A web-based self-diagnosis tool to solve print quality issues

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Abstract

Print quality is an important factor for customer satisfaction. Resolving print quality issues poses special challenges for a manufacturer's support organization. We have developed a troubleshooting web site to enable customers to self-diagnose many of their print quality issues. The diagnosis is based on images of the printed test pages that contain highly accurate simulations of potential print quality defects. We discuss the development process of the website, the results of usability experiments conducted to improve the tool, the general characteristics of the web site, and the web site navigation and diagnosis process.

Introduction

In today's businesses, high quality and competitive prices are no longer sufficient to guarantee commercial success [1]. Clients are interested in several factors, including features, warranty, and the post-sales customer support the manufacturer offers with a product. In terms of support, customers want service for the entire life span of the product. No one wants to invest money in a product that can fail at a time when service is not available to fix it. This point is especially critical for customers who run a business using the product and for whom down time can be very costly in terms of lost revenue and/or their customers' loyalty.

Print quality (PQ) issues pose special challenges for the manufacturer's support organization. The traditional method of customer service is a call center. However, as soon as the customer telephones the call center, issue resolution begins to cost the manufacturer. In addition, it may be difficult for the customer to effectively describe the PQ issues over the telephone, leading to even greater costs. In general, it is much more desirable that the customer be able to self-solve PQ issues. Most manufacturers offer a user manual or a service manual as a self-service tool. However, the processes needed to diagnose the problem may be too complex to effectively convey in a static printed document, such as a user manual. In addition, it may be too expensive to provide in a user manual high quality color images that would enable the customer to identify the PQ issues at hand.

In this paper, we describe a web-based PQ troubleshooting system (PQTS) which enables customers to self-diagnose their PQ issues with midrange color electrophotographic (EP) laser printers. This is a win-win situation for the manufacturer and the customer. For the manufacturer, the tool reduces the cost of international calls and the size of the work force. The customer does not have to wait in the service queue, and can solve the problem faster—making a better use of his/her time.

The paper is organized as follows. There are three main sections. The first section opens with the problem definition, our motivation, goals, and challenges. The remainder of this section is subdivided in two subsections. In the first subsection, we evaluate the deficiencies of previous resources for PQ troubleshooting and review the roots of the PQTS. Then we talk about the development process of the web site and the results of the usability experiments conducted to improve the tool. Then in the second section we describe the framework for the self-diagnosis tool, and also provide a detailed description of the structure of the troubleshooting web site. In the final section, we offer thoughts and conclusions about the project.

Exploration and development

Our main challenge was to improve the satisfaction and the efficiency with which customers self-solve many of their PQ issues. A web-based self-diagnosis tool is a solution that enables customers to accomplish such a task. The tool should not replicate current resources, such as the user manual and service manual. In contrast, the self-diagnosis tool should be efficient, effective, and based on a terminology comprehensible by customers. Another benefit of a web-based tool is that we can enhance the textual description of a troubleshooting procedure with high quality images illustrating the steps to be executed. In this way, we can remove any ambiguity or misunderstanding of the text. Also, we can facilitate and improve the identification of PQ issues by providing the user with highly accurate simulations of potential PQ defects, something that may not be cost effective for a user manual.

The origin of the Web-based tool

The PQTS is the result of an evolutionary process. Early experimental endeavors were the lexicon study, simulation of PQ defects, and PQ test page design. Table 1 summarizes the objectives of these projects. The lexicon study enhanced our perspective on the importance of terminology in the textual description of PQ issues. In addition, we decided to generate synthetic versions of the defects, because the occurrence and nature of the real defects is difficult to control; and we require the capability to reproducibly generate defects over a range of levels. Also, accurate simulation of defects facilitates the self-diagnosis of PQ defects by the customer. Finally, with the test pages, the customer just has to match the defect on the test page with one of the defective test page examples provided by the tool.

In the beginning, our work on the PQ lexicon and the PQ test pages was directed toward improving the current PQ troubleshooting methods, tools, and documents. This previous work definitely improved the efficiency of troubleshooting over the phone with the assistance of a CCA; but it was decided that much more could be gained by focusing on the development of a tool that would

Table 1: PQ projects prior the design of the PQTS.

Projects	Objectives
Lexicon	Examine the terminology used by customers when trying to provide a verbal description of a visual print defect [2].
Test pages	Define the features needed in a test page, which should make PQ defects visible to the customer [3].
Defect simulation	Generate highly accurate simulations of PQ defects [4].

enable customers as much as possible to self-solve their PQ issues. At that time, the only way that customers could troubleshoot print quality issues from the manufacturer's web site was to perform a search using keywords arbitrarily chosen by the customer. The result of this search would be a long list of PDF documents. A detailed examination of the documents in this list revealed that the desired information was typically in a document that was far down the list. In addition, there were cases where the issue was addressed by multiple documents which offered conflicting information regarding how to resolve the issue.

A web-based self-diagnosis tool for print quality issues was the most attractive solution. We can have a dedicated server for these troubleshooting tools and decrease the access time to their content. We can design a consistent graphical interface, (i.e. web page templates), for each printer model which can help familiarize customers with the tool. In addition, the use of web templates accelerates the generation of new web sites. With a validation tool, the web pages are easier to modify and maintain. We can add more information and visual examples at a lower cost in a web-based tool than in a user manual. Also, the customer can access this tool from virtually any computer at any time. Finally, the web-based self-diagnosis tool can replace the CCA in many cases. The next section discusses the process that led to the final design of the PQTS.

The PQTS development process

The development process of the PQTS tool is summarized in the following steps: 1) needs assessment, 2) analysis of existing resources, 3) task analysis, 4) prototype development, 5) testing, 6) tool refinement, 7) tool release, and 8) maintenance and improvement [5, 6]. The previous section already touched on the first three steps in the development process. However, part of the life cycle of any software is to revisit early stages in the development process.

The first prototype of the web site was designed using HTML and the Perl programming language. It consists of the following features (see Fig. 1): A pull down list with the defects categories. Below the drop down list, there were icons with defect examples for the selected category. The troubleshooting procedures were extracted from the user manual, print quality guide, technical service manual, input provided by the printer manufacturer CCAs, technical marketing representatives, and product support engineers.

The prototype was evaluated by a first experiment with focus groups. The results led to a second prototype (see Fig. 2). There were significant modifications. Instead of identifying the issues by the category name (i.e. banding defects) we decided to

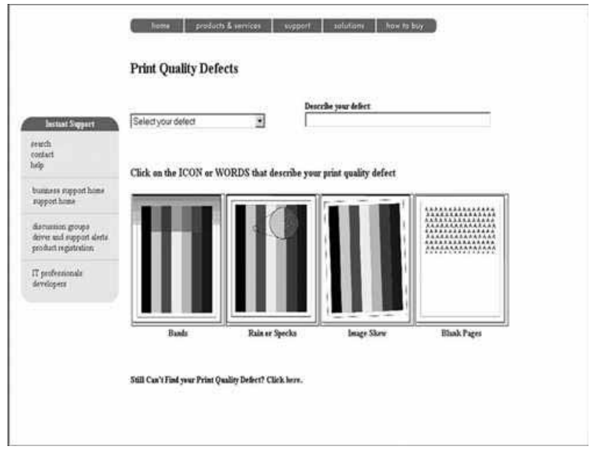

Figure 1. *Prototype 1.*

use three orientation-based categories: horizontal defects, vertical defects, and other defects. The diagnosis procedure changed as follows: the user selects a defect category with the same orientation as his/her issue, then he/she selects the defect sample that best matches his/her issue, and finally he/she follows a series of steps to solve the issue. For the participants, the terminology used to name the defects and their description was difficult to understand. Therefore, we made use of our experience in the lexicon study to identify words of common use that could replace technical or uncommon words. Also, we learned to focus on the defect description rather than the cause of the problem. Finally, another outcome from the experiment was to employ defect samples with a simple background.

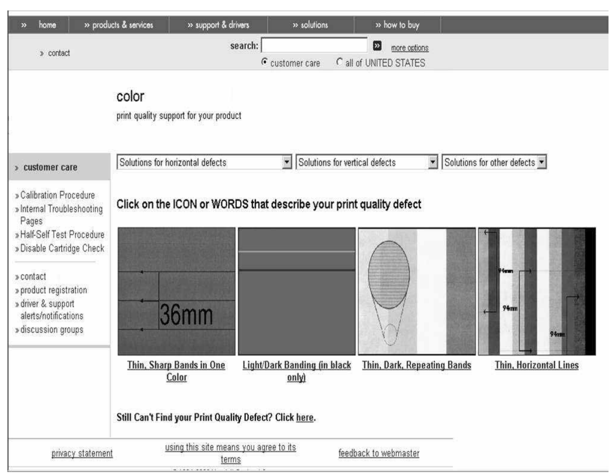

Figure 2. *Prototype 2.*

The next step was to proceed with a usability test for the second prototype. The results of this second experiment were discouraging. Users were confused and the structure of the web site was misleading. Based on the participants' comments, we made major changes and developed a third prototype (see Fig. 3). The new prototype had a different diagnosis procedure. The procedure starts with printing a set of test pages, followed by selection of the color of the defective test page. After that, the customer selects the orientation of the issue; then he/she selects the example most similar to the real defect, and finally follows the steps to solve the problem. In the new prototype, the defect samples were based exclusively on the test pages. Also, we began to try to avoid the mistake of considering a task to be simple or obvious. Therefore, each troubleshooting procedure was redesigned to guide the user in every task with text instructions and visual examples.

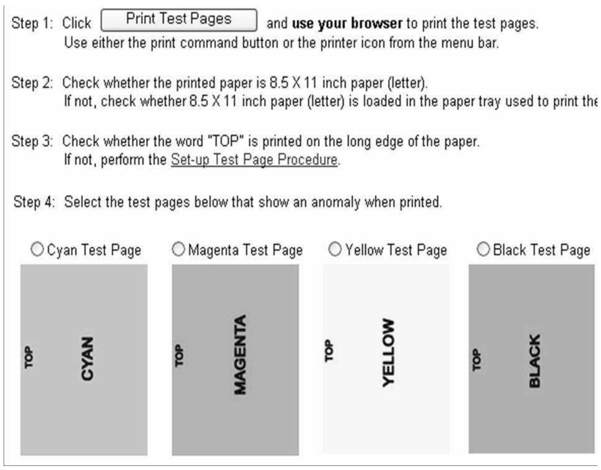

Figure 3. *Prototype 3.*

Immediately after Prototype 3 was ready, a usability test was conducted in order to observe and measure the performance of customers using the new design of the tool. In this third experiment, eight participants performed five scenarios of finding a solution for a given print having a PQ issue. The completion time for all five scenarios was below one hour. Moreover, the users' initial estimates of how long it would take to complete the scenarios were generally longer than the time it actually took them to resolve the issues. In addition, the error rate was 2.5%. This was a great improvement from our previous designs.

The tool continued its evolution after integrating suggestions from Experiment 3 (see Fig. 4). The objective of the modifications was to give the PQTS web site style consistency. We added the upper and left rulers to the test pages and modified their text. At this point, we integrated within the defect samples magnified call-outs when needed to clearly show the defect structure. Also, we colored the words cyan, magenta, yellow, and black with the color they represent. In this way, customers can identify very quickly the color to which the word refers. Additional consistency modifications included close buttons for each pop-up window, identical formatting of all tables, and capitalization of the first letter of each word in a button. Also, above the web page title, we added breadcrumbs, which helps the user navigate through the web site. Finally, we continued to make slight modifications to the wording and graphics in almost all pages.

To evaluate the new tool, we conducted Experiment 4. The objectives of this experiment were to evaluate the tool's effectiveness as a stand-alone self-diagnosis tool compared to the traditional model of talking with a CCA over the phone, and to evaluate how the tool might enhance communication between the customer and the CCA. Twelve subjects participated in this test and each subject performed three scenarios of diagnosing and repairing a PQ issue. In the first scenario, the subjects used the PQTS alone. In the second scenario, the subjects worked with a CCA only. In the third scenario, the subjects were assisted by the tool and a CCA. The entire experiment was video and audio recorded. Table 2 summarizes for each scenario the mean and standard deviation of the subjects' troubleshooting time. The experiment showed that the customer spent less time solving the problem when assisted by the web tool than when assisted by the CCA or the CCA and the tool together. In general, the subjects preferred the assistance of the PQTS over the assistance of the CCA, due to the wait on the phone for the CCA. (The wait time is not included in Table 2.) It is interesting to note that diagnosis using both the CCA and the tool took significantly longer than diagnosis with either the CCA or the tool alone [5]. One reason for this is that the customer and the CCA had difficulty jointly navigating through the PQTS.

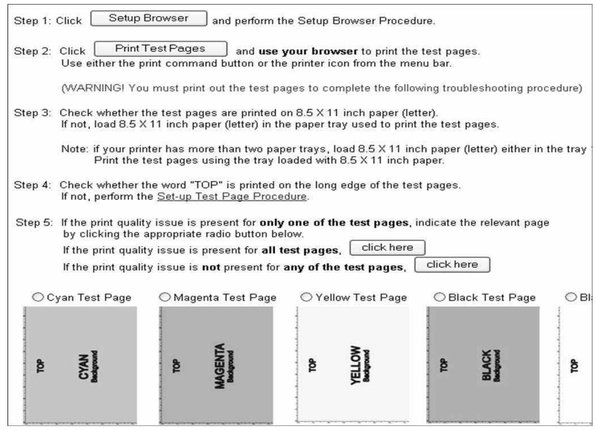

Figure 4. *Prototype 4.*

Table 2: Time to diagnose and repair a print quality problem (seconds).

Tool		CCA		Tool + CCA	
Mean	S.D.	Mean	S.D.	Mean	S.D.
856.6	407.7	934.7	304.05	1231.8	458.6

After Experiment 4, minimal modifications were made to the PQTS design (see Fig. 5). Although some modifications came from the suggestions of subjects in Experiment 4, the main contributions came from the biweekly usability reviews held by the PQTS research and development team at Purdue. The following modifications resulted from these internal reviews. The bottom and right rulers were added to the test pages. Multiple views of the same defect were added. This feature was added because some subjects expected the synthetic defect shown in the PQTS to look identical to the defect on their printed test page. The multiple views were designed to give subjects a sense of the range of different forms that might be observed for a given defect.

A fifth experiment was executed for testing and refinement of the PQTS tool. Three two-hour focus group sessions were held in different locations. Four students participated in the first session. The eight subjects in the second session were technical marketing and customer support specialists. In the third session, seven CCAs participated in the experiment. The rationale behind the three different focus group compositions was to obtain and assess the viewpoints and ideas from groups that represent different perspectives,

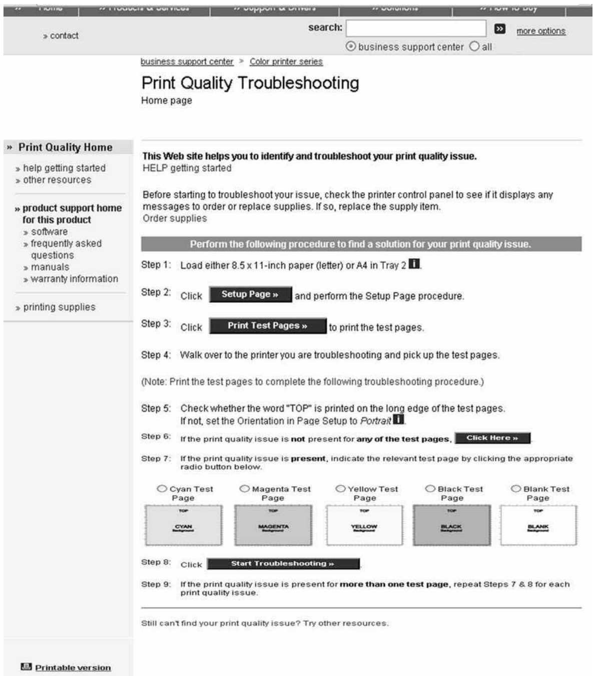

Figure 5. *Prototype 5.*

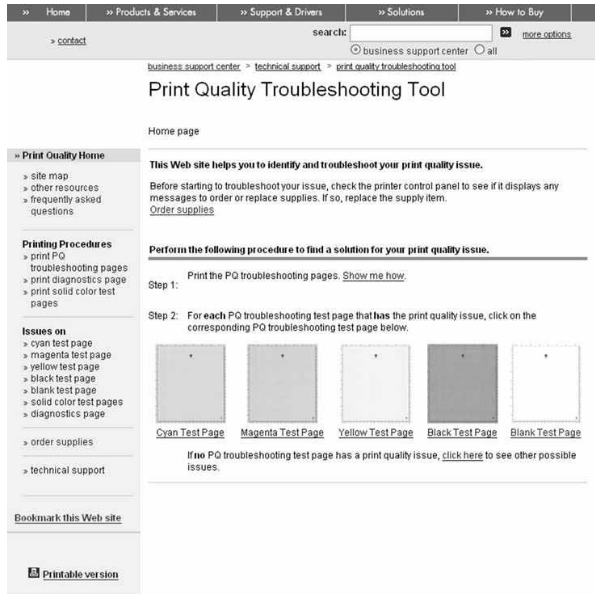

Figure 6. *Home layer of the PQTS—release version.*

i.e. the customers, the technical personnel from the product division, and the CCAs from the support center [6]. The moderator of the experiment asked questions addressed to each layer of the web site and the web site as whole. The objective of the questions was to gather information regarding functional requirements, ease of use, and ease of navigation. For further analysis, all interviews were video and audio recorded. From this experiment, 90 comments were annotated. These fell into 28 categories regarding the usability of the web site. Some of the comments were repeated several times. We considered the frequency of each comment to be indicative of the severity of the usability problem highlighted by the comment.

Additional revisions to the current design were based on human-computer interaction considerations [7]. These revisions result in the sixth and final PQTS design (see Fig. 6). The web site modifications consisted of the following: 1) Reorganization and simplification of structure. Some procedures were moved to other categories. Long procedures where simplified with fewer steps. 2) Consistency and compatibility. Most of the buttons were changed to hyperlinks. The arrow-shape cursor over a button was changed to a hand-shape cursor, which indicates to the user that the button is clickable. 3) Additional functions for flexibility and clarity. "Return to previous page" link was added to every web page in the web site with the exception of the home web page. A site map was added to the web site. 4) Eliminate features for simplicity. Radio buttons and pull-down menu were eliminated from the home page. Other comments were not addressed because of constraints imposed by the manufacturer's web design standards or the fact that the comments would necessitate changes that would ultimately decrease the effectiveness of the PQTS. For example, subjects did not like to print test pages more than once; but this step is essential to identify whether or not the issue has been resolved.

A sixth and final experiment was conducted in order to validate the improvements to the PQTS design that resulted from the previous experiment. The experiment compared the time to diagnose and repair an issue and the accuracy of the diagnosis/repair between the old and new web site designs. Twelve students participated in the test. Each subject was asked to resolve two PQ issues with both the original and the revised web sites. The order in which tasks were performed with a given version of the PQTS was randomized to counterbalance learning effects. Also, every session of the experiment was videotaped. During the experiment, the subjects attempted to resolve an issue using one of the two web sites. Then they answered six questions that provided a subjective rating of their satisfaction with the web site. After that, they started troubleshooting the next issue with the other web site. When finished with that task, they answered the same six questions for this web site. Finally, the subjects answered five questions aimed at comparing the two web sites. The results of the experiment showed that the revised version of the PQTS decreased the time of troubleshooting by 28.8% for diagnosis and 21.2% for repair. On the other hand, in terms of the rate of success of issue resolution, no significant difference was found between the old and revised versions of the PQTS, because all subjects completed their assigned tasks successfully. The responses of the subjects to the questions indicated that the revised web site was better than the original web site in terms of ease of use and clarity.

The web-based self-diagnosis tool

We have already traced the origins, the exhaustive experimentation, and the resulting refinements of the self-diagnosis tool. The work with the PQTS provided us with rich information about good practices in the design of a self-diagnosis tool. This section reviews the features and the organization of each web page in the current design of the PQTS. First, we discuss the general characteristics of the web site. Then, we describe the web site navigation and diagnosis process.

Web site characteristics

The three-layer architecture in Fig. 7 is an intuitive troubleshooting method. The first layer constitutes the initialization layer. At this point, the customer sets up the tools needed for the troubleshooting procedure. The second layer is the issue matching layer. In this level, the user reviews the printed test pages and selects the defect sample that best matches his/her problem. The third layer is the troubleshooting layer. At this stage, the customer has already diagnosed his/her problem. Therefore, this layer contains the steps necessary to solve the problem. Also the third layer redirects the customer to other resources or support if the troubleshooting procedure does not fix the problem.

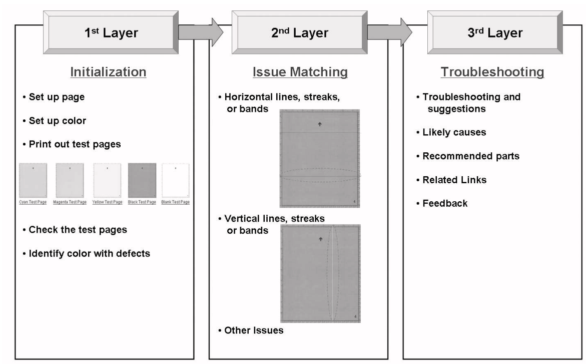

Figure 7. The PQTS three-layer architecture model.

There are other important considerations in the design of a self-diagnosis tool. The troubleshooting procedure can be decomposed in two sub-procedures, the diagnosis procedure and the repair procedure. The focus of these procedures should always be to help the customer to fix his/her problem. The designer should avoid excessive detail. Only the information that helps the user to perform the diagnosis and repair tasks should be included. The tool should not be intended to educate the customer to understand the problems or their causes; nor to educate the customer about the architecture and mechanism of the printer. An important practice is to describe defects and procedures with terms comprehensible by customers. The diagnosis and repair procedures should always contain links for additional help, and to return to previous pages. Especially, the repair procedure should contain links to order supplies and accessories, and for providing feedback about the PQTS.

The tasks where the customer has to interact with the hardware or driver should be explained in detail with textual and illustrated procedures. As an example, Fig. 8 illustrates two steps for replacing the cyan cartridge from a laser EP printer. The procedure shows a textual description of the step accompanied by a visual example. These detailed procedures should be customized for each different task. For example, the cartridge replacement procedure is customized for each of the colorants in the printer in order to minimize the possibility of confusion.

There are other features that are valuable for the user of the self-diagnosis tool. These are the content index, the site map, and the breadcrumb. Our content index is the left banner in every page of the site. This banner gives instant access to the main troubleshooting procedures, important resources, ordering supplies, and the issue matching layer for each color. This helps the user to recover from mistakes quickly, and provides immediate access to places he/she will commonly visit. The site map was added as a tool for communication between the customer and a CCA. It also gives users an overview of the web site [6]. The breadcrumb localized at the top of the web page over the title, helps the user to identify where he/she is in the PQTS. Also, the user can move quickly to the home page to repeat a procedure or move to another issue. These are features which help the user to navigate through the web site in a flexible and easy style.

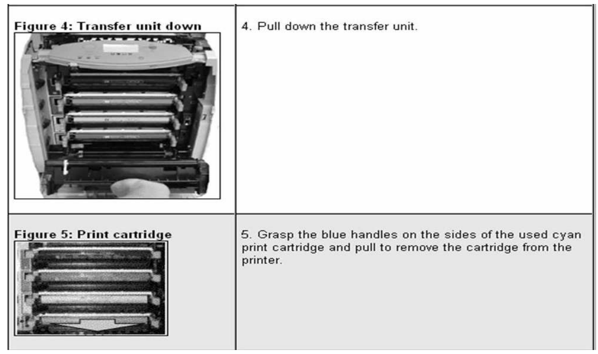

Figure 8. Segment of the replacing cartridge procedure.

Web site navigation and diagnosis process

Our print quality troubleshooting tool can be used by the printer manufacturer call center agents or as a self-help tool by customers. This section provides an illustration of customer web site navigation when resolving a PQ issue for a particular laser EP printer.

The process starts at the PQTS home page (Fig. 6). The user loads the printer with the specified paper, and prints the test pages. Then he/she reviews the printed test pages and observes which test page has an anomaly or defect in it. Then at the web site, the user selects the test page color that contains the issue. When the user clicks on the test page image, he/she advances to the second layer, where he/she selects the defect sample that matches the issue. More than one test page may show a defect. In that case, the user troubleshoots the test pages sequentially. Furthermore, it is possible that the test pages do not show a defect. If this is the case, the user is directed by a link at the bottom of the home page to another web page. This web page addresses some other potential issues. For example, the PQTS for one particular printer has a troubleshooting procedure for a defect that appears as a faded band at the top of the page. This particular defect will not be visible on the light-tint background of the regular test pages, and instead requires the printing of a special solid-fill test page. For another printer, this web page contains a troubleshooting procedure for color plane registration failure and a low density color drop-out defect.

Most of the customers visiting the PQTS with a PQ issue will find defects in the test pages. Once the user goes to the second layer, the issue matching layer, a web page with several defects is presented (see Fig. 9). As explained earlier, the defects are categorized by their orientation. Therefore, the user identifies the orientation of his/her defect and decides in which category the defect belongs. If the user has difficulty understanding what the categories: “Vertical”, “Horizontal”, and “Other” mean, there is a link which leads to another web page explaining these terms.

Also, if the user is not comfortable with his/her color selection in the initialization layer, he can use the breadcrumb or the links in the left banner to go back to the home page, or with the left banner move directly to the issue matching layer for another color.

To continue with the issue matching stage, the customer chooses that defect which is the best match for his/her issue, and clicks on the image or the defect text description located below the image. This leads to the third layer. There exists the possibility that the user may not find a proper match for his/her issue. Therefore, a link is provided to take the user to another web page with contact information for a CCA. This page also contains a table with a list of dimensions for various rollers in the print mechanism. This information is intented for use with the CCA to diagnose defects that are not included in the issue matching layer.

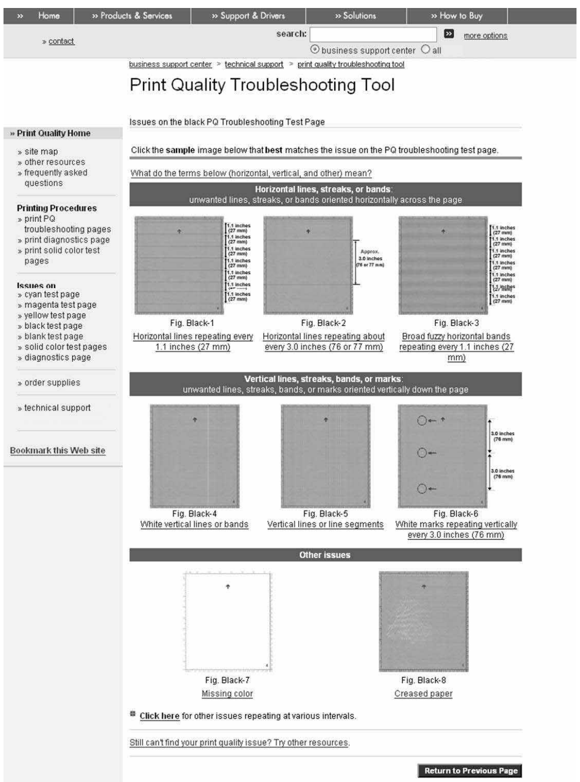

Figure 9. Defect matching layer of the PQTS.

After the customer selects the best defect sample match, he/she advances to the third layer, the troubleshooting layer (see Fig. 10). This layer contains an image of the problem, a textual description of the problem, most likely causes, troubleshooting and suggestions, and a list of recommended parts. At the top of the web page, there is a full size image sample of the defect. Below this image, there are three thumbnails with different versions of the same defect. The user can select any one of the thumbnails and see it maximized. The most likely causes, troubleshooting and suggestions, and the description of the defect are accompanied by hyperlinks with extra information for related tasks. For example, if the diagnostic procedure requires changing the cyan print cartridge, there is a hyper link that leads to the change cyan cartridge procedure. Also there is a "Related links" section in which relevant links are placed, such as ordering supplies if one of the

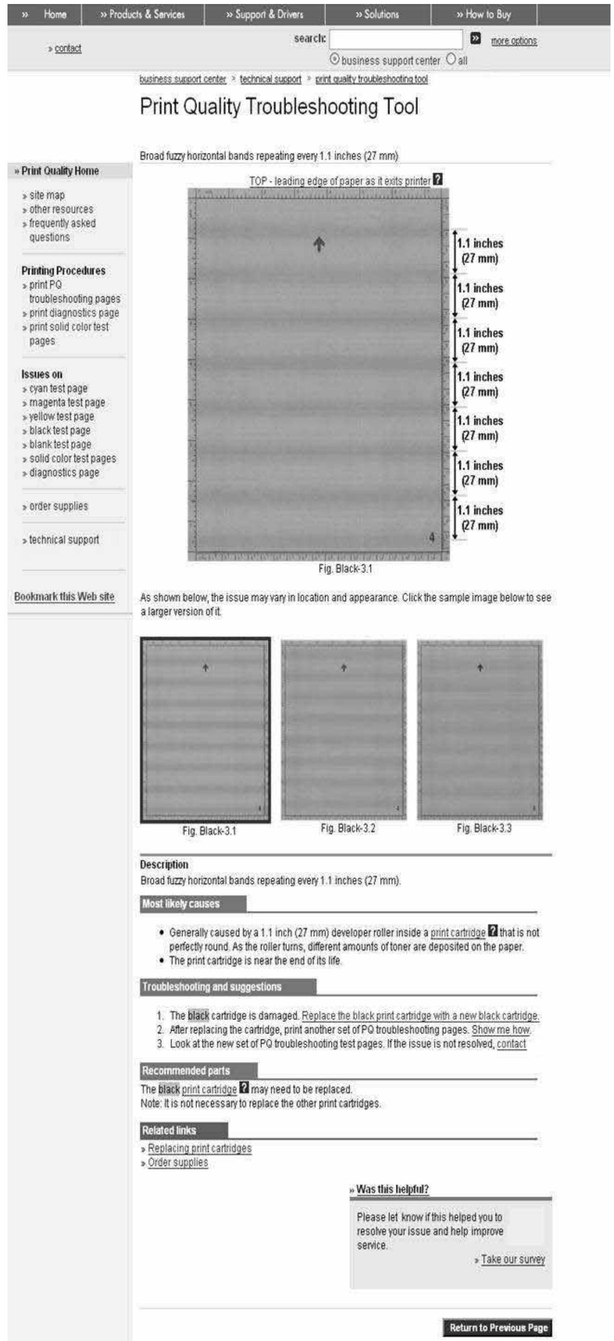

Figure 10. Troubleshooting layer of the PQTS.

most likely causes is an empty cartridge. In the final step of the troubleshooting procedure, the user prints the test pages again and reviews them to verify that the defect has been eliminated. If the issue persists, the contact information for a CCA is provided. Finally, the user can leave his/her feedback in a survey included at the end of the troubleshooting procedure.

Conclusion

Print quality issues are among the most difficult to resolve by the printer manufacturer's support organization. The traditional support model in which the customer works with a call center agent over the phone is ineffective because the agent cannot see the customer's defective printed material; and it is very difficult to describe it accurately in words. Thus, print quality issues can result in unnecessary replacement of parts or unnecessary visits by an on-site technician. To empower the customer to self-solve print quality issues as much as possible is advantageous to both the customer and the manufacturer. The customer gets the problem resolved more quickly with less frustration; and the manufacturer reduces support costs.

We have developed a web-based print quality troubleshooting tool for midrange color laser EP printers. The development process was one of extensive experimentation and revision in order to create a tool that is as straightforward as possible for the customer to use. We found that our initial assumptions regarding how customers would use the site and where they would have difficulty with it were often far from the mark. It was only by repeated subjective evaluation in the context of carefully designed usability experiments and focus group sessions that we were able to expose the errors in our thinking. In addition, the development process was one of continuous review and refinement during regular meetings of the development team.

The final tool that we created consists of three layers: initialization, issue identification, and troubleshooting and resolution. Issue identification is based on the customer printing a set of test pages that are then compared with high quality simulations of possible defects as they would appear on those test pages. The diagnosis proceeds by the customer first identifying the issue color, then the defect orientation, and finally the specific defect itself. All diagnostic and repair procedures are carefully detailed using step-by-step textual descriptions and graphical illustrations. Our experiments suggest that the tool is more effective than the traditional support model involving a call center agent for resolving the print quality issues that the tool addresses.

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