

MODERN TECHNOLOGY FOR LAND LEVELLING, BASED ON A 3D SCANNER

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Abstract: Soil levelling becomes of high importance, in modern and intensive agriculture conditions. Its effects are found in providing optimal and equal conditions to the crops, during yielding and growing. In areas with water excess, the soil levelling provides an appropriate water runoff, ensuring a better water management. The levelling works design is based on land surveying performed for surface units (parcels) which are going to be ameliorated. Based on the survey plans, the following issues are settled: - the alignments which need levelling and the necessary optimal slopes from the efficient runoff point of view; - the areas of digging/filling, depending on optimal slopes, to minimize the volume and transport distance of the ground. The calculations are performed using "Least-squares method" or other approximate methods. Unfortunately, the use of these methods needs long time and their accuracy and effectiveness are limited. The paper presents a more effective technology to carry out levelling works, which is based on the newest technology used in environmental engineering. The method is tested in Land Reclamation and Environmental Engineering Faculty, in Bucharest and consists in using the following 3 elements of high novelty: - replacement of the classical survey with modern scanning methods using LASER technology devices; - use of modern GIS applications, developed by ESRI International, for data processing, combined with efficient CAD applications, developed by Autodesk Inc., world widely utilized; - generation of a 3D model, based on the information collected and processed in accordance with the above mentioned steps. The model is then sent to dirt mover machine, by the aid of an operating device, using LASER technology. This way, the ground work machine can model the land with high accuracy, low costs and minimum fuel consumption.

Key words: LASER, scanner 3D, land levelling

INTRODUCTION

Water is a precious resource for agriculture. That's why more and more producers are turning to precision land-leveling to help preserve and expand their water resources. Effective land levelling optimizes water-use, improves crop establishment, reduces the irrigation time and the effort required to manage the crop. It reduces the work in crop establishment and crop management, and increases the yield and product quality. In areas with water excess, the soil levelling provides an appropriate water runoff, ensuring a better water management.

There are perhaps two land levelling philosophies:

- to provide a slope which fits a water supply;
- to level the field to its best condition with minimal earth movement and then vary

the water supply for the field condition.

The levelling works design is based on land surveying performed for surface units (parcels) which are going to be ameliorated. Traditional engineering practice involves placing a reference grid on the field, surveying the existing topography of the field by establishing the elevations of the grid points, and calculating the new field topography by adjusting the grid elevations to correspond to the desirable plane [1], [2].

Land levelling design methods are the following:

- Plane method - is a simple least squares method or linear regression fit of field elevations to a two-dimensional plane;

- Profile method - Essentially it consists of a trial and error method of adjusting grades

on plotted profiles until the levelling criteria are met with and the earthwork balance is attained.

- Plan inspection method - The grid point elevations are noted on the plan, and the design grade elevations are determined by inspection after the careful study of the topography. It is largely a trial and error procedure. In selecting the elevations formation level the designer must simultaneously consider the down field slope, cross slope, earth work balance and haul distance. The desired cut fill ratio and volumes of earthwork are estimated from the summation of cuts and fills. The grades are frequently adjusted to obtain favorable earthwork balance and to maintain the down field and cross slopes within safe limits.

- Contour adjustment method - The contour adjustment method of land levelling designs consists of trial and error adjustments of the contour lines on a plan map. The method is specially adapted to the smoothening of steep lands that have to be irrigated. A contour map is drawn and the proposed ground surface is shown on the same map by drawing new contour lines. The uniformity of downfield slope is controlled by the uniformity of the horizontal spacing between contours, and the cross slopes can be examined by scaling the distance between contours at right angles.

Unfortunately, the use of these methods needs long time and their accuracy and effectiveness are limited. Once the surface design has been determined, a land levelling operation begins. This is typically a private contractor utilizing his equipment to move the earth into the new position on the field, and the adequacy of the land levelling is dependent on the skill of the equipment operator.

The paper presents a more effective technology to carry out levelling works, which is based on the newest technology used in environmental engineering. The method is tested in Land Reclamation and Environmental Engineering Faculty, in Bucharest [3].

MATERIAL AND METHODS

The new technology consists in using the following 3 elements of high novelty [4]:

- replacement of the classical survey with modern scanning methods using LASER technology devices;

- use of modern GIS applications, developed by ESRI International, for data processing, combined with efficient CAD applications, developed by Autodesk Inc., world widely utilized;

- generation of a 3D model, based on the information collected and processed in accordance with the above mentioned steps.

- laser land leveling according to the generated 3D model, by the aid of a laser guided system mounted on scrapers.

Laser scan station (figure 1)

The laser scan station main features are: [4]

- measuring horizontal and vertical angles.
- measuring distances.
- recording measurements.
- computing by means of software.
- target search, recognition.

- visualizing the aiming direction and vertical axis.
- remote control of surveying products.
- data communication with external appliances

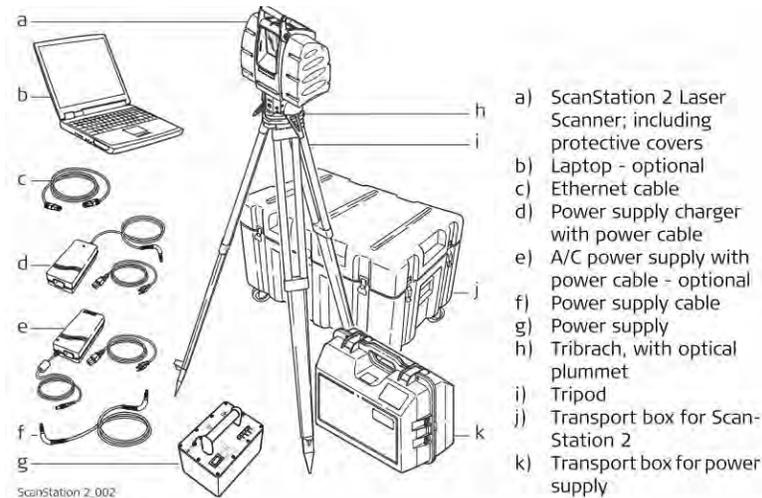


Figure 1: Laser scan station

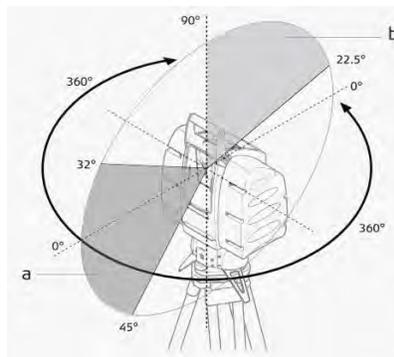


Figure 2: Scanner window system

The scanning principle consists in selecting a scanning region that uses both the main and upper windows, the instrument automatically goes through the following steps (as an example a vertical extent of -20 to 50 degrees – figure 2):

1. The instrument starts scanning using the main window and scans from -20 to 32 degrees.
2. It then makes a 180 degrees horizontal rotation.
3. It finishes the scan (32 to 50 degrees) using the upper window.

The general technical data of the instrument are:

- pulsed, dual-axis compensated, high-speed laser scanner, with survey-grade accuracy, range, and field-of-view;
- notebook or tablet PC as user interface;

- servo motor as scanner drive;
- integrated high-resolution digital camera.

The scanner software modules (HDS Cyclone) provide point cloud users with the widest set of work process options for 3D laser scanning projects in engineering, surveying, construction and related applications [4]. The software consists of four packages:

- Cyclone-Scan: allows the user to control the Scanner
- Cyclone-Register: allows the user to register multiple Scans together or to Geo-reference the point cloud
- Cyclone-Survey: gives the user basic functionality to extract and measure information out of the rich point cloud
- Cyclone-Model: gives the user the full functionality of Cyclone. The user is able to extract and measure features and to create a 3D Model out of the PointCloud.

Data processing using scanner output and GIS applications, combined with efficient CAD applications

AutoCAD® Civil 3D® software provides a range of features that help engineering project teams complete land development and environmental projects faster and with improved accuracy [5].

With respect to survey activities connected to land leveling, AutoCAD® Civil 3D® software perform the following operations:

- uses coordinate geometry (COGO) to create, import, and manage planimetric data. In addition, transparent commands give the flexibility to create more accurate objects from coordinate geometry.
- makes coordinate system transformations, converting local northing and easting to defined coordinate systems; it uses sea-level scale factors and grid scale factors to more quickly and easily transform local coordinates to projected coordinate systems;
- has extended properties for survey data, allowing surveyors to collect multiple elevations for a single point instead of the usual one elevation per location.
- Harness the power of points and manage them by using description keys, styles, and point groups.
- Set Coordinate Systems, working with more than 4,000 real-world coordinate systems to more accurately geo-reference your AutoCAD Civil 3D design data.
- Supports GPS Machine Control by exporting design models with LandXML.

3D model generation

AutoCAD® Civil 3D® software with its built-in tools for 3D model generation, quantity takeoff, and 3D visualization, helps engineers to analyze what-if scenarios and optimize land levelling project performance [5].

The steps to follow in order to generate a 3D model and to design the land leveling and are:

- pull in aerial imagery and terrain models delivered by the laser scan station, importing surveying information data, making least-squares adjustment, editing of survey observations, and automated creating the survey figures and surfaces. Most important, the result—points, survey figures, and surfaces—can be used throughout the design process.
- build surfaces from traditional survey data, such as points and breaklines. Utilize large data sets from aerial photogrammetry, and digital elevation models by taking advantage of the surface reduction tools; view the surface as contours or triangles, or create powerful elevation and slope banding analysis. Use surfaces as a reference for creating profiles, sections, grading plans, maintaining dynamic relationships to source data;

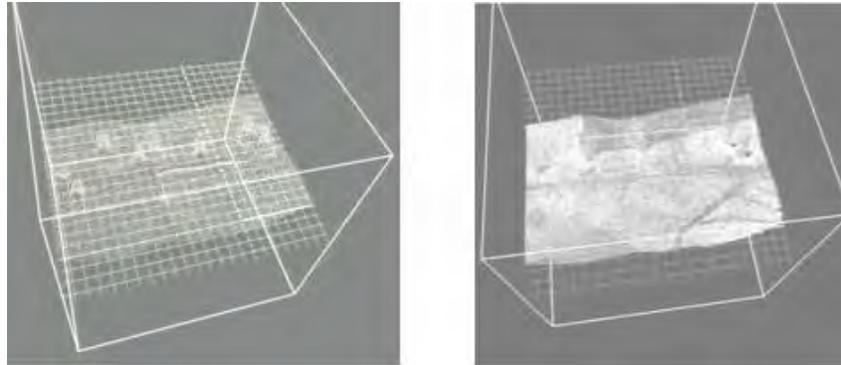


Figure 3: Building surfaces in AutoCAD Civil 3D

- generate parcels by converting existing AutoCAD ® entities or by using flexible layout tools to automate the process. The software uses a topology to manage parcels so that a change to one parcel is automatically reflected in neighboring parcels. Advanced layout tools include options for measuring frontage at an offset and laying out parcels by minimum depth and width.
- perform earthwork calculations processing earth volumes between the existing and proposed surfaces using composite volume or average end area methods; it generates mass haul diagrams for analyzing the distance over which cut and fill can balance, the amount of material to be moved, the direction of movement, and the identification of borrow pits and dump sites.
- make quantity takeoff analysis, run reports, or utilize built-in pay item lists to generate bid-ready contract documents. Make better decisions about the cost of the project earlier in the design process with accurate quantity takeoff tools.

Laser land levelling

Laser leveling is a process of smoothening the land surface (± 2 cm) from its average elevation using laser equipped drag buckets to achieve precision in land leveling. Precision land leveling involves altering the fields in such a way as to create a constant slope of 0 to 0.2%. This practice makes use of large horsepower tractors and soil movers that are equipped with global positioning systems (GPS) and/or laser-guided instrumentation so that the soil can be moved either by cutting or filling to create the desired slope/level [6]. The principle of laser land leveling is shown in figure 4.

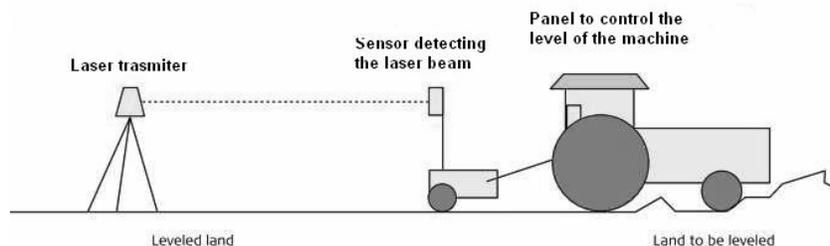


Figure 4: Laser land levelling process

The laser leveler involves the use of laser (transmitter), that emits a rapidly rotating beam parallel to the required field plane, which is picked up by a sensor (receiving unit) fitted to a tractor towards the scraper unit. The signal received is converted into cut and fill level adjustment and the corresponding changes in the scraper level are carried out automatically by a hydraulic control system. The scraper guidance is fully automatic; the elements of operator error are removed allowing consistently accurate land leveling. The set-up consists of two units. The Laser transmitter is mounted on a high platform. It rapidly rotates, sending the laser light in a circle like a lighthouse except that the light is a laser, so it remains in a very narrow beam. The mounting has an automatic leveler built into it, so when it's set to all zeros, the laser's circle of light is perfectly levelled.

RESULTS AND DISCUSSIONS

The method is tested in Land Reclamation and Environmental Engineering Faculty, Bucharest, in the frame of the project "Modernization of the GIS Laboratory for high resolution spatial data integration and processing – LABGIS" [3].



Figure 5: GIS Laboratory

The Laboratory is equipped with a laser scanner 3D - HDS Leica Geosystems consisting in a laser scanner, a laptop and the corresponding software for scanning, transfer and data processing. The system captures in 3D the surface geometry, structures and sites. The complete scanning process is captured as dense and precise 3D points, called "point clouds" which form the digital image.



Figure 6: Laser Scanner 3D - HDS Leica Geosystems

The software for 3D Point Clouds processing is structured in modules which provide to the users the most complex set of data to perform designs, engineering applications and survey plans. The information management structure of the software for 3D Point Clouds processing is represented by an architecture Object Database Client/Server type, which assures a performant environment, eliminating the need to copy and 3D point clouds large files [3]. The software modules are:

- interface and operating software of the scanner;
- software for the complete set of commands and options for the registration of point clouds resulted from the scanning process;
- software for 3D Point Clouds processing in order to generate 3D CAD models which need to be exported into CAD software to be integrated into the designs;
- software for 3D Point Clouds view;
- software for networks to allow data to be accessed by more users;
- software for AutoCAD users allowing to work with slices;
- tool for bidirectional data transfer between modules Cyclone software and AutoCAD

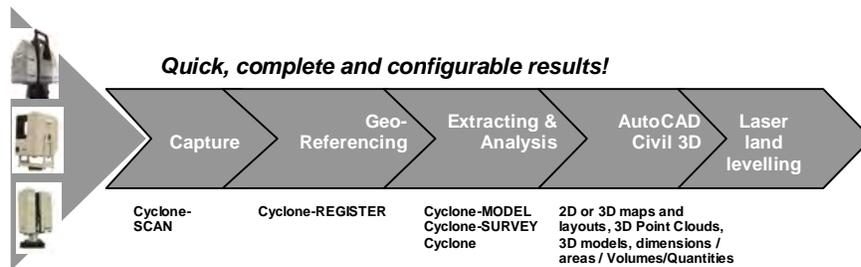


Figure 7: Land levelling modern technology chart

CONCLUSIONS

The presented new technology has the following advantages:

- low operation costs for survey measurements;
- higher safety for people performing the measurements;
- reduction or elimination of the cases when is necessary to redo the measurements;
- high accuracy in real situation capturing on site;
- shorter time and low costs to achieve the design;
- high quality results;
- the obtained information and the resulted 3D models can be utilize by more users, improving the project management;
- earthwork calculations processing earth volumes between the existing and proposed surfaces;
- better decisions about the cost of the project earlier in the design process with accurate quantity takeoff analysis
- higher accuracy in land levelling.

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