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Feed Forward Single Hidden Layer Fuzzy Neural Network with Sigmoidal Signals

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Abstract

Universal approximation of three layer fuzzy feed forward regular neural networks using sigmoidal signal as an activation function are capable of approximate continuous fuzzy valued functions an any compact set of R. we used left sigmoidal signals and right sigmoidal signals as activation function and its approximation capability is better than the existing system.

Keywords: Regular fuzzy neural networks; Fuzzy-valued polynomials; Universal approximations; Universal approximator, Left sigmoidal signal, Right Sigmoidal Signal.

1. Introduction

Fuzzy neural networks are powerful systems that combines the theory of Neural Networks and fuzzy logic, thus it can make effective use of easy way of fuzzy logic as well as leaving methods and capabilities of Neural Networks. Neural fuzzy systems are more powerful than fuzzy systems and neural systems.

The research on approximation capabilities of Feed Forward Neural Network has derived some adaptive Non-linear approximations and estimations of given function determine data information. The classical numerical approximation theory such approximation achievements can adopt themselves changing data and environment. Many authors done research in regular Fuzzy Neural Network for approximation. Such approximations are not give the accurate result in approximation. The recent research used for approximation using sigmoidal signals changing the activation signals gives better. Approximation using Neural Network Model Chen et al. (1995). Based on Chen Ramakrishnan et al (2006) introduced new sigmodial signals called left sigmoidal signals and right sigmoidal signal used for better approximation. Regular Neuro Fuzzy Models we use left sigmoidal signals and right sigmoidal signals for approximation which gives better approximation than the existing models.

Since 1994 the research on approximating ability of regular Fuzzy Neural Network has been attracting many scholars. Our main objective of this paper solving the approximation problem related to Regular Fuzzy Neural Network with two hidden layers using left sigmoidal and right sigmoidal signals as an activation function which gives better approximation.

Finally, Regular Fuzzy Neural Networks with left sigmoidal signals and right sigmoidal signal to approximate a Fuzzy function with better accuracy and this results are to be more effective.

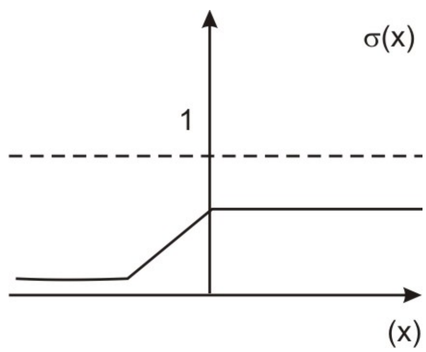
The recent research on the universal approximation by feed forward neural networks play an important role in the field of approximation and the application of neural networks. The recent studied Sigmoidal signals play in approximation problem. In particularly left sigmoidal signals and right sigmoidal signals used for approximation by feed forward neural networks. Left and Right sigmoidal signals are introduced by Ramakrishnan et al (2006).

1.1. Left Sigmoidal Signals

The function $\sigma : R \rightarrow R$ is said to be left sigmodial

if $\lim\limits_{x \to -\alpha} \sigma(x) = 0$

The following is an example of left generalized sigmoidal signals.



$$\sigma(x) = \begin{cases} e^{\alpha x}, \text{ for } x < 0, \alpha > 0 \\ \beta, \text{ for } x \geq 0, \beta > 0 \end{cases}$$

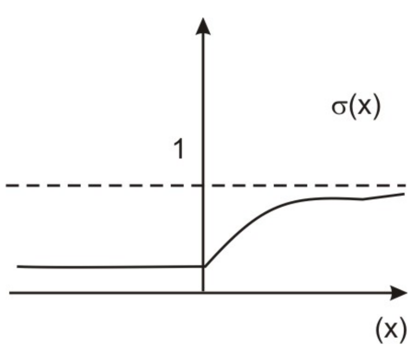
1.2. Right Sigmoidal Signals

The function $\sigma : R \rightarrow R$ is said to be right sigmoidal

if $\lim\limits_{x \to +\alpha} \sigma(x) = 1$

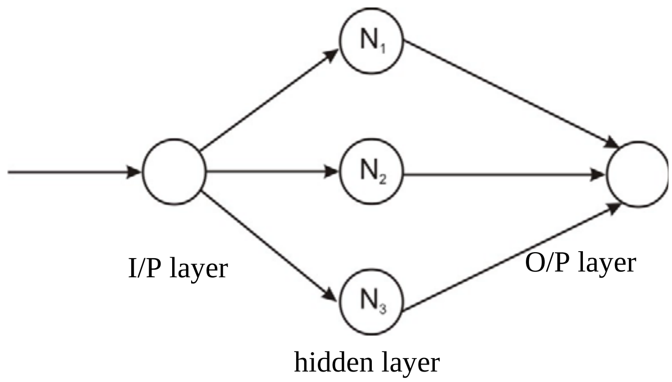
The following is an example of right generalized sigmoidal signals.

$$\sigma(x) = \begin{cases} 1 + e^{-\alpha x}, \text{ for } x > 0, \alpha > 0 \\ \beta, \text{ for } x < 0, \beta > 0 \end{cases}$$



1.3. TFFNN (Three Layer Fuzzy Feed Forward Neural Networks)

Figure: Feed forward fuzzy neural network with single hidden layer



$\sigma : R \to R\ \sigma(x) = 1,\ x \in R$

$$\text{TFFNN}(y) = \sum_{n=n_1}^{nn} g_i \sigma\left(x_i w_i + \theta_i\right) \qquad (1.1)$$

when $\sigma : R \to R$, $\sigma(x) = 1$

$\forall\ x \in R$

be a right sigmoidal signals.

$x \to$ input signal

$x \in F_o(R)$

$y \in F_o(R)$

Feed forward fuzzy neural networks cannot be universal approximator to F where F is to continuous function, feed forward fuzzy neural networks are universal approximator.

We proposed the following theorem

2.1. Theorem

Let f $R \to R$ be a continuous function for a compact set $u \in F(R)$, with

$\sigma : R \to R$

if $\lim_{x \to +\alpha} \sigma(x) = 1$

Compact set $u \in F(R)$

Then $\ni$ an $\in > 0$, $n \in N$

Wi, Vi, $\theta_i \in R$

so that

$P(f(M), \text{TFFNN}(x) < \varepsilon$

$\forall\ M \in V$

Proof:

Let $\overline{U}$ be a compact subset of F(R)

$\therefore$ Sum $U \in R$ be a compact set

Therefore sum $\varepsilon > 0$

show that

$$\left| f(x) - \sum_{i=1}^{N} V_i \sigma_v \left(w_i x_i + \theta_i\right) \right| < \varepsilon / 2 \qquad (1)$$

where σ is a right sigmoidal signal

Let $\left| g(x) - \sum_{i=n_1}^{n_n} V_i \sigma_r \left(w_i\, x + \theta_i \right) \right| x \in R$

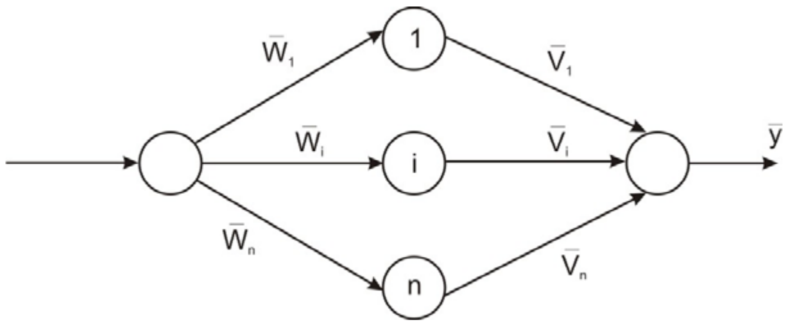
Thus from (1) such that

$$\left| f(x) - g(x) \right| < \varepsilon / 2 \quad (2)$$

D(f(x) – FFNN) < (f(x), g(x) + D(g(x), FFNN) < ε/2 + ε/2 < Σ

$\therefore$ D (F(x), FFNN) < Σ

Feed forward fuzzy Neural Networks are universal approximator.



2.2. Theorem

Let σ : R → R be a input sigmoidal signal

if $\lim_{x \to +\alpha} \sigma(x) = 1$

and σ is a bounded continuous non-constant function on R, then any p ∈ P.

FFNN(x) is me universal approximator for P.

Proof

Let U be a compact subset of R

$P(x) = [P_1(x) + P_2(x) + \dots + P_i(x)],\ \bar{A}_i$

so that

p_i is continuous function on R

$$\therefore\ FFNN(x) - P_i(x) < \frac{\varepsilon}{\left|\bar{A}_i\right|}$$

$$\Rightarrow H_i(x) = FFNN(x),\ A_i\ \forall\ x \in R$$

FFNN(x)

$$\Rightarrow \sum_{i=1}^{n} V_j - \sigma\,(u_i x + \theta_i)$$

where σ is the right sigmoidal function.

$$\left| FFNN_i\,(x),\ \bar{A}_i - P_i(x).\bar{A}_i \right|$$

$$\leq \left|\bar{A}_i\right| \left| FFNN_i(x) - P_i(x) \right|$$

$$F_i(x) = P_i(x)\ \bar{A}$$

$$\therefore P(x) = \sum_{i=1}^{n} Fi(x) = \sum_{i=1}^{n} P_i(x).\bar{A}_i$$

$$\Rightarrow FFNN_i(x) - F_i(x) < \varepsilon$$

$\Rightarrow FFNN_i(x)$ is the universal approximator for P.

2.3. Theorem

Let f : R → R be a continuous function for a compact set u ∈ F(R)

with σ : R → R

such that $\lim_{x\to-\alpha} \sigma(x) = 0$

Let be the left sigmoidal signal

then ∍ an ∈ > 0, n ∈ N

w_i, v_i, θ_i ∈ R

so that

$p(f(M), TFFNN(x) < \varepsilon \ \forall \ M \in V$

Let J be a compact subset of F(R)

∴ Sum U ∈ R be a compact set

Therefore Sum ε > 0

Show that

$$\left| f(x) - \sum_{i=1}^{n} V_i \sigma_1 \left(w_i\, x + \theta_i \right) \right| < \varepsilon / 2 \qquad (1)$$

Where σ is a left sigmoidal signal.

Let $\left| g(x) - \sum_{i=n_1}^{n_n} V_i \sigma_1 \left(w_i\, x_i + \theta_i \right) \right| x \in R$

Thus from (1) such that

$$\left| f(x) - g(x) \right| < \varepsilon / 2 \qquad (2)$$

d(f(x) – FFNN) < (f(x)), g(x) + D (g(x), FFNN)

< ε / 2 + ε / 2 < ε

∴ D(f(x), FFNN) < ε.

2.4. Theorem

Let σ : R → R be a input sigmoidal signal

If $\lim_{x\to-\alpha} \sigma(x) = 0$

and σ is a bounded continuous non-constant function in R, then any p ∈ P

FFNN(x) is the universal approximator for P

Proof

Let U be a compact subset of R

Let $P(n) = [P_1(x) + P_2(x) + \ldots + P_i(x)]$, $\overline{A}_i$

so that

p_i is continuous function an R

$$\left| FFNN(x) - Pi(x) < \frac{\varepsilon}{\left|\overline{A}_i\right|} \right|$$

$\Rightarrow H_i(x) = FFNN(x), \overline{A}_i \ \forall \ x \in R$

FFNN(x)

$$\Rightarrow \sum_{i=1}^{n} V_j \ \sigma \ (u_i\, x + \theta_i)$$

Where σ is the left sigmoidal function.

Feed forward Neural Networks are most heavily used to identity the relation between a given set of input and desired output patterns.

It is clear that a single hidden layer FNN is sufficient for the outputs of approximate the corresponding desired outputs arbitrarily close and solve we consider a single-hidden layer FNN.

3. Conclusion

In this work we used left sigmoidal signal and right sigmoidal signal as an activation function for three layer fuzzy regular feed forward neural network. The performances of these signals are better than the existing signals.

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