Geodesign meets Diggers and Dozers – Who is Afraid of Triangles?

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Abstract

Today, the usage of 3D Global Navigation Satellite System (GNSS) machine control technology is mandatory in Austria, Germany, and Switzerland on larger construction sites such as roads, parking spaces, and golf courses. More and more small diggers and dozers are equipped with 3D GNSS machine control systems. These machines work on construction sites that are typical for landscape architecture. Therefore, landscape architects need to be familiar with the technology and have to know how to prepare the TIN (Triangulated Irregular Network) data for 3D GNSS diggers and dozers.

1 Introduction

How do 3D GNSS machine control systems work? In addition to electronic control equipment installed in the machine, a reference station (the base station) and a mobile receiver (the rover) are required. Two sets of data are received, and an exact location is established with real-time calculation. Even free, natural-style site grading, common in landscape architecture, can be implemented with high accuracy using 3D GNSS machine control systems. The grading can be either fully automatic or manual. The construction crew now needs only a half an hour for labor that previously required three people for an entire day. Staking out work is completely redundant.

2 Problem

Nevertheless, the accuracy of the input data is absolutely crucial, because any calculation errors in the data set will also automatically be implemented. This shifts responsibility from the contractor to the planner, and, hence, extreme care must be taken with the data. The 3D machine control system ensures a precise implementation of the planning data. The construction company's surveyor transfers the data on site to the digger or dozer's control box via a USB stick. Any staking with pegs is unnecessary, however, the accuracy of the output data is essential. The machine will adjust immediately to the given data. Each calculation error in the data is converted, which, as mentioned above, shifts the responsibilities from the contractor to the planner. Digital grading needs to be given much more attention, because the machine implements the data on site, one-to-one. Unfortunately, many landscape architecture offices are hesitant to develop the DTM themselves, and consequently

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hire a surveyor. One example is the Glattpark project near Zurich, which was built with 3D GNSS machine control system. However, the landscape architects did not deliver the data directly; they hired a surveying company. This was understandable, considering the newness of the technology and the project dimensions. Yet, landscape architects only require some basic knowledge, to confidently provide precise and correct data directly to the site.

3 Recommendations

A group of building contractors, civil engineers, landscape architects, as well as the producer of a 3D machine control system met last year in Germany and put together a list of recommendations, regarding how to prepare a DTM for efficient use in the new 3D construction process. Here are some of the recommendations:

Site Surveys / Basic Data

The basic data should not originate from scanned or traced contour lines. The calculation of the position and elevations should be accurate within approximately two centimetres. The surveys consist primarily of breaklines and survey points. It makes sense to hire a surveyor for this work to assure high accuracy.

The DTM has to be in the national coordinate system. If the breaklines are visible as lines, the serve for better navigation on the screen in the digger or bulldozer. Other basic data from the official cadastral survey, such as buildings or land boundaries, vegetation and existing pipelines also help with navigation in the machine. Always put the triangles on one layer and other information on a separate layer.

Interchange Format

The interchange format between the CAD system and the machine is the non-proprietary LandXML (<landxml.org>). Most software providers support the 3D data format.

DTM "Surface"

Only an absolutely precise DTM will give the necessary data acuity. A fine triangulation is essential, in particular when working on a road project. The TIN must be very fine for slopes changes, and other areas with large gradient changes, such as ramps.

DTM "Subgrade"

The subgrade is the interface between the soil and structure. Since the slopes of the subgrade are often not parallel to the surface, a DTM grading "subgrade" has to be created.

Curbs

Curbs must be displayed just slightly slanted, otherwise the 3D machine control system cannot clearly distinguish whether the elevation belongs to the top or the bottom edge. Sometimes it is advisable to refrain entirely from displaying curbs in the DTM.

Road Projects

For the construction of new roads or parking spaces, the DTM “subgrade” is really the most essential. The additional layers on top of the subgrade are then built upon this DTM data. Edges are usually staked out with surveying equipment and constructed.

In new road construction where the curbs are installed first, it is absolutely imperative that their elevation is precise, since the elevation of the subgrade and other layers are then fitted according to the DTM data. Logically, the curbs are also staked out on the DTM elevation.

Engineering Structures

In engineering structures, surfaces from the bottom of strip or single foundations are processed as terrain models. The slope angle can be established by the machine operator.

Pipelines

A 3D polyline (water run) is defined as a rule for trenches of sewer and utility pipelines. Standard machine control can excavate the pipeline according to the lines.

Most important: A consultation with the contractor before creating the DTM is always recommended. A contractor experienced in 3D GNSS machine control systems made this very true statement: “Slow down, know your site, know your data”.

Assuming that construction site logistics run smoothly, 3D machine control can reduce costs of up to fifteen or twenty percent. Moreover, the increased efficiency means that high acquisition costs are amortized in a short period of time. These cost savings are a great benefit to the construction company.

Creating a DTM based project is, however, more complicated than creating a project with 2D CAD plans. But even here, costs can be saved in the long run, because changes are easier to implement, higher accuracy is assured, and errors are more quickly identified. These cost savings in turn benefit the design office. So the argument that only the construction company profits from this technology is not applicable. The use of DTM and 3D machine control systems is a win-win situation for both the construction company and the design office. How this new process influences design is an interesting topic, which will need more research as soon as more offices begin using the above workflow.

4 Projects

Schrode GmbH Tief- und Straßenbau, Hayingen, Germany already implemented various Landscape Architecture projects with their own 3D GNSS machine control technology. Several construction projects are presented.

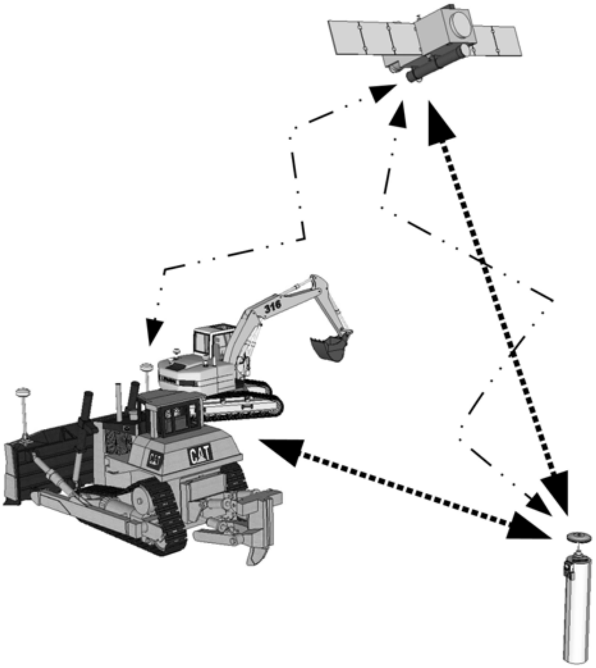

Fig. 1: A reference station (the base station) and a mobile receiver (rover) on the construction machine are required. Two sets of data are received. The exact location of the digger or dozer is established with real-time calculation based on the two data sets.

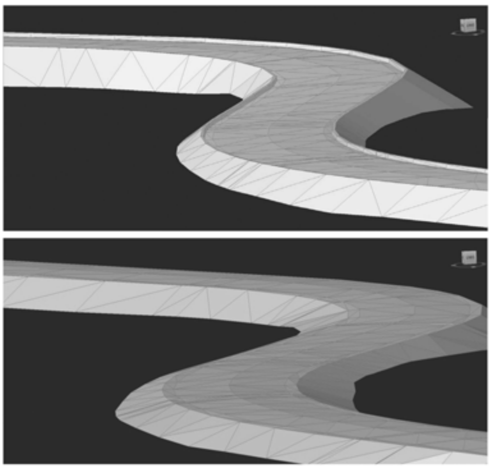

Fig. 2:
DTM "Surface" with curbs included (top image) and DTM "Subgrade" (bottom image). Most times the DTM "Subgrade" is used in road constructions.

Fig. 3: 3D GNSS machine control system installed on a digger is used at a Landscape Architecture construction site (Zoo Zurich, the new elephant area, October, 2013).

References

PETSCHEK, P. (2014), GRADING. Birkhäuser, Basel (print and enhanced e-book version).