

Towards a Meaningful Usage of Digital CNC Tools

Within the field of large-scale landscape architecture

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Abstract. *The innovative and integrative use of digital CNC technologies in the field of landscape architecture is, for the most part, quite new when compared with the field of architecture. The following paper focuses on new techniques for visualizing work processes and developments for large-scale landscape designs. The integration of these processes within a teaching environment stands at the forefront. In this context, the use of programmed tools and the immediate translation of preliminary design ideas to models using the Mini Mill in the studio allow students to investigate and test new approaches. Next steps will be explored through the use of parametric design tools.*

Keywords. *Digital Aids to Design Creativity; Generative Design; Modes of Production; Shape Studies.*

Figure 1
Automated creation of a 3D landscape model using a combination of actual images, point cloud information, and milled model data.



Introduction

Landscape architecture is increasingly becoming a focus in international discourse on urban development phenomena. This is due to the fact that the focus of the work of landscape designers has recently shifted to large-scale urban spatial developments and their associated dynamic behavior in complex urban spatial situations. In order to properly deal with these tasks, design tools such as CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) technologies have been explored with in

experimental ways for the past five years at the Chair for Landscape Architecture of Professor Christophe Girot (ILA) at the Department of Architecture at the ETH Zurich. Within the framework of the design studio and in research studies in landscape architecture, the use of CNC (computer numerical controlled) technologies has proven to be an innovative supplement to the theoretical and practical debate on public space in the contemporary city. In comparison with architecture, where CAD/CAM technologies have been an integral component of teaching and research for some time, the work being conducted at the Chair has clearly taken a pioneer role.

Especially with the newly established visualization and modeling laboratory (LVML), the Chair offers an outstanding center of expertise within the fields of 'Landscape Visualization' and 'Landscape Modeling'. Under the patronage of the Chairs for Landscape Architecture (Ch. Girot, ILA) and Planning of Landscape and Urban Systems (A. Grêt-Regamey, IRL), a lab could be established that researches new methods for the depiction, modeling and visualization of large-scale landscapes. Here, various software and hardware solutions are combined experimentally: for example a 3D landscape scanner with 1 km range is being used in order to investigate new boundaries of perception and illustration of the built environment [1].

Professional partnerships to the developers of software and hardware solutions as well as experts in the areas of landscape and urban planning allow for hands-on examination and implementation in the various research areas.

Successful research projects in collaboration with city authorities clearly show the interest and the necessity for the implementation of these technologies. We are therefore in a position to critically reflect on the work done the past few years and define new concepts for teaching and research through acquired experience. The goal of this paper is illustrate the new orientation of application areas for CAD/CAM technologies and their associated potentials within teaching and research projects.

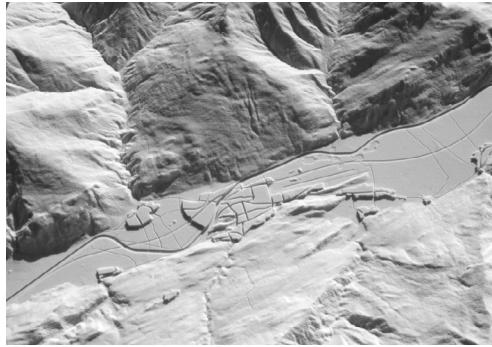
From Representation to Integration

Although CNC technologies originally were used primarily as representational tools, our current activities focus on how to use them as integrative ones. Especially in large-scale landscape architecture projects, there is a strong need to develop technologies during the design process, which already integrate digital machines as supportive tools at an early stage (Imperiale, 2000; Mertens, 2010). Our experiences have shown that the practical handling of CNC milling machines often requires considerable preparatory work, and the actual making of the model requires a lot of experience as well as time. As a result, we are beginning to integrate a mobile Mini Mill, which is both portable and requires less experience to operate. These portable CNC milling machines can be easily used in studio, at workshops, or at meetings with clients to explore new readings of landscape architectonic parameters and spatial concepts, as well as to sensitize perception. Moreover, we are developing a programmed tool in a research project, which generates simplified height data through an intuitive interface that can be directly exported to milling software as well as 3D visualization programs. Subsequently, individual technical elements are to be introduced in order to convey some insight into the overall complexity of the process.

CNC Landscape Modeling

Since the initial inclusion of CNC modeling in the landscape curriculum, the shift from sand-based models to digital models has paralleled a similar development in design process and workflow. The landscape model remains an evolving constant within this workflow, consisting simultaneously of existing site data, programmatic operations, spatial alterations, and various options and alternatives for any one moment in the design process (Bishop & Lange, 2005). The bridge between a rigorously scientific approach and a freedom of form and process is essential, enabling both feasible outcomes and unrestricted design opportunities.

Figure 2
Milled topographical model
with 1.2 million facets.



Of key importance is the interoperability with accurate site data (GIS layers, DTM, etc.) received from local authorities. These local partnerships facilitate close collaboration between students and clients, which, in turn, requires that the designs be evaluated on the basis of both atmospheric visualization and feasibility.

The process of landscape modeling is integrated into the overall 'digital chain', allowing a fluid exchange of data between different phases of the project and the generation of analytical drawings, such as plans, sections, and views. It is therefore possible to output any stage of the project into 3D form at any given time, either in studio via the Mini Mill, or the large-scale CNC router. In this scenario, the physical model becomes the verification tool, or a 'snapshot' in the design process. Working with the same

dataset from the initial intuition to the final model allows for a gradual build-up of the project within the overall development, each phase or version building on the previous one. Various project hypotheses can be explored and tested ('trial and error') and integrated within the overall design process without any loss and remain readily available to the designer.

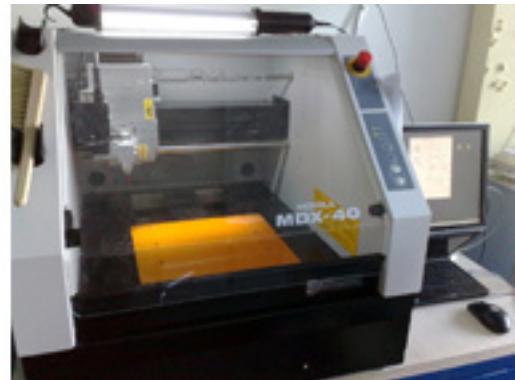
This ongoing body of work has allowed us to explore other facets of digital and manual design production: data acquisition and data output. The sculptural potential of sand models can supplement the data set through 3D scanning. In terms of communication and potential for both project and presentation, integration with Google Earth allows students to integrate and contextualize their designs at any stage of the design process.

Rapid Prototyping Working Environment

The Raplab

Raplab is a departmental group within the faculty of architecture providing access to a wide range of prototyping facilities, both to a large body of students as well as specialized users involved in research and teaching (Gershenfeld, 2008; Ramge, 2008; Sennett, 2008). It is part of Raplab's mission to continually search for new processes, reflect on current practice, and optimize access to new technologies, both

Figure 3
Portable Mini Mill



physically and intellectually [2].

Fabrication in your Studio, on Site... with the Mini Mill

Due to its mobility, the Mini Mill can easily be moved around the campus to studio spaces and presentation auditoriums. As the unit works relatively silently and the debris produced is contained within the unit, it can be safely operated in an office environment. The enclosed design ensures safe operation. The moderately sized working area of the unit (30x30x10cm) makes for fast processing of pieces and low material costs.

This thoughtful assembly of components is by no means a great scientific or artistic achievement in itself. It is however refreshing and exciting to observe how clever and user-oriented tools such as the mobile Mini Mill have liberated creative potential in technophiles and inexperienced users alike. When given easy access to equipment, users discover new aspects and inroads in their own work and very frequently produce stunning results, often surpassing the tutors' (and their own) expectations.

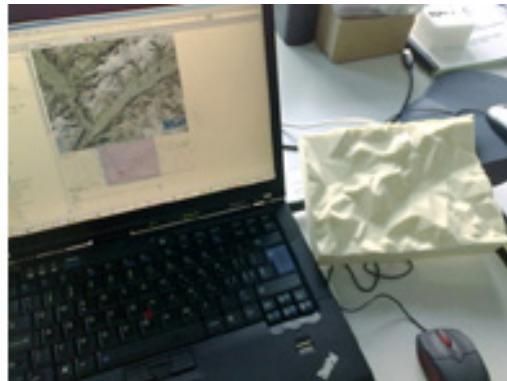
The Automated Generation of Height Data

In the early phases of many design projects, there is the necessity for quick and easy production of

physical models as a working base. A first glance at the project site can be taken using freely available geo-information services like Google Earth. How handy would it be now, to make a 3D screen shot of the perimeter as easy as a 2D screen shot using "PrtSc"?

The presented tool makes use of the possibility to include Google Earth as a plug-in in a website that can be run on a server and accessed from anywhere. Except for the browser plug-in, no further software needs to be purchased, installed, or learnt. The well-documented Google Earth API offers the possibility to add a lot of custom functionality to the geo-viewer. The handling and navigation is very easy, intuitive, and familiar to a lot of people, from professionals to amateurs. First, the user navigates to the desired location and zooms in to a representative scale. On the click of the mouse a function is called, that lays a grid of sample points over the visible area and measures the altitudes. These lines of height-information are translated in NC-code, instructions for a computer-numerically controlled 3-axis-mill, and written out in a text-document. This document can then directly be sent to the machine, without the need of creating a geometry, loading this geometry in a 3D-modeller, generating tool paths and only then post-processing them to a NC-code-file – the more conventional way of model production.

The interface is very simple and does not allow



*Figure 4
Interface: Translating altitude
values to machine code*

for too many user inputs. The visible area in the Google Earth window is automatically scaled to a standard material block size of the same aspect ratio. Also the density of sample points is predefined according to the diameter of the milling bit. This could very easily be extended to a much more detailed interface, enabling the user to change these settings.

Also possible is the translation of the array of height values to a 3D geometry file like for example the universal standard OBJ format.

Outlook

Workflow evolutions

At this moment we have been concentrating on setting up a workflow using the Mini Mill and the programmed height tool in the very beginning of the landscape design phase. This addresses an area traditionally neglected in landscape design, that of the generation and manipulation of the existing site data prior to design.

A great potential for the technique is in the pre-processing and preparation of the site data, at the onset of the design process. The site can be similarly processed in the manner in which design projects are directed and shaped by the design brief: a document that sets the goals, focus and limits of the design outcome. In practice, the site data can be re-engineered to display existing and potential activators, historic and topographical potential, as well as react directly to an applicable design brief.

The extrapolation of the potential of the Mini Mill lies more in the possibilities and applications of the models produced, rather than the development of the physical process of milling. The role of the Mini Mill within the design studio and office environment can expand in use over time, allowing not only design-testing through the process, but also enabling the generation of various scales of detailed models for focused problem resolution and concept generation.

Following our progress in the areas of data

acquisition, manipulation, prototyping, and the efficiency of data interoperability and communication between tools, we are now developing the landscape design process itself to take full advantage of these advances.

A boundary has typically existed within the field of landscape architecture between the education and the profession, often exaggerated by the oversimplification of landscape problems within schools for practical and logistical reasons (Hampe and Konsorski-Lang, 2010). The synthesis of processed datasets, based on accurate site data, and compatible with industry consultants and engineers own measurement systems, allows for enhanced industry interaction, and a true forum for comparison of actual and proposed landscape futures. The students are also empowered to refine their projects, where accuracy is of key importance.

High Resolution Laser Scanning

A potential currently under investigation lies in the integration of these techniques with current research and development in the LVML, specifically in techniques of long-range laser scanning and data manipulation. The inclusion of medium to long-range laser scanning technology within the design-modeling process facilitates high-resolution site data acquisition, integration, and adaptation. It also facilitates the selective supplementation of data, and resulting site-magnification at strategic design areas. Working with software enabled for high-density point-cloud manipulation enables the comparison, analysis, and refinement of extremely high-resolution models. This is not restricted, as is typical in such software, to past and contemporary sites as they exist but can easily be expanded to comparisons with future design models.

The possibilities of this technique have enabled simultaneously engineering decisions, succinct communication of complex site issues, and informed design decisions to be made. This also affords the designer the ability to record and reference subjective atmospheric impressions of landscape site with

objective, and quantifiable site data.

For each site, point cloud scans are taken to inform various aspects of topological detailing, insuring better coherence and connectivity to the outlying terrain. The challenge is often to reintegrate each project into surroundings with sensitive cultural, engineered or natural characteristics.

Advanced modeling and visualizing techniques are used at every stage of the design process and combined with on-site preparatory tests and recordings of the environmental impact of local seasonal variations. The adaptation of an artificial topology within its surroundings is where the extreme precision generated by point cloud scans becomes essential. The density of technical and visual information inside the point clouds allows for highly informed design decisions. Alternatively, the development of filters to deal with overly saturated datasets maintains an efficient workflow, and allows for efficient processes of data acquisition and design-use.

Through these processes, the material and physical reality of large-scale projects are rendered comprehensible and operable from within the design studio itself.

During the design and decision-making process, a multitude of possible physical, visual and natural aspects of the project can be scrutinized. The geo-referenced point cloud base also allows the



assemblage of landscape photographs, enabling a form of site viewing that relates back to the art of site panning, and form a visual history of the transformation of the site.

Strategically Parametric

The integration of such tools within a parametric workflow is the current priority, further supporting our aims of large-scale landscape design intervention and experimentation. The possibilities are clear for opening new fields of landscape research, where the research goals are open and evolving and landscape variables themselves are of an ever-changing nature.

In contrast, within a studio environment the applications for parametric workflows have proved different. Rather than aiming for a maximum of parametric variables, experience has demonstrated that it is on the contrary often beneficial to quantify only strategic variables or design criteria, in order to maximize the control the designer has over the outcomes, especially within condensed workshop and semester timeframes. For students, the learning process can be enriched through the resulting legibility of the direct implications of landscape design decisions, and the scale of their influence.

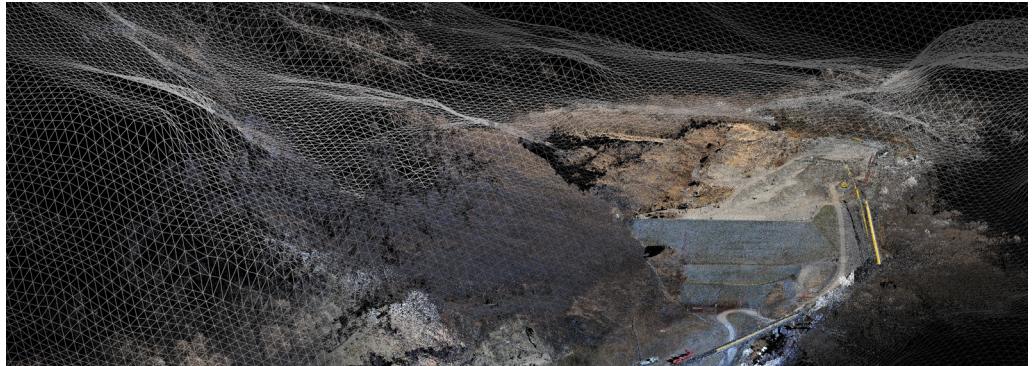
Rather than relying on a design process of random variations as often associated with parametric processes of design, controlled decision-making can lead to clear performance-oriented results. The resulting design operations are a hybrid between intuitive physical interventions and 'variable' manipulation, and are therefore conceived as 'directive' rather than 'prescriptive' in design outcome.

Practice of Landscape Architecture

The applications of this process have varied implications for landscape design education and the design practice. Within the design studio, the result potential is the focus and heightening of crucial factors to be addressed and design problems to be solved. This mode of working, which begins as directive and focused, brings the possibility to push the design

*Figure 5
Gathering data with a 3D
photographic laser scanner,
Ticino, CH.*

Figure 6
True-color 3D point cloud
model within a geo-referenced
site mesh.



project far further than is traditionally possible within the academic semester. The ability to represent and contrast landscape systems, both existing and potential, directly influences the design process, and tighten the iterations of decision-making.

The impacts for the profession of landscape architecture begin with multiple representations of site, to integrate the interests and focus of specialists and other involved stakeholders. Rather than oversimplifying landscape systems, these systems should be focused and magnified, drawing direct attention to design challenges and facilitating the comparison of landscape systems. As such, the systems should not only rely on a common base and reference, as GIS systems allow, but also effect and compare to one another in a non-destructive manner.

Swiss Futures

This potential can be clearly seen in a major contemporary design dilemma for the alpine valleys of Switzerland with its evolving hydrological system and the expanding needs of urban areas. The diverse perspectives and expertise of the engineers, local government, inhabitants and designers require new means of superposition and prioritization. This topic has grown to become the current academic and professional design focus of the landscape chair led by Prof. Christophe Girot and the LVML in the past decade.

The challenges with which we are now engaged

within the Landscape Visualization and Modeling Laboratory have already begun to influence both the techniques and design results of the current generation of Landscape students. When contrasted with a decade of student works, these first results are demonstrating the depth to which landscape design can be taught, and design processes activated, the results of which can soon influence the everyday practice of landscape architecture.

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