# Master of Technology in Knowledge Engineering

**Unit 7:**

**Developing Intelligent Systems for Performing Business Analytics**

# Hybrid Architectures

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# Hybrid Intelligent Systems

- **Hybrid Intelligent systems are intelligent systems which combine two or more techniques**
  - » e.g. neural networks, fuzzy systems, genetic algorithms, etc
- **Another common term for hybrid intelligent systems is "Hybrid Soft Computing Systems" .**

# Categories of Hybrid Architectures

- **We will examine 4 broad types of hybrid system architecture**
  1. Independent sub-problems
  2. Competing Experts
  3. Self-Tuning
  4. Cooperating Experts

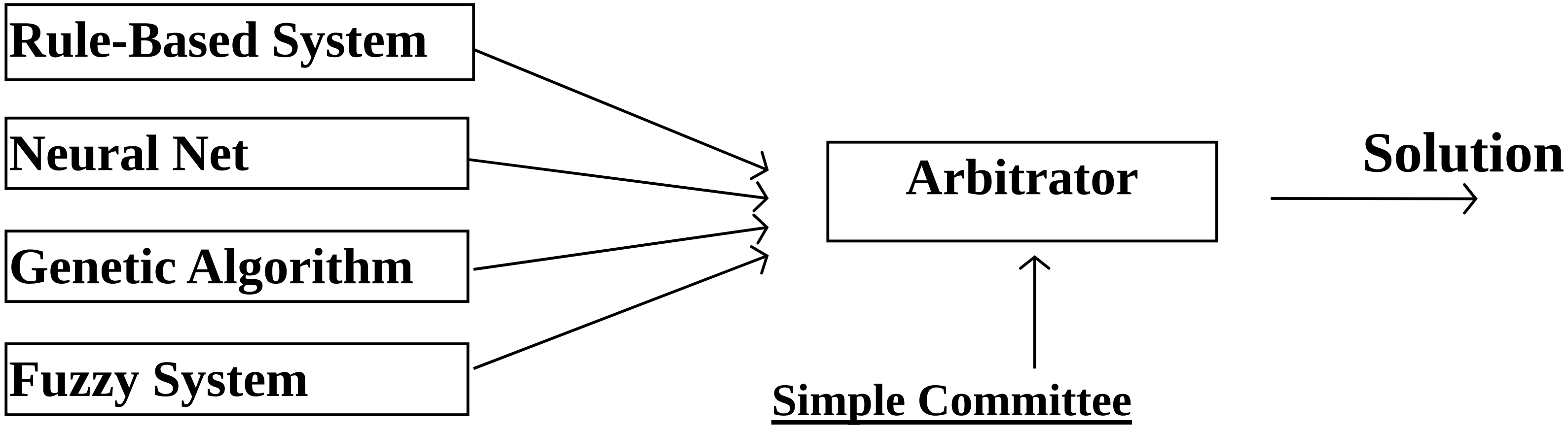
# Independent Sub-Problems

- Sub-divide problem into independent parts each solved by an appropriate solution technique
- No cooperation is required, e.g. a decision support system has several sub-systems

| Business Strategy | Production Forecast | Production Scheduling |
| --- | --- | --- |
| Rule-Based System | Neural Net | Const. Prog/ Genetic Algorithm |

# Competing Experts

- **Different solution strategies (experts) offer alternative solutions. Another process decides which solution to accept or how to combine the solutions, e.g. majority vote algorithm or a rule-based system**



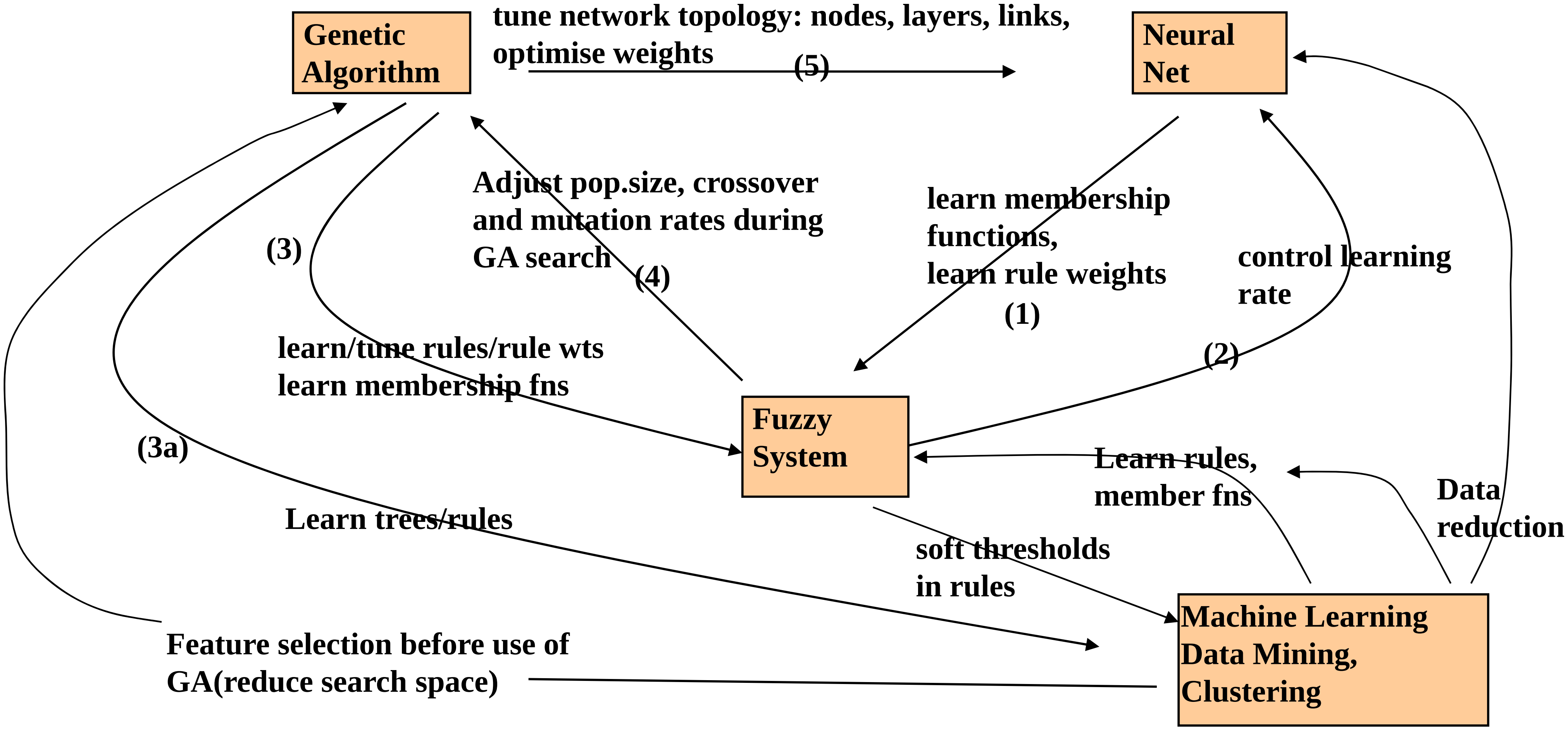

*Individual Experts*

**Simple Committee**
If majority of experts agree then good decision, else unreliable decision

**Rule-Based Arbitrator**
Weight expert judgments according to circumstances etc.

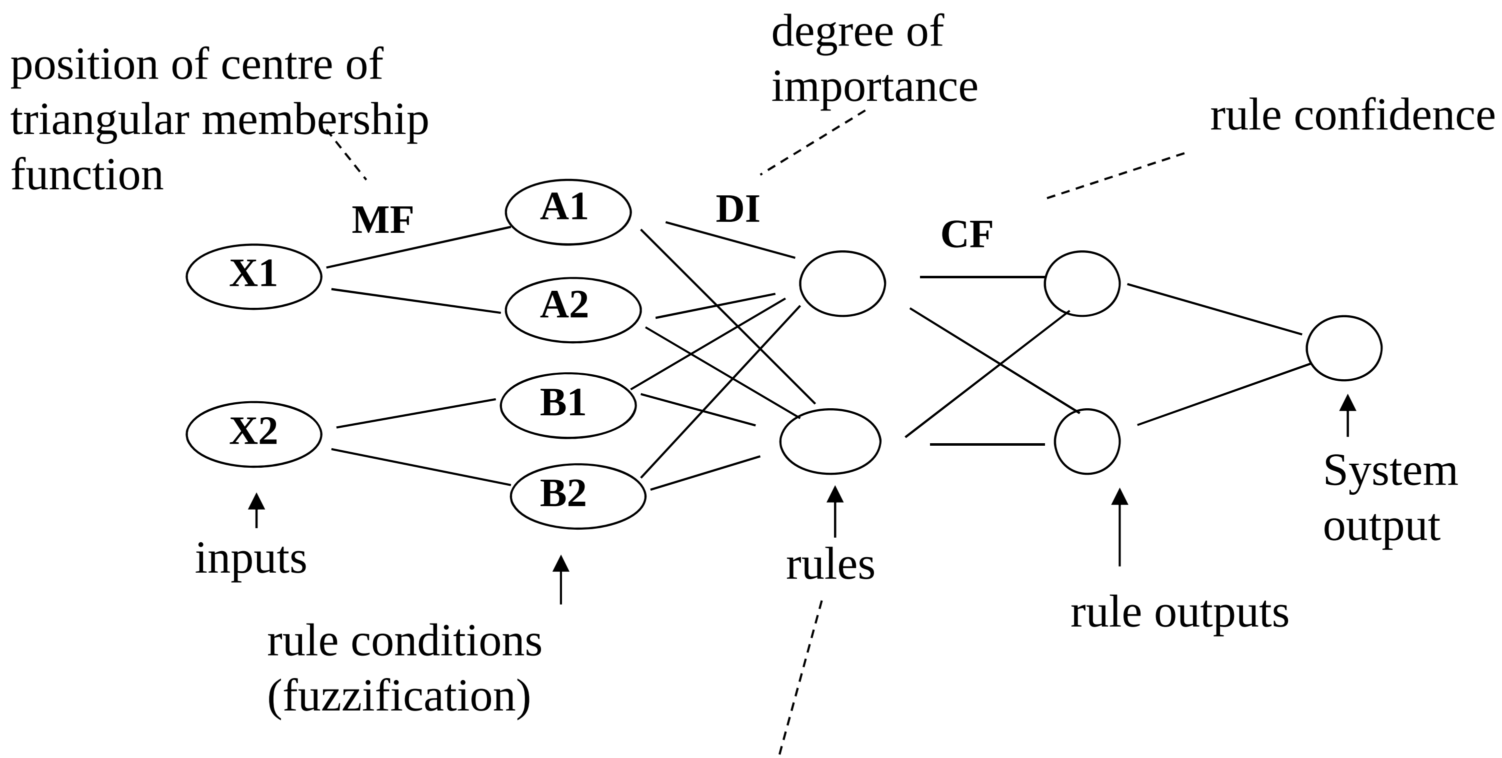
# Self-Tuning Systems

- One technique is used to tune or learn the architecture for another, e.g: NN used to learn a Fuzzy System , GA used to optimise an NN



# Self-Tuning Systems: (1) Neuro-Fuzzy

- **Neural Network is used to represent and "learn" a Fuzzy System**
- **Nodes represent rule inputs, conditions, actions etc**
- **Special training algorithm required**




*Taking only the strongest connection to each condition element yields rules like (other schemes exist):-*

e.g. If X1 is A1 (DI1) And X2 is B1 (DI2) Then output = C ( CF1)

# Self-Tuning Systems: (2) Fuzzy-Neuro

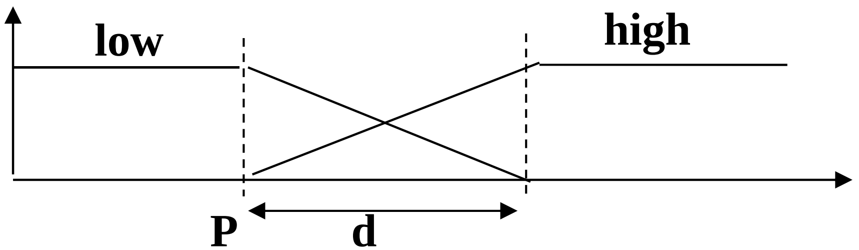
- **Fuzzy controllers have been used to control the learning rate $\eta$ and momentum coefficient $\alpha$ of Neural Networks.**
  - » In general, large $\eta$ and $\alpha$ result in fast error convergence, but poor accuracy. Small $\eta$ and $\alpha$ lead to better accuracy but slow training. However, the selections are mainly ad hoc, i.e. based on empirical results or trial and error.
- **E.g. fuzzy rule table for $\Delta\eta$ and $\Delta\alpha$**

**VS—Very Small S—Small M—Medium L—Large**

| Change of Err | Training Err | | |
|---|---|---|---|
| | Small | Medium | Big |
| Negative | VS Increase | VS Increase | S Increase |
| Zero | No change | No change | S Increase |
| Positive | S Decrease | M Decrease | L Decrease |

# Self-Tuning Systems: (3) GA-Fuzzy

- **GA tunes membership functions and/or learns fuzzy rules**
- **E.g. Each GA chromosome represents a set of fuzzy rules and input variable membership functions***
- **Inputs have two fuzzy values: *high* and *low*. Membership fns are represented using parameters P & d :**




- **Rule conditions are represented by 0 (none), 1 (var = low), 2 (var = high). Boolean output, assumed true.**
- **Consider three inputs and two rules to be learned. One chromosome could be:**

| v1 | v2 | v3 | rule1 | rule2 |
|---|---|---|---|---|
| P, d | P, d | P, d | v1, v2, v3 | v1, v2, v3 |
| 4, 3 | 1, 5 | 2, 7 | 0, 2, 1 | 2, 0, 0 |

* *Designing Breast Cancer Diagnosis Systems via a Hybrid Fuzzy-Genetic Methodology, Pena-Reyes, Sipper, 1999*

# Self-Tuning (3) : GA-Fuzzy

- **The fitness function measures the error of the rule set**
  - » e.g difference between training data and actual output from the fuzzy system

- **E.g. In the breast cancer example (previous page), fitness is similar to**

**Fitness = Fc - $\alpha$Fv**

***where***

**Fc = percentage of examples classified correctly**

**Fv = average number of variables per rule**

# Self-Tuning (3a): GA-ML

- **Learning non-fuzzy rules**
- **Example: learning rules to predict type of object**
  - » Let F1 and F2 be the input variables with
    F1 taking values {small, medium large}
    F2 taking values {sphere, cube, brick, tube}
    Let Class take values {widgets, gadgets}
  - » Then the chromosome

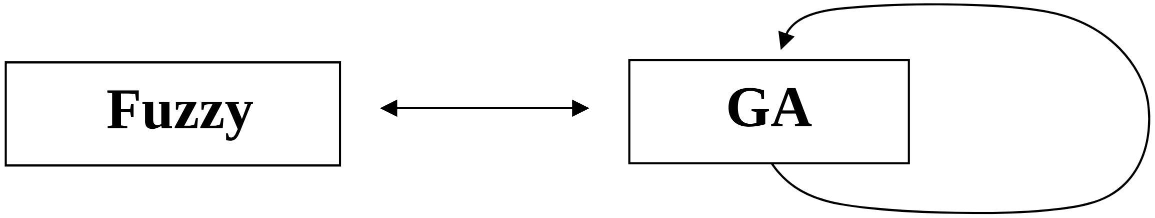
| F1 | F2 | Class |
|---|---|---|
| **110** | **0001** | **0** |

Represents the rule

**If F1 = small or medium and F2 = tube then widget**

# Self-Tuning (4): Fuzzy-GA

- **Fuzzy rules are used to adjust the GA parameters during the operation of the GA**



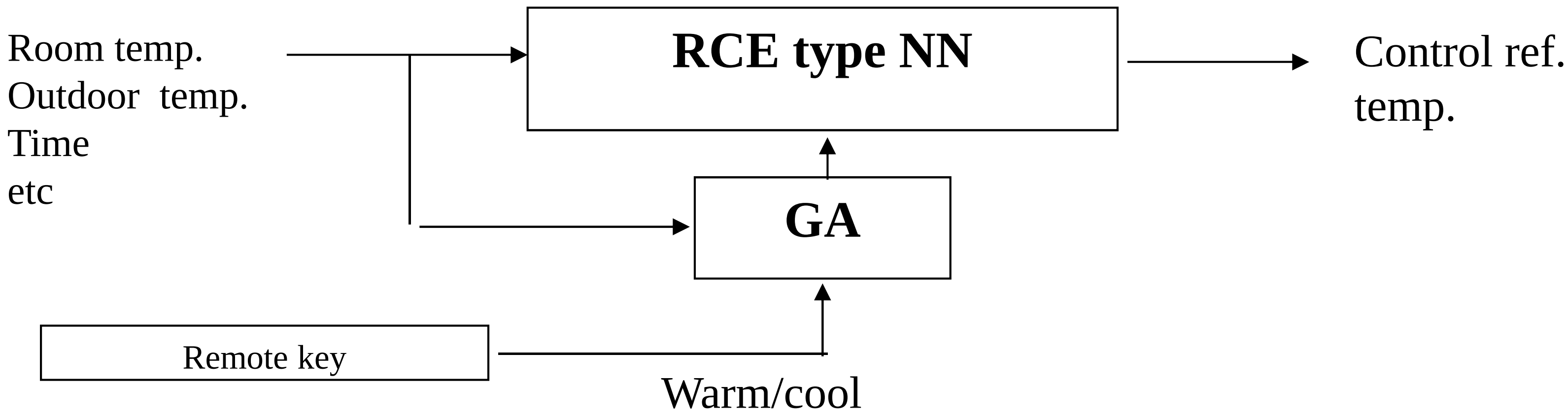

- **E.g. The Fuzzy rules take the following** <u>three inputs</u> **(Lee & Takagi 1993):**
  - » Average Fitness/Best Fitness
  - » Worst Fitness/Average Fitness
  - » Δ Best Fitness
- **And produce three outputs:**
  - » Δ Population size
  - » Δ Crossover rate
  - » Δ Mutation rate

# Self-Tuning (5): GA-Neural

- **NNs are generated/tuned by GAs**
- **GA chromosome represents NN topology**
  - » number of hidden layers, hidden nodes and number of links and/or weights
- **Pros: GA can avoid local minima more than back-prop**
- **Cons: size of chromosome gets prohibitively large if topology is being learned**

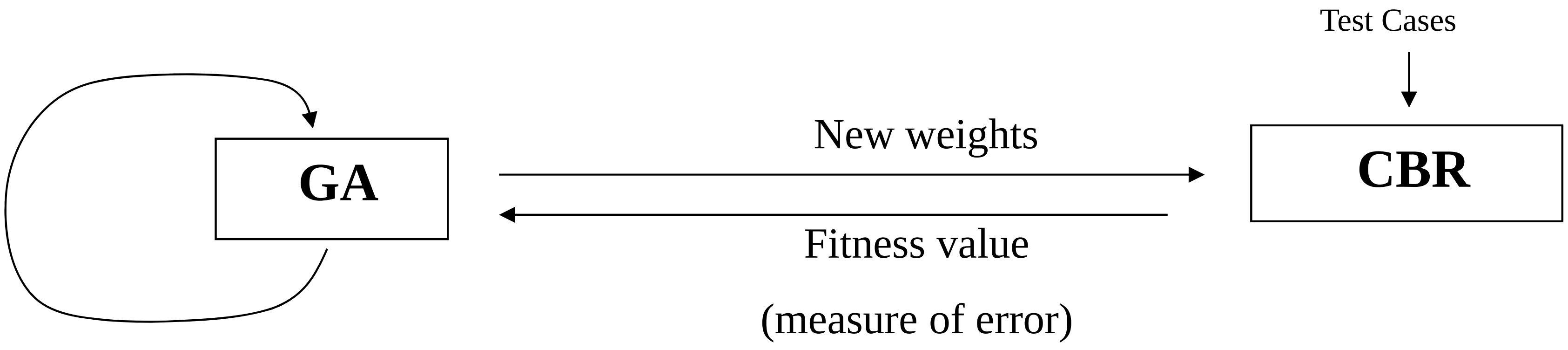
# Self-Tuning (5): GA-Neural

- **LG Electric developed an air-con controlled by an NN**
- **If the user wants the air-con to adapt to their preferences then a GA is used to change the number of neurons and weights**



# Self-Tuning (6): GA-CBR

- **GA tunes the weights of CBR Systems**

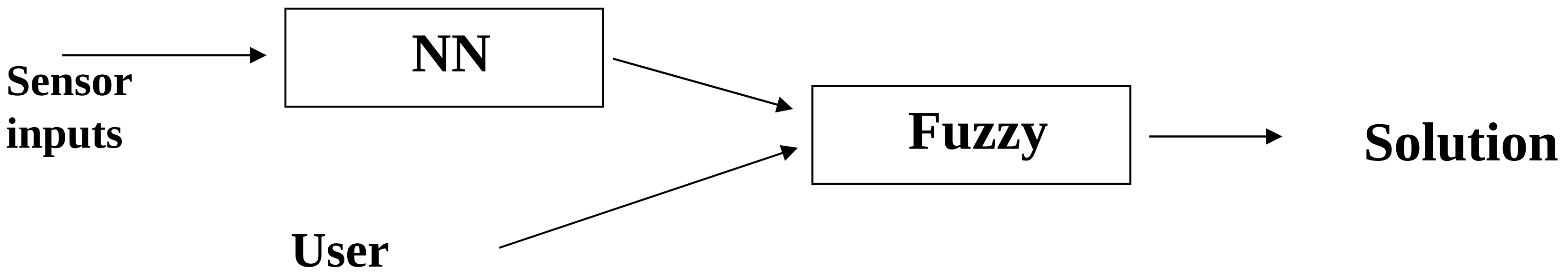



- **Cancer Recurrence Support System (CARES System)**
  - » ISS project with Singapore General Hospital
  - » Predict the recurrence of Colorectal Cancer using CBR
  - » Applied GA to data sets to search for / fine-tune the weights used in the CBR system
  - » In the preliminary trials conducted, the GA weights performed “better” than the intuitive weights given by the doctors

# Co-operating Experts

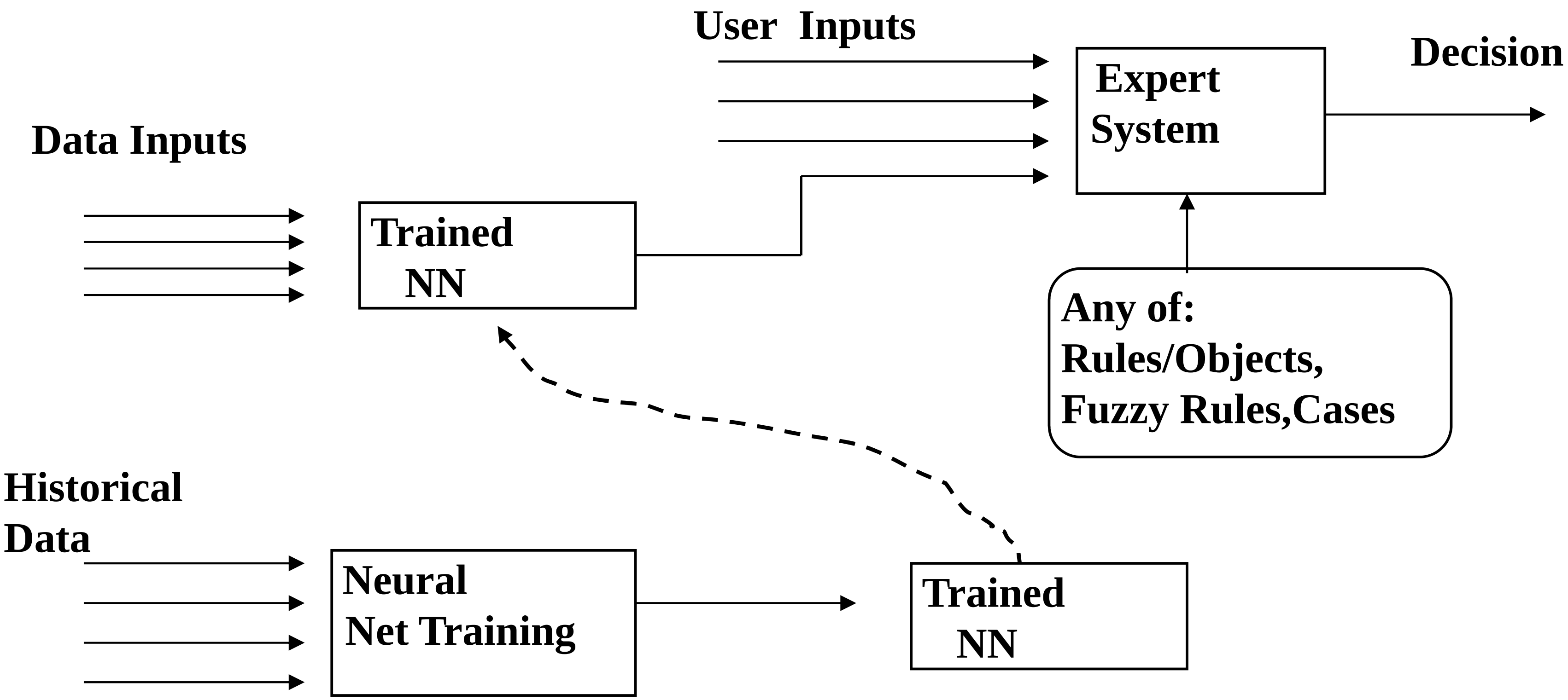
## “Pooled Expertise”

- Different KE techniques work together as a team to produce a single solution,  no single technique/expert is sufficient alone
- E.g, NN provides input to Fuzzy System



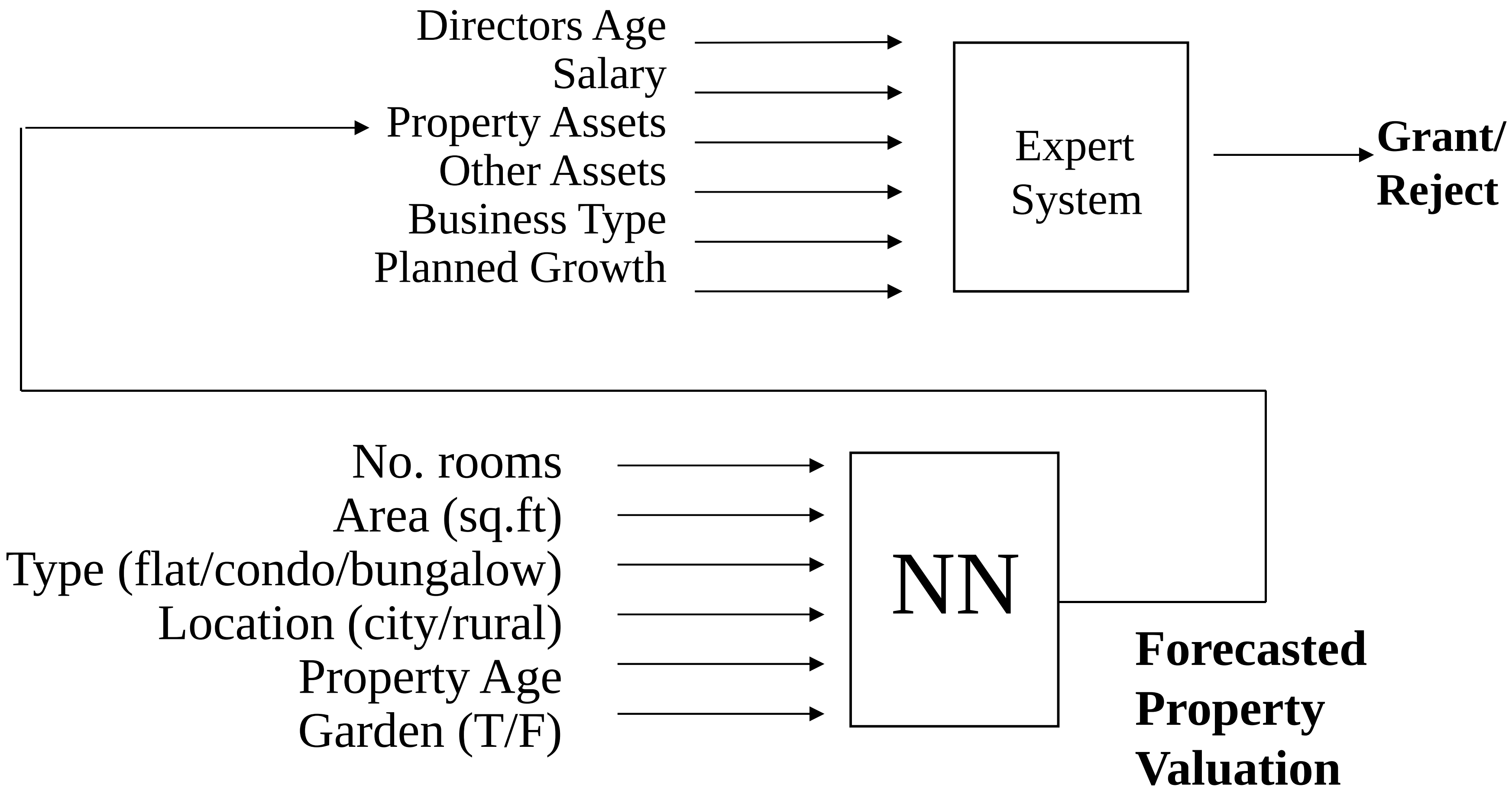
# Team Pattern 1

- An expert system has an input that cannot be measured directly or inferred by the system
- NN/machine learning/regression etc. can be used to generate the input from data (if available)



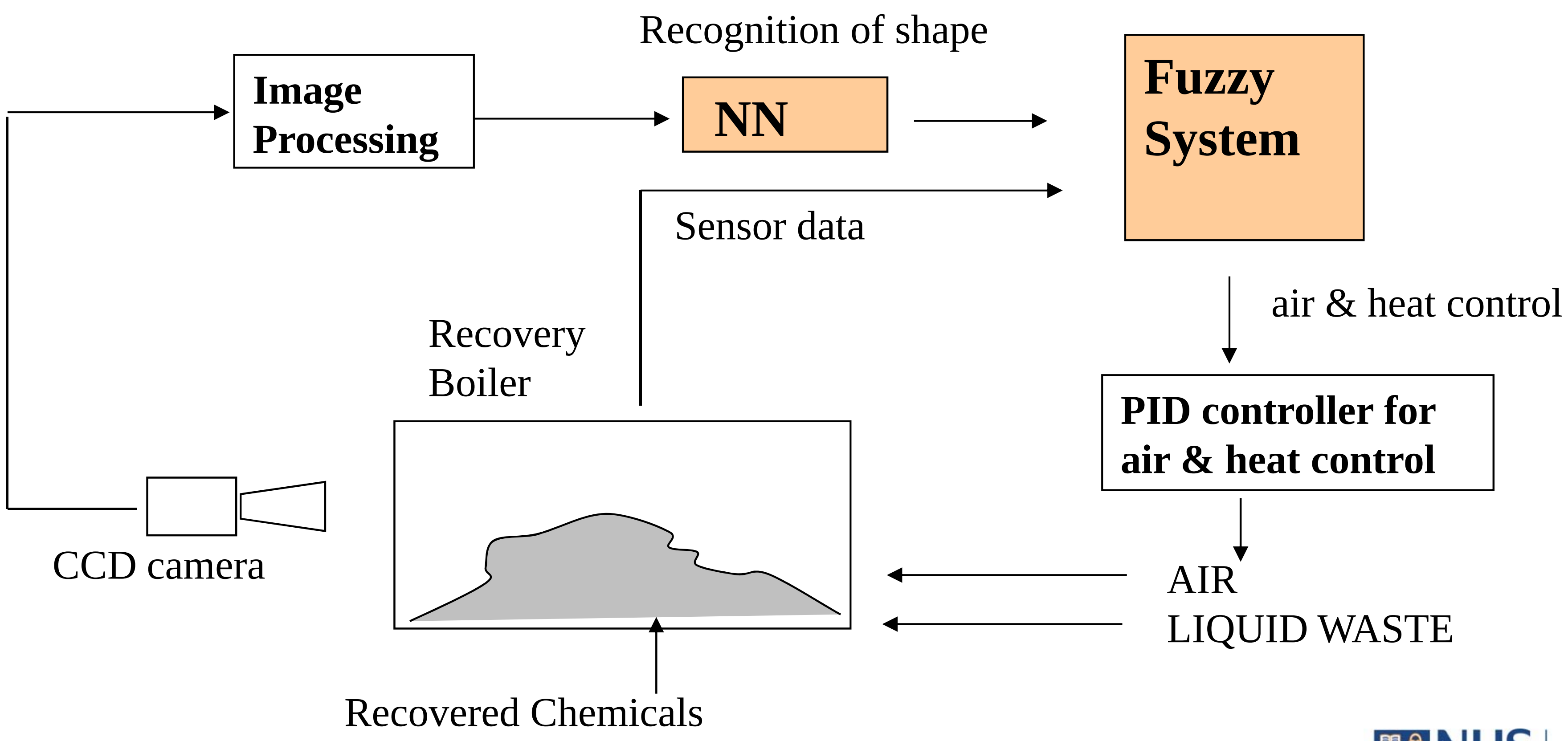
# Team Pattern 1: Example 1

- **Approving business loan to a small company**



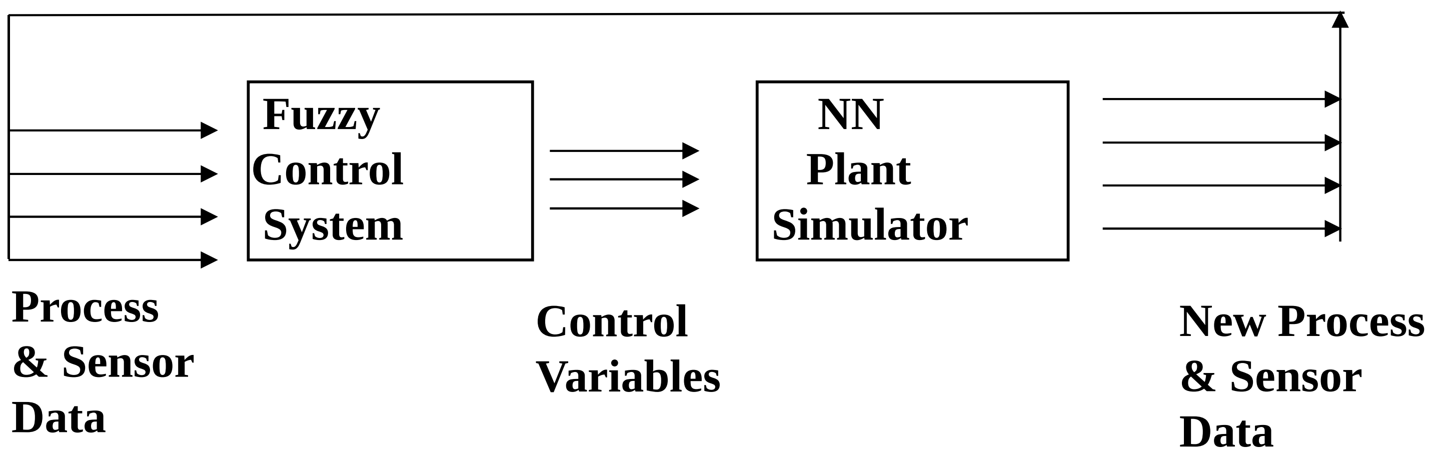
# Team Pattern 1: Example 2

- **Toshiba: Recovery of expensive chemicals at a pulp factory**
  - » Fuzzy system controls the temp. of liquid waste and air before input to recovery boiler
  - » Shape of pile in boiler influences the efficiency of the recovery process (deoxidisation). NN recognises the shape of the pile from (edge) image and passes to the Fuzzy system.



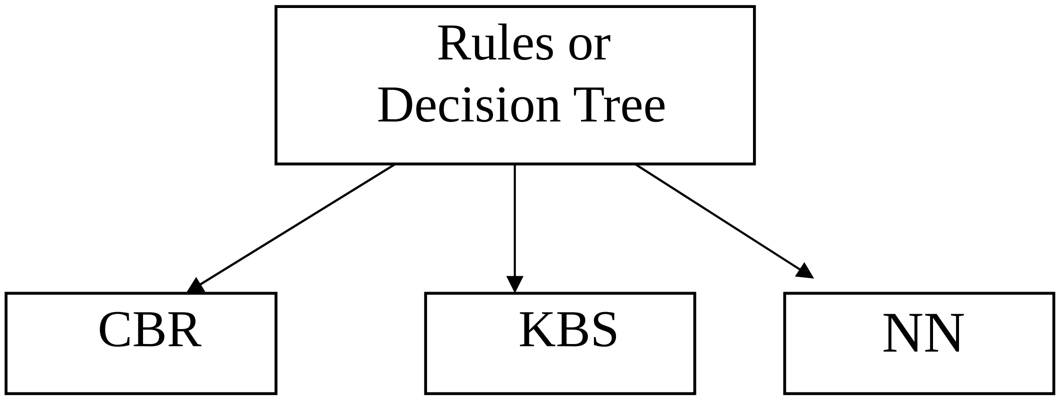
# Team Pattern 1: Example 3

- **In the process control industry, many of the processes are too complex to derive mathematical models for. Instead NNs can be used to build process control simulation models (e.g a plant model) based on recorded process data. The model can then be used in conjunction with the process control system – whether conventional (e.g. PID) or Fuzzy for evaluating the Control System's performance, undertaking what-if analysis, fault diagnosis etc.**

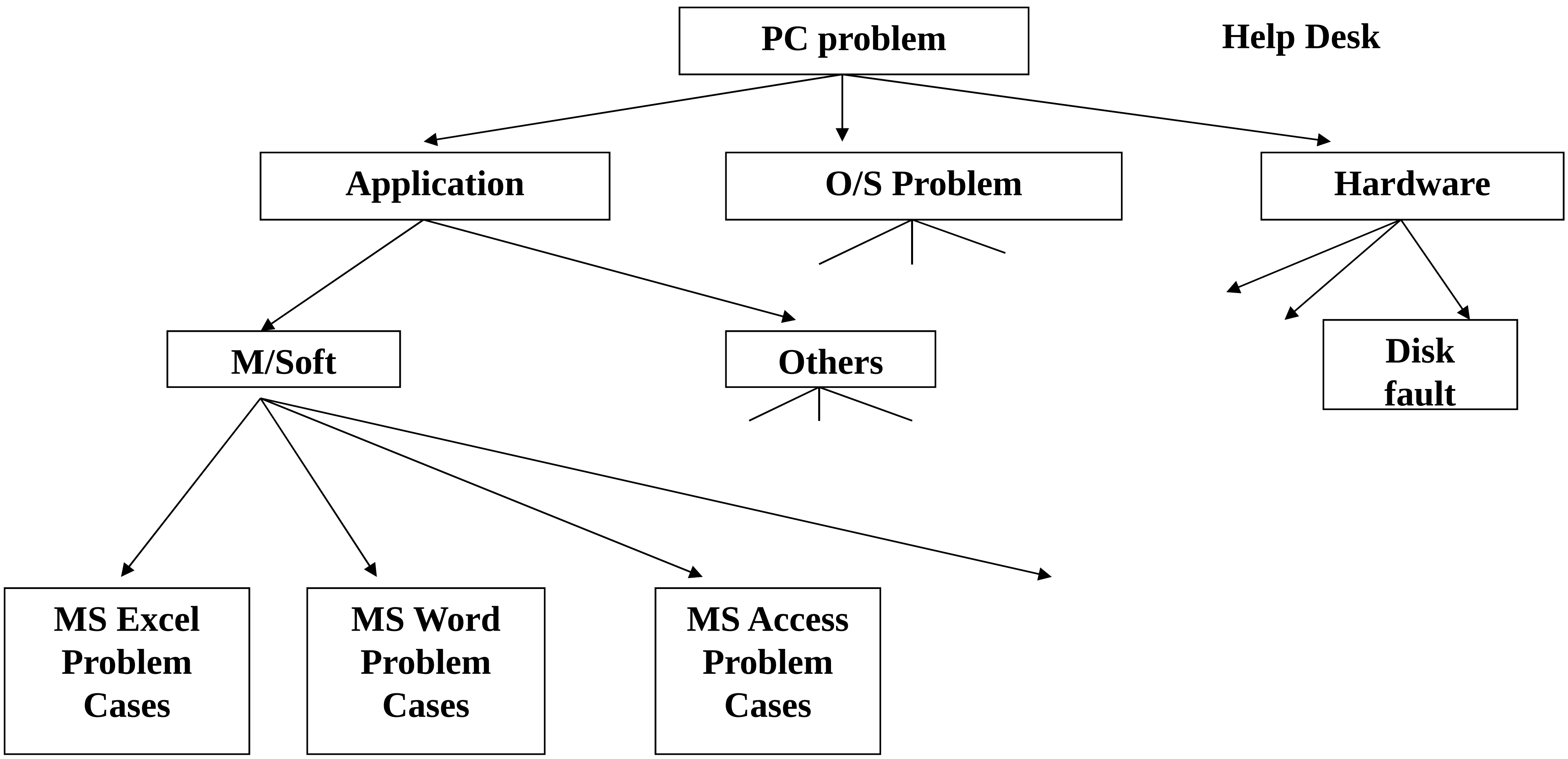


# Team Pattern 2

- **High-level rules are used to categorise the problem into a more specific category, this is then solved using an alternative KE technique, e.g. CBR**

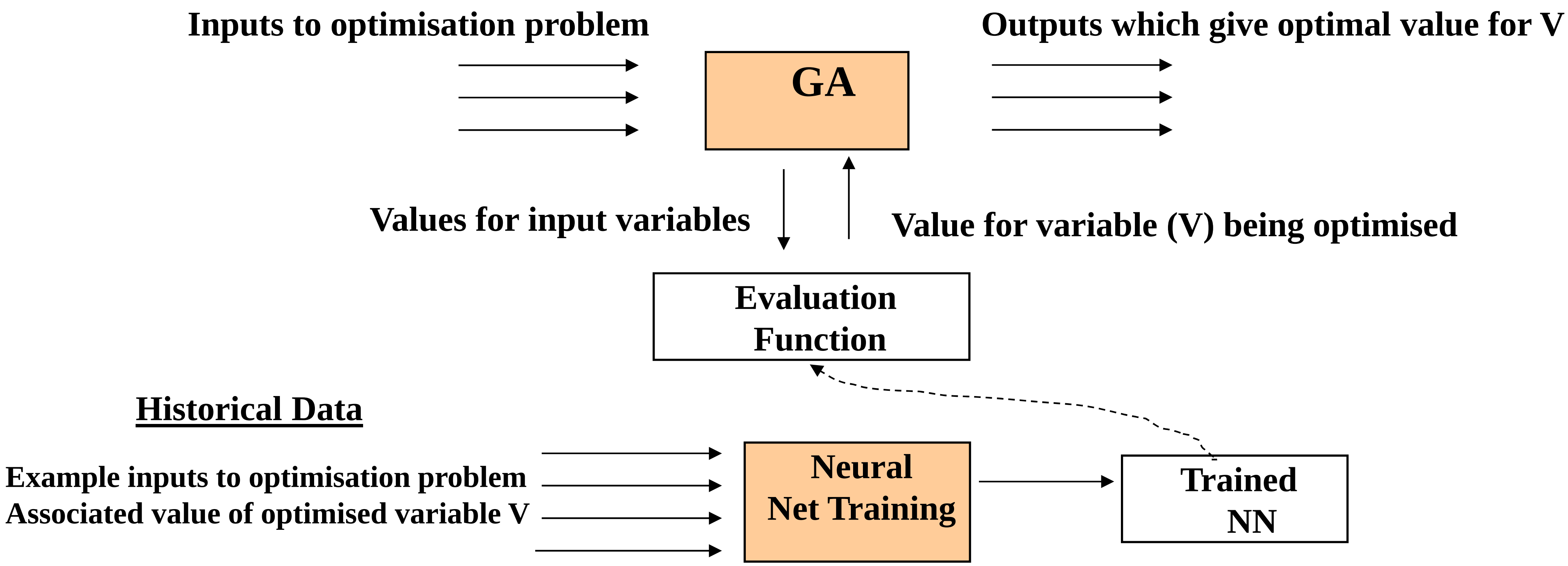


# Team Pattern 2: Example 1



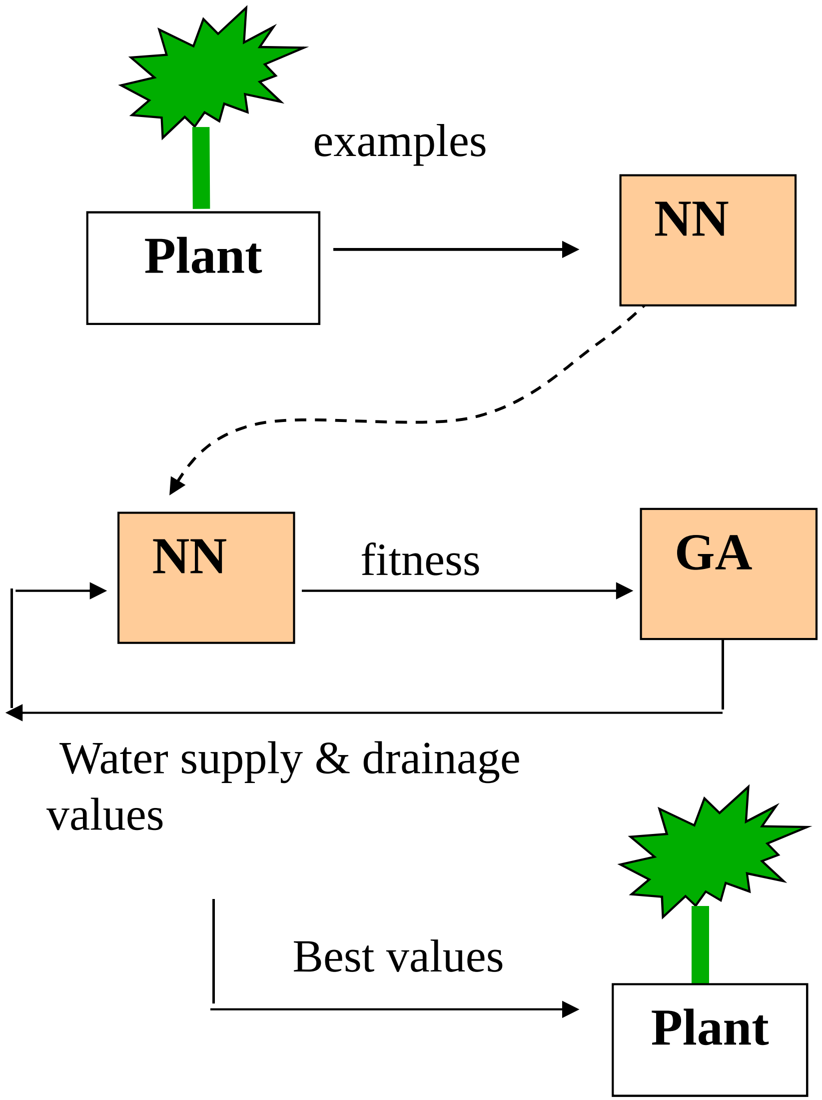
# Team Pattern 3

- An optimisation problem but the evaluation function is not known, i.e. the relationship between the inputs and the variable being optimised is unknown
- Use NN or other machine learning technique to build a model of the variable (V) to be optimised



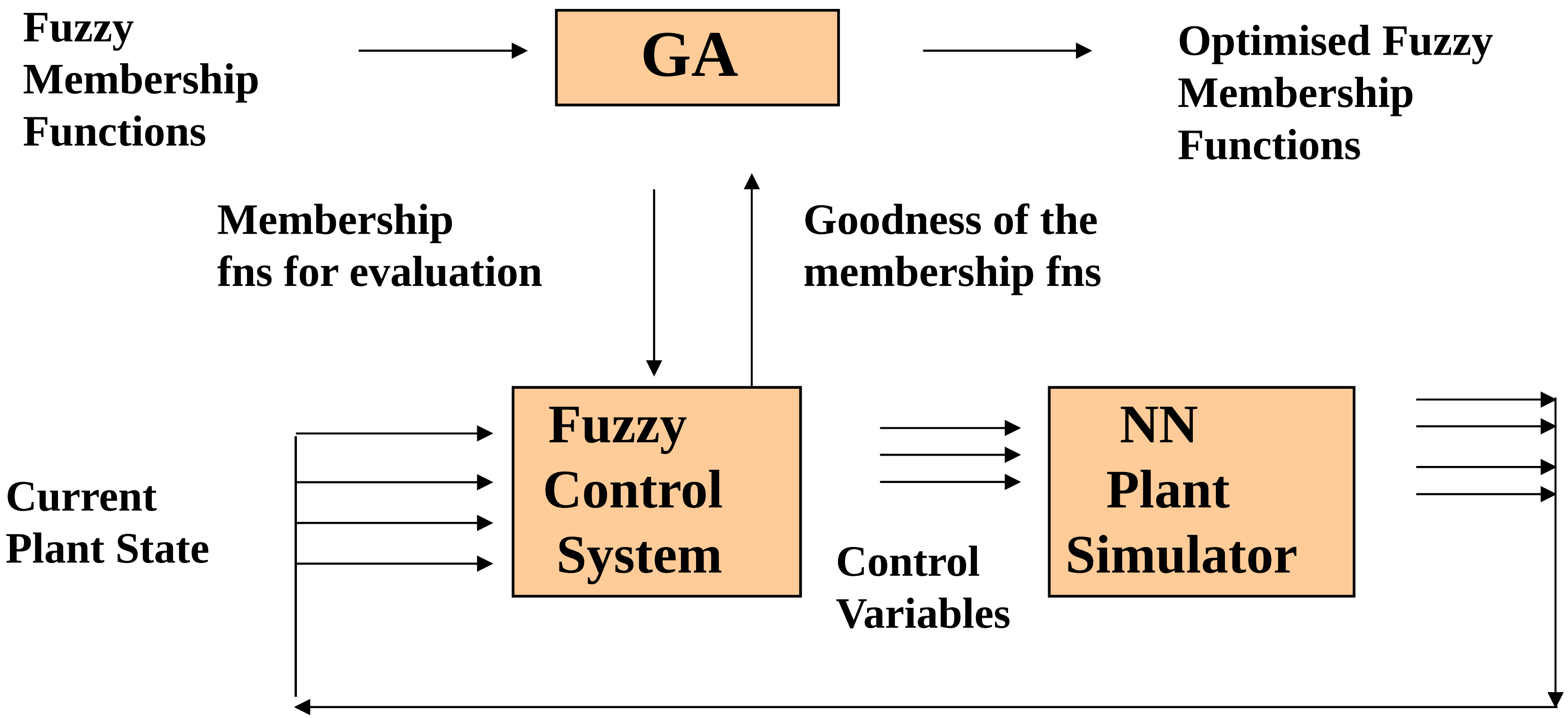
# Team Pattern 3: Example 1

- Optimal control of a hydroponics system
- Hydroponics system controls the water supply and water drainage of the target plant to maximise the plant's rate of photosynthesis
- GA is used to search for the combination of supply and drainage which maximises photosynthesis (measured using $CO_2$ absorbed)
- Using the real plant as the GA fitness function is impossible. Instead train a NN to model the plant's photosynthesis by giving it examples of supply & drainage with corresponding $CO_2$



# Team Pattern 3: Example 2

- The previous Process Control Example can be extended if we try to optimise the Fuzzy Control System using a GA. The evaluation function will measure the success of the Fuzzy Control system at maintaining the plant at a fixed point.



# Summary

- **Hybrid Systems offer solutions to a greater range of problems**
  - » "the sum is greater than the parts"
- **Four categories of Hybrid System have been identified, each with different examples & typical (pattern) architectures. These are not intended to be exhaustive - other patterns are possible.**
- **Software integration issues can be problematic – but are becoming easier**
- **System modelling is the most important task.**
- **Agent technology offers more flexibility and possibility to build hybrid distributed intelligent systems, which may be proactive, and responsive in real-time.**

# Hybrid Systems Exercise

- A soup manufacturer plans to produce a new type of canned soup. The new soup will contain up to 27 ingredients, namely 10 types of meat/fish, 7 types of vegetables, 5 flavour enhancers, 3 types of preservative, salt and sugar.
- To determine the relative quantities of each of the ingredients, the company conducts a market survey. Several hundred volunteers taste various prototype soups in which the 27 ingredients are mixed in different ratios, e.g. 30% chicken feet, 14% fish eyes, 15% turnips. Each taster is given 5 prototype soups to taste and asked to assign each to one of 7 categories.

Categories for describing the prototype soup:
(a) horrible taste
(b) would only eat if very hungry
(c) weak taste
(d) average taste
(e) good taste
(f) very good taste
(g) heavenly taste

## Class Discussion:

- Suggest a top-level design for a hybrid system that uses the results of the market survey to determine the mix of raw ingredients likely to achieve the highest consumer rating