

# VERTICAL MEASURING SYSTEM AND METHOD FOR TRACING REFERENCE POINT

## BACKGROUND OF THE INVENTION

The present invention relates to a vertical measuring system and a method for tracing a reference point in order to vertically extend a reference point on the ground and trace the reference point on each floor at a time of building a structure such as a building or the like.

Conventionally, in a case of tracing a reference point on a floor surface on a different floor, there are a method for suspending a plumb bob and setting the plumb bob to the reference point, a method for emitting a laser pointer light vertically upward, applying the laser pointer light to a plane plate and reading a center position, a method for emitting the laser pointer light vertically downward from upstairs, applying the laser pointer light to a plane plate and reading the center position and the like.

In the method for irradiating the laser pointer light, it is difficult to confirm whether the laser pointer light is irradiated in a vertical direction correctly, and it takes time to correctly adjust the laser pointer light in the vertical direction.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a vertical measuring method and a method for tracing a

reference point which enable to highly accurately perform a vertical tracing of a reference point without obtaining the verticality of a laser beam with high accuracy.

To attain the object as described above, a vertical measuring system according to the present invention comprises a measuring instrument which has a leveling module and a measuring instrument main body rotatably provided on the leveling module in a horizontal direction and is provided on a reference point, a target device installed on a part to which the reference point is transferred and a guiding terminal which has a display module and a first communication module and is used on a side of the target device, wherein the target device has a target for emitting a target light toward the surveying instrument main body, the measuring instrument main body comprises a sighting image photodetecting module for sighting a direction of a rotation axis of the surveying instrument main body and acquiring an image of the target, a tilt sensor for detecting a tilt of the surveying instrument main body, a second communication module for transmitting and receiving data to and from the guiding terminal and an arithmetic control module, wherein the arithmetic control module is configured to calculate a position of the rotation axis based on a locus of the target image obtained by rotating the surveying instrument main body and to transmit a positional information of the target image and a positional information of the rotation axis to the guiding terminal via the second terminal, and the guiding terminal is configured to display a position of the target and a position of a zenith on the display module based on the

positional information of the target image and the positional information of the rotation axis received via the first communication module.

Further, in the vertical measuring system according to a preferred embodiment, the surveying instrument main body further comprises the tilt sensor, and the arithmetic control module is configured to correct the position of the rotation axis based on a detection result of the tilt sensor.

Further, in the vertical measuring system according to a preferred embodiment, the target is a prism, the sighting image photodetecting module has a light source unit for emitting the target light onto an optical axis, and the surveying instrument main body is manually rotated.

Further, in the vertical measuring system according to a preferred embodiment, the arithmetic control module performs a time division at a predetermined time interval, acquires the target image per the predetermined time and averages data of the target image acquired within a predetermined length of time, and the arithmetic control module is configured to be capable of changing a time length of the predetermined time.

Further, in the vertical measuring system according to a preferred embodiment, the target is a prism, the surveying instrument main body further comprises a distance measuring module, the distance measuring module emits a distance measuring light onto an optical axis, the target retro-reflects the distance measuring light and projects the distance measuring light as a reflected distance measuring light and the target light, the distance measuring module

receives the reflected distance measuring light and measures a distance to the target, the surveying instrument main body is manually rotated, and the arithmetic control module is configured to display an actual deviation amount between the target and the optical axis as numeral values on the display module based on a deviation between the target image and the optical axis on an image and a distance measuring result.

Further, in the vertical measuring system according to a preferred embodiment, the target is a light emitter for emitting the target light, and the surveying instrument main body is manually rotated.

Further, in the vertical measuring system according to a preferred embodiment, the surveying instrument main body further comprises a distance measuring module, a sighting module, a horizontal angle detector, a vertical angle detector, a horizontal rotary driving module and a vertical rotary driving module, and the surveying instrument is configured as a total station.

Further, in the vertical measuring system according to a preferred embodiment, the arithmetic control module performs a time division at a predetermined time interval, obtains the target image and a distance measured value per the predetermined time and averages data of the target image and data of the distance measured value acquired within a predetermined length of time, and the arithmetic control module is configured to be capable of changing a time length of the predetermined time.

Furthermore, a method for tracing a reference point using the vertical measuring system according to the present

invention comprises a step of forming a through-hole on an upper floor in a structure above a reference point, a step of installing a surveying instrument on the reference point, a step of installing a target device in the through-hole, a step of directing a sighting optical axis of the surveying instrument to a vertical direction and rotating the surveying instrument, a step of photodetecting a target image from the target device on a photodetector by the surveying instrument, a step of calculating a zenith position based on a locus of the target image on the photodetector and a detection result of a tilt sensor of the surveying instrument and based on the reference point, a step of displaying the zenith position and the target image on a display module of a guiding terminal, a step of coinciding the zenith position with the target image, a step of marking a position of the target device on the upper floor in a state where the zenith position is coincided with the target image and a step of tracing the reference point on the upper floor based on the marking.

According to the present invention, the vertical measuring system comprises a measuring instrument which has a leveling module and a measuring instrument main body rotatably provided on the leveling module in a horizontal direction and is provided on a reference point, a target device installed on a part to which the reference point is transferred and a guiding terminal which has a display module and a first communication module and is used on a side of the target device, wherein the target device has a target for emitting a target light toward the surveying instrument main body, the measuring instrument main body comprises a sighting

image photodetecting module for sighting a direction of a rotation axis of the surveying instrument main body and acquiring an image of the target, a tilt sensor for detecting a tilt of the surveying instrument main body, a second communication module for transmitting and receiving data to and from the guiding terminal and an arithmetic control module, wherein the arithmetic control module is configured to calculate a position of the rotation axis based on a locus of the target image obtained by rotating the surveying instrument main body and to transmit a positional information of the target image and a positional information of the rotation axis to the guiding terminal via the second terminal, and the guiding terminal is configured to display a position of the target and a position of a zenith on the display module based on the positional information of the target image and the positional information of the rotation axis received via the first communication module. As a result, when the surveying instrument main body is rotated, a rotation center which indicates a position of the reference point, that is, the rotation axis can be obtained, a deviation amount and a deviation direction between a position of the rotation axis and the reference point can be easily recognized, and further since the measuring instrument main body is fixed at the time of adjusting a position of the target device, it is possible to perform a stable work.

Further, according to the present invention, the method for tracking a reference point using the above-mentioned vertical measuring system comprises a step of forming a through-hole on an upper floor in a structure above a

reference point, a step of installing a surveying instrument on the reference point, a step of installing a target device in the through-hole, a step of directing a sighting optical axis of the surveying instrument to a vertical direction and rotating the surveying instrument, a step of photodetecting a target image from the target device on a photodetector by the surveying instrument, a step of calculating a zenith position based on a locus of the target image on the photodetector and a detection result of a tilt sensor of the surveying instrument and based on the reference point, a step of displaying the zenith position and the target image on a display module of a guiding terminal, a step of coinciding the zenith position with the target image, a step of marking a position of the target device on the upper floor in a state where the zenith position is coincided with the target image and a step of tracing the reference point on the upper floor based on the marking. As a result, the target can be positioned while recognizing a relationship between the reference point and the target without highly accurately setting the sighting optical axis of the surveying instrument to be vertical, and it is possible to improve the workability.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 is a perspective view to show an outline of a vertical measuring system according to a first embodiment of the present invention.

FIG.2 is a perspective view of a target device used in the vertical measuring system from a lower side.

FIG.3 is a perspective view of the target device from an upper side.

FIG.4 is a side view of the target device.

FIG.5 is an explanatory drawing to show a positional adjustment of the target device in the vertical measuring system.

FIG.6 is a block diagram to show a schematical configuration of a surveying instrument main body in the vertical measuring system.

FIG.7 is a block diagram to show a schematical configuration of a guiding terminal in the vertical measuring system.

FIG.8A and FIG.8B are explanatory drawings to show a transfer process of a reference point.

FIG.9A and FIG.9B are explanatory drawings to show the transfer process of the reference point.

FIG.10A is a drawing of a display module of the guiding terminal at the transfer process of the reference point, and FIG.10B is an explanatory drawing to show a final step of the transferring process of the reference point.

FIG.11 is a block diagram to show an outline of a vertical measuring system according to a second embodiment of the present invention.

FIG.12 is a block diagram to show an outline of a vertical measuring system according to a third embodiment of the present invention.

FIG.13 is a block diagram to show an outline of a vertical measuring system according to a fourth embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A description will be given below on embodiments of the present invention by referring to the attached drawings.

FIG.1 shows a vertical measuring system 1 according to the present embodiment, and in the drawing, a reference numeral 2 denotes a surveying instrument, which is installed on a reference point P, irradiates a distance measuring light, receives a reflected light and performs a distance measurement and an angle measurement, and what is shown in the drawing is a total station which is one of the surveying instruments. Further, a reference numeral 3 denotes a target device, and the target device 3 has a target 4 which retro-reflects (that is, emits) an entered distance measuring light as a target light. A reference numeral 5 denotes a guiding terminal which has a communication function and a display module. As the guiding terminal 5, for instance, a smartphone, a tablet or the like, which is portable or can be held in one hand, is used.

First, a description will be given on the total station 2 in brief. It is to be noted that, as the total station 2, an already-known instrument described in Japanese Patent Application Publication No. 2000-275042 or Japanese Patent Publication No. 5196725 can be used.

A surveying instrument main body 7 is installed on a tripod 8 via a leveling module 9, and the surveying instrument main body 7 is horizontally leveled by the leveling module 9 and rotatable in a horizontal direction via a horizontal rotation shaft (not shown). The surveying

instrument main body 7 has a telescope module 11, and the telescope module 11 is rotatable in a vertical direction via a vertical rotation shaft (not shown).

Further, the surveying instrument main body 7 comprises a horizontal angle detector 28 (to be described later) for detecting a horizontal rotation angle of the surveying instrument main body 7 and a vertical angle detector 29 (to be described later) for detecting a vertical angle of the telescope module 11. Further, in the telescope module 11, a distance measuring module 22 (to be described later), which emits the distance measuring light, receives a reflected distance measuring light and performs a distance measurement, is accommodated.

A through-hole 13 is formed in a part, for instance, on an upper floor, to which a reference point P is transferred. A position at which the through-hole 13 is formed is obtained from a design drawing and is positioned directly above the reference point P. The target device 3 is installed in the through-hole 13 in such a manner that the target 4 is fitted in the through-hole 13. A diameter of the through-hole 13 is sufficiently large with respect to a diameter of the target 4 while considering a construction error of a building so that a position of the target 4 can be adjusted.

By referring to FIG.2, FIG.3 and FIG.4, a description will be given on the target device 3.

The target 4 is provided on a holding plate 14. The holding plate 14 has a shape and a size which prevent the holding plate 14 from falling from the through-hole 13, and in the drawing, the holding plate 14 is formed in a cross-

like shape having rectangular plates 15a and 15b extending in two directions and orthogonal to each other.

The target 4 is a prism or a corner cube and is provided at a center of the holding plate 14 in such a manner that a lower side can be seen through from a periphery of the target 4.

A lower surface of the holding plate 14 abuts on a floor surface of the upper floor, and an optical center (floating point) 4a of the target 4 coincides with the lower surface of the holding plate 14. Further, an optical axis of the target 4 is perpendicular to the lower surface of the holding plate 14.

Upper surfaces of tip portions of the rectangular plates 15a and 15b are tapered surfaces, respectively. Visual target lines 16a and 16b are marked in the tapered surfaces, and extensions of the visual target lines 16a and 16b are set in such a manner that the visual target lines 16a and 16b cross each other at the optical center 4a.

It is to be noted that notches may be formed at tips of the rectangular plates 15a and 15b respectively instead of the visual target lines 16a and 16b. Further, the holding plate 14 may be a rectangular or circular transparent plate.

FIG.5 shows an outline in a case where the reference point P is transferred to the upper floor. It is to be noted that, in FIG.5, a reference numeral 17 denotes the upper floor.

The telescope module 11 is rotated, and an optical axis 10 of the telescope module 11 is set to be approximately vertical.

A distance measuring light or a sighting light (hereinafter referred to as the sighting light 18) is projected from the telescope module 11. An irradiation point of the sighting light 18 is a position to which the reference point P is transferred approximately upward.

When the sighting light 18 enters the optical center 4a of the target 4, a reflected light (target light) from the target 4 coincides with the optical axis 10.

Whether the reflected light (target light) from the target 4 coincides with the optical axis 10 is judged by a sighting image photodetecting module (to be described later) which the telescope module 11 has. That is, the judgment is made by whether an image of the reflected light as acquired by the sighting image photodetecting module coincides with the optical axis 10.

By referring to FIG.6, a description will be further given on the surveying instrument main body 7.

The surveying instrument main body 7 is mainly constituted of an arithmetic control module 21, the distance measuring module 22, a sighting module 23, the sighting image photodetecting module 24, a tilt sensor 25, a storage module 26, a communication module 27, the horizontal angle detector 28, the vertical angle detector 29, a horizontal rotary driving module 31, a vertical rotary driving module 32, a display module 33, an operation module 34 and the like.

The distance measuring module 22 has a light emitter for emitting the distance measuring light, for instance, a laser diode (LD), a distance measuring photodetector for receiving a reflected distance measuring light from an object

to be measured, for instance, a photodiode (PD) or an avalanche photodiode (APD) and a distance measuring optical system for emitting the distance measuring light toward the object to be measured, receiving the reflected distance measuring light and leading the reflected distance measuring light to the distance measuring photodetector, and the distance measuring module 22 measures a distance to the object to be measured based on a time difference between a light emission timing of the distance measuring light and a light reception timing of the reflected distance measuring light and on a light velocity. The distance measuring module 22 functions as an electronic distance meter.

The sighting module 23 comprises a light emitter for emitting the sighting light, for instance, a laser diode (LD), a sighting image photodetector for receiving the reflected sighting light from the object to be measured, for instance, an image CMOS sensor or a CCD image sensor, the sighting image photodetecting module 24 for emitting the sighting light toward the object to be measured and receiving the reflected sighting light from the object to be measured and a sighting optical system for leading the reflected sighting light to the sighting image photodetector, and the sighting module 23 sights the object to be measured based on a light receiving position of the reflected sighting light on the sighting image photodetector. Here, the distance measuring optical system and the sighting optical system may be a common optical system or may be optical systems in which a part of the optical systems is common.

The sighting image photodetecting module 24 has an

image pickup optical axis (not shown), the image pickup optical axis is parallel to a distance measuring optical axis of the distance measuring module 22 and a tracking optical axis of the sighting module 23, and distances between each of the optical axes are known. Alternatively, the image pickup optical axis is common to the distance measuring optical axis and the sighting optical axis (the two optical axes coincide with each other). In the drawing, the distance measuring optical axis and the sighting optical axis are shown as the optical axis 10.

The sighting image photodetecting module 24 includes an image pickup optical system and an image sensor (not shown) and acquires an image in a predetermined range (at a predetermined field angle) with the distance measuring optical axis or the sighting optical axis as the center. Further, the image sensor is an aggregate of pixels such as a CCD or a CMOS sensor. A position of each pixel on the image sensor (the image) can be specified. For instance, a position of each pixel is specified in a coordinate system with the center of the image sensor (the image) as an origin. Therefore, a signal output from the pixel includes a positional information (coordinate information) on the image sensor as well as an image signal.

The tilt sensor 25 can highly accurately detect the horizontality. Further, as one example used as the tilt sensor 25, there is a tilt sensor which allows a detection light to enter a liquid surface, receives a reflected light reflected on the liquid surface by a photodetector and detects a tilt according to a change in a light receiving

position of the reflected light.

As the storage module 26, a storage device such as an HDD, a semiconductor memory or a memory card is used. In the storage module 26, the various kinds of programs are stored. These programs include: a sequence program which is necessary for the surveying instrument main body 7 to perform a distance measurement and a sighting, a calculation program configured to perform the distance measurement, a control program configured to control the distance measuring module 22 and the sighting module 23, an image processing program configured to process the images acquired by the distance measuring module 22 and the sighting module 23, for instance, an image processing program configured to obtain a center position of an image of the reflected sighting light acquired by the sighting module 23, an angle detection program configured to calculate a horizontal angle and a vertical angle based on the detection results from the horizontal angle detector 28 and the vertical angle detector 29, a communication program configured to transmit and receive data and image data to and from the guiding terminal 5 and other programs.

Further, in the storage module 26, measurement data, image data and the like are stored.

The communication module 27 includes a transmission/reception circuit and is capable of wirelessly communicating with the guiding terminal 5 by the communication program.

The horizontal angle detector 28 detects a horizontal rotation angle of the surveying instrument main body 7 with

respect to the leveling module 9, and a horizontal angle is detected based on the rotation angle. The detected horizontal angle is input to the arithmetic control module 21. As the horizontal angle detector 28, an encoder is used.

The vertical angle detector 29 detects a vertical rotation angle of the telescope module 11 with respect to the surveying instrument main body 7 and detects a vertical angle of the optical axis 10 of the telescope module 11. The detected vertical angle is input to the arithmetic control module 21. As the vertical angle detector 29, an encoder is used.

The horizontal rotary driving module 31 has a horizontal motor and a motor driver, drives the horizontal motor based on a control signal from the arithmetic control module 21 and rotates the surveying instrument main body 7 horizontally.

The vertical rotary driving module 32 has a vertical motor and a motor driver, drives the vertical motor based on the control signal from the arithmetic control module 21 and rotates the telescope module 11 vertically.

The operation module 34 inputs conditions required for the measurement, commands for the measurement and the like. Further, the display module 33 displays an input information of the operation module 34 and also displays a measurement state, a measurement result and the like. It is to be noted that the operation module 34 may be configured as a touch panel and also to serve as the display module 33.

As the arithmetic control module 21, a CPU specialized for this instrument or a general-purpose CPU is used. The

arithmetic control module 21 develops and executes the various kinds of programs stored in the storage module 26, controls the distance measuring module 22, performs the distance measurement, controls the sighting module 23 and sights the object to be measured. The arithmetic control module 21 controls the horizontal rotary driving module 31 and the vertical rotary driving module 32 based on the detection results from the horizontal angle detector 28 and the vertical angle detector 29, and rotates and positions the surveying instrument main body 7 and the telescope module 11 in a state as required, or measures a sighting direction.

FIG.7 shows a schematical block diagram of the guiding terminal 5.

The guiding terminal 5 has a communication function and mainly comprises an arithmetic control module 35, a storage module 36, a communication module 37, a display module 38 and an operation module 39.

As the arithmetic control module 35, a CPU specialized for the guiding terminal 5 or a general-purpose CPU is used.

As the storage module 36, a storage device such as an HDD, a semiconductor memory or a memory card is used. In the storage module 36, are stored programs such as a communication program configured to perform a communication of the data and the image data with the surveying instrument main body 7, a display program configured to display the data and the image data on the display module 38 and other programs.

The communication module 37 includes a transmission/reception circuit and is capable of wirelessly

communicating with the communication module 27 by the communication program.

The display module 38 displays an input information from the operation module 39 and the measurement data and the image data transmitted from the communication module 27.

The operation module 39 inputs a command for remotely operating the surveying instrument main body 7 and inputs a command for displaying the information from the communication module 27. It is to be noted that the display module 38 may be configured as a touch panel and also to serve as the operation module 39, and the operation module 39 may be omitted.

A description will be given below on an operation of the present embodiment by referring to FIG.8, FIG.9 and FIG.10.

The total station 2 is installed on the reference point P, and the surveying instrument main body 7 is leveled to a horizontal attitude by the leveling module 9. The attitude (tilt) of the surveying instrument main body 7 is detected by the tilt sensor 25. The target device 3 is installed in the through-hole 13 on the upper floor (FIG.8A).

Next, the worker, who installs the target device 3, remotely operates the telescope module 11 by the guiding terminal 5. The telescope module 11 is rotated in the vertical direction and makes the optical axis 10 (including the distance measuring optical axis, the sighting optical axis and the image pickup optical axis) of the telescope module 11 vertical upwardly. Whether the optical axis 10 is vertical is detected by the vertical angle detector 29. The

sighting image photodetecting module 24 sights a rotation axis direction of the surveying instrument main body 7 and acquires an image of the target device 3.

The sighting light is projected vertically upward. The optical axis 10 at this moment coincides with a rotation center of the surveying instrument main body 7. The target 4 retro-reflects the distance measuring light, and the retro-reflected light is projected from the target 4. The retro-reflected light is received by the distance measuring module 22, and a distance to the target 4 is measured. Further, the reflected distance measuring light enters the sighting image photodetecting module 24 as the target light, and an image of the target 4 is acquired by the sighting image photodetecting module 24 (FIG.8B).

In a state where a sighting function is stopped and a state where the distance measuring light is projected (that is, a state where the telescope module 11 is fixed with respect to the surveying instrument main body 7), the surveying instrument main body 7 is rotated 360° or at least 90°.

In a state where the target 4 coincides with the rotation center, a target image 4' acquired by the sighting image photodetecting module 24 coincides with a position of the rotation axis (that is, the rotation center of the surveying instrument main body 7), and a photodetecting position is not changed by the rotation of the surveying instrument main body 7.

However, as shown in FIG.9A, in a case where a position of the target 4 (optical center) deviates from a position of

the rotation axis 12, the target image 4' rotates around the rotation axis 12. It is to be noted that, in FIG.9A, a reference numeral 44 denotes an image acquired by the sighting image photodetecting module 24.

During the rotation of the surveying instrument main body 7, the target image 4' is continuously acquired by the sighting image photodetecting module 24. It is to be noted that continuous images may be acquired, or still images may be acquired at a predetermined time interval or a predetermined angle interval.

During the rotation, by continuously acquiring the target image 4', a locus 43 of a circle with the rotation axis 12 as the center is obtained. When a center 42 of the circle is calculated based on the locus 43, the position of the rotation axis 12 can be obtained. When the optical axis 10, that is, the rotation axis of the surveying instrument main body 7 is completely vertical, the center 42 of the locus 43 is a zenith position.

Since the sighting light is not a complete parallel light and has a spread, the target image 4' is an image with an area. In order to obtain an accurate position, the center of the target image 4' is required, and the center of the target image 4' is obtained by the image processing. For instance, a centroid position of a light amount of the target image 4' is obtained, and this centroid position is determined as the center of the target image 4'. In the present embodiment, since the accurate center position is obtained by the image processing, even in a case where a distance from the reference point to a traced floor is long

and a light flux diameter of the laser light is large like in a case of a work in a high-rise building or the like, the center of the laser pointer light can be obtained.

Further, at the time of installing the total station 2 on the reference point P, the surveying instrument main body 7 is leveled by the leveling module 9 based on a detection result of the tilt sensor 25, but because of a leveling accuracy or the like of the leveling module 9, an incompletely horizontally leveled state occurs.

A double circle P' on the image 44 shows a position of a vertical line (true zenith position) passing through the reference point P.

In a case where the tilt sensor 25 detects a tilt, the arithmetic control module 21 calculates a position (coordinates) of the reference point P' within the image 44 based on the detection result of the tilt sensor 25. That is, based on the center position of the locus 43 and the detection result of the tilt sensor 25, the true zenith position is obtained. Further, the reference point P' is shown on the image 44 with the true zenith position as the center.

Therefore, when the target image 4' is adjusted to coincide with the reference point P', the target 4 can be coincided with the true zenith position (FIG.9B).

Further, the arithmetic control module 21 calculates the coordinates of the current target image 4' based on a photodetecting signal from the sighting image photodetecting module 24.

The arithmetic control module 21 transmits the

coordinates of the reference point  $P'$  and the coordinates of the current target image  $4'$  to the guiding terminal 5 via the communication module 27 in real time.

On the guiding terminal 5 side, the arithmetic control module 35 receives the coordinates of the reference point  $P'$  and the coordinates of the current target image  $4'$  via the communication module 37, and the arithmetic control module 35 displays the reference point  $P'$  and the target image  $4'$  on the display module 38 of the guiding terminal 5 based on the coordinates of the reference point  $P'$  and the coordinates of the target image  $4'$ .

Further, since the surveying instrument main body 7 can measure the position of the target device 3 based on the reflected distance measuring light from the target device 3, the arithmetic control module 21 may calculate a deviation between the positions of the reference point  $P'$  and the target image  $4'$  and display the reference point  $P'$  and the target image  $4'$  on the display module 38. It is to be noted that the deviation between the positions of the reference point  $P'$  and the target image  $4'$  may be calculated by the arithmetic control module 35. When the deviation between the positions of the reference point  $P'$  and the target image  $4'$  are displayed on the display module 38, the worker can sensorially grasp an adjustment amount of the target device 3, and hence the workability can be improved.

Further, the data transmitted to the guiding terminal 5 by the arithmetic control module 21 may be coordinate data of the target image  $4'$  and coordinate data of the true zenith position or may be image data in which the coordinate data of

the target image 4' and the coordinate data of the true zenith position are shown.

In FIG.10A, the deviation between the positions of the reference point P' and the target image 4' are indicated as numeral values  $X=-54$  mm and  $Y=+35$  mm, and the worker can recognize that moving the target device 3 by 54 mm in the left direction and moving the target device 3 by 35 mm in the upward direction can suffice. It is to be noted that, in FIG.10A, a reference numeral 49 denotes a display module of the guiding terminal 5.

In a state where the target 4' coincides with the reference point P', markings are performed at four points by using the visual target lines 16a and 16b. The through-hole 13 is filled, crossing marking lines from each pair of points facing each other are marked-off, and an intersection of the marking lines is obtained. This intersection is a point to which the reference point P is transferred.

In a case of transferring the reference point P to a plurality of floors, an installation of the target device 3, a positioning of the target 4 and the markings are repeated per floor, the through-hole 13 on each floor is filled each time or after the markings on all the floors is finished, the marking lines are marked-off, and the intersection of the marking lines, that is, the point to which the reference point P is transferred is obtained (FIG.10B).

Next, a building shakes due to various causes. In a building which is under construction, a shaking due to a construction work, an oscillation of the building itself, a vibration due to a movement of the worker and the like occur.

For this reason, a laser beam which is vertically emitted vibrates, a reflected laser beam from the target 4 also vibrates, the target image 4' on an image also vibrates, and there is a case that an accurate positioning becomes difficult. Further, a distance measured value and an angle measured value also fluctuate.

In the present embodiment, a time division is performed at the predetermined time interval, data acquired within a predetermined length of time is averaged, and an influence of the vibration is reduced (smoothing). Further, a data acquirement time for averaging can be arbitrarily set so that the smoothing according to a work situation can be performed.

In the storage module 26 or the storage module 36, a smoothing program is stored. In the smoothing program, when the data acquirement time for averaging (smoothing time) is set, the data acquired within a set predetermined time is averaged (smoothing) and output.

For instance, the image data are acquired for five seconds at the interval of 0.1 second by the sighting image photodetecting module 24, and the image data corresponding to five seconds are moving-averaged in next 0.1 second after acquiring the data for five seconds. By moving-averaging, the averaged image data corresponding to five seconds is output at the interval of 0.1 second. Therefore, the target image 4' shown on the image 44 is stably displayed without vibrating, and the worker can assuredly carry out a positional adjustment work of the target device 3.

In the present embodiment, even in a case where the laser beam to be irradiated upward is not completely vertical,

the reference point can be easily transferred in the vertical direction. Therefore, a strict leveling is not required. Further, since the total station 2 is fixed and a work is carried out after obtaining the locus 43, even in a case where the laser beam is not completely vertical, a stable tilt correction can be performed.

Further, since the center of the rotation is obtained from the locus 43, even in a case where the complete verticality cannot be obtained due to an influence of an instrument error or a distortion of the optical systems, the vertical trace of the accurate reference point is likewise possible.

The worker can carry out a smoothing corresponding to a site and assuredly perform a work even in a vibrating site, and as a result, the work efficiency is improved.

Although the reference point is transferred from the lower side toward the upper floor in the above embodiment, it is needless to say that the reference point can be likewise transferred from the upper side toward a lower floor.

Next, a description will be given on a second embodiment by referring to FIG.11.

The second embodiment relates to a vertical measuring system specialized for a transfer of a reference point P.

It is to be noted that, in FIG. 11, the equivalent components as shown in FIG.1 and FIG.6 are referred by the same symbols, and a description thereof will be omitted. Further, a guiding terminal 5 is equivalent to the guiding terminal 5 in the first embodiment, and hence the guiding terminal 5 is omitted in the drawing.

In the second embodiment, a horizontal rotation is manually performed, a horizontal angle detector 28, a vertical angle detector 29, a horizontal rotary driving module 31 and a vertical rotary driving module 32 are omitted, a distance measuring function is specialized only to a vertical direction, and a tracking function is omitted.

A surveying instrument 40 has a surveying instrument main body 7, a leveling module 9 and a horizontal rotation mechanism 41, and the surveying instrument main body 7 is provided on the leveling module 9 via the horizontal rotation mechanism 41. The horizontal rotation mechanism 41 supports the surveying instrument main body 7 rotatably around a vertical axis.

The surveying instrument main body 7 is mainly constituted of an arithmetic control module 21, a distance measuring module 22, a sighting module 23, a sighting image photodetecting module 24, a tilt sensor 25, a storage module 26, a communication module 27, a display module 33 an operation module 34 and the like. The sighting image photodetecting module 24 has an optical axis 10 extending in the vertical direction, and the optical axis 10 is concentric with a rotation axis 12 of the horizontal rotation mechanism 41.

The surveying instrument 40 is installed on the reference point P, and a leveling is performed by the leveling module 9 in such a manner that the optical axis 10 becomes approximately vertical. A target device 3 is installed at a transfer position of the reference point on an upper floor.

A distance measuring light is projected onto the optical axis 10 from the distance measuring module 22, the surveying instrument main body 7 is manually rotated, and target images 4' corresponding to one rotation are acquired. A center is obtained from a circle locus of the acquired target images 4' (FIG.9A). This center becomes a position of a rotation center of the surveying instrument main body 7. When the tilt sensor 25 detects a tilt, the position of the rotation center is corrected based on this detection result, and a true zenith position is calculated.

Since the calculations of a locus center of a circle, a correction of a tilt and the calculation of a true zenith position are equivalent to the calculations in the first embodiment, a description thereof will be omitted.

FIG.12 shows a third embodiment. It is to be noted that, in FIG.12, the equivalent components as shown in FIG.11 are referred by the same symbols. Further, since a guiding terminal 5 is equivalent to the guiding terminal 5 in the first embodiment, the guiding terminal 5 is omitted in the drawing.

In the third embodiment, the distance measuring function in the second embodiment is further omitted.

In the third embodiment, a distance measuring module 22 is omitted in the configuration of the surveying instrument main body 7 in the second embodiment.

Further, a sighting image photodetecting module 24 further has a target light emitter (laser diode (LD)) (not shown), and the target light emitter emits a target light, and the target light is projected vertically upward through

an optical system of the sighting image photodetecting module 24. An optical axis 10 of the sighting image photodetecting module 24 is concentric with a rotation axis 12 of a horizontal rotation mechanism 41.

A surveying instrument 40 is installed on a reference point P, a leveling is performed by a leveling module 9 in such a manner that the optical axis 10 becomes approximately vertical, and a target device 3 is installed on a transfer position of the reference point on an upper floor.

The target light is emitted onto the optical axis 10 from the target light emitter, the surveying instrument main body 7 is manually rotated, and a target image 4' is acquired by a target light from a target 4 by the sighting image photodetecting module 24.

Since the calculations of a locus center of a circle, a correction of a tilt and the calculations of a true zenith position are equivalent to the calculations in the second embodiment, a description thereof will be omitted.

In the above description, since a prism is used as the target 4 in the first embodiment, the second embodiment and the third embodiment, the transfer in a long distance is possible.

A description will be given on a fourth embodiment by referring to FIG.13.

The fourth embodiment relates to a vertical measuring system further specialized for a transfer of a reference point P.

It is to be noted that, in FIG.13, the equivalent components as shown in FIG.1 and FIG.6 are referred by the

same symbols, and a description thereof will be omitted. Further, a guiding terminal 5 is equivalent to the guiding terminal 5 in the first embodiment, the guiding terminal 5 is omitted in the drawing.

In the fourth embodiment, a distance measuring function and a tracking function are omitted, a surveying instrument main body 7 is manually rotated, and a target device 3 is simplified.

The surveying instrument main body 7 is provided on a leveling module 9 via a horizontal rotation mechanism 41. The horizontal rotation mechanism 41 supports the surveying instrument main body 7 rotatably around a rotation axis 12.

The surveying instrument main body 7 is mainly constituted of an arithmetic control module 21, a tilt sensor 25, a storage module 26, a communication module 27, a display module 33, an operation module 34, an image pickup module 45 having a function as a sighting image photodetecting module and the like.

The image pickup module 45 has an optical axis 10 which is concentric with the rotation axis 12, and the image pickup module 45 has an objective lens 46 and an image sensor 47. It is to be noted that the object lens 46 is shown in such a manner that a lens group is simplified.

The image sensor 47 is an aggregate of pixels such as a CCD or a CMOS sensor, like the first embodiment, and a position of each pixel on the image sensor 47 (an image) can be specified.

The objective lens 46 focuses a target light projected from a target device 3 on the image sensor 47.

The target device 3 has a holding plate 14, a light emitter 48 provided at a center of a lower surface of the holding plate 14, a light emission driving module (not shown) which makes the light emitter 48 emit and a power supply (not shown). A light emission point of the light emitter 48 is set in such a manner that the light emission point of the light emitter 48 is positioned in the lower surface of the holding plate 14.

A surveying instrument 40 is installed on a reference point P, and a leveling is performed by the leveling module 9 in such a manner that the optical axis 10 of the image pickup module 45 becomes approximately vertical. Further, the target device 3 is installed on a transfer position of the reference point on an upper floor.

The light emitter 48 is turned on. The light emitter 48 emits a target light and functions as a target. Further, as the light emitter, a light-emitting diode (LED) or a laser diode (LD) is used.

A target image 48' of the light emitter 48 is acquired by the image sensor 47. In a state where the light emitter 48 is emitted, the surveying instrument main body 7 is manually rotated, and the target images 48' corresponding to one rotation are acquired.

When the light emitter 48 is positioned on the optical axis 10 of the image pickup module 45, the target image 48' is rotated without changing a position of the target image 48'. Further, when the light emitter 48 is positioned at a position deviating from the image pickup module 45, the target image 48' draws a locus of a circle (see FIG.9A). A

position of a center of the locus of this circle (the rotation axis) is obtained from the image by a calculation. Further, when the tilt sensor 25 detects a tilt, the position of the center of the locus of the circle is corrected based on this detection result, and a true zenith position is calculated.

The true zenith position is transmitted to the guiding terminal 5 via the communication module 27.

Since an obtainment of the center position of the target image 48' by an image processing, a positional adjustment of the target device 3, a smoothing of image data and the like are equivalent to the obtainment of the center position of the target image 48' by the image processing, the positional adjustment of the target device 3 and the smoothing of the image data in the first embodiment, a description thereof will be omitted.

In the present embodiment, by omitting the distance measuring function and the tracking function, it enables to omit a distance measuring module 22, a sighting module 23, a horizontal angle detector 28, a vertical angle detector 29 and the like, to simplify the instrument and to significantly reduce a manufacturing cost. Further, as a target 48 also, an LD or an LED is used instead of a prism, and hence a cost can be reduced.

## CLAIMS

1. A vertical measuring system comprising:  
a measuring instrument which has a leveling module and a measuring instrument main body rotatably provided on said leveling module in a horizontal direction and is provided on a reference point,  
a target device installed on a part to which said reference point is transferred and  
a guiding terminal which has a display module and a first communication module and is used on a side of said target device,  
wherein said target device has a target for emitting a target light toward said surveying instrument main body,  
said measuring instrument main body comprises a sighting image photodetecting module for sighting a direction of a rotation axis of said surveying instrument main body and acquiring an image of said target,  
a tilt sensor for detecting a tilt of said surveying instrument main body,  
a second communication module for transmitting and receiving data to and from said guiding terminal and  
an arithmetic control module,  
wherein said arithmetic control module is configured to calculate a position of said rotation axis based on a locus of said target image obtained by rotating said surveying instrument main body and to transmit a positional information of said target image and a positional information of said rotation axis to said guiding terminal via said second

terminal,

and said guiding terminal is configured to display a position of said target and a position of a zenith on said display module based on the positional information of said target image and the positional information of said rotation axis received via said first communication module.

2. The vertical measuring system according to claim 1, wherein said surveying instrument main body further comprises said tilt sensor, and said arithmetic control module is configured to correct the position of said rotation axis based on a detection result of said tilt sensor.

3. The vertical measuring system according to claim 1 or 2, wherein said target is a prism, said sighting image photodetecting module has a light source unit for emitting the target light onto an optical axis, and said surveying instrument main body is manually rotated.

4. The vertical surveying system according to claim 1 or 2, wherein said arithmetic control module performs a time division at a predetermined time interval, acquires said target image per said predetermined time and averages data of said target image acquired within a predetermined length of time, and said arithmetic control module is configured to be capable of changing a time length of the predetermined time.

5. The vertical measuring system according to claim 1 or 2, wherein said target is a prism, said surveying instrument

main body further comprises a distance measuring module, said distance measuring module emits a distance measuring light onto an optical axis, said target retro-reflects the distance measuring light and projects the distance measuring light as a reflected distance measuring light and the target light, said distance measuring module receives said reflected distance measuring light and measures a distance to said target, said surveying instrument main body is manually rotated, and said arithmetic control module is configured to display an actual deviation amount between said target and said optical axis as numeral values on said display module based on a deviation between said target image and said optical axis on an image and a distance measuring result.

6. The vertical measuring system according to claim 1 or 2, wherein said target is a light emitter for emitting the target light, and said surveying instrument main body is manually rotated.

7. The vertical measuring system according to claim 1 or 2, wherein said surveying instrument main body further comprises a distance measuring module, a sighting module, a horizontal angle detector, a vertical angle detector, a horizontal rotary driving module and a vertical rotary driving module, and said surveying instrument is configured as a total station.

8. The vertical measuring system according to claim 5, wherein said arithmetic control module performs a time

division at a predetermined time interval, obtains said target image and a distance measured value per said predetermined time and averages data of said target image and data of said distance measured value acquired within a predetermined length of time, and said arithmetic control module is configured to be capable of changing a time length of the predetermined time.

9. A method for tracing a reference point using the vertical measuring system according to any one of claims 1 to 8 comprising: a step of forming a through-hole on an upper floor in a structure above a reference point, a step of installing a surveying instrument on said reference point, a step of installing a target device in said through-hole, a step of directing a sighting optical axis of said surveying instrument to a vertical direction and rotating said surveying instrument, a step of photodetecting a target image from said target device on a photodetector by said surveying instrument, a step of calculating a zenith position based on a locus of said target image on said photodetector and a detection result of a tilt sensor of said surveying instrument and based on said reference point, a step of displaying said zenith position and said target image on a display module of a guiding terminal, a step of coinciding said zenith position with said target image, a step of marking a position of said target device on said upper floor in a state where said zenith position is coincided with said target image and a step of tracing said reference point on said upper floor based on said marking.