

DESCRIPTION

Invention Title: APPARATUS AND METHOD FOR SIMULTANEOUS LOCALIZATION AND MAPPING

Technical Field

[1] The present invention relates to a simultaneous localization and mapping apparatus and method having robustness for various environmental conditions.

[2]

Background Art

[3] Simultaneous localization and mapping (SLAM, SIMULTANEOUS LOCALIZATION AND MAPPING) technology is a technology for creating a map of surrounding environment while estimating locations of autonomous vehicles, robots, etc. on the created map during movement of the autonomous vehicles, robots, etc.

[4] According to the simultaneous localization and mapping technology, locations of autonomous vehicles, robots, etc. can be identified even in unknown environments, and based on this, it becomes possible to help movement of autonomous vehicles, robots, etc. such as generating movement paths or avoiding obstacles.

[5] For such simultaneous localization and mapping, images of surrounding environment acquired through sensors such as cameras can be utilized, and performance of location estimation and mapping varies according to quality of the images.

[6] In general, simultaneous localization and mapping assumes ideal conditions such as little or no occlusion or changes in surrounding environment, but depending on actual application environments, constraints such as existence of occlusion

areas due to surrounding obstacles or changes in illumination may exist.

[7] Therefore, in order to improve performance of simultaneous localization and mapping, it is necessary to present a method that can mitigate effects caused by changes in surrounding environment.

[8]

[9] The matters described as the background art are merely for enhancing understanding of the background of the present invention, and should not be taken as acknowledging that they correspond to prior art already known to those having ordinary knowledge in this technical field.

[10]

Detailed Description of the Invention

Technical Problem

[11] An object of the present invention is to provide a simultaneous localization and mapping apparatus and method having robustness for various environmental conditions by adjusting parameters for photographing conditions and reflecting various parameters to features for location estimation and mapping.

[12]

[13] The problems of the present invention are not limited to the problems mentioned above, and other problems not mentioned will be clearly understood by those skilled in the art from the description below.

[14]

Solution to the Problem

[15] A simultaneous localization and mapping apparatus according to an embodiment of the present invention for realizing the

above-mentioned problem comprises: a sensor unit provided at a moving object, photographing surroundings of the moving object during movement of the moving object, and including at least one camera capable of adjusting parameters for photographing conditions; a parameter adjustment unit for determining satisfaction status of visual field conditions according to the at least one parameter for images collected through the photographing, and adjusting the parameters so that the visual field conditions are satisfied; a visual map generation unit for generating a visual map configured such that one or more features each having multiple models according to locations and parameters of the at least one camera are connected; and a location estimation unit for estimating a location of the moving object through matching between features extracted from images satisfying the visual field conditions and features of the visual map, and outputting the estimated location of the moving object.

- [16] For example, the apparatus may further comprise a feature map generation unit for generating feature maps for each of the at least one camera by linking parameters corresponding to each of the at least one camera with the extracted features, and the visual map generation unit may generate the visual map based on the feature maps and relative locations between the at least one camera.
- [17] For example, the at least one camera may be provided at different locations of the moving object, each photographing surroundings of the moving object in different directions.
- [18] For example, the at least one camera may be provided at least one of front side, lateral side, rear side, and front-oblique side of the moving object.
- [19] For example, time information according to photographing time may be added to the images.

- [20] For example, the parameters may include at least one of focus, focal length, exposure, and gain.
- [21] For example, the visual field conditions may be determined based on at least one of occlusion range of the images, number of objects included in the images, and brightness of the images.
- [22] For example, the location estimation unit may determine reliability of the estimated location of the moving object based on number of the extracted features and number of features on the visual map corresponding to the extracted features, and output the estimated location of the moving object based on the determined reliability.
- [23] For example, the location estimation unit may further output route guidance information based on the estimated location of the moving object.
- [24] For example, the route guidance information may include waypoints for reaching a destination.
- [25] For example, the visual map generation unit may add models for each feature on the visual map based on the extracted features.
- [26] For example, the visual map generation unit may replace models for each feature on the visual map so that number of the models does not exceed a predetermined value based on weights of each model when the number of the models reaches a predetermined value.
- [27] For example, each of the multiple models may be defined according to location of the feature on the visual map, descriptor corresponding to surrounding characteristics of the location information, and the parameters.
- [28] For example, the location estimation unit may determine relative locations between the extracted features and the features of the visual map through matching between features

extracted from images satisfying the visual field conditions and features of the visual map, and estimate the location of the moving object based on the determined relative locations.

[29]

[30] A simultaneous localization and mapping method according to an embodiment of the present invention for realizing the above-mentioned problem comprises: collecting images through a sensor unit provided at a moving object, photographing surroundings of the moving object during movement of the moving object, and including at least one camera capable of adjusting parameters for photographing conditions; determining satisfaction status of visual field conditions for images collected through the photographing based on the at least one parameter, and adjusting the parameters so that the visual field conditions are satisfied; generating a visual map configured such that one or more features each having multiple models according to locations and parameters of the at least one camera are connected; and estimating a location of the moving object through matching between features extracted from images satisfying the visual field conditions and features of the visual map, and outputting the estimated location of the moving object.

[31]

Effects of the Invention

[32] According to various embodiments of the present invention as described above, it becomes possible to secure a wider range of visual field through adjustment of parameters for photographing conditions, and improve quality of images for feature extraction by mitigating effects caused by illumination changes in surrounding environment.

[33] In addition, performance of feature extraction can be improved through quality improvement of images, and through this, it becomes possible to secure performance of location

estimation and mapping even in open spaces where feature extraction is difficult, and help traveling in unknown environments without coordinate information or map information.

[34] In addition, by reflecting various parameters to features, it becomes possible to improve location estimation and mapping performance for various environmental conditions.

[35]

[36] *

[37] The effects obtainable from the present invention are not limited to the effects mentioned above, and other effects not mentioned will be clearly understood by those having ordinary knowledge in the technical field to which the present invention belongs from the description below.

[38]

Brief Description of Drawings

[39] FIG. 1 is a diagram showing configuration of a simultaneous localization and mapping apparatus according to an embodiment of the present invention.

[40] FIG. 2 is a diagram for explaining a feature extraction process according to an embodiment of the present invention.

[41] FIG. 3 is a flowchart of a simultaneous localization and mapping process according to an embodiment of the present invention.

[42]

Modes for Carrying Out the Invention

[43] Specific structural or functional descriptions for embodiments of the present invention disclosed in this specification or application are merely illustrated for the purpose of describing embodiments according to the present

invention, and embodiments according to the present invention may be implemented in various forms and should not be interpreted as being limited to the embodiments described in this specification or application.

- [44] Since embodiments according to the present invention can make various changes and have various forms, specific embodiments are illustrated in the drawings and will be described in detail in this specification or application. However, this is not intended to limit embodiments according to the concept of the present invention to specific disclosure forms, and should be understood to include all changes, equivalents, and substitutes included in the spirit and technical scope of the present invention.
- [45] Unless defined otherwise, all terms used herein, including technical or scientific terms, have the same meaning as commonly understood by those having ordinary knowledge in the technical field to which the present invention belongs. Terms such as those defined in commonly used dictionaries should be interpreted as having meanings consistent with meanings in the context of related technology, and unless explicitly defined in this specification, they are not interpreted as ideal or excessively formal meanings.
- [46] Hereinafter, embodiments disclosed in this specification will be described in detail with reference to the attached drawings, but the same or similar components will be given the same reference numbers regardless of drawing symbols, and redundant descriptions thereof will be omitted.
- [47] In the description of the following embodiments, the term "predetermined" means that numerical values of parameters are determined in advance when using parameters in processes or algorithms. Numerical values of parameters may be set when processes or algorithms start or may be set during intervals when processes or algorithms are performed according to embodiments.

- [48] Suffixes "module" and "unit" for components used in the following description are given or used interchangeably considering only ease of specification writing, and do not have meanings or roles that are distinguished from each other by themselves.
- [49] In describing embodiments disclosed in this specification, when it is determined that specific descriptions of related known technologies may obscure the gist of embodiments disclosed in this specification, detailed descriptions thereof are omitted. In addition, attached drawings are only for easily understanding embodiments disclosed in this specification, and technical ideas disclosed in this specification are not limited by the attached drawings, and should be understood to include all changes, equivalents, and substitutes included in the spirit and technical scope of the present invention.
- [50] Terms including ordinal numbers such as first and second may be used to describe various components, but the components are not limited by the terms. The terms are used only for the purpose of distinguishing one component from another component.
- [51] When a component is referred to as being "connected" or "accessed" to another component, it should be understood that it may be directly connected or accessed to the other component, but other components may exist in between. On the other hand, when a component is referred to as being "directly connected" or "directly accessed" to another component, it should be understood that no other components exist in between.
- [52] Singular expressions include plural expressions unless the context clearly indicates otherwise.
- [53] In this specification, terms such as "include" or "have" are intended to designate that features, numbers, steps, operations, components, parts, or combinations thereof

described in the specification exist, and should not be understood as precluding existence or addition possibilities of one or more other features, numbers, steps, operations, components, parts, or combinations thereof.

[54]

[55] Simultaneous localization and mapping apparatus and method according to embodiments of the present invention propose to improve quality of images for feature extraction through adjustment of parameters for photographing conditions and enable simultaneous localization and mapping to have robustness under various environmental conditions by reflecting various parameters to extracted features.

[56] Hereinafter, before describing a simultaneous localization and mapping method according to an embodiment of the present invention, configuration of a simultaneous localization and mapping apparatus according to an embodiment of the present invention will be described first with reference to FIG. 1.

[57]

[58] FIG. 1 is a diagram showing configuration of a simultaneous localization and mapping apparatus according to an embodiment of the present invention.

[59] Referring to FIG. 1, simultaneous localization and mapping apparatus 10 may include sensor unit 100, parameter adjustment unit 200, feature map generation unit 300, location estimation unit 400, and visual map generation unit 500. However, FIG. 1 shows components mainly related to descriptions of an embodiment of the present invention, and actual simultaneous localization and mapping apparatus 10 may be implemented including more or fewer components than this.

[60] Hereinafter, each component will be described.

[61] First, sensor unit 100 is provided at a moving object, photographs surroundings of the moving object during movement

of the moving object, and includes at least one camera capable of adjusting parameters for photographing conditions.

- [62] Here, parameters for photographing conditions may include at least one of focus, focal length, exposure, and gain, and resolution, sharpness, brightness, magnification/reduction ratio, etc. of photographed images may vary according to parameters for photographing conditions.
- [63] In addition, at least one camera may be provided at different locations of the moving object, each photographing surroundings of the moving object in different directions. As the number of directions that cameras photograph increases in this way, images for location estimation and mapping can have a wider visual field range, and more features can be extracted therefrom.
- [64] For this, cameras may be provided at least one of front side, lateral side, rear side, and front-oblique side of the moving object, and cameras provided at different locations may photograph images having visual field ranges that do not overlap with each other based on the moving object.
- [65] Meanwhile, when images are collected through multiple cameras in this way, time information according to photographing time may be added to the collected images.
- [66] Time information may include, for example, time when images are photographed or stored, or order of photographing or storage, etc.
- [67] Such time information may be utilized to classify images to which identical or corresponding time information is added among images collected through multiple cameras.
- [68] In particular, images classified according to time information may be combined to derive an entire visual field range for surrounding environment of the moving object.
- [69]

- [70] Parameter adjustment unit 200 may determine satisfaction status of visual field conditions according to parameters for images collected through photographing, and adjust the parameters so that visual field conditions are satisfied.
- [71] Here, visual field conditions can be understood as criteria for evaluating reliability of collected images, and satisfaction status of visual field conditions may depend on parameters.
- [72] That is, parameter adjustment unit 200 may determine reliability of collected images through determination of satisfaction status of visual field conditions, and may adjust photographing conditions of cameras to improve reliability of collected images.
- [73] In this case, visual field conditions may be determined based on at least one of occlusion range of images, number of objects included in the images, and brightness of the images.
- [74] For example, parameter adjustment unit 200 may determine that visual field conditions are not satisfied when proportion of occlusion range in collected images exceeds a predetermined proportion in entire range of images, when number of objects included in images is less than a predetermined number, when brightness of images deviates from a predetermined brightness range, when sharpness is less than a predetermined value, etc.
- [75] When visual field conditions are not satisfied in this way, parameter adjustment unit 200 may adjust parameters so that visual field conditions are satisfied.
- [76] For example, parameter adjustment unit 200 may adjust focus of cameras so that sharpness satisfies visual field conditions, or may adjust gamma so that brightness of images satisfies visual field conditions.
- [77] In this way, parameter adjustment unit 200 may adjust parameters for photographing conditions in response to

changes in surrounding environment, and through this, it becomes possible to effectively collect images for location estimation and mapping even in various environments.

[78]

[79] Meanwhile, feature map generation unit 300 may generate feature maps for each of at least one camera by linking parameters corresponding to each of at least one camera with features extracted from collected images.

[80] Number of generated feature maps may be determined according to total number of cameras, and each feature map may include features extracted from images photographed through corresponding cameras, and each feature may be associated with parameters for cameras corresponding to the corresponding feature map.

[81]

[82] Location estimation unit 400 may estimate location of the moving object through matching between features extracted from images satisfying visual field conditions and features of visual map generated through visual map generation unit 500.

[83] More specifically, location estimation unit 400 may determine relative locations between extracted features and features of the visual map through matching between features extracted from images satisfying visual field conditions and features of the visual map.

[84] When relative locations between features extracted from images and features of the visual map are determined, location estimation unit 400 may estimate location of the moving object based on the determined relative locations.

[85] When location of the moving object is estimated, location estimation unit 400 may output the estimated location of the moving object.

- [86] In addition, location estimation unit 400 may determine reliability of the estimated location of the moving object based on number of extracted features and number of features on the visual map corresponding to the extracted features.
- [87] Location estimation unit 400 may output the estimated location of the moving object based on the determined reliability, and through this, it becomes possible to improve location estimation performance of the moving object.
- [88] Furthermore, location estimation unit 400 may not only provide estimated location of the moving object, but also further output route guidance information based on the estimated location of the moving object.
- [89] Such route guidance information may include waypoints for reaching a destination, and through this, it becomes possible to help the moving object move efficiently toward the destination even under conditions where GPS (Global Locationing System), etc. cannot be utilized.
- [90]
- [91] Meanwhile, visual map may be configured such that one or more features each having multiple models according to locations and parameters of at least one camera are connected.
- [92] More specifically, each of multiple models for features may be defined according to location of the feature on the visual map, descriptor corresponding to surrounding characteristics of location information, and parameters.
- [93] For example, any one model (X_1) among multiple models for any one feature may be expressed as follows.
- [94] $X_1 = (P_1, [(D_1, C_1)_1, (D_1, C_1)_2, \dots, (D_1, C_1)_m])$
- [95] Here, P may have values for x , y , z axis coordinates on the visual map for the corresponding model, D may have descriptor

corresponding to surrounding characteristics of location information, and C may have values for parameters of cameras.

[96] In addition, visual map generation unit 500 may generate visual map based on feature maps generated by feature map generation unit 300 and relative locations between at least one camera.

[97] For example, visual map generation unit 500 may determine relative locations between each feature map based on relative locations between cameras, and may generate visual map by combining features included in each feature map according to the determined relative locations.

[98] In addition, visual map generation unit may add models for each feature on the visual map based on extracted features.

[99] In this case, visual map generation unit may replace models for each feature on the visual map so that number of models does not exceed a predetermined value based on weights of each model when number of models reaches a predetermined value.

[100] Each component of simultaneous localization and mapping apparatus 10 may be implemented including communication devices that communicate with sensors, memory that stores operating systems or logic commands and input/output information, and one or more processors that perform judgments, calculations, decisions, etc. necessary for controlling corresponding functions to perform the above functions.

[101] Hereinafter, feature extraction process will be described with reference to FIG. 2.

[102]

[103] FIG. 2 is a diagram for explaining a feature extraction process according to an embodiment of the present invention.

- [104] Referring to FIG. 2, cameras may be provided at front side, front-oblique side, lateral side, and rear side of Moving Device, and each camera may photograph surrounding environments in different directions based on Moving Device.
- [105] Features may be extracted from images photographed through each camera, and for example, may be extracted according to objects included in photographed images.
- [106] Feature maps (Feature map #1-#3) may be generated for each camera, and each feature map (Feature map #1-#3) may include features extracted from images photographed through each camera.
- [107] In addition, parameters of corresponding cameras may be reflected in each feature map (Feature map #1-#3) (Camera Parameters #1-#3).
- [108] Hereinafter, process of simultaneous localization and mapping described so far will be described with reference to FIG. 3.
- [109]
- [110] FIG. 3 is a flowchart of a simultaneous localization and mapping process according to an embodiment of the present invention.
- [111] Referring to FIG. 3, first, parameter adjustment unit 200 may collect images photographed through each camera of sensor unit 100 and parameters for each camera in step S301, and determine satisfaction status of visual field conditions of collected images in step S302.
- [112] When visual field conditions are not satisfied (No in step S302), parameter adjustment unit 200 adjusts parameters so that visual field conditions are satisfied in step S303, and when visual field conditions are satisfied (Yes in step S302), parameter adjustment unit 200 stores parameters in step S304.

[113] Feature map generation unit 300 generates feature maps including features extracted from images satisfying visual field conditions in step S305, and location estimation unit 400 matches generated feature maps with visual map in step S306 to determine relative locations between features in step S307, and estimates location of the moving object according to determination results in step S308.

[114] Thereafter, visual map generation unit 500 may update features of the visual map through newly extracted features, and updated visual map may be utilized again for location estimation.

[115]

[116] According to various embodiments of the present invention as described above, it becomes possible to secure a wider range of visual field through adjustment of parameters for photographing conditions, and improve quality of images for feature extraction by mitigating effects caused by illumination changes in surrounding environment.

[117] In addition, performance of feature extraction can be improved through quality improvement of images, and through this, it becomes possible to secure performance of location estimation and mapping even in open spaces where feature extraction is difficult, and help traveling in unknown environments without coordinate information or map information.

[118] In addition, by reflecting various parameters to features, it becomes possible to improve location estimation and mapping performance for various environmental conditions.

[119]

[120] Although the present invention has been shown and described with respect to specific embodiments as described above, it will be apparent to those having ordinary knowledge

in the art that the present invention may be variously improved and changed within limits that do not depart from technical spirit of the present invention provided by the following claims.

[121]

[122] [Description of Reference Numerals]

[123] 100: sensor unit

[124] 200: parameter adjustment unit

[125] 300: feature map generation unit

[126] 400: location estimation unit

[127] 500: visual map generation unit

CLAIMS

[Claim 1] A simultaneous localization and mapping apparatus comprising:

a sensor unit provided at a moving object, photographing surroundings of the moving object during movement of the moving object, and including at least one camera capable of adjusting parameters for photographing conditions;

a parameter adjustment unit for determining satisfaction status of visual field conditions according to the at least one parameter for images collected through the photographing, and adjusting the parameters so that the visual field conditions are satisfied;

a visual map generation unit for generating a visual map configured such that one or more features each having multiple models according to locations and parameters of the at least one camera is connected; and

a location estimation unit for estimating a location of the moving object through matching between features extracted from images satisfying the visual field conditions and features of the visual map, and outputting the estimated location of the moving object.

[Claim 2] The simultaneous localization and mapping apparatus of claim 1, further comprising:

a feature map generation unit for generating feature maps for each of the at least one camera by linking parameters corresponding to each of the at least one camera with the extracted features,

wherein the visual map generation unit generates the visual map based on the feature maps and relative locations between the at least one camera.

[Claim 3] The simultaneous localization and mapping apparatus of claim 1, wherein the at least one camera is provided at

different locations of the moving object, each photographing surroundings of the moving object in different directions.

[Claim 4] The simultaneous localization and mapping apparatus of claim 2, wherein the at least one camera is provided at least one of front side, lateral side, rear side, and front-oblique side of the moving object.

[Claim 5] The simultaneous localization and mapping apparatus of claim 2, wherein time information according to photographing time is added to the images.

[Claim 6] The simultaneous localization and mapping apparatus of claim 1, wherein the parameters include at least one of focus, focal length, exposure, and gain.

[Claim 7] The simultaneous localization and mapping apparatus of claim 1, wherein the visual field conditions are determined based on at least one of occlusion range of the images, number of objects included in the images, and brightness of the images.

[Claim 8] The simultaneous localization and mapping apparatus of claim 1, wherein the location estimation unit determines reliability of the estimated location of the moving object based on number of the extracted features and number of features on the visual map corresponding to the extracted features, and outputs the estimated location of the moving object based on the determined reliability.

[Claim 9] The simultaneous localization and mapping apparatus of claim 1, wherein the location estimation unit further outputs route guidance information based on the estimated location of the moving object.

[Claim 10] The simultaneous localization and mapping apparatus of claim 9, wherein the route guidance information includes waypoints for reaching a destination.

[Claim 11] The simultaneous localization and mapping apparatus of claim 1, wherein the visual map generation unit adds

models for each feature on the visual map based on the extracted features.

[Claim 12] The simultaneous localization and mapping apparatus of claim 10, wherein the visual map generation unit replaces models for each feature on the visual map so that number of the models does not exceed a predetermined value based on weights of each model when the number of the models reaches the predetermined value.

[Claim 13] The simultaneous localization and mapping apparatus of claim 1, wherein each of the multiple models is defined according to location of the feature on the visual map, descriptor corresponding to surrounding characteristics of the location information, and the parameters.

[Claim 14] The simultaneous localization and mapping apparatus of claim 1, wherein the location estimation unit determines relative locations between the extracted features and the features of the visual map through matching between the features extracted from the images satisfying the visual field conditions and the features of the visual map, and estimates the location of the moving object based on the determined relative locations.

[Claim 15] A simultaneous localization and mapping method comprising:

collecting images through a sensor unit provided at a moving object, photographing surroundings of the moving object during movement of the moving object, and including at least one camera capable of adjusting parameters for photographing conditions;

determining satisfaction status of visual field conditions for images collected through the photographing based on the at least one parameter, and adjusting the parameters so that the visual field conditions are satisfied;

generating a visual map configured such that one or more features each having multiple models according to locations and parameters of the at least one camera is connected; and

estimating a location of the moving object through matching between features extracted from images satisfying the visual field conditions and features of the visual map, and outputting the estimated location of the moving object.