A Fault Diagnosis System Based on an Integrated Knowledge Base

We are developing a versatile maintenance expert system, VMES, for troubleshooting electrical circuits. It diagnoses a variety of common electrical faults and easily adapts to new devices. User communication is through natural language, graphics, and menus.

Knowledge category. Structural and functional descriptions, usually referred to as design models of a device, build one type of knowledge in our integrated knowledge base. Since this kind of knowledge is readily available and well-structured, it has been widely used by fault diagnosis researchers to solve the difficulties of empirical-rule-based diagnosis systems in knowledge acquisition, diagnostic capability, and system generalization.[1] Empirical associations of individual devices impair system versatility because of their highly device-specific nature.

Domain knowledge has long been ignored by researchers of design-model-based systems. This sort of knowledge is not part of the design model, yet it consists of common rules for the domain. Though it may still be empirical, it can be applied to any device in the domain. For example, a burnt appearance in a low-level component, such as a resistor, usually means it is faulty.

System architecture. An important aspect of our research is to find a good knowledge-representation scheme for fault diagnosis. Although many researchers use predicate logic with Prolog-like syntax and semantics, its unnatural representation, resolution rule, and diagnosis assumptions are drawbacks.[2] Our implementation uses the SNePS semantic network processing system.[3]

It integrates structural and functional knowledge into a single network, has powerful nonstandard connectives that permit expressing rules of a complexity beyond most Horn-clause-based systems, and handles diagnosis assumptions naturally. It also lets us monitor the deduction process, trace inferences graphically, and expand and modify the representation easily. Procedural knowledge is represented and used.

VMES consists of an integrated knowledge base and a device-independent inference engine. A hierarchically arranged knowledge base provides abstraction levels of devices and lets the inference engine focus on a small part of the device at any time. Initially, only component types are represented in the knowledge base; an object is instantiated only when needed. Since devices in the domain share common components, this approach avoids redundant representations. When the system is adapted to a new device, only descriptions of new component *types* need to be added.

An important part of VMES is its graphical interface, a separate subsystem called Semantic Network Domain Interface Graphics. Its main part is a function display that generates a picture from a semantic network representation. Unlike the usual computer graphics approach to image generation, it is more comparable to a language-generation program that takes a semantic network as its input and generates a surface utterance, in this case a picture, from it.

The display function lets the user specify a number of parameters. With one, a modality parameter, the user can choose between a structural or functional display of a device. Using a display function as an intelligent system, as opposed to a simple mapping from a data structure to a display device, requires pruning the display to avoid overloading the user with irrelevant and therefore confusing information. One of our goals in this project is to find a method to create a cognitively appealing representation.

Our representation uses a part hierarchy with a level parameter that lets the user limit the number of levels displayed. If a part has subparts that in turn have subparts, it is possible to limit the display to the first level of subparts — without showing their subparts. To avoid overloading the user with too many effectively visible objects, an objects parameter uses breadth-first selection to limit the number of (sub)objects displayed. A complexity parameter limits the number of graphics primitives that are displayed.

Status and plans. A version of VMES has been developed and used successfully to pinpoint a faulty adder of an adder/multiplier board (a favorite example of researchers in this domain). The system marks parts it is thinking about with a question mark. Parts it has drawn a conclusion about get an exclamation point. In the final display, a faulty part is shown in red.

We have successfully adapted the system to a simplified real device, a six-channel PCM board used for telephone communication. We plan to investigate domain knowledge and to further develop the knowledge representation scheme for reasoning and display.

Acknowledgment

Work reported here was supported in part by the Air Force Systems Command, Rome (N.Y.) Air Development Center, and the Air Force Office of Scientific Research.

References

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