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THE USE OF NEURAL NETWORKS TO CHARACTERIZE PROBLEMATIC ARC SOUNDS

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ABSTRACT

Automation of electric arc welding has been at the centre of considerable debate and the subject of much research for several decades. One conclusion drawn from all this effort is that there seems to be no single system that can monitor all of the variables and subsequently, fully control any welding process. To date there has been considerable success in the development of seam tracking systems employing various sensing techniques, good progress has been made in the area of penetration measurement and worthwhile use has been made of the integration of expert systems and modelling software within these control domains.

Skilled welders develop their own monitoring and control systems and it has been observed that part of this expertise is the ability to listen subconsciously to the sound of the arc and to alter the electrode position in response to an adverse change in arc noise.

Attempts have been made to analyse these sounds using both conventional techniques and more recently expert systems, neither have delivered any usable information. This paper describes a new approach involving the use of neural networks in the identification of sounds which indicate that the welding system is drifting out of control.

INTRODUCTION

Artificial Neural Networks (ANNs) offer potential as an alternative to standard computer techniques in control technology and have attracted a widening interest in their development and application. Although the conception of ANN theory predates that of the modern digital computer, the commercial success of Von Neumann systems and the utilization of Boolean logic has over-shadowed their development.

Due to the proliferation of the digital computer the use of ANNs in 'real' applications tend to be in the form of software neural simulators. The commercial availability of dedicated neural hardware is very limited. Consequently, the techniques employed for the proposed research would involve the application of commercial simulators as well as custom compiled software.

Research within the Department of Design at Brunel University has aimed at the development of intelligent control systems incorporating ANNs. One focus of attention has been industrial welding processes. To date ANNs have been successfully implemented to process ultrasonic scans of a submerged arc welding process, Fig.1, to achieve real time kinetic control of the welding head as well as monitoring weld penetration.(1,2,3)

It has been observed that skilled manual arc welders subconsciously change the angle of electrode and arc length in response to a variation in the sound produced from the process. Much evidence exists for the successful application of ANNs in systems which imitate human attributes including the development of the "Silicon Ear" and "Retina" by Carver Mead (12), Kohonen's "Phonetic Typewriter" (13) and hand written character recognition (14,15). The goal of this work is to propose a feasible ANN oriented system to automatically control an arc welding process and thereby imitate the biological expertise of a human operator.

THE WELD VARIABLES

The creation of an ideal weld is dependent upon the optimum settings for :-

- i) weld plate preparation (fit up)
- ii) welding voltage,
- iii) welding current (determined by the rate of feed of the sacrificial electrode)
- iv) position of the electrode

and

- v) speed of travel of the welding head along the seam.

A sixth parameter which can drastically affect the quality of the weld is the feed of granular flux. This is generally gravity fed and hence not directly controllable. However a system which detects the onset of a blockage as a diagnostic feature is desirable.

Following the development of a positional control system for submerged arc welding by means of ultrasonics (1,2,3), the preliminary aim of this research is the control of parameters ii), iii) and v).

In an industrial scenario the submerged arc welder is used to join plates of between 6mm and 40mm. For initial research purposes under laboratory conditions plates of 25mm would be used. Optimum settings for each parameter would be preset by a controlling PC to obtain ideal weld penetration.

To compliment the existing ultrasonic weld penetration monitoring system (dedicated to the closed loop control of the welding current), it is considered that the prime directive of this research would be the control of the welding voltage to maintain an optimum balance and hence weld stability. However the nature of a raw acoustic emission is such that data acquired will contain information concerning other parameters which can be utilised within the diagnostic arena.

PROPOSED METHODOLOGY

Acoustic emissions, within the audible range, have been successfully employed to extract usable diagnostic information from systems such as pulsed laser welders (4) and IC engines (5). The acquisition of acoustic data creates little problem providing the transducer and associated amplifier is tailored to suit the application.

It is proposed that for this work an omni directional Electret Condenser Microphone (ECM) and pre-amplifier, are adequately noise shielded and resiliently mounted in the vicinity of the welding head. The ECM exhibits a large bandwidth with a uniform frequency response within the audible range of 15Hz to 20kHz as well as rejecting any induced noise from the 'Pinch Effect'(11) of the arc.

The signals could then be passed through a bandpass filter set to isolate the audible range from infra and ultra sound. An interim FFT analysis at this point would emphasise usable frequency ranges in response to intentionally unstable inputs to the welding system. Future development in this area will involve the hardware filtering and isolation of usable frequencies within the spectrum.

The signal could then be digitised at a frequency of 1MHz and a resolution of 8 bits and downloaded to a PC for analysis by the software simulated ANN. The outcome of the analysis will then interface the controlling software of the welding parameters.

The equipment proposed for the experimentation, Fig.4, comprises

i) SAF Devimatic submerged arc welding set
ii) IBM PS/2 70
iii) FFT analyzer
iv) Custom built transducer arrangement, filter sets and interfacing system.

Computer programs are to be compiled in 'C' and Prospero Pascal.

Neural Network Paradigms

Neural Networks are modelled on the architecture of the biological brain. The network is constructed of discrete neurons each providing an output to a given stimulus dictated by a mathematical function, Fig.5. The collective response of a network is dependent upon the topology of synaptic connections. The topology is subject to debate as various architectures exhibit differing characteristics of cognition and recognition. A simple example is shown in Fig.6. This illustrates a multi-layer fully connected system. The input layer where data is presented to the network, an output layer to communicate a response and a "hidden layer" which increases the processing ability of the system.

ANNs have been proven successful in high speed signal processing, especially in noisy or erratic systems where conventional signal processing failed.(1,2,3,5). Advantages of networks are further enhanced by their apparent ability to "generalise", which is to respond correctly to novel, erroneous or even incomplete data; an inability of expert systems.

The trend in ANN applications has steered towards the development of hybrid systems (6,7) where the characteristics of certain network topologies are used in conjunction with others or in parallel with expert systems. Complex problems require the combination of knowledge based and neural computing techniques to reach an optimum solution.

For the application to this work it was envisaged that two neural network architectures could be employed:-

i) Kohonen self organizing feature maps (8)
ii) Weightless or Logical Neural Networks (9)

The Kohonen paradigm possesses the inherent characteristic to self organize its topology by a method of competitive, "unsupervised learning". That is, the final pattern of synaptic connections is optimized by a self iterative process known as a "learning algorithm". The result is a system that can identify the organizational relationships between input patterns and map the similarities into "closeness" groups. The advantage over standard pattern recognition is its speed, because of the parallel nature of the neural process and the provision of a graphical representation of pattern relationships. This, therefore, can provide a complex pattern recognition system.(10)

The Logical Neural Network was a system devised jointly by Brunel University and Imperial College, London. It utilizes the contents of addresses within a random access memory (RAM) in its learning algorithm rather than the more usual iterative update of synaptic weights adopted by most paradigms. Hence the term a "weightless" network. If a summing device is used to process the responses from a number of RAMs a degree of similarity or "discrimination" can be established between novel input patterns and previously stored "learned" patterns. With manipulation of the neural threshold functions within the "discriminator" similar input patterns will produce similar responses and therefore exhibit properties of generalization. This technique was used in the WISARD system. Operating on real time video data it is able to distinguish between facial images and is consequently being applied to facial recognition purposes in security systems(8).

With the application of a Kohonen paradigm as a complex pattern "classifier" or feature extractor and a Logical Neural Network as a pattern "discriminator" an optimum solution for the real time processing of compound acoustic signals is proposed.

An ANN can be developed using either commercial software tools or custom compiled programs. Various topologies have proven successful in specific applications however the architecture has to be tailored to suit the application if an optimum solution is to be reached. Too many hidden layers or artificial neurons (sometimes known as Nodes) will lead to lengthy training periods and ultimately slower operating speeds.

CONCLUSIONS

It has been previously proven that ANNs have the ability to interpret chaotic ultrasonic signals in real time and provide on line weld control.(1,2,3)

With the application of hybrid systems it is feasible that real time acoustic data, both audible and inaudible, may be used to predict the onset of weld instability.

Neural Networks provide a key to a higher degree of process automation.

Research and development in the area of weld process and kinetic control continues with the aim of providing a fully integrated and hybrid automated welding system.

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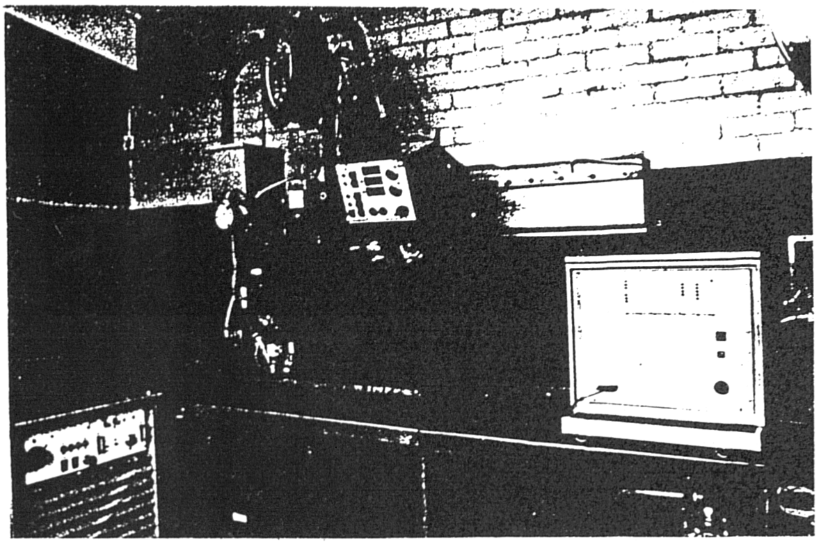

FIGURE 1.
SUBMERGED ARC WELDER

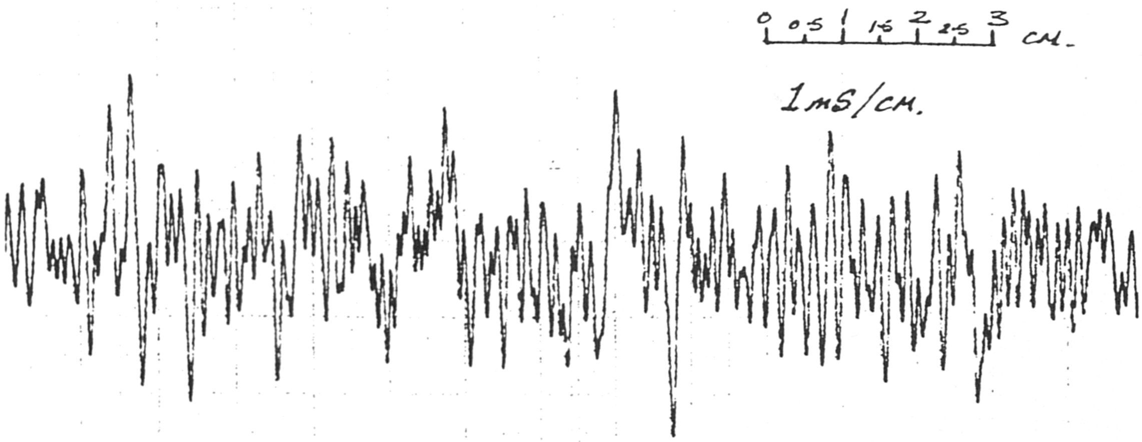

FIGURE 2.
ACOUSTIC EMISSION OF
AN OPTIMUM WELD

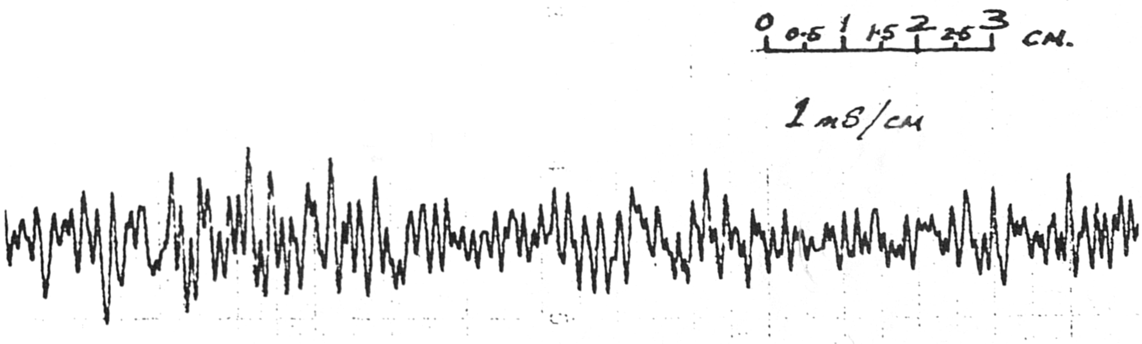

FIGURE 3.
ERRONEOUS EMISSION DUE TO
A FLUX BLOCKAGE

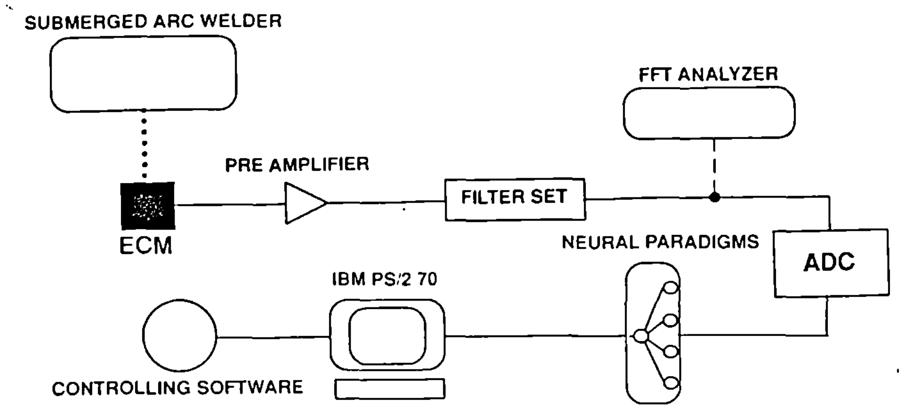

FIGURE 4.
EXPERIMENTAL SETUP

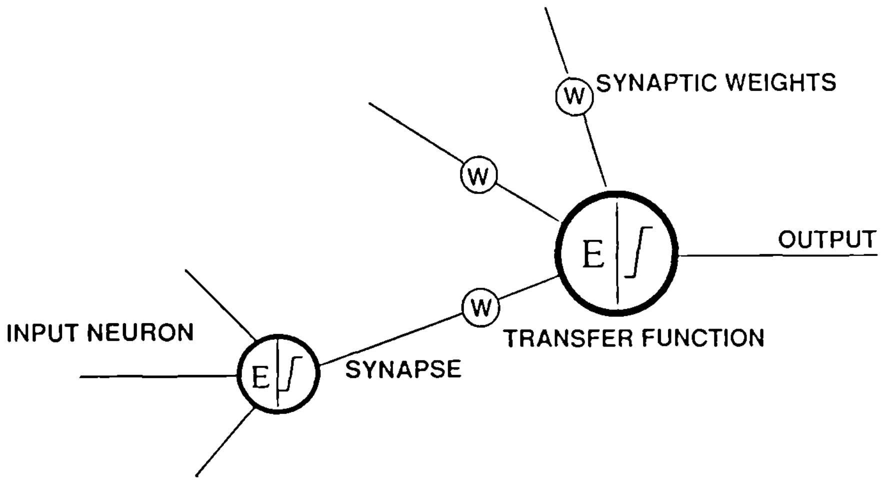

FIGURE 5.
ELEMENTS OF NEURAL CONNECTION

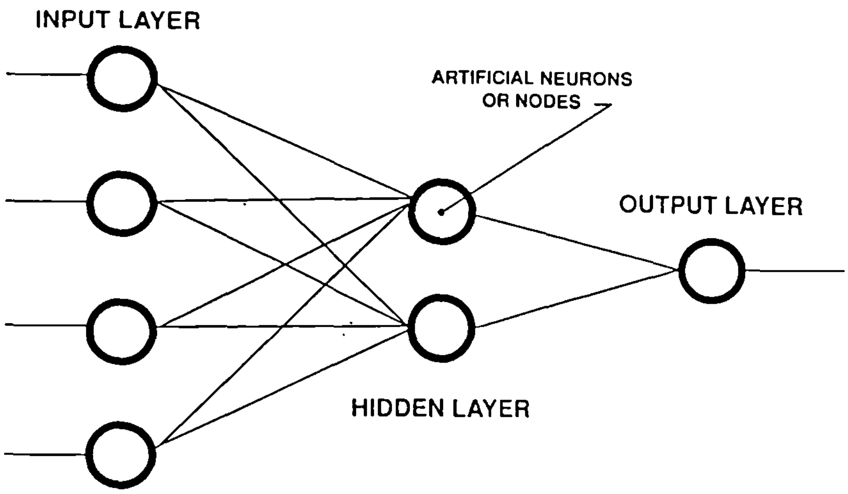

FIGURE 6.
SIMPLE MULTI-LAYER ARCHITECTURE