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Research Report

Output Readability Comparison of a SXGA Display to a Printer

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Introduction

Recently the Flat Panel Display Technologies group at Watson Research Laboratory has produced a 1280x1024 pixel panel, code named Monet, whose diagonal width is 10.5”. Much has been discussed about how at this pixel density, which is 157 pixels per inch, the image quality approaches that produced by modern printers whose resolution ranges from 300 to 1200 dpi (dots per inch). For some time, we have been observing that for many text documents, the same document has more readability, or at least better appearance, when it is printed on a printer as compared to how it displays on either the Monet screen or any other 1280x1024 display. For a text document, at least two general parameters govern its readability on a display or paper medium. The first parameter is how properly each letter can be rendered on the display medium. The parameter is chiefly determined by the number and density of pixels available for use in rendering the letter. The second parameter, which is unique to proportionally spaced font, is the correct spacing (kerning) of each letter within a word. This parameter is controlled by the discrete number of pixels available to use when spacing out the letters to form a word. I have found empirically that the second parameter, the correct spacing of letters within a word, is responsible for much of the perceived differences between output viewed on any 1280x1024 display including Monet, and that from a printer. In this report, I focus entirely on this second parameter, which is independent of the display geometry and thus can easily be studied in a paper document. I show that a printer, even printing at just 300 dpi, has many more dots available to space each letter than a 1280x1024 display. I also show that if one adjusts either the printer resolution in dots or the display resolution in pixels so that they are comparable, then the output is similar on both media. This result indicates that more pixels may be needed for visualizing output on the display screen so that it will produce output which rivals that of modern printers.

Experimental

A **list3820** file of the IBM Medical Claim form was obtained. The file was converted to a PostScript file using the IBM internal package **preps** available on the **txttools** disk. The conversion to PostScript went fine except that the IBM Logo could not be converted. The PostScript file was next converted to a PDF (Portable Document Format) by using the **Distiller** program which is part of Adobe Acrobat Pro version 2.1. The PDF file was viewed and printed with the **Adobe Acrobat** software version 2.1 (available for downloading from Adobe), along with directly printing the original PostScript file. Both printing methods yielded similar results.

Screen captures of the Adobe Acrobat output were performed using the **Hijack** screen capture utility. The screen was captured in PCX format and then embedded into this document. This document was printed on a **Lexmark Optra PostScript** printer at 1200 dpi .

A **IBM LaserPrinter 4039 Series by Lexmark** printer was used to create the printed images which were later scanned into this document. It had a default print resolution of 300 dpi. A generic PostScript printer with resolution of 300 dpi was setup on Windows 3.1 to print postscript output to a file. This output was later printed on the 4039 printer. The printed output was scanned using a **Visioneer PaperPort Vx** scanner. The output was scanned at 400 dots per inch resolution with 1 bit (black or white) depth for each dot.

A **Diamond Viper Pro** video card with 4 MBytes of video RAM running in resolution of 1280x1024 pixels, each pixel in 24 bit true color mode, was used to visualize and capture the data.

<u>Results and Discussion</u>

A PostScript converted version of the IBM Medical Claim Form was used in this experiment. Several other PostScript files were also examined and results were the same on all of them. The Medical claim form was only chosen for its wide recognition within IBM. This PostScript file was converted to a PDF file. PDF file format was developed by Adobe so that the output viewed by an Acrobat Reader would look the same as when the document is printed. One can check that this is indeed the case by examining the File->Document Info->fonts menu item in the Acrobat Reader. The information for our document is shown below:

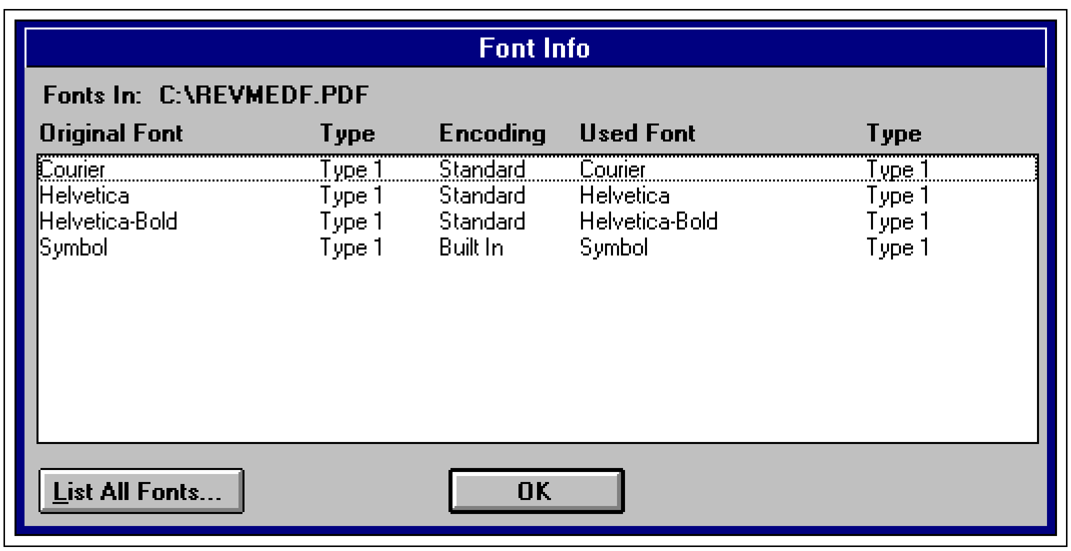
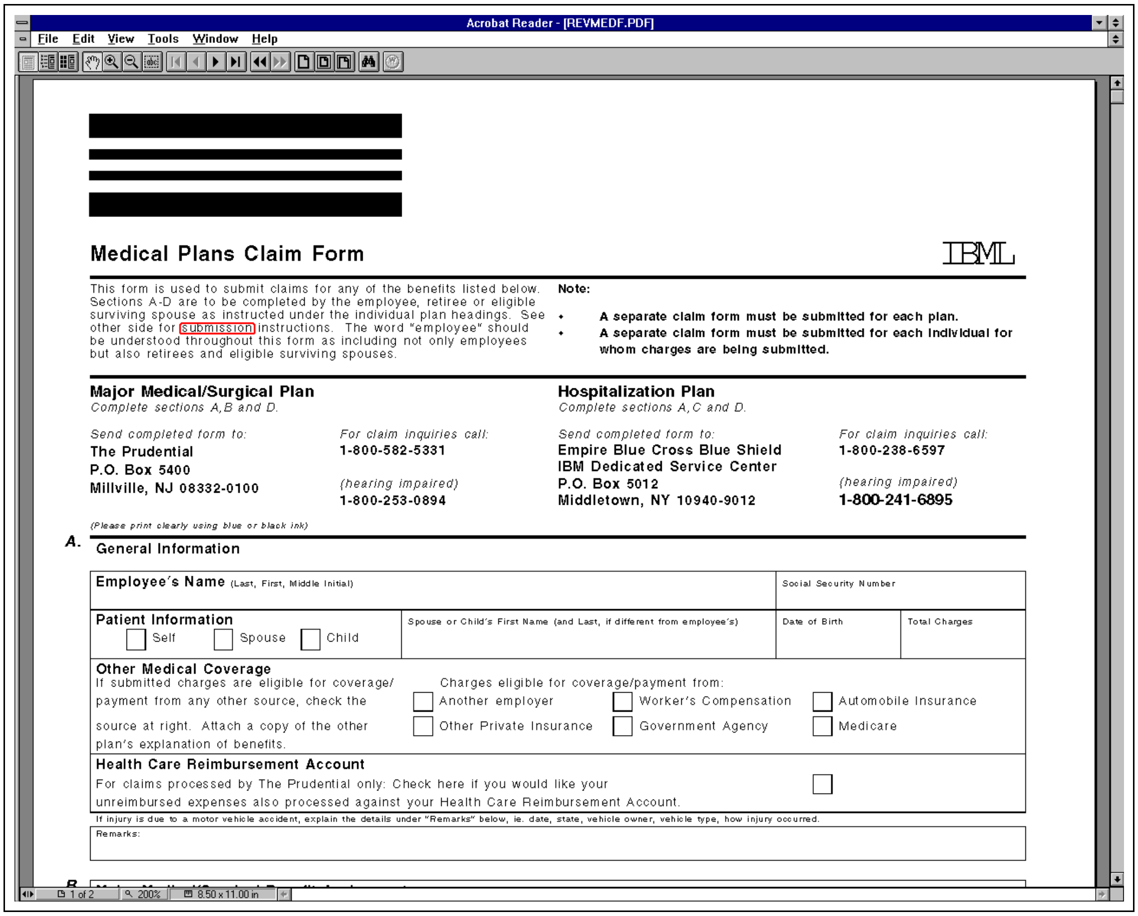


Figure 1: List of Fonts used by the Adobe Acrobat Reader to display the IBM Medical Form.

For our document four fonts have been used and they are all type 1 fonts and the same for both the original and used font. Type 1 fonts are scaleable as opposed to the older type 3 fonts which are bit mapped, insuring that the output can be properly scaled, viewed and printed.

We next show a screen capture of the output from the Adobe Acrobat viewer of the top part of the front side of this form. The screen size is 1280x1024 pixels, and was viewed at 200% magnification. This magnification was chosen since it displays output such that when shown on the Monet display, the font size is the same as that produced when the document is printed on a 8.5x11 sheet of paper. Thus this magnification is a good readability test for the Monet display.


Acrobat Reader - [REVMEDF.PDF]

File Edit View Tools Window Help

Medical Plans Claim Form IBM

This form is used to submit claims for any of the benefits listed below. Sections A-D are to be completed by the employee, retiree or eligible surviving spouse as instructed under the individual plan headings. See other side for submission instructions. The word "employee" should be understood throughout this form as including not only employees but also retirees and eligible surviving spouses.

Note:

- **A separate claim form must be submitted for each plan.**
- **A separate claim form must be submitted for each individual for whom charges are being submitted.**

Major Medical/Surgical Plan
Complete sections A,B and D.

Send completed form to:
The Prudential
P.O. Box 5400
Millville, NJ 08332-0100

For claim inquiries call:
1-800-582-5331

(hearing impaired)
1-800-253-0894

Hospitalization Plan
Complete sections A,C and D.

Send completed form to:
Empire Blue Cross Blue Shield
IBM Dedicated Service Center
P.O. Box 5012
Middletown, NY 10940-9012

For claim inquiries call:
1-800-238-6597

(hearing impaired)
1-800-241-6895

(Please print clearly using blue or black ink)

A. General Information

Employee's Name (Last, First, Middle Initial)			Social Security Number	
Patient Information ☐ Self ☐ Spouse ☐ Child	Spouse or Child's First Name (and Last, if different from employee's)		Date of Birth	Total Charges

Other Medical Coverage
If submitted charges are eligible for coverage/payment from any other source, check the source at right. Attach a copy of the other plan's explanation of benefits.
Charges eligible for coverage/payment from:
☐ Another employer ☐ Worker's Compensation ☐ Automobile Insurance
☐ Other Private Insurance ☐ Government Agency ☐ Medicare

Health Care Reimbursement Account
For claims processed by The Prudential only: Check here if you would like your unreimbursed expenses also processed against your Health Care Reimbursement Account. ☐

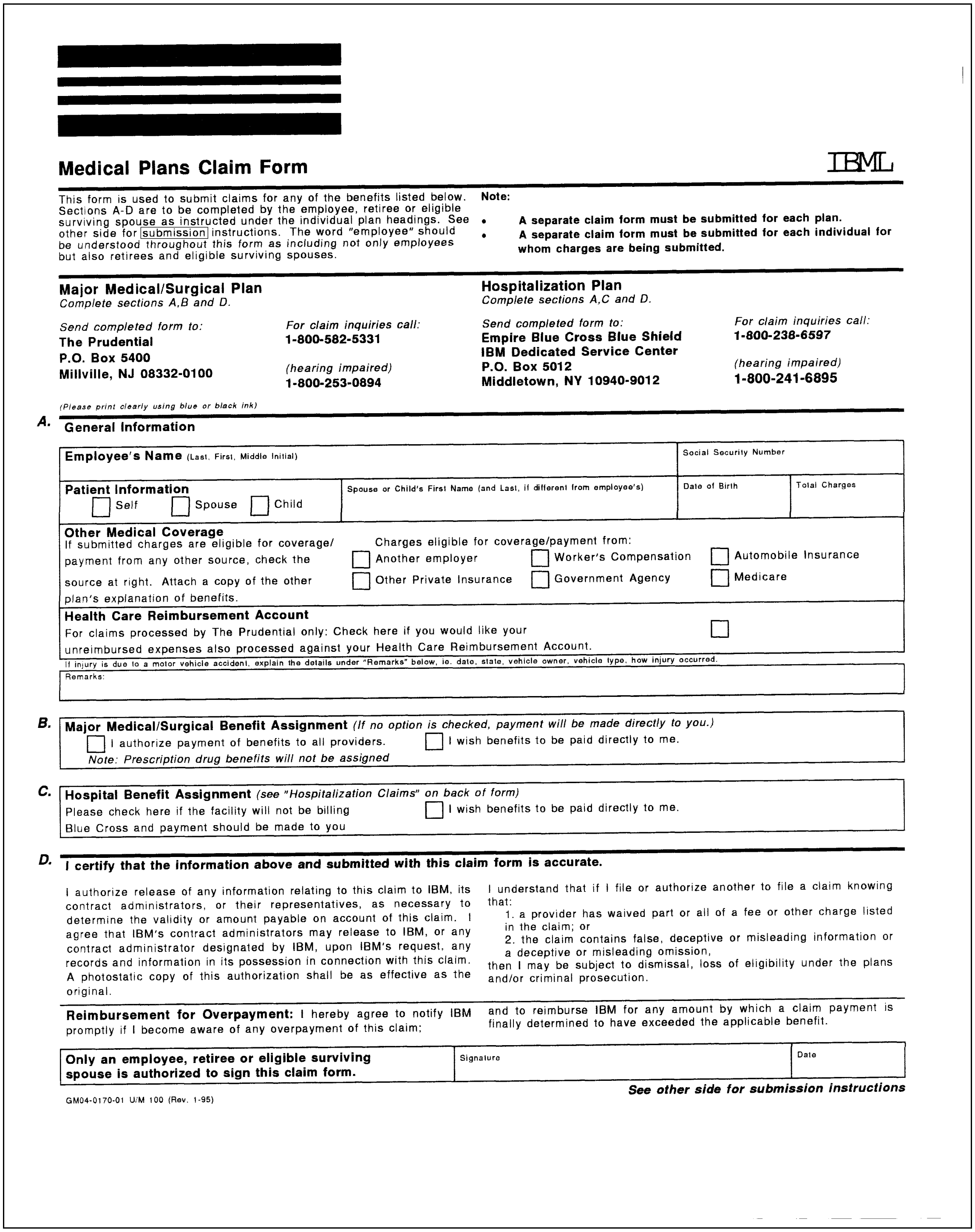
If injury is due to a motor vehicle accident, explain the details under "Remarks" below, ie. date, state, vehicle owner, vehicle type, how injury occurred.

Remarks:

1 of 2 200% 8.50 x 11.00 in

Figure 2: Screen capture of the SXGA screen on which the IBM Medical Form was viewed in the Adobe Acrobat Viewer.

If one focuses in on the screen capture output, one can see that for some words the spacing between letters in the word does not appear to be correct, though the font is a proportionally spaced font. As a concrete example, focus in on the word **submission** which is circled and found on the fourth line, fourth word in, of the section under **Medical Plans Claim Form.** The most glaring problems is that the u appears to be incorrectly spaced between the s and b. However if I print the Medical Plans claim form document on the 4039 postscript printer the letter spacing prints correctly as can be seen in Figure 3 below where I show a scanned image of the output from this printer.



[redacted]

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(Please print clearly using blue or black ink)

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Patient Information ☐ Self ☐ Spouse ☐ Child | Spouse or Child's First Name (and Last, if different from employee's) | Date of Birth | Total Charges

Other Medical Coverage
If submitted charges are eligible for coverage/payment from any other source, check the source at right. Attach a copy of the other plan's explanation of benefits.

Charges eligible for coverage/payment from:
☐ Another employer ☐ Worker's Compensation ☐ Automobile Insurance
☐ Other Private Insurance ☐ Government Agency ☐ Medicare

Health Care Reimbursement Account
For claims processed by The Prudential only: Check here if you would like your unreimbursed expenses also processed against your Health Care Reimbursement Account. ☐

If injury is due to a motor vehicle accident, explain the details under "Remarks" below, ie. date, state, vehicle owner, vehicle type, how injury occurred.

Remarks:

B. Major Medical/Surgical Benefit Assignment *(If no option is checked, payment will be made directly to you.)*
☐ I authorize payment of benefits to all providers. ☐ I wish benefits to be paid directly to me.
Note: Prescription drug benefits will not be assigned

C. Hospital Benefit Assignment *(see "Hospitalization Claims" on back of form)*
Please check here if the facility will not be billing Blue Cross and payment should be made to you ☐ I wish benefits to be paid directly to me.

D. I certify that the information above and submitted with this claim form is accurate.

I authorize release of any information relating to this claim to IBM, its contract administrators, or their representatives, as necessary to determine the validity or amount payable on account of this claim. I agree that IBM's contract administrators may release to IBM, or any contract administrator designated by IBM, upon IBM's request, any records and information in its possession in connection with this claim. A photostatic copy of this authorization shall be as effective as the original.

I understand that if I file or authorize another to file a claim knowing that:
1. a provider has waived part or all of a fee or other charge listed in the claim; or
2. the claim contains false, deceptive or misleading information or a deceptive or misleading omission,
then I may be subject to dismissal, loss of eligibility under the plans and/or criminal prosecution.

Reimbursement for Overpayment: I hereby agree to notify IBM promptly if I become aware of any overpayment of this claim; and to reimburse IBM for any amount by which a claim payment is finally determined to have exceeded the applicable benefit.

Only an employee, retiree or eligible surviving spouse is authorized to sign this claim form. | Signature | Date

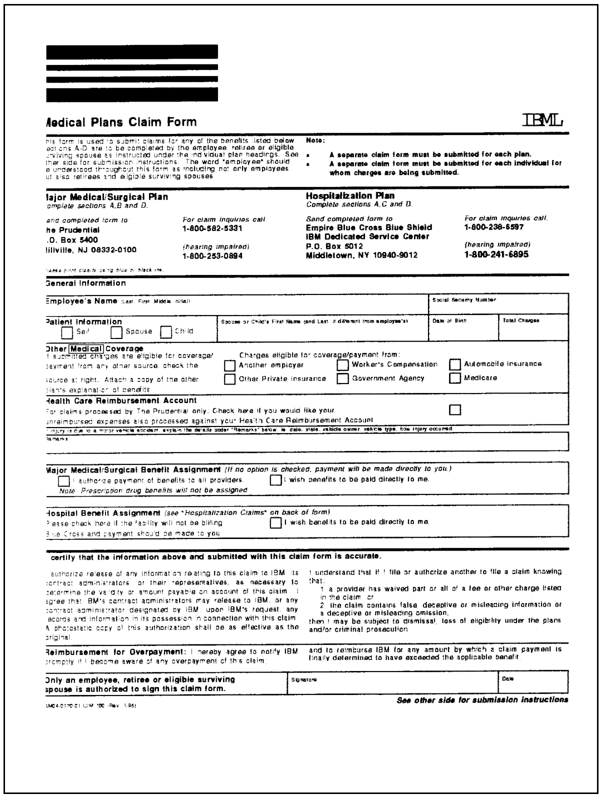
See other side for submission instructions

GM04-0170-01 U/M 100 (Rev. 1-95)

Figure 3: Scanned image of the IBM Medical Form which was printed on a 4039 postscript printer at 300 dpi resolution.

Note that the document which you are reading has been printed at 1200 dpi and thus it is the screen capture resolution and not the printer which accounts for the incorrect spacing seen in Figure 2. Moreover this incorrect spacing matches that observed on any 1280x1024 display screen including Monet.

This incorrect spacing phenomenon can be explained, if one considers that at 300 dpi a 8.5 inch width paper has 2550 dots to print with. This amount is approximately double the 1280 pixels available for use on a 1280x1024 display screen. Thus the printer, even at 300 dpi and certainly at 600-1200 dpi which is currently available on recent printers, has may more dots for spacing between letters than a 1280x1024 display screen. One can test this hypothesis by printing the IBM Medical Claims form on the 4039 printer at 48%, which gives the printer as few dots to print on for the width of the document as the screen has pixels to display on. This ratio was arrived at by measuring both the printer output and the display screen which takes into account that the Acrobat program when displaying the document uses a small portion of the display screen for its borders. In Figure 4 below I show the output printed in this fashion.



Medical Plans Claim Form IBM

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Note:

- **A separate claim form must be submitted for each plan.**
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Please print clearly using blue or black ink.

General Information

Employee's Name (Last, First, Middle Initial) | Social Security Number

Patient Information ☐ Self ☐ Spouse ☐ Child | Spouse or Child's First Name (and Last, if different from employee's) | Date of Birth | Total Charges

Other Medical Coverage
If submitted charges are eligible for coverage/payment from any other source, check the source at right. Attach a copy of the other plan's explanation of benefits.
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☐ Other Private Insurance ☐ Government Agency ☐ Medicare

Health Care Reimbursement Account
For claims processed by The Prudential only: Check here if you would like your unreimbursed expenses also processed against your Health Care Reimbursement Account ☐

If injury is due to a motor vehicle accident, explain the details under "Remarks" below, ie. date, state, vehicle owner, vehicle type, how injury occurred.

Remarks:

Major Medical/Surgical Benefit Assignment *(If no option is checked, payment will be made directly to you.)*
☐ I authorize payment of benefits to all providers. ☐ I wish benefits to be paid directly to me.
Note: Prescription drug benefits will not be assigned.

Hospital Benefit Assignment *(see "Hospitalization Claims" on back of form)*
Please check here if the facility will not be billing Blue Cross and payment should be made to you ☐ I wish benefits to be paid directly to me.

I certify that the information above and submitted with this claim form is accurate.

I authorize release of any information relating to this claim to IBM, its contract administrators, or their representatives, as necessary to determine the validity or amount payable on account of this claim. I agree that IBM's contract administrators may release to IBM, or any contract administrator designated by IBM, upon IBM's request, any records and information in its possession in connection with this claim. A photostatic copy of this authorization shall be as effective as the original.

I understand that if I file or authorize another to file a claim knowing that:
1. a provider has waived part or all of a fee or other charge listed in the claim, or
2. the claim contains false, deceptive or misleading information or a deceptive or misleading omission,
then I may be subject to dismissal, loss of eligibility under the plans and/or criminal prosecution.

Reimbursement for Overpayment: I hereby agree to notify IBM promptly if I become aware of any overpayment of this claim, and to reimburse IBM for any amount by which a claim payment is finally determined to have exceeded the applicable benefit.

Only an employee, retiree or eligible surviving spouse is authorized to sign this claim form. | Signature | Date

See other side for submission instructions

Figure 4: Scanned image of the IBM Medical Form which was printed on a 4039 postscript printer at 300 dpi resolution printed in 48% of full page size.

In Figure 4, much of the smaller text does not display well due to the scanner resolution limitation. However, if one ignore this and focus instead on some of the larger text, one notices that some of the letters are incorrectly spaced. For example focus on the word **Medical** in the section title of **Other Medical Coverage** which has been highlighted.

The phenomenon of incorrect kerning seen in Figure 4 is very similar to the incorrect kerning seen in the screen capture shown in Figure 2 of the SXGA screen.

Another method for testing this hypothesis is to magnify the document in the Acrobat Reader so that it displays at 417% magnification. This magnification is just the 100/48 ratio of the 200% magnification screen grab shown above and ensures that the same number of pixels are available to the display screen as to the document printed at 300 dpi shown in Figure 3. The screen grab at this magnification is shown below:

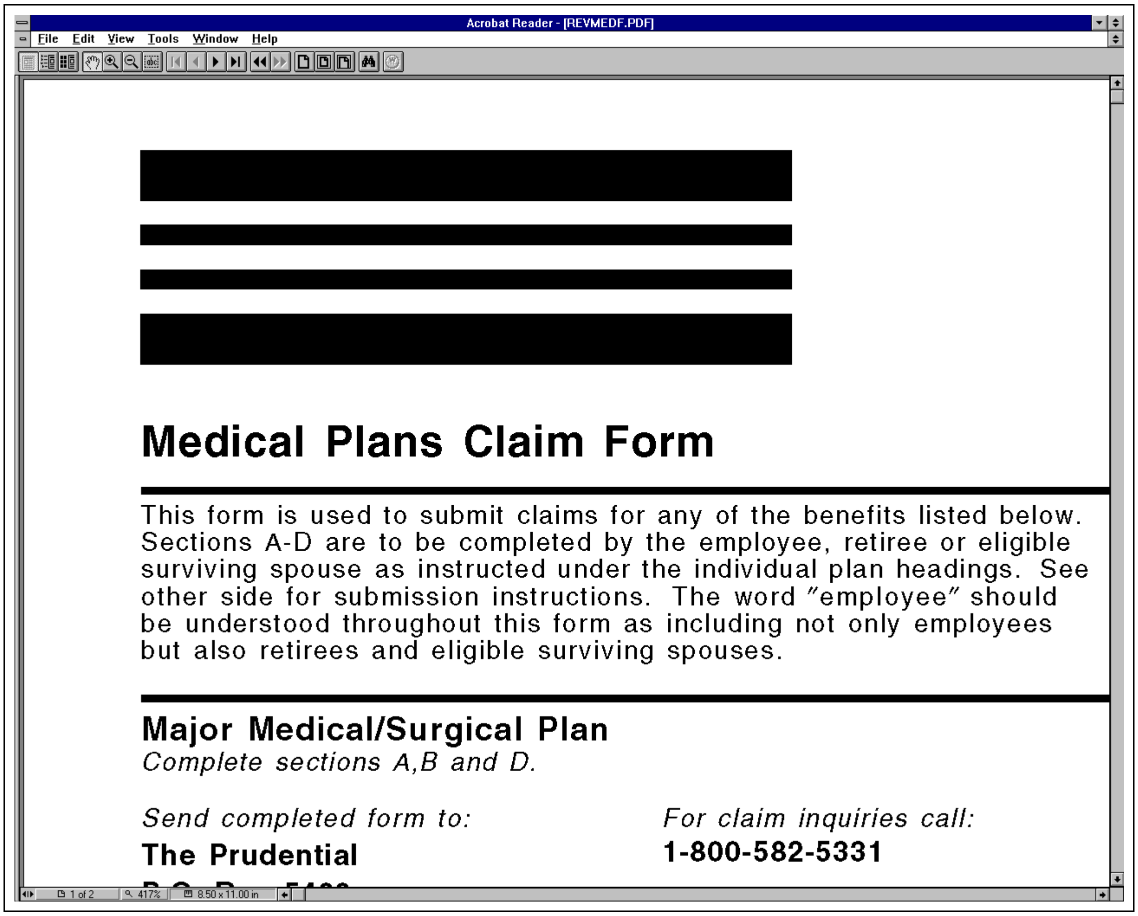

Figure 5: Screen capture of the SXGA screen on which the IBM Medical Form was viewed in the Adobe Acrobat Viewer viewed at 418% magnification.

Again, as in Figure 3, the full page printout of the medical form, the spacing between words is much better.

I examined the effect of manually adjusting the kerning between letters in a text string. I used **CorelDraw** Version 4.0 to display the word **submission** in 13 point Helvetica font on a 1280x1024 **CorelDraw** worksheet. I observed that the spacing between the u and b of this word was not esthetically pleasing. I adjusted the kerning between the u and b such that the b was moved only one point towards the m.   A screen capture of the **CorelDraw** screen appears below with the manual kerning adjusted word below the **CorelDraw** generated word. Though, it is debatable whether this small change has esthetically improved the word, this exercise does show the complexity of choosing the correct spacing between letters when the media resolution is limited.

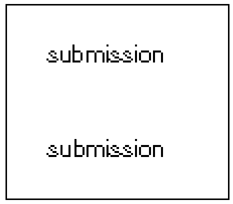

Figure 6: Screen capture of the CorelDraw screen of the word **submission** normally generated by CorelDraw (top) compared to that obtained by manually adjusting the kerning of the word (bottom).

It should be noted that other techniques exist, though I have not tried them for our Monet display, but which have the potential for improving the appearance of text images relative to those seen on printers without resorting to increasing the number of pixels. For example, color displays when displaying black and white text images have the potential use of many gray scale levels. By judiciously using these gray scale levels, in a technique called anti-aliasing, lines and thus letters can be caused to appear slightly shifted. Another technique would be intelligently choosing which subpixels to use for displaying a white or black pixel. Since the Monet LCD display is composed of alternating red, green, and blue subpixels, a judicious choice of which group of subpixels to use for displaying a black of white pixel will shift the pixel by either 1/3 or 2/3 of the pixel width. The above techniques, however are image and content dependent and might not be practical for a general use display.

Conclusions

In conclusion I have shown why the output seen on a 1280x1024 display screen, like the Monet TFT/LCD display has some words which are not correctly spaced, though the document printed on modern day printers prints correctly spaced. I have shown that this phenomenon is directly related to the fact that fewer pixels are available for spacing between each proportionally spaced font letter than in printing it. I have proved this by both printing at the same resolution of the display screen and by visualizing the font of the display screen at the same resolution as the printer. Though 1280x1024 and 150 pixel per inch resolution certainly makes the quality of many font letters rival that of printed output, in order to achieve better spacing between proportionally spaced font letters, this result indicates that more pixels would be needed.

Acknowledgments

I would like to acknowledge many helpful discussions and input to this report from Paul Alt, Kevin Warren and Bob Wisnieff.   I would also like to thank Kevin

Warren for both his technical and grammatical corrections while reading various drafts of this report.