SMALL: Support Management Automated Reasoning Technology for Compaq Customer Service

Timothy L. Acorn, Compaq Computer Corporation,
and Sherry H. Walden, Inference Corporation

Because of the increasingly competitive nature of the computer manufacturing industry, Compaq Computer Corporation has made some trend-setting changes in the way it does business. One of these changes is the extension of Compaq's call-logging sy   ste problem-resolution component that assists customer support personnel in determining the resolution to a customer's questions and problems.

Recently, Compaq extended its customer service to provide not only dealer support but also direct end user support; it is also accepting ownership of any Compaq customer's problems in a Banyan, Microsoft, Novell, or SCO UNIX operating environment. One of the tools that makes this feat possible is SMART (support management automated reasoning technology). SMART is part of a Compaq strategy to increase the effectiveness of the customer support staff and reduce overall cost to the organization by retaining problem-solving knowledge and making it available to the entire support staff at the point it is needed.
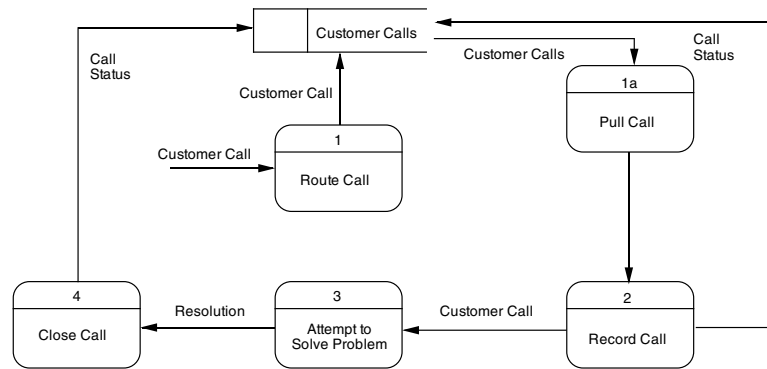
Figure 1. Problem-Resolution Work Flow.

Business Problem

Compaq is a multibillion dollar, Fortune 500 company listed on the New York Stock Exchange. Compaq is a manufacturer of personal computer systems, ranging from laptops to high-end systems. Compaq has gained a reputation for superior products, such as the Compaq LTE 386/20 notebook-sized computer and the high-end Compaq SYSTEM PRO.

In addition to providing high-quality products, one of Compaq's strategic business objectives is to provide quality support. Customer satisfaction is recognized as one of the company's top objectives.

With a tactical approach to providing customer satisfaction, personnel manning the telephone lines are required to respond to technical support requests in real time, online. The mission of the telephone support groups is to elate every customer by being accessible, responsive, enthusiastic, courteous, helpful, and caring.

Compaq utilizes an automatic call distributor to route support requests to its technical support engineers. The support engineer is required to answer the telephone, gather caller and support request information, log the call into the call-logging system, analyze the information or problem-resolution request, conduct research or perform problem duplication or resolution, and deliver the information or solution. The engineer uses various electronic and hard-copy resources as well as works with his/her peers in responding to support requests (figure 1).

As with most computer manufacturers, Compaq's price for each unit is continuing to decrease to remain cost competitive. A reduction in the price translates into fewer dollars available to implement support pro-

grams to keep up with the ever-increasing user support requirements.

Many corporations are moving from mainframe environments to distributed, local area network (LAN)–based architectures. In a recent *COMPUTERWORLD* analysis of management information system organizations, 8 of the 10 industry groups surveyed identified LANs as one of their top three critical technologies (Premier 1991).

Companies that are evaluating the use of local area network computer systems in lieu of larger computer systems still expect the level of support that is traditionally available in the mainframe world. To meet this expectation, Compaq's Customer Service Department employed a strategy using AI to develop a system that will improve the quality of support by putting known solutions at the fingertips of its technical support engineers.

Members of the Compaq customer service telephone support organizations are required to provide technical support, ranging from product information requests to problem resolution in complex network environments on a vast array of product offerings. Support requests include inquiries about product specifications as well as requests for assistance to resolve technical issues. Needless to say, there are no typical questions and no typical day.

Traditionally, Compaq provided technical support to its dealer channels, which, in turn, provided support to the millions of computer users. In an effort to enhance customer satisfaction, in March 1991, Compaq opened a Customer Support Center. The Customer Support Center provided end users with the ability to call Compaq directly to request technical support.

The implementation of a Customer Support Center has more than doubled the number of support requests received by the telephone support groups. Compaq's telephone support groups handle thousands of support requests each day. With the introduction of an ever-expanding product line to meet user support requirements in a high technology area, staffing levels to support these products would continue to grow. The Compaq Customer Service Department needed a means to more effectively and efficiently handle the increasing volume of support requests.

In anticipation of the increase in the number of calls with the advent of the new customer support services, the customer service telephone support groups grew by 100 percent. Such a significant increase in staffing levels brought with it training considerations and requirements.

Economic conditions, the cost of providing technical support, the complexity of the support environment, customer requirements and expectations, an increase in call volume, an increase in training requirements, staffing levels, desired service levels, as well as other factors, were all considerations in deciding to build additional support tools.

Business Requirement

To meet its technical support objectives, the Customer Service Department must provide the following: information at the point of need; continuous availability of expertise; consistency in answers and responses; accurate, technically sound answers and responses; a reduction in the need to resolve problems multiple times; a learning aid for employees with limited domain knowledge; and retention of corporate knowledge.

Traditionally, hotline organizations can receive the same support request numerous times each day. A mechanism was required that could capture information—or the resolution to a problem—and provide this information to the technical support engineers, who, in turn, could supply the information or resolution to the customer in real time. The information or resolution needed to be in a format similar to the way technical experts receive the support request.

Compaq's technical support organization has been in place for several years. In 1989, the Customer Service Department installed a new problem management and reporting system (call-logging system). The new problem-resolution system would need to interface with the call-logging system, as well as all existing, associated software. Also, Compaq has one of the largest LANs in the world. The problem-resolution system would need to reside in, and be compliant with, the existing network environment.

The SMART Solution

To meet the company's objective of customer satisfaction, Compaq's Customer Service Department, in conjunction with Inference Corporation, developed and installed the SMART system.

Compaq implemented a problem-determination and problem-resolution assistant, SMART, using knowledge-based system technology. The technical approach applies a case-based reasoning, problem-solving paradigm to solve the customer problems. *Case-based reasoning* is a technique that adapts stored problem solutions (as cases or examples) to solve new problems.

Work Flow

SMART is now an integral part of the customer support engineer's work flow (figure 2). Each call received by a support engineer is recorded in the call-logging system.

The phases of technical support are (1) answer the phone, (2) gather caller and support request information, (3) log the call, (4) analyze the information or resolution request, (5) conduct research or prob-
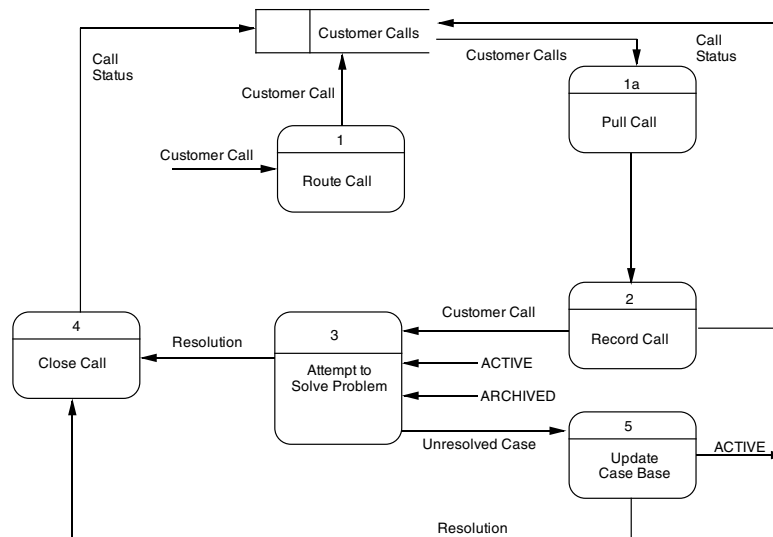
Customer Calls

Call
Status

Customer Calls

Call
Status

Customer Call

1a

Pull Call

Customer Call

1

Route Call

2

Record Call

Customer Call

4

Close Call

Resolution

3

Attempt to
Solve Problem

ACTIVE

ARCHIVED

5

Update
Case Base

ACTIVE

Unresolved Case

Resolution

Figure 2. Problem-Resolution Work Flow Using SMART.

lem resolution, and (6) deliver information or solution.

Initially, the support engineer collects basic customer or dealer, information, that is, name, address, dealer identification, and so on. The support engineer then types a textual description of the information request or problem into the summary field of the call log. If the support engineer knows the answer based on its initial description, he/she relays it to the customer, records it in the call log, and closes the call log. If the support engineer needs further information or is unfamiliar with the domain the customer is inquiring about, he/she selects the SMART button on the call-logging screen (figure 3).

The summary description is automatically extracted from the call log and propagated to the description field of the SMART screen. An initial search is then performed. SMART looks for a case that matches the information request, or problem description, by analyzing the description string at a subword level using a trigram-matching algorithm (Inference 1991) that compares the contents of the information request against the description fields of previously stored cases. A case is a problem-scenario–problem-resolution pair consisting of a textual description, relevant questions and their corresponding answers, and a recommended resolution or action (figure 4).

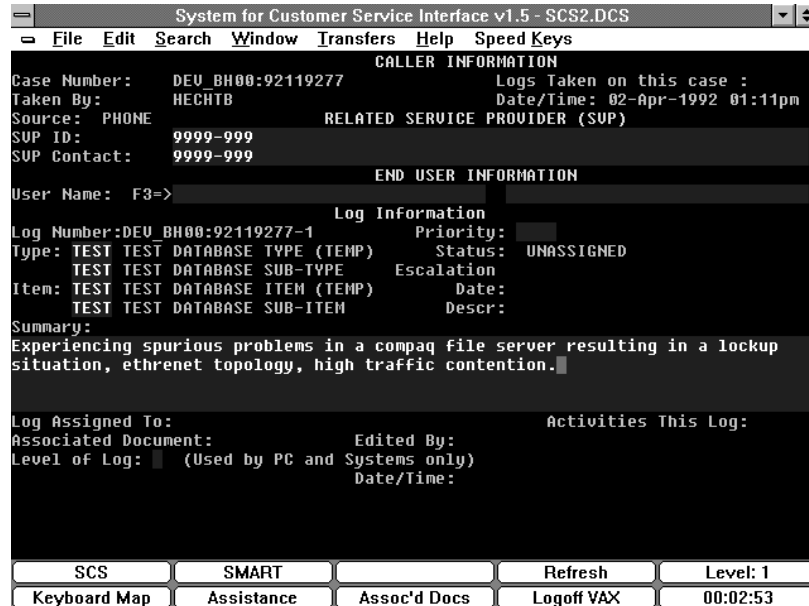After the first search, the support engineer is presented with a list of

Figure 3. Call-Logging Screen through WINDOWS-*Based Terminal Emulator.*

the best matching cases. Additionally, SMART displays the questions associated with these cases. The support engineer uses this list of questions to request additional information from the customer to better define the problem. As the answer to each question is provided to SMART, a new search is performed. As more information is provided, SMART provides an increasingly accurate set of relevant cases and associated questions. At any time in the process, the support engineer can browse through supporting information associated with the question, matching cases or associated actions (figure 5).

The numbers from 0 to 100 located to the far left of each case title represent the degree of relevance given to the case by SMART. The *degree of relevance* represents the percentage of this case's information that matches the information provided by the support engineer on the problem definition. The degree of relevance considers the worth of the description with respect to accurately representing the problem scenario, the match and mismatch weights of answered questions, and the worth of unanswered questions. In the Compaq case base, a degree of relevance equal to or greater than 70 alerts the support engineer (through a textual color change of the matching cases) to a case that is similar or identical to the one presented by the customer (figure 6).

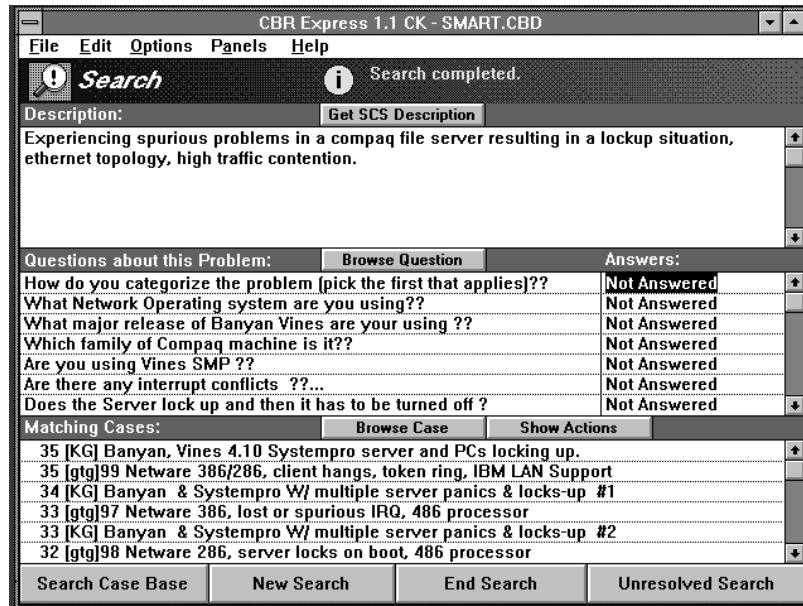Once a case representing the current customer problem is located,

Figure 4. SMART Screen after Initial Search.

the support engineer relays the information, or solution, to the customer. To complete the exercise, the support engineer highlights the case and presses the end-search button.

The *session information*, which includes the contents of the description field, all answered questions, and the selected matching case and its corresponding resolution, is copied to the WINDOWS clipboard. The support engineer then returns to the call-logging screen. The support engineer completes the call log by pasting the session information into the resolution portion of the call log and closing it (figure 7).

If a matching case is not located, the support engineer presses the unresolved-search button. The session information is then stored in a case format in the case base with a status of unresolved. A reference to the call log number, the name of the support engineer, and a time stamp are stored with the case. Unresolved cases are later developed into actual cases by the case builders.

SMART has had the most impact on the fifth technical support phase (conduct research or problem resolution) of the process. SMART has enhanced the engineer's ability to provide timely, accurate information to customers, with minimal duplication of effort.

Justification for the SMART system was based on the ability to retard growth of the staffing levels. Based on Compaq's capital model analysis
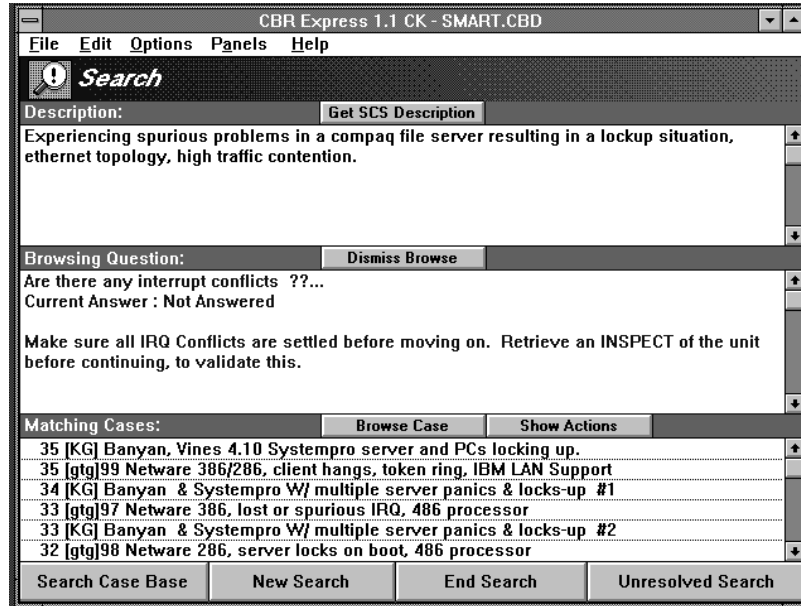
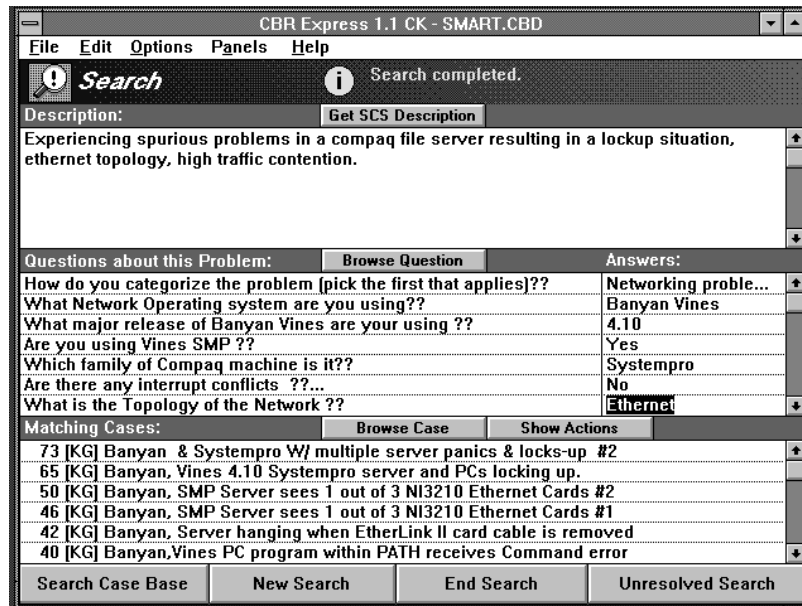*Figure 5. SMART Screen Browsing for Supporting Information.*

Figure 6. SMART Screen after Matching Case Is Located.

```
┌─                   System for Customer Service Interface v1.5 - SCS2.DCS        ▼ ♦
 ▭  File  Edit  Search  Window  Transfers  Help   Speed Keys
|02-Apr-1992 Thu 13:20 Brian Hecht
+--------------------------------------------------------------------------+
----------PROBLEM
Experiencing spurious problems in a compaq file server resulting in a situation,
ethrenet topology, high traffic contention.
----------QUESTIONS
What Network Operating system are you using?? Banyan Vines
How do you categorize the problem (pick the first that applies)?? Networking
problem ( hardware or software)
Which family of Compaq machine is it?? Systempro
What major release of Banyan Vines are your using ?? 4.10
Are there any interrupt conflicts  ??... No
Are you using Vines SMP ?? Yes
What is the Topology of the Network ?? Ethernet
----------CASE
   72 [KG] Banyan  & Systempro W/ multiple server panics & locks-up  #2
----------ACTION
   72 Install the 410CG-3 patch or Upgrade to 4.10(5) or 4.11...
SEARCH ENDED AT 1:19:43 PM ON 4/2/92.
CASE ID: SMART92845█




┌──────────┐ ┌──────────┐ ┌──────────┐ ┌──────────┐ ┌──────────┐
│   SCS    │ │  SMART   │ │          │ │ Refresh  │ │ Level: 1 │
└──────────┘ └──────────┘ └──────────┘ └──────────┘ └──────────┘
┌──────────┐ ┌──────────┐ ┌──────────┐ ┌──────────┐ ┌──────────┐
│Keyboard Map│ │Assistance│ │Assoc'd Docs│ │Logoff VAX│ │ 00:09:49 │
└──────────┘ └──────────┘ └──────────┘ └──────────┘ └──────────┘
```

Figure 7. Call-Logging Screen with Resolution Pasted in Call Log.

of SMART, payback of the system was one year, with a high internal rate of return and net present value. Once installed, the SMART system changed the way technical support engineers perform their jobs. The work flow was enhanced with the advent of the SMART system.

The SMART Architecture

In this section, we discuss the various parts of the SMART architecture: the initial deployment architecture and the current subnetwork architecture and case base architecture.

Initial Deployment Architecture

SMART is a client-server architecture with user workstations running in a WINDOWS environment (figure 8).

As mentioned in Business Requirements, it was Compaq's desire to integrate SMART with existing software, that is, the VAX-based call-logging system, without modification to existing applications. To accomplish this task, Compaq upgraded from a DOS-based terminal emulator for VAX to a WINDOWS-based VT220 terminal emulator. Propagation of information between the call-logging system and SMART is accomplished
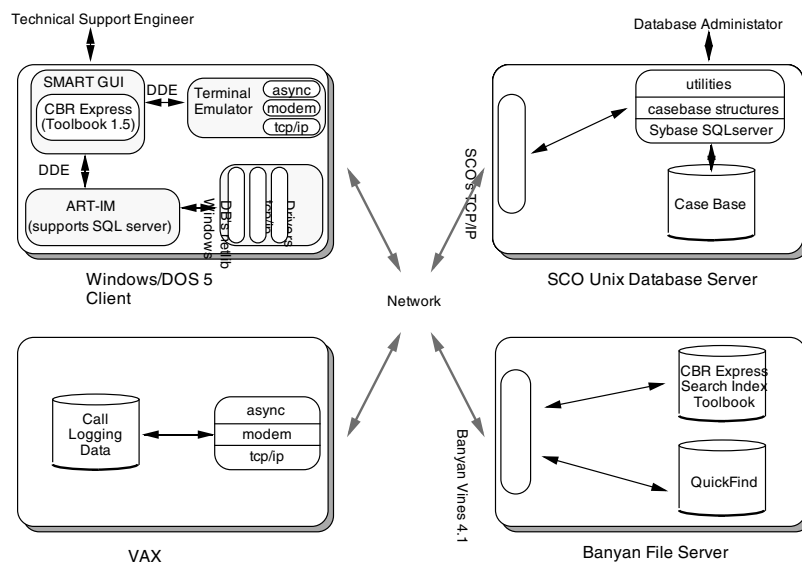
Figure 8. SMART *System Architecture.*

using the terminal emulator's scripting capability and communication with WINDOWS dynamic data exchange without any modification to the call-logging application.

Compaq promotes use of off-the-shelf products that provide an open architecture to avoid customization when additional or modified requirements are established. Therefore, cases are stored in a standard relational database, and the transport protocol between the user workstations and the case base is TCP-IP.

Multiple-Subnetwork Architecture

The system is currently deployed on two subnetworks. The Compaq campus network uses Banyan VINES. The campus LAN is composed of many subnetworks connected through a spine. To ensure consistently good network performance, each organization, which is usually located in close proximity, has its own subnetwork.

All the subnetworks travel the length of the campus. Each subnetwork supports more than 50 users, all of which are SMART users. Any user of the Compaq campus network can access the SMART system. SMART users access network files from their local subnetwork Banyan file server, and they access the case base from a local subnetwork, UNIX-

based database server.

As additional Compaq departments begin using the SMART system, the Banyan file server–based files and the database server–based case base can be duplicated on each local subnetwork. A synchronization program, called SYNC SMART, synchronizes the case bases each evening to ensure they are identical, never taking SMART offline entirely.

Case Base Architecture

Compaq's case base currently consists of nine domain partitions. A domain partition is a collection of cases, all regarding a specific product line. The domain partitions include NOVELL, LAN Manager, BANYAN, Unix, DOS, Windows, OS/2, and general hardware and software. To ensure consistency among cases, high-reuse, or focusing, questions were established that are used in all cases in which they apply. Examples of this type of question include, Which network operating system are you using? Which processor does your machine use? Which family of Compaq products are you using? What operating environment are you using?

The SMART Case-Building Process

The case building model is a tiered approach, providing a mechanism of checks and balances to ensure accurate cases (figure 9). Designated senior support engineers have been trained as case builders. The list of unresolved cases is reviewed daily, and cases are assigned to the case builders based on domain specialty. The case builders review the session information captured during the call, research the problem, incorporate the session information into a case complete with resolution, change the status to active, and save it in the case base (figure 10). SMART is in continuous operation during this process, and once saved as active, the cases are immediately accessible by all users of SMART.
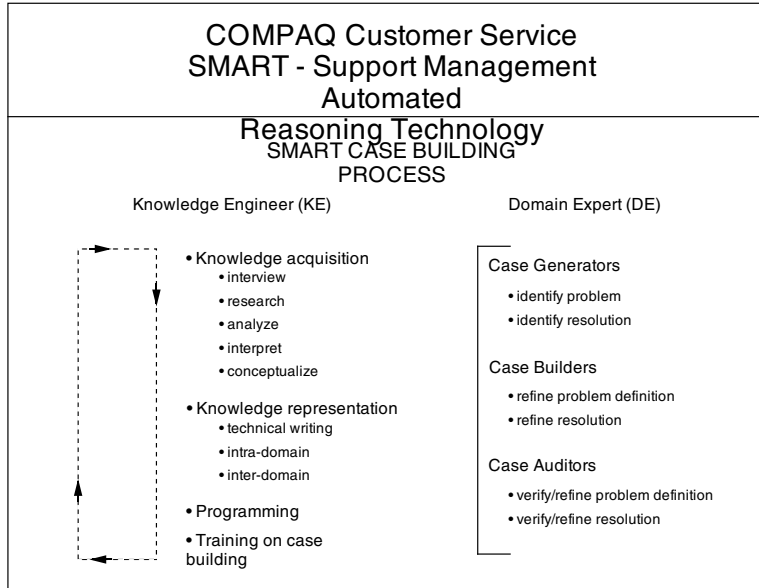
Results

This section discusses SMART's acceptance, deployment, and performance.

User Acceptance Criteria

The customer support organization—the user community—established acceptance criteria in the following areas: user interface, functions, performance, documentation, and maintenance.

The Compaq Human Factors Organization conducted a usability test of SMART in October 1991. The results of the study indicate that the probability of resolving a case is much higher when using the SMART sys-

COMPAQ Customer Service
SMART - Support Management
Automated
Reasoning Technology

SMART CASE BUILDING
PROCESS

Knowledge Engineer (KE)   Domain Expert (DE)

• Knowledge acquisition   Case Generators
  • interview
  • research   • identify problem
  • analyze   • identify resolution
  • interpret
  • conceptualize   Case Builders

• Knowledge representation   • refine problem definition
  • technical writing   • refine resolution
  • intra-domain
  • inter-domain   Case Auditors

• Programming   • verify/refine problem definition
                                                   • verify/refine resolution
• Training on case
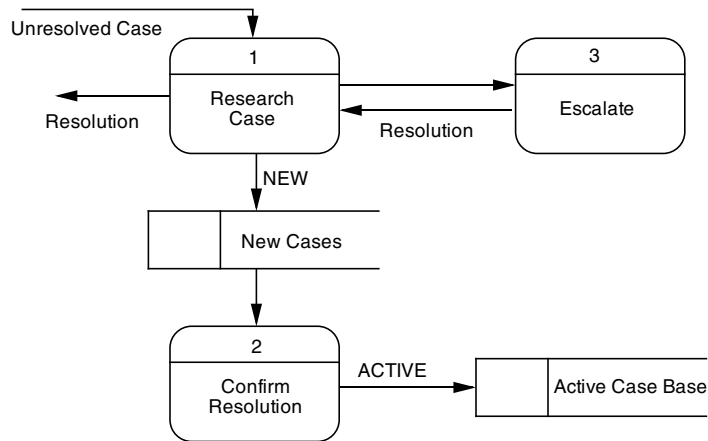 building

Figure 9. Case-Building Model.

Figure 10. Case Base Update Work Flow.

tem. Altogether, less than 50 percent of the test cases were resolved without using the SMART system. When using the SMART system, 87 percent of the test cases were resolved.

Specific results of the test show the acceptance and usability of the SMART interface to be high and identify areas of SMART that require improvement. These areas include the transitions between the call-logging system and SMART and the advice-giving aspects of some of the cases.

As a result of this analysis, the functions of SMART were extended to provide more automated propagation of information between applications: For example, the call log number is now stored with unresolved cases, and SMART session information is captured for use in the call log. In addition, more specific information on creating consistent and complete cases was documented.

A follow-on study will be conducted by the Human Factors Organization after the January multi-subnet deployment.

SMART Deployment Timeline

1991
August: Lab online to support case building

September: Multiuser access in lab

November: Case base migrated to relational database; case builders online (12 users); phase 1 users (20 additional users)

December: First LAN completed (50+ users)

1992
January: Second LAN completed (50+ users)

SMART Performance

smart's performance is measured using two perspectives: time to resolution, where actual search speed is a factor, and probability of resolution. The performance criteria require less than two minutes for a problem resolution, assuming an average of five questions answered to reach a reasonable match. Currently, smart is taking three to five seconds for each search, depending on the hardware configuration of the user workstation. The minimum configuration is a 386-based computer with 6 megabytes of memory and a 10-megabyte swap partition.

The development of SMART included an analysis of the case base after it reached reasonable coverage, approximately 600 cases. Tools were used that automated the testing of the case base by constructing search

strings that included variable amounts of randomly generated text and automated answering of questions. During the test, if questions are presented that are not associated with the case being tested, a randomly generated answer is provided. The tool also permits the tester to specify a percentage of questions that have the wrong answer provided. These tools have assisted the case builders in identifying cases that could be defined better.

Innovative Techniques and Aspects of SMART

Although the mechanics of case development are straightforward and actually trivial to grasp, effective case base development requires analysis of the domain and adherence to a style of case building. Early in the process of case development, Compaq realized a need for the development of a Case Construction Style Guide. The style guide establishes conventions and principles for case development, including the following areas: when to use list, text, yes-no, or numeric answers; what information the case description should include to increase the effectiveness of the first search; how many questions are associated with each case; how the questions are phrased; and which questions are included with each case.

As an example, one principle included in the Case Construction Style Guide is as follows:

When asking a related series of questions about an object, ask the most general questions first, and the most specific questions last (the Principle of Progressive Disclosure). If any of the specific questions make sense only for a particular answer of the more general question, make sure to use elimination scoring (Inference 1991) on the more general question (Compaq 1991).

In addition to establishing a case construction style, the style guide documents a methodology for the case-building process itself. Compaq is responsible for addressing a rapidly evolving platform of issues. The case-based reasoning paradigm provides the architectural flexibility that is required to adapt to this dynamic environment. The methodology outlines the logistical process that ensures the timely inclusion of cases that address even the most recent issues.

A bottleneck in the development of knowledge-based systems has traditionally been the knowledge-acquisition process. The SMART system is designed to permit the users to populate the knowledge themselves in the form of cases. Knowledge engineers were instrumental in the development of Compaq's Case Construction Style Guide, but case building and maintenance is the responsibility of the user community.

Compaq has always made important information available to its support engineers in the form of product manuals, technical reference notes, service advisories and bulletins, an online information resource, electronic mail, and so on. SMART is not only an information resource in a format more useful for a support organization (that is, in the form of resolutions to problems); it also ensures that information is available to the support engineer at the point it is required. Application of knowledge at the time of need reduces time to resolution significantly.

Finally, the SMART system is a real-time, online production, knowledge-based system built with off-the-shelf products on general-purpose hardware, all Compaq, of course. Compaq is committed to empowering its employees with the tools required to excel in the industry as a service provider. SMART is an innovative, leading-edge example of one such tool.

Summary

Using AI technology, Compaq now captures the knowledge its support engineers use to solve customer problems and folds it back into SMART, making it available for reuse. In addition to facilitating the business of servicing its customers, Compaq now has this information in a tangible form as well as a means of continuing to collect this information.

Compaq is now investigating methods of extending the automation of SMART in two ways: (1) adding intelligent parsing mechanisms that deduce the answers to questions from information contained in, and implied from, free-form text entries and (2) answering new questions from previously answered questions.

References

Compaq Computer Corporation. 1991. Case Construction Style Guide. Compaq Computer Corporation, Houston, Texas.

Inference Corporation. 1991. Case-Based Reasoning in ART-IM. Inference Corporation, Los Angeles, Calif.

Inference Corporation. 1991. CBR Express User's Guide. Inference Corporation, Los Angeles, Calif.

The Premier 100: Analysis of the Top 100 MIS Organizations in the United States. 1991. *COMPUTERWORLD,* Sept. 30, 1991.