The Use of Personal Computers In Metal Finishing

By Arthur W. Brace

Although computers are in wide use in plating and anodizing shops, often their capabilities are not well understood. This review is intended to offer additional background in the potential of personal computers in metal finishing and to suggest modes of operation perhaps new to many finishers.

The use of personal computers in the operation of metal finishing shops is well established. They are almost universally used in the accounting, administration and sales departments. In the shop itself, memory chips and solid state controllers are widely employed for functions such as control of the current output and bath temperature, as well as for recording and storing such data, but they are computers dedicated to a specialized function.

There are many areas where the advantages of computers are often not being fully utilized by chemists, metal finishing technologists and production staff. Such personnel always have a need to store information for easy reference and quick retrieval. With the ability of low-cost scanners to scan and store text in a readable form, there is much to be gained in having data stored on computer instead of in the form of loose sheets from technical journals, suppliers' literature and in card index form. In some quarters, people do not like using computers, often because computer people, like metal finishers, have their own special jargon that must be learned. Initially, this inhibits understanding until familiarity is acquired. Computer programs, however, have become easier to use in recent years. The jargon is that they are "more user friendly."

It is fairly widely known that in addition to the hardware (*i.e.*, the machine), "software" is needed. This enables the user to enter instructions and data into the computer in a form that it will process and store in a form acceptable to the user. The term "software" is a little misleading and is a historical term handed down from early mainframe computers. The software for personal computers is provided on discs (no longer "floppy") or as a CD-ROM (Compact Disc - Read-Only Memory). Perusal of a vendor's software catalog offers a bewildering array of choices. It is hoped that the account that follows will provide some help in understanding what can be done with such software and to provide some indication of the application of such software in metal finishing.

Operating Systems

Although it is necessary to have software available that will enable information to be processed, all computers must have a set of primary operating instructions. This is an operating system, of which MS-DOS™ and Windows™ are the most widely used on personal computers. With MS-DOS, text and numerals can be entered and processed, but they are usually displayed on the screen at the same size, so that the character size of the screen display is fixed, although the characters and size of the printed output can be varied by the printer. Windows™ is a graphical environment (*i.e.,* it can display numbers and letters in various sizes and typefaces, as well as graphs and images constructed as dot patterns from pictures or other sources).

Word Processing

This is one of the most familiar types of program, which, as its name indicates, is intended to help the user manipulate text into a form required for writing a memorandum or report, production process instruction sheets etc. The main requirement here is a willingness to learn how to use a keyboard to enter the text desired. Some of the popular programs have facilities that allow scientific and mathematical symbols to be displayed or even for a picture or diagram (a "graphic" in computer jargon) to be displayed along with text.

Databases

Databases have been in use for a number of years and there are many types, so it is hoped that some examples will be helpful. While all of these store data, it is their ability to process and retrieve data that are important to the user.

Simple Databases

One of the early databases[1] that was used in conjunction with MS-DOS was Reflex™ and this has been used by the author to provide several types of database. Figure 1 is an example of a way in which data were entered to build up a bibliographic database of papers containing data on anodizing and associated processes. The data are entered as a "record" that contains a series of "fields." Records can be retrieved from a file by specifying those fields that may contain one or more lines of information. The program requires that the nature of each field be entered because it will not perform mathematical operations on a text field. The program provides for rapid retrieval of information by using a combination of fields, also retrieval by date or author and key words.

Specialized Databases

Following these developments, programs with quite sophisticated and rapid retrieval possibilities became available.[2,3]

Title: A.C. Anodizing of aluminium in phosphoric acid
Author(s): D J Arrowsmith, D A Moth and A Maddison
Journal Ref: Trans. Inst Met Finishing 1987, 65, 38-44.
Key words: 5251 alloy Anodizing Electrolytes Phosphoric acid Morphology
Abstract: The authors have studied the growth of anodic coatings on 5251 alloy using a 10% (vol.) phosphoric acid electrolyte at 25°C and 10-60V. (rms). The morphology of the coatings was studied by SEM. It was observed that there were basic similarities in coating growth to that seen in d.c. anodizing, but the balance between oxide formation at the interface and oxide dissolution at the outer surface is affected by the extra time available for oxide dissolution during the cathodic part of the cycle.

Fig. 1—Example of a simple bibliographic database entry.

As an example, one of these[2] employed a card format designed for bibliographic databases and incorporates some useful rapid search and retrieval capabilities, but could not handle graphics. Another database with slightly fewer search facilities embodied an extra command whereby PCX graphics could be displayed, although its graphics abilities were limited. More recently, programs have become available whereby scanned text and graphics can be included in a card format.[4] This permits a wide range of text formats, colors and graphics to be displayed, so that most current programs are now based on use of the Windows™ operating system, whereas the earlier programs were originally developed for use with the MS-DOS™ operating system.

Hypertext

A useful facility that can be incorporated into databases or word processing programs is known as *hypertext.* This is a facility whereby a word or "string" of characters can be marked in a simple, predefined manner. When so marked, the program allows the user to jump immediately to another part of the file that has been programmed to form a hypertext link. These links can be made between cards, records or pages within a file or in other files that use the hypertext program. Additionally, hypertext links can be formed between text and graphics in a similar manner. This provides an impressive instantaneous cross-referencing to related data. It is especially useful if an expert system needs to be linked to a supplementary database.

Spreadsheets

Spreadsheets offer a "user-friendly" way of entering data in rows and columns to enable arithmetic operations on the data. In addition to numerical data, provision is made for text to be entered as row or column headings. Data so entered can be displayed as graphs or bar charts. Spreadsheets are frequently supplied as part of software packages installed in the computer by the supplier.[5,6] They are normally abbreviated versions of the full original software program, so there is the possibility that they do not incorporate some of the features the user might desire.

Use of Spreadsheets in SPC

One of the main attractions of spreadsheets is that once data has been entered it can be processed and displayed or printed out in a readily understood form (e.g., as a control chart for Statistical Process Control [SPC] purposes). An interesting paper[7] has been published describing the use of a spreadsheet for control of chemical additions to a zinc plating line.

In this connection it is desirable also to evaluate those programs dedicated to use of the spreadsheet format for SPC.[8] A recent paper has reported on the use of one of these programs for SPC of anodizing electrolytes and of anodic coating thicknesses.[9]

Logic-based Expert Systems

Expert system research began in the early 1950s, but it was only in 1964 that the "DENDRAL" expert system was published by researchers at Stanford University. This program is regarded as the prototype of subsequent expert systems. It was used to interpret mass spectra data for chemical analysis. It has only been during the last decade that commercially viable systems have begun to appear. The quality of expert systems is variable, however, depending on the skill of the programmer and the intended use of the system.

The programs used for expert systems are usually developed from "Expert System Shells" (*i.e*., they are a framework within which the expert can organize the relevant expertise in a "user-friendly" form). They are therefore highly dependent on the capabilities of both the expert and the programmer because the basic computer law, "garbage in, garbage out" always applies. To take into account the varying levels of computer literacy in the many metal finishing shops, expert systems must be "user-friendly" so that they can be readily understood and used by most finishers.

The principle of most logic-based expert systems so far developed is that the user is presented with a series of questions that appear on the computer screen to which a yes or no answer is required. Depending on the answers given, the expert system will provide a solution to the problem posed. In compiling the expert system, the expert draws up a number of rules that are logical deductions from the answers given by the user. The rules constructed are based on the logic premise:

If ______ and ______, then _______.
or If ______ or ______, then ______.

For example:
If the aluminum has been etched
and has a "galvanized" appearance
and the alloy is 6063 and contains more than 0.05% zinc,
then (Rule): The appearance is a result of the zinc content of the alloy.

The development of a rule-based Expert System for identifying defects in electroplated nickel deposits, based on the above principles, has been described by Schachameyer *et al*.[10] The principles of applying such logic-based expert systems to electroplating has been discussed by Hills,[11] although the details of the system have not been published. Matthews [12-15] has described expert systems developed for the selection of coatings on metals to meet specialized tribological and corrosion-resisting properties. Other expert systems are in use, but remain unpublished because the developers rightly regard them as containing their proprietary expertise, which is often specific to their own shop. It should be borne in mind, however, that such expert systems also have limitations.

The principal limitation of such expert systems is that they require a specific answer. With process problems in metal finishing, it is not always possible to answer "yes" or "no" with 100 percent certainty, because conditions at the time the problem occurred may not be known precisely. On the other hand, there are expert systems in which a series of questions may be asked and a probability computed as to the correctness of the answer obtained by the expert system analysis. Some expert systems allow the user to enter a probability factor into the answers given to questions, but this means the user is supplying part of the expertise!

Artificial Intelligence

The term "artificial intelligence" (AI) is applied to those fields of computer science dedicated to producing computer programs and hardware that attempt to simulate human intelligence. Work in this field dates back more than 40 years, but the widespread use of computers and the development of powerful, low-cost, desk-top computers has greatly stimulated interest in AI. Artificial intelligence is a broad field, however, covering many different activities, so it is only those areas of AI that seem relevant to metal finishing that will be considered. These are:

1. The fundamentals of logic-based expert systems.
2. "Fuzzy" systems as a part of an expert system.
3. Neural networks as an expert system.

Consideration of Probabilities

To a degree, some of the objections can be overcome by introducing probability factors into the rules derived from the logic-based approach. Most metal finishing problems arise from a combination of several factors. For example, the defect in bright nickel-chromium plating known as "white-wash" (*i.e.*, white areas with a clearly defined edge) can be the result of the following factors:

1. High brightener and/or high leveler content.
2. High nickel content in the drag-out tank.
3. High pH in the nickel solution.
4. Low nickel anode area in automatic plants at the end of the nickel section before the work leaves the tank.
5. A low sulfate content in the chromium plating bath.
6. High initial current density when work enters the chromium plating bath.

It is not necessary for all these features to be present for the defect to occur. In developing an expert system for identifying defects in nickel-chromium plating, the user could be asked to apply numerical values for each of these constituents and the system compiler could develop rules that would evaluate the probability of a combination of bath constituents giving rise to the defect.

"Fuzzy" Systems as a Tool for Handling Uncertainty

The incorporation of "fuzziness" and "fuzzy" logic in computer programs is a relatively recent development. The concept of "fuzziness" refers to vagueness rather than probability. The use of "fuzzy" logic embraces a computational approach that takes into account subjective judgments. Terms such as "poor throwing power," "ductile deposits," "hard coatings" etc. are frequently used by metal finishers, but are not accurate definitions; such statements are "fuzzy." The use of data, such as plating bath analyses, to trigger action to correct bath conditions involves "fuzziness," because the bath conditions may have changed by the time changes are implemented unless linked with automatic process control.

In probabilistic systems, the logical operator AND is performed by multiplying the variables. With fuzzy logic, AND takes the value of the smallest variable. With probabilistic systems, OR is performed by adding the value of the variables, but with fuzzy logic, OR takes the value of the largest variable. When using the operator NOT, both probabilistic and fuzzy systems perform NOT by subtracting the variable from the largest possible value of the variable.

When investigating problems in metal finishing, there is often a lack of accurate data about the conditions that prevailed when the problem occurred. The logic-based expert systems referred to above tend to ignore the uncertainties of the conditions that applied during the operation of a bath at the given time under production conditions. This leads to a degree of mistrust of expert systems by practical metal finishers. Fuzzy systems can take these uncertainties into account. For those wishing to read further, Ref. 16 offers a more detailed introduction to the subject.

Neural Networks

Of the types of program that fall within the definition of "artificial intelligence" is one that employs neural networks. The concept of "neural networks" is based on simplistic models that have been developed to explain the function of the human brain. The concept is that the brain receives an input signal from the nervous system, which is then processed via a neuron (Fig. 2) to give an output to the nervous system. Even very simple nervous systems involve a number of neurons. For example, when a nerve is stimulated (e.g., a finger touches something hot), input signals are received by neurons in the brain; these are referred to as input nodes (Fig. 3). These signals are processed by the brain, which passes it the information on to one or more neurons forming output nodes. In this example, the neurons process the signal and one output tells us that the object is hot, while another triggers a reflex reaction so that the finger is instantly removed from the hot item. There may also be another output signal which, from training and experience, tells us to turn off the heat source.

To simulate this process using a personal computer, there must be a means of imitating the process by which the brain receives a signal from its input neurons. In so doing, the computer remembers these inputs and forms connections between the various inputs, which then become the outputs (*i.e.*, the conclusion drawn and the action taken as a result of the information processed). The ability of the brain to build up a series of responses to external signals and events is known as "learning." It is evident that using a computer, there must be a means of imitating the process of the brain when it

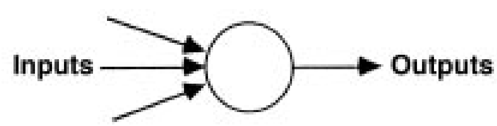

Fig. 2—Diagram of a simulated neuron.

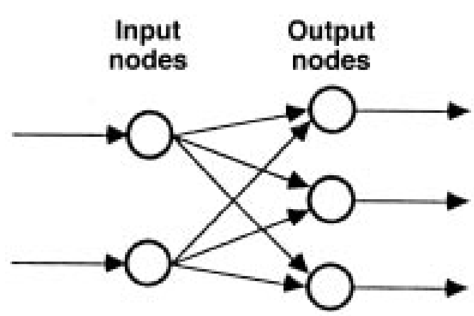

Fig. 3—Representation of a network of neurons.

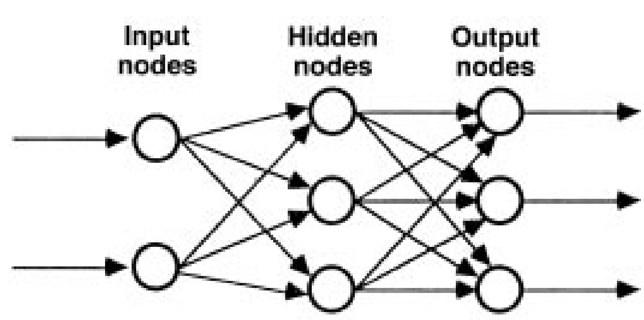

Fig. 4—Representation of a back-propagation, three-layer neural network showing input, output and hidden nodes.

learns from the input neurons and forms the connections between the different signals which form the output (*i.e.*, the action or logical conclusion drawn from this information).

Now the human brain is far more complex than any neural networks program and has developed the capacity to learn how to manipulate numbers, leading to the elaboration of mathematical theory and its practical applications. In applying computer-based artificial intelligence, it has been possible to incorporate "fuzzy" logic into neural networks programs by (1) incorporating fuzzy logic in the neural network algorithm, (2) interfacing the algorithm with complex fuzzy systems, or (3)using fuzzy sets to train the network.

The most widely used neural network is the Back Propagation Neural Network (Fig. 4). A simple input-output program is quite limited in its ability to recognize more than the simplest of patterns. To overcome this, he input nodes are treated as one "layer" of data, which is then processed via a second "hidden" layer of nodes to the output layer. The network learns by comparing the binary input values from one layer of the network with the binary outputs of the data fed in when the expert system is developed (a second layer in the network), making corrections via the neural network developed by the program. These corrections, based on the errors in the outputs, propagate back through the network via the hidden nodes during training. As training progresses, the amount of error is minimized or eliminated.

Some of the input data may be technically more important than other data and will be weighted accordingly. To do this, the weighting must be "back propagated" via the layer of hidden nodes to the input layer, thereby changing their values. When this has been done, the "learning" of these associations is stored in the appropriate computer files and is then available for use.

When asked to solve a problem, the program essentially compares the data entered by the expert with that entered by the user and computes an answer. As will be discussed in a follow-up paper, a significant advantage of neural network systems is that they will provide an output in answer to a problem.

It must be understood that because the program is based on the mathematics of probability, it can never guarantee being 100 percent correct. In fact, the probability factor displayed by the program will normally lie between 0.10 and 0.90 (*i.e.*, between 10 and 90 percent correct). By this convention, a value of 0.51 or greater indicates the probability of the answer's being correct. Obviously, the larger the numerical value displayed, the greater the probability that the answer is correct. Another attraction of the neural network approach is that it allows more than one problem to be analyzed simultaneously.

For a detailed discussion of neural networks and artificial intelligence, the reader is referred to Refs. 17 and 18. For present purposes, it should be noted that an understanding of the theory of neural networks is not needed by metal finishers if they propose to use one of the programs available commercially. A subsequent paper will describe the use of a commercial program[19] in developing an expert system for identifying defects in anodizing.[20]

Potential Applications of Neural Networks to Metal Finishing

A potential metal finishing application for a neural networks expert system is in control of bath composition, which should offer advantages over the spreadsheet approach. Usually samples for analysis are taken in the morning and results reported in the afternoon. For example, in a three-shift shop, the zinc content, the brightener content etc., may have fallen outside control limits by the end of the night shift. With enough suitable data entered, it should become possible with neural networks to predict the future consumption of these items during the next 24-hr period after analysis and to maintain far closer composition limits than would be otherwise possible. Such data can also be used to operate dosing devices etc. if suitable feedback loops can be created. In developing such programs, there is always a need for meaningful data. It is not simply a question of using measurements of one parameter to develop the control algorithm. Data on all the related factors are needed, such as throughput per day, drag-out losses, number of ampere hours of current passed etc. The more data available, the greater the probability of the system's learning the correct control response to the input data.

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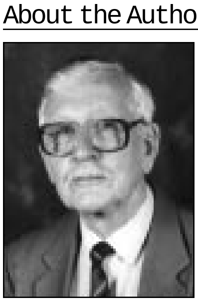

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