

Jason Griffiths

Pop-tech-flat-fab

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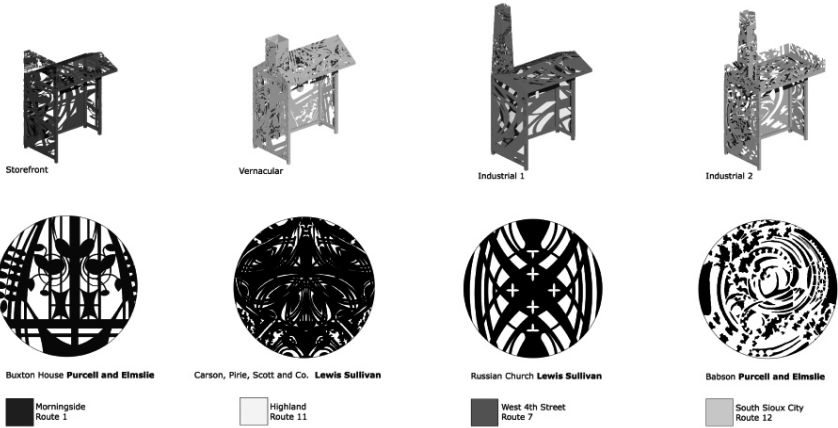
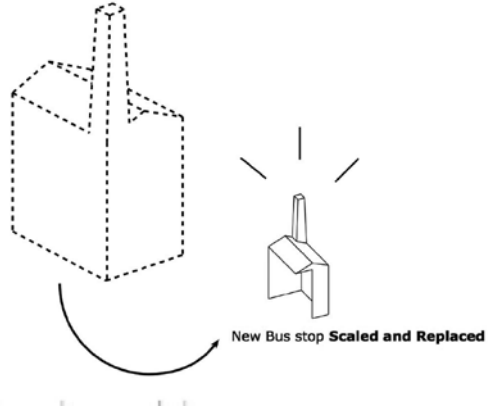
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Figure 1
 Completed bus stop and proposed multiple typologies

This paper for the EAAE / ARCC 2008 addresses the theme of simultaneity between the digital and analogue by examining the production of two projects. These are: a pair of prototype bus stops built in Sioux City¹ and a shade structure for downtown Phoenix in the USA. The conceptual basis for both these projects coincides with the question of how “phenomenon attached to a certain locality”² might be created through advanced methods of digital fabrication. Both projects offer an apology for rapid prototyping techniques applied to an understanding of “contextualism”³. Both projects are presented first as a contextual and symbolic response to an interpretation of “locality” and then re-appraised in technical terms. In both projects these technical aspects aim to advance not only the methods of physical production but also the transition of design methods to 1:1 fabrication. In the case of the Sioux City Bus Stops this idea is represented through an analysis of two-dimensional cutting techniques and developable surfaces. In the case of the Phoenix Shade project this idea is then developed through fully associative digital models. Together these projects attempt to accelerate the physical production of their symbolic and contextual content through a discussion on parametric modeling that allows an efficient production of a set of different permutations. By associating the symbolic/contextual with the parametric these projects suggest an alternative procedure to the traditional and prevalent trope of “digital architecture” and its co-dependence upon explicitly biomorphic, computational and quasi-naturalistic language.⁴



Flat Cut

The study of flatness⁵ in architecture has a particular place within the expanding discussion of digital fabrication and its relationship to the built environment. This chapter suggest that while both the additive and subtractive methods of rapid prototyping have crucial roles to play in the design process it is the various scaled operations of two-dimensional CNC cutting that offer closer ties to conventional construction methods. The following offers a description of this method in the form of two bus stops that where designed for Sioux City Iowa in the summer of 2007. This text describes the background to the project and then presents the design and fabrication process as an aligned methodological transference from the model to full scale.

Background

In this case those formal and textural qualities were the main design priorities at the beginning of the scheme. The project was initially generated in discussion with a number of Sioux City public agencies that included the Chamber of Commerce and Downtown Partners along with key contributions from various steel production companies⁶. After the schematic design had been agreed the project was presented to the first year graduate students of Iowa States Architecture program as the focus for the summer session of the “Service Learning” course. The project was then developed in detail and constructed by the students under the guidance of the studio instructor. The whole course lasted eight weeks.

The key considerations of this design center on the role of the bus stop within the physical and cultural context of downtown Sioux City. As architect Nathan Kalaher points out the city has experienced an ongoing “erasure” of the center between 1930 and 2003 and is still witnessing a depletion of its building stock⁷. Sioux City’s downtown areas are thinning out as former industrial warehouses are being demolished. This project responds to this context by mimicking those absent building typologies in quasi-historical scaled down forms. Proposals are presented as an apparition of what once existed and now reappears in a new form. The two we selected were “Smoke Stack Industrial” and “Storefront” which were chosen from a range of other reduced profiles. These forms were functionally adapted to the role of a bus stop to give shelter and provide good sight lines for the bus driver looking for waiting passengers (hence the bite out of the front left hand corner and missing leg). Another facet of this contextual reflection appears in the detail and decoration of the buildings elevations. All sides of the building are indiscriminately tattooed with abstractions of Prairie Style decoration that were generated from proximate sources. One appropriates from Steele / Purcell Elmslie’s Woodbury Court House and the other from Louis Sullivan’s Babson House⁸ which were then collaged onto the form in a manner that externalizes and brings them to the close attention of the daily bus traveler. The final consideration in terms of these contextual links is the use of sheet steel as the main construction material. Of the remaining industries within Sioux City steel fabrication is one of its most vibrant. The city is often described as “Midwestern rust belt” claiming four large steel fabrication plants each making extensive use of CNC laser and plasma cutting capabilities. It is this aspect of the projects construction that forms the focus of this text and speculation on the “flat-cut” nature of mainstream digital fabrication.

Likeness

In part this speculation is based around the likeness between the design method and the fabrication technique. The key issue here is that the stock of the design model is manipulated in almost the exact same way as the full-scale stock. The consequences of design decisions can be more effectively simulated especially when full-scale stock sizes are replicated at smaller scale and with a similar material. This relationship cannot be applied to the additive process of the three types of 3D printers wherein the full scale construction method is drastically different both in terms of the material and in the manner in which it is cast. This may be contested. At present

professor Behrokh Khoshnevis is producing a 1:1 3D printer designed to produce concrete buildings called the "Contour Graft⁹". However the issue of digital fabrication in architecture can be roughly categorized in two ways: Those that we can use today and those that we cannot. While both aspects of this discipline require extensive consideration in architecture it is the former that is focus of this paper. The following offers a detailed account of the construction process evaluated in terms of this "likeness" between design activities and method of production.

Pattern

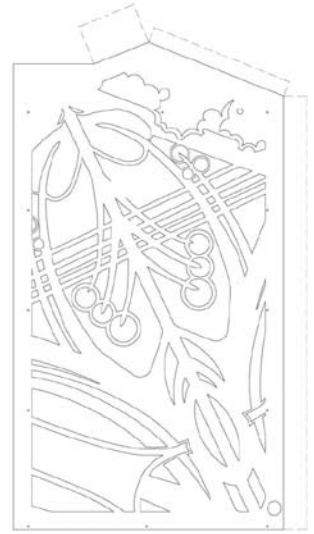
The final arrangements for the external patterns were agreed after a lengthy process of trying alternatives. These patterns were generated from photographs and hand drawings of existing Prairie school designs. Here the issue of what constituted "localities" became an issue of contention among the class and with the clients. While the students had been encouraged to base the pattern on the contextually familiar language of Midwestern Arts and crafts they had also been encouraged to re-appraise this language in terms of contemporary iconography. This study took the form of an assimilation of images and graphics that portrayed Sioux City's current economic and industrial base i.e. cows, computers, steel and so on¹⁰ (See Fig. 2). However the consensus amongst the clients and the students was that the sense of estrangement here departed from what was generally considered to acceptable within this context.

The range of alternatives (sans contemporary iconography) were then quickly tested by scanning these drawings as black solid shapes on white background and autotracing them in Illustrator to produce a set of polylines. These lines then formed the basis of the scaled down laser cut models. This process allowed us to quickly test the levels of transparency and topological continuity of the panels. The "autotrace" command could be used to produce a filled surface that can be moved around to test its integrity both as a digital model and then as a laser cut panel of the model. The method was used to analyze all the surfaces and make sure that all patterns held together. From our various choices we produced a number of models (in addition to the texture mapped renderings) used in presentations to the clients and fabricators and upon which we made our final choices. These illustrator drawings served to initiate one aspect of our discussions with both State Steel and Missouri Valley Steel on the problems with laser cutting. Initially it was hoped that these autotraced drawings would go straight to the fabricators for the final cutting although when the actual cut times were simulated using the companies NestPRO software they were considered to be too long. This testing process allowed us to get closer to the most efficient method of line quality and to iron out any unnecessary pause point during the laser cutting process. It transpired that the best line production would be an Autocad polyline that was generated from initial spline drawings and then converted to a polyline. In addition to this all acute angled junctions needed to be filleted with a radius of no less than .02 inch in order for the laser cutter to cut the junctions without burning. The final cutting including the panel profiles had a travel distance of approximately 4000 ft at a rate of 100 inches/min with a total cut time around 8hrs for all panels.



Panel I-B

Panel I-C



Panel I-E

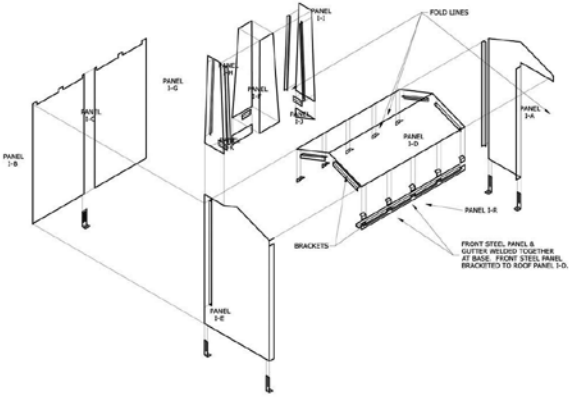


Figure 2

Contemporary iconography inserted into Arts and Crafts decoration.



PANELS 1-F & 1-G WILL BE WELDED TO PANEL 1-D PATTERN ON PANEL 1-D INCLUDES SQUARE HOLE WITHIN THE PATTERN FOR ACCESS TO WELD PANELS & BOLT BRACKETS FROM CHIMNEY TO ROOF PANELS



The issue of flatness became apparent again when we began to work on structural alternatives. Both steel companies advised us on the appropriate dimensions for their steel supplies that were principally to do with the nominal thicknesses, grain direction and overall dimensions. However the maximum steel sizes were ultimately conditioned by the 7x9 bed size of the laser cutter. All panel sizes needed to be within these proportions or capable of being efficiently nested as multiples within these proportions. Again this was something that we could simulate quickly on the laser cutter as save fabrication time. However these considerations had even greater effect on the structural solution of the project.

(Initially the designs had been based on a frame and panel system that was generated from studies of existing aluminum bus stops. This meant that the panels could be thin and non-structural. However we began to think that this might have a limitation on the longevity of the proposal. After our initial proposals to the Chamber of Commerce and open session of Sioux City Council we were encouraged to develop them as prototypes for more stops and other cities within the region. Additionally the steel companies were suggesting that they could be a flat pack system that could be delivered and assembled locally. As a consequence we changed the structural system to a folded plate method and made the decorative panels integral to the structure. The new system was to be entirely cut from sheet steel and connected with brackets. The panels were connected through tapped holes that were secured with 1/2" dia. #20 threaded stainless steel hex-headed security bolts. This system required further analysis of the topological continuity of the panels and their lateral strength that was in effect a form of cross bracing disguised within the pattern. Additional strength was generated from the right angled folded plate panel ends and in the pitched roof form. In both cases all two-dimensional laser cutting needed to be done in advance and that those patterns needed to have a solid border along the fold lines. Once they were laser cut they then folded using a 200-ton NC press brake for accurate bend angles. Panel sizes also needed to respect the brake opening and accessibility issues. As the brake is predominantly used with steel these issues translated back to the design models and simulated with the laser cut chipboard model panels.

The preference for the flat pack version was also conditioned by the painting options.

At one point during the transition to the flat pack version we had considered a fully welded version. This proposal had more of a "one off " quality to it but was considered to be a safer bet both structurally and in terms of avoiding the complexity of designing and positioning the threaded holes and corresponding slotted holes. This version would then imply that the welded whole would have to be sprayed in an auto body shop by hand and not without some difficulty (especially within the chimney on the smokestack version). In effect this meant that the bus stops were considered more as artworks than a system for potential mass production. It seemed that, for pedagogical, reasons it was important to pursue them as a hybrid of a customized and mass produced system. This was furthered by the encouraging support from Sioux City Council for further versions. This issue extended to the painting options.

Our second alternative for paint was through a company called Frisco who have a manufacturing facility also in Sioux City. A large proportion of their work includes the mass production of components for age equipment that includes an extensive powder coating facility. The design of the flat pack bolted version was also influenced by this system and essentially aligned with age equipment component production methods. In addition to the panel size restriction of the laser cutting bed we were also restricted by the size of the 5'x102" throat of the shot blasting booth, the charging and spraying booth and the infrared heating run all of which were arranged in sequence along a hanging conveyor system. At one point we had been analyzing the possibility of getting the fully welded version through. However this was restricted by the booth throat area and also because this painting system was most effective on objects that had no hidden or internal faces. Therefore our pre-assembled pieces could be more effectively painted using a system that was designed to provide a specification that would withstand all weather exposure. In this respect the most vulnerable parts of the project were the sharp edges of the pattern in that the paint would thin along the edges. This problem was reduced by the shot-blasting phase of the painting, which would effectively round these edges giving a more even coverage. This alignment with the industrial process even extended to the paint finish and solved our anxieties about the right color. Although Fimco's were happy to source color options for us the plant mainly ran on bulk cans of stock ag colors of black and the emergency colors red, yellow, green and blue. Frimco's spay schedules are arranged around large batches of components of the same color. We felt that these colors were especially appropriate not only for production reasons but also because they would have some contextual link to the agricultural foundation to Sioux City. The built versions were the blue and the yellow although future versions would incorporate the full range of colors.

Parametric versions

Initially each bus stop was to be a unique reflection of its position within the city¹¹ and as a consequence built as a "one-off". The next phase of this project considers a set of variations each based on the idea of "absent typologies" (for example a house with a chimney and a warehouse). Subsequently however clients asked for a developed proposal for multiple variants to replace existing bus stops throughout the area. This presents a direct challenge to the notion of mass customization and how it is to might be achieved through parametric modeling software. This development in the project represents one version of the much wider problem of the move from conventional methods of design production and fabrication to fully associative digital modeling and rapid prototyping. The essence of this question lies in how these software environments deliver projects of comparable quality to those that are mass-produced while retaining their individuality. Furthermore can this diversity be delivered without excessive increase in design, information production, fabrication, delivery and assembly cost? (i.e. what is the point at which it "touches the ground"¹²) Working both with the steel companies and Fimco gradually pushed the project in the direction of the flat panel system. The realization of this project became more conditioned by industry standard production techniques. Part of the reflection of this project also considers the way in which the design process might further the notion of mass customization



pattern development

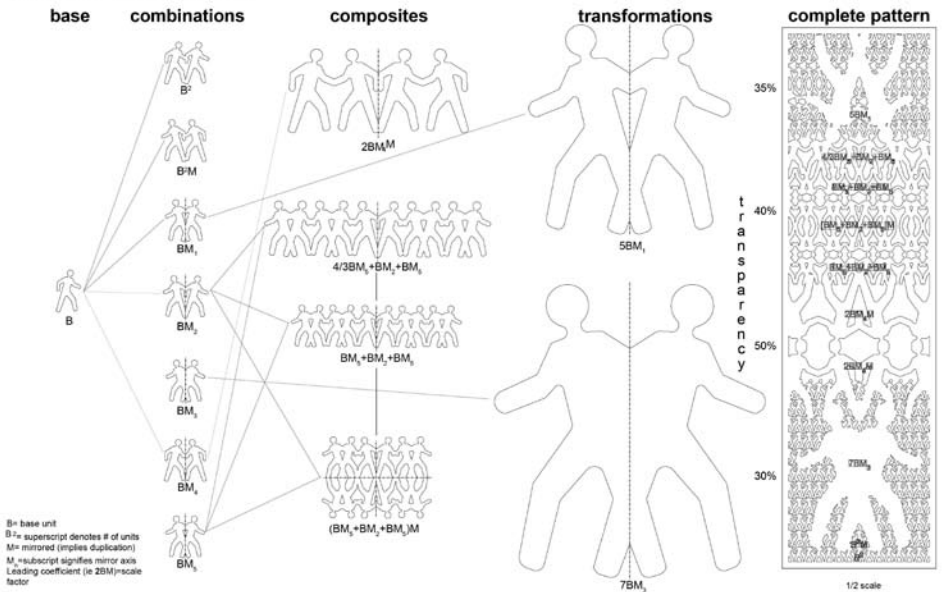


Figure 3
Permutations of "Cross Now"

while retaining a practical understanding of its effect on production information and fabrication methods. In this respect it is the earlier stages of the design that should be considered more widely in the manner in which it incorporates methods of digital morphogenesis. While the Sioux City project was not in itself developed into a parametric environment these considerations did have direct bearing on the subsequent project for Phoenix "Pocket Shade" project.

"Cross now" Context and symbols

Like the Sioux City bus stops this project began with a symbolic interpretation of the context. In this case elements of this context were: the generic condition of a typical downtown intersection, a framed view of the city skyline and the isotype figure of the "cross now" symbol for the traffic light. These cultural aspects of non-specific place are considered in relation to the functional question of providing shade for pedestrians in one of the hottest climate within the US.

Each corner of a typical Phoenix intersection presents two alternative aspects towards the city when waiting to cross the road i.e. north and east, north and west, south and east and south and west and each orientation present a particular skyline. The project responds to this skyline by mimicking its silhouette in an offset thick line that becomes the top of the shade/cantilevered structure. While the nature of this profile is largely an aesthetic device this aesthetic is arranged a marker of both a place and a time within a rapidly developing downtown environment. In the future this profile will act as register by which the public will be able to calibrate physical change within the city.

The second interpretation of "aspect" within this scheme is considered at a more local scale of the road width and crossing time. Each structure is arranged to face east west (reducing the profiles to either a north or south orientation) to provide as much shade as possible from the lower east-west sun). This vertical section of the shade provides protective screen for pedestrians waiting to cross the road and while watching the traffic lights and cross indicator. The project responds to this view by altering the percentage transparency and nature of the perforation of the screen to suit eye heights and sightlines for the pedestrians.

This aspect of the project was combined with the "prospect" of the building as a marker and pause point before crossing the road. Part of the perforated/ laser cut cladding of this project is then arranged to act as a supergraphic that describes the buildings implicit function through the larger isotype profile of "cross now" figure. This symbol was also multiplied at small scale to add a symbolic reading to the function of shade described above.

Both the screen and the profile offer separate challenges when considered in terms of the parametric model used to design and manufacture this building.

Screen

While this screen is subject to a more predicable set of constraints these constraints vary slightly from site to site. Even within the most generic and repetitious street layout each corner has its nuances and particularities. In each case the sightlines across the road will be different and the provision of shade affected by the immediate physical context of trees and building. The

specific of each site give rise to specifics of pattern which then needed to be efficiently reproduced. In order to do this each pattern was generated through a set of geometric transformations that were then given a simple code e.g. 4/3BM5+BM2+BM5 etc (See Fig. 3). While this code has not, as yet, been processed as a script its rational geometric sequence can be used to accurately describe desired levels of transparency shade and opening profile.

The second aspect of the parametric quality of this project concerns the structure and its relationship to the skyline and the site. In order for these skylines to be quickly altered and quickly converted into production drawings the project had to be generated through one fully associative model that could allow each desired variation. We considered various software packages that allowed us to make the basic shift towards fully associative solid modeling all of which were based on the Parasolid modeling kernel eventually settling on Solidworks. The nature of the project orientated us in the direction of product design software and in particular programs that are geared towards sheet steel manipulation and folded plate geometry with associative hole pattern functions and bend type modifiers. Additionally it then provides direct methods for fully documented production level drawings that translated to NC bending and laser cutting software applications. In effect Solidworks was used to unfold our three-dimensional model and generate dimensioned cutting patterns with all hole and bending information including bend factors, tapping information and bolt schedules¹³ automatically included. Each permutation of skyline could be quickly generated by manipulating the underlying sketch according to the desired profile.

This development also affected the relationship between the design activities and the steelwork fabricators. While it was more economical for the students to unfold and dimension all the drawings themselves the fabricators technicians were equally willing to do this. By using industry standard software the technicians could quickly analyze the proposal for any design flaws and fabrication problems and quickly amend them prior to fabrication. These areas of improvement mainly concerned pressbrake access and steelwork stock sizes. Our fabricators¹⁴ would have been equally satisfied with a fully formed three-dimensional Solidworks model that they would use to provide their own orthographic cutting patterns. In most cases fabricators will customize bend deductions within software to suit their particular machinery. While Solidworks encourages designers to do this in-house it is only really effective if they have a close working relationship with fabricators and an intimate knowledge of their machinery. This is also often an economic decision on the part of the designer and based on the relative rates for in house technicians compared to shop technicians¹⁵. It has the additional benefits of allowing the fabricators to compose drawings directly through nesting programs and according to their current stock availability improving cost and efficiency.

Similar aspects of the cutting procedure also had an adverse affect on production time because we used two different steel thicknesses i.e. ¼" for structure and 20 gauge for cladding. This implied two different cutting power settings for the laser cutter¹⁶ and therefore was cut in two different sessions. On reflection this procedure would have been more efficient if the design had been one gauge steel and fully composed as a folded plate construction system. This disparity

of steel thickness would also have an effect upon powdercoating times as both shot blasting times and heating temperatures also vary according to steel thickness.

A similar reflection the disparity between the pattern cutting drawing and the Solidworks models cutting drawing also reveal areas for improvement. Despite our move to full associativity these aspect of parametric modeling still remain as separate processes in the production drawing stage. While we found that we could make improvements to the sketch-to-scan-to-cutting process¹⁷ to eradicate the problem of spline curve incompatibility with NC output applications we could not include the perforation cuts directly into the Solidworks file. Generally the Solidworks file would be arranged to have a solid sheet of steel to establish the general arrangement of the perforated panel and then the pattern would be inserted at the end and directly into the fabricators nesting program as a DXF file.

This text suggests that an effective use of parametric modeling programs would enhance the role of “digital morphogenesis”¹⁸ as the alternative to the traditional duality of physical models and orthographic drawings. The alignment of scaled and full-scale laser cutting fabrication would then ensue without drastically changing the effect of the final outcome. It explores aspects of mass customization and the potential role of sheet steel parametric modeling software in producing further variants of a basic form. It reflects on further improvements to the design process with particular consideration of the morphology of digital models. It concludes by suggesting that the flat-cut technique has a consequence upon both formal and textural properties of architecture that should be consciously embraced as a language that offers direct communication with readily available modes of digital fabrication.

Conclusion

While this text charts a transition from one project to another in terms of its technical improvements through parametric modeling it does so under the constraint of the developable surface and flat cut architectural detail. While this is partly motivated by production efficiency and extensive use of laser cutting techniques it also came, in part, from an interest in contextualism, typologies and symbolism along with the desire for an intentional sense of flatness. As the project developed so too did the consideration of flatness as a specific architectural device. In both cases this two-dimensional appearance is intended as a register upon which aspects of context and locality are played out. Both the cutting and bending process became important methods by which the familiarity of the typology and decoration were estranged via these flattening techniques.¹⁹ In this way the laser cutter turned out to be particularly appropriate to these aims. The sense of compression of architecture towards an infinitely thin surface is part of its commentary and intentional aesthetic. In part this method is indebted to Venturi’s play on the overtly flat signification of cutout elements of his buildings.²⁰ While much of VSB’s work pre-empted use of CNC cutting in its detail and language it also provided important lessons on the economy of expression in architecture i.e. the flat, vertical surfaces of the building provides the most cost effective register for architectural communication. Today these expressive opportunities can be explored by architects more cheaply and quickly with advanced methods of fabrication. While digital fabrication supports

a wide range of architectural outcomes it is interesting to note that in terms of the material that many of them begin in a state of flatness after which they are formed or bent into the appropriate shape. This period of flatness is implied both in the developable surface and in the double-curved surface of lateral and bi-directional sectioned structures. These two projects look for further applications for this understanding of flatness through a consideration of the developable surface and flat-cut ornamentation. They are considered in terms a particular aspect of digital fabrication from the design process through to completion. They suggest that a rigorous analysis of the alignment of digital fabrication with contemporary methods of production will help widen its use within the built environment. In this instance the sense of flat-cut architecture arises from the most effective and readily available means of digital fabrication.

Notes

- 1 Iowa, USA
- 2 EAAE / ARCC 2008 conference text.
- 3 Term used by Venturi Scott-Brown to describe a particular relationship to context that is other than a passive or mimetic.
- 4 This relationship is set in constraints the prevalent association conjured by a set of accepted tropes of digital production. These can be briefly described as biomorphic, quasi Darwinian on the one hand or futuristic and high tech on the other.
- 5 Edward R. Tufte. *Envisioning Information – Escaping Flatland* p.14
- 6 Full team was comprised of Sioux City Chamber of Commerce, Downtown Partners, Siouxland Transit, State Steel, Missouri Valley Steel and Fimco.
- 7 “Sioux City – A Potential History” - Masters thesis Nathan Kalaheer. p.48
- 8 Carried out with George Elmslie. It is not clear how much of this design is attributed to Sullivan and how much to Elmslie. See Louis Sullivan and George Grant Elmslie by David Gebhard. *The Journal of the Society of Architectural Historians*, Vol. 19, No. 2. (May, 1960), pp. 62-68.
- 9 Behrokh Khoshnevis is a professor of Industrial & Systems Engineering and Civil & Environmental Engineering, and is the Director of the Center for Rapid Automated Fabrication Technologies (CRAFT) and Director of Manufacturing Engineering Graduate Program at USC
- 10 I introduced students to work of Wim Delvoye and particularly agricultural associations of the tattooed pigs.
- 11 This project responds to the Sioux City context by mimicking those absent building typologies in quasi-historical scaled down forms and in their tattoo of abstractions of Prairie Style decoration of the American Midwest.
- 12 EAAE / ARCC 2008 conference text.
- 13 We found that function like the “Hole Wizard” to largely in effective an instead placed holes in original components and then “converted components” in assemblies. For more information on this see <http://www.solidworks.com/pages/onlinetour/popup.cfm>
- 14 in this case a company called K-Zell
- 15 Shop technician rates range from 20 – 30 dollars per hour while a similar in-house technician usually less than 20 dollars per hour.
- 16 For 20 gauge the laser ran at 2900 mm/minute at 3600 Watts while for the ¼” ran at the same feed rate but at 3600 Watts.
- 17 Illustrator allows conversion of spline curves to polylines of different resolution.
- 18 *Architecture in the Digital Age: Design and Manufacturing* by Branko Kolarevic.
- 19 See also Wim Delvoye Madison Square Park, Manhattan Doris C. Freedman Plaza, Manhattan June 2003 to October 2003
- 20 Particularly the house in Greenville, DE, (1980) or the House in Stony Creek, CT (1984).