MONASH University

Information Technology

FIT5186 Intelligent Systems

Lecture 1

Introduction to Intelligent Systems and Neural Networks

Learning Objectives

- Understand
  - the basics of intelligent systems
  - the properties of neural networks
  - the applications of neural network systems
  - the business research areas of neural networks
  - the development of neural networks

Introduction to Intelligent Systems

- Artificial Intelligence (AI) is a combination of computer science, physiology, and philosophy.
- AI is a broad topic, involving a wide variety of research fields and domains, from machine vision, speech recognition, expert systems to business intelligence.
- AI can mean many things to many people.
  - Much confusion arises because the word “intelligence” is ill-defined.
- AI is intelligence exhibited by machines.
  - Machines mimic human cognitive functions like learning and problem solving.

Introduction to Intelligent Systems (continued)

Definitions of **artificial intelligence:**

- "The study of how to make computers do things at which people are doing better."

  – The IEEE Neural Networks Council (1996)

- "The use of computers in such a way that they perform functions normally associated with human intelligence, such as learning, adapting, self-correction and decision-taking"

  – The Chambers Dictionary (1998)

- "The theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision making, and translation between languages."

  – The New Oxford Dictionary of English (1998)

Introduction to Intelligent Systems (continued)

- What tasks are machines good at doing that humans are not?
- What tasks are humans good at doing that machines are not?
- What tasks are both good at?
- What does it mean to be intelligent?
- What does it mean to learn?
- How is learning related to intelligence?

Introduction to Neural Networks

- Are we more intelligent than computers?
- What is intelligence anyway?
- Computers are high-speed serial machines.
  - Suited to tasks such as arithmetic operations; data processing, database creation, information retrieval, etc.
    - Perform tasks quickly and accurately.
  - Hopeless at simple tasks like recognising faces, generalising (“thinking”), etc.
    - Things that any 2-year old child can do easily.

Introduction to Neural Networks (continued)

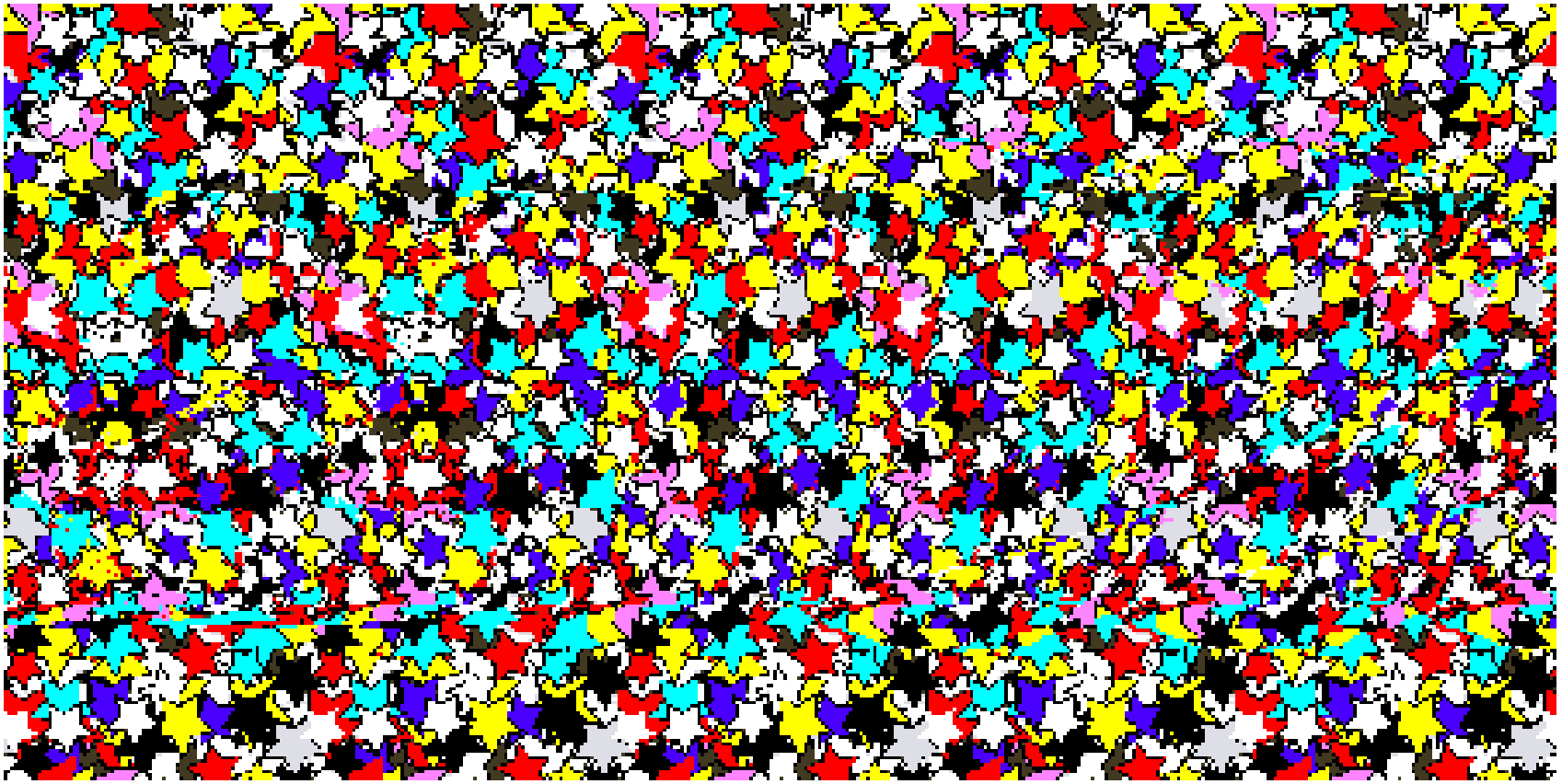
- Why? These tasks require parallel processing - many visual and external inputs need to be considered simultaneously.
- Computers therefore cannot be expected to solve these problems when they can only operate in a sequential manner.

  - cannot “see the forest for the trees”.

- Some problems cannot be solved sequentially:

Magic Eye Image

- Requires parallel processing to see it ...



See viewing instructions and solution http://www.magiceye.com/

Introduction to Neural Networks (continued)

- Neural computing is all about trying to capture the brain's ability to solve things in parallel.
- We don't know enough about neuro-physiology to mimic the brain, but we can try to borrow some successful features.
  - We can simulate the behaviour on serial machines, although it's better to run them on parallel machines (intended purpose).
- **Ability to learn** is crucial - makes a "thinking" machine.

So What are Neural Networks?

- Neural networks are very simple mathematical models of how the brain works.
- They have borrowed some of the successful features of the brain.
- They can be used to solve complex problems like pattern recognition, prediction or classification.
- Applications to business, engineering, design, medicine, law, etc.

What can Neural Networks Do?

- Excellent at tasks involving pattern recognition, classification, or prediction.
  - Able to learn relationships among patterns.
  - Able to “think” and generalise when faced with a new situation based on prior learning.

Applications of Neural Networks

- Neural networks have been around (in one form or another) for over 60 years, but only during the last three decades have there been developments which allow neural networks to be useful to business and industry.
- Neural networks have now “come of age”, with new architectures, training rules and insights giving them great value in the commercial world.
- Asian countries such as Australia, China, Korea, India and Japan are becoming increasingly interested in neural networks.
  - as evidenced by growth in membership to neural network societies & commercial interest.

So, Why the Interest?

- Neural networks are potentially very powerful due to the following capabilities:
  - their inherent parallelism (nonlinearity);
  - their hardware implementability;
  - their ability to learn and generalise (adaptivity);
  - their ability to handle “noisy” data (fault tolerant);
  - their ability to find relationships from data where other (statistical) techniques might fail (due to the lack of linear relationships).

So, Why the Interest? (continued)

- Neural networks also possess the following properties:
  - Ability to learn complex mappings from inputs to outputs, based solely on the presentation of sample patterns.
  - They require only a limited understanding of how they work from the trainer.
  - They are difficult to analyse and interpret, so it is not really possible to make firm predictions about the range of outputs.
- These properties define where they are useful.

Properties of Neural Networks

Property 1:

Neural networks have the ability to learn complex mappings from inputs to outputs, based solely on the presentation of sample patterns.

- The first property identifies problem domains where neural networks are particularly useful for
  - prediction/classification/recognition;
  - problems where a complex mapping needs to be found from inputs to outputs.

Properties of Neural Networks (continued)

Property 2:

Neural networks require only a limited understanding of how they work from the trainer.

- The second property explains why the use of neural networks is taking off so rapidly.
  - You don’t have to be a brilliant mathematician to use neural networks to solve complex problems.

Properties of Neural Networks (continued)

Property 3:

Neural networks are difficult to analyse and interpret.

- The third property warns us against using neural networks for applications which are safety critical, or where a bad prediction would be disastrous.
  - It's not that we expect the prediction to be bad, we just can't be sure it won't be.
  - Don't use a neural network to control the steering of an aircraft.
  - Critical applications can be performed (and are) if an additional system is installed to verify or override decisions which are obviously wrong.

Applications to Business

- Almost every area of business has potential for neural network applications.
- Typical application areas:
  - Marketing;
  - Operations management;
  - Banking and finance;
  - Insurance;
  - Data mining.
- Some application examples can be found from the BrainMaker Neural Network Software website:

  http://www.calsci.com/Applications.html

Credit Scoring

- Predicts loan application success.
- Inputs:
  - The input data for the credit scoring include information typically found on loan applications:

    Own/rent your home; years with employer; credit cards; store account; bank account; occupation; previous account; credit bureau.
- Output:
  - Credit score ranging from 0 to 1 to indicate the status of delinquent, charged-off, or paid-off.

Credit Scoring (continued)

- The credit scoring neural network was trained on no more than 100 loan applications yet achieved a 75-80% success rate.
- In one training trial, the network was trained with 75 loan applications and evaluated with 50 loan applications.
  - The network achieved an 80% success rate.
- More traditional and much more costly, credit scoring method used by 82% of all banks, resulted in a 74% success rate.

Marketing

- One of the main problems in marketing is the identification of segments of the marketplace which are likely to respond to a product.
  - Use a neural net to learn the relationship between a customer's characteristics (demographic and purchase pattern information) and their observed behaviour.
  - Studies have shown that neural networks can improve the response rate of direct marketing from around 2% to 95%.

Marketing (continued)

- Another marketing application is the *Airline Marketing Tactician* (AMT) developed by BehavHeuristics Inc. and USAir.
  - Neural networks are used to assist the marketing and control of airline seat allocations (together with an expert system).
  - The system is used to monitor and recommend booking advice for each departure; has a direct impact on profitability.
  - The neural network model is chosen because of the large number of interacting factors which cannot be expressed as rules; also the environment changes rapidly and constantly.

Marketing (continued)

- Modelling Customer Behaviour
  - Neural networks have been used to analyse historical patterns of customer behaviour.
  - The model is then applied to a marketing database to help predict future behaviour.
  - Recent studies include
    - Customer analysis and holiday package targeting in the travel sector;
    - Targeting cross-selling in the financial services sector;
    - Predicting computer software purchasers and insurance buyers;
    - Predicting factors influencing ATM usage.

Marketing (continued)

- Market Research Analysis
  - Clustering: use a self-organising network to reduce the large number of inputs (results of survey) onto a lower dimensional mapping.
  - This can help with the visualisation of the data.
  - It can also help to identify which data can be grouped together since they cause the same responses.
- Sales Analysis
  - Neural networks can be used to forecast future sales and to see which factors influence sales.
  - Market basket analysis: which products should be located together in the supermarket?

Banking and Finance

- Trading is one of the main areas of application
  - Time series prediction for stock prices or currency exchange rates.
  - Stock market prediction is largely unpredictable (there are many factors which need to be considered), but still some success.
  - Foreign exchange rates are a more reasonable problem to work on:
    - Hecht-Nielson Co. predicted Pound Sterling, Yen, and Deutsch Marks based on US dollar.

Banking and Finance (continued)

- Prediction of bond returns
  - A UK financial forecasting company has managed a $250M account for a US company investment. Returns are at 25% (versus 13.6% using their previous method).
- Prediction of future yield of securities
  - A Japanese Bank & Fujitsu have developed a neural network for Treasury Bond interest rate prediction: hit rate of 75% compared to human expert at 60%.
- Prediction of the DAX (a blue chip stock market index for the 30 major German companies trading)
  - Siemens trained a neural network to predict day to day movements in the DAX: a 41% return was achieved over 11 months: currently in use by a German financial institution.

Banking and Finance (continued)

- Credit Evaluation
  - Hecht-Nielson Co. has developed a credit scoring system which increased profitability by 27%
  - Mortgage assessment has been tried using a neural network, trained on the decisions of expert underwriters; the neural network produced a 12% reduction in delinquencies (failures to pay).
- Investment Screening
  - The financial characteristics of companies were extracted from a database, and analysed using a neural network.

Banking and Finance (continued)

- Accounting and Auditing
  - Credit card fraud detection
    - VISA International has an operational neural network based fraud detection system which has been used in 5 Canadian and 10 US banks, covering 40 million card holders.
    - The neural network is trained to spot fraudulent activity by comparing legitimate card usage with known cases of fraud: In 6 months, the systems has saved VISA over $40M.
    - It has the added advantage that it can be used to detect spending patterns that predict bankruptcy.
  - Insider trading detection: NN + genetic algorithm used at London Stock Exchange to detect suspicious trading.

Insurance

- Neural networks and data mining can be used to:
  - Determine which policy holders will renew their annual policy;
  - Determine which policy holders are more likely to claim;
  - Arrive at a fair formula for how premiums should be set;
  - Detect insurance fraud.

Insurance (continued)

- Data Mining
  - IBM offers “insurance solutions” to insurance companies which involve using (among other technologies) neural networks for data mining.
  - http://www1.ibm.com/industries/financialservices/doc/jsp/indseg/insurance/
- IBM Business Solutions have solutions to all sorts of industries and applications including *Business Intelligence:*
  - http://www-306.ibm.com/software/data/db2bi/
  - Many of these solutions involve using neural networks for marketing, forecasting and data mining applications.

Operations Management

- Scheduling and Planning
  - Many scheduling (optimisation) problems have been solved using Hopfield networks (or related networks) (not covered in this unit)
    - Computer task scheduling;
    - Job-shop scheduling;
    - Timetabling;
    - Electric power distribution;
    - Cutting patterns from cloth (stock cutting);
    - Satellite communications;
    - Airline and fast-food crew scheduling.

Operations Management (continued)

- Quality Control
  - Neural networks have been integrated with statistical quality control techniques to enhance their performance.
  - Traditional techniques tend to evaluate only one variable at a time, while neural networks can consider the interaction of multiple variables.
  - Examples include:
    - Monitoring soda bottles to make sure each bottle is filled and capped correctly;
    - Detecting faults in electrical and satellite equipment.

Operations Management (continued)

- Security and Signatures
  - Neural networks can be used to provide surveillance.
  - Airline baggage explosive detection system.
  - Signature verification (lots of interest from banking sector)
    - Commercially available now: 92-98% accuracy in detecting forgeries;
    - Now working on improving accuracy & speed using neural chips.
  - Much work on speech recognition (identifying speakers rather than words).
  - Pattern recognition (recognise faces).

Manufacturing

- For several years the Industrial & Building Systems Group at Siemens (Germany) has successfully used neural networks for process automation in basic industries.
- Worldwide, Siemens currently has more than 20 neural network applications running in a dozen plants, 24 hours a day.
- http://www.siemens.at/pse/ecanse/

Manufacturing (continued)

- Siemens find neural networks especially useful in the steel manufacturing industry.
- Used in control applications in electric arc furnaces and hot rolling mills to predict factors such as:
  - rolling force;
  - rolling-stock temperature;
  - natural spread;
  - short-stroke or electrode positions.
- The neural network is on-line with the operation, and controls the parameters.

Manufacturing (continued)

- The neural network optimises the parameters of the operation, so that the trade-off between maximum power absorption (shorter melting time) and increased thermal stress is balanced.
- Switching off the neural network during production decreases efficiency by 9.5%.
- The system also cuts energy costs by over $1M per year, and productivity has increased 5%.

Character Recognition

- The US Postal Service uses a neural network for handwritten digit recognition of zip codes.
- Apple Computer has used a neural network to recognise handwriting in its portable pen-based computers (in particular: Apple Computer's *Newton MessagePad*).
- http://www.beanblossom.in.us/larryy/ANHR.html

Character Recognition (continued)

- A neural network is combined with dictionaries (with a very wide coverage of the English language, as well as special constructs such as date, time and phone numbers).
- This pen-based character recognition system is said to be the first usable handwriting recognition system.
- The neural network is based on back-propagation, but is used in conjunction with other techniques such as frequency balancing, etc.

Speech Processing

- The on-going challenge in this area is the recognition of continuous, unconstrained speech.
  - Isolated word recognition is relatively easy.
- Sensory Inc. has focused on producing a range of cheap (< $5) speech recognition components for interactive toys, consumer electronics, security systems, & household appliances.
- http://www.sensoryinc.com

Speech Processing (continued)

- The neural network operates on 4 different functional levels:
  - Speaker-independent recognition
    - Recognises words regardless of user's age, accent, and gender.
    - Knows about 15 pre-defined words.
  - Speaker-dependent recognition
    - Requires user training, but can learn to recognise up to about 60 words (without knowing them in advance).
    - Can also reject a phrase not belonging to the current recognition set (i.e. "maybe" to a yes/no query).

Speech Processing (continued)

- Speaker verification
  - Recognises a stored password spoken by a particular speaker for security applications.
- Word spotting
  - Will detect if a key word has been spoken in a sentence.

- This speech recognition chip is currently used in:
  - Fisher-Price electronic learning aids;
  - Car security systems (Crime-Stoppers, Guardian International and Omega Research);
  - Sensory Inc. sold millions of these neural network based speech recognition chips in 1996.

Computer Virus Recognition

- A neural network is used by IBM in their *IBM AntiVirus* software package.
  - Detects boot sector viruses;
  - Resolves problem by generating artificial data;
  - On the training data, 90-95% correct classification was achieved;
  - On the test data, 80-85% correct classification for the viral boot sectors, and 100% for the legitimate boot sectors was achieved.
- Since the product has been released, the classifier incorporated in to *IBM AntiVirus* has caught approximately 75% of new boot viruses.

Computer Virus Recognition (continued)

- The authors of *IBM Anti-Virus* have also used neural networks to develop intelligent games such as backgammon (TD-Gammon) and Chess (the famous Deep Blue who beat Kasparov in 1997).

- http://www.research.ibm.com/deepblue/home/html/b.html

AlphaGo

- A computer program developed by Google DeepMind to play the board game Go

– A Chinese strategy game.

- A GO program at professional standard
  - A grand challenge in computing and AI research
  - Go is considered much more difficult for computers to win than other games such as chess
  - Enormous combinatorial complexity
    - More than 10^{170} possible positions; 200 possible moves in each turn; 10^{360} legal move sequences
  - Significant long-term influence of moves
  - Difficult to use traditional AI methods

AlphaGo (continued)

- In October 2015, AlphaGo became the first Computer Go program to beat a professional human Go player on a full-sized 19×19 board.
- In March 2016, AlphaGo beat Lee Sedol in a five-game match, being the first time a computer Go program has beaten a 9-dan professional.
- AlphaGo was chosen by Science as one of the Breakthrough of the Year runners-up on 22 December 2016.

AlphaGo (continued)

- The AlphaGo research project was formed around 2014 to test how well a neural network using deep learning can compete at Go.
- AlphaGo's algorithm combines a Monte Carlo tree search with deep neural networks to find its moves based on knowledge previously "learned" by extensive training, both from human and computer play.
- These neural networks take a description of the Go board as an input and process it through a number of different network layers containing millions of neuron-like connections.
  - The "policy network" selects the next move to play.
  - The "value network" predicts the winner of the game from each position.

AlphaGo (continued)

- First - learn to play GO like human experts
  - It is trained with thousands of strong amateur and professional games.
  - It mimics the play of human experts by being shown 30 million moves from a large database of real games.
  - A straightforward pattern recognition problem for NNs.
- Then - learn to win
  - To learn to play moves more likely to lead to winning.
  - It plays against different versions of itself thousands of times, each time learning from its mistakes and incrementally improving its chance of winning.
  - If a given move in a game leads to a win, the network was trained to be more likely to play moves like that in the future, and vice versa.

AlphaGo Zero

- A paper published in *Nature* in October 2017.
  - Sliver et al. (2017). “Mastering the game of Go without human knowledge”, Nature 550, 354–359 (19 October 2017) doi:10.1038/nature24270
- Without using data from human games, AlphaGo Zero learns to play simply by playing games against itself, starting from completely random play.
- It played 4.9 million games against itself in quick succession in three days.
  - It defeated AlphaGo Lee by winning 100 games to 0.
- It defeated all the versions of AlphaGo after 40 days of training.

AlphaGo Zero

- At a high level, AlphaGo Zero works the same way as AlphaGo:
  - It plays Go by using a Monte Carlo tree search, intelligently guided by a deep neural network.
  - The neural network generates evaluations of what the best moves are.
  - The neural network is trained and updated to predict moves that reflect the improved evaluations from performing the “lookahead” search.
  - It continually improves the neural network’s evaluation of board positions during self-play games, instead of using human games.

AlphaGo Zero

- AlphaGo Zero uses a “residual” NN architecture, instead of a purely “convolutional” NN architecture.
- It uses a novel form of reinforcement learning (RL) to train the NN.
- It does not use any classical or advanced reinforcement learning concepts, such as Deep Q Learning.
- It simply uses simulations to generate training data for its neural nets to learn from in a supervised fashion.
- “Ironically, the major advances in RL over the past few years all boil down to making RL look less like RL and more like supervised learning.”

– Denny Britz on Twitter 30 Oct 2017

Film Industry

- Science Fiction is frequently referring to artificial intelligence and neural networks.
- Terminator 2 used a neural network consultant (since there is a substantial amount of dialogue referring to neural networks).
  - The consultant was Larry Yaeger from Apple Computers (who developed the pen-based handwriting recognition system) http://www.beanblossom.in.us/larryy/T2Tech.html

Product Design

- Neural network models are used to formulate the relationship between design elements of a product and image values of the product perceived by customers.
- A customer oriented approach based on Kansei Engineering - describing the relationship between customers' psychological feeling (Kansei) of a product (characterized by pairs of image words) and design elements of the product.
- The NN models have the ability to predict the product image value for a new product with given design elements.
- The NN models can be used to construct a design support database to determine the best combination of design elements of a product for matching a desirable product image.

Product Design (continued)

- Example: Form design of mobile phones
- Inputs:

  27 types of 9 form elements, such as top shape, body shape, function button, screen size, etc.
- Output:

  Product image of the Simple-Complex value (1 to 7).
- Various NN models are constructed with different inputs and different numbers of hidden neurons, which are trained and evaluated with 33 sample mobile phones.
- The best performed NN model is used to help designers work out the best form design combination for mobile phones.
- The NN approach can also be applied to product colour design.

Web Page Design

- Neural network models are used to formulate the relationship between 7 key design elements of a web page and 3 image values of the web page perceived by users, including easy-difficult (E-D), clear-confusing (C-C), and realistic-fancy (R-F).
- Inputs: 23 neurons for 23 types of 7 web page design elements.
- Outputs: 3 neurons for the E-D, C-C, and R-F image values.
- 4 NN models with different numbers of hidden neurons are developed, which are trained and evaluated with 33 sample homepages of university sites.
- The NN models have the ability to
  - Predict the web page image value for a new web page with given design elements;
  - Determine whether a specific combination of web page design elements meets desirable web page images;
  - Work out the best web page design for meeting desirable web page images.

Web Page Design (continued)

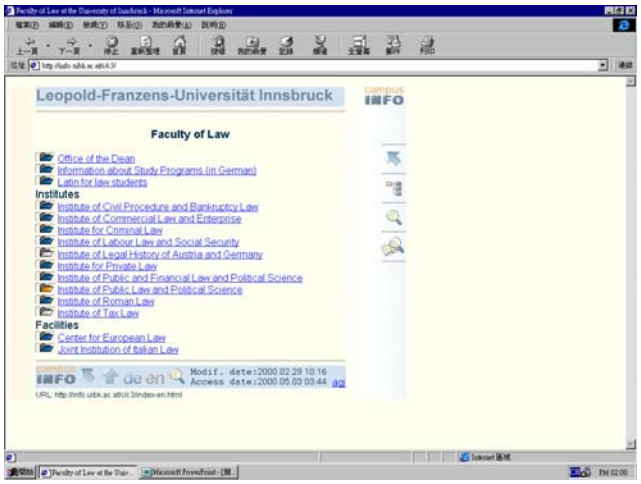
- 7 key design elements of web pages

	Elements	Type 1	Type 2	Type 3	Type 4	Type 5
X_1	Ratio of graphics to text	Above 3	Between 3-1	1	Between 1-1/3	Below 1/3
X_2	Blank ratio	0%-20%	20%-40%	40%-60%	60%+	
X_3	Layout style	2 columns	3 columns	3+ columns		
X_4	Frame style	Up and down	Left and right	Compound style		
X_5	Hyperlink style	Text only	Text and symbol	Text and icon		
X_6	Number of colors	Below 4	4-7	Above 7		
X_7	Background color	Cold	Warm	Neural		

No. 2

Easiest (E-D value = 2.11)

Easiest + clearest + most realistic

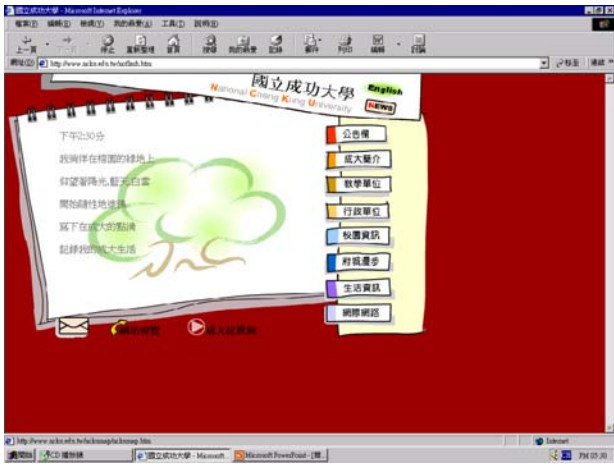


No. 25

Most difficult (E-D value = 4.11)

Most difficult + most confusing

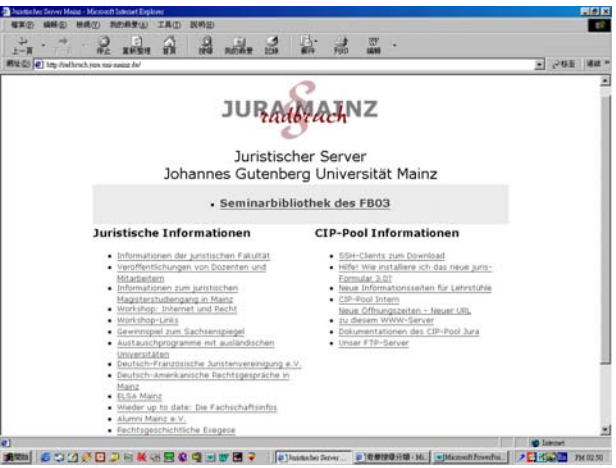
Most difficult + most confusing + fanciest



No. 1

Clearest (C-C value = 1.70)

Easiest + clearest



No. 4

Most confusing (C-C value = 3.48)

No. 14

Most realistic (R-F value = 2.21)

No. 9

Fanciest (R-F value = 4.06)

Artificial Neural Networks in Business Research: 1994 to 2015

- Tkac. M. and Verner, R. (2016). Artificial neural networks in business - Two decades of research. *Applied Soft Computing, 38, 788-804.*
  - A review of 412 papers
- Application areas
  - Auditing and accounting; Cost monitoring; Credit scoring; Customer metrics; Decision support; Derivatives; Exchange and interest rates; Financial analysis; Financial distress and bankruptcy; Fraud analysis; Inflation; Marketing; Sales; Shares and bonds
- Types of neural networks
  - The most popular: multilayer feedforward network
- Learning algorithms
  - The most popular: backpropagation learning

A Brief History of Neural Networks

- Neural networks have had a surprisingly long and turbulent history.
- What impact has this history had on the business community?
- The history of the neural network development can be divided into 5 main stages.

STAGE 1: Preliminary

- 1835 Babbage invents analytical engine.
- 1890 William James' *Psychology*: early insights into brain activity.
- 1936 Turing uses brain as computer paradigm.
- 1943 McCulloch & Pitts paper on neurons.

- In the business world:
  - 1900 Analytical engines used in 1900 census (USA).
  - 1914 International Business Machines (IBM) formed to capture this growing market.

STAGE 2: Age of Computer Simulation

- 1946 Wilkes designs first operational computer
- 1949 Donald Hebb's *The Organization of Behaviour* - Hebbian learning rule
- 1950's Age of computer simulation.
  Hebb's theories tested and modified.
- 1956 Dartmouth Summer Research Project
  AI and Neural Computing fields launched
- 1957 Rosenblatt developed Perceptron model,
  lots of excitement, and excessive hype
- In the business world:
  - 1954 General Electric Co. uses a computer for payroll.

STAGE 3: The Quiet Years

- 1969 Minsky and Papert's *Perceptrons* showed limitations of Perceptron model and basically killed the field.
- 1969 -1982 Some research continued but not much
- 1982 Hopfield's associative memory work
- 1982 Kohonen's self-organisation work
- In the business world:
  - 1971, 1st microprocessor by Intel
  - Mid 1970's, many statistics companies formed
  - 1981, IBM PC introduced

STAGE 4: Re-birth of Neural Networks

- 1983 DARPA funding for neural networks
- 1985 Backpropagation discovered
- 1986 Rumelhart & McClelland PDP (Parallel Distributed Processing)
- During late 1980's many international conferences and journals on neural networks were created.
- In the business world:
  - During late 1980's, some early neural network companies started to form.

STAGE 5: Industry Driven

- 1990's research continues, but is driven by needs of industry and business.

- In the business world:
  - 1991, Neural networks used in banking industry
  - Early 1990's, Many NN companies formed
  - 1995, IBM Business Intelligence formed
  - 1996, 95% of top 100 US banks using data mining
  - 1997, SAS Enterprise Miner software released
  - 1998, IBM announces initiative for estimated $70 Billion (USD) business intelligence market
  - Market will be worth $148 billion (USD) by 2003 according to survey.com

Developments beyond 2000

- The initial dream of imitating the brain shelved.
- The artificial neural network (ANN) models are used as tools to enhance competitive advantages for businesses.
- Research on hybrid systems by combining ANNs with fuzzy logic, genetic algorithms, etc.
- Many software vendors incorporate ANNs in their software packages and marketed as “Intelligent” or “Business Intelligence” tools (e.g. Cognos, Oracle, SPSS, SAS).

Data Mining

- Data mining is an exciting new area of research and application.
- It uses intelligent techniques like neural networks to extract hidden information from databases and data warehouses.
- This can be used to give an organisation a competitive advantage.
- Data mining and other applications of neural networks have driven research in the 1990's ... more on data mining later.

Selected Reading

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