Enhancing Coatings Diagnostics, Selection, and Use Through Computer Based Knowledge Systems

Lawrence J. Kaetzel and Mary McKnight

National Institute of Standards and Technology
Gaithersburg, MD 20899

Abstract: Today, virtually every organization is increasing its emphasis on coatings knowledge. This could result in improved decision-making, competitiveness, and access to world-wide knowledge bases. For wide-scale use, standards and new procedures must be developed for the representation, exchange and use of coatings knowledge. This paper discusses the need for standard formats for knowledge, new technologies, and methods that will have an impact on knowledge based system development. A view of how SSPC can play an important role in this process, a description of some existing applications, and a proposed architecture for a global system is presented.

INTRODUCTION

The electronic storage of coatings knowledge, information and data in computer based systems is growing exponentially. New computer technologies and increased capabilities now allow coatings users to access virtually all forms of knowledge such as published documents, databases, photographs, video, and sound electronically on their desktop and portable computers and through communications mediums. As the volume of knowledge increases, so does the time required to access, decipher, validate, and use the knowledge in decision-making. Improved decision-making allows companies to remain competitive, reduce operating costs, and improve the service life of coatings systems. Improved methods for representing, communicating, and accessing knowledge will be necessary to manage knowledge into the 21st century. Technologies such as expert systems, and intelligent software agents must be evaluated and implemented. Standard formats for representing and exchanging knowledge in the form of databases, published literature, guides, and high-level reasoning must be established. This task is enormous and will require the collaboration of industry and government organizations to be successful.

This paper presents information on how coatings knowledge is stored and used today. Factors that affect the changing dynamics and use of knowledge and a proposed architecture for establishing a coatings body of knowledge is presented.

KNOWLEDGE, INFORMATION AND DATA

The distinction between knowledge, information and data lies in its form and use. Knowledge is the highest form when used in decision-making. It is developed through the analysis of information and data, by experts. An example of knowledge is high-level expert reasoning represented in an expert system in the form of rules. Information is organized data. It is organized into a meaningful form often for a specific purpose. An example of information is a coatings guide for the selection and use of coatings systems. Data is the most primitive of the three forms. Data supports information and knowledge in decision-making. Examples of data include the elements of a coating manufacturer's data sheet (e.g., properties of the coating). Figure 1 shows the relationships, examples, and sources of the three entities. Marchionini [1] provides a detailed description, relationships, and use of knowledge and information in electronic environments. This paper focuses primarily on the representation, access, and use of coatings knowledge and information that is represented in high-level expert systems.

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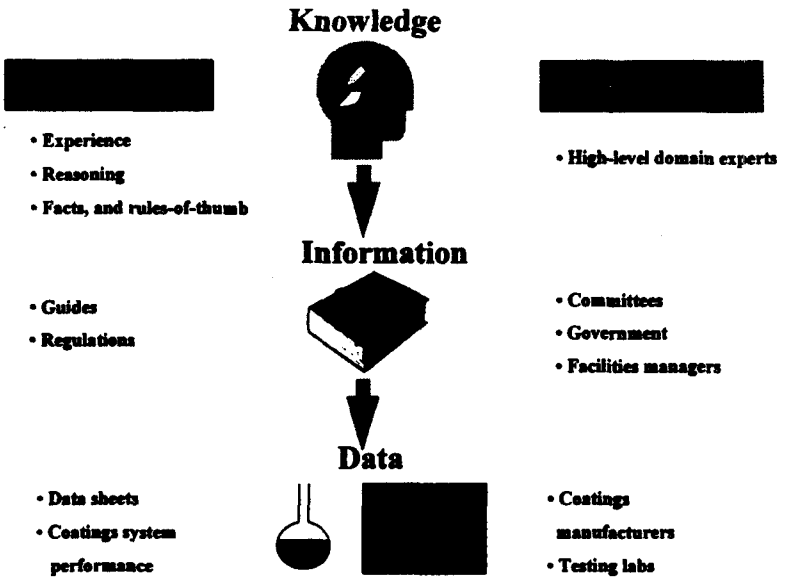

Figure 1: Knowledge, information, and data source relationships and examples

COATINGS KNOWLEDGE AND ITS USE IN DECISION-MAKING

Coatings knowledge is important to both coating suppliers and users in making decisions. Suppliers may want to know about market opportunities, raw material supply, cost, and methods to predict coating performance. User's interests include life-cycle costs and performance attributes of new coatings, application processes, and coating practices meeting environmental and safety regulations. There are increased needs for improved coatings knowledge in these areas for several reasons. For users, examples include satisfying tighter budgets which may require improved appraisals of life-cycle costs and meeting new regulatory actions which may call for changes in coating practices. For producers, the time to profitably develop and market new materials is greatly reduced because of user demands and regulatory actions. Data and information are rapidly being generated to meet these and other decision-making needs. A problem for both users and producers is accessing the relevant information. The following sections identify some knowledge-related projects that are underway and provide recommendations for additional integrated knowledge-system activities.

KNOWLEDGE BASED SYSTEMS DEVELOPED FOR THE COATINGS INDUSTRY

Knowledge based systems for industrial coatings are used to store many different forms of information. Except for those developed for use within organizations, most systems are prototypes. This is characteristic of many systems developed for construction industry applications. Coatings knowledge based systems are used to represent product data supplied by coatings manufacturers, historical data maintained by users on the application and performance of coatings systems, and guidelines for the diagnostics, selection, and application. Knowledge forms include: databases, spreadsheets, expert systems (high-level expert reasoning), digitized photographs and drawings, and special purpose computer programs. The characteristics and status of these can be stated as follows;

- They are developed as proprietary systems for use within an organization.
- They are developed as demonstration or operational prototypes by academia and contain very focused knowledge about a topic.
- The lack of standards for representing their content makes them difficult to interface to other knowledge based systems.

- The knowledge base has not been validated (reviewed by domain experts) and their quality may be questionable.
- They become obsolete quickly and are often difficult to maintain.
- Their use may be limited due to a lack of awareness.

More generally, several knowledge based systems have been developed specifically for coatings materials applications. Table 1 lists examples of the coatings areas and intended use of the systems. A recent RILEM Committee TS-93 report on "Knowledge Based/Expert Systems for the Construction Industry" [2] describes methods and systems that have been developed for the construction industry.

ADVANCES IN KNOWLEDGE REPRESENTATION, ACCESS, AND DISSEMINATION

Four factors will significantly affect the acceptance of coatings knowledge based systems of the future: 1) increased capabilities involving computer hardware and software technologies, 2) access to global knowledge, electronically, 3) efforts by industry and government groups to develop standards for knowledge representation and exchange, and 4) increased awareness of the availability of these systems through promotion by coatings organizations (e.g. SSPC).

COMPUTER HARDWARE AND SOFTWARE TECHNOLOGIES

Computer hardware technologies such as CD-ROM, high-speed modems, and wide-area networks will continue to provide users with instantaneous access to large repositories of coatings knowledge. More functions such as wide-area network communications and peripheral interfaces will be integrated into computer software operating systems. It will be possible to significantly reduce the number of different computer vendors necessary when purchasing computer operating system and application software. Also, users will demand that vendors develop new hardware and software products with "plug and play" features.

ELECTRONIC ACCESS TO KNOWLEDGE

Since the development of the first computer, no topic has received so much attention as the Internet, often called the information super highway. Although the Internet is useful to many, more work is needed to improve its usefulness. Efficient methods must be developed to allow computer-to-computer and human-to-computer interactions. One tool that is just beginning to surface in some information technology research institutions is "intelligent agent" or "softbot" technology. Intelligent agents or softbots are software programs that allow a user to define and retrieve their interest(s) or topical view of knowledge that resides in a geographically dispersed environment. The technology is described by Wayner in "Agents Unleashed: A Public Domain Look at Agent Technology" [9]. An intelligent agent can be "trained" to seek out knowledge in a network environment and report back its findings to the user. This process is performed in an unattended mode, freeing knowledge seekers to conduct other activities while the intelligent agent is performing its search. Several companies are currently selling software systems that employ intelligent agent capabilities. However, the search capabilities are closely-coupled to proprietary formats and commercial products [10,11].

Widespread acceptance of intelligent agents will depend on the successful development of standard formats and methods for representing, interfacing, and accessing knowledge repositories. These repositories will reside in a heterogeneous computing environment that will continue to exist in the foreseeable future. A graphical description of the use of intelligent agent technology interfaces is shown in Figure 2.

Application Area	Intended Use	System Name and Reference
Maintenance	1. best time to recoat bridges 2. coatings failures, remedial action, and selection for defense structures	1. Bridge Paint Expert System (BPES) [3] and Coatings Evaluation and Expert System for Bridges [4]. 2. Coatings Expert Advisory System (COEX) [5].
Design and Manufacturing	1. selection of coatings 2. design of coatings	1. Surface Coatings and Material Selection-PRECEPT [6]. 2. Database for Coating Design [7]
Coatings Application	1. coatings application in a manufacturing environment	1. Coatings Control Knowledge System (CCKS) [8].

Table 1. Examples of knowledge based systems designed for coatings materials.

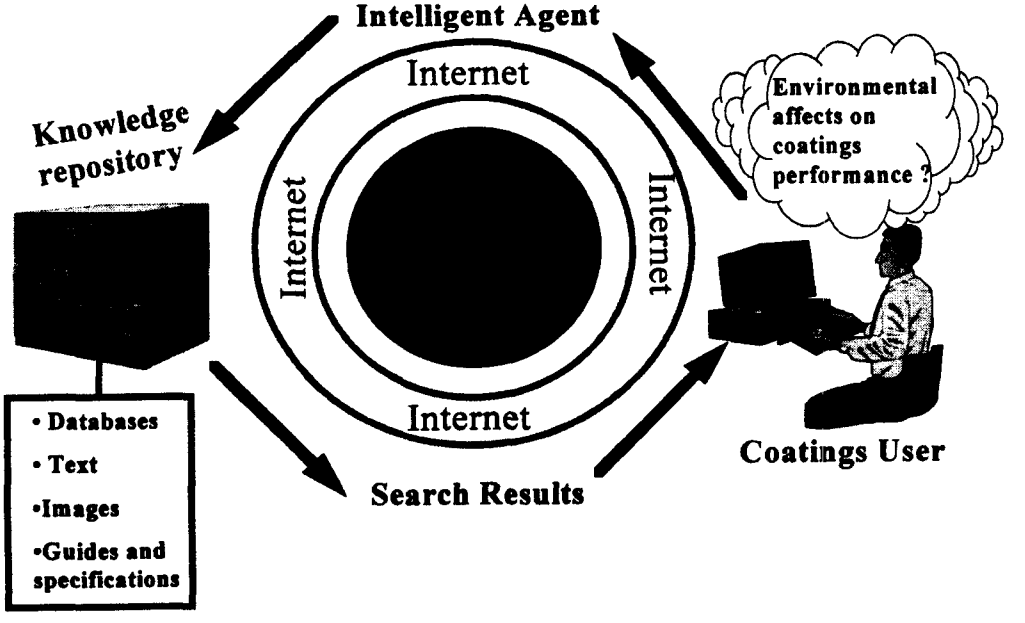

Figure 2. Figure showing the use of intelligent agent technology.

STANDARDS FOR KNOWLEDGE REPRESENTATION AND EXCHANGE

There are few standards development activities currently underway that address the area of coatings knowledge representation and exchange. Although this area could have a positive impact on advancing the exchange of coating knowledge, it requires the resources of many different organizations and involves a lengthy process. Five to ten years is normal for developing a mature standard. Undoubtedly, the most intense effort involves the ISO TC184 activity, Standard for Product Data Exchange (STEP). The STEP activity has its roots in the architectural and design disciplines and not until recently was a working group established to address the materials area. Part 45 [12] of STEP specifically addresses materials knowledge exchange. STEP's goal is to develop standard methods for the exchange of information between different organizations and computer platforms. An example of the STEP process involves the development of Application Protocols (AP's) that provide a framework for information such as Computer Aided Design (CAD) drawings to be exchanged between the architect and the designer of a structure.

To include industrial coatings knowledge as part of STEP will involve obtaining the answers to several questions; 1) is there sufficient interest and resources in the coatings industry to devote time to the lengthy standards development process?, 2) is it possible to develop a standard that can be applied to a global environment where building codes and the variations in different materials sources can be resolved? and 3) will the coatings industry be receptive to the required organizational changes (for information processing) that will be necessary to implement an international standard?

Another international standard that already has application to coatings knowledge is the ISO 8879, Standard Generalized Markup Language (SGML) [13]. A subset of SGML known as the Hyper Text Markup Language (HTML) [14] is being widely implemented on the Internet on World Wide Web (WWW) servers. HTML provides a mechanism to represent multiple knowledge formats such as text, images, sound, and video. This feature and the ability to navigate within a computer based document and to access remote sites provides significant enhancement over conventional systems that are solely text-based. The Internet Gopher space is an example of text-based systems.

Standards for representing knowledge are often undertaken separately from exchange standards. The most significant progress in developing standard formats for materials properties is in the ASTM Committee E-49 on the "Computerization of Materials Property Data". The committee's goal is to develop standard formats for representing the material properties of metals for database systems. Organizations have successfully implemented the formats and numerous publications have been authored that address their development and application [15,16]. A similar activity is underway in the American Concrete Institute (ACI). The ACI Committee 126, on "Materials Property Databases" is currently developing documents that will become proposed ACI guides for representing the constituent materials and processing of concrete. Currently, draft guides have been developed for nomenclature, mineral admixtures, and cements. If adopted, these guides will be useful for exchanging information between materials suppliers, designers, and contractors. A similar activity could be undertaken within the new Steel Structures Painting Council (SSPC) committee C.4.10 on "Knowledge Based Systems for Coatings."

ROLE OF SSPC

SSPC could play an important role in advancing the state-of-the-art for coatings systems and the use of coatings knowledge. The organization represents all segments of the coatings industry including raw materials suppliers, coatings manufacturers, quality control specialists, testing laboratories, contractors, facilities managers, and government organizations. The new committee C.4.10 will serve as a forum for identifying important activities that should be addressed. The objective of the new committee is:

"To investigate and report on knowledge systems design, selection, application, and performance"

The first task of the committee is to develop a SSPC "Technology Update" and will describe the state-of-the-art for knowledge systems that apply to industrial coatings. This document will provide the SSPC constituency with an understanding of knowledge based systems terminology, components, and their use.

Additional tasks proposed for the committee involve the development of a guide or standard that can be used for representing and exchanging coatings knowledge among different organizations and disciplines. Long-term goals could involve the establishment of a

more comprehensive system for representing knowledge. Such a system could be accessed electronically, through a world wide network. Components of the system would include all information that is currently disseminated by SSPC including printed guides, visual standards, CD-ROM, and committee business and documents. Before such a system can be developed and implemented, several barriers must be overcome and mechanism developed. They include; 1) a mechanism for the recovery of fees for the use of electronic information, 2) intelligent methods for finding knowledge, and 3) standards for representing and exchange knowledge. It is obvious that this is a futuristic view of what knowledge systems can be in the years to come. In the interim, research on new and innovative methods are necessary to influence the computer hardware and software industry in their development of tools that serve the interests of and applications for the coatings industry.

A PROPOSED ARCHITECTURE FOR AN INTEGRATED KNOWLEDGE SYSTEM FOR COATINGS

An Integrated Knowledge System (IKS) can be defined as follows:

> ***"A computerized system that contains knowledge, information, and data about a specific domain (e.g., industrial coatings). The knowledge is represented and accessed in such a way that it is presented to the user in a seamless manner and aids in decision-making."***

The components of an IKS include all forms of coatings knowledge. Examples are shown in Figure 3 identified as the "Body of Coatings Knowledge". The IKS knowledge forms and examples of their source are defined in Table 2. The left portion of Figure 3 graphically depicts the sources as being inputs to the IKS. The remaining two portions of Figure 3 includes an interface, represented by the objects "Interpreters and Filters", and methods of knowledge access and dissemination. Interpreters and Filters are computer modules or programs that allow the user to define a desired view, area of interest, or focus on a subset of the Body of Knowledge. They are the user interface. Expert systems and intelligent agents that contain high-level reasoning, and guidance for using knowledge are examples of interpreters and filters. The following scenario is provided to help in the understanding of how the IKS could be used.

> ***Problem definition:*** Analysis of a coatings system failure on a steel substrate, a bridge for example.

User interface: A facility manager uses a CD-ROM based expert system to determine the cause of the coating system failure, obtain recommendations on remedial action, preparation of substrate, selection of an overcoat, and finally guidance on specifications for coatings application.

Knowledge components: The components include; high-level reasoning in the form of rules that guide the user-computer dialogue, digitized color images that represent the coatings failure, explanatory text to assist the user in responding to questions. Bibliographic references to industry standards, guides, test methods, and quality control for application such as a audio/video clip showing steps important for proper application, and finally, a database on the properties and information from coatings manufacturers data sheets can be interrogated to select the best coating.

Results: The decision-making process is enhanced through the use of an high-level reasoning system and access to a comprehensive body of knowledge that provides information and recommendations that could go unnoticed.

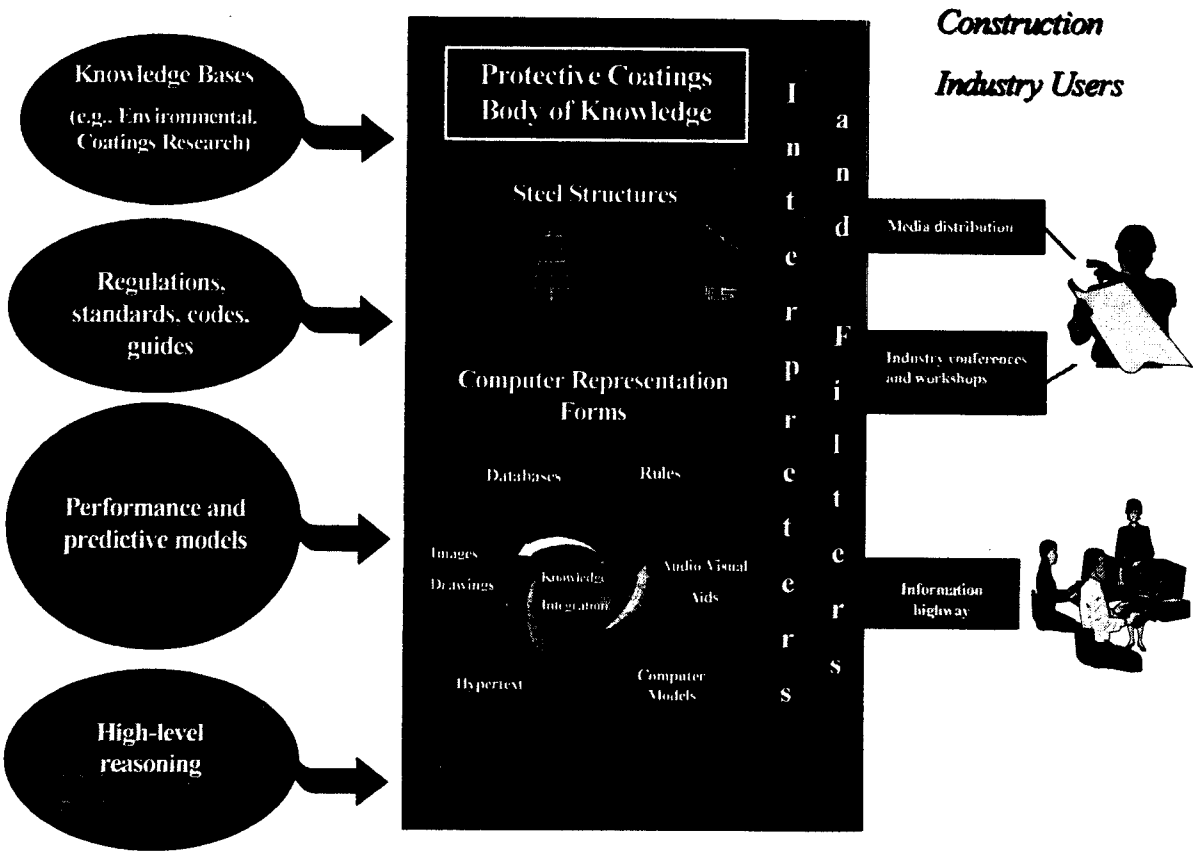

Figure 3. IKS architecture for coatings knowledge.

Knowledge Form	Example	Source
Databases	1. exposure data from field tests 2. environmental data (e.g. solar UV spectra) 3. manufacturers data sheets 4. coatings performance	1. test laboratories 2. solar UV data collection networks (e.g, Smithsonian, NIST) 3. coatings manufacturers 4. DOD facility managers
Reasoning (rules-of-thumb, facts, experience)	5. IF-THEN-ELSE rules and conclusions on the cause of coatings failures	5. high-level coatings experts
Bibliographic information	6. references to published information on coatings studies, tests, guides, and manuals of industry accepted of practice	6. SSPC guidelines
Digitized images and drawings	7. visual information depicting the symptoms and nature of coatings failures	7. scanned photographs and drawings
Computer based models	8. A model for predicting the environmental affects of solar radiation on the performance of coatings	8. academia and other research organizations
Regulations, standards, and guides	9. SSPC-PA Guide 3 [17]	9. SSPC

Table 2. Component forms, definitions, and examples for an IKS.

SUMMARY

This paper has presented an overview of the use, representation, and exchange of coatings knowledge. Examples of existing knowledge based systems and their application were provided to show the state-of-the-art and usefulness of such systems. Also, a proposal for an architecture and development of a global body of coatings knowledge was presented. Future advances in the representation, communications, and use of knowledge for decision-making will depend on successes of current systems. Clearly, computer technologies will advance. However, a greater emphasis must be placed on the development of standards for representing and exchanging coatings knowledge (e.g. databases) and improving the human-computer and computer-computer interactions. This will require collaboration between industry and government. SSPC will provide a forum for this interaction and can greatly influence the access, quality, and use of knowledge based systems.

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