Transactions on Information and Communications Technologies vol 6, © 1994 WIT Press, www.witpress.com, ISSN 1743-3517

Tools for corrosion intelligence

P.R. Roberge

Department of Chemistry and Chemical Engineering, Royal Military College of Canada, Kingston, Ontario, Canada, K7K 5L0

Abstract

The application of artificial intelligence in performing expert functions has opened new communication channels between various strata of corrosion knowledge holders. The adequate transfer of information covering corrosion problems and solutions involves the development of information processing strategies that can become very complex. A typical corrosion engineering task requires handling different types of knowledge and disciplines such as metallurgy, chemistry, cost engineering, safety and risk analysis. The expected corrosion behavior of engineering materials is thus only one component of the multi-facet life cycle management of systems. The increasing availability of computerized information is making the topic of software accessibility and portability also increasingly important. While it has become possible to consult either shallow or very deep information systems at the touch of a few buttons, it remains difficult to move horizontally between these systems without going through series of menus and introductory screens. This paper will review some of the tools which have recently been developed to bring artificial intelligence to problem solving strategies applied to corrosion control and protection.

1 Introduction

While the costs attributed to corrosion damages of all kinds (Table 1) have been estimated to be of the order of 4.2 % of North American gross national product (GNP), the responsibilities associated with these corrosion problems are sometimes quite diffuse. Major corporations, industries and government agencies have established groups and committees to look after corrosion related issues but in many cases the responsibilities are spread between the

Transactions on Information and Communications Technologies vol 6, © 1994 WIT Press, www.witpress.com, ISSN 1743-3517

manufacturers or producers of systems and their users. Such a situation can easily bread negligence or ignorance which can be quite costly in terms of dollars and human lives.

Table 1 1993 costs attributed to corrosion damages in North America[a].

Category	Cost (B $)	Avoidable[b] (B $)	Avoidable[b] (% cost)
Energy industries	184	3.8	2.1
Electric utilities	18.2	0.6	3.3
Manufacturing industries	38	1.1	2.9
Infrastructures & governments	49	12	24
Private automobiles	44	29	65
Total	333	46.5	14

[a] adapted from [1].

[b] avoidable by applying known prevention and control methods.

But a major obstacle to actuating corrosion protection and prevention schemes stems from the complexity of the information necessary to describe even the simplest corrosion situation. The multidisciplinary nature of corrosion science and engineering is a serious challenge that is normally met by employing a team of specialists. The following list of disciplines and their specific fields of applications in corrosion science and engineering summarizes the complexity of such a topic:

- Chemistry: organic coatings, water chemistry, inhibitors
- Electrochemistry: measurement techniques, fundamental processes
- Management: cost analysis, maintenance, liability & risk analysis, inspection scheduling
- Mechanical engineering: structural integrity, failure mechanisms
- Metallurgy: materials performance, selection and fabrication of materials
- Solid state physics: hot corrosion, inorganic coatings
- Statistical analysis: reliability engineering, lifetime prediction
- Computer science: applications of artificial intelligence
- Surface science: surface modifications: laser, ion bombardment, microscopic techniques

In real life situations the multi domain expertise required to perform a simple task of cost and risk evaluation for specific corrosion prevention schemes is a good illustration of the need to cover all basic disciplines to a functional level in any good training program.

2 Intelligent Information Management

Until recently, it was difficult to include expertise derived from years of experience into a form which could be compatible with other computerized information media. But a few types of intelligent information management technologies have gained the general confidence of both developers and users of these technologies and reached the mainstream of software products.

Expert systems

The advantages and limitations of using ES technology to mimic expertise were analyzed in great details in an early attempt to combat corrosion with ES tools [2]. The Stress Corrosion Cracking (SCC) ES (SCCES) had been created to calculate the risk of various factors involved in SCC, such as crack initiation, when evidence was supplied by the user. The main goal of this initial effort was to support the decision process of "general" materials engineers. The system would be initially called to play the role of a consultant but it was anticipated that SCCES had the potential to become:

- an intelligent checklist
- a trainer
- an expert sharpener
- a communication medium
- a demonstration vehicle

As better software became available, SCCES, which had been primarily developed to evaluate the ES technology, became the seed for a larger ES, Auscor. Auscor dealt with the corrosion of stainless steels in a wide variety of environments [3]. As the Auscor developing group had previously established a solid experience with mathematical models for the prediction of localized corrosion problems [4-6], it was a natural exercise for them to compare their experience with the newest software technology. In this context, the ES approach was recognized as possessing the following advantages over mathematical modeling:

- ability to reach conclusions with incomplete information.
- ability to provide information on request
- less programming extensive
- flexible knowledge representation schemes.

The transfer of expertise into ES prototypes was since then attempted in a multitude of projects. The National Association of Corrosion Engineers (NACE) annual conference proceedings, for example, contain series of papers which illustrate the growing interest in this technology and the increasing progress made to the tools available. A recent survey of the open literature [7] revealed the existence of quite a few systems dealing with many important aspects of corrosion prevention and control.

Unfortunately, many systems reported in the literature have never been commercialized. This has resulted in a lack of impartial information concerning the performance and accuracy of these systems. In order to remedy to this situation, the European Federation of Corrosion (EFC) and the Materials Technology Institute (MTI) have performed two surveys, between 1988 and 1990, requesting recognized developers of ESs in corrosion or related areas to provide very specific information concerning the availability, scope and performance of their systems. A compiled list of the 57 systems reported in the EFC and MTI surveys was compared to the literature survey published in 1992 [8]. Approximately half of the total number surveyed by EFC and MTI were also covered and referenced in the literature survey. The systems which had not been revealed by the literature search were broken into different categories in an attempt to define the reasons why some systems remained invisible to a simple literature search. Most of these categories were self explanatory. It is natural to expect, for example, that systems developed in Japan would take a long time to become visible in mainstream scientific publications and would thus have little points of reference. The fact that the MTI survey indicated that none of the Japanese systems were available supports this conclusion.

The list of non overlapping systems also contained a series of systems, reported in the MTI survey, which had only very indirect links to corrosion and would thus never show up in a search restricted to corrosion issues. Another category, a series of Data Bases reported mostly in the EFC survey, would simply not have been picked up by the keyword 'expert system'. Two systems listed under the category 'to be developed' were probably abandoned before being reported to a broader public. The final category contained specialized systems dealing with the prevention of corrosion problems associated with very specific processes. These specialized systems apparently dealt only incidentally with corrosion problems explaining why they had not been reported in the literature under a corrosion heading. The distribution of expert systems between these categories and the overlap with the literature search is illustrated in Fig. 1.

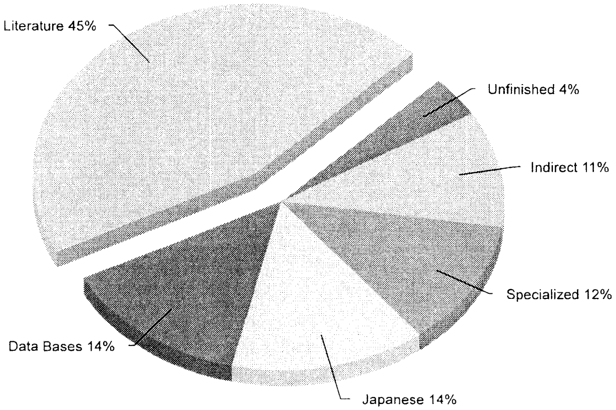

Figure 1 - Distribution of experts systems reported in the EFC and MTI surveys and their overlap, by categories, with the literature survey [7].

Non linear writing and reading (Hypertext)

During the early days of the telephone only a few people could afford the technology and only highly trained operators were qualified to operate the telephone. As telephone became an accepted part of life its proliferation forced the telephone industry to seek simpler and less operator intensive schemes. Eventually direct dialing became easy to use and openly available. Nowadays everyone has become an operator.

Similarly the portable computer has become an essential commodity among many other information processing tools and the computer industry has evolved from a very elitist market to a broad based general public market. As the proliferation of computers continues, the technologies that make computers more intuitive and easier to operate are being developed and new standards of graphical and manual interactions between computers and humans are set. Graphical User Interfaces (GUIs) such as Microsoft Windows™ are making the computer acceptable to a broader public and just as direct dialing allowed the general public to become its own operators, GUIs are now allowing the general public to become computer operators [9].

While the term hypertext was coined by Ted Nelson during the 1960s [10], the concept itself can be traced back to Vannevar Bush's 1945 description of 'the memex' [11]. The first serious attempt to build a memex did not take place until 20 years after Bush's description. In 1968, Doug Engelbart, then at the Augmented Human Intellect Research Center (Stanford Research Institute), conducted a dramatic live demonstration of his Augment system during the Fall Joint Computer Conference where he worked collaboratively on a hypertext document with a colleague 500 miles away [12]. Engelbart's system was centered on consoles which were sophisticated by the standards of these days. The consoles included television images and a variety of input devices such as Engelbart's best known invention, the mouse. In the following years both interest and activity in hypertext have grown steadily. Some of the more important milestones have been described in a well known introductory paper [13]. An excellent survey of existing hypertext systems with a critical review of their strengths and weaknesses was published in 1987 [14]. In this article the operational advantages of hypertext were described to be the following:

- ease of tracing references
- ease of creating new references
- hierarchical or non-hierarchical information structuring
- global and local views can be mixed effectively
- multiple functions customized documents
- modularity and consistency of information
- task staking

There are many ways in which associative linking or non-linear writing and reading can be used. Today hypertext links can be found in on-line help systems in a great variety of systems such as Microsoft Windows™, personal information managers, text retrieval systems, ESs and application generators. These methodologies will have a definitive impact on how corrosion engineers and scientists will process information. A good example of application of this technology to corrosion is what is now called the Active Library® on Corrosion (ALC). In 1988, the Materials Processing Systems (MIPS) group at the University Catholic of Leuven built this system in collaboration with Elsevier Science Publisher [15]. The ALC was designed as a sort of handbook that could be used by anybody i.e. from corrosion experts to novices. The ALC thus offers a number of 'access gates' through which the user can locate and use materials data to solve specific corrosion problems:

- A 'Library Map' which offers a visual map of the contents and organization of the ALC
- A 'Reference Cube' serves as an innovative 3-D table of contents in which the user can navigate between materials, environments and corrosion types
- ALC contains all the typical hypertext features such as backtracking, noting, trailing and even trained trailing
- ALC contains a series of selected documents or books that contain a repertoire of information of corrosion inhibitors, cathodic protection, protective coatings, design principles, etc.
- ALC contains a large database of case histories with pictures and descriptive text of the cases and remedial actions taken
- A 'Corrosion Control' contains series of guidelines on preventive measures for materials selection, choosing inhibitors and coatings, how to proceed with cathodic or anodic protection, etc.
- A 'Quick Reference' section offers access to a bibliographic database and to a dictionary of corrosion terminology

The functionalities of the ALC demonstrated the advantages of using hypertext technology for the computerization of corrosion information. It was found [15] that the hypertext inherent flexibility and ease of use added to the possibility to link and address heterogeneous forms of information made it an ideal tool for implementing a guide for corrosion problems analysis.

Neural Networks

One of the main ideas underlying the interest in neural computing is that it may be possible to develop new computational paradigms that will make important aspects of programming both more simple and robust. These systems, which are loosely based on biological neural networks, offer a computer technology that is a useful tool in process modeling and signal processing. Two applications of ANS to solving corrosion problems have been reported so far. In the first project [16], the risk of encountering a stress corrosion cracking (SCC) situation was functionalized in terms of temperature, chloride and oxygen concentrations. ANS was found to outperform, during this project, traditional mathematical regression techniques where the functions have to be specified before performing the analysis. In a second project [17], ANS was put to the task of recognizing certain relationships in potentiodynamic polarization scans in order to predict the occurrence of general or localized corrosion such as pitting and crevice. The network was shown to be able to make appropriate predictions using scans outside the initial training set. The resulting ANS was imbedded in an ES to facilitate the input of data and the interpretation of the numerical output of the ANS.

3 Conclusion

On a very general note it can be said that the knowledge engineering aspect of developing intelligent systems for corrosion applications is directly related to the progress in the software and hardware tools which are made available. The fact that these tools are improving at an incredible speed is very promising for the future. The ability to use information effectively in order to convey ideas and concepts is one of the most important assets of modern society. While visions of systems which would answer all questions and solve all corrosion related problems are slowly fading away, very focused software systems are being integrated in larger design and control systems in order to prevent corrosion damages. Other focused intelligent systems are also being built and tested to simplify the requirements for multidisciplinary expertise associated with corrosion engineering practices. A few of these computerized methodologies have already reached mainstream applications and are readily available.

4 References

1. Economic Effects of Metallic Corrosion in the United States, a report to the Congress by the National Bureau of Standards (NBS), U.S. Dept. Commerce, March 1978.
2. Basden A., On the Applications of Expert Systems, *International Journal of Man-Machine Studies*, 1983, **19**, 461-472.
3. Hines, J.G. and Basden, A. Experience with Use of Computers to Handle Corrosion Knowledge, *British Corrosion Journal*, 1986, **21**, 151-156.
4. Hines, J.G. Analysis of Complex Polarisation Curves, *British Corrosion Journal*, 1983, **18**, 10-14.

5. Edeleanu, C. and Hines, J.G. Modelling Approach to Corrosion Prediction, *British Corrosion Journal*, 1983, **18**, 6-9.
6. Hines, J.G. and Basden, A. Implications of Relation Between Information and knowledge in Use of Computers to Handle Corrosion Knowledge, *British Corrosion Journal*, 1986, **21**, 157-162.
7. Roberge, P.R. Bridging the Gap Between Corrosion Laboratories and the Real World: the Expert System Approach *Proceedings of Computers in Corrosion Control Vol. III*, pp. 258/1-13, National Association of Corrosion Engineers, Houston, TX, U.S.A., 1992.
8. P.R. Roberge, A Critical Review of Expert Systems for Corrosion Prevention and Control," *Proceedings of Computers in Corrosion Control Vol. IV*, pp. 1-10, National Association of Corrosion Engineers, Houston, TX, U.S.A., 1994.
9. McCord, J. Windows *Programmer's Guide to Borland C++ Tools, (SAMS Publishing*, Carmel, IN, USA, 1992), p. xviii.
10. Nelson, T.H. Getting it out of our systems, p. 191, I*nformation Retrieval: A Critical Review*, ed G. Schechter, Thompson Books, Washington, DC, 1967.
11. Bush, V. As we may think, *Atlantic Monthly*, July 1945, **176**, 101.
12. Engelbart, D.C. and English, W.K. A Research center for augmenting human intellect, p. 395, *Proceedings of the 1968 Fall Joint Computer Conference*, Montvale, NJ, AFIPS Press, Fall 1968.
13. Smith, J.B. and. Weiss, S.F. Hypertext, *Communications of the ACM*, 1988, **31**, p. 816.
14. Conklin, J. Hypertext: An introduction and survey, *IEEE Computer*, 1987, **2**, p. 17.
15. Bogaerts, W.F.L. and Arents, H.C. The Active Library on Corrosion: Novel Hypermedia Technology for Corrosion Training and Engineering, p. 1825, *Progress in the Understanding and Prevention of Corrosion*, ed J.M. Costa and A.D. Mercer, Vol. 3, The Institute of Materials, London, 1993.
16. Smets, H.M.G. and. Bogaerts, W.F.L. Deriving Corrosion Knowledge from Case Histories, pp. 259/1-10, *Computers in Corrosion Control*, ed P. Mayer, A.C. Van Orden and T. Hakkarainen, Vol. III, National Association of Corrosion Engineers, Houston, TX, U.S.A., 1992.
17. Silverman, D.C. and Rosen, E.M. Corrosion Prediction from Polarization Scans Using an Artificial Neural Network Integrated with an Expert System, pp. 264/1-18, *Computers in Corrosion Control*, ed P. Mayer, A.C. Van Orden and T. Hakkarainen, Vol. III, National Association of Corrosion Engineers, Houston, TX, U.S.A., 1992.