PERGAMON

Computers & Operations Research 27 (2000) 1045–1076

computers & operations research

www.elsevier.com/locate/dsw

A bibliography of neural network business applications research: 1994–1998

Bo K. Wong[a,*], Vincent S. Lai[b], Jolie Lam[c]

[a]*Department of Information Systems, Lingnan University, Tuen Mun, N.T., Hong Kong*
[b]*Chinese University of Hong Kong, Hong Kong*
[c]*City University of Hong Kong, Hong Kong*

Abstract

The purpose of this paper is to present a comprehensive bibliography of neural network application research in business during the period of 1994–1998. Our extensive literature searches have identified a total of 302 research articles. A classification of these articles by year reveals that a large amount of research has been published in the last five years. Production/operations, finance, marketing/distribution, and information systems were found as the most popular application areas. Information on neural network development language/tool, learning paradigm, computing operating environment, journals and authors are included. An in-depth comparison with the previous survey findings and potential future research trend in the neural network business research are discussed.

Scope and purpose

Due to the breakthrough of the neural network technology, there has been an increasing amount of neural network application research in the last decade. As a result, a considerable amount of published research has appeared, with a significant portion focusing on actual neural network development for business applications. But a comprehensive bibliography of these research published in the last five years is not documented.

Keywords: Neural network; Bibliography

1. Introduction

Neural network computing is an approach that attempts to mimic certain processing capabilities of the brain. This machine learning technology has the ability to represent knowledge based on

* Corresponding author. Tel.: + 852-2616-8096, fax: + 852-2892-2442.
E-mail address: bokwong@ln.edu.hk (B.K. Wong)

0305-0548/00/$ - see front matter
PII: S0305-0548(99)00142-2

massive parallel processing and recognize patterns based on experience. Since the 1980s, the drastic breakthrough of the computing technology has led to an increasing amount of neural network research on a wide variety of business functional applications. Most of these research findings pointed out that neural network technology could be successfully used in business and most of the time is superior to other techniques or technologies. A bibliography of these research studies published during the period of 1988–September 1994 was documented in Wong et al. [1]. The purpose of this paper is to present a comprehensive bibliography of these neural network business applications published after this period, compare the major changes of the research between the two periods, and discuss the future potential research trend.

2. Research methology

The literature search process involved three major steps. First, both ABI/INFORM database and *Business Periodical Index* (BPI) were searched using the keyword 'neural network' for the period covering 1994–1998. The ABI/INFORM database was the most important step in our literature retrieval process since it included more than 800 different business-related international journals. In this database, we were able to retrieve about 920 abstracts from the specified period.

Second, a reference search of textbooks on neural networks and related topics was conducted. We considered a total of 14 textbooks: Bose and Liang [2], Browne [3], Chen [4], De Wilde [5], De Wilde [6], Golden [7], Goonatilake and Treleaven [8], Hagan et al. [9], Hunt et al. [10], Irwin et al. [11], Korn [12], Parks [13], Rzempoluck [14], and Van Rooif et al. [15]. However, these books were not that helpful since most references were on scientific applications.

Third, 10 additional journals were also included in our manual search. The rationale was that (1) several prestigious journals known to publish neural network articles were either partially or not included in the ABI/INFORM database or BPI, and (2) some of these journals were deemed as being important in the MIS discipline [16–18]. These 10 journals were *ACM DATABASE*, *AI Expert*, *Communications of the ACM*, *Expert Systems*: *The International Journal of Knowledge Engineering and Neural Networks*, *IEEE Expert* (renamed as *IEEE Intelligent Systems & Their Applications in 1998*), *IEEE Transactions on Software Engineering*, *IEEE Transactions on Systems*, *Man*, *and Cybernetics*, *Information Systems Research*, *International Journal of Human-Computer Studies*, and *International Journal of Production Research*.

Not all the articles retrieved were included in our survey. Two criteria were applied in the selection process of the articles. Each article (1) should present the application of neural network in business and discussed either a prototype or a fully developed system, and (2) should have a stringent research methodology and have detailed discussions on the development process of neural networks. A large number of articles were eliminated because they were not business application types of research.

3. Results

We have identified a total of 302 journal articles. The Refs. [19 – 320] present the bibliography of these neural network business applications. Fig. 1 shows the distribution of articles published by year, including years 1988–1993.

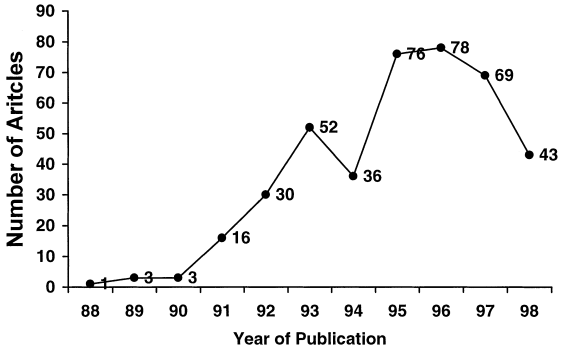

Fig. 1. Distribution of articles by year.

Table 1 shows 302 articles by area of application. Production/operations had the largest number of applications, followed by finance, marketing/distribution, information systems, accounting/auditing, and human resources. In production/operations, the most popular research areas were part family/machine grouping, job shop scheduling, cellular manufacturing system design, and equipment/machine fault diagnosis/detection. Bankruptcy prediction of banks/firms was the most common application in the area of finance.

The language/tool used in the development, the learning paradigm, and the type of computer operating environment of each neural network application are presented in Table 2. It is not surprising to find that the most common programming language was C/C++, and the most common tools were NeuralWorks Professional, NeuroShell, and BrainMaker. In addition, back-propagation, ART, Hopfield and Radial Basis Function were the most popular learning paradigms of these neural networks.

There were a total of 94 articles reporting the types of computing platform. Approximately 62.8% (59 articles) reported the use of microcomputer, 35.1% (33 articles) reported the operation on minicomputer or mainframe, and 2.1% (2 articles) reported the utilization of both.

Table 3 lists the journals that published the most neural network business applications. Journals such as *Computers and Industrial Engineering*, *International Journal of Production Research*, *European Journal of Operational Research*, *Computers in Industry*, *Journal of Manufacturing*, and *Computers and Operations Research* are the more popular journals. The reason is quite obvious since there are many neural network applications in the area of production/operations, and these journals are more suitable for publishing in this area.

These 302 articles were written by a total of 601 authors. Six authors did not report their affiliations. Out of 595 authors, approximately 87.1% (518 authors) were affiliated with 219 different academic institutions and 12.9% (77 authors) were affiliated with 60 non-academic or business-related institutions. Also, approximately 47.5% (104 institutions) of the academic institutions were US institutions and 52.5% (115 institutions) were non-US institutions. Thirty-one of the 60 business-related institutions (51.7%) were US institutions and the remaining 29 (48.3%) were non-US institutions.

Table 1
Distribution of articles by application area[a]

Accounting/auditing
- Audit judgement task supporting [88]
- Auditor's going concern uncertainty decision prediction [178]
- Fraud risk assessment [115]
- Preliminary control risk assessment [87]
- Quarterly accounting earnings forecasting [49]

Total: 5

Finance
- Acquired and liquidated firms discrimination [214]
- Bankruptcy prediction of banks/firms [42,62,133,175,188,194,289,309]
- Bond trading [97,231,232,259]
- Capital market index forecasting [313]
- Change card default risk assessment [280]
- Commercial bank's market efficiency assessment [27]
- Commercial loan credit worthiness evaluation [111]
- Commodity future trading [216]
- Company failure analysis [251]
- Construction contract bond claims prediction [279]
- Corporate health estimation [166]
- Country risk rating prediction [58]
- Credit authorization [91]
- Credit evaluation [227]
- Credit scoring [177]
- Derivative securities pricing and hedging [129]
- Distress financial firms classification [161]
- Exchange rate forecasting [106,138]
- Federal reserve decision making [264]
- Financial distress forecasting [24]
- Financial prediction and trading strategies [221]
- Financial risk classification [226]
- Financial statement analysis and interpretation [158]
- Future spot rates predication [277]
- Futures trading volume forecasting [142]
- Initial public offering forecasting [119]
- Initial public offering pricing [136]
- Insurance problem examination [295]
- Insurer insolvency prediction [43]
- Interest rate prediction [215]
- Intermarket analysis [244]
- International equity risk premium prediction [94]
- Investment banking hiring prediction [192]
- Investment behavior investigation [98]
- Investment management [239]
- Loan classification [90]
- Mutual fund net asset value forecasting [67]
- Non-life insurance companies evaluation [157]
- Nonpayment prediction [206]
- Portfolio optimization [127,270]

Table 1 (*continued*)

Real estate appraisal [314]
Residential property values evaluation [78]
Shipbuilding's scheduling system development [173]
Spot exchange rates prediction [222]
Stock market index prediction [152,281]
Stock market holding period return investigation [312]
Stock market indexes structure testing [19]
Stock market volatility forecasting [44,92]
Stock performance/selection prediction [34,316]
Stock's systematic risk forecasting [311]
Successful new ventures identification [137]
T-bond market prediction [245]
Total: 67

Human resource
Salesperson hiring [308]
Total: 1

Information systems
Character recognition for personal digital assistant [315]
Computer assess security [218]
Computer program risk analysis engineering [147]
Computer users authentication [242]
Computer viruses recognition and classification [93,282]
Database tables clustering [139]
Document semantic indexing [60]
Information retrieval [81,185]
Intelligent networks' feature interaction management [284]
Internet user modeling [201]
Knowledge discovery and concept exploration [59]
Organizations' IT adoption identification [252]
Production systems' information integration [99]
Software cost estimation [169,247]
Software development [269]
Software development effort estimation [103,310]
Software fault prediction [255]
Software maintenance task effort prediction [140]
Software quality prediction [168]
Text-editing goals identification [296]
Total: 24

Marketing/distribution
Competitive retail coffee market structure identification [118]
Consumer choice prediction [306]
Consumer segments identification [86]
Franchising decision making improvement [187]
Future order forecasting [204]
Gasoline demand forecasting [174]
Industrial market segmentation [104]
International airline passenger forecasting [212]
Long distance telephone usage [253]

(*continued on next page*)

Table 1 (*continued*)

Market responses prediction [292]
Market segmentation [31]
Market share forecasting [20]
New investment product promotion [108]
Product design [30]
Product purchase frequency prediction [97]
Relationship quality investigation [37]
Sales forecasting [25,163,164,189]
Solo mailing [317]
Target marketing [318,319]
Telephone interview response analysis [205]
Total: 24

Production/operations
Abrasive flow machining operation [223]
Acoustic emission behaviors evaluation [66]
Adaptive optimal controlling [155]
Aging aircraft component inspection prediction [257]
Aging aircraft safety prediction [190]
Aircraft and machine tool pattern recognition [176]
Arm trajectory formation [195]
Automated guided vehicle system optimization [74]
Automated material handling [121]
Barley malting process [102]
Beam landing adjustment [229]
Bean vibration minimization [46]
Bearing faults prediction [268]
Boundary defect recognition [154]
Building text's automatic content recognition [200]
Capacity allocation [113]
Car sequencing [262,263]
Cell formation [71]
Cellular manufacturing system design [70,165,237,238]
Cerebellum motor learning [146]
Charts pattern identification [22]
Cold bending steel reinforcing bars automation [96]
Colored object recognition [304]
Complex grinding processes controlling [256]
Computer vision inspection [55]
Computer vision precise measurement [271]
Control charts pattern recognition [131,132,260]
Cost estimation [39,40,83,89]
Cost estimation predictive modelling [261]
Cost flow forecasting [41]
Cutting tool monitoring [202]
DC motor speed controlling [243]
DOF stanford manipulator design [208]
Design retrieval [29]
Electricity demand prediction [79]
Equipment/machine fault diagnosis/detection [85,109,156,184]

Table 1 (*continued*)

Facility layout optimization [285]
Featured-based product cost estimation [320]
Flexible beam's torque control [287]
FMS designed analysis [191]
Gas furnace identification [33]
Group technology [143]
Image inspection and verification [117]
Incipient object slippage detection [51]
Integrated circuit fabrication [272]
Intelligent manufacturing control [124]
Intelligent package [29]
Job scheduling [123]
Job shop scheduling [45,135,170,224,233,246,248,258]
Lime granule quality inspection [53]
Machine design [95]
Machine fault diagnosis [126]
Machine performance degradation measurement [171]
Machine tools' thermal deformation [293]
Machinery diagnosis [63]
Machining knowledge acquisition [82]
Manufacturing diagnosis [236]
Manufacturing process control and monitoring [35]
Manufacturing process parameter change detection [235]
Manufacturing processes simulation [141]
Manufacturing system simulation optimization [128]
Manufacturing systems design and real-time reconfiguration [198]
Manufacturing systems prediction [153]
Material selection [112]
Message passing system [160]
Multi-objective FMS scheduling [149,199]
Multicriteria solid transportation optimization [181]
Multiple I/O data network routing optimization [288]
Musculo-skeletal system modelling [150]
Naphtha cut point prediction [297]
Nonlinear process control improvement [274]
Non-stationary manufacturing process tracking [299]
Oil quality rating [194]
Part family grouping [75,148]
Part family/machine grouping [47,61,84,100,144,159,182,275,276,294]
Part positioning [54]
Part-tool grouping [26]
Peg-into-hole assembly operation [217]
Plant identification and control [33]
Plant location classification [38]
Plant location optimization [291]
Plasma etch processing [241]
Process control [64,101]
Process mean shift detection and classification [57]
Process modelling and controlling [307]
Process planning [197]

(*continued on next page*)

Table 1 (*continued*)

Product manufacturability controlling [73]
Products quality modelling [120]
Progressive die design [186]
Quality control [191]
Quality controller [68]
Raw material purchasing [151]
Resource constrained scheduling [266]
Retrieving systems design [56]
Road tunnel ventilation controlling [107]
Robot arm impedance controlling [286]
Robot manipulator controlling [179]
Robot tracking controlling [219]
Robotic die polishing [162]
Robotic grasping system design [209]
Rolling mill - process control [107]
Rotating-Machinery performance analysis [183]
Schedule assessment [114]
Sheet metal parts classification [116]
Signal monitoring system [145]
Single machine mean tardiness [246]
Slip resistance prediction [290]
Star-LAN design optimization [110]
Statistical process control [65,80]
Steel manufacturing [249]
Steel mill prediction scheduling [302]
Steel plant's real-time process control [250]
Steel temper mill presetting [225]
Surface flows identification [298]
System reliability estimation [77]
Tandem cold mill production model [69]
Three-link robot's smooth trajectory tracking [130]
Tool path planning [273]
Tool wear monitoring [230]
Touch trigger probes' travel map establishment [254]
Toys and consumer electronics' speech processing [210]
Trickling filter performance prediction [228]
Unit commitment and power demand prediction [36]
Vehicle controller [32]
Vehicle detection [193]
Vehicle driving comfort prediction [48]
Vehicle routing problem [283]
Waste treatment [267]
Wave soldered joints inspection [134]
Wear equation identification [211]
Welding quality improvement [203]

Total: 163

Others

Airline passenger volume prediction [213]
Autoregressive moving average model identification [172]

Table 1 (*continued*)

Business value and organizational variables identification [234]
Construction firms' subcontractor rating [23]
Consumer's expenditure forecasting [76]
Economic growth forecasting [21]
Electronic meeting output classification [220]
Expenditure system model estimation [301]
Forecasting method selection [72]
Forecasting model selection [240,265]
Industrial production index analysis [105]
Organizational decision making [303]
Organizational structure modelling [300]
Real-time macroeconomic forecasting [278]
Residential construction demand forecasting [125]
Risky projects' economic analysis [28]
Simultaneous equation systems forecasting [52]
Strategic business planning [180]
Time series analysis [50]
Time-series forecasting [122,167]
Time-tabling problem [196]
Total health care costs prediction [207]
Warranty claims forecasting [305]
Total: 25

[a]There are two applications in article [29,33,97,107,191,194,246].

4. Comparisons with the previous survey [1]

Overall, the amount of research has been increasing in the last decade. It should be noted here that the number of research studies has stayed almost the same in years 1995–97 and has dropped significantly in 1998. We believe that it is not that simple to draw any conclusion on this situation. The possible explanation is that researchers are beginning to have more interest to conduct research in other artificial intelligence techniques, such as genetic algorithm and fuzzy logic. Also, some new journals that published neural network applications might not be included in the scope of our search.

As compared with the last survey, production/operations and finance were still the most common research application areas. It is interesting to find that the number of research studies in marketing/distribution and information systems has significantly increased. On the other hand, there were still only a few research studies in accounting/auditing and human resources, and their number of articles stayed approximately the same.

In the area of production/operations, the most popular research applications were still part family/machine grouping, job shop scheduling, and equipment/machine fault diagnosis/detection. However, less amount of research has been conducted on the area of process control.

Bankruptcy prediction of banks/firms remained a common research area in finance, but there was a sharp decrease in the number of studies on stock performance/selection prediction in comparison with the previous survey. Instead, our survey indicated that there were more in-depth

Table 2
Neural network characteristics by article[a]

Article	Language/tool	Learning paradigm	Computer operating environment
[19]	LENNS	NR	Fujitsu VPX 240/10 Vector Processor
[20]	MATLAB	Backpropagation	NR
[21]	NeuroForecaster	NR	NR
[22]	NR	ART-1	NR
[23]	NeuralWorks Professional II	Backpropagation	NR
[24]	NR	Backpropagation	NR
[25]	NR	Backpropagation	NR
[26]	NR	NR	NR
[27]	NR	Backpropagation	NR
[28]	NeuralWorks Professional II	Backpropagation	NR
[29]	C++	ART-1	Microcomputer
[30]	NR	Backpropagation	NR
[31]	NR	Frequency-Sensitive Competitive Learning	NR
[32]	NR	Backpropagation	NR
[33]	NR	Backpropagation	NR
[34]	BrainMaker, NeuralWorks Professional II/Plus	Backpropagation	486 Microcomputer
[35]	C++	Backpropagation	NR
[36]	Professional II	Backpropagation	NR
[37]	NR	Backpropagation	NR
[38]	ANSim, NeuroShell	Backpropagation, ART-2	NR
[39]	NR	Backpropagation	486 56 MHz Microcomputer
[40]	NR	Backpropagation	NR
[41]	NR	Backpropagation	NR
[42]	NR	Backpropagation	NR
[43]	NR	Backpropagation	NR
[44]	NR	NR	NR
[45]	NR	NR	NR
[46]	NR	NR	486 Microcomputer
[47]	NR	Fuzzy ART	486 Microcomputer
[48]	NeuralWares Professional II/Plus	Radial Basis Function, Backpropagation	NR
[49]	NR	Backpropagation	NR
[50]	NR	NR	NR
[51]	NR	Backpropagation	386 100 MHz Microcomputer
[52]	NR	Genetic Adaptive NN Training Algorithm	NR
[53]	NR	Backpropagation	NR
[54]	Borland C++	Backpropagation	486 DX 66 MHz Microcomputer
[55]	Parallel Distributed Processing Software	NR	ITEX 100 Image Processing System with Microcomputer
[56]	C	ART-1	486 DX 50 MHz Microcomputer
[57]	NR	Backpropagation	NR
[58]	NeuralWares Explorer	Backpropagation, Counter Propagation Network	NR

Table 2 (*continued*)

Article	Language/tool	Learning paradigm	Computer operating environment
[59]	C	NR	DEC Station 5000/120
[60]	C	Hopfield	UNIX
[61]	NR	ART-1	NR
[62]	NeuralWorks Professional II/Plus	NR	NR
[63]	NR	Radial Basis Funciton	NR
[64]	Turbo C	Backpropagation	486 with a Math Coprocessor Microcomputer
[65]	NR	Backpropagation, Modular	486 Microcomputer
[66]	C	Backpropagation	NEC EWS 4800 Workstation
[67]	C, SAS	Backpropagation	Apollo Workstation
[68]	NR	Backpropagation, Radial Basis Function	NR
[69]	NR	Backpropagation	Sun Sparc 20 Workstation
[70]	NR	Backpropagation	Sun Sparc, Pentium Dos Machine
[71]	Basic, Turbo C	Interactive Activation and Competition	586 Microcomputer
[72]	Basic, BrainMaker	Backpropagation	Microcomputer 8 MHz
[73]	NR	Backpropagation	NR
[74]	FORTRAN	NR	NR
[75]	NR	Backpropagation	Microcomputer
[76]	NR	Backpropagation	NR
[77]	NR	Backpropagation	NR
[78]	NR	Backpropagation	NR
[79]	NR	NR	NR
[80]	NR	Radial Basis Function	NR
[81]	NR	NR	Macintosh Quadra, DEC Station 5000/200
[82]	NR	NR	NR
[83]	PlaNet	NR	NR
[84]	NR	NR	HP-Apollo Workstation
[85]	FORTRAN	Backpropagation	Microcomputer
[86]	NR	Backpropagation	NR
[87]	NR	Backpropagation	NR
[88]	NR	Backpropagation	NR
[89]	NR	NR	NR
[90]	NeuralWorks Professional II/Plus	Backpropagation	486 33 MHz Microcomputer
[91]	NR	NR	NR
[92]	NR	NR	NR
[93]	C	NR	Microcomputer
[94]	NR	Backpropagation	NR
[95]	NR	Backpropagation	NR
[96]	NR	Backpropagation	NR
[97]	NR	Backpropagation	Microcomputer 20 MHz
[98]	NeuralWares Professional II, NeuralWares Predict	Backpropagation, Cascade Correlation	NR

(*continued on next page*)

Table 2 (*continued*)

Article	Language/tool	Learning paradigm	Computer operating environment
[99]	NETS, PlaNet v5.6	NR	NR
[100]	CNAPS-C	ART-1	CNAPS Neurocomputer
[101]	NR	Backpropagation	NR
[102]	NR	Backpropagation	Sun Ultrasparc 1
[103]	NR	Backpropagation	NR
[104]	NeuroForecaster	NR	486 50 MHz Microcomputer
[105]	NR	NR	486 Microcomputer
[106]	NR	NR	NR
[107]	NR	NR	NR
[108]	NR	Backpropagation	386 Microcomputer
[109]	MS C version 6.0	Backpropagation	Microcomputer
[110]	NR	Boltzmann Machine	NR
[111]	NR	Adaptive Linear Element (ADALINE), Adaptive Non-linear Element (ADANLINE), Backpropagation, Pocket Algorithm with Ratchet	NR
[112]	C++	Backpropagation	Microcomputer
[113]	NR	NR	NR
[114]	MATLAB, CELESTIN	Backpropagation	NR
[115]	NeuroShell 2	Backpropagation	NR
[116]	NR	ART-2	NR
[117]	NR	NR	NR
[118]	Microsoft Visual Basic 3.0, Ward System Group Neuro Windows	Backpropagation	NR
[119]	Gauss ANN	NR	NR
[120]	NR	NR	NR
[121]	FORTRAN	Kohonen's Self Organizing Feature Map	Sun Sparc Station 330
[122]	NR	Backpropagation	NR
[123]	C	Backpropagation	NR
[124]	C++ for Windows	NR	486 66 MHz Microcomputer
[125]	NR	Backpropagation	NR
[126]	Turbo C++, Logical Systems C	ARTMAP	486 33 MHz Microcomputer
[127]	NeuroShell	Backpropagation	NR
[128]	NR	Backpropagation	NR
[129]	NR	Backpropagation	Sun Sparc Workstation II
[130]	NR	Adaptive Heuristic Critic	NR
[131]	NR	NR	NR
[132]	NR	ART	NR
[133]	NR	Ontigenic	NR
[134]	C	Backpropagation	386 Microcomputer
[135]	NR	Hopfield, Backpropagation	486 333 MHz Microcomputer

Table 2 (*continued*)

Article	Language/tool	Learning paradigm	Computer operating environment
[136]	NR	NR	NR
[137]	NeuralWorks Professional II/Plus	Backpropagation	486 Microcomputer
[138]	NR	Backpropagation	NR
[139]	NR	Kohonen	NR
[140]	PlaNet v5.6	NR	NR
[141]	C, SNNS	Backpropagation	Sun Sparc 5 Workstation
[142]	NTRAIN	NR	486 DX 266 MHz Microcomputer
[143]	NR	ART-1	386 Microcomputer
[144]	NR	ART-1/KS, ART-1/KSC, Fuzzy ART	NR
[145]	NR	ART-2, ART-2A, Cascade Correlation	NR
[146]	NR	Backpropagation, Parallel Layer Weight Recursive Least-Squares, QR Decomposition Algorithm	NR
[147]	NR	Backpropagation	NR
[148]	C++	NR	IBM RS/6000
[149]	NR	Kohonen	NR
[150]	NR	NR	NR
[151]	NR	Backpropagation	NR
[152]	NR	Backpropagation, Probabilistic Neural Network, Recurrent Neural Network	NR
[153]	NR	NR	NR
[154]	NR	Backpropagation, Hopfield	NR
[155]	NR	Backpropagation	NR
[156]	NR	ART-2	NR
[157]	Pascal	Backpropagation	NR
[158]	C	Boltzmann Machine	Sun Sparc, SLC, NeXT computer
[159]	C++	NR	IBM RS/6000
[160]	NR	Backpropagation, Neocognitron, Hopfield	NR
[161]	NR	Backpropagation	NR
[162]	NR	Backpropagation	Microcomputer
[163]	NR	NR	NR
[164]	NR	Backpropagation	NR
[165]	NR	Backpropagation	NR
[166]	C	NR	NR
[167]	Hybrid Backpropagation, Turbo-Pascal, Turbo Vision	NR	486 50 MHz Microcomputer

(*continued on next page*)

Table 2 (*continued*)

Article	Language/tool	Learning paradigm	Computer operating environment
[168]	Freeware Program Developed at U. of Bari	Backpropagation	NR
[169]	NR	NR	NR
[170]	NR	Backpropagation	SIMD Type of Parallel Computer with 256 Processor
[171]	NR	CMAC	NR
[172]	NR	Backpropagation	NR
[173]	UNIK-NEURO	NR	Sun Sparc
[174]	UNIK-NN	Backpropagation	NR
[175]	NeuralWorks Professional v5.0	SOFM, LVQ	NR
[176]	NR	Backpropagation	486 DX 66 MHz Microcomputer
[177]	NR	Backpropagation	HNC neurocomputer
[178]	N-NET	NR	Microcomputer
[179]	NR	Hebbian, Backpropagation	NR
[180]	Visual Basic	Backpropagation	Microcomputer
[181]	*Mathematica* tool	NR	Pentium 133 MHz Microcomputer
[182]	Turbo C	ART-1	NR
[183]	NR	Enhanced CMAC	486 Microcomputer
[184]	C	Backpropagation	NR
[185]	NR	Kohonen's Feature Map Algorithm	Cray Super Computer
[186]	NR	Backpropagation	NR
[187]	BrainMaker	Backpropagation	386 DX 40 Microcomputer
[188]	NR	NR	NR
[189]	NeuroShell 2	Backpropagation, General Regression NN	386 Microcomputer
[190]	NeuroShell 2	Backpropagation, General Regression NN, Probabilistic Neural Network	NR
[191]	C, SIMAN	Fuzzy ARTMAP	Intel's Personal Supercomputer (IPSC)
[192]	NR	NR	NR
[193]	NR	Radial Basis Function	NR
[194]	NeuralWorks Professional II	NR	NR
[195]	NR	NR	NR
[196]	C	Hopfield	486 33 MHz Microcomputer
[197]	NR	NR	NR
[198]	NR	Backpropagation	NR
[199]	MATLAB	Kohonen	NR
[200]	KBS-Class	NR	NR
[201]	NR	Backpropagation	NR
[202]	NR	Kohonen's Unsupervised Feature-Maps, Backpropagation	NR
[203]	SAS	Backpropagation	Microcomputer
[204]	NeuralWorks Professional II	NR	NR
[205]	CATPAC	Clustering Algorithm	NR

Table 2 (*continued*)

Article	Language/tool	Learning paradigm	Computer operating environment
[206]	NR	General Regression NN, Backpropagation	NR
[207]	NR	General Regression NN	NR
[208]	NR	Backpropagation	NR
[209]	NR	NR	NR
[210]	NR	Backpropagation	NR
[211]	NR	Neuro-Fuzzy GMDH algorithm	NR
[212]	NR	NR	NR
[213]	NR	Backpropagation	NR
[214]	NR	Backpropagation	NR
[215]	C	NR	NR
[216]	NR	Backpropagation	NR
[217]	NR	Reinforcement Network	NR
[218]	C	Backpropagation, Sum-of-Product Algorithm, Hybrid Sum-of-Products Algorithm	486 Microcomputer
[219]	NR	NR	486 Microcomputer
[220]	NR	Kohonen SOM	NR
[221]	NR	NR	NR
[222]	NR	NR	NR
[223]	BrainMaker	Backpropagation	486 DX 66 MHz Microcomputer
[224]	NR	Backpropagation	NR
[225]	NR	Backpropagation	NR
[226]	NR	Modified Backpropagation	Sun-4 Machine
[227]	NR	Backpropagation	Convex-C240
[228]	NETS Software	NR	386 SX 25 Microcomputer
[229]	NR	NR	NR
[230]	NR	Backpropagation	NR
[231]	NR	NR	NR
[232]	NR	NR	NR
[233]	NR	NR	NR
[234]	NeuroShell	NR	NR
[235]	NR	NR	NR
[236]	NR	Backpropagation	NR
[237]	NR	NR	NR
[238]	NR	Cluster Centre Seeking (CCS) Algorithm	NR
[239]	NR	Backpropagation	NR
[240]	FORTRAN	NR	IBM Mainframe
[241]	NR	Backpropagation	NR
[242]	NR	NR	NR
[243]	NR	Extension to Hopfield, Cohen-Grossberg	NR
[244]	NR	Back-Percolation Algorithm	NR
[245]	Predict	NR	NR
[246]	C	Modified Hopfield Network	Sun Sparc 2 Workstation
[247]	NR	CMAC	NR

(*continued on next page*)

Table 2 (*continued*)

Article	Language/tool	Learning paradigm	Computer operating environment
[248]	NR	Hopfield, Boltzmann	NEC PC-980/DA
[249]	NR	NR	NR
[250]	Quick C, NeuralWares Nworks Explorer	Backpropagation	NR
[251]	NR	SOFM	NR
[252]	NR	Backpropagation, Newton-Raphson Algorithm	NR
[253]	GRG2-Based System	Backpropagation	IBM RS/6000 model 530
[254]	BrainMaker	Backpropagation	Microcomputer 90 MHz
[255]	NR	NR	NR
[256]	NR	Radial Basis Function	NR
[257]	NeuroShell 2	Backpropagation	386 Microcomputer
[258]	NR	Backpropagation	386 33 MHz Microcomputer
[259]	Pascal	Quickprop Algorithm, Cascade-Correlation	NR
[260]	NR	NR	NR
[261]	NR	Backpropagation	NR
[262]	NR	SOF, Hopfield	NR
[263]	NR	Hopfield	NR
[264]	NR	NR	NR
[265]	BrainMaker	NR	Microcomputer
[266]	NR	Backpropagation, ART	NR
[267]	NR	NR	NR
[268]	NR	Cascade Correlation	NR
[269]	NR	Backpropagation	386 Microcomputer
[270]	NR	Probabilistic Neural Networks	NR
[271]	Parallel Distributed Processing Software	NR	486 DX2 Microcomputer
[272]	NR	ART	Microcomputer
[273]	NR	SOM	486 Microcomputer
[274]	NR	NR	NR
[275]	FORTRAN 77	Fuzzy ART, ART-1	IBM 4381 Mainframe
[276]	NR	Fuzzy ART	Notebook
[277]	NR	NR	NR
[278]	NR	General Regression NN	NR
[279]	C	NR	DEC Station 5000/200 Ultrix Workstation
[280]	WinNN™	Backpropagation	Microcomputer
[281]	NR	Radial Basis Function	NR
[282]	NR	Backpropagation	NR
[283]	C	SOFM	Sun Sparc 10 Workstation
[284]	ASPIRIN/MIGRAINES	NR	NR
[285]	NR	Backpropagation	Sun Sparc 10, HP9000/710 computer
[286]	NR	Backpropagation	NR

Table 2 (*continued*)

Article	Language/tool	Learning paradigm	Computer operating environment
[287]	NR	Backpropagation	NR
[288]	NR	NR	NR
[289]	NR	Backpropagation	NR
[290]	NR	NR	NR
[291]	NR	Hopfield-Tank Network	NR
[292]	NR	NR	NR
[293]	MATLAB	Backpropagation	NR
[294]	NR	Competitive Learning, ART, SOFM	Microcomputer
[295]	C	NR	NR
[296]	SunNet Simulator	Backpropagation	SUN 4
[297]	NR	Backpropagation	486 DX2 33 MHz Microcomputer
[298]	NR	Backpropagation	NR
[299]	NR	Radial Basis Function	NR
[300]	NR	NR	NR
[301]	NR	Monotonic Backpropagation	NR
[302]	NR	Monotonic Backpropagation	NR
[303]	NR	Backpropagation	NR
[304]	NR	NR	NR
[305]	NR	Backpropagation	NR
[306]	NR	Backpropagation	NR
[307]	C	Counterpropagation	SUN Microsystem
[308]	NR	Convergence Algorithm	NR
[309]	BrainMaker	Backpropagation	Microcomputer
[310]	NR	Backpropagation	NR
[311]	NR	General Regression NN	NR
[312]	NR	NR	NR
[313]	NevProp Software	Backpropagation	NR
[314]	@Brain, NeuroShell	NR	486 33 MHz Microcomputer
[315]	NR	Backpropagation	NR
[316]	C	Backpropagation	VAX 11/750
[317]	NR	NR	NR
[318]	NR	Backpropagation	NR
[319]	NR	Backpropagation	NR
[320]	MATLAB	Backpropagation	NR[a]

[a]NR = not reported.

studies on stock market, including stock market index prediction [152,281], stock market holding period return investigation [312], stock market indexes structure testing [19], stock market volatility forecasting [44,92], stock's systematic risk forecasting [311].

In the information system area, there was only one study on software application in the last survey. However, our review had eight software application related studies, including software cost

Table 3
Top journals publishing neural network applications

Journal	Count
Computers and Industrial Engineering	37
International Journal of Production Research	30
Computers in Industry	23
European Journal of Operational Research	21
Decision Support Systems	18
IEEE Transactions on Systems, Man, and Cybernetics	16
Journal of Manufacturing Systems	10
IEEE Expert (Intelligent Systems & Their Applications)	9
Computers and Operations Research	8
IIE Transactions	8

estimation [169,247], software development [269], software development effort estimation [103,310], software fault prediction [255], software maintenance task effort prediction [140], and software quality prediction [168].

In terms of the computer platform, approximately 60% of the research studies used microcomputer in both surveys. Of 53 applications reporting the types of languages in this survey, only three (5.7%) studies used Pascal to develop neural networks. Since there was 29.2% in the last review, it is quite obvious that Pascal is not a popular language anymore. Instead, the percentage of using C/C++ has increased from 50% to approximately 67.9% (36 articles). It is also interesting to find that NeuralWorks Professional, NeuroShell, and BrainMaker remained the most popular tools, and backpropagation, ART, Hopfield, and Radial Basis Function were still the most common learning paradigms.

Both *Computers & Industrial Engineering* and *International Journal of Production Research* remained the most popular journals publishing neural network business applications in both surveys. Interestingly, *European Journal of Operational Research* was not in the ranking list in the last survey, but became the third most popular journal in this survey.

The majority of authors still came from academic institutions and remained almost the same percentage as compared with the last review. However, the percentage of US institutions has dropped from approximately 70 percent to less than 50 percent.

5. Future trend

There is no doubt that production/operations and finance will still be the most common research areas in the future. Three possible reasons are accounting for this: (1) production/operations and finance usually involve a lot of difficult, complex, and non-linear applications, and neural networks technology is a tool that can handle these problems efficiency and effectively; (2) the accessibility of raw data is relatively easy; and (3) there are many potential real-world applications in the area of production/operations and can, therefore, simulate academics' and practitioners' interest in conducting research.

Marketing/distribution is also a fast growing research area. More marketing researchers and practitioners are beginning to become aware of the value of neural networks in classification and forecasting since they have been applying this technology successfully in market segmentation and sales forecasting. In fact, some studies pointed out that neural networks could outperform other techniques/technologies traditionally used in the marketing analysis (e.g. [20,25,37,163]).

Academics and practitioners will be more interested in applying neural networks to explore real world applications and to conduct in-depth applications analysis, as evidenced by those applications in computer software and market segmentation/forecasting in our survey. This trend will probably continue since neural networks become a mature technology after more than 10 years' research in the business area.

Since there are many powerful neural network tools developed for the microcomputer platform, many researcher/developers still prefer to use microcomputers even though its processing speed could be a concern in some sophisticated applications. It should be noted here that these neural network tools always have upgrade versions with additional capabilities, such as NeuralWorks professional II/Plus v5.23, NeuralShell 2, and BrainMaker v3.7. This also explains why they can remain the most popular tools for development.

Those journals publishing production/operations will probably still dominate in the future since there are a variety of potential research applications in this area. Also, the relatively ease of accessing raw data and the actual implementation of real-world application simulate a lot of neural network research studies in the manufacturing environment.

Although there is an increasing percentage of non-US institutions involved in the development of neural network applications, the authors speculate that such growth will not persist. This is due to the fact that many countries' information technologies are not as advanced as that of US, and their adoption of neural network technology can lag behind a few years. Therefore, such an increase only reflects the fact that neural networks have started catching the attention of the non-US researchers/developers in the last five years.

6. Limitations of the study

Readers should be cautious in interpreting the results of this survey, since the findings are based on data collected only from journal articles. The results therefore do not include all actual neural network applications. Second, due to the lengthy journal review process, the neural networks reported in our surveyed articles are likely to lag behind the actual adoption of neural networks in the real world. Third, we have reviewed academic/professional journal articles only. Conference proceedings and doctoral dissertations are excluded, as we assume that high-quality research is eventually published in academic/professional journals. Also, many foreign journals and new journals might not be included in our review since they were not within the scope of our computer/manual search.

7. Conclusion

Our literature survey results and the comparisons with the previous review has revealed some insights into the trends of neural network research. It is hoped that this can help

researchers/practitioners to better understand the current status of this state-of-the-art technology in the business applications.

Acknowledgements

The authors would like to acknowledge Dr. Li Jiang, Ms. Yuen Chiu Yim, and Ms. Pui Sze So, for their assistance in this project.

References

[1] Wong BK, Bodnovich TA, Selvi Y. A bibliography of neural network business applications research: 1988-September 1994. Expert Systems 1995;12:253–62.
[2] Bose NK, Liang P. Neural network fundamentals with graphs, algorithms, and applications. New York: McGraw-Hill, 1996.
[3] Browne A. Neural network analysis, architectures, and applications. Bristol, UK: Institute of Physics Publishing Company, 1997.
[4] Chen CH. Fuzzy logic and neural network handbook. New York: McGraw-Hill, 1996.
[5] De Wilde P. Neural network models: an analysis. UK: Springer, 1996.
[6] De Wilde P. Neural network models: theory and projects. UK: Springer, 1997.
[7] Golden RM. Mathematical methods for neural network analysis and design. Cambridge, MA: MIT Press, 1996.
[8] Goonatilake S, Treleaven P. Intelligent systems for finance and business. Chichester: Wiley, 1995.
[9] Hagan MT, Demuth HB, Beale MH. Neural network design. Boston: PWS Publishing Company, 1996.
[10] Hunt KJ, Irwin G, Warwick K. Neural network engineering in dynamic control systems. Berlin: Springer, 1995.
[11] Irwin GW, Warwick K, Hunt KJ. Neural network applications in control. UK: Institution of Electrical Engineers, 1995.
[12] Korn GA. Neural networks and fuzzy-logic control on personal computers and workstations. Cambridge, MA: MIT Press, 1995.
[13] Parks RW. Fundamentals of neural network modeling: neuropsychology and cognitive neuroscience. Cambridge, MA: MIT Press, 1998.
[14] Rzempoluck EJ. Neural network data analysis using simulnet. Berlin: Springer, 1998.
[15] Van Rooij AJF, Jain LC, Johnson RP. Neural network training using genetic algorithms. Singapore: World Scientific, 1996.
[16] Gillenson M, Stutz J. Academic issues in MIS: journal and books. MIS Quarterly 1991;15:447–52.
[17] Hamilton S, Ives B. The journal communication system for MIS research. Database 1983;14:3–14.
[18] Hardgrave BC, Walstrom KA. Forums for MIS scholars. Communications of the ACM 1997;40:119–24.
[19] Abhyankar A, Copeland LS, Wong W. Uncovering nonlinear structure in real-time stock-market indexes: the S&P 500, the DAX, the Nikkei 225, and the FTSE-100. Journal of Business and Economic Statistics 1997;15:1–14.
[20] Agrawal D, Schorling C. Market share forecasting: an empirical comparison of artificial neural networks and multinomial logit model. Journal of Retailing 1996;72:383–407.
[21] Aiken M, Krosp J, Vanjani M, Govindarajulu C, Sexton R. A neural network for predicting total industrial production. Journal of End User Computing 1995;7:19–23.
[22] Al-Ghanim A. An unsupervised learning neural algorithm for identifying process behavior on control charts and a comparison with supervised learning approaches. Computers and Industrial Engineering 1997;32:627–39.
[23] Albino V, Garavelli AC. A neural network application to subcontractor rating in construction firms. International Journal of Project Management 1998;16:9–14.
[24] Altman EI, Marco G, Varetto F. Corporate distress diagnosis: comparisons using linear discriminant analysis and neural networks (the Italian experience). Journal of Banking and Finance 1994;18:505–29.

[25] Ansuj AP, Camargo ME, Radharamanan R, Petry DG. Sales forecasting using time series and neural networks. Computers and Industrial Engineering 1996;31:421–4.
[26] Arizono I, Kato M, Yamamoto A, Ohta H. A new stochastic neural network model and its application to grouping parts and tools in flexible manufacturing systems. International Journal of Production Research 1995;33:1535–48.
[27] Athanassopoulos AD, Curram SP. A comparison of data envelopment analysis and artificial neural networks as tools for assessing the efficiency of decision making units. Journal of the Operational Research Society 1996;47:1000–16.
[28] Badiru AB, Sieger DB. Neural network as a simulation metamodel in economic analysis of risky projects. European Journal of Operational Research 1998;105:130–42.
[29] Bahrami A, Lynch M, Dagli CH. Intelligent design retrieval and packaging system: application of neural networks in design and manufacturing. International Journal of Production Research 1995;33:405–26.
[30] Balakrishnan N, Chakravarty AK, Ghose S. Role of design-philosophies in interfacing manufacturing with marketing. European Journal of Operational Research 1997;103:453–69.
[31] Balakrishnan PV, Cooper MC, Jacob VS, Lewis PA. Comparative performance of the FSCL neural net and K-means algorithm for market segmentation. European Journal of Operational Research 1996;93:346–57.
[32] Baluja S. Evolution of an artificial neural network based autonomous land vehicle controller. IEEE Transactions on Systems, Man, and Cybernetics 1996;26:450–63.
[33] Barada S, Singh H. Generating optimal adaptive fuzzy-neural models of dynamical systems with applications to control. IEEE Transactions on Systems, Man, and Cybernetics — Part C: Applications and Reviews 1998;28:371–91.
[34] Barr DS, Mani G. Using neural nets to manage investments. AI Expert 1994;9:6–21.
[35] Barschdorff D, Monostori L, Wöstenkühler GW, Egresits C, Kádár B. Approaches to coupling connectionist and expert systems in intelligent manufacturing. Computers in Industry 1997;33:5–15.
[36] Bataineh S, Al-Anbuky A, Al-Aqtash S. An expert system for unit commitment and power demand prediction using fuzzy logic and neural networks. Expert Systems 1996;13:29–40.
[37] Bejou D, Wray B, Ingram TN. Determinants of relationship quality: an artificial neural network analysis. Journal of Business Research 1996;36:137–43.
[38] Benjamin CO, Chi S-C, Gaber T, Riordan CA. Comparing BP and ART II neural network classifiers for facility location. Computers and Industrial Engineering 1995;28:43–50.
[39] Bode J. Decision support with neural networks in the management of research and development: concepts and application to cost estimation. Information and Management 1998;34:33–40.
[40] Bode J. Neural networks for cost estimation. Cost Engineering 1998;40:25–30.
[41] Boussabaine AH, Kaka AP. A neural networks approach for cost flow forecasting. Construction Management and Economics 1998;16:471–9.
[42] Brockett PL, Cooper WW, Golden LL, Pitaktong U. A neural network method for obtaining an early warning of insurer insolvency. The Journal of Risk and Insurance 1994;61:402–24.
[43] Brockett PL, Cooper WW, Golden LL, Xia X. A case study in applying neural networks to predicting insolvency for property and casualty insurers. Journal of the Operational Research Society 1997;48:1153–62.
[44] Brooks C. Predicting stock index volatility: can market volume help?. Journal of Forecasting 1998;17:59–80.
[45] Bugnon B, Stoffel K, Widmer M. FUN: a dynamic method for scheduling problems. European Journal of Operational Research 1995;83:271–82.
[46] Burke L, Flanders S. Using ontogenic classification networks in a smart structures application. Computers and Operations Research 1995;22:871–81.
[47] Burke L, Kamal S. Neural networks and the part family/machine group formation problem in cellular manufacturing: a framework using fuzzy ART. Journal of Manufacturing Systems 1995;14:148–59.
[48] Burke LI, Storer RH, Lansing LL, Flanders SW. A neural-network approach to prediction of vehicle driving comfort. IIE Transactions 1996;28:439–52.
[49] Callen JL, Kwan CCY, Yip PCY, Yuan Y. Neural network forecasting of quarterly accounting earnings. International Journal of Forecasting 1996;12:475–82.
[50] Canarelli P. Analysing the past and managing the future using neural networks. Futures 1995;27:325–38.

[51] Canepa G, Petrigliano R, Campanella M, de Rossi D. Detection of incipient object slippage by skin-like sensing and neural network processing. IEEE Transactions on Systems, Man, and Cybernetics — Part B: Cybernetics 1998;28:348–56.
[52] Caporaletti LE, Dorsey RE, Johnson JD, Powell WA. A decision support system for in-sample simultaneous equation systems forecasting using artificial neural systems. Decision Support Systems 1994;11:481–95.
[53] Carvalho P, Costa N, Ribeiro B, Dourado A. Industrial visual inspection of lime granules by neural networks. Computers and Industrial Engineering 1998;35:539–42.
[54] Chang CA, Lo CC, Hsieh K-H. Neural networks and fourier descriptors for part positioning using bar code features in material handling systems. Computers and Industrial Engineering 1997;32:467–76.
[55] Chang CA, Su C-T. A comparison of statistical regression and neural network methods in modeling measurement errors for computer vision inspection systems. Computers and Industrial Engineering 1995;28:593–603.
[56] Chang CA, Tsai CY. Using ART1 neural networks with destructive solid geometry for design retrieving systems. Computers in Industry 1997;34:27–41.
[57] Chang SL, Aw CA. A neural fuzzy control chart for detecting and classifying process mean shifts. International Journal of Production Research 1996;34:2265–78.
[58] Chattopadhyay SP. Neural network approach for assessing country risk for foreign investment. International Journal of Management 1997;14:159–67.
[59] Chen H, Ng T. An algorithmic approach to concept exploration in a large knowledge network (Automatic Thesaurus Consultation): symbolic branch-and-bound search vs. connectionist hopfield net activation. Journal of the American Society for Information Science 1995;46:348–69.
[60] Chen H, Zhang Y, Houston AL. Semantic indexing and searching using a hopfield net. Journal of Information Science 1998;24:3–18.
[61] Chen SJ, Cheng CS. A neural network-based cell formation algorithm in cellular manufacturing. International Journal of Production Research 1995;33:293–318.
[62] Chen SK, Mangiameli P, West D. The comparative ability of self-organizing neural networks to define cluster structure. Omega: The International Journal of Management Science 1995;23:271–9.
[63] Chen Y, Li X, Orady E. Integrated diagnosis using information-gain-weighted radial basis function neural networks. Computers and Industrial Engineering 1996;30:243–55.
[64] Cheng C-S. A multi-layer neural network model for detecting changes in the process mean. Computers and Industrial Engineering 1995;28:51–61.
[65] Cheng C-S. A neural network approach for the analysis of control chart patterns. International Journal of Production Research 1997;35:667–97.
[66] Cheng R, Tozawa T, Gen M, Kato H, Takayama Y. AE behaviors evaluation with BP neural network. Computers and Industrial Engineering 1996;31:867–71.
[67] Chiang WC, Urban TL, Baldridge GW. A neural network approach to mutual fund net asset value forecasting. Omega; The International Journal of Management Science 1996;24:205–15.
[68] Chinnam RB, Kolarik WJ. Neural network-based quality controllers for manufacturing systems. International Journal of Production Research 1997;35:2601–20.
[69] Cho S, Jang M, Yoon S, Cho Y, Cho H. A hybrid neural-network/mathematical prediction model for tandem cold mill. Computers and Industrial Engineering 1997;33:453–6.
[70] Christodoulou M, Gaganis V. Neural networks in manufacturing cell design. Computers in Industry 1998;36:133–8.
[71] Chu C-H. An improved neural network for manufacturing cell formation. Decision Support Systems 1997;20:279–95.
[72] Chu C-H, Widjaja D. Neural network system for forecasting method selection. Decision Support Systems 1994;12:13–24.
[73] Chu X, Holm H. Product manufacturability control for concurrent engineering. Computers in Industry 1994;24:29–38.
[74] Chung Y, Fischer GW. A neural algorithm for finding the shortest flow path for an automated guided vehicle system. IIE Transactions 1995;27:773–83.
[75] Chung Y, Kusiak A. Grouping parts with a neural network. Journal of Manufacturing Systems 1994;13:262–75.

[76] Church KB, Curram SP. Forecasting consumers' expenditure: a comparison between econometric and neural network models. International Journal of Forecasting 1996;12:255–67.
[77] Coit DW, Smith AE. Solving the redundancy allocation problem using a combined neural network/genetic algorithm approach. Computers and Operations Research 1996;23:515–26.
[78] Collins A, Evans A. Aircraft noise and residential property values an artificial neural network approach. Journal of Transport Economics and Policy 1994;28:175–97.
[79] Connor JT. A robust neural network filter for electricity demand prediction. Journal of Forecasting 1996;15:437–58.
[80] Cook DF, Chiu C-C. Using radial basis function neural networks to recognize shifts in correlated manufacturing process parameters. IIE Transactions 1998;30:227–34.
[81] Cortez EM, Park SC, Kim S. The hybrid application of an inductive learning method and a neural network for intelligent information retrieval. Information Processing and Management 1995;31:789–813.
[82] Cox LD, Al-Ghanim AM, Culler DE. A neural network-based methodology for machining knowledge acquisition. Computers and Industrial Engineering 1995;29:217–20.
[83] Creese RC, Li L. Cost estimation of timber bridges using neural networks. Cost Engineering 1995;37:17–22.
[84] Dagli C, Huggahalli R. Machine-part family formation with the adaptive resonance theory paradigm. International Journal of Production Research 1995;33:893–913.
[85] D'Antone I. A parallel neural network implementation in a distributed fault diagnosis system. Microprocessing and Microprogramming 1994;40:305–13.
[86] Dasgupta CG, Dispensa GS, Ghose S. Comparing the predictive performance of a neural network model with some traditional market response models. International Journal of Forecasting 1994;10:235–44.
[87] Davis JT. Experience and auditors' selection of relevant information for preliminary control risk assessments. Auditing: A Journal of Practice and Theory 1996;15:16–37.
[88] Davis JT, Massey AP. Lovell RER II. Supporting a complex audit judgment task: an expert network approach. European Journal of Operational Research 1997;103:350–72.
[89] De la Garza JM, Rouhana KG. Neural networks versus parameter-based applications in cost estimating. Cost Engineering 1995;37:14–8.
[90] Desai VS, Crook JN, Overstreet GA. A comparison of neural networks and linear scoring models in the credit union environment. European Journal of Operational Research 1996;95:24–37.
[91] Didner RS. Intelligent systems at American Express. In: Goonatilake S, Treleaven P, editors. Intelligent systems for finance and business. Chichester: Wiley, 1995. p. 31–7.
[92] Donaldson RG, Kamstra M. Forecast combining with neural networks. Journal of Forecasting 1996;15: 49–61.
[93] Doumas A, Mavroudakis K, Gritzalis D, Katsikas S. Design of a neural network for recognition and classification of computer viruses. Computers and Security 1995;14:435–48.
[94] Dropsy V. Do macroeconomic factors help in predicting international equity risk premia? testing the out-of-sample accuracy of linear and nonlinear forecasts. Journal of Applied Business Research 1996;12:120–32.
[95] Dunk K, Lee C, Martin P. An attribute design method: a new approach to flexible welding machine design. International Journal of Production Research 1994;32:2525–40.
[96] Dunston PS, Ranjithan S, Bernold LE. Neural network model for the automated control of springback in rebars. IEEE Expert 1996;11:45–9.
[97] Dutta S, Shekhar S, Wong WY. Decision support in non-conservative domains: generalization with neural networks. Decision Support Systems 1994;11:527–44.
[98] Eakins SG, Stansell SR, Buck JF. Analyzing the nature of institutional demand for common stocks. Quarterly Journal of Business and Economics 1998;37:33–48.
[99] Eberts R, Habibi S. Neural network-based agents for integrating information for production systems. International Journal of Production Economics 1995;38:73–84.
[100] Enke D, Ratanapan K, Dagli C. Machine-part family formation utilizing and ART1 neural network implemented on a parallel neuro-computer. Computers and Industrial Engineering 1998;34:189–205.
[101] Eppinger SD, Huber CD, Pham VH. A methodology for manufacturing process signature analysis. Journal of Manufacturing Systems 1995;14:20–34.

[102] Espuña A, Delgado A, Puigjaner L. Improved batch process performance by evolutionary modelling. Computers in Industry 1998;36:271–8.
[103] Finnie GR, Witting GE, Desharnais J-M. A comparison of software effort estimation techniques: using function points with neural networks, case-based reasoning and regression models. Journal of Systems Software 1997;39:281–9.
[104] Fish KE, Barnes JH, Aiken MW. Artificial neural networks: a new methodology for industrial market segmentation. Industrial Marketing Management 1995;24:431–8.
[105] Franses PH, Draisma G. Recognizing changing seasonal patterns using artificial neural networks. Journal of Econometrics 1997;81:273–80.
[106] Franses PH, Homelen PV. On forecasting exchange rates using neural networks. Applied Financial Economics 1998;8:589–96.
[107] Funabashi M, Maeda A, Morooka Y, Mori K. Fuzzy and neural hybrid expert systems: synergetic AI. IEEE Expert 1995;10:32–40.
[108] Furness P. Neural networks for data-driven marketing. In: Goonatilake S, Treleaven P, editors. Intelligent systems for finance and business. Chichester: Wiley, 1995. p. 73–6.
[109] Gan R, Yang D. Case-based decision support system with artificial neural network. Computers and Industrial Engineering 1994;27:437–40.
[110] Gen M, Tsujimura Y, Ishizaki S. Optimal design of a star-LAN using neural networks. Computers and Industrial Engineering 1996;31:855–9.
[111] Glorfeld LW, Hardgrave BC. An improved method for developing neural networks: the case of evaluating commercial loan creditworthiness. Computers and Operations Research 1996;23:933–44.
[112] Goel V, Chen J. Application of expert network for material selection in engineering design. Computers in Industry 1996;30:87–101.
[113] Gong D, Gen M, Yamazaki G, Xu W. Neural network approach for allocation with capacity. Computers and Industrial Engineering 1996;31:849–54.
[114] Grabot B. Objective satisfaction assessment using neural nets for balancing multiple objectives. International Journal of Production Research 1998;36:2377–95.
[115] Green BP, Choi JH. Assessing the risk of management fraud through neural network technology. Auditing: A Journal of Practice and Theory 1997;16:14–28.
[116] Greska W, Franke V, Geiger M. Classification problems in manufacturing of sheet metal parts. Computers in Industry 1997;33:17–30.
[117] Griffiths BJ, Wilkie B. A low-cost vision system combining conventional and arificial intelligence techniques for complex image inspection and verification. International Journal of Production Research 1995;33:2133–46.
[118] Gruca TS, Klemz BR. Using neural networks to identify competitive market structures from aggregate market response data. Omega: the International Journal of Management Science 1998;26:49–62.
[119] Haefke C, Helmenstein C. Forecasting Austrian IPOs: an application of linear and neural network error-correction models. Journal of Forecasting 1996;15:237–51.
[120] Hanna MM, Buck A, Smith R. Fuzzy petri nets with neural networks to model products quality form a CNC-milling machining centre. IEEE Transactions on Systems, Man, and Cybernetics 1996;26:638–45.
[121] Hao G, Lai KK. Solving the AGV problem via a self-organizing neural network. Journal of Operational Research Society 1996;47:1477–93.
[122] Hill T, O'Connor M, Remus W. Neural network models for time series forecasts. Management Science 1996;42:1082–92.
[123] Hill T, Remus W. Neural network models for intelligent support of managerial decision making. Decision Support Systems 1994;11:449–59.
[124] Holter T, Yao X, Rabelo LC, Jones A, Yih Y. Integration of neural networks and genetic algorithms for an intelligent manufacturing controller. Computers and Industrial Engineering 1995;29:211–5.
[125] Hua GB. Residential construction demand forecasting using economic indicators: a comparative study of artificial neural networks and multiple regression. Construction Management and Economics 1996;14:25–34.
[126] Huang H-H, Wang H-PB. Machine fault diagnostics using a transputer network. Computers and Industrial Engineering 1996;30:269–81.

[127] Hung S-Y, Liang T-P, Liu VW-C. Integrating arbitrage pricing theory and artificial neural networks to support portfolio management. Decision Support Systems 1996;18:301–16.
[128] Hurrion RD. An example of simulation optimization using a neural network metamodel: finding the optimum number of kanbans in a manufacturing system. Journal of Operational Research Society 1997;48:1105–12.
[129] Hutchinson JM, Lo AW, Poggio T. A nonparametric approach to pricing and hedging derivative securities via learning networks. The Journal of Finance 1994;49:851–89.
[130] Hwang KS, Lin CS. Smooth trajectory tracking of three-link robot: a self-organizing CMAC approach. IEEE Transactions on Systems, Man, and Cybernetics — Part B: Cybernetics 1998;28:680–92.
[131] Hwarng HB. Proper and effective training of a pattern recognizer for cyclic data. IIE Transactions 1995;27:746–56.
[132] Hwarng HB, Chong CW. Detecting process non-randomness through a fast and cumulative learning ART-based pattern recognizer. International Journal of Production Research 1995;33:1817–33.
[133] Ignizio JP, Soltys JR. Simultaneous design and training of ontogenic neural network classifiers. Computers and Operations Research 1996;23:535–46.
[134] Jagannathan S. Automatic inspection of wave soldered joints using neural networks. Journal of Manufacturing Systems 1997;16:389–98.
[135] Jain AS, Meeran S. Job-shop scheduling using neural networks. International Journal of Production Research 1998;36:1249–72.
[136] Jain BA, Nag BN. Artificial neural network models for pricing initial public offerings. Decision Sciences 1995;26:283–302.
[137] Jain BA, Nag BN. Performance evaluation of neural network decision models. Journal of Management Information Systems 1997;14:201–16.
[138] Jamal AMM, Sundar C. Modeling exchange rates with neural networks. Journal of Applied Business Research 1997;14:1–5.
[139] Johnson A, Fotouhi F. Adaptive indexing in very large databases. Journal of Database Management 1995;6:4–12.
[140] Jørgensen M. Experience with the accuracy of software maintenance task effort prediction models. IEEE Transactions on Software Engineering 1995;21:674–81.
[141] Jula P, Houshyar A, Severance FL, Sawhney A. Application of artificial neural networks in interactive simulation. Computers and Industrial Engineering 1996;31:417–20.
[142] Kaastra I, Boyd MS. Forecasting futures trading volume using neural networks. The Journal of Futures Markets 1995;15:953–70.
[143] Kamal S, Burke LI. Fact: a new neural network-based clustering algorithm for group technology. International Journal of Production Research 1996;34:919–46.
[144] Kaparthi S, Suresh NC. Performance of selected part-machine grouping techniques for data sets of wide ranging sizes and imperfection. Decision Sciences 1994;25:515–39.
[145] Keyvan S, Durg A, Nagaraj J. Application of artificial neural networks for the development of a signal monitoring system. Expert Systems 1997;14:69–79.
[146] Khemaissia S, Morris A. Use of an artificial neuroadaptive robot model to describe adaptive and learning motor mechanisms in the central nervous system. IEEE Transactions on Systems, Man, and Cybernetics — Part B: Cybernetics 1998;28:404–16.
[147] Khoshgoftaar TM, Lanning DL. A neural network approach for early detection of program modules having high risk in the maintenance phase. Journal of Systems Software 1995;29:85–91.
[148] Kiang MY, Kulkarni UR, Tam KY. Self-organizing map network as an interactive clustering tool — an application to group technology. Decision Support Systems 1995;15:351–74.
[149] Kim C-O, Min H-S, Yih Y. Integration of inductive learning and neural networks for multi-objective FMS scheduling. International Journal of Production Research 1998;36:2497–509.
[150] Kim J, Hemami H. Coordinated three-dimensional motion of the head and torso by dynamic neural networks. IEEE Transactions on Systems, Man, and Cybernetics — Part B: Cybernetics 1998;28:653–66.
[151] Kim JK, Park KS. Neural network-based decision class analysis for buliding topological-level influence diagram. International Journal of Human — Computer Studies 1997;47:513–30.
[152] Kim SH, Chun SH. Graded forecasting using an array of bipolar predictions: application of probabilistic neural networks to a stock market index. International Journal of Forecasting 1998;14:323–37.

[153] Kim SH, Lee CM. Nonlinear prediction of manufacturing systems through explicit and implicit data mining. Computers and Industrial Engineering 1997;33:461–4.
[154] Kim T, Kumara SRT. Boundary defect recognition using neural networks. International Journal of Production Research 1997;35:2397–412.
[155] Kim W, Lee JK. UNIK-OPT/NN neural network based adaptive optimal controller on optimization models. Decision Support Systems 1996;18:43–62.
[156] Ko TJ, Cho DW, Jung MY. On-line monitoring of tool breakage in face milling using a self-organized neural network. Journal of Manufacturing Systems 1995;14:80–90.
[157] Kramer B. N.E.W.S.: a model for the evaluation of non-life insurance companies. European Journal of Operational Research 1997;98:419–30.
[158] Kryzanowski L, Galler M. Analysis of small-business financial statements using neural nets. Journal of Accounting, Auditing and Finance 1995;10:147–70.
[159] Kulkarni UR, Kiang MY. Dynamic grouping of parts in flexible manufacturing systems — a self-organizing neural networks approach. European Journal of Operational Research 1995;84:192–212.
[160] Kumar MJ, Patnaik LM. Mapping of artificial neural networks onto message passing systems. IEEE Transactions on Systems, Man, and Cybernetics 1996;26:822–35.
[161] Kumar N, Krovi R, Rajagopalan B. Financial decision support with hybrid genetic and neural based modeling tools. European Journal of Operational Research 1997;103:339–49.
[162] Kuo R-J. A robotic die polishing system through fuzzy neural networks. Computers in Industry 1997;32:273–80.
[163] Kuo R-J, Xue KC. A decision support system for sales forecasting through fuzzy neural networks with asymmetric fuzzy weights. Decision Support Systems 1998;24:105–26.
[164] Kuo R-J, Xue KC. An intelligent sales forecasting system through integration of artificial neural network and fuzzy neural network. Computers in Industry 1998;37:1–15.
[165] Kusiak A, Lee H. Neural computing-based design of components for cellular manufacturing. International Journal of Production Research 1996;34:1777–90.
[166] Lacher RC, Coats PK, Sharma SC, Fant LF. Theory and methodology a neural network for classifying the financial health of a firm. European Journal of Operational Research 1995;85:53–65.
[167] Lachtermacher G, Fuller JD. Backpropagation in time-series forecasting. Journal of Forecasting 1995;14:381–93.
[168] Lanubile F, Visaggio G. Evaluating predictive quality models derived from software measures: lessons learned. Journal of Systems Software 1997;38:225–34.
[169] Lee A, Cheng CH, Balakrishnan J. Software development cost estimation: integrating neural network with cluster analysis. Information and Management 1998;34:1–9.
[170] Lee HC, Dagli CH. A parallel genetic-neuro scheduler for job-shop scheduling problems. International Journal of Production Economics 1997;51:115–22.
[171] Lee J. Measurement of machine performance degradation using a neural network model. Computers in Industry 1996;30:193–209.
[172] Lee JK, Jhee WC. A two-stage neural network approach for ARMA model identification with ESACF. Decision Support Systems 1994;11:461–79.
[173] Lee JK, Lee KJ, Park HK, Hong JS, Lee JS. Developing scheduling systems for Daewoo shipbuilding: DAS project. European Journal of Operational Research 1997;97:380–95.
[174] Lee JK, Yum CS. Judgmental adjustment in time series forecasting using neural networks. Decision Support Systems 1998;22:135–54.
[175] Lee KC, Han I, Kwon Y. Hybrid neural network models for bankruptcy predictions. Decision Support Systems 1996;18:63–72.
[176] Lee S-K, Jang D. Translation, rotation and scale invariant pattern recognition using spectral analysis and hybrid genetic-neural-fuzzy networks. Computers and Industrial Engineering 1996;30:511–22.
[177] Leigh D. Neural networks for credit scoring. In: Goonatilake S, Treleaven P, editors. Intelligent systems for finance and business. Chichester: Wiley, 1995. p. 61–9.
[178] Lenard MJ, Alam P, Madey GR. The application of neural networks and a qualitative response model to the auditor's going concern uncertainty decision. Decision Sciences 1995;26:209–27.
[179] Lewis FL. Neural network control of robot manipulators.. IEEE Expert 1996;11:64–75.

[180] Li X, Ang CL, Gay R. An intelligent scenario generator for strategic business planning. Computers in Industry 1997;34:261–9.
[181] Li Y, Ida K, Gen M, Kobuchi R. Neural network approach for multicriteria solid transportation problem. Computers and Industrial Engineering 1997;33:465–8.
[182] Liao TW, Lee KS. Integration of a feature-based CAD system and an ART1 neural model for GT coding and part family forming. Computers and Industrial Engineering 1994;26:93–104.
[183] Lin C-C, Wang H-P. Performance analysis of rotating machinery using enhanced cerebellar model articulation controller (E-CMAC) neural networks. Computers and Industrial Engineering 1996;30:227–42.
[184] Lin H, Yih Y, Salvendy G. Neural-network based fault diagnosis of hydraulic forging presses in China. International Journal of Production Research 1995;33:1939–51.
[185] Lin X. Map displays for information retrieval. Journal of the American Society for Information Science 1997;48:40–54.
[186] Lin Z-C, Chang H. Application of fuzzy set theory and back-propagation neural networks in progressive die design. Journal of Manufacturing Systems 1996;15:268–81.
[187] Lu L-C, Chen W-H, Kim D, Hwang C-P. Artificial neural systems improve franchising decision making. International Journal of Management 1996;13:25–32.
[188] Luther RK. An artificial neural network approach to predicting the outcome of Chapter 11 bankruptcy. The Journal of Business and Economic Studies 1998;4:57–73.
[189] Luxhøj JT, Riis JO, Stensballe B. A hybrid econometric-neural network modeling approach for sales forecasting. International Journal of Production Economics 1996;43:175–92.
[190] Luxhøj JT, Williams TP, Shyur H-J. Comparison of regression and neural network models for prediction of inspection profiles for aging aircraft. IIE Transactions 1997;29:91–101.
[191] Malkani A, Vassiliadis CA. Parallel implementation of the fuzzy ARTMAP neural network paradigm on a hypercube. Expert Systems 1995;12:39–53.
[192] Mann LH. Gaining global insights: using neural networks for marketing research can give you access to uncharted territories. Marketing Research 1997;9:24–30.
[193] Mantri S, Bullock D, Garrett J. Vehicle detection using a hardware-implemented neural net. IEEE Expert 1997;12:15–21.
[194] Markham IS, Ragsdale CT. Combining neural networks and statistical predictions to solve the classification problem in discriminant analysis. Decision Sciences 1995;26:229–42.
[195] Massone LLE, Myers JD. The role of plant properties in arm trajectory formation: a neural network study. IEEE Transactions on Systems, Man, and Cybernetics 1996;26:719–32.
[196] Mausser HE, Magazine MJ. Comparison of neural and heuristic methods for a timetabling problem. European Journal of Operational Research 1996;93:271–87.
[197] Mei J, Zhang H-C, Oldham WJB. A neural network approach for datum selection in computer-aided process planning. Computers in Industry 1995;27:53–64.
[198] Mezgár I, Egresits C, Monostori L. Design and real-time reconfiguration of robust manufacturing systems by using design of experiments and artificial neural networks. Computers in Industry 1997;33:61–70.
[199] Min H-S, Yih Y, Kim C-O. A competitive neural network approach to multi-objective FMS scheduling. International Journal of Production Research 1998;36:1749–65.
[200] Modin J. KBS-CLASS: a neural network tool for automatic content recognition of building texts. Construction Management and Economics 1995;13:411–6.
[201] Moghrabi C, Eid MS. Modeling users through an expert system and a neural network. Computers and Industrial Engineering 1998;35:583–6.
[202] Monostori L, Egresits C. On hybrid learning and its application in intelligent manufacturing. Computers in Industry 1997;33:111–7.
[203] Moon H-S, Na S-J. A neuro-fuzzy approach to select welding conditions for welding quality improvement in horizontal fillet welding. Journal of Manufacturing Systems 1996;15:392–403.
[204] Moon YB, Janowski R. A neural network approach for smoothing and categorizing noisy data. Computers in Industry 1995;26:23–39.
[205] Moore K, Burbach R, Heeler R. Using neural nets to analyze qualitative data by reducing the complexity of text data, automated coding saves time and money. Marketing Research 1995;7:35–9.

[206] Morrison J, Lee T. Forecasting nonpayment behavior of customers for a mail order company. The Journal of Business Forecasting 1996;15:11–4.
[207] Morrison JR, Johnson JD, Barnes JH, Summers K, Szeinbach SL. Predicting total health care costs of medicaid recipients: an artificial neural systems approach. Journal of Business Research 1997;40:191–7.
[208] Moussa MA. An experiment in approximating an end effector positional error of a 6 D.O.F. manipulator using neural network. Computers and Industrial Engineering 1998;35:547–50.
[209] Moussa MA, Kamel MS. Requirements and design of a grasping system for personal robots. Computers and Industrial Engineering 1998;35:475–8.
[210] Mozer MC. Neural-network speech processing for toys and consumer electronics. IEEE Expert 1996;11:4–5.
[211] Nagasaka K, Ichihashi H, Leonard R. Neuro-fuzzy GMDH and its application to modelling grinding characteristics. International Journal of Production Research 1995;33:1229–40.
[212] Nam K, Schaefer T. Forecasting international airline passenger traffic using neural networks. Logistics and Transportation Review 1995;31:239–51.
[213] Nam K, Yi J, Prybutok VR. Predicting airline passenger volume. The Journal of Business Forecasting 1997;16:14–6.
[214] Nath R, Rajagopalan B, Ryker R. Determining the saliency of input variables in neural network classifiers. Computers and Operations Research 1997;24:767–73.
[215] Nikolopoulos C, Fellrath P. A hybrid expert system for investment advising. Expert Systems 1994;11:245–50.
[216] Ntungo C, Boyd M. Commodity futures trading performance using neural network models versus ARIMA models. The Journal of Futures Markets 1998;18:965–83.
[217] Nuttin M, Brussel HV. Learning the peg-into-hole assembly operation with a connectionist reinforcement technique. Computers in Industry 1997;33:101–9.
[218] Obaidat MS, Macchairolo DT. A multilayer neural network system for computer access security. IEEE Transactions on Systems, Man, and Cybernetics 1994;24:806–13.
[219] Oh S-Y, Part H-G, Nam S-H. A neural network-based real-time robot tracking controller using position sensitive detectors. Expert Systems 1995;12:115–22.
[220] Orwig RE, Chen H, Nunamaker JF. A graphical, self-organizing approach to classifying electronic meeting output. Journal of the American Society for Information Science 1997;48:157–70.
[221] Pantazopoulos KN, Tsoukalas LH, Bourbakis NG, Brün MJ, Houstis EN. Financial prediction and trading strategies using neurofuzzy approaches. IEEE Transactions on Systems, Man, and Cybernetics — Part B: Cybernetics 1998;28:520–31.
[222] Parhizgari AM, De Boyrie ME. Predicting spot exchange rates in a nonlinear estimation framework using futures prices. The Journal of Futures Markets 1997;17:935–56.
[223] Petri KL, Billo RE, Bidanda B. A neural network process model for abrasive flow machining operations. Journal of Manufacturing Systems 1998;17:52–64.
[224] Philipoom PR, Rees LP, Wiegmann L. Using neural networks to determine internally-set due-date assignments for shop scheduling. Decision Sciences 1994;25:825–51.
[225] Pican N, Alexandre F, Bresson P. Artificial neural networks for the presetting of a steel temper mill. IEEE Expert 1996;11:22–7.
[226] Piramuthu S, Ragavan H, Shaw MJ. Using feature construction to improve the performance of neural networks. Management Science 1998;44:416–30.
[227] Piramuthu S, Shaw MJ, Gentry JA. A classification approach using multi-layered neural networks. Decision Support Systems 1994;11:509–25.
[228] Pu H-C, Hung Y-T. Use of artificial neural networks: predicting trickling filter performance in a municipal wastewater treatment plant. Environmental Management and Health 1995;6:16–27.
[229] Purnomo MH, Tada A, Shimizu E. Beam landing adjustment for color purity of integrated tube component using artificial neural network. Computers and Industrial Engineering 1995;29:153–7.
[230] Purushothaman S, Srinivasa YG. A procedure for training an artificial neural network with application to tool wear monitoring. International Journal of Production Research 1998;36:635–51.
[231] Quah T-S, Tan C-L, Raman KS, Srinivasan B. Towards integrating rule-based expert systems and neural networks. Decision Support Systems 1996;17:99–118.

[232] Quah T-S, Tan C-L, Raman KS, Teh H-H, Srinivasan BS. A shell environment for developing connectionist decision support systems. Expert Systems 1994;11:225–34.
[233] Quiroga LA, Rabelo LC. Learning from examples: a review of machine learning, neural networks and fuzzy logic paradigms. Computers and Industrial Engineering 1995;29:561–5.
[234] Raggad BG. Neural network technology for knowledge resource management. Management Decision 1996;34:20–4.
[235] Ramirez-Beltran ND, Montes JA. Neural networks for on-line parameter change detections in time series models. Computers and Industrial Engineering 1997;33:337–40.
[236] Ransing RS, Lewis RW. A semantically constrained neural network for manufacturing diagnosis. International Journal of Production Research 1997;35:2639–60.
[237] Rao HA, Gu P. Expert self-organizing neural network for the design of cellular manufacturing systems. Journal of Manufacturing Systems 1994;13:346–58.
[238] Rao HA, Gu P. A multi-constraint neural network for the pragmatic design of cellular manufacturing systems. International Journal of Production Research 1995;33:1049–70.
[239] Refenes AN, Zaprainis AD, Connor JT, Bunn DW. Neural networks in investment management. In: Goonatilake S, Treleaven P, editors. Intelligent systems for finance and business. Chichester: Wiley, 1995 p. 177–208.
[240] Reynolds SB, Mellichamp JM, Smith RE. Box-jenkins forecast model identification. AI Expert 1995;10:15–28.
[241] Rietman EA, Patel SH, Lory ER. Modeling and control of a semiconductor manufacturing process with an automata network: an example in plasma etch processing. Computers and Operations Research 1996;23:573–85.
[242] Rogers J. Neural network user authentication. AI Expert 1995;10:29–33.
[243] Rovithakis GA, Christodoulou MA. Neural adaptive regulation of unknown nonlinear dynamical systems. IEEE Transactions on Systems, Man, and Cybernetics 1997;27:10–22.
[244] Ruggiero MA. Training neural nets for intermarket analysis. Futures 1994;23:42–4.
[245] Ruggiero MA. Build a real neural net. Futures 1995;24:44–6.
[246] Sabuncuoglu I, Gurgun B. A neural network model for scheduling problems. European Journal of Operational Research 1996;93:288–99.
[247] Samson B, Ellison D, Dugard P. Software cost estimation using an albus perceptron (CMAC). Information and Software Technology 1997;39:55–60.
[248] Satake T, Morikawa K, Nakamura N. Neural network approach for minimizing the makespan of the general job-shop. International Journal of Production Economics 1994;33:67–74.
[249] Schlang M, Poppe T, Gramchow O. Neural networks for steel manufacturing. IEEE Expert 1996;11:8–9.
[250] Schmidt DC, Haddock J, Marchandon S, Runger GC, Wallace WA, Wright RN. A methodology for formulating, formalizing, validating, and evaluating a real-time process control advisor. IIE Transactions 1998;30: 235–45.
[251] Serrano-Cinca C. Self organizing neural networks for financial diagnosis. Decision Support Systems 1996;17:227–38.
[252] Setiono R, Thong JYL, Yap C-S. Symbolic rule extraction from neural networks an application to identifying organizations adopting IT. Information and Management 1998;34:91–101.
[253] Shanker M, Hu MY, Hung MS. Effect of data standardization on neural network training. Omega: The International Journal of Management Science 1996;24:385–97.
[254] Shen Y, Moon S. Mapping of probe pretravel in dimensional measurements using neural networks computational technique. Computers in Industry 1997;34:295–306.
[255] Sherer SA. Software fault prediction. Journal of Systems Software 1995;29:97–105.
[256] Shin YC, Vishnupad P. Neuro-fuzzy control of complex manufacturing processes. International Journal of Production Research 1996;34:3291–309.
[257] Shyur HJ, Luxhøj JT, Williams TP. Using neural networks to predict component inspection requirements for aging aircraft. Computers and Industrial Engineering 1996;30:257–67.
[258] Sim SK, Yeo KT, Lee WH. An expert neural network system for dynamic job shop scheduling. International Journal of Production Research 1994;32:1759–73.
[259] Siriopoulos C, Perantonis S, Karakoulos G. Artificial intelligence models for financial decision making. Information Strategy: The Executive's Journal 1994;11:49–54.

[260] Smith AE. X-bar and R control chart interpretation using neural computing. International Journal of Production Research 1994;32:309–20.
[261] Smith AE, Mason AK. Cost estimation predictive modeling: regression versus neural network. The Engineering Economist 1997;42:137–61.
[262] Smith K, Palaniswami M, Krishnamoorthy M. A hybrid neural approach to combinatorial optimization. Computers and Operations Research 1996;23:597–610.
[263] Smith K, Palaniswami M, Krishnamoorthy M. Traditional heuristic versus hopfield neural network approaches to a car sequencing problem. European Journal of Operational Research 1996;93:300–16.
[264] Smith PA, MacLin OH. Have presidents influenced monetary policy: new evidence from an artificial neutral network. Studies in Economics and Finance 1995;16:23–45.
[265] Sohl JE, Venkatachalam AR. A neural network approach to forecasting model selection. Information and Management 1995;29:297–303.
[266] Song IR, Yang T, Chen JJ-G. Enhanced exchange heuristic based resource constrained scheduler using ARTMAP. Computers and Industrial Engineering 1997;33:469–72.
[267] Spall JC, Cristion JA. A neural network controller for systems with unmodeled dynamics with applications to wastewater treatment. IEEE Transactions on Systems, Man, and Cybernetics 1997;27:369–75.
[268] Spoerre JK. Application of the cascade correlation algorithm (CCA) to bearing fault classification problems. Computers in Industry 1997;32:295–304.
[269] Srinivasan K, Fisher D. Machine learning approaches to estimating software development effort. IEEE Transactions on Software Engineering 1995;21:126–37.
[270] Steiner M, Wittkemper H-G. Portfolio optimization with a neural network implementation of the coherent market hypothesis. European Journal of Operational Research 1997;100:27–40.
[271] Su C-T, Chang CA, Tien F-C. Neural networks for precise measurement in computer vision systems. Computers in Industry 1995;27:225–36.
[272] Su C-T, Tong L-I. A neural network-based procedure for the process monitoring of clustered defects in integrated circuit fabrication. Computers in Industry 1997;34:285–94.
[273] Suh S-H, Shin Y-S. Neural network modeling for tool path planning of the rough cut in complex pocket milling. Journal of Manufacturing Systems 1996;15:295–304.
[274] Sun G, Dagli CH, Thammano A. Dynamic neuro-fuzzy control of the nonlinear process. Computers and Industrial Engineering 1997;33:413–6.
[275] Suresh NC, Kaparthi S. Performance of fuzzy ART neural network for group technology cell formation. International Journal of Production Research 1994;32:1693–713.
[276] Suresh NC, Slomp J, Kaparthi S. The capacitated cell formation problem: a new hierarchical methodology. International Journal of Production Research 1995;33:1761–84.
[277] Swanson NR, White H. A model-selection approach to assessing the information in the term structure using linear models and artificial neural networks. Journal of Business and Economic Statistics 1995;13:265–75.
[278] Swanson NR, White H. A model selection approach to real-time macroeconomic forecasting using linear models and artificial neural networks. Review of Economics and Statistics 1997;79:540–50.
[279] Taha MA, Park SC, Russell JS. Knowledge-based DSS for construction contractor prescreening. European Journal of Operational Research 1995;84:35–46.
[280] Tana SS, Koh HC. A multi-layer perceptron model of credit scoring for assessing default risk in charge card applicants. International Journal of Management 1997;14:250–5.
[281] Teixeira JC, Rodrigues AJ. An applied study on recursive estimation methods, neural networks and forecasting. European Journal of Operational Research 1997;101:406–17.
[282] Tesauro GJ, Kephart JO, Sorkin GB. Neural networks for computer virus recognition. IEEE Expert 1996;11:5–6.
[283] Torki A, Somhom S, Enkawa T. A competitive neural network algorithm for solving vehicle routing problem. Computers and Industrial Engineering 1997;33:473–6.
[284] Tsang S, Magill EH. Learning to detect and avoid run-time feature interactions in intelligent networks. IEEE Transactions on Software Engineering 1998;24:818–30.
[285] Tsuchiya K, Bharitkar S, Takefuji Y. A neural network approach to facility layout problems. European Journal of Operational Research 1996;89:556–63.

[286] Tsuji T, Ito K, Morasso PG. Neural network learning of robot arm impedance in operational space. IEEE Transactions on Systems, Man, and Cybernetics 1996;26:290–8.
[287] Tsuji T, Xu BH, Kaneko M. Adaptive control and identification using one neural network for a class of plants with uncertainties. IEEE Transactions on Systems, Man, and Cybernetics — Part A: Systems and Humans 1998;28:496–505.
[288] Tsujmura Y, Gen M, Ishizaki S. Optimal routing in multiple I/O data network using neural network with perturbed energy function. Computers and Industrial Engineering 1997;33:477–80.
[289] Tsukuda J, Baba S-I. Predicting Japanese corporate bankruptcy in term of financial data using neural network. Computers and Industrial Engineering 1994;27:445–8.
[290] Twomey JM, Smith AE, Redfern MS. A predictive model for slip resistance using artificial neural networks. IIE Transactions 1995;27:374–81.
[291] Vaithyanathan S, Burke LI, Magent MA. Massively parallel analog tabu search using neural networks applied to simple plant location problems. European Journal of Operational Research 1996;93:317–30.
[292] Van Wezel MC, Baets WRJ. Predicting market responses with a neural network: the case of fast moving consumer goods. Marketing Intelligence and Planning 1995;13:23–30.
[293] Vanherck P, Dehaes J, Nuttin D. Compensation of thermal deformations in machine tools with neural nets. Computers in Industry 1997;33:119–25.
[294] Venugopal V, Narendran TT. Machine-cell formation through neural network models. International Journal of Production Research 1994;32:2105–16.
[295] Versaggi MR. Understanding conflicting data. AI Expert 1995;10:21–5.
[296] Villegas L, Eberts RE. A neural network tool for identifying text-editing goals. International Journal of Human — Computer Studies 1994;40:813–33.
[297] Wadi I. Neural network model predicts naphtha cut point. Oil and Gas Journal 1996;25:67–70.
[298] Wang C, Huang S-Z. A refined flexible inspection method for identifying surface flaws using the skeleton and neural network. International Journal of Production Research 1997;35:2493–507.
[299] Wang G-N, Go YC. On-line neuro-tracking of non-stationary manufacturing processes. Computers and Industrial Engineering 1996;30:449–61.
[300] Wang S. A dynamic perspective of differences between cognitive maps. Journal of the Operational Research Society 1996;47:538–49.
[301] Wang S. Nonparametric econometric modeling: a neural network approach. European Journal of Operational Research 1996;89:581–92.
[302] Wang S. Neural networks in generalizing expert knowledge. Computers and Industrial Engineering 1997;32:67–76.
[303] Wang S, Archer NP. A neural network based fuzzy set model for organizational decision making. IEEE Transactions on Systems, Man, and Cybernetics — Part C: Application and Reviews 1998;28:194–203.
[304] Wang YS, Griffiths BJ, Wilkie BA. A novel system for coloured object recognition. Computers in Industry 1996;32:69–77.
[305] Wasserman GS, Sudjianto A. A comparison of three strategies for forecasting warranty claims. IIE Transactions 1996;28:967–77.
[306] West PM, Brockett PL, Golden LL. A comparative analysis of neural networks and statistical methods for predicting consumer choice. Marketing Science 1997;16:370–91.
[307] Whittaker AD, Cook DF. Counterpropagation neural network for modelling a continuous correlated process. International Journal of Production Research 1995;33:1901–10.
[308] Wilson RL. A neural network approach to decision alternative prioritization. Decision Support Systems 1994;11:431–47.
[309] Wilson RL, Sharda R. Bankruptcy prediction using neural networks. Decision Support Systems 1994;11: 545–57.
[310] Wittig G, Finnie G. Estimating software development effort with connectionist models. Information and Software Technology 1997;39:469–76.
[311] Wittkemper H-G, Steiner M. Using neural networks to forecast the systematic risk of stocks. European Journal of Operational Research 1996;90:577–88.

[312] Wong SQ, Long JA. A neural network approach to stock market holding period returns. American Business Review 1995;13:61–4.
[313] Wood D, Dasgupta B. Classifying trend movements in the MSCI U.S.A. capital market index — a comparison of regression, arima and neural network methods. Computers and Operations Research 1996;23:611–22.
[314] Worzala E, Lenk M, Silva A. An exploration of neural networks and its application to real estate valuation. The Journal of Real Estate Research 1995;10:185–201.
[315] Yoeger L. Neural networks provide robust character recognition for Newton PDAs. IEEE Expert 1996;11:10–1.
[316] Yoon Y, Guimaraes T, Swales G. Integrating artificial neural networks with rule-based expert systems. Decision Support Systems 1994;11:497–507.
[317] Zahavi J, Levin N. Issues and problems in applying neural computing to target marketing. Journal of Direct Marketing 1995;9:33–45.
[318] Zahavi J, Levin N. Issues and problems in applying neural computing to target marketing. Journal of Direct Marketing 1997;11:63–75.
[319] Zahavi J, Levin N. Applying neural computing to target marketing. Journal of Direct Marketing 1997;11:76–93.
[320] Zhang YF, Fuh JYH, Chan WT. Feature-based cost estimation for packaging products using neural networks. Computers in Industry 1996;32:95–113.

Bo K. Wong is currently an associate professor of Information Systems (IS) in the Department of IS, Lingnan University. His current research interests are in neural network and genetic algorithm business applications. He has published extensively in a variety of journals, including articles in *Journal of Decision Support Systems*, *European Journal of Operational Research*, *Information and Management*, *International Journal of Operations & Production Management*, and other professional Journals. Dr. Wong has also involved in consulting activities in many organizations, including 3M Company, Commercial Intertech Corporation, Delpi Packard Electric Systems, and The Open University of Hong Kong. He received the Most Distinguished Research Paper Award in the Society for the Advancement of Information Systems in 1996 and was listed in Who's Who in 1993.

Lai is an associate professor of MIS at the Chinese University of Hong Kong. His research focuses on database design, network management, business processing reengineering, and technology management. His articles on these topics have been published in the *Communications of the ACM*, *Data Base*, *Decision Support Systems*, *European Journal of Information Systems*, *IEEE Transactions on Engineering Management*, *Information and Management*, and many others.

Jolie Lam is currently a Ph.D. candidate in Management Information Systems at the City University of Hong Kong.