Device Independent Digital Reprographics

Joseph S Czyszczewski *, James T Smith *

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Abstract: While digital copiers enable new reprographics supply chain models, conventional techniques and devices do not allow open and heterogeneous distribution. E-commerce exacerbates this problem by offering immediate and global access. While digital scanning, electronic distribution, and remote printing are practical, bilevel images are used which are not device independent. We describe a high performance technique with superior copy quality, based on two years of research, development, and production, that enables low skill operators to freely distribute copy jobs. This approach integrates common devices with original image quality techniques, culminating in flexible distribution options to support new digital reprographics business models.

Introduction

As organizations increasingly benefit from collaboration and knowledge management, the gap between digital and paper information broadens. The problem is that paper is often not available to the rich collaboration and knowledge management tools that have evolved at the desktop. The challenge is to eliminate the barriers to paper distribution rather than mandating an all-digital workflow. Eliminating the barriers requires an incremental business transformation and a technology evolution.

Fortunately, document solutions are undergoing an evolution where analog devices are being replaced by low cost digital devices. Typically large expensive analog copiers are replaced by smaller inexpensive digital copiers which are increasingly network accessible. At the same time, digital copiers, fax machines, scanners, and printers are also being consolidated into multifunction devices. While this secondary evolution is driven by cost and reliability improvements, it is more significant because it is accelerating the network accessibility of these pervasive devices. Network access is key to the conversion from paper to digital

* IBM Printing Systems

because it allows the device to communicate with other more powerful services to add value to the document.

We describe a system in which paper documents can easily be converted into digital documents and transparently made available to collaboration and knowledge management tools using pervasive network attached office appliances.

Business Transformation

The gap between digital documents and paper documents is large. The issue is that the capabilities at the desktop in the office far surpass the capabilities of traditional paper handling devices, such as copiers and FAX machines. The required business transformation is to move the capabilities of the desktop to traditional paper handling devices, without having to replace the traditional devices. Productivity and competitiveness are improved by providing the functionality of the desktop at the pervasive office appliances and by increasing availability and flexibility.

This system provides the ability to connect pervasive office appliances together to support the application of traditional desktop processing to the paper workflow. Fully integrating the scanning and printing components of office devices with the network infrastructure allows copies to be made remotely to reduce distribution time and cost. Investment protection is improved because adding a scanner component to an existing printer component creates a new copy capability without having to replace or upgrade any of the individual preexisting components. Availability and scalability are improved because any component can scan or print to any other component in the system. The introduction of a digital scanner to the system improves FAX capabilities by supporting double sided high speed FAX. Integration with a directory service allows for the automatic generation of cover sheet information based on the sender and recipients information from the database.

Copy and FAX in many cases can be replaced with e-mail distribution. A key benefit to this system is the ability to send e-mail from a traditional FAX machine without having to replace the traditional device with one that supports e-mail internally. The outgoing e-mail can be further enhanced through the application of additional processes such as OCR without having to license, deploy, and support a traditional desktop OCR application throughout the company.

Secure printing of sensitive documents is possible through integration with an existing employee identification system on the network. Secure print documents are held in the system until the appropriate user is identified to the system and requests a destination device. The recipient can log into the system and be identified through a secure web site and identify the location of the device that should receive the paper document for printing. The secure site is browse-able via a web-enabled wireless device allowing the user to be in any location and receive a secure document at any device.

Technical Challenges

Delivering the business transformation described in the previous section requires common office appliances which are independently network accessible or modular in nature. Devices that include both a scanning and a printing component must allow full integration of each component to the network infrastructure. Integrated digital copiers, for example, that do not allow access to the scanning component of the copier block the ability to provide features such as remote copying, OCR, server based FAX, and scalability.

Traditional devices have closed image-processing paths and are a challenge to the system that needs to be overcome. These closed devices provide output that is often device dependent and are usually dependent on their own output capabilities. For example, low resolution devices such as FAX machines produce 200 dpi bilevel images which are optimized for printing on FAX machines. The problem also exists with high resolution multifunction devices that include image-processing algorithms for high quality output optimized for their print engine. Their output cannot be redirected to a different print engine in another part of the world with the expectation that copy quality can be maintained. The bit map that the device generates for output is device-dependent and relies on the characteristics of its own print engine. Typically this results in a dramatic loss in quality when the bit map is sent to a different device for printing. Fortunately, most large organizations work to standardize their purchasing in order to reduce costs, which limits the variety of device dependent images, providing some manageability to the problem.

Optimizing end-to-end solution performance across a variety of open scanning and printing components requires some unique solutions. Standard printers are not optimized for full-page image data and suffer performance problems in a copier environment. Document scanners are not optimized for the necessary image quality required to please customers in a copier environment.

Providing a walkup user interface, or worse, a web enabled interface for wireless devices, to the rich capabilities required across a wide range of user skill levels is another key technical challenge. Additionally each component in the system may have its own user interface that further compounds the problem.

The final technical challenge is custom integration with each organization's infrastructure. Traditional standalone devices mandate the use of their capabilities instead of integrating with existing infrastructure. For example, a FAX machine has a speed dial feature that requires users of the FAX machine to reenter every FAX number that they regularly dial at each machine used. This approach often fails because a typical FAX machine is shared in the organization among a large number of individuals and each has their own set of numbers that they frequently dial. Some FAX machines solve part of the problem by supporting a large number of speed dial entries. However, this causes each person to hunt for their number. This and other factors lead to the speed dial feature often going unused. Through integration with an existing infrastructure it is possible for the system to provide individuals with an environment that is unique to them. Dynamic creation of FAX cover sheets where all recipient and sender information is automatically entered by the system on the users behalf is possible through integration with an existing infrastructure. The information that the user requires is available to them when they need it at every device without the need to manage it at each device.

Solution Architecture

In order to meet the technical challenges identified above in the modern office environment, it is necessary to create an open system that is easily adapted to new environments. This requires a fundamental modularity and openness in the system design. Also, the solution requires two system interfaces. One system interface is similar to that of a traditional multifunction device with integration points for services provided by the network infrastructure. The second system interface is a back office network server that provides connections to traditional pervasive office appliances and adds the system's functionality to them without requiring their individual replacement. This interface enables a workplace transformation from the traditional isolated office devices to the modern network attached system with the full range of functionality to the office worker.

The use of open interfaces and standard output formats is necessary for the system to be able to work with any device on the network but it is not sufficient. The inherent openness of the system requires it to be designed with a lack of output device knowledge as a design guideline. Being open to a variety of document file formats and scanner interface standards is important, but more is required to support devices such as FAX machines which are pervasive and used to support both input and output. In order to include FAX machines into the set of system enabled devices requires the system design to be modular at a very granular level. FAX implies the arrival of a low quality digital image that is nearly inextricably linked to the output device for which it is intended. By providing a broad and flexible set of low level modular components that can be arranged to fit the requested workflow, it is possible to take low quality digital into the system and output true text that can be e-mailed, translated or printed.

The use of standard scanner interfaces, such as ISIS and TWAIN, for input from scanning devices supports a wider range of devices which increases the flexibility of the system compared to hardware integration of specific scanning devices.

Output formats such as PDF and PostScript provide building blocks for designing portable output files that can be used on any output device. Even still the system must be cognizant of device dependency and strive to avoid generating image files that contain device dependent bit maps.

Device dependent bit maps must be used at some level in the system in order to attain the highest level of image quality and performance. The key is to maintain the image as device independent for as long as possible in the system. In order to ensure the highest quality output for any given device the system provides the ability to calibrate its output for any given output device in the system. When a new output device is added to the system it can be calibrated to a standard with a supported input device in order to achieve the highest possible quality.

Image Processing Architecture

All image processing components in the system are modular. This allows them to be connected in a sequence of actions commonly known as a pipe. A pipeline architecture allows the system to maximize first-page-out time as well as overall performance. Performance is crucial to success in a copier environment where users expect copies to be created within a short time. Streaming of data through a pipe from a scanner to a printer while performing cleanup actions inside the stream makes this short time constraint and full performance an attainable goal. The pipe architecture allows the system to remain open, while adhering to a well defined interface, and perform inside strict performance constraints.

There is no constant to performance and flexibility. We have found that users are tolerant of performance slow downs when using features of the system that provide function that was not previously possible. Walkup OCR combined with e-mail is an example of this type of new feature that is free from the typical performance constraints. Users are more tolerant of the time consuming OCR process because it was not previously possible and provides significant value because it eliminated the need to re-key a document. Copying pages, on the other hand, is subject to strict time expectations. We found that a short first-page-out time for copying is a requirement among most copier users.

The use of a pipeline of data allows the system to place only necessary components in the code path at scan time in order to optimize performance when the user requires a low first page out time as well as introducing additional function such as OCR into the pipe when it is required. The modularity of the pipeline allows new function to be added to the system incrementally without having to stop the system and replace old components to add new function.

Modularity and pipe lining allow the system to become a background application that exists on the network as a server providing functions that can be configured to meet the organization's needs when they arise. The interface to the system becomes a means of communicating what is required, where, and potentially when. The system then takes that information and constructs a custom pipe to meet that user's requirements as they occur.

There are several user interfaces to the system. The first is a walkup user interface that is used to make copies and send e-mail at high speed and with the highest fidelity. The second is a desktop user interface for linking desktop digital output to secure output devices. The third is the wireless web based user interface for communicating with traditional devices that are not network enabled or do not have a user interface with the extensions required to access network services. Using a web-phone or wireless PDA, a user can communicate with the system and inform it that a document is coming and what operations should be performed on that document. For example, a user with a wireless PDA can request that the system OCR a French document sent from a FAX machine, translate it from French to English, and then present the resulting document on-line to the user via their PDA as well as faxing the English copy back to their FAX machine. All of this is possible through the system due to its modular integration with network services and available devices.

The amount of processing that can be handled by other devices increases as the other devices network communication abilities increase. In the FAX example an analog phone line is the least common denominator and the early parts of the transmission happen through that analog phone line. Using a network accessible scanner or similar input device, the amount of integration into the system increases to where the user is directly controlling the device through their wireless connection to the system.

Image Processing Algorithm

Using a pipeline architecture enables the system to insert custom filters to perform image processing techniques. The system uses a technique for detecting the frequency of halftone originals and using an optimized filter for eliminating that halftone frequency. This is hampered by the need to distinguish between image areas with low frequency and text areas with no frequency. Normally, this requires the entire image in order to perform image segmentation, so that only image areas would be filtered. By coupling this frequency analysis technique with a pipeline architecture it becomes possible for the system to automatically insert the filter required for descreening into the pipeline as it is needed, creating an auto segmentation for the descreening process. By performing the descreening and subsequent screening in this way, images can be cleaned and customized for any output device that the system is aware, without any user intervention.

The effective solution is to provide a special kind of segment to the pipeline that takes gray scale data as input and probes it for image data vs. text data. This pipe segment has the capability to split the pipe into two pipes in order to apply distinct processing to each of the data paths. This also requires the ability to merge the pipes down stream from the descreening process. The text stream travels through a dynamic thresholding process that generates clean text to be rendered at the end of the process. While the image data is broken out and sent to the descreening filter and then subsequently re-screened for the new output device. Following the processing of this sub-path the data is inserted back into the text, or bilevel, stream for output.

This process has two challenges, splitting the pipe at the appropriate location and seamlessly merging the pipes. Splitting the pipe requires the system to be able to effectively cut out subsections of lines of data in order to prevent passing text to the descreening process. Likewise the merge process requires the ability to merge lines of data at offsets in the data stream in order to replace the lines that were cut out through the splitting process. The described mechanism is currently limited to only convex polygons. A future development effort is under way to be able to smoothly break up concave image areas into sub-image areas and seamlessly merge those sub-images into a continuous halftone image.

This automatic segmentation and descreening method enables the copier to achieve superior reproduction of bilevel halftone data. It is also the key solution to the problem or repurposing image data from low resolution devices such as FAX machines or high resolution devices such as multifunction devices with device dependent image processing. A similar mechanism is being investigated for color in order to automatically descreen color halftone image data and preserve text quality. Additionally the pipeline allows for the inclusion of OCR filters for text data there by increasing the quality of text reproduction and supporting the transmission of clean device independent gray scale or color image data with OCRed text data.

Conclusion

The simple objective of this system is to allow users to enjoy the level of productivity and value with hard copy documents that they enjoy with digital documents. This enables business transformation by changing the way people work. The key is to turn pervasive office appliances into edge-of-network devices which are fully integrated with the enterprise collaboration and knowledge management infrastructure. Monitored use of this system demonstrated, for example, an immediate shift from FAX and copy distribution to faster and less costly e-mail distribution of hard copy documents.

This system also extends the reach of collaboration and knowledge management tools to employees without sophisticated desktop application skills or access and those who do not work with PCs regularly by providing a simple walk up user interface. Similarly, this solution serves the growing mobile workforce by enabling desktop-like tasks at the "copier". Again, monitored use of this system demonstrated the usefulness and acceptance of sophisticated applications such as OCR by general walkup office users.

One challenge was to logically separate input and output components of traditionally monolithic offerings and reconnect them with performance, image quality, and simplicity. Monitored use of this system demonstrated user acceptance of the modular architecture even with copying, which is the most demanding application and in competition with traditional monolithic copiers by general walkup office users.

Another challenge was to support rather than compete with existing traditional office devices and deliver an affordable system. Business case and ROI models demonstrated that supporting existing devices strengthened the models. Also, monitored use of this system demonstrated support for workflows across distributed devices in cases where redundancy was provided to avoid single points of failure and additional flexibility was gained.

The ongoing challenge is organizational and applies to multifunction devices in general. The issue is that different organizations own the strategy, budget, deployment, and support of the various devices and applications represented by a consolidated and integrated system such as this. Getting these diverse organizations to pool budgets and coordinate control is difficult. The challenge is worth pursuing because, as the deployment experience has proven, the rewards in end user productivity and competitiveness are compelling.

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