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## A NEURAL NETWORK AND AN EXPERT SYSTEM FOR THE ANALYSIS OF BASIC METRIC CHARACTERISTICS OF COMPOSITE MEASURING INSTRUMENTS

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*A modification of Hopfield neural network is implemented, and designed to estimate partial image of items and then to compute the following metric characteristics of composite measuring instruments (e.g. motor, psychological, etc.): (1)  $\psi^4$ , Momirović's modification of Kaiser-Rice measure of representativeness; (2)  $\lambda^6$ , Guttman sixth lower bound to reliability of summation score; (3)  $\beta^6$ , Momirović lower bound to reliability of component score; (4)  $h^2$ , Momirović estimation of homogeneity of items set. Formal definitions and derivations of the implemented measures can be found in any modern textbook of measurement theory. Because of a modest educational level of most professionals in the theory of measurement, a primitive expert system is added to the main body of program in order to facilitate the interpretation of the obtained results in spite of a negative opinion of the first author about the real utility of interpretative expert systems.*

*KEY WORDS: neural networks / expert systems / theory of measurement*

## INTRODUCTION

Neural networks can emulate almost any method in data analysis, multivariate statistics and measurement theory. Some simple networks can be used to estimate basic metric characteristics of composite measuring instruments (*e.g. motor, psychological, physiological, anthropometrical, etc.*) on the basis of a reasonable compromise of scaling strategy, advocated and used by Birnbaum, Samejima, Rash and others, are adapted to this approach to theory of measurement, and classic scoring strategy, based on the works of Spearman, Lord, Guttman and Cronbach.

The aim of this paper is to present a modification of Hopfield neural network (Hopfield, 1982), designed to estimate partial image of items transformed to sigmoidal (0,1) form and then to compute the following metric characteristics: (1)  $\psi^4$ , Momirović's modification of Kaiser-Rice measure of representativeness; (2)  $\lambda^6$ , Guttman sixth lower bound to reliability of summation score (3)  $\beta^6$ , Momirović lower bound to reliability of component score (4)  $h^2$ , Momirović's estimation of homogeneity of item set. Formal definitions and derivations of the implemented measures can be found in Momirović, Wolf and Popović (1999). Unfortunately, educational level of most professionals in theory of measurements is relatively modest, so that a primitive expert system is added to the main body of program in order to facilitate the interpretation of obtained results in spite of a negative opinion of the first author concerning the real utility of interpretative expert systems (Momirović, 1989a; 1989b).

## PROGRAM RTT3HNNE

As it is well known, algebraic description of neural networks is usually very cumbersome, especially if the network is accompanied by even a rudimentary expert system. However, the methods implemented and techniques of implementation can be easily recognized from the source code of program by every user with a reasonable knowledge of programming in modern statistical meta languages.

*Zbornik IKSI, 1-2/2005 – K. Momirović and G. Bala*  
*„A Neural Network and an Expert System for the Analysis of Basic Metric Characteristics of Composite Measuring Instruments“, (str. 21-32)*

```
preserve
set printback=off
set decimal=dot
```

```
*-----
*           RTT3HNNE
*   EMULATION OF A MODIFICATION OF HOPFIELD NETWORK
*   FOR CALCULATION OF METRIC CHARACTERISTICS OF MEASURING INSTRUMENTS
*   ACCOMPANIED WITH AN EXPERT SYSTEM FOR THE INTERPRETATION OF RESULTS
*
*           Version 1.0.
*           12.4.2002
*
*           Written by
*           Konstantin Momirovic and Gustav Bala
*
* RTT3HNNE can be run with the following statements:
* INCLUDE 'RTT3HNNE.SPS'.
* RTT3HNNE VARS=input variables names.
*
* The basic idea of Hopfield networks is described in
*
* Hopfield, J.J. (1982):
* Neural networks and physical systems with emergent collective
* computational abilities.
* Proceedings of National Academy of Sciences, 79:2554-2558
*
* The image analysis by Hopfield networks is described in
*
* Momirovic, K. (2002):
* Image transformation by Hopfield neural network.
* Technical report, Institute of criminological and sociological research.
*
* Methods implemented in program are described in
* Momirovic, K. (2002):
* Estimation of metric characteristics by a modification of Hopfield
* neural networks.
* Technical report, Institute of criminological and sociological research.
*
* This program is described in
* Momomirovic, K.; Bala, G. (2002):
* A neural network and an expert system for the analysis of basic metric
* characteristics of composite measuring instruments
* Technical report, Institute of criminological and sociological research.
*-----

define rtt3hnne (vars=!charend('/'))

preserve
```

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*„A Neural Network and an Expert System for the Analysis of Basic Metric*  
*Characteristics of Composite Measuring Instruments“,(str. 21-32)*

```

set printback=off mxloop=999 mprint off
*-----
* Saving the original file.
*-----

save outfile='tmp_hpf.sav'
*-----
* Standardization and sigmoidal (0,1) transformation of data.
*-----

matrix

print/title'          RTT3HNNE'/space 1
print/title'  EMULATION OF A MODIFICATION OF HOPFIELD NETWORK'/space 0
print/title'    FOR COMPUTATION OF METRIC CHARACTERISTICS'/space 0
print/title'      OF COMPOSITE MEASURING INSTRUMENTS '/space 0
print/title'  WITH INTERPRETATION OF RESULTS BY AN EXPERT SYSTEM '/space 0

get x/file=*/variables=!vars/names=nx

compute num=nrow(x)
compute nvr=ncol(x)

print num/format "f8.0"/title 'Number of entities'
print nvr/format "f8.0"/title 'Number of items'

compute en=make(num,1,1)
compute mmm=csum(x)&/num
compute mmmm=en*mmm
compute x=x-mmmm
compute c=(t(x)*x)&/num
compute dc=sqrt(inv(mdiag(diag(c))))
compute x=x*dc

compute ec=2.718281828459

loop i=1 to num
loop j=1 to nvr
.compute x(i,j)=1/(1+ec**(-x(i,j)))
end loop
end loop

compute mmm=csum(x)&/num
compute mmmm=en*mmm
compute x=x-mmmm
compute c=(t(x)*x)&/num
compute dc=sqrt(inv(mdiag(diag(c))))
compute x=x*dc

compute rmat=(t(x)*x)&/num
compute rmat=(rmat+t(rmat))&/2

```

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```

compute rinv=inv(rmat)
compute imat=mdiag(diag(rmat))
compute u2=inv(mdiag(diag(rinv)))
compute beta=imat-rinv*u2

*-----
* Estimation of initial axons
*-----

call svd(beta,y1,psi,y2)

compute y1=y1(:,1:nvr)
compute y2=y2(:,1:nvr)

compute w0=y1*t(y2)

*-----
* Iterative estimation of axons.
*-----

compute a0=w0
compute a2=make(nvr,nvr,1)

loop i=1 to 99 if ((msum(abs(a2-a0)))/(nvr*nvr))>0.0001

compute b1=(rmat**i)
compute b1=b1*a0
call svd(b1,y1,psi,y2)
compute y1=y1(:,1:nvr)
compute y2=y2(:,1:nvr)
compute a1=y1*t(y2)
compute a2=a0
compute a0=a1

end loop

print i/title'Number of iterations'

compute w=a0

*-----
* Results of image transformation by Hopfield network.
*-----

compute y=x*w
compute cmat=(t(y)*y)&/num
compute cmat=(cmat+t(cmat))&/2
compute dmat=inv(sqrt(mdiag(diag(cmat))))
compute cmat=dmat*cmat*dmat
compute rinv=ginv(cmat)
compute imat=mdiag(diag(cmat))
compute u2=ginv(mdiag(diag(rinv)))
compute beta=imat-rinv*u2

```

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```

compute cmat=(beta)*cmat*beta
compute cmat=(cmat+t(cmat))&/2
*-----
* Measure of sampling adequacy of items set.
*-----

compute amat=rmat-cmat
compute amat=amat-mdiag(diag(amat))
compute rmat=rmat-imat

compute psi4=1-(msum(amat&*amat))/(msum(rrmat&*rrmat))
*-----
* Measure of reliability under simple summation model.
*-----

compute u2=imat-mdiag(diag(cmat))
compute lambda6=1-(msum(u2))/(msum(rmat))
*-----
* Measure of reliability under component model.
*-----

call eigen(rmat,v,lambda)

compute v=v(:,1:1)
compute lambda=lambda(1)
compute beta6=1-(t(v)*u2*v)/lambda
*-----
* Measure of homogeneity.
*-----

compute tvr=trace(cmat)
call eigen(cmat,v,lambda)
compute lambda=lambda(1)
compute h2=lambda/tvr
*-----
* Printout of obtained results.
*-----

print/title 'Results are obtained by a modification of Hopfield neural'/space 1
print/title 'network designed to estimate partial image of the items'/space 0
print/title 'and then to compute the following metric characteristics:'/space 0
print/title '(1) psi4, a Momirovic modification of Kaiser-Rice'/space 0
print/title 'measure of representativeness'/space 0
print/title '(2) lambda6, Guttman sixth lower bound to reliability'/space 0
print/title 'of summation score'/space 0
print/title '(3) beta6, Momirovic lower bound to reliability'/space 0
print/title 'of component score'/space 0

```

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```

print/title '(4) h2, Momirovic estimation of homogeneity of item set./space 0
compute kit1=špsi4,lambda6,beta6,h2ć
compute kit2=š"psi4", "lambda6", "beta6", "h2"ć
print kit1/format "f10.3"
      /title 'Representativeness, reliability and homogeneity measures'
      /cname=kit2
*-----
* Interpretation of sampling adequacy.
*-----

do if psi4>.950
.print/title 'An excellent sample of items is included in the test./space 1
end if

do if psi4<=.950 and psi4>=.900
.print/title 'A very good sample if items is included in the test./space 1
end if

do if psi4<=.900 and psi4>=.850
.print/title 'A fair sample of items is included in the test./space 1
end if

do if psi4<=.850 and psi4>=.800
.print/title 'A bad sample if items is included in the test./space 1
end if

do if psi4<.850
.print/title 'A very bad sample if items is included in the test./space 1
end if

do if psi4<=.850
.print/title 'Low sampling adequacy can be result of the following'/space 1
.print/title 'not mutually exclusive causes:/space 0
.print/title '(1) Bad selection of items due to inadequate theory'/space 0
.print/title '(2) Existence of tautological items./space 0
end if

do if psi4>=.900
.print/title 'Good sampling adequacy can be result of the following'/space 1
.print/title 'not mutually exclusive causes:/space 0
.print/title '(1) Selection of items based on a good theory'/space 0
.print/title '(2) Elimination of tautological items./space 0
end if

*-----
* Interpretation of reliability estimates.
*-----

do if lambda6>.950

```

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*Characteristics of Composite Measuring Instruments“, (str. 21-32)*

```
.print/title 'An excellent reliability of summation score is obtained. '/space 1
end if

do if lambda6<=.950 and lambda6>=.925
.print/title 'A very good reliability of summation score is obtained. '/space 1
end if

do if lambda6<=.925 and lambda6>=.900
.print/title 'A fair reliability of summation score is obtained. '/space 1
end if

do if lambda6<=.900 and lambda6>=.875
.print/title 'A poor reliability of summation score is obtained. '/space 1
end if

do if lambda6<.875
.print/title 'Unacceptable reliability of summation score is obtained. '/space 1
end if

do if lambda6<=.875
.print/title 'Low reliability of summation score can be result of the '/space 1
.print/title 'following not mutually exclusive causes: '/space 0
.print/title '(1) Bad selection of items due to inadequate theory '/space 0
.print/title '(2) Existence of unreliable items '/space 0
.print/title '(3) Inadequacy of simple summation model. '/space 0
end if

do if lambda6>=.900
.print/title 'Good reliability of summation score can be result '/space 1
.print/title 'of the following not mutually exclusive causes: '/space 0
.print/title '(1) Selection of items based on a good theory '/space 0
.print/title '(2) High reliability of the most of items '/space 0
.print/title '(3) Good representation of items by their sum. '/space 0
end if

do if beta6>.950
.print/title 'An excellent reliability of component score is obtained. '/space 1
end if

do if beta6<=.950 and beta6>=.925
.print/title 'A very good reliability of component score is obtained. '/space 1
end if

do if beta6<=.925 and beta6>=.900
.print/title 'A fair reliability of component score is obtained. '/space 1
end if

do if beta6<=.900 and beta6>=.875
.print/title 'A poor reliability of component score is obtained. '/space 1
end if

do if beta6<.875
.print/title 'Unacceptable reliability of component score is obtained. '/space 1
```

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```
end if
do if beta6<=.875
.print/title 'Low reliability of component score can be result of the '/space 1
.print/title 'following not mutually exclusive causes:'/space 0
.print/title '(1) Bad selection of items due to inadequate theory'/space 0
.print/title '(2) Existence of unreliable items.'/space 0
end if
do if beta6>=.900
.print/title 'Good reliability of component score can be result '/space 1
.print/title 'of the following not mutually exclusive causes:'/space 0
.print/title '(1) Selection of items based on a good theory'/space 0
.print/title '(2) High reliability of the most of items'/space 0
.print/title '(3) High variance of the component score.'/space 0
end if
compute dd=beta6-lambda6
do if dd<=.01
.print/title 'Summation and component models are almost equivalent.'/space 1
end if
do if dd>.01
.print/title 'Component models is more adequate for the'/space 0
.print/title 'computation of test results.'/space 0
end if
*-----
* Interpretation of homogeneity estimates.
*-----
do if h2>.700
.print/title 'A formidable homogeneity of test is obtained.'/space 1
end if
do if h2<=.700 and h2>.600
.print/title 'A very good homogeneity of test is obtained.'/space 1
end if
do if h2<=.600 and h2>=.500
.print/title 'An acceptable homogeneity of test is obtained.'/space 1
end if
do if h2<.500 and h2>=.400
.print/title 'Relatively poor homogeneity of test is obtained.'/space 1
end if
do if h2<.400
.print/title 'Unacceptable homogeneity is obtained.'/space 1
end if
```

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```
do if h2<=.500
.print/title 'Low homogeneity can be result of the '/space 1
.print/title 'following not mutually exclusive causes:'/space 0
.print/title '(1) Bad selection of items due to inadequate theory'/space 0
.print/title '(2) Existence of different clusters of items.'/space 0
end if

do if h2>.600
.print/title 'Good homogeneity can be result '/space 1
.print/title 'of the following not mutually exclusive causes:'/space 0
.print/title '(1) Selection of items based on a good theory'/space 0
.print/title '(2) Existence of not very distant clusters of items'/space 0
end if

*-----
* End of program and reconstruction of original file.
*-----

end matrix

get file='tmp_hpf.sav'

restore
!enddefine.
restore
```

## A NUMERICAL EXAMPLE

Test of oral aggressiveness SIGMA 3, constructed in its final form by Wolf, Džamonja, Radovanović and Momirović (1992) was applied to a sample of 314 adult criminals, fairly representative for the population of sentenced and condemned criminals in this country. The complete output of the program RTT3HNNE is presented in the sequel.

### RTT3HNNE

Emulation of a Modification of Hopfield Network for Computation of  
Metric Characteristics of Composite Measuring Instruments with  
Interpretation of Results by an Expert System

Number of entities	Number of items	Number of iterations
314	30	2

Results are obtained by a modification of Hopfield neural network designed to estimate partial image of the items and then to compute the following metric characteristics:

- (1)  $\psi_4$ , a Momirovic modification of Kaiser-Rice measure of representativeness
- (2)  $\lambda_6$ , Guttman sixth lower bound to reliability of summation score
- (3)  $\beta_6$ , Momirovic lower bound to reliability of component score
- (4)  $h_2$ , Momirovic estimation of homogeneity of item set.

Representativeness, reliability and homogeneity measures

$\psi_4$	$\lambda_6$	$\beta_6$	$h_2$
.938	.919	.922	.564

A very good sample if items are included in the test.

Good sampling adequacy can be the result of the following not mutually exclusive causes:

- (1) Selection of items based on a good theory
- (2) Elimination of tautological items.

A fair reliability of summation score is obtained.

Good reliability of summation score can be result of the following not mutually exclusive causes:

- (1) Selection of items based on a good theory
- (2) High reliability of the most of items
- (3) Good representation of items by their sum.

A fair reliability of component score is obtained.

Good reliability of component score can be result of the following not mutually exclusive causes:

- (1) Selection of items based on a good theory
- (2) High reliability of the most of items
- (3) High variance of the component score.

Summation and component models are almost equivalent.

An acceptable homogeneity of test is obtained.

## REFERENCES

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## NEURONSKA MREŽA I EKSPERTNI SISTEM ZA ANALIZU OSNOVNIH METRIJSKIH KARAKTERISTIKA KOMPOZITNIH MERNIH INSTRUMENATA

*Izvršena je modifikacija Hopfieldove neuronske mreže, tako što je dizajnirana da prvo procenjuje parcijalni imaż itema, te da izračuna sledeće metrijske karakteristike kompozitnih mernih instrumenata (npr. motoričkih, psiholoških i dr.): (1)  $\psi_4$ -Momirovićevu modifikaciju Kaiser-Rice-ova mera reprezentativnosti; (2)  $\lambda_6$ -Guttman-ovu šestu donju granicu pouzdanosti sumacije skorova; (3)  $\beta_6$ -Momirovićevu donju granicu pouzdanosti komponentnih skorova; (4)  $h_2$ -Momirovićevu procenu homogenosti skupa itema. Formalne definicije i izvodi implementiranih mera mogu se naći u savremenim udžbenicima o teoriji merenja. Zbog skromnog obrazovanja većine stručnjaka o problematici oblasti teorije merenja, dodat je jednostavan ekspertni sistem, kako bi se olakšala interpretacija dobijenih rezultata, uprkos negativnom stavu prvog autora u vezi stvarne koristi ekspertnih sistema.*

*KLJUČNE REČI: neuronska mreža / ekspertni sistemi / teorija merenja*