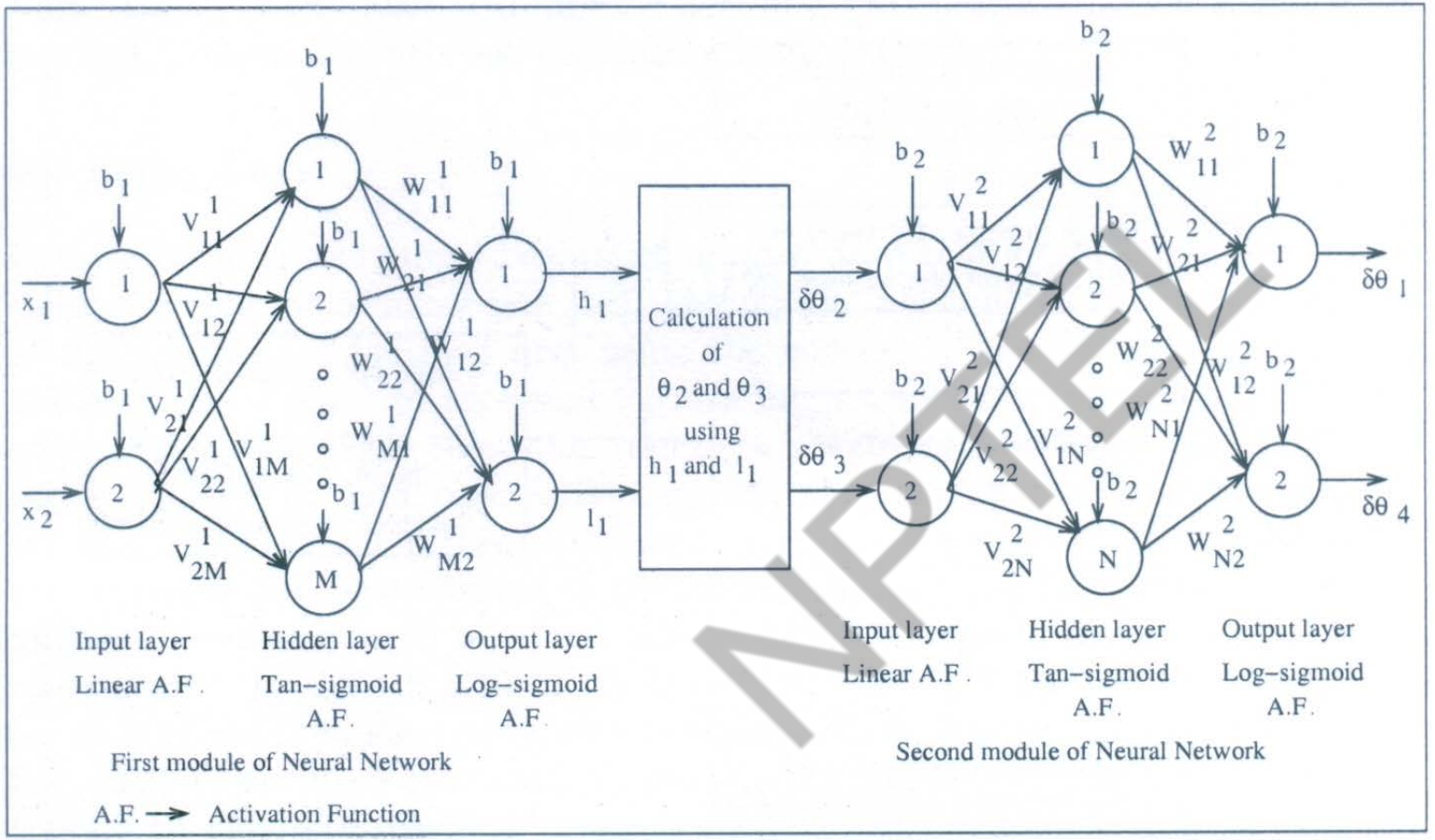


Fig. Architecture of the proposed Neural Networks

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Genetic-Fuzzy system

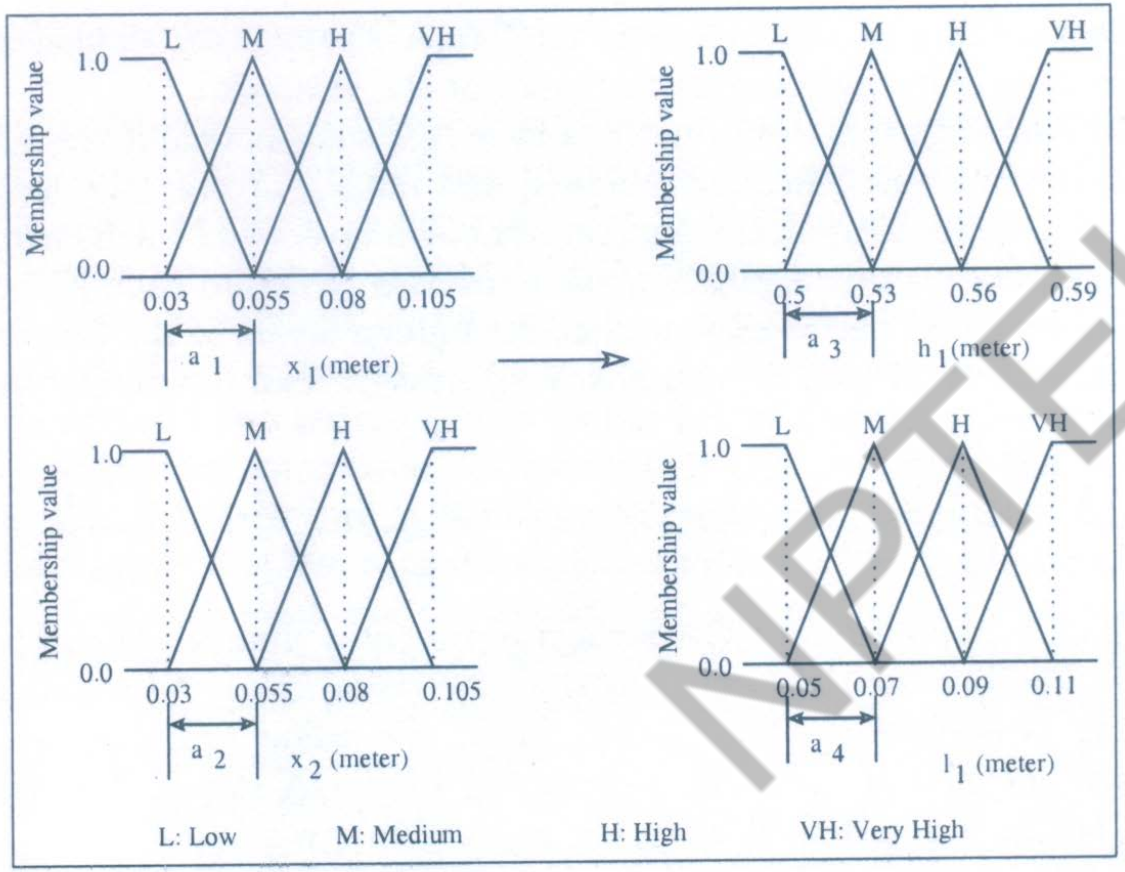


Fig. Membership function distributions for input and output variables of the first module of FLC - ascending gait generation

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Genetic-Fuzzy system (contd.)

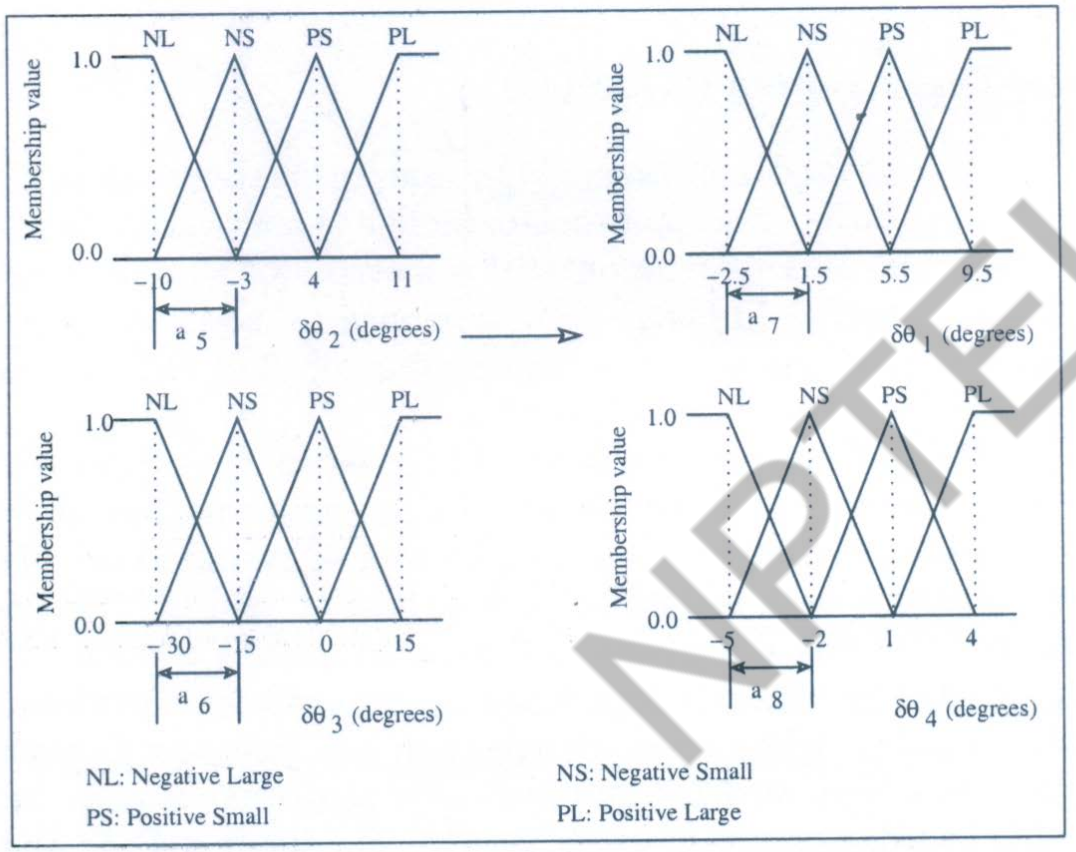
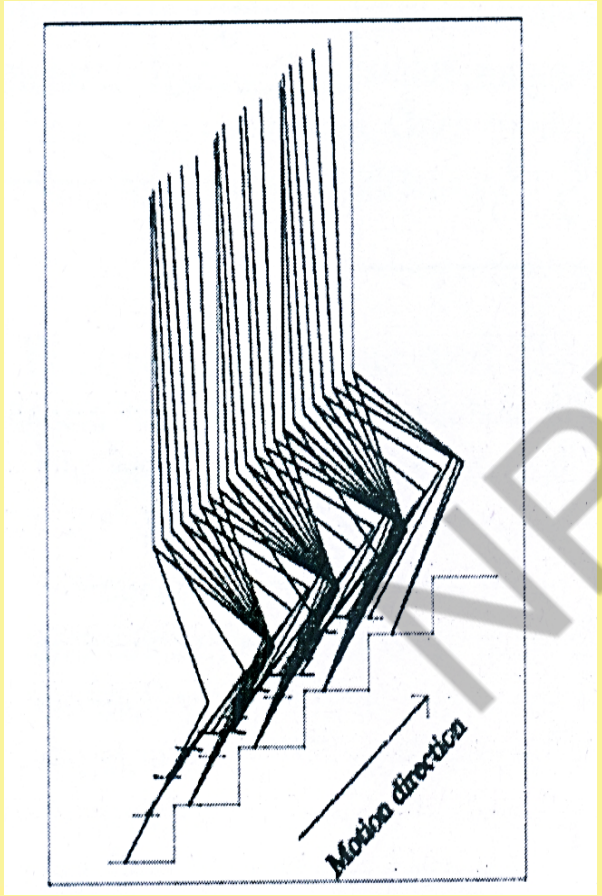


Fig. Membership function distributions for input and output variables of the second module of FLC - ascending gait generation

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Results of single support phase during ascending the staircases



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Results of Double support phase during ascending the staircases

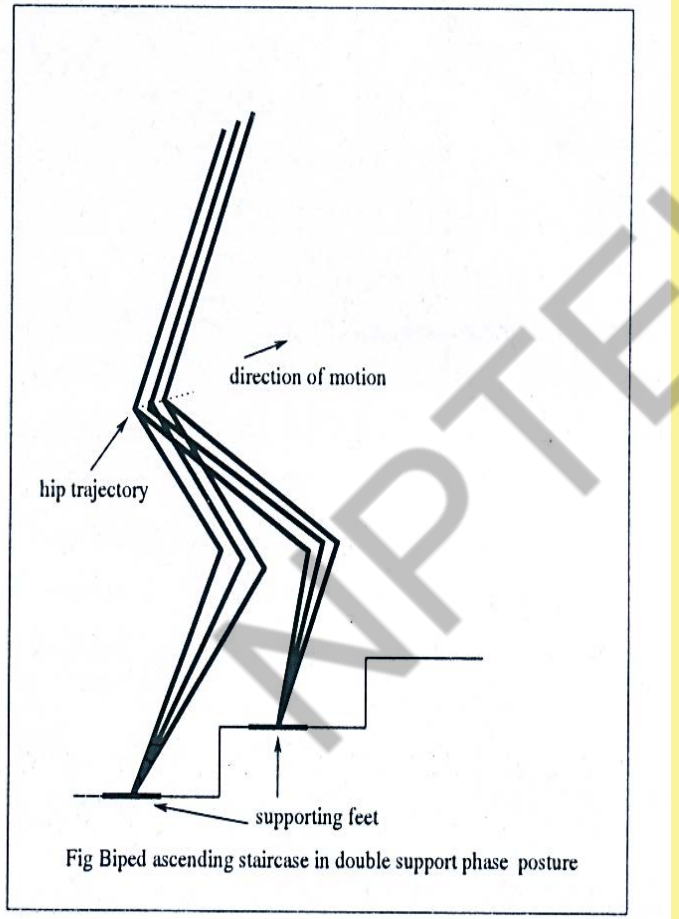


Fig Biped ascending staircase in double support phase posture

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Intelligent Data Mining

- Input-Output data are clustered based on similarity
- Dimensionality reduction for visualization
- Fuzzy Reasoning using clusters' information
- Fuzzy Reasoning tools may be developed cluster-wise

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Screening and Prediction of Psychoses

- 24 symptoms were identified according to BPRS-F2
- Data were collected with the help of 40 doctors
- Screening is done using clustering
- Prediction is done utilizing fuzzy reasoning tool

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Psychiatric data collection : Factors From BPRS-F2

- Somatic concern (A)
- Anxiety (B)
- Depression (C)
- Suicidality (D)
- Guilt (E)
- Hostility (F)
- Elated mood (G)
- Grandiosity (H)
- Suspiciousness (J)
- Hallucinations (K)
- Unusual thought content (L)
- Bizarre behavior (M)

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- Self-neglect (N)
- Disorientation (O)
- Conceptual disorganization (P)
- Blunted affect (Q)
- Emotional withdrawal (R)
- Motor retardation (S)
- Tension (T)
- Uncooperativeness (U)
- Excitement (V)
- Distractibility (W)
- Motor hyperactivity (X)
- Mannerism & posturing (Y)

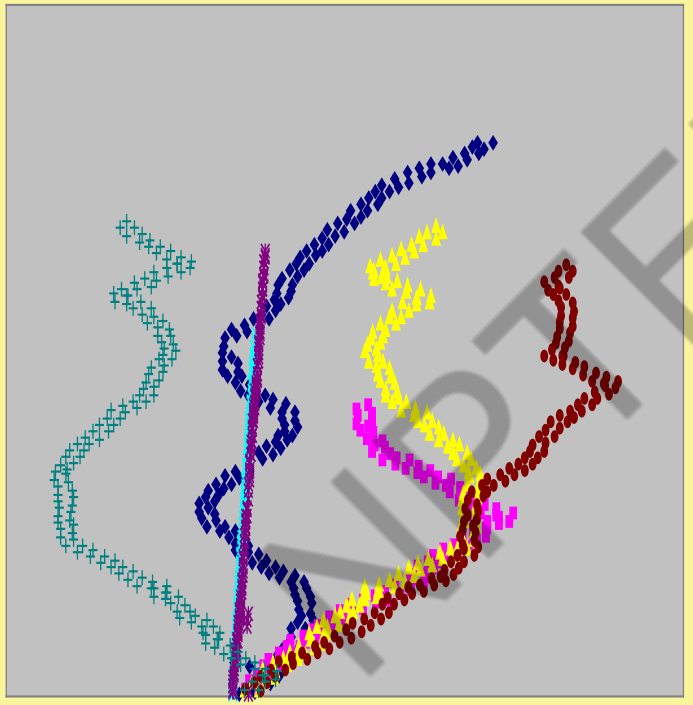
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Psychiatric data collection : Identifiable Illnesses

- Schizophrenia (R-1)
- Mania (R-2)
- Depression with psychosis (R-3)
- Delusional disorder (R-4)
- Schizoaffective disorder (R-5)
- Organic psychosis (R-6)
- Catatonia (R-7)

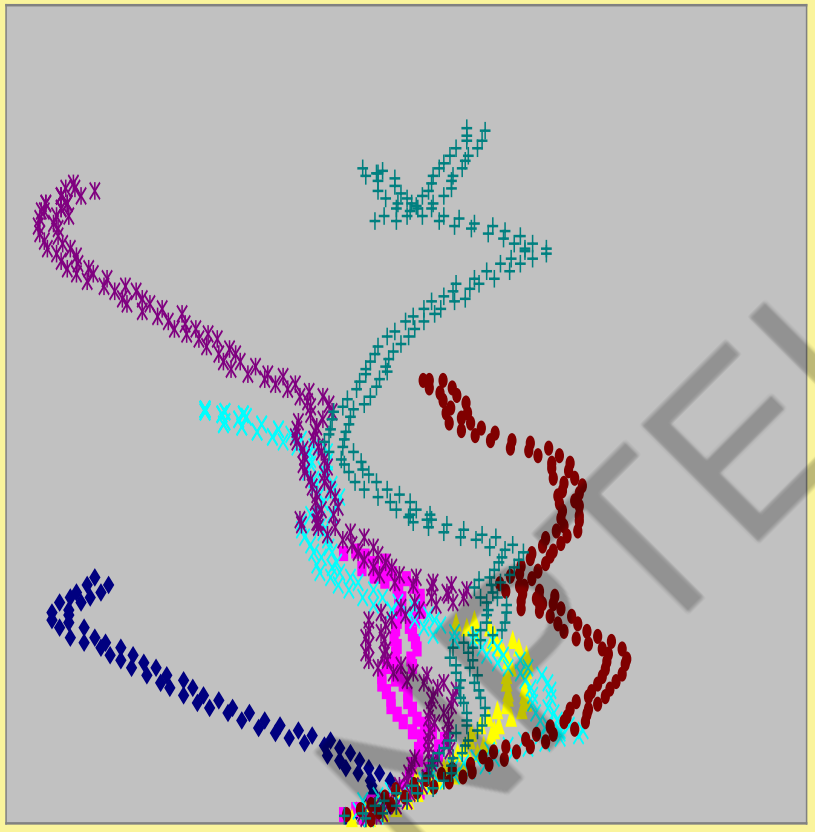
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2-D mapping with SOM



FCM-generated clusters

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EFC-generated clusters

Intelligent Data Miner

- It will be able to perform the clustering in optimal sense after adjusting its parameters in an adaptive way, so that useful information can be extracted from the data-set

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Summary of the Course

- Introduction to Fuzzy Sets; Properties of Fuzzy Sets; Standard Operations
- Fuzzy Reasoning: Mamdani Approach, Takagi and Sugeno's Approach
- Hierarchical Fuzzy Logic Controller
- Fuzzy C-Means Clustering, Entropy-based Fuzzy Clustering
- Fundamentals of Neural Networks
- Multi-Layer Feed-Forward Neural Network, Radial Basis Function Network
- Recurrent Neural Networks, Self-Organizing Map, Counter-Propagation NN
- Genetic-Fuzzy System, Genetic-Neural System, Neuro-Fuzzy Systems
- Soft Computing, Expert System
- A Few Applications

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Conclusion

Conclusion:

- Soft Computing, Hard Computing, Hybrid Computing
- Expert Systems
- A Few Applications
- Summary of the Course

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