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Case study
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Colour management of tablet devices

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Abstract

As of now, the creation and use of tablet devices in society have been strictly focused on the benefits for commercial use. While other devices such as monitors or cameras are capable of device-specific colour management, tablet devices have been left behind with only manufactured colour adjustments available. This has resulted in a limited use of tablet devices such as the Windows Surface, Apple's iPads and Samsung's Galaxy Tab S, in the professional/printing industry. In particular, the use of these tablets have had limited integration with an already existing and functioning colour management workflow. This study analyzed and identified the colour reproduction capabilities of specific tablet devices so that possible workflow or industry integrations can be established. The study evaluated each device through the creation of an ICC profile using i1Profiler. The profiles were then compared using Macbeth ColorChecker Classic Chart for key colour comparison and IT8.7/4 for colour difference values (ΔE_{00}). Amongst all profiles, general colour gamut was observed using ColorThink Pro software. The outcome of the tests has shown that each device tested thoroughly resulted in an acceptable industry set CIEDE2000 standards with average values below 3. It was also seen that each device is limited by various roadblocks or concerns when looking for future integration into professional industry workflows. Overall, while technically usable, the use of tablet devices in the professional/printing industry depends on the extent to which this industry accepts to integrate these devices in their workflows.

Keywords: colour reproduction, colour differences, colour management workflow, colour gamut

1. Introduction and background

In the commercial setting of electronic displays, it is evident that a difference in colour exists between various brands and specific devices including televisions, cameras, monitors, mobile, and tablets. While some of these devices such as monitors and cameras can undergo device-wide colour management, others including tablet devices are left behind with only manufactured colour adjustments being made available. These adjustments cannot be changed, creating limited control over colour accuracy especially if the purpose of the device requires specific colour management. From an average consumer standpoint, colour management capabilities are not a dire necessity with many being accustomed to middling colour accuracy. With basic technology, consumers are capable of viewing devices that are comparable to the best electronic displays of the past and thus, today's manufacturers do not see the importance of incorporating the feature of expanded colour management inclusion; beyond the standardized sRGB profile traditionally found in tablet devices. From a professionally related standpoint, specifically with regards to the printing industry, tablet colour management is promising for an integration to the practical production workflow – especially with regards to commercial monitors used for average viewing and respectively targeted colour managed monitors. For instance, a recent study shows an increasing interest of some professional stakeholders in the packaging industry to use 3D mock-ups software on iPad devices as an enhancement tool to their existing proofing workflow (Whyte, et al., 2017). With colour management, these devices would be capable of mediocre comparisons; moreover, they would be capable of colour accuracy for soft proofing, beyond proofing just content.

Display Mate Technologies conducted a set of lab experiments to understand display technologies of various tablet devices (Soneira, 2014; 2015). In these experiments, the analyzed absolute colour accuracy indicators were reference points that were devised from four sub-categories including full colour gamut accuracy, facial skin tone colour accuracy, organic colour accuracy, and blue region (cyan to magenta range) colour accuracy. In light of this, Display Mate Technologies research was limited to the commercial use of tablet devices, particularly aiming at home photography rather than professional work. As such, identifying and understanding factors brought upon by the printing industry would be beneficial. Additional research was conducted by the University of Novi Sad, with a set of experiments regarding tablet colour management as it relates directly to their use in colour soft proofing or another colour accurate dependent applications (Zorić, 2014). The devices were tested using digital versions of the Macbeth ColorChecker Chart (calibrated TIFF files used on the device) as well as Datacolour's SpyderGallery application, which allowed for colour management calibration. The research evaluated in-application colour management but identified the limitations to using specific device software for viewing rather than expanding hardware capabilities.

While in-application colour management would benefit particular industries, the inability to connect with our devices limits integration with print. With this belief, there resides a need for research and experimentation on various tablet devices to examine existing colour reproduction capabilities of hardware and identify future industry possibilities.

2. Materials and methods

In order to study the colour reproduction capability and identify possible future uses of tablet devices in the printing industry, a set of quality reports were produced for each tablet. The tablet devices employed and tested in this study were the Windows Surface Pro 3, Apple's iPad 2, and Samsung's Galaxy Tab S. Each tablet was measured with a 5-point method (the centre and four corners) using the i1Profiler software to check for validity and consistency. An i1Pro 2 spectrophotometer was used to calibrate and identify an ICC profile based on the centre measurement. Measurement conditions for each device used were: a white point correlated colour temperature (CCT) of D65, a luminance value of 105 ± 3 cd/m^2, a gamma of 2.2 and a contrast ratio based on measured luminance. All these settings were used to best simulate standard device conditions on average brightness.

Prior to testing, each device screen was turned on and left to warm up for about 30 minutes to ensure optimal measurement conditions. The Surface Pro 3 was capable of installing i1Profiler software directly on the device, which is not the case with either iPad or Samsung devices. Therefore, to perform the measurements, additional Duet Display software was used to simulate the iPad as a second monitor for a desktop computer that has installed i1Profiler software. The Samsung device required the use of TeamViewer's remote desktop software both on the tablet and the desktop computer. Each device was then set to view the desktop computer on maximum quality settings, allowing the tablet to be measured while the i1Profiler ran on the desktop monitor. The luminance value chosen for this experiment was based on readable values on the tablet devices and provided greater consistency for measurement comparison.

Profiles were generated based on the largest patch set available in i1Profiler's Display settings. The measurements were then compared to the 24-patch Macbeth ColorChecker Chart and a standard IT8.7/4 target embedded in the i1Profiler software. This was then used to identify and evaluate the colour difference (ΔE_{00}) in CIE $L^*a^*b^*$ colour space. The CIEDE2000 equation was used, as it is an accepted method to quantify colour difference in standards such as ISO 12647 (International Organization for Standardization, 2013). In addition, this equation has been found to better correlate with small differences of colour in a human observer (Habekost, 2013). The colour gamuts of the generated ICC profiles were compared and evaluated using ColorThink Pro 3.0.3 software.

3. Results and discussion

3.1 Colour gamut evaluation

When analyzing the results of this study, two major categories were considered. These included the device-specific colour gamut and general colour reproduction capabilities. Beginning with gamut, Figures 1 to 3 demonstrate the graphs of colour gamut of the tested devices with original CIELAB values of the Macbeth ColorChecker Chart for reference. As seen in Figure 1, the Samsung tablet produced the widest colour gamut volume when compared against the iPad and Surface, which shared similar results.

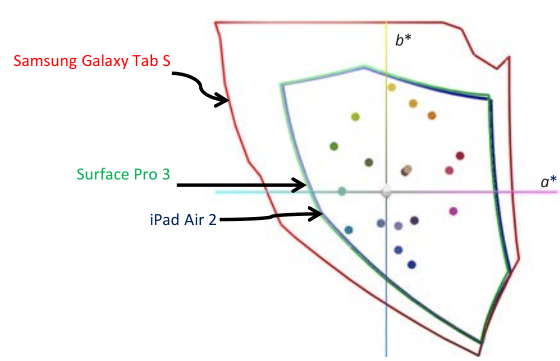

Figure 1: 2D graphs of all device gamuts tested (With original CIELAB values of Macbeth ColorChecker Chart for reference)

When examining and comparing each device gamut, as demonstrated in Figure 2, it was seen that the Apple-based device was capable of achieving slightly more colours within the red to the violet range of the CIE colour space. This outcome could be attributed to the manufactured screen characteristics, which aim for a warmer white point; thus allowing for more vibrant colours. This is done for commercial photo viewing purposes. The Surface Pro produced a gamut with an extended blue to green range. The Surface Pro is aimed towards traditional desktop computer use (word documents, web browsing) and as such has limited manufactured screen adjustments for colour. In general, both devices share similar results when tested under consistent methods.

The Samsung Galaxy Tab S far exceeded the gamut of the iPad and Surface. Samsung was the only device capable of changing its viewing settings based on use. For this test, the default setting was used which primarily focused on vibrant photo viewing. It should be noted that the Samsung's gamut carries some irregularities with regards to the red region and overall uniformity. This is most likely a result of the TeamViewer testing method implemented.

In addition to device-specific gamut, it can also be seen that almost all colours tested using the Macbeth ColorChecker Chart sat within gamut, allowing for accurate colour reproduction measurements of key gamut areas. For the iPad and Surface, the cyan patch sat outside gamut as illustrated in Figure 3. Reproduction of cyan colour is traditionally an issue with LCD technology. Ultimately, by examining colour gamut, it was possible to identify how the hardware and internal colour management of each device influenced its capability to display a range of colour. Notably, it determined how the white point of each device affected a further function for colour management purposes.

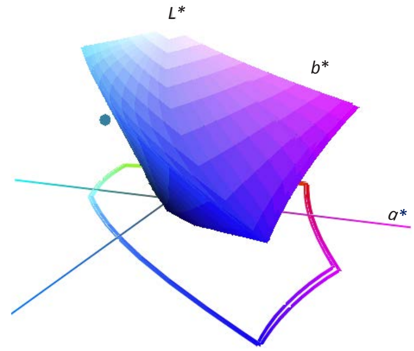

Figure 3: 3D graphs of out-of-gamut cyan colour for iPad and Surface Pro

3.2 Colour reproduction capabilities

Table 1 summarizes the ΔE_{00} comparison between the tested tablet devices and the IT8.7/4 target based on a GRACoL 2006 Coated 1 Reference (NPES, 2007). The average ΔE_{00} values were 1.22 for Surface Pro 3, 2.75 for iPad 2 and 2.81 for Samsung Galaxy Tab S. A significant difference can be seen as the Surface Pro showed the smallest gamut volume, but ultimately achieved better colour reproduction capabilities. This is associated with the Surface Pro's ability to incorporate ICC profiles in oreder to improve or alter manufactured colour reproduction. This proficiency is unachievable using the Apple-based or this particular Samsung device. A significant statistic identified was that for all devices, 90 % values measured resulted in a ΔE_{00} of less than 3. From this, it can be expected that regardless of device, it is possible to achieve a colour difference that is not significantly noticeable to the human eye. In addition, industry soft proofing tolerances would consider these results acceptable (IDEAlliance, 2009). With this in mind, it was also made apparent that for the remaining 10 % colour patches the average ΔE_{00} measured for all devices would be considered noticeable, and does fall under the maximum toler-

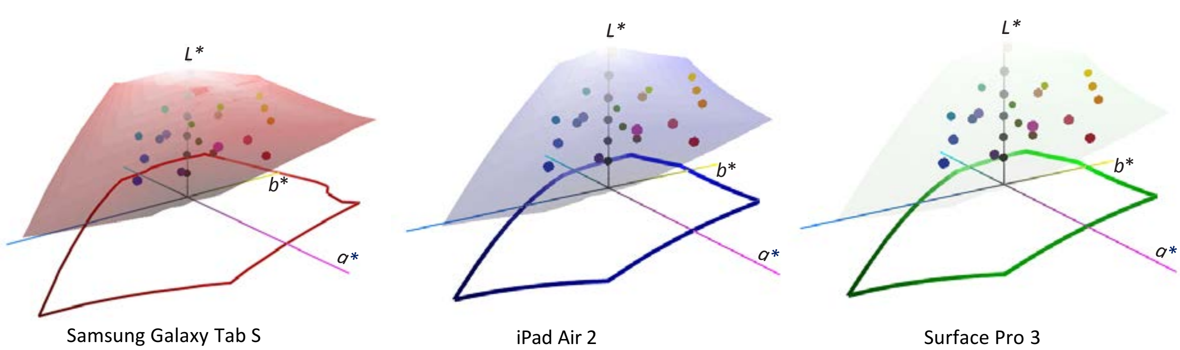

Figure 2: 3D graphs of individual device gamut tested (With original CIELAB values of Macbeth ColorChecker Chart for reference)

Table 1: Summary of ΔE_{00} comparison for tested tablet devices

	Average ΔE_{00}	Average of lowest 90 % ΔE_{00}	Average of highest 10 % ΔE_{00}	Max. ΔE_{00}
Surface Pro 3	1.22	0.84	4.60	8.15
iPad Air 2	2.75	2.34	6.36	10.51
Galaxy Tab S	2.81	2.35	7.02	12.57

ance expected for soft proofing. While the soft proofing tolerances do not necessarily match the tablet device conditions, it does provide a strong baseline for comparison.

When further examining the maximum ΔE_{00} measured, it was determined that for the LCD devices (iPad and Surface) the cyan patch was culpable. From analyzing each device gamut, it can be recognized that the cyan patch falls outside the available gamut. For the OLED display (Samsung), the white patches were the cause for the colour differences. Based on the examined gamut and general device capabilities, the Samsung device accommodates greatly for its intended viewing condition through internal colour management settings, shifting the CCT white point purely for viewing purposes.

3.3 Tablet's technology considerations

It is evident that manufactured colour accuracy and external colour management on tablet devices will improve in the future, but this is dependent on various impacting factors that need to be considered both in the hardware and software. The screens available today that are used in various tablet devices are targeted for commercial and practical consumer use, which do not meet standard lighting conditions used in the printing industry. Commercial devices traditionally target and use the sRGB colour space by using a white point close to D65. The purpose relies on the profile's broad use across digital media. Steps are also taken to adjust internal profiles to accommodate for commercial viewing as seen on the Samsung device. For each device tested, the CCT exceed 7 000 K at full brightness to better suit consumer activities. The use of higher CCT values of 7 000 K and above results in bluer screens, thus producing inaccurate colour, regardless of the ΔE_{00} measured (Monoyios, 2012); further reason to create consistency by using a controlled luminance value. This could also be looked upon by examining possible subjective tendency with relation to viewing device choice. This could ultimately alter image/photo choice despite the specific devices colour accuracy.

It is indisputable that as screen technologies such as LED, OLED, and LCD continue to advance, colour accuracy and reproduction will improve; particularly seen for the Samsung's OLED display. This, however, can only go so far with regards to colour management for industry applications. Due to this, the need for colour adjustment capabilities within the devices operating system is vital in allowing colour accuracy to spread across the entire device. As of now colour management is only available on tablet devices through specific software applications, which allows viewing images with accurate colours only through these applications. An example of such applications includes the previously mentioned SpyderGallery and X-Rite's ColorTRUE applications. While applications such as these do allow for the illusion of available colour soft proofing options, the main purpose and fundamental reason for colour management is to provide accurate

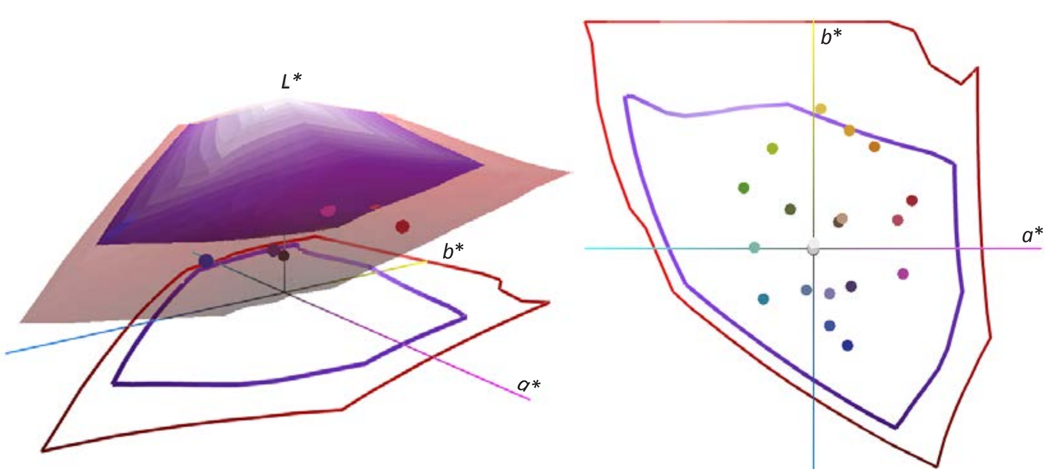

Figure 4: Graphs of Samsung Galaxy Tab S measurement inconsistency

colour display across numerous devices such as cameras, monitors, proofers, and printers.

That being said, most general image viewing applications do not incorporate extensive colour managed settings. The inability to inject and extract ICC colour profiles from individual devices leads to a limited connection to the overall colour workflow. Furthermore, manufactured alternations to typically included colour profiles such as sRGB discourage standardization across devices. Those of which are capable will ultimately be limited by the screen technology used. A comparison of this capability was seen in the Surface Pro 3 as it runs a Windows OS and can make use of the ICC workflow. Overall, the devices tested show a capability of reproducing colour to a standard fitting of the printing industry, particularly the Surface tablet.

In light of this, numerous hardware and software roadblocks limit the functionality of tablet devices for conventional purposes within a workflow. This was particularly seen during the testing process for the Samsung Galaxy Tab S. Due to complications in the Samsung's measurement availability and method, the ICC colour profile and ΔE_{00} colour differences results represented extremely obscure and inconsistent data from measurement to measurement, seen in Figure 4. It was necessary to lower the brightness of the device in order to maintain black detail on the device that is otherwise lost at maximum brightness, though this did not entirely solve the issue. As such, while the Samsung's results prove fruitful for the device gamut in the experiment, performing regular measurements on the device would be considered cumbersome.

4. Conclusions

For the experiment, it can be concluded that tablet devices have yet to become a simple solution or possibility for soft proofing. Out of all devices examined, the Surface Pro 3 was the most promising, as it basically is a mobile computer. The other devices required troublesome testing method or provided inconsistent results that would prove problematic when used for frequent client viewings. In general, a streamlined method of consistency, calibration, and characterization for tablet colour management is necessary before becoming a convenient soft proofing or viewing tool within the print industry.

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