This paper will examine the recent transformations to architectural drawing that are occurring in the presence of information based drawing procedures and their potential for new fabrication methods. The mathematical organization of information has resulted in a more systemic, intricate, and variable approach toward making things—characteristics that have historically been associated with manual forms of craft. The shift from a geometric to an information based paradigm is allowing a wide range of industries to more easily converge. Consequently, a much broader range of interdisciplinary fabrication processes are now available to architects and designers. This confluence of numerical based machinery in other fields is providing new possibilities for architects to visualize data using a broader range of materials and techniques.
1 Introduction

The numerical transfer of information is increasingly becoming part of every trade. One example of an interdisciplinary convergence between architecture and other disciplines is the introduction of CNC tooling in the fashion industry. Similar file formats to those used in architectural drawing are now commonplace in the production of textiles using digital embroidery machines. The opportunity for architects to interface with other industries is expanding, and it offers new possibilities for fabrication. The work that is featured in this paper combines three realms of information: digital fabrication, the mathematical re-sampling and scripting of data using the open source software, Processing, and the innovative staging and integration of information in the pursuit of alternative forms of craft, in particular the use of data to produce digital embroidery. The focus of this research is to identify a workflow methodology that allows for the transfer of data to be outputted using a CNC embroidery machine. The work presented here was developed as part of a graduate level architectural drawing seminar that examined how information gains expression through the capacities of a particular set of materials and in conjunction with digital fabrication tools. Over the last several years the course has focused on developing new forms of drawing in the presence of CNC tools. Given the limits of time, materials, size, and cost, the course tested the parameters of the embroidery machine, such as stitch count, stitch pattern, thread length, stitch sequence (layering), stitch position, stitch speed and color.

2 Architecture, Drawing and Craft

Drawing and materiality can now be investigated through a wide range of numerically controlled tools. This is a significant advancement in the history of drawing for two reasons. First, it means that the act of drawing and the nature of material organization, like the dynamics observed in liquids and textiles, can be studied and generated using computation. This has fundamentally changed our relationship to material. Architects and designers can now develop form through a direct engagement with the computational structures of matter itself. Likewise, the distinctions that once separated architectural drawing from other drawing techniques such as engraving, etching, and tattooing are distinct techniques that can be merged in the presence of digital tools. Second, with increased precision and computational power, we can now draw upon the surface of materials in a way we have not been able to do previously. But more importantly the nuance of materials is no longer the enemy of architectural production. The variability of material has become an inspiration for the generation of form, texture, and character, and the scripting of data offers new possibilities for manifesting information.

3 Digital to Analog Production

The work was conducted in three phases and is identified in Figure 1. The information cascade consists of: 1) Coding: scripting with the open source programming language, Processing, to develop line work using data, 2) Conversion: file conversion and optimization to export data from Processing to Wilcom Embroidery Studio, 3) Fabrication: material and thread selection and sample preparation, for the execution of a final embroidery piece using a digital embroidery machine. A final stage was developed to use the code to optimize the parameters of the stitches and this was fed back into the coding stage in order to refine the piece and reduce costs. At the outset, the transfer of data from Processing to the embroidery machines was not a given and the procedure had to be mapped out (Figure 1). A similar approach had
been mapped out using sewing machines, but it proved too tedious and time consuming and hence a more fluid transfer of the data was needed. The drawing research focused on finding machines to interface with Processing and methods to transfer the data into a material that would amplify or preserve the fidelity of the data. The embroideries were fabricated from a combination of numeric data and manual procedures that cannot be accomplished through the sole use of a single process or machine. Drawing scripts were written to re-sample images and fields of color to convert RGB data into geometry with a set of parameters that could control density, color, and quantity (Figure 2). The drawing sequences that emerged from the loop structures in Processing resulted in the sequential layering of lines on top of each other. This sequence could be preserved and edited in the Wilcom software and it resulted in very systematic stitch sequences that preserved the layering of the code and the thread. Equal value was given to the development of manual ingenuity and the use of alternative technologies when it came to fabrication. The scripts were executed on a variety of textiles, including suede, leather, vinyl, and canvas, using colored thread (Figure 3). Fabrication costs were based on the number of stitches, the speed of the needle relative to the geometry, and the number of color changes. Excessive translations of the textile across the machine bed increased the costs and could be minimized using the software or by adjusting the Processing script.

It remained the choice of each student to determine whether the final piece was executed by hand or by a professional embroiderer and considerable consultation was required. The final textiles were fabricated using threads, airbrush and paper as well as other materials. The process of selecting the threads, stretching the final piece, and preparing it for presentation were all considered an integral part of the designs. A considerable amount of time was dedicated toward making samples to test the fidelity and mixture of materials as well as the labor associated with making them. This meant that failures could be identified. The preparation of samples became an extremely important part of the course and a testament to the success of the final work. The samples exposed problems and opportunities but they also helped establish a methodology that could be carefully sequenced in order to be executed effectively. With very few exceptions, the best results were achieved when the materials exceeded their individual characteristics in favor of a new material whole.
4 Embroidery

The difference between sewing and embroidery requires clarification. In sewing, yarns are woven together using a needle, something that has traditionally required bi-directional, warp, and weft yarns. In embroidery, there are two sets of thread, one is the colored thread that is visible and the other is a bobbin thread that is typically not visible. The bobbin thread holds the visible thread in place and therefore it does not rely on a bi-directional logic. The relationship of the thread to the surface is closer to tattooing than sewing. In this sense, threads are sewn onto the surface of the textile. Only in special cases is the textile removed to leave only threads. Traditional embroidery emerged in China from the practice of weaving human hair (Dowdey & Zhang, 1986). Unlike weaving, it never adopted the structural necessities associated with structural integrity. This meant that it was developed as a means of embellishment rather than structure, and as such, it provided the embroiderers with tremendous flexibility to invent signature stitches. This tradition continues today in China at the Suzhou Embroidery Research Institute (SERI), and it is one of the last schools that teach hand embroidery with a focus on the mastery of the photorealistic techniques and the invention of new stitches using silk thread (Dowdey & Zhang, 1986). When observed side by side, all other forms of embroidery pale in comparison to the handwork produced at SERI. Painterly techniques have been incorporated into the tradition by dying the silk thread for different durations to change its saturation. These threads are then laid down in sequence to reflect a wide range of gradients that can also change intensity across parallel threads as well as gradients that change along the length of a single thread. The liberal and masterful flexibility of the handcraft is no longer part of commercial embroidery because its automation cannot be reproduced with digital machines where the needle is limited to single axis movements. The tradition of sewing threads more parallel to the surface is no longer possible using the machines. The work at SERI was used as a benchmark in the seminar for what could be achieved without digital tooling and raised challenges for how the limitations of the machine could be overcome using manual means or by controlling the thread structure in novel ways through the use of the script. This question is now central to the development of digital craft.
Over the last 5 years, traditional embroidery techniques, once considered too costly to produce, have now become possible again with digital embroidery machines (Figure 4). Images can be digitized and converted to stitches with desktop software and can be edited parametrically using the computer. This data can now be output via USB or with special memory cards using desktop embroidery machines (by hand) or alternatively it can be embroidered (industrially) on freestanding machines. Ironically this software has exposed many of the misgivings of architectural software when it comes to material. The production software used, Wilcom’s Embroidery Studio, is designed to keep track of the amount of material required to execute the job, and it also provides real time animations based upon the speed of the machine that will be used to fabricate the job. Like the laser cutter, it can be used to draw out information, but the added dimensionality of the thread, its reflectivity, and its structure make it a more complex craft. As such, it is a medium that parallels advancements in architectural thought in the writings of Gottfried Semper and the ornamental work of Louis Sullivan, among others who sought to develop systems of architectural order from nature and the inherent layering of material. In embroidery, the thread is not woven through the surface. Instead the thread is laid down on top of the textile and the bobbin thread sutures the finishing threads to the material from below. As a result, the final piece is an inherently layered construct. The sequential accumulation of threads that was generated in the loop structure of the Processing scripts was preserved in the laying down of the threads. With digital machines, the needle is only required to move up and down, and this makes the automation relatively simple. Unlike the laser cutter or CNC router, where the head moves over the surface, the needle in the embroidery machines only moves vertically, and the material is translated numerically under the needle. 

5 Information Cascades: Staging of Platforms and Digital Tools

The distinctive aspect of these drawings is that each student sought a marriage of materials that is situated in between drawing and the presence of a novel material assembly. Each project focused on engaging the organization, texture, and color in a painterly manner. Students were encouraged to engage variability, including the writing and implementing of scripts that promote variation through numerical data (Figure 5). The initial drawings were coded using Processing and focused on how line work could be developed numerically and transferred to thread later in the process.

The recent influx of digital manufacturing tools across a variety of trades is now allowing architects to participate in a wider interdisciplinary context. More importantly, a universal language of information gives us the capacity to make things with materials that have not been previously considered. This possibility becomes even more potent in the design process when one considers the chain of fabrication processes that can now occur by linking craftsmen and manufacturers together in new sequences and relationships. The writing of code allows designers to embed the intelligence and constraints of the fabrication tools at a generative level. In the best of circumstances the code represents an information cascade that preserves a level of material intelligence, and this process can be designed to participate in the tooling sequence. The clarity and intelligence of the cascade requires its own design and intuition; this is a rather new phenomenon concerning the integration of information. It is a process that must be carefully structured, outlined, and efficiently designed to produce good results.

6 Conclusion

As an art form, the excessive nature of embroidery offers interesting possibilities for visualizing large amounts of data and it provides a useful parallel for testing material combinations. It represents a territory of making that is color and sequence based. As such, it raises new questions for the development of other formats using different materials. The possibility for developing interior and architectural applications for the embroidery remains an open question and was not heavily considered in the seminar. The course focused more on tool flow, color, and integration of embroidery machines. Wall coverings, furniture, and fabrics could all be designed using this process. The students employed the use of vinyl, cotton, leather, and suede, with the stiffer materials yielding better results. Many of the concepts behind the tools that are native to embroidery software would be beneficial for architectural software, especially where large quantities
of material repetition are involved. Granted, making buildings is far more complex than making tapestries. Nonetheless, one of the advantages is that embroidery software is written for machine operators and it has the ability to playback or animate the job, run in real time. Watching an animation of the job helps identify trouble spots and color changes—something that architectural software has also begun to benefit from. Cost is a product of time and the number of stitches, and this makes cost estimating foolproof. Also, most embroidery programs can count the total length of thread without the presence of placing every stitch. This saves a tremendous amount of time without storing excessive data; most BIM software requires a complete model, and it is not as fluid in its approximation capabilities. The potential to expand these processes to the third-dimension, and to the scale of structural components for architecture is an interesting possibility and remains open for development.

Acknowledgements

I want to thank Detlef Mertins for his support of this course at the University of Pennsylvania, and Kristen Smith for her extended efforts in developing the bridge between the various platforms, materials and tools. I am also thankful to Wilcom for lending us their software and to all of the students for their efforts: Kapil Agarwal, Jessica Bayuk, Emily Bernstein, Julio Guzman, Hui Ying Chen, James Ketover, Jeff Nesbitt, Karmen Rivera, Kirsten Shinnamon, Kristen Smith, So Sugita, Tao Zhang, Difeng Zhou.

References