

Digital Tectonics, an Instrument for CNC Milling Efficiency and Experimentation

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Abstract

Since the practice of landscape architecture, designers and practitioners have always struggled acquiring the necessary and valuable height data or any other terrestrial information needed. This precise data set acquisition has evolved from commodity to absolute necessity especially in sites that are prone to flooding, where even centimeters of height difference can have a huge impact.

From the perspective of education, it is also vital that a studio can have any site as fast and as costless as possible in order to have a common base and point of reference for the students to work on. In this experimental study we have developed a digital tool, or instrument if you like, that can provide a point cloud of any site in the world with varying point density and precision. This is a standalone JavaScript program which extracts height information from the Google Earth data base and produces a parametrized list of points as well as the g-code that the CNC milling machine needs in order to automatically cut the predefined geometry with its parameters. The machine used for our research is ShopBot, currently in RapLab ETH Zurich, Chair of Prof. Girot. The code of this application is adapted for this specific machine.

1 Introduction, Technical Description

The overall aim of this paper is to describe and analyse how this new experimental tool works, as well as to showcase tests and examples of how it can be utilised for a design/planning base. We coined the term “Digital Tectonics” for this application and it shall be referred as such hence forward.

1.1 Technical features

We implement our digital instrument as an HTML file with embedded JavaScript code (CROCKFORD 2008). Using HTML and JavaScript allows the tool to be run on any modern Web browser (such as Firefox, Chrome, Safari, Internet Explorer, Opera and so on). An additional constraint is that we require the Google Earth browser plug-in to be installed before the tool can run. This plug-in is available for both Windows and Mac operating systems, and Google makes it freely downloadable from the Internet. If it is not already present, the user will be automatically prompted to download and install it, making our tool easy to use.

The input Data in this platform is the desired map area which the user selects as well as a series of parameters regarding the milling that will follow. Those are, Foam size X (in mm), Foam size Y (in mm), Foam Thickness (in mm), Milling step size (in mm), and Milling speed as you can see in Fig. 1.

They can choose between the two output formats (point cloud or NC file [also known as “G-code” for this machine (GREEN et al. 1996)] for the ShopBot mill) by clicking on the appropriate button. At this point our tool generates the desired textual output that the user can copy into a file of his choice.

We will now give a brief technical description of the implementation of the tool. It was intended to be modular and easy to both understand and, if necessary, change and extend. Given the user's selection and milling parameters, we first create a coordinate grid of appropriate density. The grid is represented as a JavaScript array of (x, y) coordinate pairs. At this point the x- and y- values are determined as follows. If one thinks of the coordinate grid as a matrix, the value of each x- and y- coordinate will be the matrix index of its point. I.e., the top left point of the grid will have the coordinates (0, 0), the one right of it the coordinates (0, 1), and the one below it the coordinates (1, 0). Since the coordinates are kept in an array, they are ordered. We use this ordering to determine the milling "strategy": we will mill each point in the grid in the order it appears in the array. The order (and thus strategy) we choose is simple: we go through the grid in a row-by-row fashion, alternating the direction in each row.

After this, the rest of the program is simply a series of point-wise transformations of the array representing the grid (GERSHENFELD 2008). We do three transformations. First, we obtain an array of altitudes (in meters), by projecting each grid point onto the user's selection and querying the Google Earth plugin for the corresponding altitude. Second, we then further transform the resulting altitudes array to obtain an array of corresponding drill z- coordinates (by scaling and negating each altitude value). Third, we obtain an array of mill x- and y- coordinates, by project the grid points onto user defined milling area. Lastly, we simply combine the array of (x, y) coordinates with the one of z- coordinates, yielding a new array that contains all the necessary coordinate information for drilling (SMID 2010).

Having obtained these coordinates, all that is left is to present them in a format appropriate for the intended usage, i.e. milling or point-cloud export. This includes formatting each coordinate appropriately, and adding some headers or footers if necessary (e.g. to adjust some parameters of the milling process). Since the tool is modular, we envision that it can easily be adjusted to work with other models of CNC machines as well, by simply changing the headers, footers, and the coordinate formatting operation.

The tool also does some basic safety checks at the moment, by making sure that we do not try to mill through the table (that could happen when trying to mill a topography such as the one of Matterhorn, while using a large, but thin piece of foam). However, the tool currently makes no considerations of the material used for milling, and will happily instruct the machine to drill very deep, which can potentially be hazardous (SMID 2010). A desirable extension of our work would be to add automatic support for roughing.

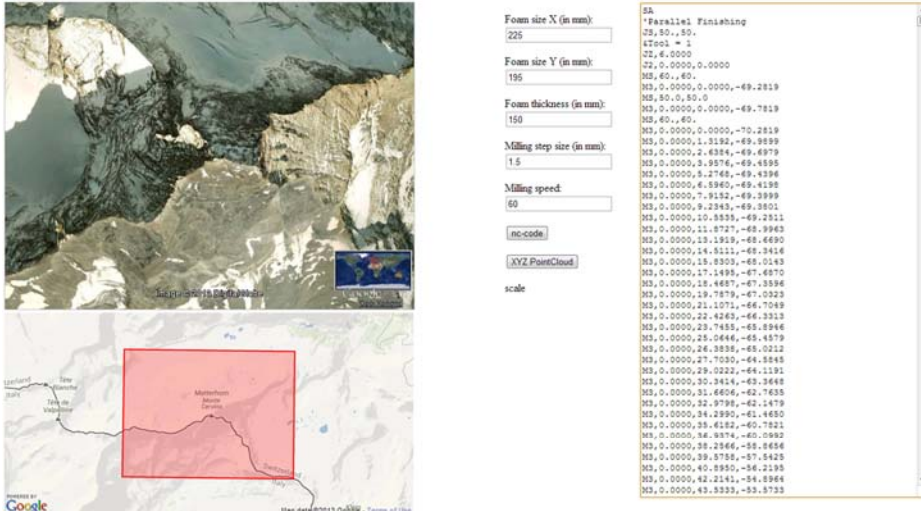


Fig. 1: Digital Tectonics Interface (source: Georgios ORFANOPOULOS)

An important feature in this tool that we have developed, is the ability to select a region and instantly mill it, thus avoiding and bypassing the 3D CAD-CAAM programs that are otherwise used to produce the code. This was tested as an individual research project at ETH, ILA with exciting results and it could be a way to have quick draft landscape models instead of first sketches and images. Students can benefit from this as it can be a fast way to preview the site and work on it. Traditionally, in landscape design people start from plans and sections and may end up in a three dimensional outcome, usually a model. Lately, the 3D software development is reaching towards landscape practices with promising future results (BISHOP & LANGE 2005). With the Digital Tectonics tool we target towards an opposite workflow, first having the 3D of any site and then working on it with any means, even with an analogue way and then 3D scanned. The change in technique can convey also a difference in methodology and capabilities (MAAS 1998). This is the main contribution that the Digital Tectonics, and its further versions, can make for the practice.

2 From Digital Development to Analogue Praxis

2.1 Testing, Experimenting

The tests that were carried out in the ETH premises showed varying results that are influenced by different input data as well as the usual material parameters. For example, foam or wood's quality, Mill's quality, milling speed etc.

Matterhorn was chosen as the test site for D.T. in Switzerland as you can see in Fig. 2 and Fig. 3, with varying definition. For example, in Fig. 2 we used a very low grid density (on the left) and large scale. The Matterhorn is merely visible in the middle of this small model whereas in the right side of Fig. 2 we have the same scale but a denser grid so you can

already recognise some basic landscape features (ridges, mountains, valleys). Continuing this process of zooming in and increasing the point density brings us to a much more clear result, as seen in Fig. 3, where we now completely recognize Matterhorn with a much better definition.

Imagine that the task given is to design a mountain path, or to design anti avalanche infrastructure, or even a mountain chalet, then the model of Fig. 3 is already a very quick and suitable base to start with. If the designer then needs to go further in detail and precision, it's also possible, you would just have to rerun the D.T. and redefine the equivalent parameters (size, step size) and then you can sculpt, or engrave, or design as you would in any other model.



Fig. 2: Matterhorn, first tests: Different stepsize and precision (source: GEORGIOS ORFANOPOULOS)



Fig. 3: Matterhorn, larger scale, larger precision (source: GEORGIOS ORFANOPOULOS)

The added parameters give more versatility and flexibility in the use of this terrestrial instrument. For example, one can take advantage of the varying definition and precision of the data set deriving from Google Earth and create really abstract or rather precise models (around 10 m definition, depending on the site). So, this fact combined with the scale of the work within the domain of landscape architecture, leads to an easily transformable and yet palpable outcome. This ability and flexibility stems from the custom tool making logic which is arguably the future in our practices. Specific tools developed for specific needs, created by each practice or university, with control and use of as much open source programs as possible (SENNETT 2008).

The user of D.T. can choose how dense he needs the grid to be and then how much one dimension of the cut material (“traditionally” styrofoam) should be and then the software scales the model and checks if the z height of your outcome model is adequate, otherwise it gives a warning message in order to avoid cutting the surface of the mill.

As we saw in Fig. 1, the interface is very user friendly and any student could immediately use it and start his project. What is more, in our century of technology and customization, the new generation are more and more trained and accustomed to programming, so that every student could alter the program itself (HELFT 2007). In Fig. 4 we see the equivalent 3D model with the same selection and density parameters as the one milled in Fig. 3.

The medium also influences the methodology and the workflow, which influence the conception and production of space itself. One could say that we reach the same goals by discrepant means and the contemporary means that are now implemented in landscape architecture are more compatible with each other, digital meets digital in a sense (ARANDA & LASCH 2006).

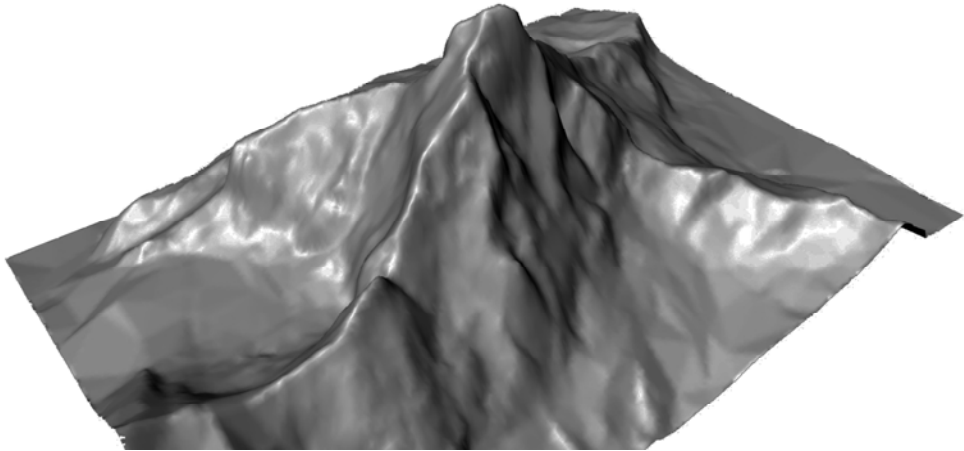


Fig. 4: The 3D model of Matterhorn, obtained through the pointcloud from the Digital Tectonics application (source: Georgios ORFANOPOULOS)

2.2 Speed, Efficiency, Cost

The speed of milling through D.T. is unquestionably an asset of the tool as you can bypass the intermediate steps of 3D software that are traditionally needed, as well as extra software to export the G-code in compatible machine language. So, within minutes of selecting the desired area to be milled along with its parameters, you can produce the G-code and directly cut your model in the CNC mill. Time saved makes it extremely efficient for a starting site model (lesser definition chosen for example) and even precise enough for further steps of your project.

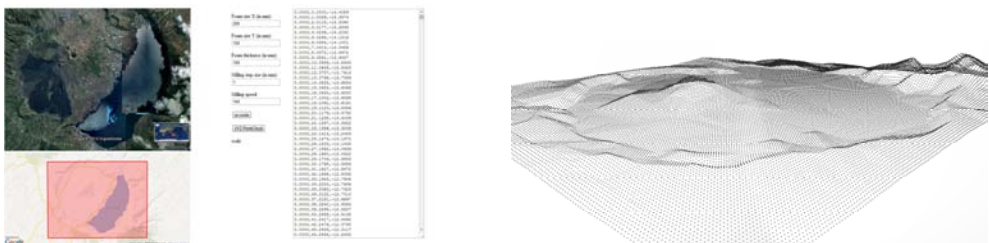


Fig. 5: Test of D.T. in Danau Batur, Indonesia (source: Georgios ORFANOPOULOS)

The cost remains the same as far as materials are concerned but you avoid using any 3D software as well as the expensive extra software that exports the G-code originally thus making the process much cheaper. The only thing one needs is a CNC mill but for now it is mainly for educational and research purposes. Those machines become cheaper and easier to get and have already started appearing in practices which make the development and use of such tools highly valued as it intervened with the overall workflow within projects in such firms. Notable examples are Herzog & De Meuron as well as Foster & Partners and in the future as this technology will get cheaper, more smaller practices could start using such tools so those research instruments and “digital shortcuts” could serve greatly in each case.

In Fig. 5 and Fig. 6 we can see how we obtain a pointcloud through the D.T. and transform it into a working surface. That can be done through any software that has a Delaunay triangulation, in our example we used the parametric Grasshopper tool, a plugin for Rhino. So, in this case, D.T. is used as a mean to get the digital geometry (instead of the milled, analogue one) and instantly convert it to a surface that can be worked on in an also conventional 3D manner.

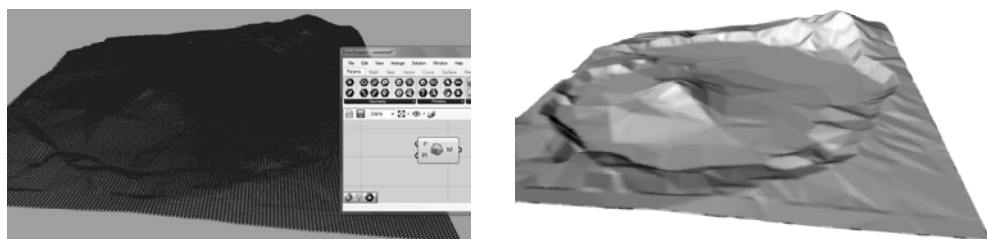


Fig. 6: Further processing of the pointcloud: Delaunay Meshing (source: Georgios ORFANOPOULOS)

3 Utilization in Education, Utilization as a Research / Application Instrument

As implied above, with the special scaling and parametric control features, the D.T. can be useful as a template for further testing and development by students as well as actually used for their projects. We can distinguish a direct and an indirect use for educational purposes.

The indirect is using it as a platform for further digital / analogue research which also adds to the open source community as everything used for it is free and available for use (JavaScript, any kind of browser).

From the perspective of direct application in education, it is also vital that a studio can have any site as fast and as costless as possible in order to have a common base and point of reference for the students to work on. So, towards this direction, a student can mill directly and really fast, his project site from the first day of his studio. Combining varying density and precision (always with the maximum that the Google Data Set can provide), the student can range from relatively abstract large scale “landscape 3D sketches” for the initial conception part of the project to precise models of intermediate and smaller scales for the later stages of the project. This can enhance the flexibility of changing scales while always

remaining in actual 3D environment, features that add to the deeper understanding and grasping of the site.

The D.T. instrument is an attempt to strengthen the Digital / Analogue interplay within spatial education (architecture, urbanism, landscape architecture) while making it as easy and as fast as possible (IMPERIALE 2000). A usual setback when fusing digital / analogue techniques is data conversion and long, complicated workflows.

With the aid of D.T., a large scale design office or university studio, can produce models faster. Faster production means more design/analysis options and better design comparisons which (“trial and error” logic within the design synthesis) eventually leads to a better outcome. Also, an important aspect of this approach (“the more the merrier”) is that you gain time that can be spent in the design decisions and the project itself. Nowadays, images are inevitably more and more used in the design process and production, whereas models have lost their grandeur. This tool experimentation is an attempt to bring back the lost materiality of models and can complement a methodology of working which evaluates tested, real 3D results. Trial and error becomes more efficient and analogue, thus helping the design process.

4 Conclusions: Limitations and Future Development

The main limitation of D.T. is the fact that it is, for now, Google Earth dependent thus maximizing the pointcloud density to roughly 10 m per point. So, it is much more effective and applicable with large scale and vast height differences in mind. The crucial fact that one needs a CNC mill to make full use of D.T. limits its use to Institutions, Universities and big practices, something that can change with time and lesser future costs of CNC technology. One can purchase a CNC mill even today with much less than 10,000\$, cost similar with a large plotter which is found in every office.

Future development can include a live scale tools that defines the current scale at any point when selecting the area for analysis.

Other possible features are the following:

- Adaptation of the code in order to work for any kind of milling machine (they use g-code and read similar text formats)
- Addition of different milling operations, such as Horizontal Roughing, Spiral Machining etc as well as the option to have an upcut or a conventional cutting pattern.
- Use of given precise data set, other than Google’s.
- Optimization tools, for example a tool to calculate the shortest path in order to cut through a selected area (potential for large scale crops farming, reaping).

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