

Routing Time Evaluation Fis-Anfis Technique Of A Mechanical Component

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ABSTRACT: This paper presents the result of a routing evaluation method analysis utilising a DSS, based on an hybrid architecture FIS-ANFIS, for time and subsequently cost prevision of a mechanical component, in a critical region where the decision process is not many articulated but a complex knowledge representation it is required, (great number of involved variables). It is important to highlights that the mentioned hybrid architectures are very appropriated in problems with a considerable number of inputs (more than five or six) and only one output, very common possibility in the realisation of decision support system in production domain on the contrary of systems based on use of single-technique-based tools. As matter of fact, most of real cases present characteristics unsatisfactory to the hypothesis of only one technique of AI, and then they cannot be effectively solved through such approach.

KEYWORD: Time manufacturing, Flexible Manufacturing System, Neuro-Fuzzy Expert System

INTRODUCTION

In addition this paper follows our research already presented in previous conferences [9] [72] [73].

Such system, implemented at an important aeronautical firm, allows a fast and reliable evaluation of routing times and costs of some components in order to "drive" the firm strategic decisions to accept or not an industrial order. The mentioned hybrid architectures are very appropriated in problems with a considerable number of inputs (more than five or six) and only one output, very common possibility in the realisation of decision support system in production domain on the contrary of systems based on use of single-technique-based tools.

As matter of fact, the use of neural networks isn't able to solve such problem, since in this cases, the great number of inputs requires an identical number of nodes in the first net level and in general, more than an hidden level, that makes more difficult not only the net architecture but also the optimisation phase [23] [25] [26] [30]. In addition, for the learning phase, the net needs a number great enough of numerical examples real strongly depending on the number of inputs and on the number of levels and nodes of each level constituent the network.

THE FIS-ANFIS MODEL

The more common production on order is the chip machining (job shop) for mechanical components having specific characteristics of size and quality.

The detailed analysis, in case of lathe routings, has been conducted in [9] [73]. The evaluation routing time of the item represents the difficulty recognition phase.

Starting from a built model Multi-FIS we have realised a new one of the evaluation model based on the architectures FIS-ANFIS (fig. 1 - fig. 2). Firstly, the first part of the model (Multi-FIS) makes the size input reduction, 31:2, necessary to the right and reliable use of the learning hybrid algorithm, since that ANFIS architecture has applying limits, especially when there is a large number of relevant parameters, and, there aren't a large number of examples to train the network, as we already have seen in to refine and set system parameters in the best way . [25][26].

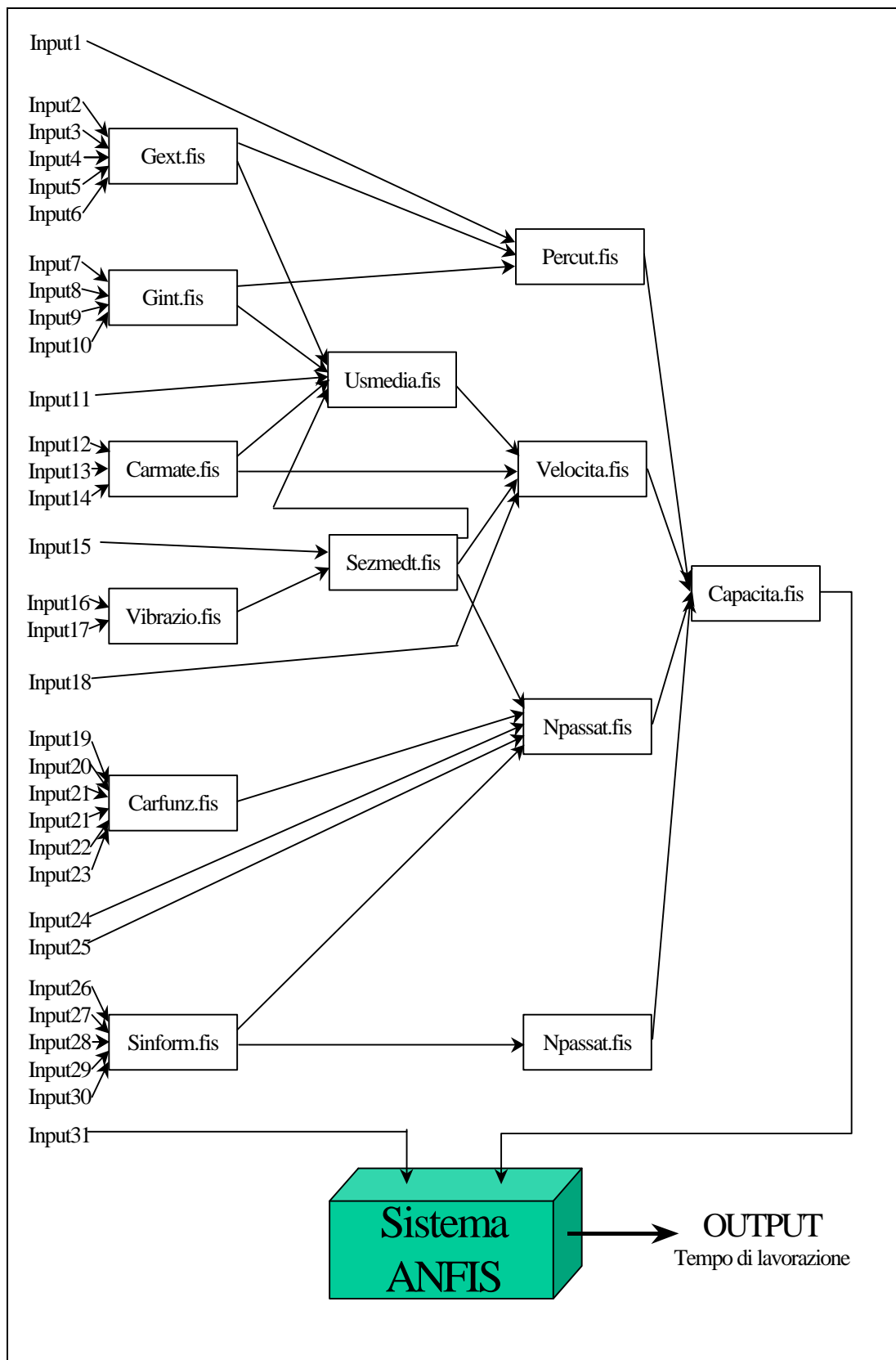


Fig. 1

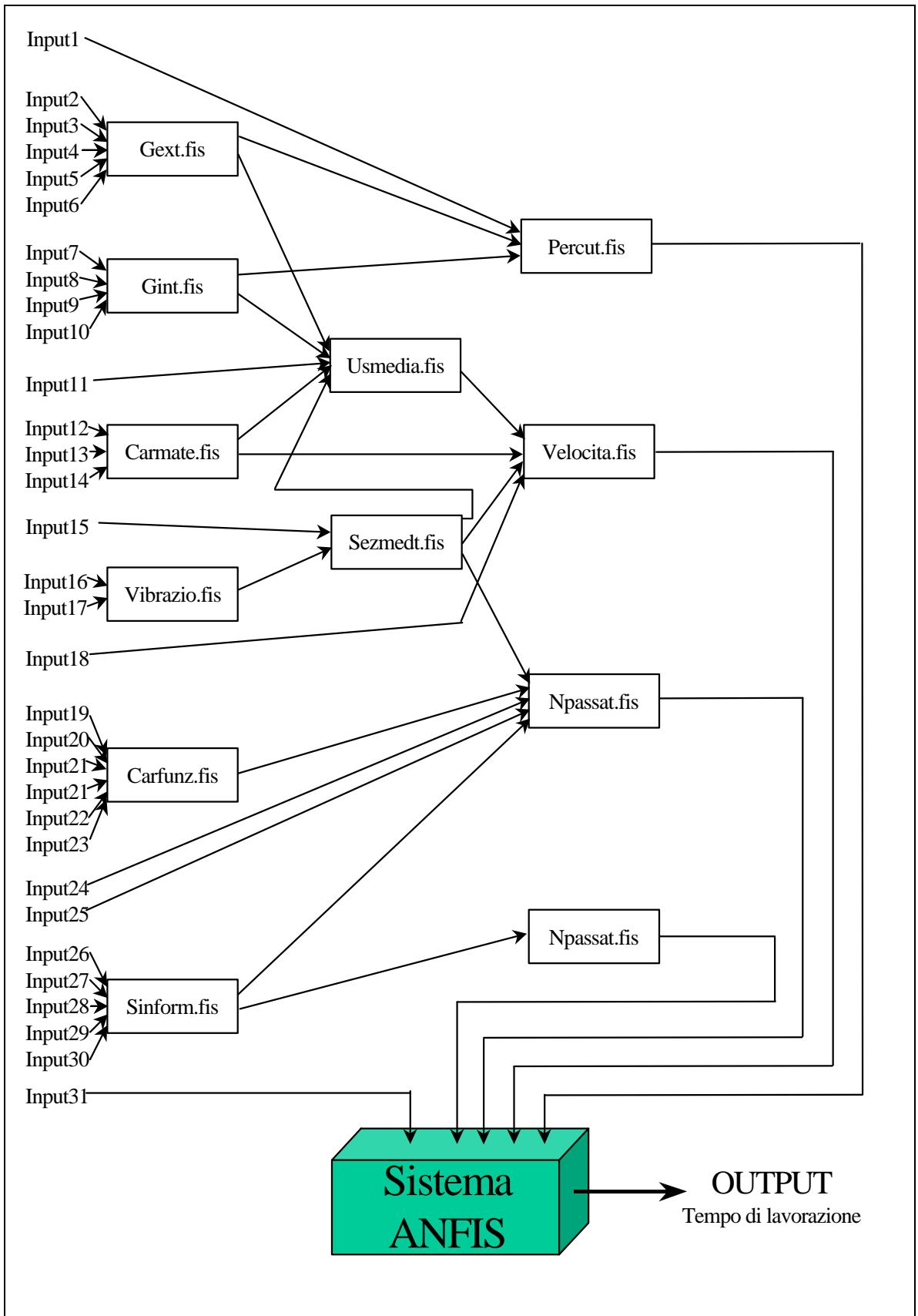


Fig.2

The last model system, learning from the modified examples set constituted by three element vectors (2 inputs and 1 output), reproduces the real system behavior, recovering the possible mistakes done in the systems upstream. The union of the different sub-systems has been carried out through a "link" algorithm (Tab. 1, 2).

<pre> load totin; insis=totin'; % Geometria esterna gext=readfis('ageoext'); ingext=insis(:,2:6); outgext=evalfis(ingext,gext); % Geometria interna gint=readfis('ageoint'); ingint=insis(:,7:10); outgint=evalfis(ingint,gint); % Durezza dur=readfis('adurezza'); indur=insis(:,12:14); outdur=evalfis(indur,dur); % Vibrazioni vib=readfis('avibraz'); invib=insis(:,17:18); outvib=evalfis(invib,vib); % Caratteristiche funzionali richieste carfun=readfis('acarfun'); incarf=insis(:,19:23); outcarf=evalfis(incarf,carfun); % Singolarità di forma sinfor=readfis('asinform'); insinf=insis(:,26:30); outsinf=evalfis(insinf,sinfor); </pre>	<pre> % Sezione media del truciolo sez=readfis('aseztruc'); insez=[insis(:,16) outvib]; outsez=evalfis(insez,sez); % Percorso utensile percut=readfis('apercors'); inpercut=[outgext outgint insis(:,1)]; outpercut=evalfis(inpercut,percut); % Usura utensile us=readfis('ausura'); inus=[outgext outgint outdur insis(:,11) outsez]; outus=evalfis(inus,us); % Velocità velox=readfis('avelox'); invel=[outdur outsez outus insis(:,15)]; outvel=evalfis(invel,velox); % Numero approssimativo di passate numpa=readfis('anpassat'); inpas=[outsinf outcarf outsez insis(:,24:25)]; outpas=evalfis(inpas,numpa); % Capacità di asportazione unitaria cau=readfis('acau'); incau=[outpercut outsinf outvel outpas]; outcau=evalfis(incau,cau); dv2input=[outcau insis(:,31)]; </pre>
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1. Tab

```

load dv2input
load toty
XY=[X toty];
X1=XY(1:53,:);
X2=[X1;XY(67,:);XY(70:109,:)];
[m n]=size(X2);
trnData=X2(1:m,:);
chkData=X2(2:2:m,:);

Fismat=genfis1(trnData,3,'gbellmf');

% training options: numero di epoche, goal error, initial step size
[0.01],
%          step-size decrease rate [0.9], step-size increase rate [1.1]
trnOpt=[250;0.001;0.01;0.9;1.1];

[sis2,trnError,ss,Fismat1,chkError]=...
anfis(trnData,Fismat,trnOpt,NaN,chkData);

%*****GENERA ANFIS
OUTPUT*****
xtf90=trnData(:,1:n-1);
trnOut = evalfis(xtf90, Fismat1);
epoch = 1:250;
ytf90=trnData(:,n);
for i=1:m, err(i)=(abs(ytf90(i)-trnOut(i))/abs(ytf90(i))), end;
errmed=mean(err)

```

2. Tab

The results shown in fig. 3 and fig. 4 are not satisfactory since:

- the minimum mean square error on training set is

$$\text{RMSE}_{ts} = 0,2863$$

- the minimum mean square error on checking set is

$$\text{RMSE}_{cs} = 0,3051$$

then the root mean square error is:

$$\sigma_A = 87\%.$$

The two graphs of RMSE (Fig. 4) show that they are approximately constant vs. time. This means that the last system isn't able to learn, due to the non linear function structure that it must reproduce (in consequence of the high error done in the upstream FIS systems) and due to the small number of parameters which can be varied of the last ANFIS model.

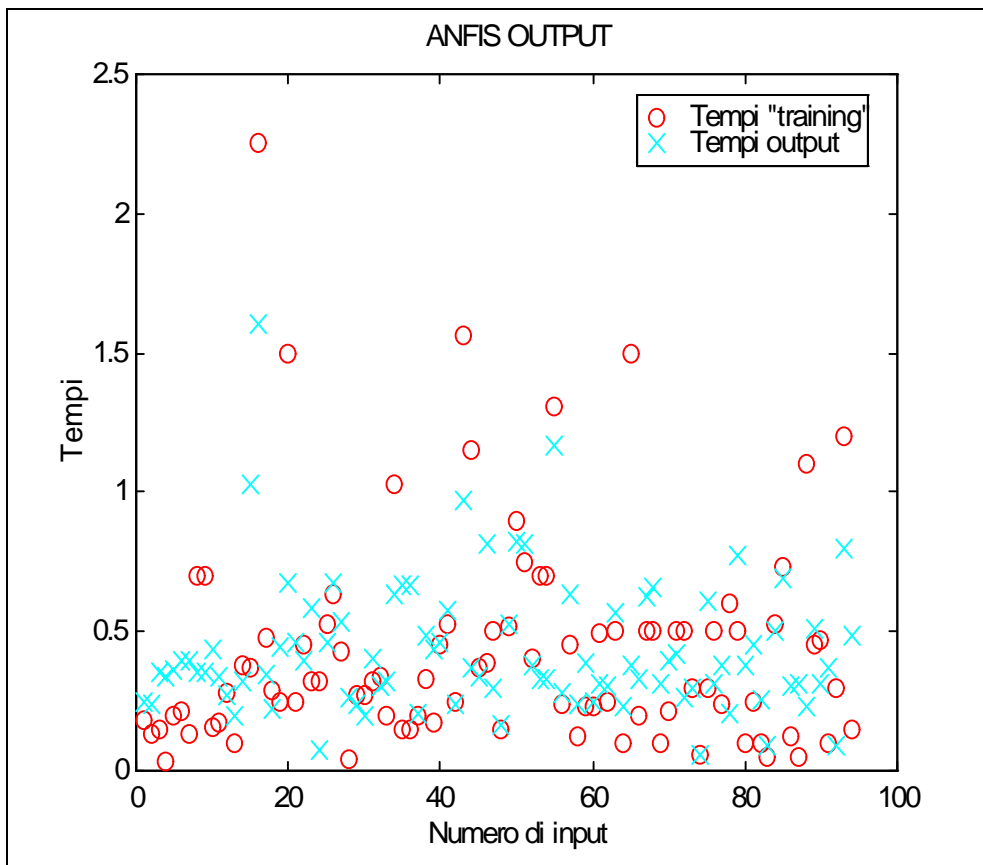


Fig. 3: Time error between training times and model evaluated times on training, admissible error $\sigma_A = 87\%$

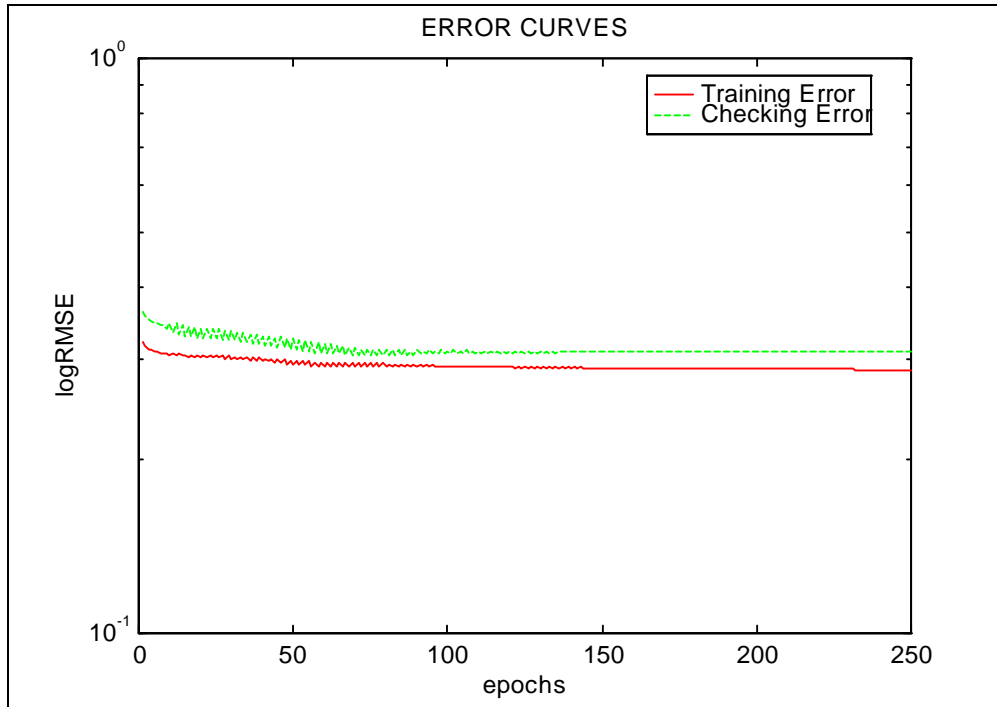


Fig. 4 - Mean square error trend (RMSE). Minimal training RMSE = 0.2863
Minimal checking RMSE = 0.3051

For this reason, we have built another hybrid system, according a FIS-ANFIS architecture, as depicted in fig. 2. This new system is different from the previous one in the first part of the Multi-FIS architecture. As matter of fact, in this fourth case, the Multi-FIS system has 5 outputs, reducing the input space size from 31 to 5 variables. In this way, the ANFIS architecture system has, as output, a larger number of parameters which can be varied, thus more flexibility in the learning phase.

<pre> load totin; insis=totin'; % Geometria esterna gext=readfis('ageoext'); ingext=insis(:,2:6); outgext=evalfis(ingext,gext); % Geometria interna gint=readfis('ageoint'); ingint=insis(:,7:10); outgint=evalfis(ingint,gint); % Durezza dur=readfis('adurezza'); indur=insis(:,12:14); outdur=evalfis(indur,dur); % Vibrazioni vib=readfis('avibraz'); invib=insis(:,17:18); outvib=evalfis(invib,vib); % Caratteristiche funzionali richieste carfun=readfis('acarfun'); incarf=insis(:,19:23); outcarf=evalfis(incarf,carfun); % Singolarità di forma sinfor=readfis('asinform'); </pre>	<pre> insinf=insis(:,26:30); outsinf=evalfis(insinf,sinfor); % Sezione media del truciolo sez=readfis('aseztruc'); insez=[insis(:,16) outvib]; outsez=evalfis(insez,sez); % Percorso utensile percut=readfis('apercors'); inpercut=[outgext outgint insis(:,1)]; outpercut=evalfis(inpercut,percut); % Usura utensile us=readfis('ausura'); inus=[outgext outgint outdur insis(:,11) outsez]; outus=evalfis(inus,us); % Velocità velox=readfis('avelox'); invel=[outdur outsez outus insis(:,15)]; outvel=evalfis(invel,velox); % Numero approssimativo di passate numpa=readfis('anpassat'); inpas=[outsinf outcarf outsez insis(:,24:25)]; outpas=evalfis(inpas,numpa); dv5input=[outsinf outpercut outvel outpas]; </pre>
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3. Tab

ANFIS architecture system downstream to the Multi-FIS network shows a grid partition of the 5 dimension input space, and two fuzzy set has been assigned to each input variable (see row "NumMFs = 2" of the program list in Tab.4), in order to assure a not excessive growth of the parameters which can be varied and therefore a system instability. The results are showed in fig. 5, and 6. The error curves clearly show that the model has learned very well the behaviour of the real system, having:

RMSE ts = 0,0056

and

RMSE cs = 0,0042

This means that the system has wholly learned the behaviour represented by the training set, and in addition it shows that the found error in the checking set is comparable to the training set one (in our case is even lower). Moreover, the system presents an admittable standard deviation of 1%, that is very lower compared to the results obtained from the previous models.

```

load dv5input
load toty
XY=[X toty];
X1=XY(1:53,:);
X2=[X1;XY(67,:);XY(70:109,:)];
[m n]=size(X2);
trnData=X2(1:m,:);
chkData=X2(2:2:m,:);

NumMFs = 2;
MfType = 'gaussmf';

%*****GENERA MATRICE FIS*****
Fismat = genfis1(trnData,NumMFs,MfType);

%*****GENERA MATRICE ANFIS*****
[Fismat1, trnError, StepSize, Fismat2, chkError] = ...
anfis(trnData, Fismat, [250;0.001;0.01;0.9;1.1], [], chkData);

%*****GENERA ANFIS OUTPUT*****
xtf90=trnData(:,1:n-1);
trnOut = evalfis(xtf90, Fismat1);
epoch = 1:250;

%*****CALCOLA ERRORE MEDIO*****
for i=1:m, err(i)=(abs(ytf90(i)-trnOut(i))/abs(ytf90(i))), end;
errmed=mean(err)
ytf90=trnData(:,n);

```

4. Tab

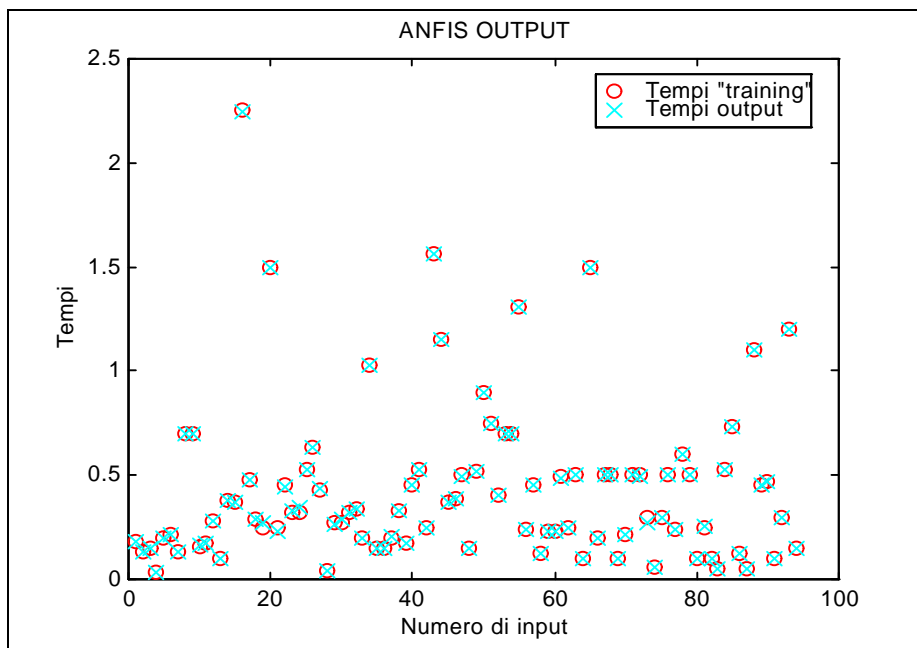


Fig. 5: Time error between training times and model evaluated times on training, admitteble error , admittable error $\sigma_A= 1\%$

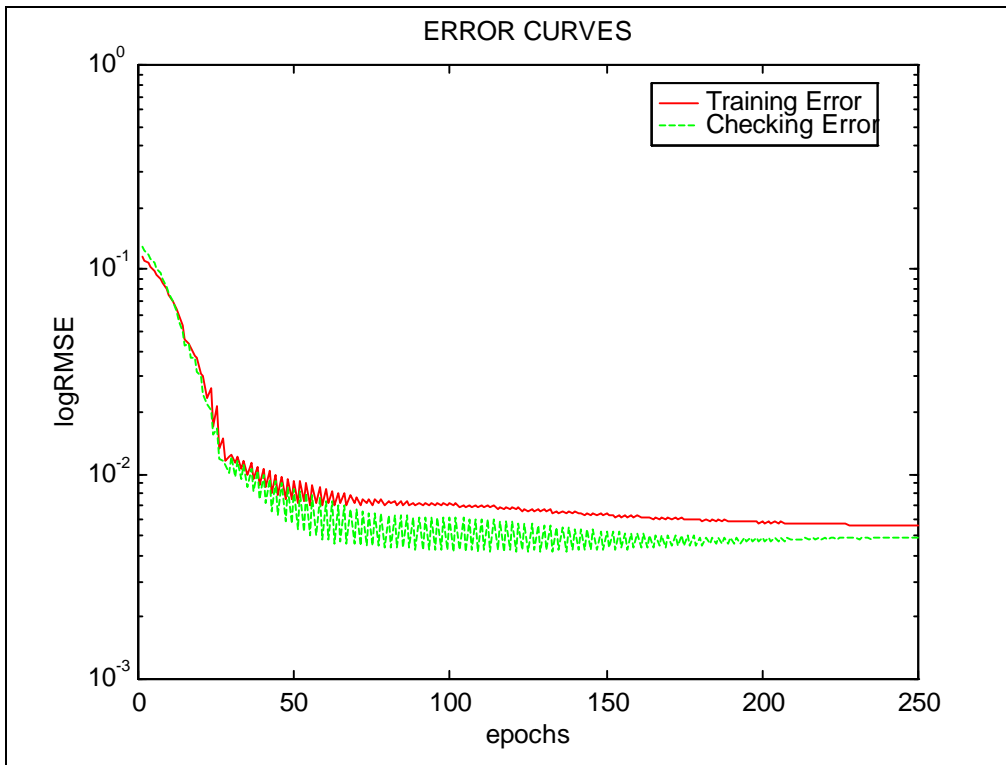


Fig. 6: Mean square error trend (RMSE). Minimal training RMSE = 0.0056 Minimal checking RMSE = 0.0042

We have obtained a further improvement of the model realising a scatter partition (Tab. 5) of the last system 5 dimension input space according to an ANFIS architecture of the above presented model.

```

load dv5input
load toty
XY=[X toty];
X1=XY(1:53,:);
X2=[X1;XY(67,:);XY(70:109,:)];
[m n]=size(X2);
trnData=X2(1:m,:);

datin=trnData(:,1:n-1);
datout=trnData(:,n);

chkData=X2(2:2:m,:);

%NumMFs = 2;
%MfType = 'gaussmf';

%*****GENERA MATRICE FIS*****
%Fismat = genfis1(trnData,NumMFs,MfType);
Fismat=genfis2(datin,datout,0.5);

%*****GENERA MATRICE ANFIS*****
[Fismat1, trnError, StepSize, Fismat2, chkError] = ...
    anfis(trnData, Fismat, [500;0.001;0.01;0.9;1.1], [], chkData);

%*****GENERA ANFIS OUTPUT*****
xtf90=trnData(:,1:n-1);
trnOut = evalfis(xtf90, Fismat1);
epoch = 1:500;

ytf90=trnData(:,n);

for i=1:m, err(i)=(abs(ytf90(i)-trnOut(i))/abs(ytf90(i))), end;
errmed=mean(err)

```

5. Tab

As matter of fact, in this way (fig. 7 - fig. 8) we have obtained errors even lower and they are, respectively:

RMSE_{ts} = 0,0014

and

RMSE_{cs} = 0,0012

On this purpose, it is interesting to remark that in the previous case the system presented a slight phenomena of overtraining but not at all in this last case. Moreover, in this last case we have a value of the mean error very low compared to the others that it is equal to 0,6%.

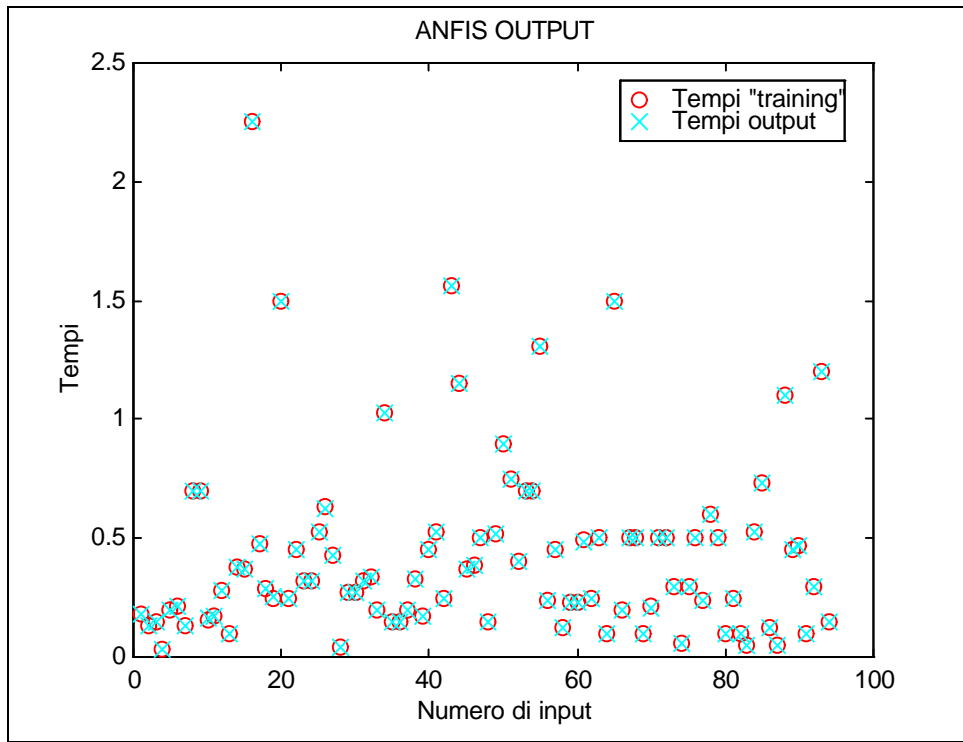


Fig.7: Scostamento fra i tempi di "allenamento" ed i tempi stimati dal modello, scostamento ammissibile $\sigma_A = 0,6\%$

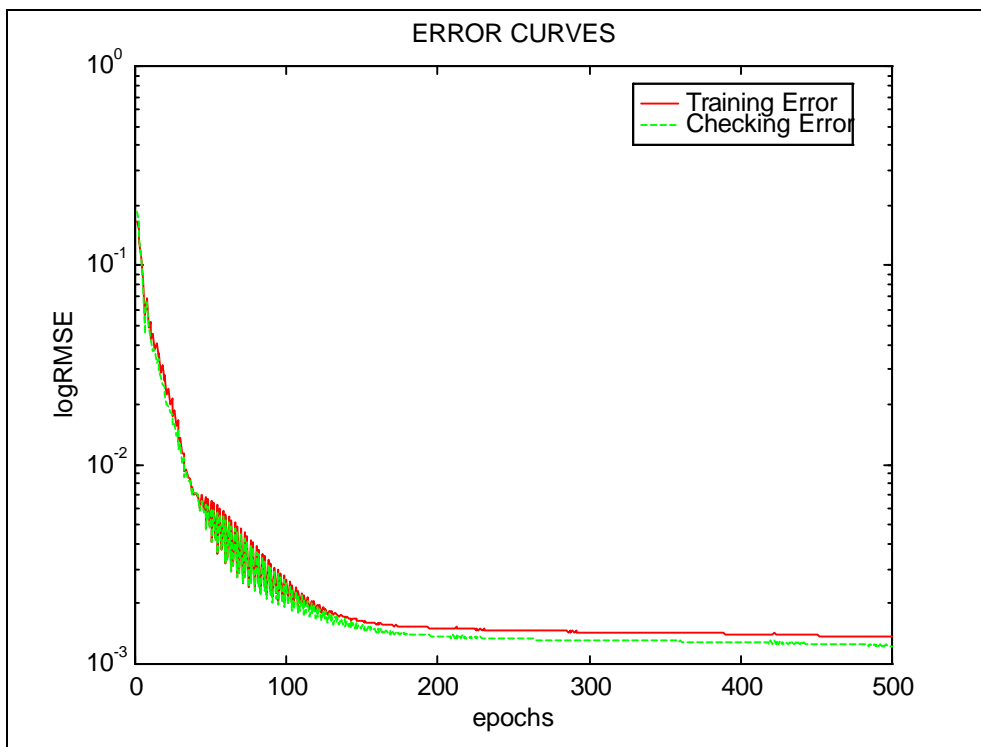


Fig. 8: Mean square error trend (RMSE). Minimal training RMSE = 0.0014 Minimal checking RMSE = 0.0012

CONCLUSION

This paper deals with the development of an expert system of support to decisions in a critical region, the industrial order evaluation. In fact, the decision process is not so articulate whilst a complex knowledge representation is required and then it is useful the use of AI techniques. For this reason hybrid architecture have been successful used.

The peculiarity of the proposed hybrid architecture systems is the one of marrying in a optimised way the two AI techniques: fuzzy logic and neural networks.

The FIS- ANFIS architecture perfectly matches the neural networks (learning from numerical examples) and the fuzzy logic (direct and immediate knowledge representation) and that is a Multi-FIS and Neuro-ANFIS architecture synthesis. The first one mainly uses the fuzzy logic potentialities, imitating neural networks in knowledge organisation way that it is distributed among different sub-systems constituent the main net elements. The network is the linking system that simulates the typical expert structured reasoning in solving complex problems. This architecture is useful in case of such well-knowledged experts aren't available, such as numerical data of the real system behaviour are not sufficient. The presented model simulates the reality but doesn't have high reliable answer. On the other side, the neuro-ANFIS architecture auto-models itself based on real numerical examples, in this way it learns from the experience, instead of using severe rules. Such architecture is useful in case of vague knowledge of the system to model providing acceptable reliable level.

As matter of the fact, the FIS-ANFIS architecture is based on knowledge experts and knowledge based on real numerical.

In this way it is possible to recover the approximations and the errors done both on knowledge engineering phase, and knowledge representation.

This kind of architecture of expert system reproduce almost exactly the real system behaviour to model ($\sigma_a=0,6\%$) requiring:

- a knowledge engineering phase not too long and deep;
- a few number of numerical examples to train the system, and
- remarkable reduction of time implementation.

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