Plainly speaking

Natural language interaction in industrial automation

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When seeking information in a public library, readers can choose between different ways of finding the right shelf. One way involves consulting the library's classification index. This can, for trickier enquiries, be a time consuming and confusing activity that misses vital information from related categories. When unsure, it is preferable to ask the librarian. The librarian understands a question formulated in plain language and can point to the desired shelf immediately.

Similarly, when accessing plant information from the control room, an operator may have to drill down through several layers of sub-menus to access fragments of information that only make sense when combined with further fragments from elsewhere in the system. This may take a well-trained operator in a frequently recurring situation just a couple of mouse clicks – but is much more challenging for rarer scenarios. If only the computer, like the librarian, could understand natural language! This is exactly what a joint research project of ABB and MIT is out to achieve.

How much training is required to access key process information at an industrial plant? How can knowledge and experience be easily exchanged between the skilled staff members that need to work with it? Industrial facilities continually face such questions, as more specialized personnel are needed to operate and maintain production lines at ever more competitive output levels. What if the ever increasing information processing and storage capacity could be better utilized by making its data accessible more easily? MIT and ABB research labs have jointly demonstrated a technology that will enable users of the future to query an automation system in plain English. This tool can handle large amounts of process and plant information, building upon the flexibility of modern ABB automation system software. Challenges ahead lie in automatic annotation of information and extraction of knowledge from query sessions.

Background

A system for industrial automation is typically characterized by several thousand I/O signals, controlling several hundred real-life objects on the plant floor, eg., valves, tanks, motors, reactors and the like. Operators and other users interact with the system by way of a GUI (graphical user interface). A display system manages a hierarchy of up to several hundred screens representing the various sections of the process and/or groups of process objects.

Retrieval of process information can nevertheless be painstaking – object information is stored in multiple repositories following industry standards such as OPC for data access, history, alarms and events, etc. Naming conventions for objects and their values or properties vary from plant to plant. Furthermore, it is often necessary to additionally access maintenance and condition-monitoring data in order to make better operational decisions.

Human in the loop

The central problem lies in finding a way to empower the user to come to grips with this over-abundance of information, while keeping him in the

loop. Is there a mode of communication that can facilitate interaction while keeping decisions in human hands? One response offering multiple advantages is the user's natural language. It requires no training and encourages interaction. A system that can remember a user's question and answer sessions can later recall them in similar situations, building up a personal knowledge base. This can be of great value for trouble-shooting under stress, particularly in seldomly recurring scenarios. Moreover, the user can choose to share this knowledge with other operators, shifts and even other plants. In other words, it is useful for building an informal knowledge management system. Such a system is especially powerful when senior expert staff contribute.

1 Web interface to the START question translation

Related research

The advantages of using natural language for queries are apparent in systems which can search information on the web.

The START system [1] is a good example. It answers natural language questions by presenting components of text and multi-media information drawn from a set of information resources hosted locally or on the Internet. These resources contain structured, semi-structured and unstructured information. START targets high precision in its question answering. Its ability to respond to questions derives from its use of natural language annotations as a mechanism by which questions are matched to candidate's answers [2]. START's potential for use in industrial automation was identified in discussions between researchers at MIT's CSAIL lab and ABB visiting scientists.

Innovative approach for industrial automation

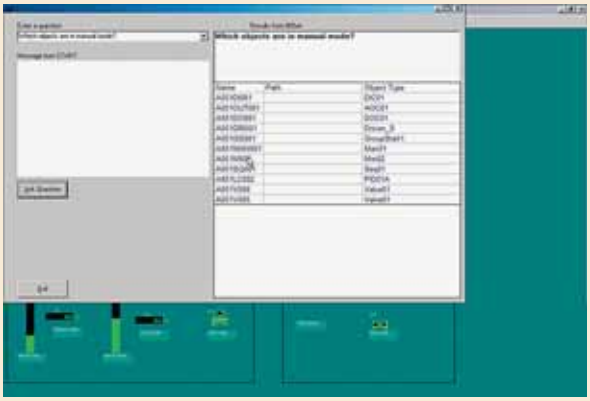
ABB researchers identified the main types of information requests and validated them through field interviews at customer plants. XML schemas with classes of process objects were developed in close cooperation with MIT, whose researchers customized the START server to handle these requests 1. Current development is based on queries in English, but future developments could see other languages being addressed.

The project initially focused on four types of requests. These were requests to
(1) display all members of a class (eg, „Show all inputs“)
(2) display those members of a class that meet a specified condition (eg, „Get all drives that are interlocked“)
(3) display all members of a class, accompanied by related items of another class (eg, „Get position unit for all control valves“)
(4) display those members of a class for which a related item meets a specified condition (eg, „Which digital inputs have unacknowledged alarms?“)

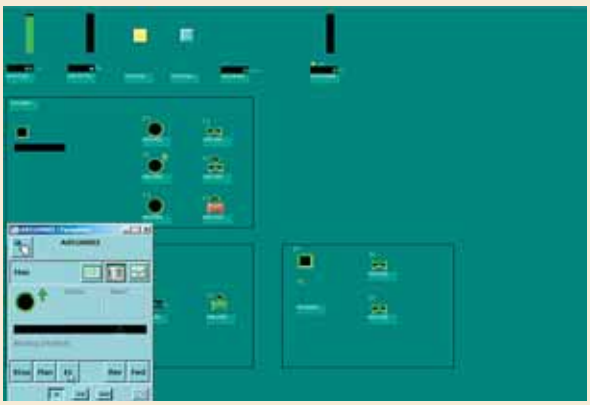
The START system answers natural language questions by presenting components of text and multi-media information drawn from a set of information resources hosted locally or on the Internet.

MIT's START system translates English requests into standardized symbolic expressions that can be easily converted into database requests. As an example, the English request, “What manual stations have active interlocks?” is translated by START into the following expression:

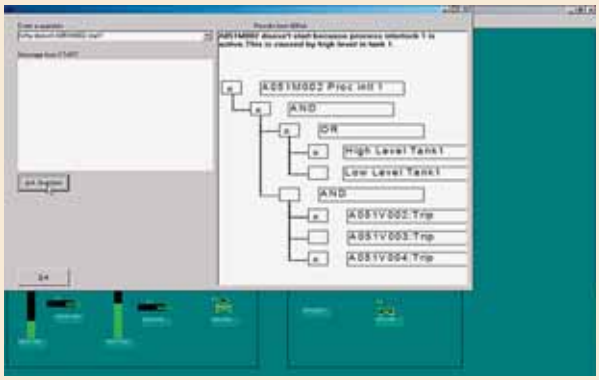
2 When starting a process section, the operator wants to check the control mode of the included objects before enabling the automatic start-up sequence



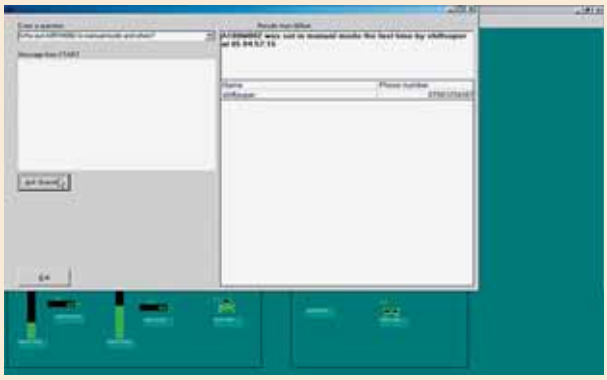
3 The motor found to be in manual by the plain-language query is now put into automatic mode through a faceplate



4 The start-up sequence was aborted. It takes only a simple question to make the system reveal what went wrong



5 The problem is corrected but the operator wants to find out why motor A051M002 was in manual to begin with. With a phone call he knows.



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<?a, "is a", "manual station">
<?b, "is related to", ?a>
<?b, "is a", "interlock">
<?b, "is", "active">
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The standardization performed by START allows the human user to enter requests in many variants. For example, START will translate each of the following requests into the symbolic expression listed above:

- List the active interlocks for manual stations.
- What are the interlocks that are active from each manual station?
- What are all manual controls with active interlocks?
- Let me see all manual controls with interlocks that are active.
- Find the interlocks that are active for manual stations.
- Get me a list of active interlocks from all manual stations.

At ABB, the company's 800xA system was used as a test bed for these ideas. Its flexible software architecture enabled a relatively straightforward implementation of query responses. A simple dialogue interface was also added to existing GUI facilities 2 3. This demonstration system featured live online connectivity with the customized START server at MIT.

Further challenges

Users have shown a keen technical interest in the demonstration system and have provided much feedback. Estimated benefits in use depend on the type of industry and the target user group. Casual users, eg., maintenance engineers, and operators of flexible processes could benefit the most from being able to pose open queries in plain written language. At the other end of the spectrum, operators of highly standardized plants receiving periodic training probably benefit the least because the facilities for graphically navigating 800xA data structures from the GUI are adequate.

The START system can be of great value for troubleshooting under stress, particularly in seldomly recurring scenarios.

The foremost challenge consists in finding a way to produce annotations semi-automatically, with minimal, data-driven manual guidance. In particular, in order to process requests such as those illustrated in 4 and 5, high-level annotation techniques must be developed that allow application developers to specify entire classes of explanation procedures with a few descriptive annotations.

Depending on the type of decisions that must be based on system responses, the annotations and underlying explanation procedures may need to provide responses that are 100 percent reliable and complete if the system is to have any value at all. In current automation systems, this is achieved by manual configuration of a limited number of queries. Is there a use and value for queries that return, eg, 90 percent complete answers, in terms of correct interpretation and processing? If so, this project has already found an application. If not, the challenge remains.

Secondary challenges are the adaptation to languages other than English, and of modes such as responding to spoken language rather than writing. None of these challenges are trivial, but technologies are commercially available that can be added to this demonstrator, enabling it to perform such tasks.

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References

[1] http://start.csail.mit.edu/

[2] Boris Katz, Gary Borchardt, Sue Felshin, Natural Language Annotations for Question Answering. Proceedings of the 19th International FLAIRS Conference (FLAIRS 2006), May, 2006.