Patent claims:

1. A method for the positionally correct capture of exposed infrastructure elements having a diameter of less than 30 cm and which are arranged underground, in particular in an open excavation, by means of a mobile capture apparatus (1), wherein:

- by means of a 3D reconstruction device (4) of the mobile capture apparatus (1), image data and depth data of a scene containing at least one exposed infrastructure element arranged underground are captured and a 3D point cloud having a plurality of points is generated on the basis of these image data and depth data;
- by means of one or more receivers (2) of the mobile capture apparatus (1), signals of one or more global navigation satellite systems are received and a first position indication of the position of the capture apparatus (1) in a global reference system is determined; and
- a plurality of second position indications of the position of the capture apparatus (1) in a local reference system and a plurality of orientation indications of the orientation of the capture apparatus (1) in the respective local reference system are determined,
  a. wherein the determination of one of the second position indications and of one of the orientation indications is effected by means of an inertial measurement unit (3) of the mobile capture apparatus (1), which captures linear accelerations of the mobile capture apparatus (1) in three mutually orthogonal principal axes of the local reference system and angular velocities of the rotation of the mobile capture apparatus (1) about these principal axes, and

b. wherein the 3D reconstruction device (4) comprises more than one 2D cameras, by means of which the image data and the depth data of the scene are captured and the determination of one of the second position indications and of one of the orientation indications is effected by means of visual odometry on the basis of the image data and the depth data; and

c. wherein the 3D reconstruction device (4) comprises a LIDAR measuring device, by means of which the depth data of the scene are captured and the determination of one of the second position indications and of one of the orientation indications is effected by means of visual odometry on the basis of the depth data;

- a respective georeference is allocated to the points of the 3D point cloud on the basis of the first position indication and a plurality of the second position indications and also a plurality of the orientation indications,
- wherein the mobile capture apparatus (1) is able to be carried by a person, wherein the mobile capture apparatus (1) is able to be held by both hands of a person, preferably by one hand of a person, and has a housing (9), the largest edge length of which is less than 50 cm, wherein the receiver(s) (2), the inertial measurement unit (3) and the 3D reconstruction device (4) are arranged in the housing (9).

2. The method as claimed in claim 1, characterized in that the underground infrastructure element is a fiber-optic cable or a power cable or a telecommunication cable.

3. The method as claimed in either of the preceding claims, characterized in that the underground infrastructure elements are part of a distribution

network, in particular part of a fiber-optic, power or telecommunication cable distribution network.

4. The method as claimed in any of the preceding claims, characterized in that image data and depth data of a plurality of frames of a scene containing a plurality of exposed infrastructure elements arranged underground are captured and a 3D point cloud having a plurality of points is generated on the basis of these image data and depth data.

5. The method as claimed in any of the preceding claims, characterized in that the one or more receivers (2) are additionally designed to receive signals, in particular reference or correction signals, from land-based reference stations.

6. The method as claimed in any of the preceding claims, characterized in that the LIDAR measuring device of the 3D reconstruction device (4) is configured as solid-state LIDAR.

7. The method as claimed in any of the preceding claims, characterized in that respective color or grayscale value information is assigned to the points of the 3D point cloud, wherein the color or grayscale value information is preferably captured by means of the more than one 2D cameras of the 3D reconstruction device (4).

8. The method as claimed in any of the preceding claims, characterized in that a textured mesh model is generated on the basis of the 3D point cloud and the image data of the more than one 2D cameras.

9. The method as claimed in any of the preceding claims, characterized in that

- the first position indication of the position in the global reference system and/or raw data assigned to this position indication; and

- the one or more second position indications; and
- the one or more second orientation indications; and
- the captured image data and/or the captured depth data and/or the captured linear accelerations of the mobile capture apparatus (1) in three mutually orthogonal axes of the local reference system and also the angular velocities of the rotation of the mobile capture apparatus (1) about these axes;

are stored in a temporally synchronized manner, in particular in a storage unit (7) of the capture apparatus (1).

10. The method as claimed in any of the preceding claims, characterized in that the one or more second position indications in the respective local reference system are transformed into the global reference system, preferably by means of a rigid body transformation or Helmert transformation or by means of a principal axis transformation.

11. The method as claimed in any of the preceding claims, characterized in that allocating the georeference to the points of the 3D point cloud is effected by means of sensor data fusion, wherein a factor graph as a graphical model and/or an applied estimation method, in particular according to Levenberg-Marquardt, are/is preferably applied for optimization purposes, wherein the first position indications of the position in the global reference system are preferably used.

12. The method as claimed in any of the preceding claims, characterized in that the sensor data fusion is based on a nonlinear equation system, on the basis of which an estimation of the position and of the orientation of the mobile capture apparatus is effected.

13. The method as claimed in claim 12, characterized in that on the basis of the image data and depth data

captured by the 3D reconstruction device, at least one infrastructure element, in particular a line or a connection element, is detected and classified and the estimation of the position and of the orientation of the mobile capture apparatus on the basis of the nonlinear equation system is additionally effected on the basis of the results of the detection and classification of the infrastructure element.

14. The method as claimed in any of the preceding claims, characterized in that by means of the one or more receivers (2) of the mobile capture apparatus (1), signals from a maximum of three navigation satellites of the global navigation satellite system are received, wherein a respective georeference is allocated to the points of the 3D point cloud with an accuracy in the range of less than 10 cm, preferably less than 5 cm, preferably less than 3 cm.

15. The method as claimed in any of the preceding claims, characterized in that the second position indications of the position of the capture apparatus and/or the orientation indications of the mobile capture apparatus as prior information assist the resolution of ambiguities of differential measurements of carrier phases in order to georeference infrastructure elements even if the receiver reports a failure or determines a usable second position indication and/or orientation indication only for a short time by means of the inertial measurement unit.

16. The method as claimed in any of the preceding claims, characterized in that with the aid of the sensor data fusion regions of infrastructure elements recorded multiply or at different times, such as overlaps between two scenes, for example, are recognized and reduced to the temporally most recent captured region of the infrastructure elements.

17. The method as claimed in any of the preceding claims, characterized in that in order to ensure the quality of the one or more first position indications in the global reference system determined by the receiver(s) (2), one or more quality parameters of the global navigation satellite systems, for example DOP (abbreviation of Dilution of Precision), are monitored.

18. The method as claimed in any of the preceding claims, characterized in that a plausibility of a temporal sequence of first position indications of the position of the capture apparatus (1) in the global reference system is determined, preferably by a first velocity indication being determined on the basis of the temporal sequence of first position indications and a second velocity indication being calculated on the basis of the captured linear accelerations and angular velocities and being compared with the first velocity indication.

19. The method as claimed in any of the preceding claims, characterized in that on the basis of the 3D point cloud and/or on the basis of the image data, at least one infrastructure element, in particular a line or a connection element, is detected and classified.

20. The method as claimed in claim 19, characterized in that one or more methods of image segmentation such as, for example, threshold value methods, in particular histogram-based methods, or texture-oriented methods, region-based methods, or else pixel-based methods such as, for example, support vector machine, decision trees and neural networks are used for the detection, classification and/or segmentation of an infrastructure element.

21. The method as claimed in claim 19 or 20, characterized in that at least one histogram of color and/or grayscale value information, and/or saturation value information and/or brightness value information

and/or of an electromagnetic wave spectrum of a plurality of points of the 3D point cloud is generated for the detection, classification and/or segmentation.

22. The method as claimed in claim 21, characterized in that in the histogram or histograms local maxima are detected and among the local maxima such maxima with the smallest separations with respect to a predefined color, saturation and brightness threshold value of an infrastructure element are detected.

23. The method as claimed in claim 22, characterized in that a group of points whose points do not exceed a predefined separation threshold value with respect to the color information composed of the detected local maxima is extended iteratively by further points which do not exceed a defined geometric and color separation with respect to those of the group, in order to form a locally continuous region of an infrastructure element with similar color information.

24. The method as claimed in any of claims 19 to 23, characterized in that for the detection, classification and/or segmentation of the infrastructure elements and/or for improved distance measurement and/or for initialization of the absolute orientation, a light spot of a laser pointer (5) of the capture apparatus (1) is captured and/or displayed in a display device(8).

25. The method as claimed in any of claims 19 to 24, characterized in that for the detection, classification and/or segmentation of the infrastructure elements, color or grayscale value information of the captured image data, in particular color or grayscale value information of the points of the 3D point cloud, and/or the captured depth data and associated label information are fed to an artificial neural network for training purposes.

26. The method as claimed in any of the preceding claims, characterized in that for each detected

infrastructure element an associated 3D object is generated, in particular on the basis of the 3D point cloud.

27. The method as claimed in any of the preceding claims, characterized in that an optical vacancy between two 3D objects is recognized and a connection 3D object, in particular as a 3D spline, is generated for closing the optical vacancy.

28. The method as claimed in claim 27, characterized in that for recognizing the optical vacancy, a feature of a first end of a first 3D object and the same feature of a second end of a second 3D object are determined, wherein the first and second features are compared with one another and the first and second features are a diameter or a color or an orientation or a georeference.

29. The method as claimed in claim 27, characterized in that the mobile capture apparatus (1) is put into an optical vacancy mode and is moved proceeding from the first end to the second end.

30. The method as claimed in any of the preceding claims, characterized in that the mobile capture apparatus (1) comprises a device for voice control.

31. The method as claimed in claim 30, characterized in that an acoustic output of input requests and/or information, in particular feedback messages and/or warnings, is effected by means of the device for voice control.

32. The method as claimed in either of claims 30 and 31, characterized in that auditory information is recognized by means of the device for voice control and the georeference is allocated to the points of the 3D point cloud additionally on the basis of the auditory information.

33. The method as claimed in any of the preceding claims, characterized in that by means of a display device (8) of the mobile capture apparatus (1)

- a representation of the 3D point cloud and/or
- a textured mesh model generated on the basis of the 3D point cloud and the image data of the more than one 2D cameras and/or
- 3D objects corresponding to infrastructure elements and/or
- a 2D location plan and/or
- a parts list of infrastructure elements and/or
- a superposition of image data of a 2D camera of the capture apparatus with a projection of one or more 3D objects corresponding to an infrastructure element and/or
- a superposition of image data of a 2D camera of the capture apparatus with a projection of a plurality of points of the 3D point cloud

are/is displayed.

34. A mobile capture apparatus (1) for the positionally correct capture of exposed infrastructure elements having a diameter of less than 30 cm and are arranged underground, in particular in an open excavation, comprising:

- a 3D reconstruction device (4) for capturing image data and depth data of a scene containing at least one exposed infrastructure element arranged underground, and for generating a 3D point cloud having a plurality of points on the basis of these image data and depth data;
- one or more receivers (2) for receiving signals of one or more global navigation satellite systems and for determining a first position indication of the position of the capture apparatus (1) in a global reference system;
- an inertial measurement unit (3) for determining a second position indication of the position of the capture apparatus (1) in a local reference system and an orientation indication of the

orientation of the capture apparatus (1) in the local reference system, wherein the inertial measurement unit (3) is designed to capture linear accelerations of the mobile capture apparatus (1) in three mutually orthogonal principal axes of the local reference system and angular velocities of the rotation of the mobile capture apparatus (1) about these principal axes; and

wherein the 3D reconstruction device (4) comprises more than one 2D cameras, by means of which the image data and the depth data of the scene are capturable, wherein a second position indication of the position of the capture apparatus in the local reference system and the orientation indication are determinable by means of visual odometry on the basis of the image data and the depth data;

and

wherein the 3D reconstruction device (4) comprises a LIDAR measuring device, by means of which depth data of the scene are capturable, wherein a second position indication of the position of the capture apparatus in the local reference system and the orientation indication are effected by means of visual odometry on the basis of the depth data;

- wherein the capture apparatus is configured to allocate a respective georeference to the points of the 3D point cloud, on the basis of the first position indication and a plurality of the second position indications and also a plurality of the orientation indications;
- wherein the mobile capture apparatus (1) is able to be carried by a person, wherein the mobile capture apparatus (1) is able to be held by both hands of a person, preferably by one hand of a person, and has a housing (9), the largest edge length of which is less than 50 cm, wherein the receiver(s) (2), the inertial measurement unit

(3) and the 3D reconstruction device (4) are arranged in the housing (9).

35. The mobile capture apparatus as claimed in claim 34, characterized in that the receiver(s) (2) is/are designed to receive and to process signals of land-based reference stations, preferably with correction data from reference services.

36. The mobile capture apparatus as claimed in either of claims 34 and 35, characterized in that the 3D reconstruction device (4) comprises a time-of-flight camera, a structured light camera, a RADAR measuring device and/or a combination thereof among one another.

37. The mobile capture apparatus as claimed in any of claims 34 to 36, characterized by a display device (8) for displaying display data and a data processing device (6) designed to provide display data comprising

- a representation of the 3D point cloud and/or
- a textured mesh model generated on the basis of the 3D point cloud and the image data of the more than one 2D cameras and/or
- 3D objects corresponding to infrastructure elements and/or
- a 2D location plan and/or
- a parts list of infrastructure elements and/or
- a superposition of image data of a 2D camera of the capture apparatus with a projection of one or more 3D objects corresponding to an infrastructure element and/or
- a superposition of image data of a 2D camera of the capture apparatus with a projection of a plurality of points of the 3D point cloud.

38. The mobile capture apparatus as claimed in any of claims 34 to 37, characterized by a laser pointer (5) for optically marking infrastructure elements and/or for extended distance measurement and/or for initializing the orientation in the display direction.

39. The mobile capture apparatus as claimed in any of claims 34 to 38, characterized by a polarization filter for avoiding glare, specular reflection and reflections for the purpose of increasing quality and optimization of the observation data.

40. The mobile capture apparatus as claimed in any of claims 34 to 39, characterized by one or more illumination devices for improved detection, classification and/or segmentation of infrastructure elements.

41. The mobile capture apparatus as claimed in any of claims 34 to 40, characterized in that the mobile capture apparatus (1) comprises a device for voice control.

42. The mobile capture apparatus as claimed in claim 41, characterized in that the device for voice control is designed to enable an acoustic output of input requests and/or information, in particular feedback messages and/or warnings.

43. The mobile capture apparatus as claimed in any of claims 34 to 42, characterized in that the LIDAR measuring device of the 3D reconstruction device (4) is configured as solid-state LIDAR.