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DiNi 10®T - the First Digital Total Level Station

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The various discussions with users during the successful launching of the DiNi 10 stimulated Carl Zeiss into providing this digital level with a digitally readable horizontal circle. The resulting DiNi 10T, first presented in public at the "Intergeo" Surveyors' Meeting in Dortmund, 1995, is the first instrument on the market to combine the functions of a digital level and a total station.

Many surveying assignments consist in three-dimensional point observations to an accuracy that a total levelling station such as the DiNi 10T can positively satisfy. The point accuracies (standard deviations) of $s_p = \pm 0.10$ m and $s_p = \pm 0.30$ m at target distances up to 100 or 120 m, achieved with stadia diagram tacheometers and classical levels, respectively, are cases in point. These instruments have over many decades been used for tacheometric surveys (especially in flat terrain) and for longitudinal and cross sections - jobs that the DiNi 10T can now perform with considerably greater productivity, to higher accuracy and with the possibility of automatic data processing. In other words, the digital level has been advanced into a universally applicable total level station.

1. The metrological principles employed in the DiNi 10T

1.1. Distance measurement

The concept of the Total Level Station, while based on the principles of optical tacheometry, makes use of the high accuracy with which a one-line CCD array arranged in the telescope's image plane detects the staff graduation edges. The staff intercept and the base in the telescope's image plane (i.e. the pixel spacing) have been dimensioned so as to make the resulting distance measuring error s_D increase in linear proportion with distance.

For accurate distance measurements, the DiNi 10T is operated in the total station mode, using a staff intercept up to about 1 m in length. The height reading is obtained from a staff intercept of 0.3 m lying symmetrically to the telescope crosshairs, as tried and approved with the DiNi 10. Thanks to the higher accuracy of the objective staff reading system compared with visual reading, and software compensation for the properties of the imaging systems, the DiNi 10T measures distances with a standard deviation not greater than

$s_D = 0.5 \times D \times 10^{-3}$ m with invar staves, and
$s_D = 1.0 \times D \times 10^{-3}$ m with folding staves.

The additive constant in the formula for the accuracy of a distance measurement can be dropped, as it is below 10 mm and thus negligible in the applications for which the DiNi 10T has been conceived. The distance measuring system has a maximum range of 100 to 110 m, the shortest observable distance being 1.5 m.

1.2. Angle measurement

The angle measuring accuracy of a digital total levelling station should match its optical distance measuring accuracy. The play of the instrument's vertical axis, the accuracy of concentricity between the code-graduated circle and the fixed vertical axis bushing, and the reading accuracy of the absolute rotary encoder have been dimensioned so as to ensure that the bearing of a target at a distance of 100 m can be taken with a standard deviation of s_r = 2 mgon (20^{cc}) for a single direction. If the distance to the staff to be sighted in the horizontal direction is shorter, the staff's code divisions may prove too wide to allow sighting to the required accuracy. This problem does not exist with staves having an E-type graduation pattern, which marks the staff's centre line. In order to lessen the problem, the telescope reticle has oblique lines arranged symmetrically to the centre hair, which allow the staff graduation to be bracketed symmetrically with sufficient accuracy.

1.3. Further aspects

Point observation with the DiNi 10T Total Level Station profits from a number of supplementary facilities.

The instrument can be centred above the station centre mark with a plumb bob. Centring the staff with the target centre mark to the required accuracy of s_p = 0.05... 0.1 m is easily accomplished by the rodman's estimation.

Thanks to measures taken in the imaging system, the electronics and the software, the measuring time with the DiNi 10T has been brought down to 3 s. This means speedier measurements despite the introduction of two additional functions. Moreover, the dynamic range has been extended at the lower brightness end by a factor of 1.5 to 2 compared with the DiNi 10.

Since an angle reading is available 0.3 s after setting to a target point, the instrument is suitable for tracking work.

Another characteristic of the total levelling station to be noted is that its line of collimation is always strictly horizontal, since all heights are determined by geometric levelling. This makes the instrument ideal for use especially in flat and gently rolling terrain.

We made it a special point to ensure that the entire staff range, i.e. 3 m for the invar staff and 4 m for the folding staff, ia available to the DiNi 10T for covering the height distance between the instrument and staff stations.

In lines of levels, fast tie-up between the various stations is possible by means of line levelling programs available. A considered, foresighted arrangement of instrument and staff stations provided, the software will also support surveys on rolling ground.

2. Design of the DiNi 10T

The outer appearance of the DiNi 10T equals that of the DiNi 10, except for some pushbutton functions added to the control panel, and the lack of the conventional external horizontal circle.
Therefore we abstain from giving a detailed description of the instrument here and refer the reader to our report on DiNi 10 [1].

As the sectional diagram shows, the DiNi 10T is provided with a new axis system featuring an optical code disc instead of the conventional horizontal circle, and an electro-optical circle-reading encoder system. The circle has a number of code tracks of about 40 mgon (4^{c}) width, from which the encoder system determines the absolute position. Within a code disc interval , interpolation is effected with an internal resolution of 0.1 mgon (1^{cc}). A reading takes about 0.2 s. In the tracking mode, measurements can be made with setting speeds of up to about 5 gon/s (5^{g}/s) with the horizontal fine-motion screw. If the entire instrument is turned faster than that, the current reading will be displayed after a delay of <0.3 s. After every measurement, the measuring system is switched off automatically in order to save on battery power. This is one of the advantages of an absolute-reading system.

The accuracy and performance data of all other components are identical to those of the DiNi 10.

3. The operating concept of the DiNi 10T

3.1 Functions

Selecting the measuring mode

The new capabilities added to the existing DiNi program can be harnessed by selection between different measuring modes. The selection decides on which computation procedure is used for the measurements made in that mode, and whether or not the measurement is to include horizontal angles.

The modes can be selected from a plain-text menu as known from the DiNi 10. The same menu allows the contents of the recording data record to be compiled as required. This is accomplished by means of appropriate recording filters.

Fig. 2: Selection of measuring mode and recording data

The system provides the following measuring modes:

Level mode: The levelling program does not differ from that of the DiNi 10/20. Height and distance are computed from a staff intercept of maximally 30 cm length, and the same recording filters can be selected. Horizontal angles are not taken.

Total station mode: All measurements include observation of the horizontal angle in the horizontal mode selected. The distance measuring program known from the DiNi 10/20 has been modified so as to yield greater accuracy. Distance observations are taken from a staff intercept of about 1 m. Two additional recording filters may be selected.

Coordinate mode: In case of single measurements and intermediate sights, the program computes local coordinates and records them in another data line. The coordinate system can be oriented in the horizontal measurement program by setting a known horizontal angle relative to a control point.

Irrespective of the mode selected, the DISP key allows you to select which of the data are to be displayed, as soon as more than three computed values are available.

Setting the horizontal mode

On pushing the measurement trigger button, the horizontal angle is normally taken immediately before the start of staff reading, a procedure analogous to that followed by almost all electronic total stations. In what is termed the simultaneous horizontal mode, horizontal angle, distance and height are collected almost at the same time.

Now and then it will happen, though, that horizontal angles and staff readings cannot be taken simultaneously. Where the staff has to be positioned off centre or obscures the target, the instrument needs to be rotated between the two operations. As the algorithm that decodes the code disk data will at first process any information offered to it, it would detect meaningless values that would cause the measurement to be aborted. This is different in a total station, where the detector in such a case will not receive sufficient energy, so that the result cannot be degraded by wrong, though at least formally analysable information.

For that reason the DiNi 10T offers the user a so-called separate horizontal mode. If the measure button is pushed in this mode, the system first only takes the bearing of the point sighted and stores it. To start staff reading, the operator needs to hit the measure button again. Once all observations have been taken, the stored readings are analysed together and the results finally presented and recorded same as in a simultaneous measurement.

Program for horizontal tracking

A program for horizontal tracking has been added to the functions known from the DiNi 10/20. With this function called up, the system takes horizontal bearings at intervals of about 0.3 s, while constantly updating the display. Same as with an electronic theodolite whose telescope has been fixed for horizontal sighting, any bearing can now be taken or set out.. It is possible to enter a nominal angle and assign it to a sighted direction for orienting the horizontal code circle. For special assignments the operator may need to reverse the circle counting sense. All these functions can be activated through soft keys.

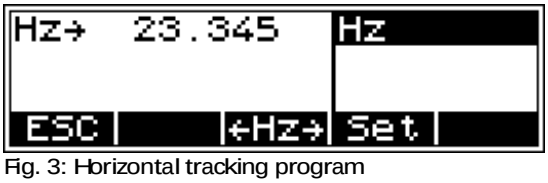

Fig. 3: Horizontal tracking program

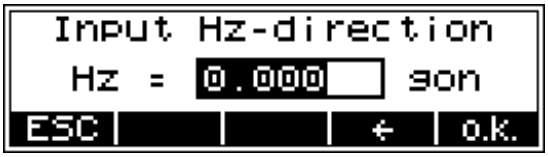

Fig. 4: Input of a nominal direction

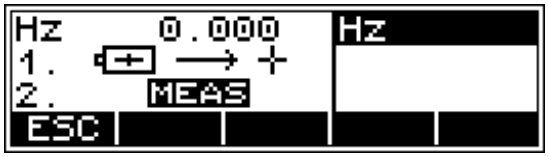

Fig. 5: Prompt for measurement

3.2 Operating procedures

Basically, the operating procedures are equal to those tried and approved with the DiNi 10/20. (The user interface of this instrument had already been conceived with later expansion in mind.)

The essential operating features are
- high flexibility through soft keys to which functions can be assigned depending on the current assignment,
- operator guiding prompts for recurrent procedures,
- easily handled setting, selecting and input menus,
- automatic data storage in the exchangeable Mem E module, and
- integrated checks that monitor the operating procedure and the measurement cycle.

The Total Level Station is liable to gain ground among surveyors who have not yet taken to using automatic instruments so far . Due to negative experience with certain products in the consumer electronics line, they may shy away from software-supported operation. We therefore made it a point for the DiNi software to build up familiarity from the start, mainly by means of the highly explicit operator prompting. Experience with the DiNi 10/20 shows that surveyors feel very comfortable with the instrument, even if they use it only now and then while carrying out the bulk of their assignments with a (non-levelling) total station.

Foreign users can profit from the possibility of retrofitting foreign language versions of the prompts and options displayed. Where necessary, this also includes special national character sets with all diacritics required.

The data records available are those known from the DiNi 10/20. Any existing PC-run data analysis programs in use with the digital level can readily be employed for processing the DiNi 10T levelling data. Moreover, the total station and coordinate modes allow two extra recording filters to be selected, which cause output of either the original staff readings or the height derived from them together with distance and bearing, respectively, to the Mem E memory module or to the V.24 interface. The data records in these cases are essentially similar to those of the RecElta series of total stations.

4. Applications

Thanks to the selectable measuring modes, the DiNi 10T can handle the following types of observations:

- Spot heights (single measurements) and lines of levels same as with the DiNi 10/20

- Spot heights and lines of levels same as with the DiNi 10/20, but with higher distance accuracy. Horizontal angles are taken, but neglected in data analysis.
- Simultaneous observation in plan and height (cylindrical coordinates)
- Simultaneous observation in plan and height (Cartesian coordinates)
- Observation and setting out of horizontal angles only

Accordingly, the DiNi 10T can be used for
- 1st and 2nd order levelling, and lines of levels of medium and lower accuracy,
- observations of structures, deformation measurements and safety observations at short intervals (controlled via PC),
- tacheometric surveys in flat and gently rolling terrain,
- area levelling including the planimetric data,
- longitudinal and cross sections simultaneously with planimetric checks,
- quantity measurements, and
- mapping of traffic routes, parks and gardens.

5. Summary

The DiNi 10T constitutes the transition from the two-dimensional (digital level) to a three-dimensional sensor. Its salient features are the high accuracy of its encoder system, excellent resolution especially along the CCD line, and precise angle measurement.

In the course of time, surveyors will come to use the instrument for applications which it was not even intended for initially and which other surveying methods fail to cope with, unless with extra expenditure. Remote control of the instrument via the interface (triggering of observations, instrument settings) opens up new prospects for safety and deformation observations as well as for special applications in industry.

The attractive price and the simplicity of operation, compared to familiar total stations, and the multifunctional use as a level, with all its facilities for automatic surveying, are certain to convince surveyors that the DiNi 10T is a highly efficient surveying tool.

Reference:

[1] Feist, W., Gürtler, K., Marold, T., Rosenkranz, H.: Die neuen Digitalnivelliere DiNi 10 und DiNi 20, VR57 (1995), pp. 65-76

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