

Need for Semantic Classification of Maintenance Information

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Bendix Test Systems Division is a military contractor specializing in test and maintenance equipment. In internal research and development, one of our areas of concentration is focused on developing hypermedia maintenance manuals and other maintenance-aiding software: e.g., artificial intelligence (AI) diagnostic system. At Bendix, we have developed a general purpose set of utilities called the "Allied-Signal Aerospace Co. User Interface Management System" or "AUIMS" which we use to create prototypes we need for our research. The AUIMS is actually a cluster of tools, and one of them -- the "Scenario Editor -- is used to author special manuals in the form of hypermedia [Ventura Conway 1990]. Here, the term *hypermedia* refers to multimedia information organized as a network. Nodes in this network correspond to units of information in databases, and generally consist of a section of text or a single graphic. Links correspond to indexes integrating this information.

Over the past four years we have developed many small scale prototypes of hypermedia manuals for a wide variety of maintenance situations. Each prototype is equivalent to about 100 paper pages of information. These prototypes are used to develop and test techniques and organizational schemes that would be used on a much larger scale hypermedia. A full-scale hypermedia could contain an amount of information equivalent to 500,000 pages of paper manuals. Due to the large amount of information, it becomes extremely difficult for maintenance technicians to find, understand, and use information they require. This difficulty has become a significant problem [Ventura 1987]. The development of hypermedia maintenance manuals is now the focus of efforts to solve this problem.

A global semantic classification for units of maintenance information is a practical necessity for the full scale hypermedia. For purposes of this paper, semantic means "in a way that reflects the central point or topic the unit of information was meant to convey." Units of information might be: sets of instructions for performing a maintenance action (e.g., for performing a particular diagnostic check); detailed parts information (e.g., tolerances and part diagrams); historical, maintenance tracking and recording information (describing maintenance previously accomplished on the equipment being maintained); personnel information (describing technicians' training background and skill level), etc. The amount of information in the hypermedia is so large that a semantic classification is necessary in order for technicians to be able to find anything.

Our research is addressing the problem of developing semantic classifications for these units. Our approach to this is "top down" rather than "bottom up". It is "top down" based on analysis of the process of doing maintenance, rather than "bottom up", as would be the case of generalizing a classification from evidence gathered through instances of classifying (i.e., indexing) maintenance information. Secondly, our approach is focused on finding a method for developing classifications rather than on developing a single specific global classification. This distinction is perhaps best explained by an analogy: in chemistry, different atoms are distinguished by the number and type of protons, neutrons, and electrons they contain. This is a *method*. It has been

used as the basis for different classifications of atoms and elements, e.g., the periodic table of elements, classification of certain types of atoms as isotopes, etc. These are *classifications*. In summary, our approach is focused on finding a method for developing global classifications for units of maintenance information — classifications that are based on analysis of the maintenance activity.

In the course of our work, we have noticed peculiarities of military maintenance technicians as users, and of their work location as a use environment, that potentially limit the classification scheme used for this type of information. For example:

- As a user, military maintenance technicians tend to accumulate less experience than other types of maintenance technicians: typically spending less than five years on the job. They typically have at best a high school education. As a result, the classification scheme must be simple, clear, and uncomplicated to use.
- The use environment is not the controlled office environment ordinarily associated with hypermedia. The location where maintenance is done may be out-of-doors where dust, dirt, sun glare, snow, etc., interfere with the technician's ability to use the hypermedia. Also, the hypermedia may in some situations be used on a small, portable, "lap top" computer, with limited computational resources. The computer would be subject to rough handling and vibration that would further limit resources: e.g., precluding use of secondary storage devices like spinning media (magnetic or optical disk).

We also notice certain characteristics of military maintenance information that make it a good candidate for semantic classification. For example:

- Intuitively, we would expect concepts involved in maintenance (e.g., "remove engine", "turn adjustment screw with wrench") to be simpler and more concrete than concepts involved in other types of information (e.g., "public opinion" in politics).
- Numbering systems already exist that organize many of the objects involved in maintenance.
 - A "work unit code" or "WUC" numbering system identifies systems, subsystems, and components in an item of equipment according to their function and functional relationships (e.g., the breakdown of equipment into functional systems, subsystems, etc.). For example, an engine might be assigned the WUC identifier 2A000, its main oil system might be WUC 2A500, and the main oil pump that is part of that system might be WUC 2A530. The digits of WUC provide a system, subsystem functional breakdown of an item of equipment.
 - A part numbering system uniquely identifies assemblies, subassemblies, components, and parts and relationships based on the way the equipment is assembled. For example, the engineering drawing for a main oil pump (part number 37934221) might list as its "next higher assembly" the main oil pump assembly (part number 37934761). The "next higher assembly" field on the drawing provides an assembly, subassembly breakdown for an item of equipment.

- **Expendable materials** (e.g., wire, nuts, bolts, fuel, oil) are identified by a material stock number (e.g., lockwire MS56333296) rather than a part number or a WUC.
- **Codes** exist to identify many of the actions involved in maintenance. For example, as part of the system for recording and tracking maintenance accomplished on an item of equipment, "HOW MAL" codes are used to identify how the equipment malfunctioned, and "ACTION TAKEN" codes are used to show what was done to correct the malfunction. These codes enumerate actions that might be involved in a semantic classification scheme.
- **Numbering systems** exist that identify and describe the personnel involved in maintenance. Technicians are assigned specialty codes that reflect the type(s) of training they have received, and their level of expertise in each specialty. For example, each digit of the specialty code B43151C is an encoding of the occupational training and proficiency of a maintainer — here, a skilled F-15 aircraft mechanic. These codes list personnel characteristics that might be used as part of a semantic classification.
- **Standards** exist that, to some degree, control and limit the structure, style, format, and content of maintenance instructions in manuals. Standards ensure that all manuals of a certain type (e.g., illustrated parts breakdown manual) are organized in the same way (e.g., same order and type of front matter, same type of chapter-section-subsection divisions). They also ensure that all manuals of the same type use consistent formatting (e.g., with regard to fonts and special marks used, page layout, etc.). They also specify properties of the contents of the manual, such as allowable vocabulary and acronyms, and the allowed reading grade level for the manual.
- **Lexicons** already exist for use in limiting and standardizing the vocabulary used in maintenance instructions.

We believe all of these factors contribute toward making this body of information a good candidate for classification. Having identified the positive effects of these factors, we should also mention some possible limitations:

- For each type of numbering system or code that was mentioned, the specific numbering system or set of codes that is used may differ from service to service, location to location, or equipment purchase program to program. For example, Air Force specialty code (AFSC) B43151C might identify a skilled mechanic in the Air Force. A totally different code might be used to denote a skilled mechanic in the Navy or Army.
- Standards for manuals are flexible enough that they are subject to interpretation. As a result, there is room for variation, even among manuals that all conform to the same standard. Also, there are hundreds of standards. When manuals are purchased, they must conform to (say) five or six of them. This provides yet more room for variation, since each set of manuals conforms to a different collection of standards.
- Also, these numbering systems, codes, and standards were not developed with classification needs in mind. Inconsistencies between equivalent numbering systems may exist. For example, a Navy specialty code might provide a field for specifying the part of

maintenance (e.g., electro-mechanical systems) that a mechanic is trained in. The equivalent Air Force specialty code might not. Or there may be inconsistencies even within a single numbering system. For example, there are pages of "ACTION TAKEN" codes listed for maintaining a C-141 aircraft. Some of these codes may never be used; some may be redundant, referring to equivalent ways of expressing the same action.

- While lexicons are provided for use in controlling and standardizing vocabulary, we do not know how extensively they are actually used.

To date, we have developed one method for creating a semantic classification for units of maintenance information. We hope to test this method and a resulting classification by using them in several applications:

- to organize units of information in a hypermedia network, so that searching is easy and so that needed information can be found in a way that is quick, predictable, and uncomplicated.
- to organize knowledge in knowledge bases, and define knowledge representations used by a diagnostics system.
- as a standard for exchanging information between different components of maintenance-aiding software. For example, in one of our prototypes, a diagnostic expert system gathers information from an aircraft engine, and based on the information obtained, chooses the next best diagnostic test to do in order to isolate a fault in the engine. This diagnostic system must communicate its choice to an online manuals tool, so it can present instructions for performing the test to a technician. We hope to use the method (and a resulting classification) to classify the test chosen in such a way that it is meaningful to both the diagnostic expert system tool and the online manuals tool.

REFERENCES

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