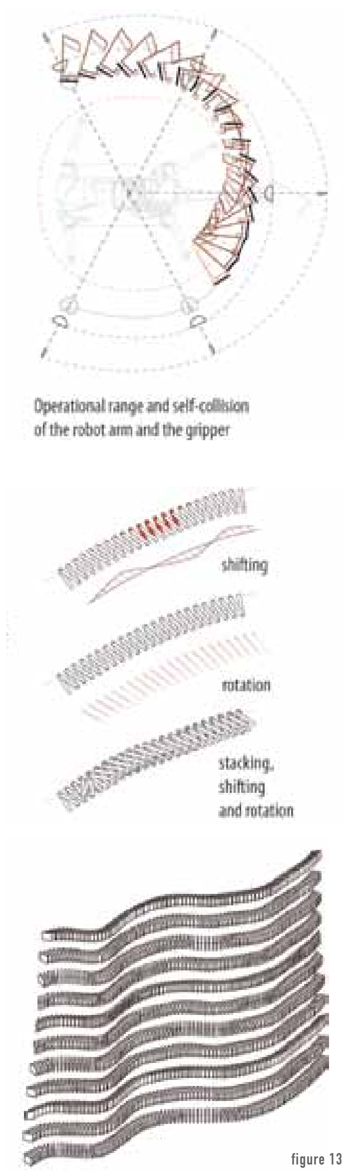

figure 13

Diagrams showing the design concept. The design drivers include the operational range and the self-collision of the mobile unit (in particular the gripper), along with the superposition of algorithmic rules.

directly derived from the surrounding spatial conditions—one, for instance, being the ceiling height. The structure was designed by the students taking part in an elective course, "The Fragile Structure," under the professorship of Gramazio and Kohler, which also investigated the self-collision and the positioning of the fabrication unit, in addition to the operational range of the robot arm (Figure 13). These are systemically used and simulated on the software side. Through a collaborative process in design scripting and offline programming, the fabrication data from the CAD model of the structure is exported to the robot controller.

The geometrically differentiated wall structure consists of more than a thousand individually positioned timber building blocks. In its overall assembly strategy, a new form of articulation in digital fabrication processes in architecture was intended.

8 CONCLUSION

The key contribution this in situ robotic fabrication potentially makes to architecture is the direct application of mobile units on construction sites; the intention here is to demonstrate the feasible objectives and potentials for the use of such a novel method of mobile fabrication.

Unlike in other sectors, the implementation of computer-controlled manufacturing has been relatively slow in the construction sector. Still, every building is designed with a unique complexity that is based on specific design drivers, and accordingly, the algorithmic description of complex architectural building projects demands more rapid progress in this field. The direct in situ application of mobile robotic fabrication units in response to these conditions is one way of providing accurate and customized solutions. To enable a deeper interaction and collaboration between humans and machines, the technical requirements and the interface for communicating with these robotic fabrication tools have also been simplified.

The work outlined in this paper was intended as a first step in the evolution of mobile robotics on construction sites. In contrast to previous research projects, the fabrication unit shown here is intended to be an open system that is adaptable to different applications and situations; accordingly, the main objective of our research has been to identify different application scenarios, in addition to additive strategies, and to illustrate various communication and data acquisition systems. The scanning systems integrated into the process aim to respond to changing conditions in the workspace or construction site, thus informing the building cycle in real time as a feedback mechanism, altering and adapting the outcome when necessary. This is intended as the extension of stationary digital fabrication processes to in situ fabrication.

The building system proposed in this paper can respond flexibly to the rapidly changing requirements of the construction industry and might help close the gap between the design and in situ construction of complex, nonstandard structures.

REFERENCES

Andres, J., T. Bock, F. Gebhart, and W. Steck. (1994). First Results of the Development of the Masonry Robot System ROCCO. Proceedings of the 11th ISARC International Symposium on Automation and Robotics in Construction, 87–93.

Bock, T., T. Linner, W. Lauer, and N. Eibisch. (2010). Automatisierung und Robotik im Bauen. Arch + Zeitschrift für Architektur und Städtebau, May 2010, 34–39.

Bonwetsch, T., F. Gramazio, and M. Kohler. (2007). Digitally Fabricating Non-Standardized Brick Walls. ManuBuild, First International Conference, 191–96. Rotterdam: D. M. Sharp.

Gramazio, F., and M. Kohler. (2008). Digital Materiality in Architecture. Baden: Lars Muller Publishers.

Han, C-s. (2011). Human-Robot Cooperation Technology: An Ideal Midway Solution Heading Toward the Future of Robotics and Automation in Construction. Proceedings of the 28th ISARC International Symposium on Automation and Robotics in Construction, 13–18.

Pritschow, G., M. Dalacker, J. Kurz, and M. Gaenssle. (1996). Technological Aspects in the Development of a Mobile Bricklaying Robot. Automation in Construction 5 (1): 87–93.

Ueno, T. (1998). Trend Analysis of ISARC. Proceedings of the 15th ISARC International Symposium on Automation and Robotics in Construction, 5–12.

Warszawski, A., and R. Navon. (1996). Survey of Building Robots. Proceedings of the 13th ISARC International Symposium on Automation and Robotics in Construction, 205–11.

MORPHFAUX:
PROBING THE PROTO-SYNTHETIC NATURE OF PLASTER THROUGH ROBOTIC TOOLING

ABSTRACT

Morphfaux is an applied research project that revisits the virtually lost craft of plaster to explore its potential for producing innovative architectural elements through the use of contemporary digital technology. The research challenges the flatness of modern, standardized drywall construction and explores plaster's malleability as a material that can be applied thick and thin, finished to appear smooth or textured, and tooled while liquid or cured. If the invention of industrialized modern building products such as drywall led to the demise of the plasterer as a tradesperson, our research seeks alliances between the abilities of the human hand and those of automation. By transforming historic methods using new robotic tools, Morphfaux has broadened the possibilities of architectural plaster. While our research has produced forms not possible by human skill alone, it also clearly illustrates a symbiotic relationship between the human body and robotic machines where human dexterity and robotic precision are choreographed in the production of innovative plastering techniques (Figure 1).

Joshua Bard
Carnegie Mellon

Steven Mankouche
Taubman College
University of Michigan

Matthew Schulte
Taubman College
University of Michigan

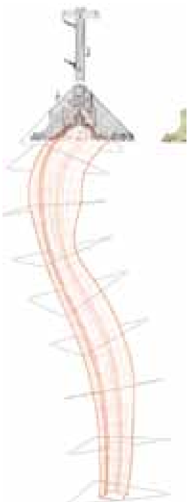
figure 2

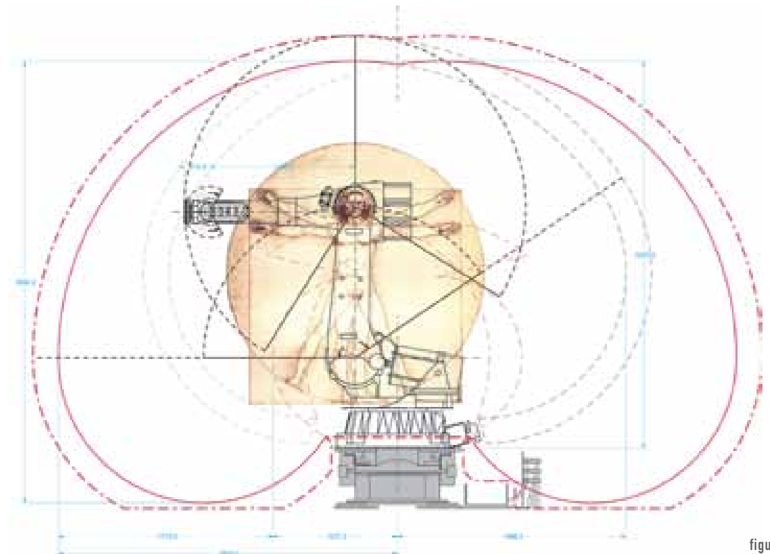
figure 1

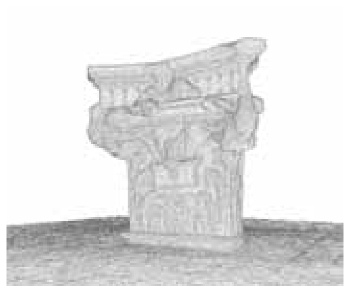
figure 3


figure 4

figure 1
Measure of the augmented body.

figure 2
Variable extrusion projected off of 19th-century hand-cut plaster profiling tool.

figures 3 and 4
Digital scans of Corinthian columns.

1 CONTEMPORARY CONTEXT

Morphfaux participates in and extends conversations surrounding one of the most consistent contemporary trends in digital practice—the reformulation of historic craft relative to digital design and fabrication tools. Among other things, this focus re-posits the means and methods of making in relation to informed material knowledge. Mario Carpo, in The Alphabet and The Algorithm, is particularly helpful at setting the stage: "Acting almost like prosthetic extensions of the hands of the artisan, digital design and fabrication tools are creating a curiously high-tech analog of preindustrial artisanal practices" (Carpo 2011) (Figure 2). An interest in craft suggests a fundamental turn in architectural ideation toward tacit knowledge gained over time through direct bodily engagement with material processes. Morphfaux anticipates the knowledge garnered through material engagement as it folds back into the logics of tooling, making, and design.

In the process of formulating a sense of digital craft, developments in digital media and fabrication are pushing back on our tacit assumptions about the assumed unreality of digital entities. Contrary to the perception of the digital as "virtual," digital media has in practice become increasingly embedded, ambient, and haptic. Digital fabrication has exploded into DIY culture with the promise of rapid prototyping, suggesting that the transition from digital model to physical object is just a click away. The digital and physical realms are increasingly interrelated, which suggests that the reality on the ground of digital practice is a synthetic one where a complex and ever-thickening web conjoins physical and digital entities. Beyond the delineation of objects, physical and digital contexts are also becoming increasingly interconnected. Digital imaging and scanning along with simulation of physical forces and material behaviors promise context-rich modeling environments (Figures 3 and 4). It is not the objective of this paper to provide precise historical delineation to these developments but rather to probe potential trajectories within this emerging context via robotically applied plaster.

2 HISTORICAL BACKGROUND

In 1894, the year following Chicago's Columbian Exhibition and its famous White (plastered) City, Augustine Sackett invented Sackett Board, a sheet-based building product that would all but render the craft of plastering in its many architectural applications obsolete (Figure 5). Just in time for Chicago's second World's Fair in 1933, the United States Gypsum Co. (USG), which purchased the Sackett Board patent in 1909, constructed its first building skinned almost entirely in Sheetrock™. Since that time, drywall has become a ubiquitous building material and has had a drastic impact on the economic, environmental, and qualitative makeup of the built environment.

The demise of architectural plaster was not entirely the making of large corporations. Modernist ideology, with its insistence on "truthfulness" in materials, certainly contributed to vilifying plaster's architectural uses (Smith 2002). Plaster was rejected primarily because of its association with the cheap replication of neoclassical Beaux-Arts style architecture and its application as a faux finish in place of real stone. Commenting on the White City, Louis Sullivan set the stage for modernity's rejection of plaster, listing it as a "material of decay" (Figure 6). Industrially produced gypsum board walls and ceilings provided modern architects flat, regular surfaces, which emphasize pure orthogonal forms. Drywall's utility—it is fireproof and easy to install—combined with a modern aesthetic quickly made it an industry standard. As a result the typical wall section has ceased to be a locus for variability in thickness, integrated color, and finish, or decorative form in architectural design. Sullivan later popularized the dictum "form follows function." But Sullivan failed to remind us, or to predict, that form often follows industry specifications driven largely by the availability of cheap material and optimized manufacturing (Figure 7). Fully industrialized modern architecture tends to produce homogeneous flatness. This flatness is literally coded into our built environment, which is covered in a 5/8" film of fire-rated gypsum wallboard.

3 HISTORICAL JUMP CUT

Morphfaux locates value in framing new tools and methodologies by reimagining marginalized materials and forgotten construction systems. This approach uncovers latent assumptions about our past, the perceived present, and our shared future. In terms of shaping the future, the research envisions a culture of design (in practice and theory) where materials and forms can break from the thinness of the built environment and express a wider range of design intent. Much more than a source of nostalgia, the turn toward pre-industrial technologies acknowledges the correlation between mechanization and homogeneity in industrial production and attempts to recover the jettisoned logics of material craft. Manuel De Landa best describes the link between material predispositions and formal expression: "Instead of imposing a cerebral form on an inert matter, materials were allowed to have their say in the final form produced. Craftsmen did not impose a shape but rather teased out a form from the material, acting more as triggers for spontaneous behavior and as facilitators of spontaneous processes than as commanders imposing their desires from above. In all there was a respect for matter's own form-generating capabilities and the ability to deal with heterogeneity" (De Landa 2001). Given its unique material properties (its heterogeneous behavior), plaster deserves renewed architectural consideration relative to the synthesis of material knowledge and digital production.

figure 5


figure 6

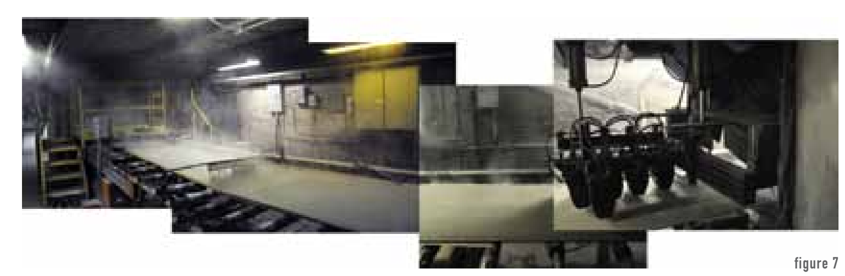
figure 7

figure 5
First drywall, Sackett Board.

figure 6
Plaster relief, Louis Sullivan.

figure 7
Authors' visit to USG Plant, River Rouge, Michigan.

top to bottom: figures 8, 9 and 10

figure 8

Scaled plaster model of Parthenon in the foreground; full-scale plaster cast of Ionic column, capital, and entablature from the Tomb of King Maussollos in the background. All from the Architectural Plaster Collection, Carnegie Museum of Art in Pittsburgh, whose great hall of architecture is surrounded by Ionic plaster columns.

figure 9

Plaster casts of Doric, Ionic, and Corinthian columns in the Carnegie Museum collection in relation to Piranesi drawings of the orders.

figure 10

Brill-Schilling plaster mathematical surface model M-07-001, Harvard University Department of Mathematics.

4 PROTO-SYNTHETIC MATERIAL

In his exhaustive historical treatise on architectural plaster, William Millar muses, "Into that dim, obscure period we cannot penetrate far enough to see clearly, but the most distant glimpses we can obtain into it show us that man had very early attained almost to perfection in compounding material for plastering. In fact, so far as we yet know, some of the earliest plastering which has remained to us excels, in its scientific composition, that which we use at the present day, telling of ages of experimental attempts" (Millar 1899). Developed in the eighth millennium BCE (Tubb 1998), plaster is the protosynthetic architectural material and has been used in a variety of interior and exterior applications for protection against weather, fire, and the spread of disease. Plaster's synthetic qualities are relevant to architectural design in four respects:

1. Plaster is compositionally synthetic. Virtually artificial stone, plaster is made of a combination of a few key ingredients (gypsum, lime, water) that when mixed create an exothermic reaction resulting in a hard, smooth white finish. After initial curing, plaster takes weeks to fully hydrate and reach full strength. Like many synthetic materials, there is no single recipe for plaster. In fact plaster can be mixed in many ways to affect its workability, performance, and finish quality. By way of example, the quality of lime used in the mix, its terroir (what region it was extracted from, how long it has been slaked), will drastically affect the performance of the material such that European plasterers developed drastically different schools of thought based on the lime available to them (Italian vs. English). The use of additives to either accelerate or retard plaster's chemical processes ranges from the folk (e.g., beer, urine) to the chemical precision of modern-day material science. Adding to its synthetic value, plaster can be pulverized, rehydrated, and reused countless times.

2. Plaster is formally synthetic. As a material, plaster has an ambiguous relationship to physical scale. It has a smooth, monolithic finish, which lacks color and texture like grain or veining as a register of overall size. In addition, plaster has historically been used at multiple scales: from the miniature size of dentures and architectural models to the monumental extent of building components (Figure 8). Due to its changing viscosity as it sets from liquid to paste, plaster has a wide range of material effects and is viable across a range of architectural systems, from the ornamental to the structural. Yet plaster's castable and highly workable nature has given it the stigma of being an inauthentic, synthetic material that copies. Our research reframes the concept of the copy (faux) through the lens of morphology and typology, where iterative form making is linked to historical precedent and relational computer modeling.

3. Plaster is pedagogically synthetic. As an archaeological material, plaster has played a central role in museum collections of architectural artifacts from antiquity. While most present-day museums and architecture schools have since discarded their collections, during the Beaux-Arts movement plaster was foundational in the education of architects. Plaster casts were measured, analyzed, drawn, and synthesized. They were used as objects for taxonomical analysis and iterative design development (Figure 9). Because of its prevalent use, plaster was well understood as a material, and its craft was taught not only for replication of artifacts but also for generating new forms. Plaster was a synthetic tool for linking drawing, three-dimensional models, and physical space. This is evident in Brill-Schilling's plaster mathematical models, which became foundational to contemporary digital modeling (Figure 10). Our research deploys a constellation of tools (3D scanning, robotic tooling, parametric modeling) that expands upon the tradition of pedagogical synthesis between physical artifacts and informed representation.

4. Finally, plaster is operatively synthetic. Attention to the historical craft of plaster uncovers compelling procedural logics for digital fabrication. Plaster is workable in multiple physical states: liquid, semiplastic, cured (Figure 11). This malleability has historically been leveraged to skillfully shape intricate forms through a series of interconnected operations. For example, a plasterer might build up a form with a trowel or float; sculpt it with a chisel while it is still green; then polish it once the plaster begins to fully cure. Plaster's chemical qualities permit multiple techniques to be simultaneously deployed. Historic plaster ornamentation was often precast and then seamlessly blended with on-site cast or extruded elements. This synthetic ability makes plaster an ideal material for both on-site and off-site CNC operations. Our research leveraged the challenge of working plaster in its multiple states as it rapidly sets to generate compelling design feedback for CNC fabrication.

figure 11

figure 12

5 VARIABLE TOOLS

Transitioning from craft-based practices of applied architectural plaster—where both additive and subtractive tools must be applied in the same workflow —to the domain of CNC fabrication requires retooling traditional approaches to machining. Rather than associating individual operations with separate dedicated machines (e.g., CNC router, water jet cutter), Morphfaux utilized a six-axis robotic arm equipped with workstations positioned along a 50-foot linear external axis (Figure 12). Custom end-of-arm tooling was designed and fabricated to shape plaster in its multiple states. The robot was seen as an open platform of programmable means anticipating the guiding telos of new tools. In each instance, we developed contemporary plaster tools to explore connections to tacit material knowledge and craft precedent and to provoke speculative making made possible by robotic motion.

Four tools were developed to investigate plaster's multiple physical states—liquid, paste, semicured, and fully cured. Three of these tools were robotically controlled. The following sections describe the development of contemporary plaster approaches, their reliance on material knowledge and craft precedent, and the innovative possibilities opened up by custom tools.

5.1 Inflated Mold

In order to shape liquid plaster an inflatable mold was developed that regulated the flow of compressed air to produce variable three-dimensional tiles (Figure 13). As with many casting techniques, the production of custom molds for single applications can be expensive and wasteful. The inflatable mold allowed for repeated use and production of dimensionally unique tiles by altering the tension in the membrane and by modulating the internal pressure while curing. Plaster casting has a long tradition at both architectural and model-making scales, and plaster is one of the few materials that can also be used to make its own molds. Experiments were conducted where an initial shell was cast using the mold. The plaster was allowed to cure, and the mold was slightly deflated wherein a second layer of plaster was cast, creating a double-walled tile. The gap between the two walls could then be filled with a lightweight material to improve tile strength and insulating properties (Figure 14). In future tests a secondary water jet cutting operation will be added to the tile to trim the outer boundary and add custom perforations.

figure 13

figure 11

Material states of plaster: liquid, 3–15 minutes; paste, 16–45 minutes; "cheese state" or semicured, 45– 47 minutes; and "green" or fully cured, 47 minutes to one week.

figure 12

Robotic arm profiling plaster at Taubman College digital fabrication laboratory.

figure 13

Finished variably inflated plaster ceiling tile construct.

top to bottom: figures 14, 15, and 16

figure 17

5.2 Robotic Profiling

Running molds have historically been the primary vehicle for producing decorative molding with architectural plaster. Traditional running molds are run by hand and require fixed rails to guide the tool repeatedly over multiple gauges of setting plaster (Figure 2). Because repeatability in this process is essential, running molds tend to be straight or composed of simple geometric elements (e.g., circles) and run in two dimensions. This fact stems not only from limitations of the human body in controlling the speed, pressure, and angle of the tool along the running mold, but also from limitations in fabricating complex geometries in the molds themselves. Even a small departure from simple geometries requires an extremely complicated mold. In typical running molds, the profile along the run is also constant. Where variation in the profile is desired (e.g., dentil molding), elements need to be cast or else tooled subtractively with a gouge or chisel. Creating a profiling tool for the robot provided two opportunities for new plaster forms (Figure 19). First, a robot has no need for fixed rails to guide the profiling tool. Unlike the human hand, a robot can shape profiles freely in 3D space according to any geometric trajectory that can be digitally produced (Figure 18). By adding an additional axis to the profiling tool, variability can be introduced into the profile along its path. The tool has two interchangeable plates actuated by a stepper motor. As plates slide past one another, the resulting profile morphs along the length of the molding (Figure 15).

figure 14

Inflating mold until maximum desired point.

figure 15

Finished robotically profiled plaster and lath construct in fabrication laboratory.

figure 16

Robotic plaster profiling: first passes, third, and final pass.

figure 17

Detail of variable plaster profile.

figure 18

Robotic wire saw designed and developed by authors.

figure 18

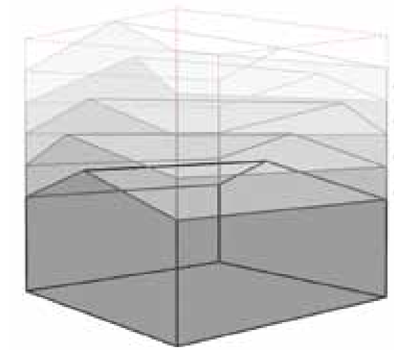

figure 19

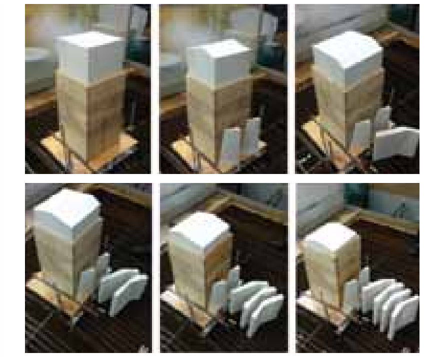

figure 20

figure 21

figure 22

figure 23

5.3 Robotic Wire Saw

A robotically mountable wire saw allowed for ruled surface cutting of semicured and cured wet plaster (Figure 18). The saw provides a rough cutting throat of 24"×18" and uses a round wire blade (a derivation of surgical cutting wire common in custom band saw applications) for cutting in any direction. The tool is designed to slice sections from large plaster blocks with very little waste. Because plaster can fully adhere to itself across cold joints, the block could be regenerated with a fresh plaster pour and continue to be shaped through subsequent cuts (Figure 19). Through repeated testing it was found to be optimal to perform slicing operations on plaster stock with an elevated moisture content to minimize the spread of dust (Figure 20). Test cuts revealed that wetted plaster will produce fine shavings rather than ultrafine airborne particles. As an added benefit, the pastelike slurry formed during wet cutting acts as an impromptu fixture, securing the cut portion via capillary action. Fully cured and dried plaster may be easily rehydrated prior to cutting by simply soaking the stock in plain water (Figure 21).

5.4 Robotic Water Jet Cutting

Lastly thin (1 1/2" to 4 1/2" thick) slabs were cut using a robotic water jet tool (Figure 23). Similar to the wire saw, the water jet results in ruled surface geometry but is much more constrained in the overall depth of its cut (Figure 22). Unlike the wire saw, the water jet can cut fully interior holes into a piece without leaving an entry and exit path. Note: this tool was not developed by the authors (Figure 24).

Although the tools developed during the research have led to promising results, they have also exposed areas of need for future development. Presently, the variable profiling tool relies on a separate Arduino processor to control its external axis. The global positioning of the robot arm and the local movement of the sliding blades are synchronized manually, making it nearly impossible to cut multiple passes with the tool. Using an integrated controller activated within the robot's protocol would be more ideal. The development of an automated mixing and delivery method for wet plaster when profiling would also allow the tool to be operated more independently. Currently a dry run is

figure 19

Drawing of matching ruled surfaces through a single block.

figure 20

Wire saw cuts through a single semicured "green" block of plaster.

figure 21

Assembled plaster ruled surfaces.

figure 22

Drawing of material subtraction from water jet cutting through tool approach.

figure 23

Water jet movement on robotic arm.

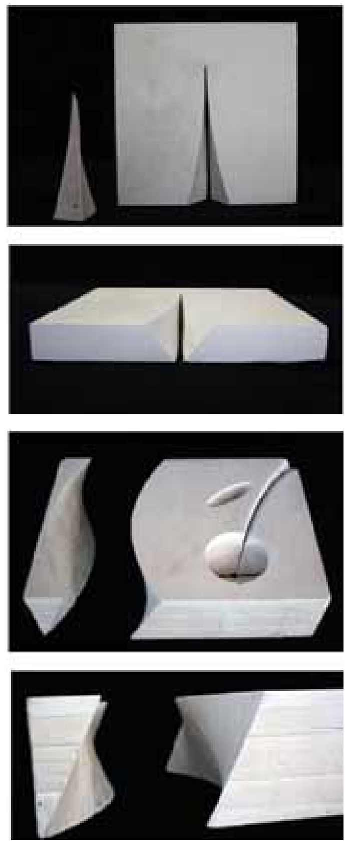

figure 24

figure 24
Sample water jet cuts through cured plaster block.

necessary to mark off the location of each variable profile. Plaster is then applied by hand in the marked off areas. Given the rapid onset of plaster's curing phase, there are significant technical challenges to fabricating such a delivery method. The research team has recently contacted United States Gypsum, which is interested in partnering to develop an automated delivery system.

6 TRANSITIVE SITES

Because architectural plaster is often applied in situ, envisioning digitally applied plaster encouraged rethinking the assumed contexts of off-site fabrication and on-site construction. Historically, the space of fabrication—for production—and the place of the architectural site—for installation—have evidenced competing logics, which most approaches to digital fabrication in architecture must mitigate. With the advent of robotic manufacturing in architectural design, the authors would like to conceptualize a third, transitive space for the production of architecture.

The promises of off-site fabrication (e.g., higher quality, increased efficiency, lower cost) often align with the logics of industrialized manufacturing and standardized building materials. The factory as a locus for these ambitions provides both a physical context for the efficient production of the architectural body and also an underlying framework influencing architectural ideation. The homogenizing tendencies of the factory environment—an engineered tabula rasa—encourage standardized components aligned to the legible measure of the factory (e.g., true, plumb, square...). Architects often struggle to resolve the conflicting spatial paradigms of the precise factory and irregular singularities of the construction site. Sites are seldom flat; lines are seldom straight; corners are seldom square. Filler strips, shims, and joints often negotiate the disparity in relative tolerance from the factory to realities in the field.

Digital fabrication suggests alternative inroads to the problems of homogenization and the disjoint between the spaces of on-site vs. off-site production. One already established theme is the ability of CNC machining to push standardized manufacturing toward customization at an architectural scale. While the promise of "mass customization" suggests one antidote to the ubiquitous industrial production of the built environment, many CNC machines actually reinforce the abstract datum of the factory through work cells sized to mass-produced sheet materials. The inherent dimensional limitations of these tools often trap designers in a translational loop between abstract, flattened cut sheets (sized to the work space of the CNC machine) and the tectonic assembly of the three-dimensional construct.

Robotic fabrication brings these constraints into clearer relief because the work cell of a robotic arm more closely approximates the 1:1 space of the architectural body. Thus a robot can work at the scale of and directly in the three-dimensional space of the architectural construct. Furthermore, robots are becoming increasingly portable and may both operate within the physical limits of the factory and in situ at the construction site. This possibility begins to bridge the divide between conflicting logics of fabrication and installation.

The possibility of robotically working in multiple sites relies on the transitive space of digital models in robotic tooling. While the robot functions in a physical context, it is programmed relative to the digital context of a constructed model. Models can contain multiple organizational structures (e.g., the limits of a machine, the work space of a factory, and elements in an architectural site). Furthermore, with advances in digital scanning, imaging, and surveying, digital models are increasingly adept at accounting for irregularities in site topography and organization, making it possible to translate the specificity of the architectural site into the fabrication environment of the robot.

In the case of Morphfaux a full-scale lath and plaster wall was designed for an off-site exhibition. The piece was simultaneously designed in the space of the robot (taking into account its dimensional limits and path of travel) and the space of the exhibit (adjusting for a sloping floor and irregular footprint). Detailed digital models were used to shape the lath wall to its multiple sites and to produce toolpaths to be followed by the robot in the space of the laboratory (Figure 25). These

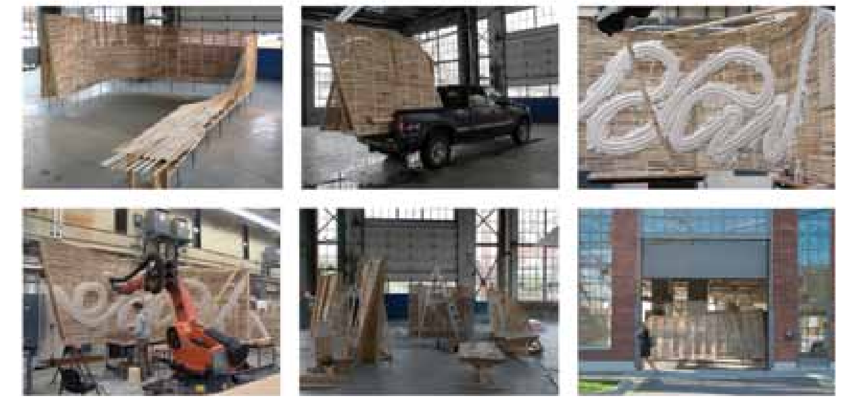

figure 25

figure 26

geographically distinct but logistically relevant spaces were combined in a digital context to create a synthetic site of design and fabrication without flattening the geometry to a series of cut sheets whose component parts would then be reassembled in the space of the final artifact. Instead plaster was applied directly in the three-dimensional orientation of the wall. Work at this scale required use of the robot's external axis, with a 50' track bisecting the workspace of the lab. This configuration proved viable during the research, but Morphfaux anticipates increased mobility in robotic fabrication where plaster could be applied on-site (Figure 26).

7 CONCLUSIONS

The challenges inherent to robotically shaping plaster present contemporary designers with much more than a series of obstacles to be overcome, and to a certain extent begin to address Santiago Perez's provocation in his essay "Towards an Ecology of Making": "How may we embody the role of (material) intentionality, resistance, play and skill, within digital/generative culture of (detached) CNC production? The development of 'functional Ecologies of Making' suggests a hybrid practice drawing from both traditional craft practices and advanced digital production as a means towards a synthesis

figure 25
Lath construct on site; being relocated to fabrication laboratory; plaster profile cut to take components apart for relocation back to site; components on site prior to reassembly and final site context.

figure 26
Kuka Pick-up, speculative montage of portable robotic tool visiting site.

figure 27

Final robotic plaster profile construct on site.

figure 27

of MAKER + MATERIAL in contemporary expanded practice" (Perez 2012). Attending to material constraints within this body of research has encouraged promising trajectories for architectural production. In particular, the research leveraged material feedback to inform the creation of variable robotic tools. Custom tools in turn provided a constellation of operations activated through the open-ended platform of robotic motion. Each operation required synchronization with the phase-changing properties of plaster as it transitioned from liquid to solid and relied on a multidimensional context where physical limits, durational constraints, and digital intelligence (from on-site singularities to tool geometry) were mapped into the procedural space of fabrication. While there are many topics worth further consideration and development relative to robotically applied plaster, the work also serves as an extendable model where new tools and machining operations can participate in the intelligent shaping of heterogeneous, synthetic materials (Figure 27).

REFERENCES

Carpo, M. (2011). The Alphabet and the Algorithm. Cambridge, MA: MIT Press.

De Landa, M. (2001). Philosophies of Design: The Case of Modeling Software. In Verb Processing, eds. J. Salazar et al. Barcelona: Actar.

Millar, W. (1899). Plaster Plain and Decorative: A Practical Treatise on the Art and Craft of Plastering and Moulding. London: B. T. Batsford.

Perez, S. (2012). Towards an Ecology of Making. In Matter: Material Processes in Architectural Production, eds. G. Borden and M. Merideth. London: Routledge.

Smith, C. (2002). The Plan of Chicago: Daniel Burnham and the Remaking of the American City. Chicago: University of Chicago Press.

Tubb, J. N. (1998). Canaanites. London: British Museum Press.

WORK IN PROGRESS

DIGITAL VERNACULAR

ABSTRACT

"In a computer-designed world the next logical step is to move straight from the digital models to 3D printed buildings" *(Kapoor 2009). In a computer-designed world "it is now possible to conceive customized prototypical architectures, which can be adaptable to differentiation with various inputs, distributed across global networks and for building in different parts of the world" (Malé-Alemany 2008). The research project Digital Vernacular has investigated the potential of using CNC technology for the production of housing, where the material system constantly feeds back into the loop with design systems. It has focused on the design of machinic devices as well as computational design tools, and revolves around the concept of fabrication on-site. Using an additive, layered manufacturing process and locally available material, the project proposes a revolutionary new digital design and fabrication system that is based on one of the oldest and most sustainable construction methods in the world. The main goal of this method is not to create complex forms for the sake of design, but to use parametric control to adapt each design to the specificities of its site. Guided by geometric rules found during many research experiments with real material behavior, a new architectural language is created that merges several environmental functionalities into a single integrated design.*

Shankara Kothapuram
Architectural Association—
Design Research Laboratory

Song Jiawei
Architectural Association—
Design Research Laboratory

Lin Mei-Ling
Architectural Association—
Design Research Laboratory

Ling Han
Architectural Association—
Design Research Laboratory