2010
VOLUME 22
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– RIT TAGA
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Introduction

The twenty-second volume of the Rochester Institute of Technology student chapter’s TAGA journal was crafted to explore and experiment with the interactions between reader and content. The publication embraces the convergence of creativity and technology—promoting tactile sensations through the use of dimensional printing, and further inter-activity through carefully designed features that heighten the traditional reading experience.

For further information about the interactive features as well as the design and production processes of this journal, please look to the afterword and production notes located in the colophon.

This publication came to life through the dedication of RIT TAGA members, the support of the University, and industry partners. This journal represents the synergy between students of photography, design, new-media, and printing, and demonstrates our love for all facets of the graphic arts.

We are truly excited about the multiple levels of inter-activity this year’s publication presents, and it is our hope that you thoroughly enjoy this interactive experience.

Angelica Li
RIT TAGA 2009-2010
Technical papers and select sections of this journal have been tagged with QR-codes that link directly to supplementary online content. Each web page holds additional interactive and multimedia assets for the corresponding sections.

QR-Codes are 2D tags containing data that can be read by many cellular phone models with a camera and freely available software. The reading software scans codes using a camera and decodes embedded information, such as web page addresses. This provides a quick and convenient way to connect to online content.

How to Use the Codes

To access content, download a QR-code reader that supports Version 2 codes. The reader should be used with a mobile device that has an integrated camera.

Follow the instructions provided by the software to capture each code and connect to the online content. The code to the left may be used to check for successful setup.
Technical Papers
Modification of an Inkjet Printer for Improved Operation in a Microgravity Environment

Eric Evans, Alexandra Artusio-Glimpse, Ross Dawson, & Bryan Zaczek

This work studied the effects of microgravity on ink drop trajectories, behavior, and printed resolution of an inkjet printer. This research built on the findings of the RIT team who participated in the 2008 Reduced Gravity Student Flight Opportunities Program (RGSFOP).

Inkjet technologies have been utilized in applications such as circuit board printing, bioprinting, and three-dimensional prototyping (Calvert, 2001). It was shown by the previous RIT team that basic functions of a piezo-electric inkjet print head are effective in microgravity and provide satisfactory resolution results for general print applications (Ubelacker, Craven, Sharp, & Whetstone, 2008). In this work, the team further investigates how gravity changes may affect drop shapes produced using a piezo-electric process in microgravity as a predicate to future application for high precision printing, as a scientific tool. The scope of this work is limited to the effects resulting from shift in flight path and velocity caused by changing gravity conditions, and the resulting inaccuracies on a modified device.

To facilitate data gathering, a Kodak ESP5 printer was optimized to function under changing gravity. The experimental apparatus employed a drop imaging device (DID) with a high-speed video camera and optical system to image an operating print head nozzle for analysis. Video from the DID shows ink drop ejection and flight.

Results from normal, micro-, and hyper-gravity showed an insignificant dependence on gravity for proper functionality of the core inkjet technology.
Introduction

The experiment carried out by the 2009 RIT team tested the feasibility of inkjet printing in microgravity, and attempted to optimize a commercially-available printer for this environment. The inkjet printer illustrated the operational difficulties presented by reduced gravity, while a high-speed camera system focused on the behavior of a print head nozzle and ink drops being ejected. In most inkjet systems, hundreds of these nozzles are used in an array to increase printing speed and precision.

Research Problem

In recent years, inkjet printers have become ubiquitous in the personal and commercial printing fields. As a result, many areas of research have used the underlying technology as a scientific tool for placing very small drops of liquids at precise locations. This has been done or proposed in the fields of biomedical research (Hill, 2008), chemical testing, and circuit board fabrication (Calvert, 2001). As such, inkjet-based devices could one day be useful to people living, working, or conducting research in sustained microgravity environments. Some possible applications for these technologies as they mature include extraterrestrial geological sample testing and circuit board printing for equipment repairs or upgrades.

Method

Utilizing the results of the 2008 RIT team* (Ubelacker et al., 2008), the work of the 2009 team began with a problem already developed and a more informed hypothesis. It was believed that the ink drops were being ejected at a great enough velocity that gravity played an insignificant

*Overall the results were positive in microgravity. Neither ink-delivery system (thermal or piezo-electric) showed severe degradation of droplet size or displacement, reduction in resolution, or decreased print density. Drop displacement was actually more uniform and predictable under microgravity, which could result in increased drop precision, and therefore resolution, in a purpose-built system. A primary functional problem encountered was the movement of the entire cartridge mechanism in microgravity, specifically seen on the Epson printer tested. This gravity-dependent apparatus lifted or rotated away from the page during zero-g tests, causing the drops to fire at an angle and the different colorants to reach the page mis-registered. In conclusion, it is possible to achieve usable functionality of both thermal and piezo-electric print head technologies in a microgravity setting, but purpose-built devices are required to take full advantage of this environment.
role in their flight paths, considering the short nozzle-to-substrate travel, or platen gap, of most inkjet systems. This hypothesis was based on the limited finding of last year’s RIT team, as well as preliminary testing done with the isolated inkjet nozzle used for the experiment.

As far as equipment, the structural framework of the experimental rig was still intact, so modifications and additions were the primary preparations needed. Approximately half of the apparatus contained a high-speed camera setup, which was completely redesigned and centered around an isolated inkjet nozzle. This area also contained a power supply and function generator to run the nozzle. The other half of the apparatus housed a modified inkjet printer that produced test targets. Safety-related aspects of the rig included: ratcheting tie-downs for all large internal components, a removable plexiglass housing around the nozzle, and a switch on the light source to prevent overheating.

Initial testing was done to assess the benefits of the modifications made to the printer, as well as to fine-tune the high-speed video system. The printer was run while inverted to test the paper holding mechanism and the cradle-stabilizing bar. Sensors were also removed or circumvented to allow access to and viewing of the print head during operation. High-speed video tests were limited due to the short period for which the camera was loaned. Subsequent tests of the lens, nozzle, and light configurations were done using a digital still camera as a substitute. The chosen lens was used for its magnification capability and large aperture, which allowed for a fast shutter speed. Once the high-speed camera was available, testing focused on image resolution, shutter speed, frame rate, and software-driven image enhancements such as increasing brightness and contrast.

During flight, high-speed video was captured in segments of 1500 frames, or just under 0.7 seconds, which each included nearly 30-drop ejections. The ejection often resulted in a large droplet and one or more smaller ink droplets, of which only the main drop was tracked for analysis. Logger Pro data gathering software was used to derive position, velocity, and acceleration data from the video files. Within each file several drops were tracked and measured, providing a set of data from several trials. Trend-lines fit to this data then acted as averages over multiple independent trials, reducing errors and leading to more reliable conclusions. Distance measurements in the images were made in pixels.
and converted to standard units using a scale photographed with the high-speed video system before the flights. Figure 1 is a sample of the images used for analysis.

**Results**

Testing in normal gravity suggested that the inkjet systems examined relied very little on gravity for ink drop flight. Drop accelerations over the period measured were near zero, showing that exit velocity from the print head was generally maintained until the normal point of contact with the substrate. The distance that the drop travels to the substrate was largely a result of the ratio of ejection velocity to platen gap. Information from normal gravity testing supported the hypothesis that inkjet technologies would function properly in microgravity. These results are represented in Figure 2 and explained in more detail.

The bulk of testing was done in microgravity, where several segments of high-speed video were captured and test targets were printed. To examine the effects of microgravity on the inkjet system, analysis of drop flights were arranged as comparisons between normal, micro-, and hyper-gravity (1G, 0G, and 2G, respectively). This comparison is illustrated in Figure 2, which shows tests conducted in each of these conditions. Each trend-line is an effective average, being fit to data from between nine and twenty individual drops, all being fired in rapid succession. Measurements were taken from three frames of video for each drop, seen as the width and number of data points on the graph.

The trend lines in Figure 2 show that although ink drop accelerations vary slightly both in magnitude and direction, these changes are extremely small in relation to gravitational acceleration, and do not
appear to rely on normal gravity. 1G and 0G (Flight 1) cases closely overlap, and all accelerations measured were below 0.6 m/s² in magnitude. This correlates to drops maintaining a near-constant velocity during the short flight from print head to substrate, which is generally less than two millimeters (Komatsu, Ota, & Ishihara, 2005). The ability to maintain this operation in all tested gravity conditions proves the hypothesis that inkjet printing systems are capable of functioning in microgravity without any significant impediment to the resulting print quality. *

*The difference between the Flight 1 and Flight 2 trend-lines for 0G is based on some anomalous datapoints for Flight 2, likely a result of ink drops breaking up in flight, or not cleanly ejecting. This could be more prevalent in the second flight as the nozzle became clogged or dirty from use in the first flight. This could also partly be due to variability in the data gathering and measurement system.
Although testing priority was on microgravity trials, time allowed for some data to be gathered during hypergravity as well. The intended applications of data from this experiment were microgravity environments, but hypergravity testing was done to further understand the behavior of the ink system. This was useful as it simply provided more data on whether the print heads rely on or are affected by gravity for ink drop placement. Results from hypergravity corroborated the findings in normal gravity and microgravity. These results are summarized in Figure 2.

**Discussion**

One challenge throughout the preparation process was the inability to make serious modifications to the printer. This would have required far more time, expertise, and resources than were available. Failing to eliminate gravity-dependent mechanical design features prevented the test target printer from yielding definitive data during microgravity tests. Being an integral part of the experiment, this greatly reduced the overall effectiveness of the research. Also, using the isolated inkjet nozzle introduced benefits and challenges, since it was simpler to control but not identical to a conventional print head.

Most commercially-available inkjet printers, including the Kodak ESP 5, make more than one pass over any printed area. The printing overlapping duplicates images to build ink density. Since the print head carriage relied on gravity to maintain its alignment, these multiple passes resulted in blurred and double images, seen in Figures 3 and 4. Careful inspection shows that each pass did produce a fine line.

The greatest problem encountered was the inability to assess drop shape and tail behavior with the high-speed video system. This problem resulted from a lack of spatial resolution on each drop, a characteristic of the optical system and camera used. Resolution and magnification were compromised to provide more drop flight data, increase frame rate to the necessary level, and facilitate alignment. The available camera and lenses also imposed limitations. Greater magnification would have shown more about the shape of drops and any tail phenomena that occurred during flight, but this precision was beyond the scope of this experiment.
A successful aspect of the project was the organization of and preparation for each team member’s role with the experiment, which prevented any serious problems during the flights. This also maximized the data gathered during each flight and allowed the flyers to enjoy the weightless experience. Any minor issues were handled quickly and calmly and were corrected without any damage to equipment or loss of data. All mechanical, electrical, and computer-related aspects of the experiment rig functioned properly and as tested. These aspects allowed for a great deal of high-speed video to be captured, which provided excellent data on the nozzle’s operation in microgravity.
Conclusion

The primary outcome of the experiment was the high-speed video and the data gathered from it. The data gathered showed that the ejection velocity of an inkjet print head, along with the short platen gap which the drop traveled, limited any effects of the gravitational condition to be insignificantly small for the applications discussed. With this knowledge, mechanical considerations in device-design become the key focus in creating an inkjet system for use in microgravity, as they are likely to have more adverse effect on operation than the fundamental inkjet technology. Also, knowing the characteristics that limit gravity’s effects on the technology, devices can be built to further minimize any potential problems.

In a system with only a few known substrates, such as a purpose-built inkjet circuit board printer, the platen gap can be made very small, further limiting possible effects of gravity. Commercially-available devices are generally made to accept many types and thicknesses of substrates from multiple manufacturers. This requires some leeway in spacing between the substrate and the print head to avoid contact between the two, which can damage the printer. (Rasmussen, Pinkernell, & Jackson, 1993) Without this consideration the platen gap can be decreased, shortening the drop flight distance and time and therefore any possible effects of the gravitational condition. Similarly, increasing ejection velocity will decrease the drop flight time and the possibility of gravitational effects. This must be tested to ensure acceptable impact, absorption, and adherence to the given substrate.

With the data and experience from two years of related microgravity testing, the next step would be to construct a purpose-built and customized printer, specifically for operation in microgravity. The modifications made to the stock printer were insufficient to overcome the mechanical design elements that relied on normal gravity and hindered the usefulness of the test target data. Additionally, designing a system which served one of the scientific functions outlined above, such as circuit board printing or chemical testing, would be a true test of functionality, not just concept. This would require a great deal more effort and expertise, as these uses are largely experimental and not matured technologies.
Another shortcoming of the printer was the lack of a sensor-driven gravity record on the test targets. As a substitute, the printer operator marked each sheet manually as they were printed. This introduced error, as it was difficult to be sure what part of the target was printed during the desired gravity condition. This could have been avoided by isolating the printing to a specific time using a faster printer or smaller test targets, or by including a device to chart the gravity directly onto the printed sheets.

As for the drop imaging system, the quality of data could be improved using an actual print head. Because of problems experienced by the 2008 team, this element was changed from an actual print head to the current configuration for the second attempt. If the researchers were able to control each nozzle individually, the problems experienced by the 2008 team could be circumvented. This would likely require a microcontroller and a better understanding of the electrical engineering of the printer, perhaps gained through closer work with manufacturers. This system would also benefit from imaging the entire drop trajectory through ejection, flight, and impact with the substrate. This was not implemented due to difficulties it introduced with lighting, optical magnification, alignment and the mechanical issues of securing a moving substrate within the imaging system.

The research conducted on inkjet technologies has practical applications in any future NASA endeavor which would involve long-term microgravity settlements, or even short-term operations such as those conducted by the Space Shuttle missions. Inkjet technologies could help high-precision chemical testing in new environments, where a great deal of samples will likely be taken and analyzed. Additionally, the potential application of circuit board printing could prove valuable to a permanent settlement, such as on the Moon or Mars. The ability to rapidly create one-off electronic components would allow for quicker upgrades and repairs of equipment without relying only on costly and time-consuming delivery missions.

In addition to the experiment, the flight team participated in several outreach activities before and after our flight. These included booths at an elementary school science fair and Imagine RIT, an annual...
innovation festival, which featured pictures and videos of the 2008 and 2009 RIT teams’ microgravity flights. Flyers explained the program, process, and experiment in simple terms to students, parents, and other visitors. The project was also featured in the RIT News and Events newsletter and in the Niagara Gazette and Buffalo News newspapers. With the assistance of faculty mentors, results will also be submitted to Tech Directions magazine and IS&T Journal.

Acknowledgements

We would like to thank Kodak and Barnes & Noble for their donations to our project. For their generous monetary donations, we thank Michael D’Arcangelo of RIT Center for Campus Life, Mary-Beth Cooper of RIT Student Affairs, and Joan Stone, Dean of RIT’s College of Imaging Arts and Sciences. We would also like to thank Scott Williams and Andrew Davidhazy for their time and assistance with the project, and Kelly Downs at RIT’s University News for publicizing our work. We would like to extend a special thank you to 2008 RIT flyer Christopher Ubelacker, an original member of our team who could not participate in flight week due to scheduling conflicts.

References


Development and Testing of Cathode-type Flexographic Inks

Andrew Henry

Printed electronics have been used for some time in RFID (Radio Frequency Identification) circuits and many other aspects of the printing and packaging world. Recent commercial attempts to develop “battery inks” have high manufacturing costs and only produce small nominal voltages. A small paper battery printed by screen-printing has been created but still has a high production cost and a long time to print and assemble. Our recent results, however, can direct us to a functional printable battery capable of, but not limited to, a nominal 1.5 volts, equal to that of a standard AA/AAA battery. The flexographic-printed battery, developed at Rochester Institute of Technology, involves three different ink formulations: the cathode ink, whose main component is manganese dioxide; the electrolyte ink of potassium hydroxide; and the anode ink of zinc. These three formulations represent the same ingredients contained in a standard alkaline battery. This printed battery uses less material in production, is more cost efficient, and is quicker to produce. Unlike a standard battery, it is both compact and malleable.
Introduction

Applications of printed electronics have impacted our everyday lives. They are in the checks you write, magnetic strips in credit cards, and RFID to increase security of merchandise in retail stores. Recent innovations have been in the field of printable batteries. Currently, the technology produces a battery with an output of 1.5 volts, the capacity of a regular AAA or AA battery, and is easily printed using silk-screen-printing (Fraunhofer-Gesellschaft, 2009). Once, printed electronics were mostly seen with the formation of inks containing metallic pigments capable of holding information, and now the printed electronics industry and the science of printing functional products have advanced considerably.

Recent commercial attempts to develop “battery inks” have yielded high manufacturing costs and only produced small nominal voltages. The high costs stem from the usage of screen-printing, which places a cap on the scalability of manufacturing, yielding higher costs to produce and longer times to print and assemble.

The State of Printed Electronics

“Printed electronics” is a broad term that encompasses a large range of applications and processes. Currently, 31.6% of printed electronics produced are focused on conductive inks, sensors, and Organic Light Emitting-Diodes and is predicted to rise to 90.3% by 2017 (Smith, 2007). An advantage of printing electronics and batteries using flexography is that they can be printed inline in order to produce integrated smart packages or novelty electronic products at high manufacturing speeds.

Today, many printing technologies are capable of producing electrical components with functional polymers and materials on flexible media, patterning them in a variety of ways. With the use of specially formulated conductive inks in the screen-printing, flexography, inkjet, and lithography processes, a variety of products are now reproducible. These inks can be formulated for use in such products as sensors, RFID tags, LED lights, solar cells, and fabricated circuits. (Karwa, 2006, p. 18-19) It is only a matter of time before these technologies and applications advance to a level where they can be mass-produced in more complex forms, such as car batteries and portable electronics. Printed electronics offer a potential for high-volume manufacture, driving down production cost and making everything more compact and portable.
As the technology continues to develop, a key issue to keep in mind is that printing defects in these applications would not only degrade the visual quality of the products, but it would also translate into defective units that may not operate as intended, or pose safety concerns for the end user. For non-charged products, these potential defects may not become evident until the unit is first used. However, for printed batteries, a defect can translate into danger during manufacturing, storing, shipping or use. As such, refinements in areas of printability and material quality and performance are essential for researchers to pursue with diligence and care.

**The Design of Batteries**

A battery is a device made up of one or more cells that convert chemical energy directly into electrical energy. An oxidation-reduction (redox) reaction is the means by which these cells convert the active material into electricity (Linden & Reddy, p. 25). A battery’s cell consists of three components: an anode (negative/reducing electrode), a cathode (positive/oxidizing electrode), and an electrolyte bridge (ionic conductor). These three components make up the core foundation of a battery.

![Figure 1. An example of a Galvanic cell. (“Voltaic pile,” 2009)](image)

Many advantages have been made over primary batteries since the discovery of the voltaic pile, which is “a set of individual Galvanic cells placed in series” (“Voltaic pile,” 2009). This assembly promoted the idea of placing battery cells in arrays to provide additional voltage, which is commonly practiced today (Figure 1). This concept was
invented by Alessandro Volta in the years between 1796 and 1800. During this time, Volta formed the creation of an electric battery using a redox reaction between two metals (Dibner, 1964, p. 65-66).

There are two major types of batteries in existence today: primary and secondary batteries. Primary batteries are single-use, disposable batteries, most familiar in AA and AAA formats, providing a 1.5 volts discharge. Secondary batteries are rechargeable and are more widely seen in portable electronics such as laptops and cell phones. Secondary batteries are also produced in the common AA and AAA formats. According to Linden & Reddy (2002, p. 173), the major advantages of primary batteries include convenience and simplicity. It is also easy for manufacturers to design their products to suit these standard formats. Secondary batteries have the advantage of being rechargeable, but come with additional construction and format requirements.

Batteries can be made up of different materials for anodes, cathodes, and electrolytes. This helps define the type of battery and properties such as the discharge capacity and voltage. Major formulations include zinc-carbon (Leclanche cell), zinc-chloride, and alkaline. The research described in this report has been conducted to mimic the functionality of the latter, a primary-type alkaline battery.

**Printed Battery Construction & Functionality Considerations**

The scope of this work is focused on conductive inks, but takes into consideration a single construction model, also being researched and further developed at RIT for final application. The model borrows from commonly found concepts and is presented conceptually in Figure 2.

*Figure 2. Conceptual diagram of the layers of a printed battery.*
A battery’s electrical energy comes from the electron flow of the redox reaction within the cell. Figure 2 shows what Linden & Reddy (2002) describes as the electrochemical operation of a cell. In the construction model used for this research, conductive inks are printed as solid films and are separated by a substrate barrier to form each battery cell.

![Figure 2](image)

**Figure 2.** Depiction of the electrochemical operation of a cell. In the construction model used for this research, conductive inks are printed as solid films and are separated by a substrate barrier to form each battery cell.

When the anode of a battery is connected to the cathode, electrons are able to flow from the anode to the cathode, producing the electrical charge in the process. This connection is normally provided by a host device, which in turn powers the device through the flow of electrons. The circuit is then completed by the flow of anions to the anode and cations to the cathode (p. 29). The process of connecting the conductors causes a reduction (or oxidization) of the cathode material. The battery will continue to discharge, providing electrical energy until all of cathode material is reduced.

**Conductive Inks & Flexography**

Printing of conductive inks for printed electronics using flexography has been successfully tested using conductive water-based flexographic printing ink containing silver, a conductor. A major disadvantage to the use of silver in conductive inks formulations is that silver by itself is expensive (Sperry & Weisenmiller, 2006).

Conductive inks can come in two forms: carbon-based and metal-based. Although carbon-based conductive inks produce a weaker voltage, and therefore a weaker RFID signal, they are more environmentally friendly and generally more cost effective than metallic inks like silver.
Currently, conductive inks have been developed for use in all forms of print methods except toner based digital printing, and are typically formulated specifically for a certain substrate and printing process (Cole, 2007, p. 27). A great advantage of using flexography for printing electronics and batteries is the speed and potential to producing integrated smart packages or novelty products with inline finishing (Sperry & Weisenmiller, 2006).

**Basic Notes on the Formulation of Flexographic Battery Inks**

In order to produce the previously described battery construction, this research focused on testing two key formulations of cathode inks.

The key component of the cathode ink formulations covered here is manganese dioxide (MnO$_2$), which is the cathode of an alkaline battery, and is considered the ink’s pigment. However, the use of this chemical component requires analysis to identify which additives and other ink components will enable it to function as flexographic printable ink.

Extensive research was conducted to address additives that would:

- Mimic the chemistry of a AA/AAA alkaline battery.
- Replicate the necessary conditions for the ink components to react in the same fashion as the battery components.
- Produce the required flow of electrons between printed cathodes and anodes.
- Provide necessary flexographic ink characteristics for use with a flexographic press.

**FORMULATION OF BETA1— THE BASELINE CATHODE INK**

The first goal was to create a stable MnO$_2$ dispersion. Many trials with different dispersion agents such as E-Sperse, Zeta-Sperse, and Solsperse failed; therefore, solvents were not considered as possible dispersants. Organic solvent blends were also researched, but the pigment would flocculate over time so a new approach was examined. This new approach uses the water-soluble compound potassium permanganate (KMnO$_4$).
By taking potassium permanganate ($\text{KMnO}_4$), a water soluble Mn(VI) oxidizing agent, and putting it in contact with paper (a reducing agent), a redox reaction occurred where the oxidation level of Mn(VI) in the permanganate was reduced to Mn(IV). The presence of MnO$_2$ was tested and verified by using hydrogen peroxide. MnO$_2$ is known to be a catalyst for creating a highly exothermic conversion of hydrogen peroxide to hydrogen and oxygen.

Unfortunately, MnO$_2$ alone is not conductive (the cathode of a battery often has a copper rod or graphite to allow the flow of electrons). Carbon black (graphite) was added into the formulation to act as a conductor. Research done by Danilov, Melezhik, and Danilenko (2005) involved the creation of carbon nanotubes (CNT) modified with MnO$_2$ deposits by a reaction with the CNT and KMnO$_4$ shown by this formula (p. 1849):

$$4\text{KMnO}_4 + 3\text{C} + \text{H}_2\text{O} \rightarrow 4\text{MnO}_2(\text{aq}) + 2\text{KHCO}_3 + \text{K}_2\text{CO}_3$$

Adding carbon to the KMnO$_4$ produced a similar reaction to the one between Mn(VI) and the paper cellulose. The active MnO$_2$ was now achieved by a redox reaction between Mn(VI) and the carbon surface. However, this reaction happened over the course of a week. To speed up the reaction with the carbon, many different mixtures of carbon + KMnO$_4$ were tested. The discovery of adding CMC
(carboxymethylcellulose) and KOH (potassium hydroxide, an electrolyte) yielded an instantaneous conversion of KMnO₄ to MnO₂ and added the proper viscosity to the ink. Conclusively, the addition of KOH, and CMC completed the creation of the Beta1 formulation.

**FORMULATION OF BETA2— THE READJUSTED CATHODE INK**

By testing characteristics and performance of Beta1 for flexographic printing, some concerns were identified and readjustments were made to address these concerns, resulting in the readjusted Beta2 formulation.

Beta2 is a modification of Beta1 to remedy noticeable drying problems on press and focuses on the use of an acrylic binder and its effect on the printability of the ink. In the Beta1 testing, after about 30 seconds to 1 minute the ink began to dry on the rollers. Due to this observation, it was concluded that the ink formulation needed modifications, giving rise to Beta2. The major modification to the formulation consisted of the addition of a humectant, a compound that absorbs water from the air, to help aid in the drying. In addition, the binder was changed to an acrylic resin, to potentially provide more stability on press. In Beta2, Joncryl 60, an acrylic resin, replaced the CMC and propylene glycol was added as a humectant.

**Research Objectives**

Through the summarized literature review and preliminary testing outlined above, this research identifies key problems relating to the printability of two cathode inks. Specifically, the combination of the Beta1 formulation with commonly used flexography substrates under normal printing settings has print quality issues, including but not limited to:

- Mottled solid prints and discontinuity of transferred film affecting the safe function of the final product represented by unpredictability of continuous material volume and truthful charge capacity of the product.

- Drying time was significantly long, preventing suitability for inline finishing of complete product due to instability of the film for perceived transport requirements.
The objectives of this study are:

- To further investigate factors that may result in key printing defects, i.e., mottling of printed film and excessive drying time. This is conducted through test prints of both Beta1 ink for solids and tints.

- To investigate the effect of adding acrylic resin, a binder used in the Beta2 formulation, outlining the correlation between the acrylic-to-water content ratios with preferable print characteristics.

- To summarize key concerns regarding the formulations with regards to performance and suitability of use.

**Methodology**

To address the outlined objectives, this study was divided into four distinct tests in three phases: 1) preliminary ink testing, 2) test printing, and, 3) prototype testing. The tests are defined as follows:

- Testing ink characteristics of Beta1 & Beta2 for solid content proportions & rheology to define expected effects of the addition of acrylic content.

- Testing of print characteristics of Beta1 formulation for printing solids and tints with two printing pressure settings (75N & 500N) and on two substrates (coated & uncoated) to identify preferable test settings.

- Testing of print characteristics of the Beta2 formulation for printing solids with three acrylic-to-water ratios, under constant pressure-speed-anilox combinations, with two substrate types (coated & uncoated).

- Testing of functional characteristics for both Beta1 & Beta2 cathode type batteries using temporary anode and electrolyte inks.

- The focus of this report is on the test printing and prototype testing; however, ink characteristics are crucial and will be presented as an integral part of the methodology.
Formulation and Testing of the Cathode Inks

For the formulations of Beta1 and Beta2, a few things need to be clarified to properly understand the tests and their results. Foremost, both Beta1 and Beta2 are different formulations, Beta2 being a modification of Beta1 with the use of an acrylic resin as a binder.

Beta1 is intended to show the concept of a printable cathode as well as demonstrate whether it can be functionally formulated to print and, if so, how does it print. Beta2 is intended to ascertain how a change in the acrylic-to-water ratio of the ink can affect how the ink prints.

Both inks were printed on coated and uncoated cover weight stock. To test the voltage of the cathode inks and to further display the concept of a printable cathode as being functional, a temporary ink formulation for the electrolytic and anode inks were used.

It is important to note that the tests and results are not intended compare the cathode inks to determine which ink is better, but intended to display how the two inks behave when printed, relative to their formulation and the substrate they are printed on, and to convey a preference over which ink would likely be used in respect to the conditions.

Table 1. Percent Solids and Rheological properties of Beta1 and Beta2 formulations.

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Beta1</th>
<th>Beta2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids</td>
<td>27%</td>
<td>24%</td>
</tr>
<tr>
<td>C &amp; MnO₂</td>
<td>9%</td>
<td>8%</td>
</tr>
<tr>
<td>Water</td>
<td>73%</td>
<td>76%</td>
</tr>
<tr>
<td>Rheology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscosity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Speed</td>
<td>147.0 cP</td>
<td>142.5 cP</td>
</tr>
<tr>
<td>High Speed</td>
<td>8300.0 cP</td>
<td>9200.0 cP</td>
</tr>
</tbody>
</table>

Using ASTM-D4713-92(2007), the standards test for nonvolatile content of heatset and liquid printing ink systems, the amount of nonvolatile content in Beta1 and Beta2 formulations was calculated.
The formulation of Beta1 contained 73% water and 27% solids, 9% of which are carbon and MnO$_2$, whereas Beta2 contains 76% water and 24% solids, and 8% of which are carbon and MnO$_2$.

A test of the ink’s rheology, the viscosity of an ink over a given time, was performed using a Brookfield viscometer and #1 spindle across multiple RPM’s 0.3 to 100.

The viscosity of Beta1 in Centipoise (cP) ranged from 8300cP at low speeds to 147cP at high speeds. It can be seen from the data that the ink formulation has sheer thinning properties. Beta2 shares the same properties as Beta1 but with an overall viscosity range from 9100cP at low speeds to 142.5cP at high speeds (see Figure 4).

**Test Prints**
To test the printability of Beta1, a simple flexographic plate consisting of a 100% solid, a 50% solid, and a gradient step patch from 100% to 5% was created (see Figure 5). This plate was used to test the halftone and gradient abilities of Beta1. There was more concern about 100% patches
than dot size or halftones, so another set of plates was designed for later testing, which consist of 100% solids. An IGT Reprotest Flexography Printability Tester (Model F1, Serial 432.B.033) was used to print at various pressure settings on both coated and uncoated substrates.

The Beta2 formulation focused on the effects of an acrylic resin on print quality of the ink. To compare the effect, multiple formulations with different acrylic-to-water ratios were made. These were then printed using a flexographic plate containing a 100% solid patch on an IGT proofer (Model F1, Serial 432.B.033).

Prototype Construction and Testing

For the purpose of prototype testing of the cathode inks, temporary anode and electrolyte inks were formulated as follows:

- The electrolytic ink was a simple 35% solution of KOH with CMC to modify the resulting viscosity. The anode ink consisted of zinc powder with KOH as an electrolyte, propylene glycol as a humectant, and Joncryl 60.

- Both of these inks are temporary placeholders for final formulations. They may be responsible for some differences in the reported voltage of the tested cathode inks but this is unconfirmed, pending further research and development to improve the circuit.

- Testing of the finished prototypes only covered voltage checking using a simple voltmeter.

**Figure 5.** Test plate used to test printability of solid 50%, 100% and 5-100% gradient patched on uncoated and coated substrates.
Results & Discussion

Table 2. Printability comparison of Beta1 on coated and uncoated substrates with various pressures.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Printing Pressure</th>
<th>Evenness of Solids</th>
<th>Halftone Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coated</td>
<td>500 N</td>
<td>Even (Best for coated)</td>
<td>Smudged</td>
</tr>
<tr>
<td>Coated</td>
<td>75 N</td>
<td>Uneven</td>
<td>Smudged</td>
</tr>
<tr>
<td>Uncoated</td>
<td>500 N</td>
<td>Even</td>
<td>Lost</td>
</tr>
<tr>
<td>Uncoated</td>
<td>75 N</td>
<td>Even</td>
<td>High TVI</td>
</tr>
</tbody>
</table>

For Beta1, the results can be viewed in Table 2 and were as followed: On the coated substrate at a high pressure of 500 newtons there was a blur in the halftones but a clean 100% solid consistency is achieved. At a lower pressure of 75 newtons, the halftones were printable, though a little smudged, but lack the 100% solid consistency we received in the high-pressure print. On the uncoated substrate at a high pressure,
Battery Patch Printing
*Beta2: Cathode Ink Formulation with Acrylic Resin*

Inking Force: 100N  Printing Force: 30N  Speed: 0.3 m/s

![Image comparison of 100% solid patches of the Beta2 formulations, varying the acrylic to water ratios across coated and uncoated substrates.](image)

*Figure 7.* Image comparison of 100% solid patches of the Beta2 formulations, varying the acrylic to water ratios across coated and uncoated substrates.
the halftones are completely lost, and a moderately okay density was achieved in 100% solid. At a lower pressure, the halftones print beautifully, but anything above 50% looks the same. The preferred settings outlined from this test were suited using for this run of Beta1 ink, however, may not apply to the Beta2 formulation or with other printing devices. The correlations made through these observations may be useful for future reference.

Referring to the patches in Figure 7, it was observed that as the acrylic concentration in the formulation rises, the print quality increases; conversely, as the acrylic concentration decreases, the print quality decreases. In addition, on the coated substrates, the less acrylic present the more crazing is apparent. Furthermore, the uncoated substrate absorbs ink faster, producing a better print.

Using the placeholder electrolytic and anode inks mentioned prior to the discussion of the Beta1 and Beta2 formulations, a voltage of 1.0 to 1.5 in Beta1 and 0.5-1.1 in Beta2 was achieved using a standard voltage meter. The variation in the voltage is the result of where the point of contact for each voltage meter prong touches on each of the anode and cathode inks. Also, difference in voltage depends on how much moisture is present within the system at the time of the reading.

### Table 3. Comparison of the Beta2 formulation with focus on the printability of different acrylic to water ratios.

<table>
<thead>
<tr>
<th>Acrylic Ratio</th>
<th>Substrate</th>
<th>Evenness of Solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:15</td>
<td>Coated</td>
<td>Even</td>
</tr>
<tr>
<td>27:15</td>
<td>Coated</td>
<td>Uneven</td>
</tr>
<tr>
<td>75:15</td>
<td>Coated</td>
<td>Even (Best for uncoated)</td>
</tr>
<tr>
<td>13:15</td>
<td>Uncoated</td>
<td>Uneven</td>
</tr>
<tr>
<td>27:15</td>
<td>Uncoated</td>
<td>Even</td>
</tr>
<tr>
<td>75:15</td>
<td>Uncoated</td>
<td>Even (Best for uncoated)</td>
</tr>
</tbody>
</table>

### Conclusion

The overall goal of the ink formulations is to demonstrate a cathode ink formulation that can be printed by flexographic means. This cathode ink in combination with an electrolyte and zinc mimics a battery,
ultimately proving the concept of a flexographically printable battery. Beta1 and Beta2 display different functionality depending upon the substrate they are printed on, and change depending upon which binder is used during formulation. Given the results, for most applications it would appear that an uncoated substrate has greater reliability in functionally printing the cathode. Coated substrates are unfavorable due to the difficulty of attaining a quality print on this surface (i.e. crazing), and one key concern in printing the paper battery would be getting the most material down onto the substrate.

The voltage meter clearly shows that Beta2 achieves a lower voltage range than Beta1. This could be due to the inability for electrons to flow within the cathode ink due to the nature of the specific resin. This could cause undesired results in the long run. If printing on a coated substrate, Beta2 would be preferred over Beta1 due to its printing stability on a coated substrate. Furthermore, a Beta2 ink formulated to contain more acrylic resin than water content will produce a stable print, but may lack desired printed matter. However, it may be more desirable to print on the uncoated side of a coated-1-side paper, so the coating can provide a moisture barrier on the back side of the sheet. When using the cathode in a printable battery concept, an externally placed terminal may want to be considered. Future work will be comprised of modifications and additional tests. Tests for voltage and discharge of the printable battery concept will be performed. The electrolytic and anode ink formulations will be modified to perform more efficiently with the cathode ink.

References


Using XMP Metadata to Optimize Publishing Production Workflow

Ben Vanderberg

It is crucial in the publishing industry to have an efficient workflow that transfers information from one step in the workflow to the next. This paper describes the advantages of using Adobe XMP (Extensible Metadata Platform) to optimize production workflow. The background and history of XMP metadata will be examined to understand its benefits. Case studies from the Image Permanence Institute and RIT Digital Publishing Center are examined for their excellent use of XMP metadata in automated workflows. XMP metadata opens the potential for any number of workflows to be developed based on the technology.
Introduction

Efficiency is crucial to a good workflow system regardless of what industry, with the publishing industry being no exception. Regardless of whether a print provider, a website administrator, or an editor for a publication, speed and efficiency is vital for business. Without an efficient workflow, a publication may miss print deadlines, costing potentially thousands in sales; it can cost a printer a customer; it can reduce traffic revenue for a website developer.

In the publishing industry, one may encounter some of the following problems:

• Miscommunication between the designer and a printer or website in how a creation should be displayed or outputted.

• Inability to regain author information to give appropriate credit.

• Information crucial to the next step in a workflow, such as a printer job ticket, may not be accurately submitted.

• Redundant information may cause miscommunication between departments.

• While producing many versions of a file, it may be difficult for a company to decipher what changes were made to the document.

These issues can cost great amounts of time trying to resolve. The ability for this information to travel with documents consistently can be extremely valuable and can alleviate several efficiency problems. XMP metadata helps alleviate these issues.

This report will examine the power of XMP (Extensible Metadata Platform) metadata for use to optimize workflows within the publishing industry. The area this report will concentrate on is workflows where content is needed to be passed off to several different companies or departments in order to produce their products.

Background

In order to understand the benefits of what XMP metadata is and how it can be beneficial to production workflow, it is important to understand metadata technology and the fundamentals of XMP.
What is metadata?

Many places define metadata as “data about data” (Boiko, 2005). While this statement is true, a bit of clarification is needed. Narrowing the scope to the purpose of this paper, metadata is information that depicts additional descriptive information that is not contained within the content of a digital file. Metadata can be many pieces of information that are already taken for granted: file size, file name, date created, date modified, etc. (Boiko, 2005). All of these pieces are additional information beyond what is contained within the content of the file. In addition to the metadata mentioned previously, there are also other pieces of metadata that can be useful with media files. Metadata can be seen as a way to answer the questions people may have regarding a file (Figure 1). Information such as a document’s title, author, and descriptions are able to be stored to give users and systems the ability to get information about the file without having to read and analyze the internal content. These different additional pieces of information are called metadata.

XMP is a technology developed by Adobe Systems Inc. to standardize the embedding of metadata into digital files and documents based on XML (Extensible Markup Language) (Figure 2) (“Adobe XMP Adding,” n.d.). XMP brings great potential innovation to media files. XMP allows for the easy tracking of media assets to be retrieved quickly. It is able to track the origin and modifications to a document for later examination. Also, it is able to track the spoken word in a video document, allowing for faster context searching of content. It is able to

![Figure 1. When looking at a digital file, there are many questions that may be asked about the file. Metadata can be used as means to store and answer some of the questions people may have about a file.](image-url)
embed this information into a variety of different file formats commonly used in a variety of different media industries including JPEG, TIFF, MOV, INDD and others (see below for additional supported formats).

- AI
- CIFF
- CR2
- CRW
- EMC
- CS1
- DCM, DC3, DIC
- DCP
- PNG
- EPS
- EPSF
- PS
- EXIF
- GIF
- HDP, WDP
- ICC, ICM
- IND, INDD
- JP2, JPX
- JPG
- MEF
- MOS
- MOV
- MRW
- NEF
- NRW
- ORF
- PDF
- PEF
- PNG, JNG, MNG
- PPM, PBM, PGM
- PSD
- RAF
- RAW
- RW2
- RWL
- THM
- TIFF
- XMP

(Harvey, n.d.)
XMP allows for easy retrieval of files using embedded metadata information. Bodies such as Dublin Core, IPTC (International Press Telecommunications Council), and the EXIF (Exchangeable image file) format established by JEIDA (Japan Electronic Industries Development Association) have developed schemas based on this specification that match their fields used in their organizations (“Adobe in depth,” n.d.). Information such as the title of a document, the location of an image, as well as many other variables can be embedded into a media file (XMP specification, 2005, p. 55). Using applications such as Adobe Bridge, users or systems are able to search the embedded metadata in order to find their appropriate file (“Adobe Bridge CS4,” n.d.).

The tracking of modifications is made easier using the XMP technology. Applications such as Adobe Photoshop allow for the tracking of changes to be written right into the file (Chastain, n.d.). This allows the user to evaluate what modifications were done to the file, whether for investigative use or to track the amount of time a document was worked on. The development of raw images in high-end digital cameras has expanded the use of tracking changes even more. When modifications are made to a raw file, no new pixels are written to the file. Rather, XMP metadata is embedded into the file indicating what changes need to be rendered. When the document is open, the computer then re-processes those changes. This allows for photographers to work on files nondestructively, as the file is not being re-written.

Figure 3. Adobe Creative Suite “Get Info” panels allow users to embed and read XMP metadata.
One of the new innovations in XMP metadata with its search function is the ability to search the context of what is spoken in a video file. Using technologies such as Adobe Premiere Pro’s Speech Search technology, speech is processed by the application and the words are embedded into the video files (Ebberts, n.d.). This information is temporal metadata, meaning it will embed the word that is said as well as the time in the clip in which the word was stated. Using the Premiere software, this information can be played in context. In addition, because the information is embedded into the file, this can be searched when using applications such as Adobe Bridge.

XMP is an impressive technology that will continue to develop over time. The ability to search across several different files allows users to quickly find their files they need, even if they do not remember the file name. The tracking of changes is able create new ways people track and monitor the modifications and the time allocated to a file. The ability to search temporal metadata allows a user to pinpoint specifically when a certain phrase was said in a file. The innovations in XMP will continue to develop as the need for better workflows evolve.

**The Case for Portable Metadata**

In many publishing workflows, there are many media files that are passed from department to department. A designer may pass his or her work to a publisher, a publisher may pass their files onto a printer, and so on (Figure 4). As these files are handed off to different departments,

![Figure 4. Portable metadata allows important information to travel wherever a media file goes.](image)
there is often the problem where information is not passed to the next department. Therefore, metadata that is able to travel with a media file can be crucial for seamless hand-off between departments. The following are a few fictional examples of where portable metadata using XMP could be a valuable asset for a print job, a web job, and a publishing company when the hand-off of information is essential.

**PRINT JOB**

A job is submitted to a print shop. The job is a 30-page project proposal to be handed out to potential business investors. The file is submitted to the printer and told to print it. However, the customer did not give specific specifications of how they wanted their final output. Did they want the pages duplexed (printed on both sides)? Did they want any binding options, like stapling, etc? Did they want the document in color? How many copies are needed? Should the cover be glossy? What size page should the document be printed on? Assumptions made in any of these categories could be devastating to the business, as well as for printer. One might have to call or send e-mail messages to the client to get these specifications clarified, which is more down time, particularly when it is holding up production.

**WEB JOB**

A company runs a website that hosts a large amount of stock images and videos. When relating to image and video media, one has to take into account what is in the image, who took the image, where was the image, licensing terms of the image, the size of the image, the format of the image. When searching stock image websites, clients often have specific criteria that they are looking for. For example, they may be searching for an image of a yellow flower. Without this additional information, clients have to browse through thousands of images before finding the image that they are looking for.

**PUBLISHING COMPANY**

An American local newspaper called Smalltown Daily is nearing its deadline to submit to its printer. In this edition, President Obama is meeting with different important contributors to the community. Layouts have been designed and are waiting for content. Articles and photographs are
being submitted from the field. As the layout designer is placing the content, he/she runs into a problem: the images have President Obama shaking hands with important leaders in the community, however there is no caption explaining the relevance and who is in the photograph. It can be difficult to identify and find the relevance of a photograph and can hold up publication trying to track down the information.

As shown in the previous examples, a difficulty in the transfer of information from one party to the next can hinder the productivity of the next party while trying to figure out their required information. How do you easily transfer that information over? That is where Adobe XMP comes in.

**Automation**

The potential of XMP becomes evident when automation comes into play. There are many tasks in the graphic arts industry that are automated processes. If the information from the beginning used XMP accurately, then automated systems can be designed to automatically process files based on the specifications in the metadata. Much like the production line changed the automobile industry, XMP has the potential of changing the publishing workflow.

Take for example a simple process often done on a daily basis: image conversion and resizing. In many workflows, for example professional photography, there are standard sizes that images are resized to. Let us say that a photographer will offer prints for specific photos in 2.5x3.5" wallet size, 4x6", and 8x10". These options may be contained within the metadata. For example, one may enter in the metadata that the output will only include a 2.5x3.5" image and an 8x10" in an order. We may also want to have another field with the quantity of each print. When sent to an automated system, the system could then read the metadata, create appropriate resized images and tell a printer the appropriate quantity to print. In this instance, information is inputted once, and many actions can be automated afterwards.

Organization within a computer file system is another example where XMP metadata is useful. For example, there are several images that are coming in from a variety of different photographers with a variety of
different versions. An organization may have specific locations that it places its “original files” and its “edited files.” The organization may also want to separate these files based on the photographer. With XMP metadata, a file that contains a field with the photographer’s name and whether the image is an edited version or not, would be able to be placed automatically in the correct location in a file system. This ensures that everything is in the right place.

**Support from Current Systems**

Today, XMP has broad support by a number of different companies and software. Support from these different companies allows for the XMP information to be transferred from system to system and be integrated into a variety of different workflows. Some of the companies that support XMP include (“Adobe XMP partners,” 2009):

- Adobe Systems Inc.
- BrandWizard Technologies
- ClearStory Systems
- Context Media
- EMC | Documentum
- eRoket
- Extensis
- FotoWare
- GLOBALedit
- Google
- IBM
- Interwoven
- Microsoft
- IXIASOFT
- MediaBeacon
- MerlinOne
- NetXposure
- North Plains Systems
- Optima SC
- Pound Hill Software
- Profium
- PTFS
- Triple Triangle Inc.
- Widen Enterprises Inc.
- WoodWing Software
- Xinet

**XMP in Production Workflows**

Companies from all over the world have already integrated XMP in their production workflows. It is used by companies such as Getty Images, Associated Press, Interwoven, North Plain Systems, WebWare Corp., and the Rochester Institute of Technology (“Adobe XMP Customer,” n.d.). In addition, a number of standard bodies have adapted to use
Using XMP Metadata to Optimize Publishing Production Workflow

XMP to implement their standards. Some of these standards include AdsML, Creative Commons, Digital Image Submission Criteria (DISC), Dublin Core Metadata Initiative (DCMI), International Press Telecommunications Council (IPTC), and many others (“Adobe XMP in depth,” n.d.). Here are two case studies to highlight some of the ways XMP can be utilized to optimize production workflow. The first case study focuses on the use of metadata by the Digital Publishing Center at RIT, while the second describes the unique uses of XMP metadata by the Image Permanence Institute for their Graphics Atlas project.

**Digital Publishing Center at RIT**

The Digital Publishing Center (DPC) is a facility within the School of Print Media in the College of Imaging Arts and Sciences at the Rochester Institute of Technology in Rochester, New York. The facility provides printing services for students and professors within the school, and is completely run by students (Lehman, 2009). The system utilizes the Xinet digital asset management system to manage the submission of jobs and the transfer of files to link with DALiM TWiST to process pre-press files before sending different print RIPs (raster image processor) (Lehman, 2009).

Customers are required to submit their jobs to the DPC using a portal which utilizes Xinet’s WebNative engine. The client must fill out necessary fields detailing the specifications. These job ticket specifications include contact information, type of printer to print to, quantity, finishing options, and other specifications. Based on this metadata, the files will be placed in the appropriate queues and job tickets will be printed out for the pressroom to correctly process the job (Lehman, 2009).

The DPC also provides customers with the option of downloading and installing custom Get Info Panels for the Adobe Creative Suite to allow customers to embed all their job ticket information within the metadata (Lehman, 2009). This information is then embedded into the file. When the file is uploaded to the portal website, the information is parsed from the XMP metadata and auto populates all the information needed for the job ticket (Figure 5). Adobe’s Get Info Panels also allow templates to be saved, which allows the customer to create different templates for output through the DPC. This makes their workflow faster and more optimized.
Here is an example of how a student might use metadata to increase his or her productivity in the DPC. As shown above, the DPC requires the customer name, academic program code, e-mail address, and phone number. This information is the same each time the student submits a job to the DPC, which can therefore be saved within an XMP metadata template. The student may want to have a few more templates, as it is often that this student will want to output jobs that are for Digital Color, 8.5x11” and glossy coated. If these are specifications that are common, they can be saved by the customer and applied to several different documents at once, or saved for when they need to be used in the future. In addition, this information is stored within the file, which means when the file is archived, the output information will stay in the file. This may be important when needing to reprint a file and remembering what the output specifications of a specific project were. All the customer has to do is re-upload the file and immediately all the specifications are included.

**Image Permanence Institute Graphics Atlas**

The Image Permanence Institute is a non-profit, university-based laboratory devoted to the research of preservation. Sponsored by the Rochester Institute of Technology and the Society for Imaging Science and Technology, the institute is the largest independent laboratory for this type of research (“IPI: About IPI,” n.d.).
One of its projects is an online resource called the Graphics Atlas that “brings sophisticated print identification and characteristic exploration tools to archivists, curators, historians, collectors, conservators, educators, and the general public” (“Graphics Atlas: Welcome,” n.d.). The site features different samples to explain the different print processes and allow for zooming and other features to explore the different processes in-depth. The Graphics Atlas team uses a combination of XMP metadata and customized plugins for Adobe Bridge CS4 to automate and process their workflow (Vanderberg, 2009, p. 10). For each sample shown on the website, many images have to be taken at different magnifications. Some of the information that needs to be tracked for each sample include: type of printing process, category of printing process, magnification, specific areas of interest from a specific view, and other fields.

Based on the metadata that is inputted, the samples are renamed to the appropriate naming convention outlined for their workflow (Vanderberg, 2009, p. 14). Each file will have a unique file name because it relates to the unique metadata that each file has. Once the file has been renamed, the file will be moved to a specific location within a folder hierarchy based on its metadata.
Once the files are there and ready, the files can be processed for web. Based on the metadata provided, files will be renamed and resized to specific different dimensions. These will then all be placed in a folder ready to be uploaded to the website. When the images are uploaded to the website, the metadata is parsed from image files and placed correctly into the website’s database and placed on the appropriate pages. Throughout the workflow, metadata is used to determine what needs to be done in the next automated step.

![Workflow Diagram]

**Figure 7.** Image Permanence Institute workflow process for Graphics Atlas.

**Tools for Developing Customized Metadata**

One of the great benefits of XMP is the freely available programming tools which integrate reading and writing of XMP metadata into a currently developed system. Already, many systems currently have support for XMP reading and writing. The following resources provide additional information regarding the XMP specification and tools to integrate XMP into a current workflow system.
• Adobe XMP SDK (Software Development Kit)
  http://www.adobe.com/devnet/xmp/
• Adobe Custom File Info Panels
  http://www.adobe.com/devnet/xmp/
• ExifTool
  http://www.sno.phy.queensu.ca/~phil/exiftool/
• XMP Library for ActionScript
  http://labs.adobe.com/technologies/xmplibrary/

Conclusion

XMP is an impressive technology that can optimize publishing production workflow. Its ability to embed metadata directly into files alleviates issues related information transfer between different departments of a workflow. This ensures that the data related to a file stays with a file, so the information sent is always accurate and accessible. It affords companies to use this information to automate file processing based on embedded XMP specification in a file. XMP makes production workflows by streamlining the transfer of information into a single transferrable and reliable medium.

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Ben Vanderberg
Color Difference Equations and Their Assessment

Scott Millward

In 1976, the International Commission on Illumination, CIE, defined a new color space called CIELAB. It was created to be a visually uniform color space. At the same time the color difference equation \( \Delta E_{ab} \) was developed to communicate color tolerances. However, CIELAB is not truly visually uniform, making colors having the same \( \Delta E_{ab} \) magnitude in different regions of the color space appear of different magnitude. Instead of developing a new color space, the color science community has developed several other color difference equations that use higher order mathematics to give more or less weight to CIELAB values in different areas of the color space, resulting in color difference equations that better correlate with visually perceived differences.

This research uses ten reference Pantone color samples, and four other Pantone colors, which are distanced about 6 \( \Delta E_{ab} \) around each reference color. A paired comparison test was conducted so that the perceived color differences between the reference color and the four sample colors could be ranked. Five color difference equations (\( \Delta E_{ab} \), \( \Delta E_{94} \), \( \Delta E_{00} \), \( \Delta E_{CMC} \), and \( \Delta E_{DIN99} \)) were evaluated to determine which best correlates with the perceived color difference. The results show (1) that only four out of ten paired comparison tests had significant agreement among all 10 observers; (2) the \( \Delta E_{ab} \) equation did a good job in predicting color differences for near neutrals; and (3) there is no clear winner for a color difference equation that outperforms the rest.
Introduction

CIELAB color space was intended to represent color by numbers in a visually uniform way. The difference between two colors can be calculated easily using an equation developed by the CIE in 1976 called ∆E_{ab}. This equation calculates the linear (Euclidian) distance between two points in the L*a*b* 3D space. Even though, L*a*b* is not truly visually uniform, it is the standard color space used by the graphic communications industry.

The human visual system is more sensitive to different kinds of changes and perceives these differences in different magnitudes even though they may have the same calculated difference. For instance, the eye is more sensitive to changes in neutrals than in high-chroma colors having the same lightness. In addition, the eye is more sensitive to changes in chroma than changes in lightness for neutrals, but this is not so for yellows. Thus, the same vector distance may not be perceptually the same for all colors.

Many ∆E equations have been created to try to calculate the perceived difference between two colors by giving more tolerance to areas that the eye is not as sensitive to. This research will try to identify which of five equations best describes the perceived color difference in areas of interest.

Methodology

This study is a small-scale experimentation of a possible way of evaluating color difference equations. Only ten areas of interest were chosen due to the limitation of using pre-printed Pantone colors. This section explains how the areas of interest were chosen, preparation of patches for evaluation, and the evaluation procedure.

Choosing Areas of Interest

There are data sets, e.g., RIT-DuPont and others with equal visual differences, which have been developed and used by researchers to evaluate the performance of different color difference equation. This research is organized to identify color patches with equal, but noticeable color differences as the first step in the assessment of color difference equations.
Using colorimetric values from measurements taken from a Pantone swatch book, the $\Delta E_{ab}$ of all possible combinations were calculated. Pantone colors which have at least four other Pantone colors with a $\Delta E_{ab}$ of 6.0 ($\pm 0.5$) were determined. An automated script was written to generate this list for this study. From this list, ten patches were selected as areas of interest with different hues, saturations, and lightnesses, and marked as References R1 to R10. Four Pantone colors with a color difference of 6.0 $\Delta E_{ab}$ ($\pm 0.5$) were selected for each reference patch and marked as Samples S1 to S4.

**Paired Comparison Evaluation**

References and samples were prepared by cutting squares from a Pantone Solid Chip book and mounting them flush on mounting board. Two reference tiles were placed side-by-side separated by about four inches on the gray table inside a light booth (D50 lighting was used). Two samples were placed against the outside edges of the references (Figure 1). Observers were asked, “Which pair demonstrates the smaller color difference?” Pairs of samples were switched for each combination and the observer’s response was recorded.

![Figure 1. Paired comparison setup.](image)

**Results and Analysis**

Results are reported by selected areas of interest and paired comparison evaluation, followed by analyses of the five color difference equations that were used.

**Selected Areas of Interest**

Figure 2 shows the Pantone swatches that were used as reference and sample patches. The Pantone Library is an example of a large database
Figure 2. Selected Reference and Sample Pantone swatches. Note: This figure was printed with CMYK and may not represent the actual Pantone colors listed. An effort was made to maintain a similar perceptual difference.
of colors with preprinted samples. It does not consist of evenly distributed colors and therefore does not include a large selection of patches that meet the requirements for this test. Most of the viable patches are in the L* 75 to 85 range and are not representative of a typical color gamut. An effort was made to select areas of interest with different hues and saturations.

Reference 1 (R1) represents a saturated red hue and Reference 2 (R2) is a chromatic blue. Reference 3 (R3) is a neutral gray that will show colorcasts and changes in lightness. Reference 4 (R4) is a less chromatic pink than R1; Reference 5 (R5) is a mint green. References 6 (R6) and 7 (R7) are both low chromatic yellows with Reference 7 being less chromatic. All of the surrounding samples are more or less chromatic or have slight hue or lightness shifts. Reference 8 (R8) is a pale blue color that will show hue shifts in color. Reference 9 (R9) is a dark maroon color. Reference 10 (R10) is a flesh tone area and represents one of the memory colors.

Observers
Ten observers were chosen from within RIT’s College of Imaging Arts and Sciences building. The ages of the observers ranged from 18 to 30 years old. Eight participants were male and two were female. The group consisted of observers from India, China, Denmark, and North America for cultural diversity. Five observers were graduate students in the School of Print Media with interest and a high degree of experience in color theory. Three observers were undergraduate students who have some experience with color and images because they were enrolled in programs within the College of Imaging Arts and Sciences. The tenth observer was a visitor to the school with little experience with judging color. None of the observers were aware if they had any level of color deficiency when asked.

Paired Comparison Evaluation
Each observer was asked to identify the sample that demonstrated less color difference to the reference in each pair. These rankings reflect the sample that shows the smallest to largest difference to the reference. Only four of the ten areas of interest showed a significant agreement among judges (R1, R3, R4, R6), which indicates for many of the areas of interest
it is difficult to choose between two samples that are approximately the same difference, just in different ways. There were relatively few triads found in all of the observations, indicating that the judges are fairly consistent within themselves. These triads were excluded from the analysis.

In light red Reference 1, there was a significant agreement among the judges, with a coefficient of concordance of 0.9. The darker and slightly less saturated sample (R1S4 – Pantone 700C) was viewed to be the least different of all the samples and the much more saturated sample (R1S1 – Pantone 189C) was viewed to be the most different. These two sample patches differed mostly in the $a^*$ where the less saturated patch matched closer than the more saturated color.

In the light, chromatic blue Reference 2, the sample that was viewed as the least different (R2S2 – Pantone 324C) did not change in lightness very much but was more yellow than the other samples. Sample 4 (R2S4 – Pantone 636C), which was deemed to have the largest change, was darker than the other patches and the hue shifted to be more purple. This would indicate that we see more change in lightness than chromatic changes. However, there was a low agreement among judges, with a coefficient of concordance of 0.32, so this set may not be an accurate measure.

The neutral gray set (Reference 3) had the highest agreement among judges, with a coefficient of concordance of 0.95. The slightly darker and more yellow sample (R3S1 – Pantone 413C) was viewed to be the most like the reference. The sample that was viewed as the worst match (R3S3 – Pantone 5315C) was much lighter and redder than the reference even though the third most different sample (R3S4 – Pantone 538C) was lighter. Neutral colors are more susceptible to changes in hue and lightness because it does not take much deviation to get away from the neutral axis and become noticeable.

In low chromatic pink Reference 4, the patch that was observed to be the least different (R4S2 – Pantone 678C) was the patch with the lowest hue difference. It was darker and less chromatic but there was no hue shift, indicating that this is important. The largest difference was viewed in the patch that was greatly darker and more saturated (R4S4 – Pantone 7430C). This patch actually had a significantly higher $\Delta E$ than the others so this is to be expected. This set also had a high coefficient of concordance of 0.90.
In high chromatic mint green Reference 5, the smallest difference was seen in the patch that was significantly lighter but approximately the same chromaticity (R5S2 – Pantone 337C). The largest difference (R5S1 – Pantone 3248C) was much more chromatic than the reference indicating that saturation is the influence in this area. However, there was little agreement among judges, with a coefficient of concordance of 0.35, so opinions varied.

In low chromatic yellow Reference set 6, the lowest difference (R6S2 – Pantone 5797C) was seen in the lighter and more chromatic patch and the most (R6S1 – Pantone 452C) was seen in the much darker patch. Again this indicates sensitivity to lightness over other factors. The agreement among judges was high with a coefficient of concordance of 0.90.

Reference 7, another low chromatic yellow, was difficult to judge according to the coefficient of concordance of 0.66. The sample that was judged as the least different (R7S2 – Pantone 5855C) actually had the largest change in lightness (darker) and was much more chromatic than the others. It was also the patch that had the smallest hue shift along with the second least different (R7S3 – Pantone 614C), which also had a large lightness difference (lighter) and was also more chromatic. This indicates that a hue shift is very important rather than lightness and chromaticity. Because the patches ranked first and second were both very similar in their changes, just in different degrees, this would explain the lower agreement among judges. The worst patch (R7S1 – Pantone 468C) had only slight changes in lightness and chromaticity but had a significant hue shift.

Reference 8, a pale blue, also had a low agreement among judges with a coefficient of concordance of 0.44. The patch that showed the least difference (R8S2 – Pantone 649C) was lighter and significantly less chromatic but had a very small hue shift. The worst patch (R8S1 – Pantone 290C) had little change in saturation and was a little darker but the major change was in the hue. Again this indicates that a hue shift is most noticeable.

Reference 9, a dark maroon, also had low agreement among judges with a coefficient of concordance of 0.60. The observers stated that this was a hard set to judge because the difference of each pairing seemed so similar. Both the observed lowest (R9S2 – Pantone 222C) and second
lowest (R9S3 – Pantone 229C) patches had a small hue difference and the least different was darker the change in saturation was lower than the second. The worst patch was significantly less chromatic and much darker than the reference.

The 10th reference set, the flesh tones, did not have a statistically high agreement among judges (coefficient of concordance of 0.73) but agreement was close. In this case the chromaticity was a factor in choosing the least different (R10S2 – Pantone 481C) since the second least different (R10S3 – Pantone 727C) had less of a hue shift and both were darker. The worst sample (R10S4 – Pantone 7513C) and second worst sample (R10S1 – Pantone 4745C) both had large hue shifts.

While not all judges could agree, it seems that, in lighter colors, a hue shift is most important, seconded by lightness and chromaticity. Because this study was limited to patches in the lighter areas of a typical color gamut, the results can only be attributed to these areas. The limited number of observers also makes the data susceptible to bias. A more finely tuned study would require a more comprehensive selection of areas of interest that would represent all hues, saturations, and lightnesses of a color gamut as well as a larger observer base.

**Color Difference Equations**

Color difference equations are designed to quantify the color differences as perceived by the human visual system. The paired comparison test above sets guidelines as to how people perceive color difference in the areas of interest. Next, the color difference equations are used to quantify the perceived differences and compare them to the guideline.

Each of the five color difference equations used in this study tries to more accurately match the visual difference seen by the human visual system than the traditional $\Delta E_{ab}$ equation. Some work better than others in different areas. For instance, if we compared two colors with $L^a^*b^*$ values of 50; 48; 73 and 48; 47; 60 the $\Delta E_{ab}$ would be 13.19, which is considered to be very poor and unacceptable. The same patches when considered using other formulas produce very different results: $\Delta E_{94}=4.20$, $\Delta E_{00}=4.91$, $\Delta E_{CMC}=6.84$, $\Delta E_{DIN99}=3.54$, $\Delta E_{94}$, $\Delta E_{00}$, and $\Delta E_{DIN99}$ predict that the patches are different but may be visually
acceptable. $\Delta E_{\text{CMC}}$ was getting to the point of being unacceptable but was half of the $\Delta E_{\text{ab}}$ equation.

The color difference equations are identified and shown below with explanations based on the results and analyses of findings.

**CIE1976 ($\Delta E_{\text{ab}}$)**

As discussed this is the Euclidian distance between two points in a 3D space. This would work fine if the L*a*b* color space were visually uniform, but it is not. This equation is mathematically easy but does not generally correlate with a visual difference.

$$\Delta E_{ab} = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$  
(ISO/DIS 13655, 1996)

**CIE1994 ($\Delta E_{94}$)**

In 1994 the CIE made an attempt to correct for the visually non-uniformity of L*a*b* by weighting lightness, chroma, and hue in different proportions (Habekost, 2007). The math is not overly complicated and correlates better to the visual difference.

$$\Delta E_{94} = \sqrt{\left(\frac{\Delta L}{K_L S_L}\right)^2 + \left(\frac{\Delta C}{K_c S_C}\right)^2 + \left(\frac{\Delta H}{K_h S_H}\right)^2}$$  
(Hunt, 2004)

**CIE2000 ($\Delta E_{00}$)**

$\Delta E_{00}$ was an attempt to improve upon the 1994 equation by adding more weighting factors depending on the hue angle of the color (Habekost, 2007). This is the most complicated color difference equation mathematically but does tend to correlate better to the visual difference. There is some question about the data that was used to create this equation but it seems to work (Granger, 2008).

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{K_L S_{L'}}\right)^2 + \left(\frac{\Delta C'}{K_c S_{C'}}\right)^2 + \left(\frac{\Delta H'}{K_h S_{H'}}\right)^2 + R_T \left(\frac{\Delta C'}{K_c S_{C'}}\right)\left(\frac{\Delta H'}{K_h S_{H'}}\right)}$$  
(Hunt, 2004)
COLOR MEASUREMENT COMMITTEE ($\Delta E_{\text{cmc}}$)

This equation was not created by the CIE but by the Color Measurement Committee (of the Society of Dyers and Colourists of Great Britain) and is used primarily in the textile industry. Again, there is weighting placed on the lightness, chroma, and hue of the colors (Habekost, 2007). It is similar to the $\Delta E_{94}$ equation but is slightly more complicated.

$$\Delta E_{\text{cmc}} = \sqrt{\left(\frac{\Delta L}{S_L}\right)^2 + \left(\frac{\Delta C}{c \cdot S_c}\right)^2 + \left(\frac{\Delta H}{S_H}\right)^2}$$  

(Hunt, 2004)

DIN99 ($\Delta E_{\text{DIN99}}$)

DIN99 is a German standard not well known in North America. This equation warps the actual color space to a more uniform model before calculating the difference. This unique method makes the math relatively simple; in fact, the color difference equation is the same as $\Delta E_{ab}$ after the color space is warped.

$$\Delta E_{\text{DIN99}} = \sqrt{\Delta L_{99}^2 + \Delta a_{99}^2 + \Delta b_{99}^2}$$  

(DIN 6176, 2001)

Discussion and Conclusion

As discussed earlier, the different color difference equations give weightings in different parts of the color space to better match the differences seen by the human eye. This means that different areas of the color space will show difference more than others and different factors of the color difference are more perceivable than others. Table 1 shows two examples of how visual ranking and calculated rankings agree. The agreement increased if calculated rank matched the visual rank of a specific sample.

Figure 3 shows the agreement between the observers’ ranking, of least different patches to greatest difference, to the calculated difference of each color difference formula. In some cases none of the calculated rankings matched the observed rankings and resulted in a zero agreement.

In R1, all five of the equations predicted the smallest differences as compared to the visual observations, but did poorly ranking the rest.
Table 1. Examples of agreement between visual ranking and calculated rankings. Red indicates match.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Visual Rank</th>
<th>$\Delta E_{ab}$ Rank</th>
<th>$\Delta E_{94}$ Rank</th>
<th>$\Delta E_{00}$ Rank</th>
<th>$\Delta E_{CMC}$ Rank</th>
<th>$\Delta E_{DIN99}$ Rank</th>
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<td>1</td>
<td>1</td>
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<td>2</td>
<td>2</td>
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</tr>
<tr>
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<td>4</td>
<td>4</td>
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<td>4</td>
<td>4</td>
</tr>
<tr>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Agreement</td>
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<td>2</td>
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<tr>
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<td>0</td>
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</tbody>
</table>

Figure 3. Agreement between observer ranking and color difference equation rankings. Note: This figure was printed with CMYK and may not represent the actual Pantone colors listed. An effort was made to maintain a similar perceptual difference.
In R2 $\Delta E_{\text{DIN99}}$ predicted the two least differences and $\Delta E_{94}$ predicted the worst two, but there was little agreement between observers. In R3 all of the equations predicted the two least different patches but switched the more different patches indicating that neutrals can be calculated by any equation. Using R4 the $\Delta E_{94}$ and $\Delta E_{\text{DIN99}}$ predicted the entire ranking correctly and the others predicted only the least and worst patches. This set is a good indicator of the validity of each equation. In R5 all but $\Delta E_{94}$ predicted the least different and $\Delta E_{00}$ and $\Delta E_{\text{CMC}}$ the third smallest, however there was little agreement between the judges on this set. Using R6 all of the equations agreed with the visual rankings with the exception of $\Delta E_{94}$, which swapped the two least different. R7 was not agreed upon between judges very well but $\Delta E_{00}$ and $\Delta E_{\text{CMC}}$ predicted the least different, $\Delta E_{99}$ predicted the second least different, and $\Delta E_{\text{DIN99}}$ predicted the third different. $\Delta E_{94}$ was way off in R8 not predicting any and actually transposing the least and most different samples. The other four equations predicted the least different and $\Delta E_{\text{CMC}}$ predicted them all.

Using R9 $\Delta E_{ab}$ agreed with all the visual rankings and $\Delta E_{\text{CMC}}$ and $\Delta E_{\text{DIN99}}$ with the two worst patches. In R10 all but $\Delta E_{\text{CMC}}$ predicted the least different and $\Delta E_{00}$ agreed completely.

As seen in Figure 3, the equation that agrees most with the visual observations is $\Delta E_{\text{DIN99}}$ followed by $\Delta E_{\text{CMC}}$, $\Delta E_{00}$, $\Delta E_{ab}$, and finally $\Delta E_{94}$. This means that $\Delta E_{\text{DIN99}}$ or $\Delta E_{\text{CMC}}$ are most likely to provide a color difference factor that most closely matches the difference perceived by the human visual system. Since $\Delta E_{\text{CMC}}$ and $\Delta E_{00}$ are very complex formulas, $\Delta E_{\text{DIN99}}$ may be a valid choice for everyday use.

Other studies on the assessment of color difference equations have said that $\Delta E_{00}$ quantify small perceived color differences more accurately than other equations (Luo et al., 2004; Johnson, 2006; Habekost, 2007). While others hold $\Delta E_{\text{CMC}}$ to more consistently correlate with perceived differences (Habekost, 2008). These studies use various methods, color sample base and observer group sizes, which will vary their final conclusions.

**Future Research and Limitations**

In this research, the assessment of color difference equations is based color on samples selected from an existing Pantone color swatchbook.
with noticeable visual difference of around $6 \Delta E_{ab}$. Exact measured color differences between samples and their reference are not critical because these color difference pairs are judged visually to form a visual scale. These visually derived color difference scales are used to evaluate the performance of five color difference equations.

Color has three dimensions. It is difficult to tell if one of the three attributes carries more influence in the visual color assessment than the other two. A possible improvement of the experiment is to limit color samples with similar lightness values by producing color patches varying in hue and chroma, only using ICC color management.

This study does not look at the scale of the color difference, only the rank. Further study is needed to see how accurately and how uniformly these equations perform in placing a usable scale of difference on two colors.

A greater number of observers than this study sampled would also be necessary to average out the inherent personal bias of two equally different sample patches.

**Acknowledgments**

I would first like to thank Professor Robert Chung for his encouragement for this study and guidance with the evaluation format. I would also like to thank Dr. Martin Habekost of Ryerson University for his help in interpreting the different equations.

**References**

*DIN 6176: Colorimetric calculation of color differences with the DIN99 Formula (2001).* Berlin, Germany: German Institute for Standardization.


Optical Character Recognition and the Chinook Language

Micah Stupak & Garret Voorhees

Under the guidance of Professor Charles Bigelow, we have investigated the digitization of Kiksht, a moribund Native American language of the Pacific Northwest with an orthography dissimilar to many other languages using the Latin alphabet. Our source was printed text, which we then digitized using optical character recognition (OCR). While largely unknown to the general public, OCR is a common technology and our research has shown that it is highly reliable under specific conditions but less than ideal for certain types of multilingual usage. The final stage in our research is the redistribution of these texts, formatted to meet Unicode standards for digitization of text, via new publishing technologies, such as XML, XSLT, CSS, web applications, and electronic reading devices.
Introduction

We have been working for RIT Professor Charles Bigelow on a project to digitize texts in a Native American language, Clackamas Chinook. The printed material is scanned and then converted to an international character standard, enabling its display on a range of computer platforms and media. The primary goal of this project is to increase scholarly, literary, linguistic and community access to these texts by making them electronically available. A secondary goal is to test the performance of optical character recognition (OCR) software in the conversion of texts in Americanist phonetic orthographies, thereby providing methods and models for further digitizations of these types of texts. A third goal is to share the verbal artistry of an under-appreciated Oregon author, Victoria Howard, and to provide further illustrations for textual analysis of Clackamas Kiksht pioneered by linguistic anthropologists Melville Jacobs and Dell Hymes.

Kiksht

The language on which this project is focused has been called “Clackamas Chinook” by linguistic anthropologists and “Kiksht” by its speakers. Kiksht is a member of the Chinook language family, indigenous to the Pacific Northwest. Chinookan languages and dialects were formerly spoken along the Columbia River in Oregon and Washington states. The Clackamas dialect of Kiksht was spoken in native villages in the vicinity of what is today Portland, Oregon, and south along the Willamette River to the vicinity of the present day cities of Oregon City and West Linn, as well as along the Clackamas River. The Clackamas dialect has been extinct for approximately seventy-five years. A closely related dialect, Wasco-Wishram, is still spoken by a few members of the Warm Springs Reservation in Oregon.

The Chinook language family played a significant role in 20th century American intellectual history, because Chinookan languages were studied by, and influenced the thought of, several American linguistic anthropologists, including Franz Boas, Edward Sapir, Walter Dyk, Melville Jacobs, Dell Hymes, Michael Silverstein, and others. For the non-specialist reader, the surviving texts in Chinookan languages, offer a glimpse of a world that vanished after colonization by European-Americans. In both linguistic and narrative structures, Chinookan
texts, and especially those in Kiksht, reveal a once-rich oral literature. (Jacobs, 1959; Hymes, 1981)

Victoria Howard and Melville Jacobs

The Clackamas Chinook Texts were narrated and translated by Victoria Howard, a native speaker of Kiksht, who resided in West Linn, Oregon, near the ancestral home of the Clackamas people. Mrs. Howard dictated the Kiksht narrations and English translations to Melville Jacobs, a linguistic anthropologist from the University of Washington, who conducted extensive interviews with Mrs. Howard in 1929 and 1930. Jacobs, a former student of Franz Boas, transcribed Mrs. Howard’s Kiksht dictations using a phonetic alphabet devised by American linguists. Jacobs later edited his hand-written field notes into a publication that appeared in 1958 and 1959 as “Clackamas Chinook Texts” (Jacobs 1958, 1959a). Amounting to more than five hundred pages of narrative (in two languages), the Howard-Jacobs texts are the largest and richest corpus of narrative texts in any of the Chinookan languages, and constitute one of the most remarkable examples of Native American literature.

Because Victoria Howard is little known, some words about her and the conditions under which she worked with Dr. Jacobs may be helpful in understanding the context of the narratives.

Mrs. Victoria Howard was one of the last two, or at most three, of the surviving speakers of the Clackamas dialect of Chinook. She spoke good English, and at all times cooperated with efficiency, speed, and delightful humor. (Jacobs 1959b, p. v)

Here is the unsurpassably intelligent and sublimely loquacious informant. Her dictation, too, is nicely distinct, perfectly timed for the most rapid dictation and never a moment hesitant. (Jacobs, 2000)

She exhibited fine humor, sharp intelligence, and excellent diction in both Clackamas and English. ... I was also mindful that few modern Chinook raconteurs could have attained the mastery of literary repertoire and technique that Mrs. Howard seemed to possess. ... Few interruptions marred the hours spent in her home. Mr. Howard, the Howards’ daughter, the latter’s children, and
occasional guests rarely intruded in the small quiet room where I sat writing comfortably on a Singer sewing machine, with Mrs. Howard in a rocking chair beside me. (Jacobs, 1959a, p. 1)

**The Texts**

Jacobs typeset the “Clackamas Chinook Texts” texts in a serifed typeface (IBM “Modern”) using a modified IBM Executive electric typewriter. The IBM Executive typewriter was unusual because its typeface is proportional-width: the characters may be of five different widths. (Frank Romano, personal communication, January 16, 2010) The resulting text therefore bears a closer resemblance to traditional typographic composition. Modifications to Jacobs’ typewriter included addition of Americanist phonetic characters for Kiksht, as well as diacritics and a stress mark. In the published texts, there are approximately 30 characters in the Kiksht alphabet.

```
p t c ć ƛ k kʷ q qʷ ?
p’ t’ c’ ć’ ƛ’ k’ k’ʷ q’ q’ʷ
b d g gʷ ɡ ɡʷ
l s š Ŵ x xʷ ɕ ɕʷ h
m n w y u a i ɛ ə
```

*Figure 1. Kiksht alphabet.*

In addition to segmental characters, such as the barred-l, barred-lambda and schwa, Jacobs’ published transcription makes frequent use of diacritics, some to modify vowels, others to modify consonants. There is also frequent use of a prime mark to indicate syllabic and word stress, as well as a raised dot to indicate vowel lengthening. While these various diacritics and markers are useful in visual interpretation, we found that they created confusion for the OCR applications we used in the project.
Original printed volumes of Clackamas Chinook Texts were photo-copied in 1974 on a Xerox copier (model unknown), as part of research conducted by Charles Bigelow on Clackamas narrative. The photo-copied caused slight expansion of the character strokes, similar to ink feathering in traditional ink-on-substrate processes, which made some of the letter spacing tighter and caused some counters (enclosed spaces in letterforms) to shrink. These distortions do not detract appreciably from the visual legibility of the texts, but we found that they did cause some problems in the OCR process.

![Figure 2. Enlargements of scanned characters showing character degradation.](image)

Using a Xerox DigiPath Series 2000 scanner, we made bitmap scans directly from the original printed texts at 300ppi. The copy available to us had been rebound, however. This caused some distortion of the image of the edge of the page nearest the spine, as it is impossible to get that part of the paper to lie completely flat upon the glass of the scanner. However, this distortion rarely results in an appreciably degraded image.

**Optical Character Recognition**

Optical character recognition (OCR) is the mechanical or electronic process of converting printed or written characters into machine-editable text. The name “optical character recognition” continues to be used, though contemporary OCR applications use digital technology.

In this phase of this project, we discovered that several commonly available commercial OCR applications were not able to produce consistently accurate results from texts composed in the Americanist phonetic alphabet, which contains several characters not found in the orthographies of European languages based on the Latin alphabet.

In addition to image processing and pattern recognition techniques, modern OCR software analyses linguistic context for error correction.
Optical Character Recognition and the Chinook Language

Lexicons of known words in a specific language ("dictionaries"), character and n-gram (multiple character) frequencies, and other statistical and probabilistic methods are used to determine whether a "recognized" character sequence is likely to be a word in the target language. (Nagy, 1999.) Such a "language model" provides very high levels of accuracy for scans of well-known languages such as English, French, Spanish, German, etc. Language models are created through analysis of a large body of text. RIT Professor Richard Zanibbi, who researches document recognition, suggested that a language model might take hundreds of pages to create. (Personal communication, December 2, 2009) However, the entire corpus of Clackamas Kiksht is approximately 500 pages, over half of which is English translation, so there simply may not be enough Kiksht text to create a reliable language model.

**Early History of OCR**

Gustav Tauschek first invented OCR in 1926 in Germany. Tauschek’s machine used templates of letterforms and an electric eye. The templates were placed on a wheel that rotated in-between the printed text and the electric eye. A light shone toward the electric eye, through the template and the character to be recognized, and when no light reached the electric eye, a match was made and the character was recognized. Obviously, Tauschek’s patent is more of a “proof of concept” than a useful system to recognize printed text. In 1950, when David H. Shepard, a cryptanalyst for the Armed Forces Security Agency, with help from Harvey Cook Jr., a friend with mechanical and electrical talent, patented a machine that could recognize the alphabet and numbers. He licensed his machines to IBM and Farrington Identification Company. Farrington was the first to put his technology to commercial use, reading the numbers in gas station pumps. (Martin, 2007)

Jacob Rabinow, who designed systems for the U.S. Post Office to use in the 1960s, split the electric eye into a 5x5 grid and map the possible permutations of characters onto the grid. This afforded more flexibility for the machine, giving it an ability to recognize different typefaces. (Brown, 1992) Concurrently, the financial world developed magnetic ink character recognition. In a process very similar to magnetic tape for audio, characters that have been printed in magnetic ink are recognized by the waveforms they generate when passing by a magnetized reading
head. New typefaces were developed to improve the process, most notably OCR-B by Adrian Frutiger. (Winter, n.d.)

**Digital OCR Technology**

Rabinow’s system was the last optically based one, however. In 1974, Ray Kurzweil created a system that used a computer to recognize characters. By using a computer instead of an electro-mechanical process, Kurzweil’s system was able to recognize a wide range of text faces. From this point forward, digital technology became the dominant method for character recognition and electro-mechanical methods were no longer developed. Even though optics no longer played a role in character recognition, the process is still known as optical character recognition.

Since the late 1990s, OCR technology has been very reliable, with accuracy rates for simple text in a single language on clean pages exceeding 99%. (Nagy, 1999) One of the remaining areas in which OCR has difficulty is in the recognition of texts in multiple languages or in a language the software is unfamiliar with. Before the recognition process is begun in OCR software, the user is asked to choose which language the document is written in. Some applications offer many languages to choose from, and some applications let the user choose more than one language.

**Software**

We tested six OCR software packages with Kiksht. Four are for Macintosh OS X 10.5, one is for Microsoft Windows XP, and one is a Linux application.

- Xerox DigiPath 4.0’s built-in OCR engine on the scanner we originally used to scan the book
- Adobe Acrobat built-in OCR features
- OmniPage X, originally developed by Nuance Communications (Kurzweil’s company) and then purchased by ScanSoft
- ReadIRIS 11.6 CE from Image Recognition
- Integrated Systems Group S.A.
As we learned more about how Kiksht interacted with OCR processes, we came to see which features would improve the process and which features would hinder it. The first two applications can be considered together. Both of them offer no user input during the OCR process in the form of training.

**Xerox DigiPath 4.0 and Adobe Acrobat**

Both the Xerox scanning/OCR application and Adobe Acrobat simply OCRs the text and embeds it in the PDF as searchable text. It is possible to then export that text from the PDF, but if the document is imperfect, the results will be garbled. Both applications offer the ability to choose a language for OCR, but only Acrobat has a wide selection of languages. The success of these two applications varied widely: the Xerox software produced nearly worthless results in Kiksht (less than 30% accuracy), but Acrobat had success on par with OmniPage and ReadIRIS. Acrobat's comparable results are likely because Adobe chose ReadIRIS to be its supplier of OCR technology in September 2006. (Dheedene, 2006) [see Table 1]

The following three applications allow the user to “train” the software. Training is a process whereby the application informs the user when it has made a doubtful identification of character and asks the user what the character should be.

**OmniPage**

The next application we tried was ScanSoft’s OmniPage. When its “OCR & train” process starts, OmniPage recognizes an entire page and then brings up a window with a grid of all doubtful characters. The user then goes through and corrects any character that OmniPage has incorrectly identified, after which the program OCRs the page and returns results. This approach may work well for texts in English (or one of the other nine languages that OmniPage supports), but it fails for Kiksht, primarily because OmniPage only supports the “high ASCII” or “extended
ASCII” character set. ASCII (American Standard Code for Information Interchange) was first published in 1967. It is a 7-bit, 128 character code which contains the alphabetic characters for English plus numerals, punctuation, and control characters. So-called “high ASCII” 8-bit encoding adds another 128 characters for additional punctuation marks, symbols, and accented characters for several Western European languages (such as French, German, Spanish, etc). High ASCII is not an international standard, so there are different interpretations of the encodings, which leads to confusion. Neither standard ASCII nor high ASCII have all the characters needed for Kiksht in Jacobs’ phonetic orthography, which has many special characters. We worked around this limitation of OmniPage by mapping the special Kiksht characters for others that are in the high ASCII character set. We planned that after OCRing the texts, we would go back and do find-and-replace actions in a word processor to return the proper characters to their proper locations.

OCR of Kiksht would have been better in OmniPage if it had Unicode support. Unicode is the international standard for the digital encoding of characters (letters, numbers, punctuation, diacritics, symbols, and control characters), intended to ensure accurate translation across different computer platforms and fonts. The goal of the Unicode Consortium is to assign a unique hexadecimal value to each known character of every language. Unicode was developed to address the aforementioned shortcomings of ASCII.

This plan failed when we discovered that OmniPage allows only a limited number of corrections to be made to its “dictionary” of suspect characters. After correcting around a dozen pages, we discovered that the training process wasn’t learning many of the corrections we made to its misrecognized characters. Eventually, the dictionary would fill up and the user would lose all the work. The results showed approximately 70% accuracy on Kiksht. [see Table 1]

**ReadIRIS**

ReadIRIS, developed by the Belgian corporation I.R.I.S., offers full Unicode compatibility and advertises an ability to recognize over 120 languages. It also advertises a more robust training routine. When ReadIRIS worked, it produced good results, often upwards of 90%
accuracy on Kiksht, but software bugs that caused its training dictionaries to corrupt randomly degraded the application, and it was afflicted with unpredictable program crashes.

Training with ReadIRIS was easy. It would go through the text line by line, and each time it saw a suspect word, it would show the user the image of that word and the user would type in what the word should be beneath it. When the “dictionary” was finished with training on a page, it would load that same dictionary for the next page. The training process had a “learning curve” of about four pages before we started to see accurate results.

The problem that slowed our progress was that the dictionary files would become corrupt for no obvious reason. We worked with technical support at the I.R.I.S. Corporation to find ways of fixing the problem, but it was never wholly fixed in software version 11. (Version 12 of ReadIRIS was released in August 2009, after the OCR testing phase of this project was completed.)

Although ReadIRIS’ accuracy was good for typical languages and orthographies, it would not be suitable as-is for phonetic texts like Kiksht. However, we employed alternate methods that helped us increase the initial accuracy of the training process. ReadIRIS has the ability to recognize texts in two languages, so we selected Slovak as a secondary language for the texts. By choosing Slovak, ReadIRIS recognized vowels with acute accents as well as č and š (all common in Kiksht) without any further training necessary for those characters.

**ABBYY FineReader 10**

FineReader 10 from ABBYY was the best application. It has a feature that aided the recognition of Kiksht, which might suggest that it would perform similarly in OCR of other obscure languages. Another feature improves the recognition of printed texts of less-than-perfect quality, which also helped our project.

Most helpful is the ability to create alphabets for languages that aren’t one of the 186 languages that FineReader already knows. This allowed us to create an alphabet for Kiksht, an easy task considering the full Unicode support. The only blemish of this feature is that Unicode’s combining characters are not allowed. A combining character is a subcharacter, such
as an accent mark, that combines with the character before it in a word. In Kiksht, two characters are formed from this combining feature: g and x. We chose to use the OmniPage workaround: mapping these two characters to characters the software supports, followed by later performing find-and-replace operations on the text in a word processor.

The other useful feature of FineReader pertains to its ability to recognize degraded or imperfect images of text. In the training process, the user is given the ability to resize the character bounding box of suspect characters. This is helpful with the Jacobs texts, as, due to the typewriting and xerography processes, two characters (or more) were often merged into one character in other OCR applications. This allows the user to correct the FineReader, and these corrections carry through as part of the training process.

FineReader performs better and responds to training quicker. We were able to see 90% accuracy in Kiksht text within five pages of training, whereas ReadIRIS often needed fifteen pages to reach that level of accuracy.

**Ocropus**

Ocropus is a descendant of the Tesseract OCR engine developed by Hewlett Packard Corporation from 1985 to 1995. Ocropus has a steeper learning curve than other tested applications because the user initiates and has greater control of the OCR process. For ease of use, these processes are normally hidden and/or combined in commercial applications.

After the user performs layout analysis, responsible for finding page margins and what is text and what is image, the next step is line segmentation, whereby Ocropus determines line spacing and creates a TIFF file for each line. After this step, Ocropus performs character recognition based solely on perceived letterforms. It knows what a character is, and it knows about letter-spacing and contrast, and this is how it determines where each character starts and ends. The OCR option we chose yields Unicode text strings. The user then compares each text string against its corresponding line in the original document and make corrections. From corrected recognition files (called “ground truth”), a language model can be generated and, if the language model is good enough, it may now be used without the “ground truth” correction step for future scanned text in that language.
Ocropus performs acceptably on English text before training. However, Kiksht text is only erratically recognized by Ocropus without further training, so a language model is required. Proofreading and correcting the ground truth files is a slow process; one page of Kiksht in our texts averages 45 lines, meaning that around 45 lines must be proofread and corrected per page. Untrained English recognition is approximately 85% accurate, with most errors occurring in punctuation, but Kiksht is 50% accurate at best.

Entering Kiksht text requires direct access to the deeper areas of the Unicode character set. This means that for all of the characters not found on keyboards, the user must use one of two methods: entering the four-digit Unicode code point for a character, or finding it in the character map (a table of every Unicode character) and double-clicking the character to insert. Neither of these methods is fast, and doing either method on the multitude of (albeit short) “ground truth” files to correct makes this slow going. Our first language model used 15 pages of Kiksht and English, but the results were only approximately 5% better than untrained recognition.

Table 1. Averages for ten pages of untrained recognition.

<table>
<thead>
<tr>
<th>Software</th>
<th>English characters per page</th>
<th>English errors per page</th>
<th>Chinook characters per page</th>
<th>Chinook errors per page</th>
<th>Chinook percent correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrobat</td>
<td>2940</td>
<td>6</td>
<td>1060</td>
<td>277</td>
<td>73.87</td>
</tr>
<tr>
<td>OmniPage</td>
<td>2940</td>
<td>2</td>
<td>1060</td>
<td>276</td>
<td>73.97</td>
</tr>
<tr>
<td>ReadIRIS</td>
<td>2940</td>
<td>9</td>
<td>1060</td>
<td>238</td>
<td>77.55</td>
</tr>
<tr>
<td>FineReader</td>
<td>2940</td>
<td>3</td>
<td>1060</td>
<td>70</td>
<td>99.40</td>
</tr>
</tbody>
</table>

Analysis of Common Errors

OCR software that claims it can process any font in a document – known as the omnifont style – has been shown to be not nearly as accurate as OCR software set up specifically to work with one document. (Xu & Nagy, 1999) As our project deals with one body of text set in the same typeface and coming from the same printed source, a software package that is created specifically to deal with our environment should
yield greatly improved results. However, large corporations or organizations that envision dealing with lots of text over years, in a usage where speed is also greatly valued, undertake creating an OCR application to work in a specific environment. This is beyond the scope of our project.

Another recurring issue with OCR software is its difficulty in discerning single characters in a poor quality document, or one typeset with ligatures. Ligatures are two characters that have been joined into the same character, for aesthetic and/or technical reasons. For example, typographers have chosen to join f and i into fi (in most typefaces) because the dot of the i would awkwardly connect to the hook of the f if printed normally. Joining them as one character ahead of time yields the more aesthetically pleasing and legible ligature, representing two characters. Most OCR recognizes ligatures, but with even slightly degraded documents, occasions will arise where two characters meet either due to ink feathering or not enough letter-spacing. Jacobs’ texts are not typeset in a method that used ligatures; however, the degradation of the text due to the xerographic process has resulted in many instances of joined or nearly-joined characters. While not technically ligatures, these apparent digraphs pose problems to many OCR packages. (FineReader’s ability to realign the character bounding box is a solution to this problem.)

A third problem has to do with a perceived shift in the baseline. In this situation, OCR software might consider super- or subscript characters shifted off the baseline to be the “real” baseline of that line of text. The software might then cut off the top or bottom of that line of text, or add space to its top or bottom, or shift the baseline randomly. For example, in the Jacobs texts, we often saw instances where a raised dot followed by a prime mark was misinterpreted as a period followed by a raised dot, or a quotation mark was misinterpreted as a 99.

**Unicode and OpenType**

When Kiksht texts are converted into a digital format through OCR software or manual input, they need to be encoded in a way that will allow for portability across computing platforms and media, and which will provide flexibility in other textual forms. Simple imaging, such as microfilming, photocopying, or digital image scanning, can reproduce the text images but the typographic parameters cannot be changed.
Typeface style and size, line width and spacing, arrangement of lines, interrelationship of Kiksht to English, formatting of the page: none of these are alterable. Moreover, the texts cannot be ported to other media and devices, except as static image formats, like PDF. Furthermore, static text images cannot be searched and parsed by digital tools and applications for linguistic, folkloric, literary, or other studies.

Almost all of the characters used in the Kiksht texts exist in the Unicode system, an international standardized coding system that aims to assign every character of every language a unique computer-readable number so they can be referenced accurately. Correct Unicode identification ensures the font’s correct display of words across different fonts, as long as they have those glyphs available.

There are, however, two characters used in Jacobs’ Kiksht orthography that do not yet exist in Unicode. For these instances we use font development software to customize a font and automatically substitute the correct glyphs. OpenType, a cross-platform font format, allows the inclusion of “features” that dictate special case rules about the font. These features can be used to include alternate designs of characters and automatically substitute glyphs for pre-defined character pairings. Our custom Kiksht font uses the OpenType LIGA (ligature) feature that replaces two glyphs with one. This is normally used to create ligatures such as fi from the text string f + i, but allows us to insert a dotted g or x when a “g + dot below” or “x + dot below” occurs in the text. The switch is seamless as the user is typing a new document, but switching an existing document to the OpenType font will also make the substitution.

Using digital tools, we can make aesthetic enhancements in addition to technical ones. In order to create many of the Kiksht characters that have diacritics on his typewriter, Jacobs had to type a letter and then the diacritic afterwards. This creates awkward empty spaces that disrupt the flow of reading. We no longer have those limitations and can customize the characters with diacritics so that they harmonize with the rest of the text.

We are using FontLab Studio, a popular application for font development, and modifying Lucida Sans for the Kiksht text. The resulting font files, in OpenType format, can be distributed online and used for printed or digital materials.
Typographic Design

For Kiksht, as for any language reduced to digital typography, once a text is encoded in a Unicode standard and a custom font is developed, it is important to consider how these texts can be best presented and how they can reach a large audience. This is a matter of typographic design. For a given text, there are a number of possible configurations and each offers distinct advantages. In the most basic form, the Kiksht and English can be presented independently but in parallel. In a book, this would likely have the Kiksht on the left pages and English on the right, making it possible, but slightly inconvenient, to compare equivalent passages directly. For readers of the English only, this provides an uninterrupted flow of reading.

For deeper exploration into the relationship between the Kiksht and English, the text can be presented in alternating stanzas. The paragraph of the original Kiksht would come first, followed by the same paragraph in English. This allows for easy and direct comparison but makes reading only the English or Kiksht a jumpy process.

A combination of the two is possible but may not be as effective. Each page is divided into two columns, with Kiksht in the left column and...
English in the right. Each stanza begins at the same point but can end at variable points, since the lengths vary. This results in some larger gaps between some stanzas but allows for direct comparison and minimally interrupted reading flow in either language.

In each case, it is important that there is a visual distinction between the English and Kiksht. Our custom Lucida Kiksht font is used for all Kiksht texts and Lucida Bright, a serifed typeface, is used for the English translations. These typefaces were designed to harmonize with each other but each has a distinct texture and gives a unique voice to each text.

The flexibility of the digital format allows us to adopt the texts into different formats to maximize accessibility across multiple reading platforms. The texts are no longer confined to the traditional codex form. Through the use of common new media publishing tools such as XML, CSS, and XSLT, we have adapted the texts for the Amazon Kindle, iPhone/iPod Touch and a standard web browser. All of these provide an opportunity to distribute the Kiksht texts for free and to a large audience but each one has unique interface constraints.

**Amazon Kindle**

The Amazon Kindle is the most static of the three options but simulates a traditional reading experience well. If custom fonts can be embedded in the Kindle book, Kiksht texts could be distributed through the official Amazon Kindle store and would support features like resizing of type and a hypertext table of contents. It would be difficult to create a two-column layout, but the alternating stanzas option would be effective on the Kindle.

Outside of the Kindle store, the book could be distributed as a PDF that is formatted to fill the screen. Any users of a Kindle DX can copy files from their computer onto the device using the included USB cable. This eliminates the possibility of resizing the type but provides better opportunities to use a two-column format or add other graphic elements.

**iPhone/iPod Touch/iPad**

The iPhone/iPod Touch/iPad is another emerging platform for reading but is better suited for shorter reading sessions. The full-color, high-resolution
screen and tactile input possibilities have potential for a very dynamic format. There are already many reader apps that allow for customization of text and background color, choice of typeface and size. However, none of them allow the user to change the entire layout. In a Kiksht reader app, it would be possible to allow the user to select how their text is presented: alternating stanzas, English-only, two-column parallel text, etc. Users could select passages and email them to a friend or jump to a web browser for references. The app could be offered for free through Apple’s App Store and it would be easy to offer additional texts and features through software updates. We have not developed such an application yet, but it could be a component of further work on this project.

**Figure 4.** Kiksht texts on Amazon Kindle DX.

**Figure 5.** Kiksht texts on iPhone.

**Web Browser**

Possibly the most accessible route to these texts is simply through a web browser. There are now a number of ways to display custom fonts, like Lucida Kiksht, by loading them from a central server to the
browser. Embedded OpenType, Web Open Font Format and embedding of TrueType fonts via Cascading Style Sheets are all emerging options. These methods are generically referred to as “web fonts”, though there are a few different technical and commercial approaches to the problem. Just like the iPhone/iPod Touch/iPad, the users could select the layout they prefer and the page can dynamically adjust. Since reading in a browser can be a tiring experience for most readers, a PDF edition could also be offered online for users to download and print themselves. Distribution costs and makes the texts available to anyone with a computer. The democratization of the publishing process enables us to create and distribute texts like these Kiksht narratives, which have great cultural and intellectual value, even though they may not have immediate commercial value. Texts like these are priceless and ensuring they reach as many people as have an interest is the goal of this project. As the current publishing landscape becomes more amenable to this kind of material, we will doubtless see further work on texts of this kind.

Coyote and Skunk lived there. They would look for something, they would eat it. I do not know how long they did like that. Then he (Coyote) said to him, "Younger brother. Supposing I tie you (your anus), and then I summon everyone, they will come to see you."

"Oh no!" (in a pained tone). I do not know how many times he spoke to him (urging him), before he permitted him to. Then he (Coyote) tied him (his anus). He (Skunk) lay down. Then he (Coyote) went outside, he hallooed and hallooed, "Who will come? Our younger brother might die (because of) his stomach."

Pretty soon a Doe came. "Oh dear! my older brother! oh dear! my older brother!" She came, she got to there. There Skunk lay. He was saying, "It is coming out! Hurry! It is coming out!"

**Figure 6. Screenshot of Kiksht texts as a webpage.**

**Conclusion**

OCR technology may be at a critical point. Led by Google Books, digitization of printed matter is happening on an unprecedented scale. Google has refined the Tesseract OCR engine for their use, and has since released it back to the public as open source software. While this
might seem that the power of Google Books’ OCR technology is now available to anyone, the truth is that digitizing a book via OCR is more than just reading the letters on the page. The actual character recognition technology is well-developed and understood; the challenges that remain are in the field of document image analysis. This includes determining how many columns the page has, whether or not it is skewed, and the difference between line art, text, and noise. The Tesseract engine does not perform any of these tasks, so it responds best when given images of single column text that is unskewed and is relatively free of marks and defects.

There are currently Kiksht texts available online, through the Internet Archive’s American Libraries collection. The user can read these texts as scanned images online or via a downloadable PDF, plain text, and special formats for e-reader software and/or devices. The scanned images are, of course, highly readable and look just like the real book, but the OCR of the Kiksht text is highly inaccurate, because of the kinds of OCR problems we discovered, such as the inability of common OCR applications to recognize a non-European language in unfamiliar, quasi-Latin phonetic orthography.

Our project to digitize a long dead, obscure language might seem minor compared to Google’s massive digitization project, but we are working from the same inspiration: to see that the knowledge contained in print is not neglected in the digital age. We also believe that our project to digitize these Kiksht texts may benefit other projects working with texts that are in multiple and/or obscure languages, or special orthographies.

A Kiksht scholar might currently see opportunities for sharing his enthusiasm. Among the interesting linguistic features of Kiksht are ejective consonants, also called glottalized consonants, in which the sounds of p, t, k, and q are pronounced with a strong vocal force, as though the sound were being ejected from the mouth. Ejective phonemes are typographically distinguished from plain versions of the consonants, also occurring in Kiksht, by an apostrophe following the letter. A typical example is the spelling of the Clackamas word for “Coyote” /it’alap’as/, which includes ejective p and t. Ejective phonemes do not normally occur in English, but they have been heard by tens of millions of Americans, and millions more people worldwide, vastly more than have ever studied Kiksht, because the fictional language, “Na’vi”, spoken by
the indigenous humanoids in the popular film, “Avatar”, has a similar series of ejective consonants. (Kiksht has more than Na’vi.) (Frommer, 2009.) Our project demonstrates that such interesting languages, with real literature in them, are found right here on Earth.

The ultimate goal of this project is to keep these priceless texts in circulation as part of American (and pre-Colonial) history. In some ways, these texts have linguistic, anthropological, literary, and cultural value greater than the collected works of Shakespeare, as they represent the weltanschauung of an entire culture. No matter how much importance is justifiably attached to Shakespeare, no one English writer can claim to speak for his or her entire culture and history as Mrs. Howard has done for Clackamas. As University of Rochester Professor Jarold W. Ramsey (1977) states in an analysis of a Kiksht text:

One ought to wince all the more, then, in realizing that although our libraries contain a wealth of carefully transcribed and translated Indian texts from all over Western America, collected by men like Melville Jacobs and other students and followers of Franz Boas, the literary significance of this wealth is still, forty to seventy-five years later, virtually unknown. Such opportunities as we have we have so far ignored.

There are serious obstacles to our study of America’s first literatures, to be sure — ignorance of original languages, incomplete ethnographic information, difficulties with the oral basis of the material, academic biases, and so on. But as the work of Jacobs and Hymes demonstrates, and as I hope this essay has at least suggested, the art of native storytelling is worth trying to elucidate, both for itself and for the light it may shed on the literature we call our own.

Ramsey makes an undeniable point about the value of a culture’s literature in aiding in the interpretation of another culture’s literature. Though talking coyotes, salmon, plants, and winds may populate the Clackamas Chinook myth age, their actions and motivations are entirely human and can speak to any human society.
Linguistically, these texts carry immeasurable value as well. Linguists recognize their utility, but the survival of the Kiksht language (in any state) is a worthy cause in and of itself. Kiksht has been moribund for approximately 75 years, and many other languages are facing extinction today. Up to 90% of all languages could disappear within a generation. (Abrams & Strogatz, 2003). Melville Jacobs (2000) greatly feared for the loss of language and culture, and, near the end of his life, had harsh words for cultures that dominate and assimilate heedlessly:

“This hunting-fishing-gathering population could once have yielded a million or more versions of myths, smaller numbers of tales, and no one can estimate how much of other genres. ... Myths of most variable merit that have been collected over the region total less than a thousand and will never exceed that number. Tales amount to a few hundred, forever so. The bleak harvest is almost finished. It is maybe one percent of what could have been obtained if the culture-bound, condescending, and racist invaders had the slightest capacity to perceive merit in the heritages of non-Europeans.”

In the graphic arts industry, technical advances are often lauded because they allow us to reproduce accurate color, achieve faster turn-around times, or reduce cost. Little is said about the possible social implications of new technology. Printers proudly feel responsible for much of the development of the modern world, because we have always been important players in the dissemination of information. New technologies that democratize the publishing workflow allow everyone to add to the content stream.

Some lament the quality of the content that has spread over the past decade. It’s not important whether or not this influx is “worthwhile”. The history of printing includes many rebellious spirits who had something to share. Denying someone a voice is not in our nature. When the voices that want to speak have been denied access to a greater audience, or even denied access to their own language and cultural heritage, then we have the opportunity to continue to change the world for the better.
Acknowledgments

This work would not have been possible without the guidance and assistance of Professor Charles Bigelow, who has provided focus and encouragement throughout the project. We are grateful for the support of the Mary Flagler Cary Charitable Trust, which has made possible this typographic research at RIT.

This project is based in part on prior research by Charles Bigelow on Chinookan typography, supported variously by the National Endowment for the Humanities, the National Endowment for the Arts, the Oregon Arts Foundation, and the Jacobs Research Funds. All are gratefully acknowledged. The prior research would not have been possible without encouragement from Melville Jacobs and David French, and guidance, assistance, and support from Dell Hymes, to whose memories this project is a grateful tribute.

Additional thanks to Jedd Schrock for his previous work in proofreading and identifying errors in the OCR-ing of Clackamas, Dr. Scott Williams for his guidance and advice on scholarship, Professor Richard Zanibbi for his consultation on OCR software and application, and Steve Matteson and Haik Avanian for their assistance with FontLab.
Bibliography


**Image Sources**

All images created by Garret Voorhees and Micah Stupak.
Colophon
Afterword

This year RIT TAGA strove to enhance the traditional reader experience, and we hope that you have enjoyed interacting with this publication.

The concept of this journal was to provide various levels of inter-activity through an innovative fusion of creativity and technology. To accomplish this, we designed interactive features to supplement the focus of the publication, which is the research content. Dimensional elements were thoughtfully chosen within the journal, and QR-codes link to additional multimedia content online. Also, the cover and fore-edge designs create a unique tactile experience.

The creation of this journal has been a unique and synergistic process—simulating a true-to-life production environment in order to provide a one-of-a-kind, hands-on experience for all those involved.

The Editorial department worked closely with authors in a cyclical-review process, and consulted with Design and Premedia to enhance presentation while maintaining content integrity. The Design department created a unifying aesthetic and conferred with Premedia and Production on details of feasibility. The Premedia department guided all stages of file preparation and was integral in the execution of interactive features. The Production department made design goals a reality by working directly with packaging and graphic arts companies to coordinate test samples, press runs, folding, collating, and finishing.

From conception to creation, students have been the driving force behind this publication. Through this unique collaborative project, we hope that they will take with them experience that will be invaluable towards their future in the graphic arts.

Angelica Li

RIT TAGA 2009-2010
Production Notes

Design

This year’s journal focused on creating a tactile interactive experience as there is a lot more to a book than just the text within. The aesthetic feel of the book and the way in which one interacts with it is just as important. Everything from the appearance of the box as the book moves in and out of it, to the texture of the box material, paper and dimensional printing was designed. The book size is portable and comfortable to hold and the fore-edging adds another level of interactivity. Also, all graphs and figures were redesigned for readability.

Typography

The publication type was set in Sabon and Archer. Designed by Jan Tschichold in 1964 and published by Monotype, Linotype and Stempel in 1967, Sabon was intended to work consistently with all forms of production. It was chosen for its flexibility, expanded character set and its readability, optimal for paragraph text and technical information.

Archer, designed by Hoefler & Frere Jones in 2001 hits the right notes of credibility and charm. It has a modern elegance that fits the overall aesthetic of this year’s publication. It has a large spectrum of weights that work with the traditional body text Sabon.
Premedia

Premedia implemented a workflow model using DALiM MiSTRAL (job management), TWiST (workflow solution), DiALOGUE (online softproofing), and Xinet FullPress and WebNative (digital asset management). Customization of these applications for our purposes was built on-the-fly during the production. For the variable data spread in the journal, a custom Javascript was written to merge the contents of our database of journal recipients into an InDesign layout.

Color Management

The book uses a late-binding concept for color management. All figures and images were left in their original color space tagged with their native profile. Final conversion to the output space was done at the Kodak NexStation RIP that drives the Kodak NexPress S3000. This schema maintains the highest level of flexibility for re-purposing content for other media. The two Pantone colors, 108 U (yellow) and 123 U (orange), have also been maintained throughout the workflow and were converted to CMYK equivalents at the RIP for consistency.
Fore-edge Design

The fore-edge of the text block can be fanned out to create the illusion of a printed image on the face of the book. This was done by splitting an image into slices and placing them on separate pages throughout the book. The process down-samples the original image to the number of pages in the book, then selects each row of pixels as an individual slice and stretches it to the printed size. Two images were used on the left and right sides to produce the two images seen by fanning the book in different directions. Two Applescripts were created to automate the process of generating the image slices and then placing them into the layout in InDesign.

Planning for Dimensional Printing

To test the results of Dimensional Printing on the chosen substrates, two test-runs were completed on the Kodak NexPress S3000 at the RIT Printing Application Laboratory (PAL). The first run included test targets designed to observe thickness and overprinting by varying coverage values, as well as resolution by varying line-widths. Design patterns were also printed for visual and tactile evaluation. The second run tested various combinations of Pantone colors and dimensional patterns on the final cover design.

Materials

All paper was donated by Mohawk Fine Papers. The book was printed on Color Copy 98 uncoated 32# bond and 110# uncoated cover. The parent sheets were 12 inches by 18 inches and trimmed down during binding to the finished size of 6.5 inches by 10 inches.
Printing

The text block and book cover were printed in-house at the RIT Printing Application Laboratory (PAL) on the Kodak NexPress S3000. A total of 16,400 sheets were printed duplex using four-color process and Dimensional Clear Dry Ink in the fifth imaging unit.

Packaging

The box was die-cut at Diamond Packaging in Rochester, New York and hand-assembled by the student chapter. The sticker was printed and cut in-house at the RIT Digital Publishing Center (DPC) on the Roland VersaUV LEC-300.

Finishing

Printed sheets were cut-down by the student chapter to 10.5 inches by 13.875 inches, according to bindery specifications. The text block for the journal included 10, 16-page signatures (consisting of 4, 4-page forms). These signatures were folded at the RIT Print/Postal HUB and hand-collated by the student chapter. The folded, collated signatures were bulk packed, and delivered to Hoster Bindery in Ivyland, Pennsylvania where the book was Smyth-sewn and bound.

Software and Tools

Adobe Creative Suite 4 Design Premium, Preps 5.3, Kodak NexStation RIP, Microsoft Office 2008, 37Signals Basecamp, Enfocus Pitstop 8.5, AppleScriptEditor 2.3, Roland VersaWorks RIP, DALiM TWiST, MiSTRAL, and DiALOGUE, Xinet FullPress and WebNative.
Acknowledgements

Charles Bigelow
Barbara Birkett
Marcia Carroll
Renee Charbonneau
Edline Chun
Robert Chung
Jason Clark
Dr. Mary-Beth Cooper
Frank Cost
Dr. Twyla Cummings
Lisa DeRomanis
Ross Dawson
Dr. William Destler
John Eldridge
Eric Evans
Barbara Giordano
Alexandra Artusio-Glimpse
Jim Hammer
Chris Harrold
Andrew Henry
Downey Hoster
Norma Hoster
Stephanie Janisch
Erich Lehman
John Meyer

Pamela Munn
Bill Pope
Kathy Prozeller
Michael Ricciardi
Michael Riordan
RIT Student Affairs
RIT Student Government
Frank Romano
Merry Schading
Joseph Schember
Dave Semrau
Franz Sigg
Dr. Patricia Sorce
Cristina Stoll
Ben Vanderberg
Jeremy Vanslette
Garret Voorhees
Sarah Whitmore
Steve Whittaker
Jonathan Widder
Ken Widder
Dr. Scott Williams
Bryan Yeager
Douglas Yeager
Bryan Zaczek

RIT College of Imaging Arts and Sciences
RIT Printing Applications Laboratory
Charles Bigelow | Melbert B. Cary, Jr. Professor
Acknowledgements
Frank Romano

Rochester Institute of Technology, Professor Emeritus
Acknowledgements
Member Directory
Student Chapter Members

Executive Board

President  Alexander Mouganis
Vice President  Angelica Li
Secretary  Vicki Julius
Treasurer  Elli Vandegrift
Public Relations  Kyle Cole

Department Chairs

Premedia  Scott Millward
Design  Andrew Lakata
Production  Nick Gawreluk

Faculty Advisors

Charles Bigelow
Robert Chung

Members

Dennis Albert
Kathy Bedard
Meredith Bobrow
Max Cameron
Ashley D’Agostino
Lisa Giroud
Andrea Hickey
Casey Jabbour
Ben Lang
Kristina Lozar
Cate McNelis
Ellie Morello
Saleh Abdel Motaal
Ashlea Pulleyn
Matthew Rogers
DENNIS ALBERT

MAJOR New Media Publishing

YEAR Undergraduate Senior

HOMETOWN Cincinnati, OH

DEPARTMENT Premedia

EMAIL dennisjalbert@gmail.com

FAVORITE TYPEFACE Optima

FAVORITE PANTONE 320C
Kyle Cole

**Major** New Media Publishing

**Year** Undergraduate Senior

**Hometown** Windham, NH

**Department** Production, Premedia

**Email** kylepcole@gmail.com

**Favorite Typeface** Bodoni Black Italic

**Favorite Pantone** 647C
ASHLEY D’AGOSTINO

MAJOR Graphic Design
YEAR Undergraduate Junior
HOMETOWN Ballston Lake, NY
DEPARTMENT Creative
EMAIL ald3762@rit.edu
FAVORITE TYPEFACE Gotham
FAVORITE PANTONE 298C
NICK GAWRELUK

MAJOR New Media Publishing

YEAR Undergraduate Freshman

HOMETOWN St Paul, MN

DEPARTMENT Production

EMAIL ntg5533@rit.edu

FAVORITE TYPEFACE Trade Gothic

FAVORITE PANTONE 299C
LISA GIROUD

**Major** New Media Publishing

**Year** Undergraduate Freshman

**Hometown** Henrietta, NY

**Department** Editorial

**Email** lmg4747@rit.edu

**Favorite Typeface** Bodoni

**Favorite Pantone** 202C
Andrea Hickey

Major: Graphic Design
Year: Undergraduate Junior
Hometown: Keene, NY
Department: Creative
Email: agh7005@rit.edu
Favorite Typeface: Akzidenz Grotesk Super
Favorite Pantone: 426C
Casey Jabbour

Major: New Media Publishing
Year: Undergraduate Freshman
Hometown: Baldwinsville, NY
Department: Editorial
Email: clj8807@rit.edu
Favorite Typeface: Futura
Favorite Pantone: 18-4043
VICKI JULIUS

MAJOR Graphic Design
YEAR Undergraduate Junior
HOMETOWN Johnstown, NY
DEPARTMENT Creative
EMAIL victoriajulius@gmail.com
FAVORITE TYPEFACE Trade Gothic
FAVORITE PANTONE 306C
Andrew Lakata

Major: Graphic Design
Year: Undergraduate Junior
Hometown: Johnstown, NY
Department: Creative
Email: alakata@gmail.com
Favorite Typeface: Gotham HTF
Favorite Pantone: 254-6 U
Ben Lang

Major: Visual Media
Year: Undergraduate Junior
Hometown: Amherst, MA
Department: Creative
Email: bl7556@rit.edu
Favorite Typeface: Gotham Book
Favorite Pantone: 534C
Angelica Li

Major: Print Media

Year: 2nd Year Graduate

Hometown: Los Osos, CA

Department: Production, Editorial

Email: aclitho@gmail.com

Favorite Typeface: Avenir

Favorite Pantone: 253U
Kristina Lozar

Major: Biomed Photo Communications

Year: Undergraduate Senior

Hometown: Brooklyn, NY

Department: Editorial

Email: lozar.kristina@gmail.com

Favorite Typeface: Helvetica Neue Ultralight

Favorite Pantone: 2587U
CATE McNELIS

MAJOR New Media Publishing
YEAR Undergraduate Senior
HOMETOWN Albany, NY
DEPARTMENT Editorial, Premedia
EMAIL cem3856@rit.edu
FAVORITE TYPEFACE Gill Sans Light
FAVORITE PANTONE 371C
Scott Millward

Major MS Print Media
Year 2nd Year Graduate
Hometown Brantford, ON Canada
Department Premedia
Email sxm9825@rit.edu
Favorite Typeface Palatino
Favorite Pantone 295C
SALEH ABDEL MOTAAL

MAJOR MS Print Media

YEAR 1st Year Graduate

HOMETOWN Toronto, ON Canada

DEPARTMENT Editorial

EMAIL saleh.motaal@mail.rit.edu

FAVORITE TYPEFACE Bell Gothic Std

FAVORITE PANTONE 222-2C
ALEX MOUGANIS

MAJOR Graphic Media
YEAR Undergraduate Senior
HOMETOWN Brockport, NY
DEPARTMENT Executive Board
EMAIL amm5926@rit.edu
FAVORITE TYPEFACE Adobe Caslon Pro
FAVORITE PANTONE 17-1-6C
Ashlea Pulley

Major: New Media Publishing
Year: Undergraduate Freshman
Hometown: West Henrietta, NY
Department: Editorial
Email: akp1336@rit.edu
Favorite Typeface: Zapfino
Favorite Pantone: 15-5519
Micah Stupak

**Major:** New Media Publishing  
**Year:** Undergraduate Senior  
**Hometown:** New York, NY  
**Department:** Premedia  
**Email:** micah@benthic.cc  
**Favorite Typeface:** Electra  
**Favorite Pantone:** 7497C
Elli Vandegrift

**Major**: New Media Publishing

**Year**: Undergraduate Junior

**Hometown**: Middletown, MD

**Department**: Editorial

**Email**: eev9937@rit.edu

**Favorite Typeface**: Didot

**Favorite Pantone**: 368C
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tagaga.rit.edu
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