Usage of Media Sensing in Printers

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Abstract

While printers are already very technologically advanced, companies are still continuously striving to improve their products. Through a summer internship at HP with the Writing Systems team, I was able to research an aspect that may be used to add extra aspects to products in production. The goal of this research was to determine whether using the Gaz sensor, which can detect different light responses, can be used to determine what media is being printed on as to determine the correct print mode. This was done through several tests over a period of two months, involving scanning various medias with Gaz sensors and analyzing data that resulted from these tests. Media sensing is not an entirely new concept, but the Gaz sensors were prototype sensors that had been recently developed, and to use these for media sensing would mean an opportunity to use components for not just a single purpose, and thus lessening the amount of parts necessary.

Usage of Media Sensing in Printers

Ever since there was the written word, there was also the desire to reproduce it. First developed centuries ago, printing has been a convenient and practical way of preserving and replicating knowledge in large quantities. While there was contact across earlier civilizations, many groups seem to have developed printing almost independently. Seeing as how common they are, printers are an essential part of life that are very easily overlooked. It's a part of almost everyone's daily lives, and it's undeniable that they're useful. Even with the negative impacts they have on the environment, the main focus of development is always on improving the functionality and efficiency of printers.

Historical Overview

The printed word has had a consistent presence in civilizations across history, developing wherever and whenever there was a need for mass reproduction of some text or image. The first type of printing that was actually used on a paper medium was woodblock printing, originating in East Asia between the 4th and 7th century. It was used by Buddhists to produce religious texts, then quickly adapted and used as an art form (Salter, 2001). Movable type was the next major printing method developed in the 11th century in China to print books. Instead of a single block, the components of a document were able to be moved around, as the name suggests (Needham, Ling, 1962).

The movable type system was also developed in Europe by Johannes Gutenberg in Germany, seemingly separate from the print developed in China. While these printing systems had already been used for centuries in Asia, Gutenberg's printer was developed in the 15th century. The press he developed expanded rapidly and spread throughout Europe while continuing to be streamlined and improved.

Typewriters, which were first seen in 1874, were similar to movable type printers, but much more accessible (Cortada, 1993). Instead of moving blocks on a large press, the user would type out the words on a set of keys, which would strike an ink ribbon against paper to print words on the paper.

In the 20th century, the computer printer started being developed, originating from a dry printing technique invented by Chester Carlson. It used electrophotography, also known as Xerox, which would later be developed into laser printers, one of the many common printing methods used today (Bellis, 2017). The first laser printer was also developed at the Xerox Palo Alto Research Center in the mid 20th century. However, the first printer to have a place in the home and set printers on a road to becoming an almost necessity in any household was an inkjet printer developed by Hewlett-Packard in the 1980s.

Current Trends and Practices

Modern printers are used for a wide variety of functions, and different printing methods have been developed for various functions. There are a couple printing technologies that are commonplace in modern printers, including toner-based printing, inkjet printing, solid ink printing, thermal printing, dye-sublimation printing, digital printing, and even 3D printing. All of these are fairly modern, given the scale of how far back this art goes.

Even though printing is constantly being streamlined, the demand seems to not be on the method itself, but instead to make the process of something being printed easier and more consistent. This is achieved in most modern printers through the use of sensors. The sensor most commonly used in industries today are self-contained sensors that use LED lights, with the LED also functioning as the light sensor (Hymel, 2016). Diffuse sensors can detect the edges of paper, which lets the printer know how big the image it's scanning is. With how versatile sensors can be, they can also be used to detect both how glossy paper is and how thick it is, which can help determine what color maps to use when printing, since medias with different gloss levels require different amounts of ink.

Controversies and Debates

While no one would think to argue on the utility and convenience of printers, their sustainability leaves much to be desired. Everything about printers, from the machine itself to the materials it uses, leaves a concerning amount of waste. Modern printers are made of many materials in addition to plastic, such as the metal in the wiring, circuitry, etc. They also contain traces of the ink that was used in them, which also contain many toxic chemicals. One example of such a site is Guiyu, in Guangdong Province of China, where a study was done on the pollution in the area and sources of that. The study found that there were many persistent toxic contaminants that had spread throughout the environment, and that printer roller dump sites had almost two times as high a concentration of pollutants as Canadian Environmental Quality Guidelines deem acceptable (Cai, Leung, & Wong, 2005). Although printing facilities are not major sources of ozone according to the United States Environmental Protection Agency (EPA), they emit volatile organic compounds, which lead to ozone.

Besides the machinery of a printer, there's also the issue of printing inks. Printers can contribute to contamination in electronic waste dumping sites, but the ink itself also has many components containing various toxins and heavy metals. In companies that use ink regularly, printer ink cartridges must be disposed separately from other waste because they've been contaminated with high concentrations of ink and may have traces remaining, since many ink cartridges are changed when there is still some ink remaining.

Electronic waste is already an extremely prevalent problem, and printers are a major part of this issue. Besides that, there's also the issue of paper waste. When considering what usually gets printed in one's daily life, a large portion of what was printed could be redistributed digitally, and many things are printed just to be disposed of not long after. According to an article published by ImageOne, a printing company, the average office worker prints 10,000 pages per year (Reardon, 2018). And while this number is by no means exact or representative of every single office worker, it shows that paper is used at a rapid rate, which is indisputably detrimental to the environment. According to an article published by *Sierra*, the magazine of the Sierra Club, that much paper is around how much paper is produced by a single tree (Schildgen, 2014).

Conclusion

While there seem to be few moves made to improve disposal methods of printers and other electronic waste, the technology of printers themselves will also progress, with new technologies being integrated to make them both more convenient and more multipurpose. The sensors within printers are being streamlined so there are less parts involved in the process. Other seemingly unrelated parts, such as bluetooth speakers, are being integrated into printers as to both save space and to appeal to consumers. With all that being said, it's undeniable that printers and similar technologies are an integral part of many people's lives, whether it be the convenience that it brings or the pollution it inevitably results in.

Materials and Methods

Setup

The first task in the project was testing the apparatus used to gather the light responses, the script that would give back the responses, and the sensors themselves. The testing was set up with the sensor and media clipped to testing apparatus (see Figure 1.) with the sensor connected to an Arduino, which connects to a computer.

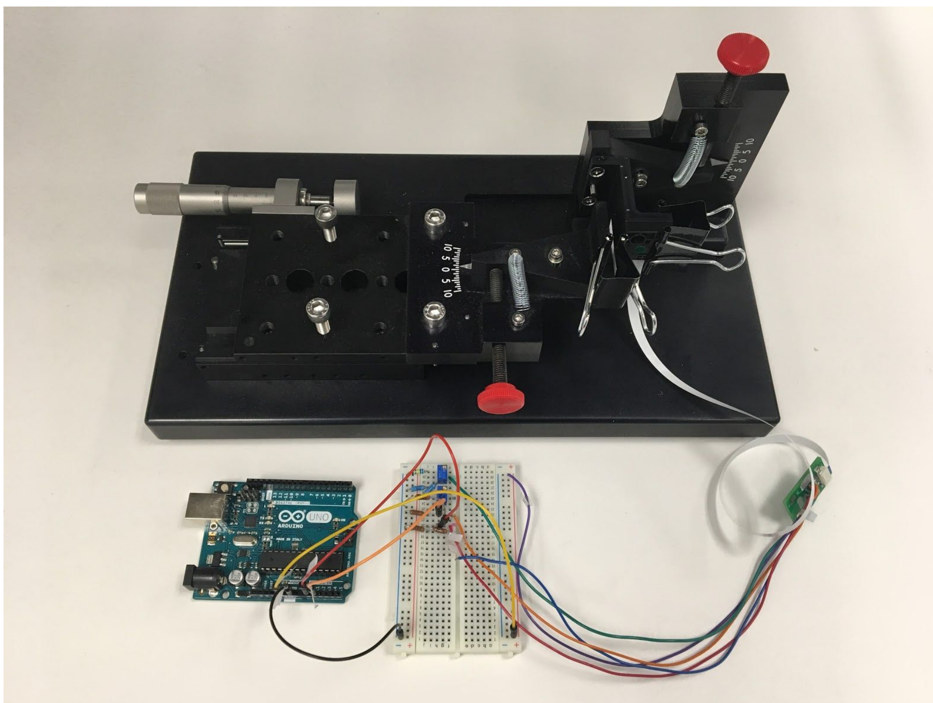

Figure 1. Stationary scan apparatus with sensor clipped, as well as arduino board attached.

While plugged in, the sensor would send the light responses it detected to the computer, where it would be displayed through a program used at HP called Sift2. Every half-second, the sensor would send back both the specular and diffuse light responses. There were nine available sensors to test, and were handmade as prototypes for testing instead of factory-made.

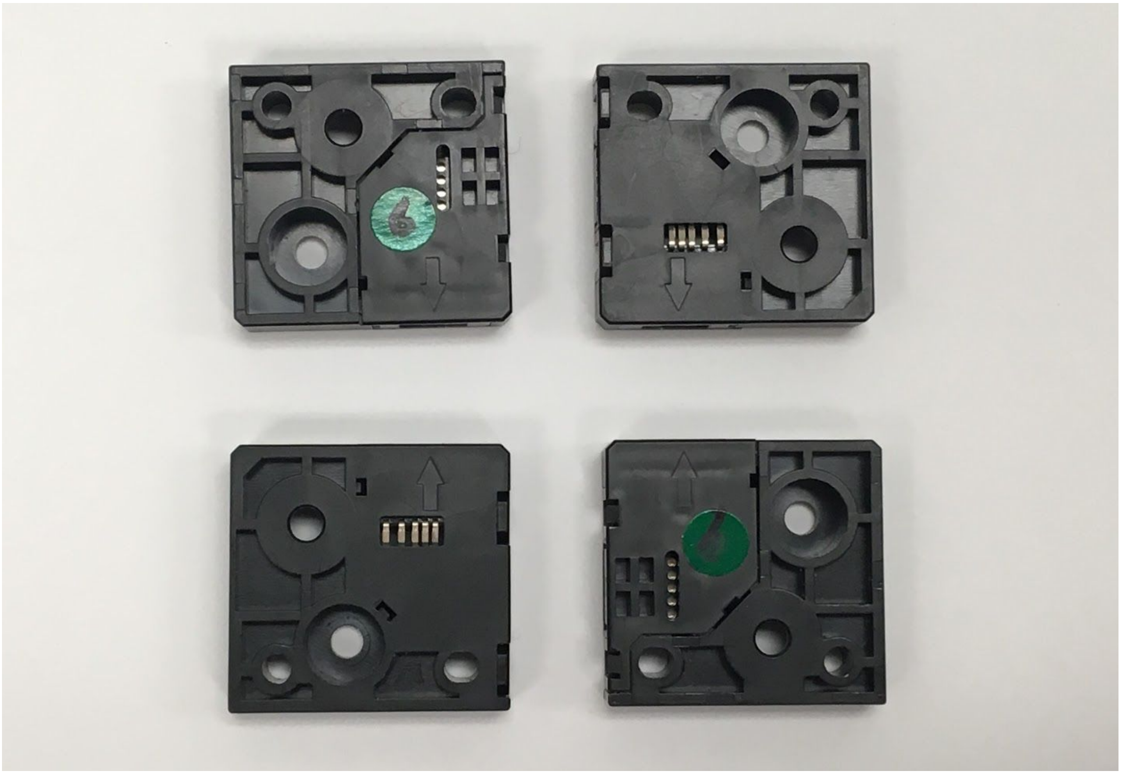

Figure 2. Four of the nine sensors used in the tests.

These were tested on a few different medias to make sure both the script and the sensor were in working order. I also measured the distance between the media and the sensor LED, making sure that it was at a distance of 5 mm, and that the sensor and LED were parallel. When it was certain that all the parts of both the apparatus and script were set up and functioning correctly, I was able to move on to the next step.

Media Sensing

With the functionality of the setup confirmed, I ordered a number of media types from HP's inventory to test. Out of the medias ordered, the majority were plain medias, which consisted of plain paper, relatively thin, and without any gloss. The second most common medias were the photo medias, which consisted of thick photo paper with relatively high gloss levels. The third type of media tested were brochure medias, which were relatively thick and mostly semi-gloss. When ordered, these medias were delivered in reams, so part of the process was to collect 20 sheets of each type of media and file them. Each media type was stored in an individual manila folder and labeled with the name of the media and the number code of the media.

From each media, I clipped a small sample of the media off to use in testing, at around one square inch. I then recorded the specular and diffuse light responses for each media sample from each of the nine sensors, through both the green and blue LED lights for each sensor. The responses were organized in a spreadsheet, and the ratios of the light responses were found by dividing the diffuse response by the specular response. These ratios were graphed together with the medias grouped together by categories: plain, photo, and brochure medias.

Print Tests

The next portion of the project consisted of print testing, the purpose of which was to determine how the printed result would look on each media type if the sensor wasn't able to correctly determine the media type and an incorrect color map for the printer was used. I tested with four different images/print samples that spanned across the page, and used the color maps photo normal and plain normal for each images.

Angle Tests

After the print tests, I returned to using the apparatus for testing sensors and medias. Instead of testing out all the different medias available to me with all the sensors, I tested a single sensor on three different medias at different angles, with only one media from each category: a plain media, a photo media, and a brochure media. Each media was tested with only the green LED at angles up to 5° away from parallel, in both directions, and on both *x* and *y* axises. The diffuse:specular response ratio was taken at each of the angle measurements and recorded, then graphed as well. On the first testing trial with all the medias, I noticed that from 5° to 0° on the *x* axis as well as the *y* axis, the distance was different because the apparatus would be pushed apart when at a certain angle. However, when tested again after it was adjusted so the media stay the same distance from the sensor, the data did not change.

Page Scans

After the angle tests, I returned to scanning all the various medias, but in a different way than the first portion of the tests. Instead of scanning only a small stationary sample of media, I scanned across sheets of media. A Gaz sensor was it was installed into an HP ENVY Printer, replacing the sensor that was previously there. The script used in this portion of the testing instructed the printer to pick a piece of paper and keep it stationary while the sensor scanned across the page, taking 4000 light responses. Since it could only do either specular or diffuse at a time, I used the switch to manually switch between the two. After the switch was flipped, then the sensor would scan across the page for the other light response. These responses were then transferred from a text file onto a spreadsheet, where I could graph the responses. Using the organized manila folders of medias, I scanned across each media that I had previously gathered.

Results

The purpose of this project was not to just test out different medias; it was to determine whether the **gaz** sensor specifically could differentiate between media types and decide the print mode. When the diffuse:specular response ratios are graphed, it shows how distinguishable each media type is.

Sample Scanning

The diffuse:specular responses are graphed here as ratios divided by general media category, and then each specific brand and type of media. Each individual mark on the graph is a response from a different sensor, and in the case of Figure 3, an individual sensor LED setting as well.

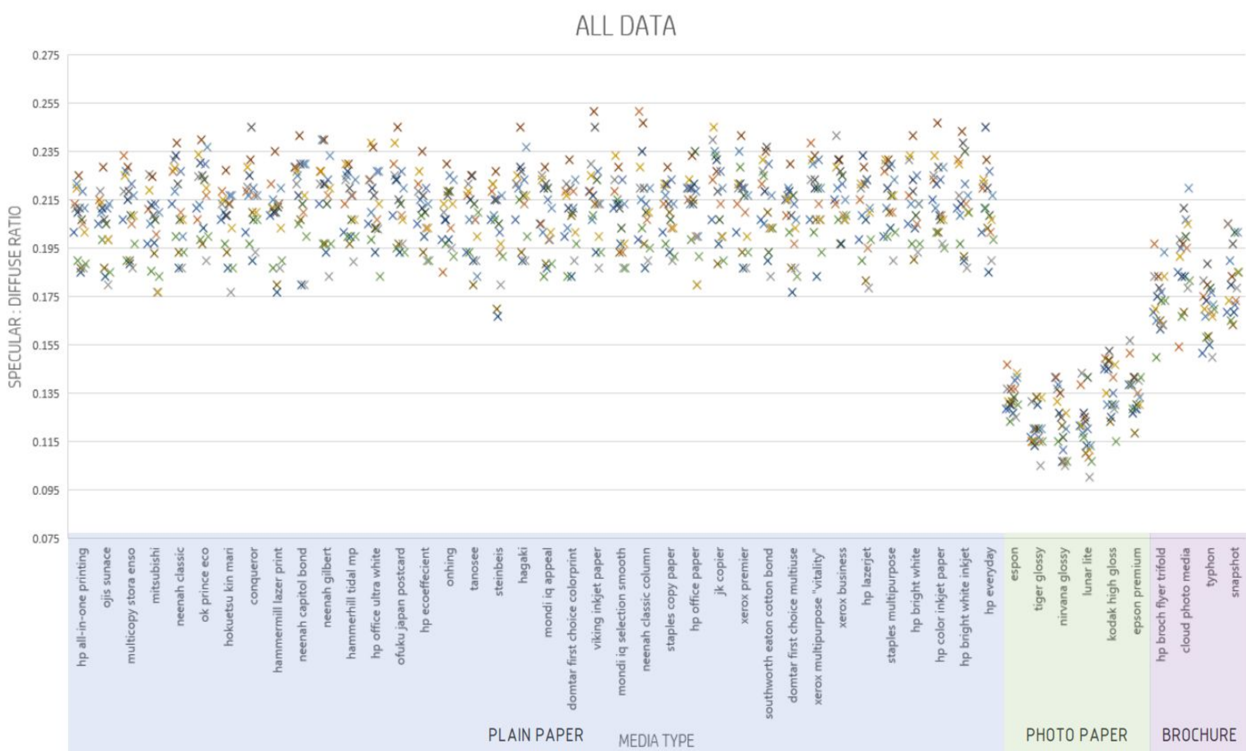

Figure 3. Ratios of light responses of blue and green LED for all sensors.

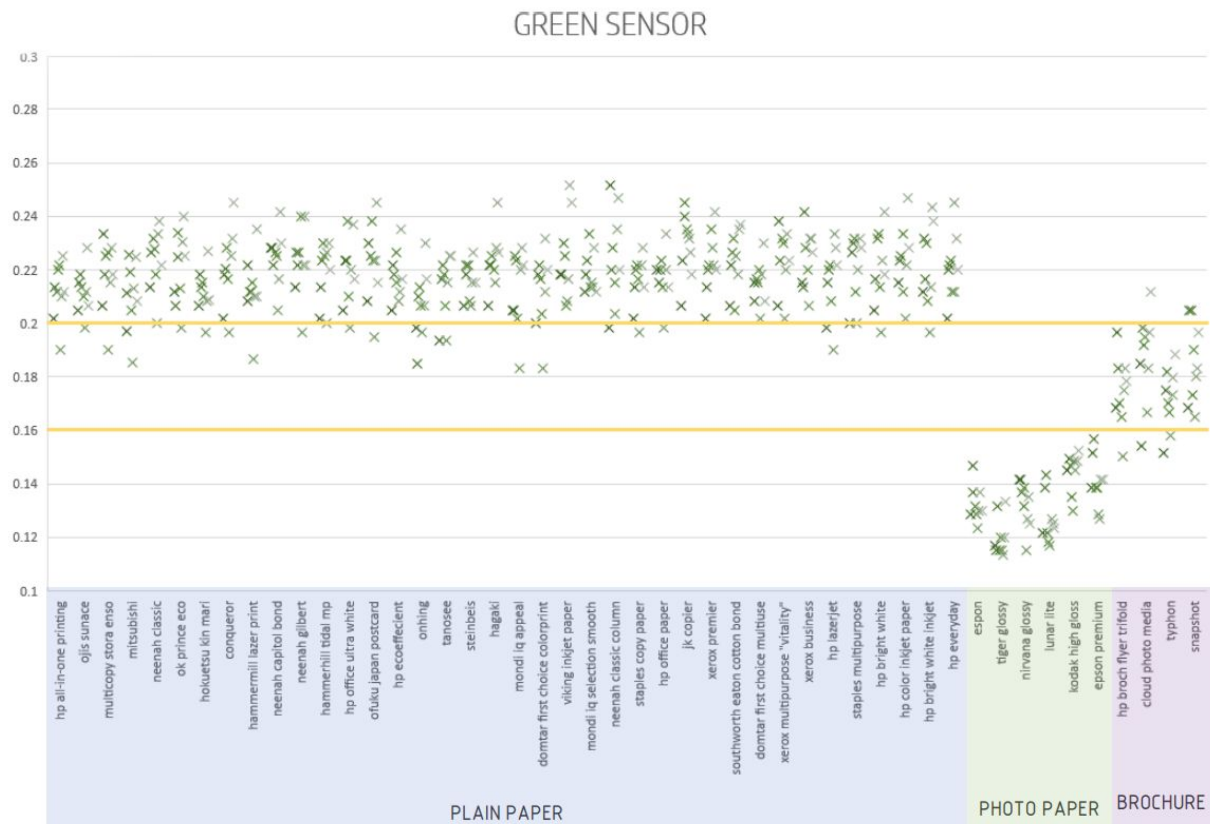

Figure 4. Ratios of light responses of green LED for all sensors.

Print Tests

The print tests didn't have specific data to graph, as it was an evaluation of whether the color maps would work on each media. For the most part, the prints looked fairly normal, with the intended color map looking better than the other color map. In some instances, when the paper was particularly thin, the photo normal color map, which deposits a much larger amount of ink, the paper will jam inside the printer. However, this is only with particularly thin medias and regular printer paper doesn't have problems this extreme. For the brochure medias, which weren't the intended media for either color map, both color maps had their strengths and shortcomings. On one hand, the colors were more accurate on the photo normal color map while the black didn't look as dark because of ink restrictions. On the other hand, while the colors were less accurate with the plain normal color map on brochure paper, the areas with black ink are a much darker black than the photo normal color map.

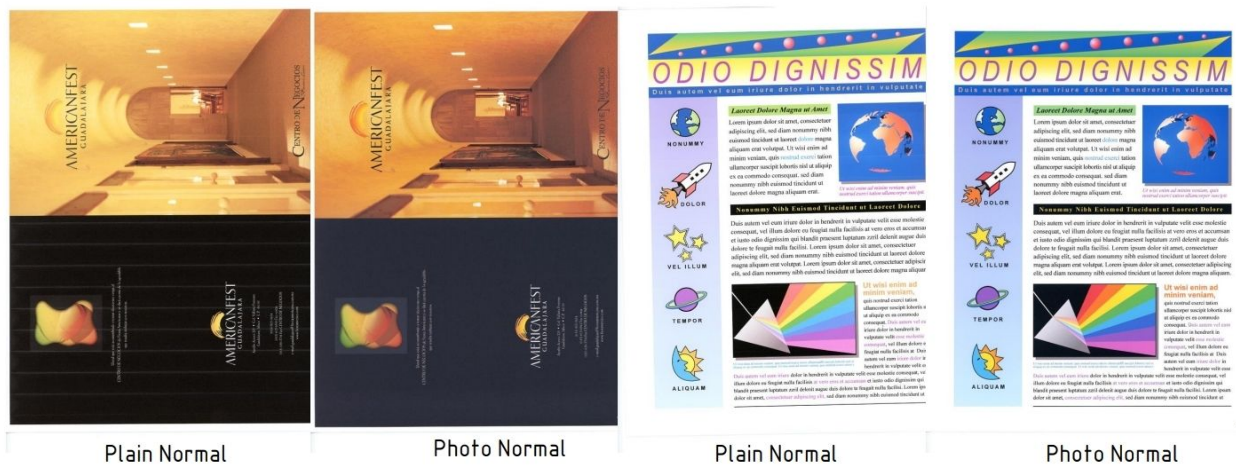

Figure 5. Contrasting color maps on brochure media.

Angle Tests

There was a clear difference between the plain media and the other two, but it's difficult to distinguish between photo and brochure media. When using a different ratio to divide the responses, the way the media can be seen as changes.

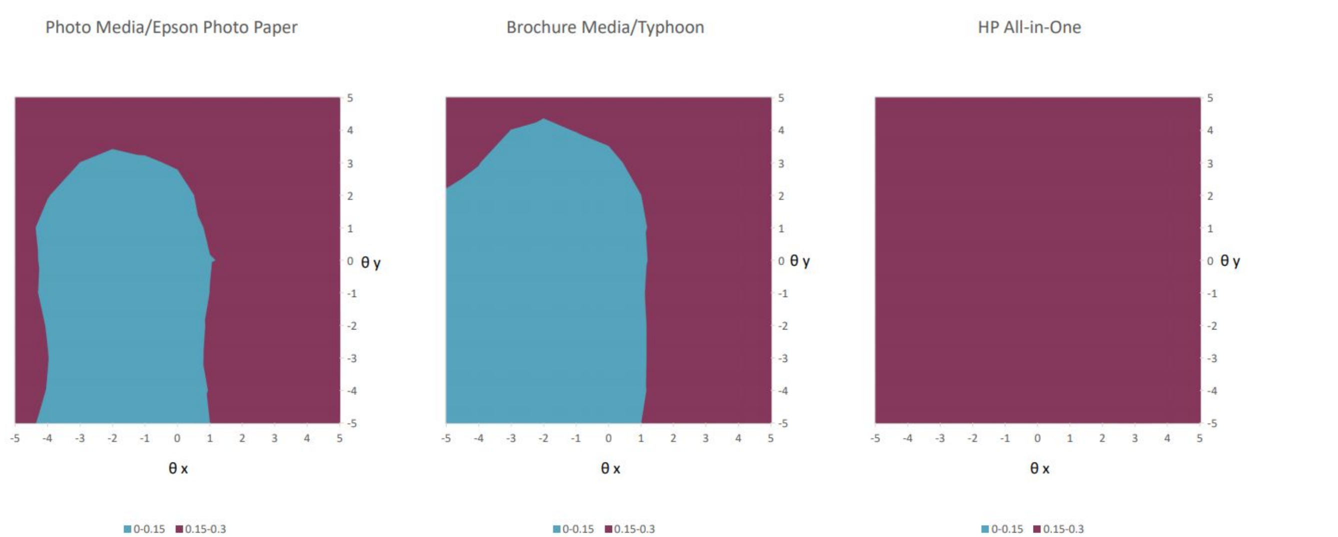

Figure 6. Angle tests with the dividing ratio of 0.15.

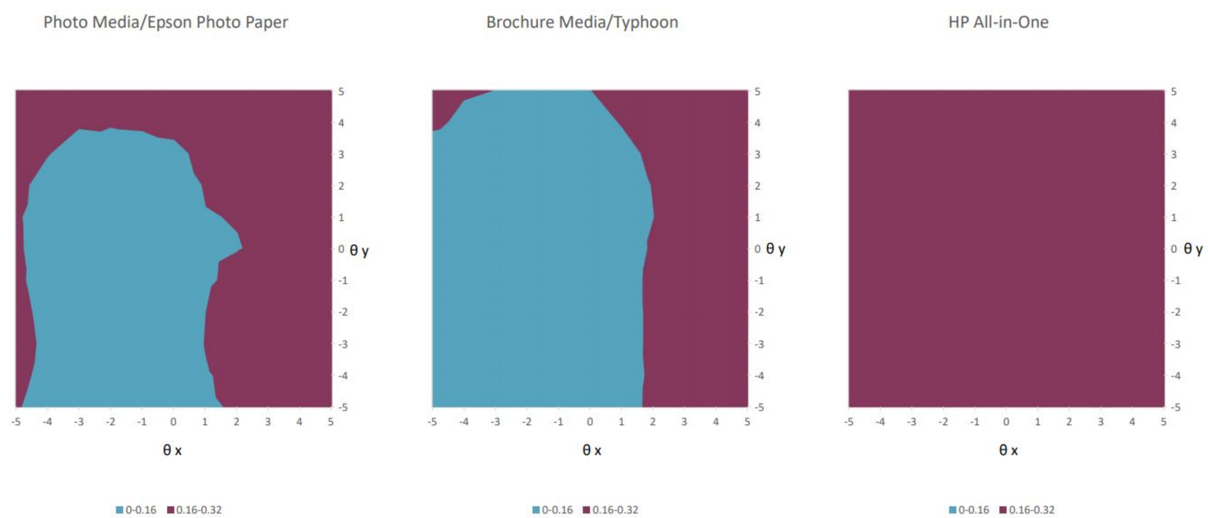

Figure 7. Angle tests with the dividing ratio of 0.16.

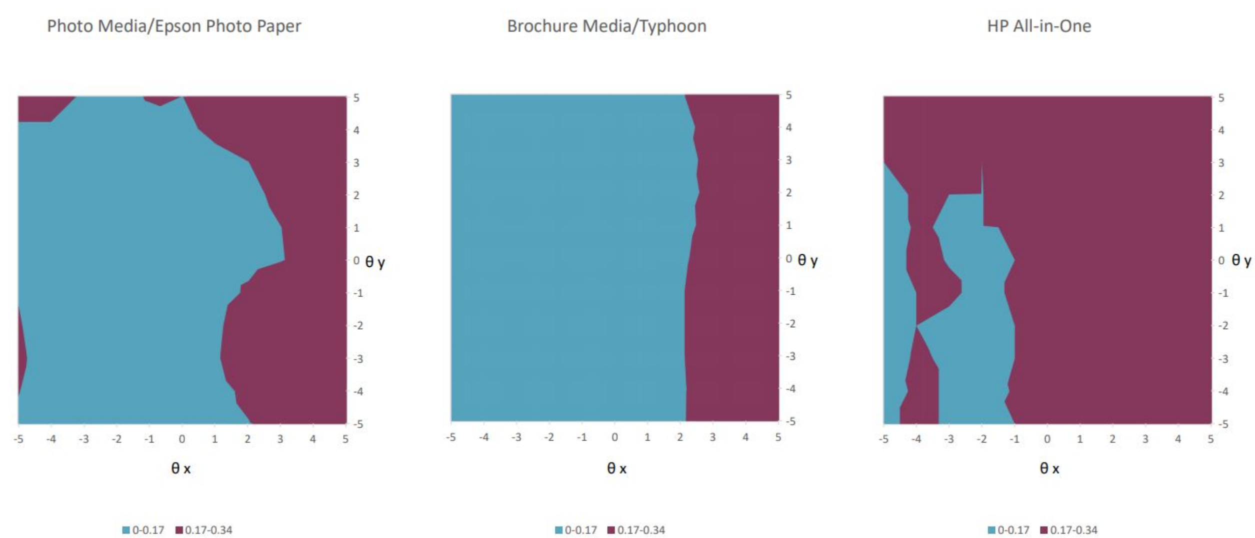

Figure 8. Angle tests with the dividing ratio of 0.17.

Scan Tests

The scan tests weren't graphed by the diffuse:specular ratio like the other scanning test. Instead, both the diffuse and specular responses were graphed to show a clearer picture of how the responses would be read. Only 3 medias were graphed, one from each category of medias, while the rest were left as text files.

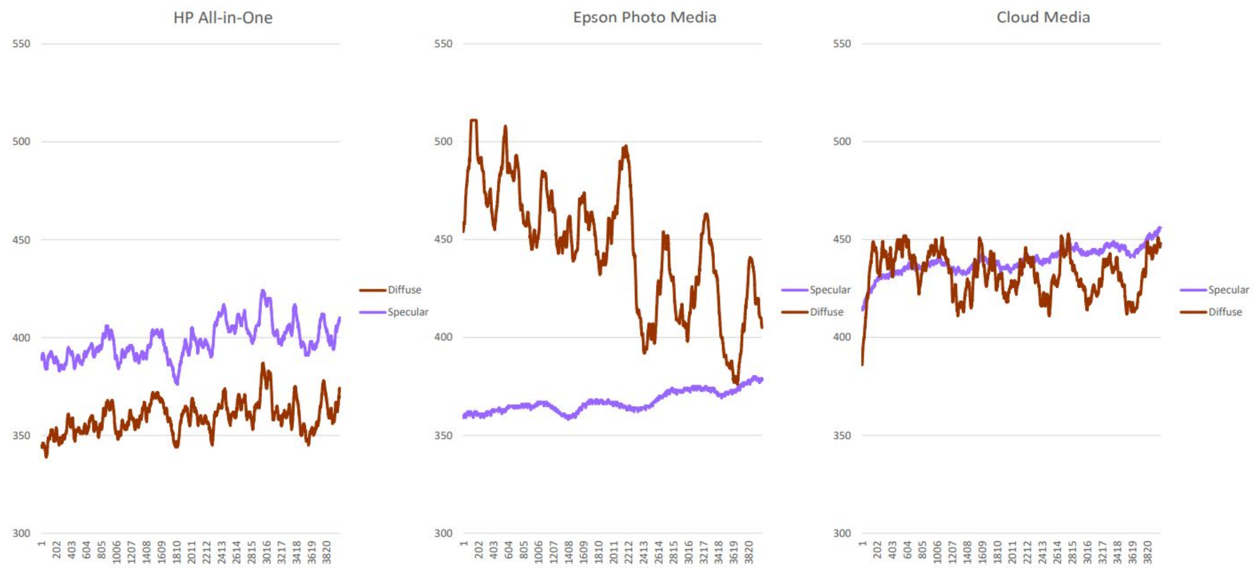

Figure 9. Across-the-page scans graphed by diffuse and specular responses.

Discussion

The goal was to determine whether it would be possible to distinguish between the three distinct media categories. As seen in the graphs from the stationary scans, there are clear differences between the photo media and plain media, while there brochure media is in between the two and can be mistaken for one or the other. I had the chance to speak to a few people who had done previous media sense studies at HP, and found that the results I gathered were similar to the general idea that they had as well, even with different specific sensors.

In the across-the-page scans, the unevenness of the graph could be used to determine which type of media is being printed on. However, the problem with that is that the unevenness may come from the vibrations in the printer instead from the texture of the paper. In the case of it being because of the texture of paper, different medias, even if they were the same category, could have different textures that might cause confusion.

Other inconsistencies in the data or possible differences also may be caused by the sensors themselves. Because these specific sensors used were prototypes, they weren't built on a factory line, and were instead assembled by hand, and it's unclear whether they were all built by the same person. The cables used during experimentation also were changed a few times after the pins on the cable wore out, and both the difference in cables and the wearing on the pins may have caused slight differences in data.

Conclusion

While brochure medias may cause some difficulties, it doesn't seem unreasonable for the sensors to be used to determine what media is being printed on to make it more convenient for users. The data I have gathered shows that sensors can clearly tell a difference between at least plain and photo media. When I spoke to HP representatives about this, one mentioned that very few people used brochure paper overall, and those who did print on brochure paper wouldn't rely on the printer to determine color map for them. In that case, the lack of clear distinction between brochure media and other media types isn't as big an issue. By using the same sensor to determine media type as well as perform other functions, it allows the printer to require less parts while maintaining performance.

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