様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

令和　６ 年　 ６ 月 １３ 日現在

機関番号：３２６４１
研究種目：研究活動スタート支援
研究期間：2020～2023
課題番号：２０Ｋ２２３８３

研究課題名（和文）360-Degree Camera based Fast Indoor Localization using Image Gradients

研究課題名（英文）360-Degree Camera based Fast Indoor Localization using Image Gradients

研究代表者
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交付決定額（研究期間全体）：（直接経費）　　2,200,000円

研究成果の概要（和文）：本研究で屋内環境内で360度動画像からリアルタイムで位置姿勢推定方法を構築した．360度正距円筒画像内で映る環境の直線情報を検出するに基づきカメラの姿勢を算出し、環境のモデルとのフィッティングにより位置を算出した．直線情報の検出には画像の勾配情報のみを持つことで高速な処理を可能となった．その結果、15.5FPSの高速な位置姿勢推定が可能となった．

研究成果の学術的意義や社会的意義
This research made it possible to estimate 360-degree camera position and orientation at high speed using only image gradients. It showed that it was possible to use image gradients for detection in textureless environments without depending on explicit detection of lines or other features.

研究成果の概要（英文）：In this research, a novel method to use the 3D line information to perform 6 degree-of-freedom localization in indoor environments was proposed. This method was based on using 360-degree image gradient information to calculate 2D image lines and match them to 3D lines in the environmental model.

研究分野：Image processing

キーワード：360-degree images　localization　image processing

１．研究開始当初の背景

Fast and accurate 6 DoF positioning in indoor environments is necessary for many applications such as drone navigation, robot-based inspection, etc. It can be solved using artificial landmarks and motion capture systems. However, these require prior preparation and installation and are costly and inefficient. Instead, architectural maps of indoor environments can easily be obtained. These maps contain 3D line information of the environment. These lines can also be detected in 2D, inside image frames captured from a spherical camera. In this research, a novel method to use the 3D line information to perform 6 degree-of-freedom localization of a drone in indoor environments was proposed. This method was based on using 360-degree image gradient information to calculate 2D image lines and match them to 3D lines in the environmental model.

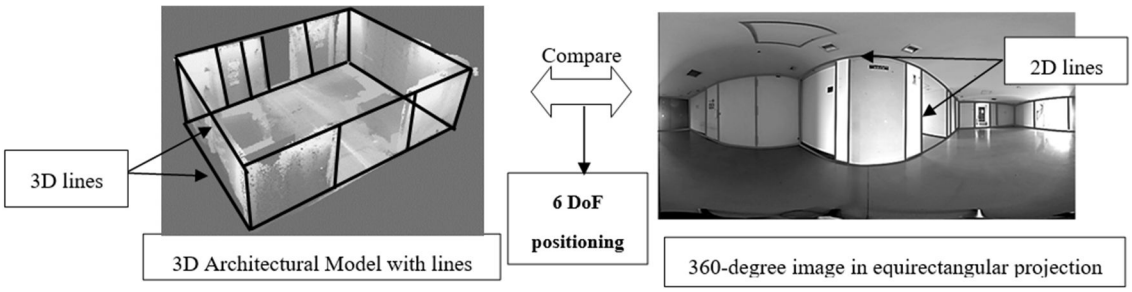


Fig. 1: Aim of the proposed research: Using image gradients to compare 3D lines (left) with 2D lines in a 360 degree image (right) for 6 DoF Positioning

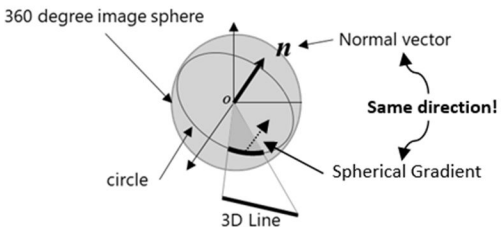
２．研究の目的

The main aim of this research was to develop a novel method to use image gradient information for fast 6 DoF localization in indoor environments. To perform indoor positioning using cameras, it is necessary to compare some features (landmarks) between the images and the environment. However, indoor environments are textureless, making this difficult. Moreover, easily available architectural maps of indoor environments contain information only about the edges and lines. The precise goals of this research, as shown in Fig. 1, were to 1. extract line features fast 2. compare them to 3D environment map [1], to achieve fast 6 degree-of-freedom indoor positioning. The originality of this research is to calculate line features using only 360-degree image gradients.

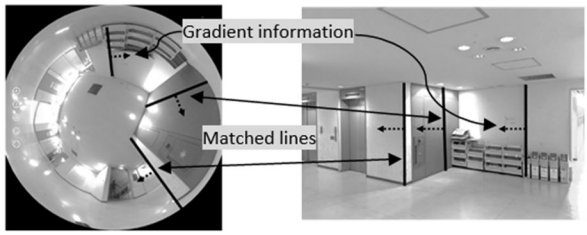
３．研究の方法

The following novel idea was used for this research. For a planar image, multiple lines can exist with the same gradient, as shown in Fig. 2. However, for a 360-degree image, due to the curvature, only one gradient direction uniquely defines the projection of the 3D line. The core method for orientation estimation was as follows: 1. First, spherical image gradients were extracted along all the edges of the image. 2. Image gradients were filtered and only those gradients that lie along three perpendicular directions were retained, via a filtering algorithm that excluded outliers (gradients/lines not lying along three perpendicular directions). 3. The three perpendicular directions in the image were fitted using a method similar to [2] and the orientation was estimated.

Position estimation: Once the orientation was found, the gradients lying in the perpendicular directions were compared to the architectural model in order to estimate the position. The comparisons were done individually in the xy, yz, and xz planes using least squares fitting to obtain the orientations in the z, x, and y directions, respectively.



a) Calculation of lines via Spherical Image Gradient



b) Calculation of 360-degree image lines based on gradients (left) and comparison to 3D environment model (right)

Fig. 2: (a) Unique 360-degree spherical image gradients are calculated (b) Gradient directions are compared to the environment line directions for fast localization.

4．研究成果

The algorithm was tested quantitatively by rendering 360-degree images in a virtual "Blender" environment. Qualitative testing in real environments was also done. Fig. 3 shows the gradients in 3 directions that were fitted on the 360-degree image. The gradients in black points are the outliers. Meanwhile, Fig. 4 shows the orientation estimation errors. As can be seen, they are much lower than other conventional methods. The processing speed was 15.5 frames per second, indicating close to real-time performance. Unfortunately, position estimation errors were high at 0.57 m, average.

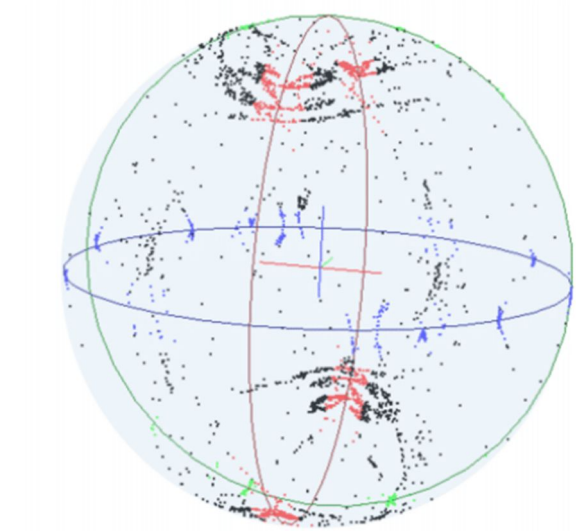


Fig. 3: Gradients on the 360-degree spherical image. Black gradients are the outliers.

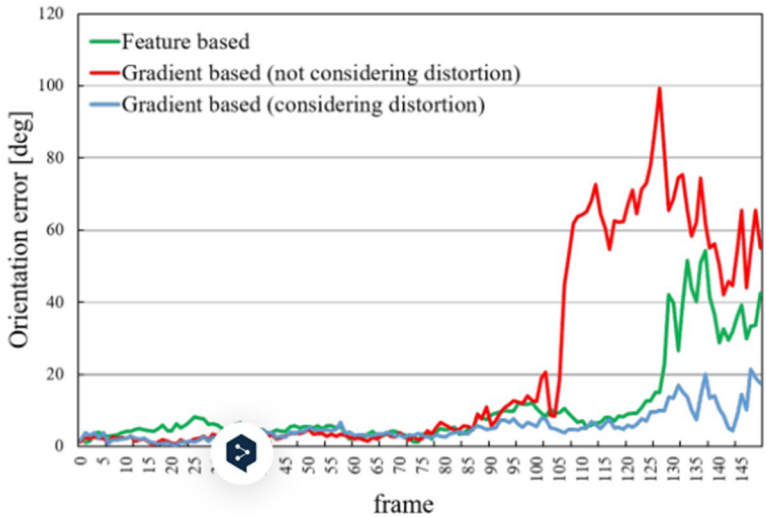


Fig. 4: Orientation estimation using different methods (blue: proposed method)

参考文献

[1] James M Coughlan and Alan L Yuille: "The Manhattan World Assumption: Regularities in Scene Statistics Which Enable Bayesian Inference", Proceedings of the 13th International Conference on Neural Information Processing Systems (NIPS2000), pp. 809-815, January 2000.

[2] Tsubasa Goto, Sarthak Pathak, Yonghoon Ji, Hiromitsu Fujii, Atsushi Yamashita and Hajime Asama: "Line-based Global Localization of a Spherical Camera in Manhattan Worlds", Proceedings of the 2018 IEEE International Conference on Robotics and Automation (ICRA2018), pp. 2296-2303, May 2018.

５．主な発表論文等

〔雑誌論文〕　計1件（うち査読付論文　1件／うち国際共著　1件／うちオープンアクセス　0件）

１．著者名 Iriyama Shingo、Pathak Sarthak、Umeda Kazunori	４．巻 2024
２．論文標題 Three-Dimensional Environmental Measurement of Surroundings Using Camera Pose Estimation Base on Line Features	５．発行年 2024年
３．雑誌名 Proceedings of the 2024 IEEE/SICE International Symposium on System Integration (SII)	６．最初と最後の頁 135,140
掲載論文のDOI（デジタルオブジェクト識別子） 10.1109/SII58957.2024.10417421	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

〔学会発表〕　計4件（うち招待講演　0件／うち国際学会　0件）

１．発表者名 入山 真伍, Pathak Sarthak, 梅田 和昇
２．発表標題 直線特徴量に基づくカメラの姿勢推定による屋内環境の3次元計測
３．学会等名 精密工学会学術講演会講演論文集
４．発表年 2023年

１．発表者名 陽 東旭, 樋口 寛, Sarthak Pathak, Alessandro Moro, 山下 淳, 淺間 一
２．発表標題 線分特徴とエッジのマッチングによる全天球カメラの位置推定
３．学会等名 動的画像処理実利用化ワークショップ2022（DIA2022）
４．発表年 2022年

１．発表者名 小笠 遼太, 濱田 拓海, Sarthak Pathak, 梅田 和昇
２．発表標題 全天球カメラによるドア高さ情報を用いた 自己位置推定のためのディスクリプタ設計
３．学会等名 日本機械学会ロボティクス・メカトロニクス講演会2022（ROBOMECH2022）
４．発表年 2022年

１．発表者名 入山 真伍, Pathak Sarthak, 梅田 和昇
２．発表標題 全天球カメラとリングレーザを用いた屋内3次元計測のためのキャリブレーション
３．学会等名 日本機械学会ロボティクス・メカトロニクス講演会2024（ROBOMECH2024）
４．発表年 2024年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関