실내환경에서의 2차원/3차원 Map Modeling 제작기법

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A 2D / 3D Map Modeling of Indoor Environment

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요 약

In large scale environments like airport, museum, large warehouse and department store, autonomous mobile robots will play an important role in security and surveillance tasks. Robotic security guards will give the surveyed information of large scale environments and communicate with human operator with that kind of data such as if there is an object or not and a window is open. Both for visualization of information and as human machine interface for remote control, a 3D model can give much more useful information than the typical 2D maps used in many robotic applications today. It is easier to understandable and makes user feel like being in a location of robot so that user could interact with robot more naturally in a remote circumstance and see structures such as windows and doors that cannot be seen in a 2D model.

In this paper we present our simple and easy to use method to obtain a 3D textured model. For expression of reality, we need to integrate the 3D models and real scenes. Most of other cases of 3D modeling method consist of two data acquisition devices. One for getting a 3D model and another for obtaining realistic textures. In this case, the former device would be 2D laser range-finder and the latter device would be common camera. Our algorithm consists of building a measurement-based 2D metric map which is acquired by laser range-finder, texture acquisition/stitching and texture-mapping to corresponding 3D model. The algorithm is implemented with laser sensor for obtaining 2D/3D metric map and two cameras for gathering texture. Our geometric 3D model consists of planes that model the floor and walls. The geometry of the planes is extracted from the 2D metric map data. Textures for the floor and walls are generated from the images captured by two 1394 cameras which have wide Field of View angle. Image stitching and image cutting process is used to generate textured images for corresponding with a 3D model.

The algorithm is applied to 2 cases which are corridor and space that has the four wall like room of building. The generated 3D map model of indoor environment is shown with VRML format and can be viewed in a web browser with a VRML plug-in. The proposed algorithm can be applied to 3D model-based remote surveillance system through WWW.

Keyword : 3D modeling, 2D map, Texture mapping, VRML

1. Introduction

In large scale environments like airport, museum, large warehouse and department store, autonomous mobile robots will play an important role in security and surveillance tasks. Robotic security guards will give the surveyed information of large scale environments and communicate with human operator with that kind of data such as if there is an object or not and a window is open. Both for visualization of information and as human machine interface for remote control, a 3D model can give much more useful information than the typical 2D maps used in many robotic applications today. It is easier to understandable and makes user feel like being in a location of robot so that user could interact with robot more naturally in a remote circumstance and see structures such as windows and doors that cannot be seen in a 2D model.

In this paper we present our simple and easy to use method to obtain a 3D textured model. For expression of reality, we need to integrate the 3D models and real scenes. Most of other cases of 3D modeling method consist of two data acquisition devices. One for getting a 3D model and another for obtaining realistic textures. In this case, the former device would be 2D laser range-finder and the latter device would be common camera. Our geometric 3D model consists of planes that model the floor and walls. The geometry of the planes is extracted from the 2D metric map data. Textures for the floor and walls are generated from the images captured by two 1394 cameras of our own making. Image stitching and image cutting process is used to generate textured images for corresponding with a 3D model.

So our approach builds a hybrid model of the environment by extracting geometry and using texture mapping. We believe that such hybrid techniques will outperform pure image based techniques like Aliaga's work [2]. In case of hybrid method that uses laser-range finder, the method needs to have the process of building a 2D map such as Peter's work [1]. In Peter's work, calibrated lager-range finder and panoramic camera used for generating 3D model and texture but those textures' quality is not very good enough to know situation of model for remote observer. Our method consists of building a 2D map and 3D model and mapping textures to corresponding model. The acquisition process is not operated simultaneously so that we need to add process that link a texture with a 3D model. This segmented process gives us advantage which is more realistic texture map.

2. System Overview

This section gives an overview of our method to build a 3D model of an indoor environment. From 2D flat drawing that we measure, we set the vertex point of 2D map especially for wall. We acquire texture images from 2 cameras at known location. The experimental devices that we use are described in section 3. From this data, the textured 3D model is constructed. Fig. 1 gives an overview of the method and shows the 3 main data flow between different modules. Our method consists of 4 main steps as follows.

① Calibration of Camera
② Data Collection
③ Building 2D map
④ Texture Generation

These processes are operated manually, semi-automatically and automatically. Data collection and image cropping parts are executed manually, and camera calibration and image stitching part are done semi-automatically with a user interface. The rest of the processing part is done automatically. 2D map measuring part is done manually in this case. After describing the hardware that we use for texture generation, above procedures are mentioned in remaining sections.

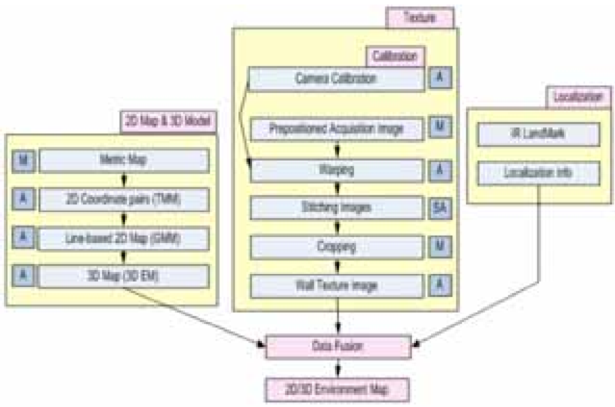


Fig. 1. An overview of our method to build 2D/3D model of an indoor environment.

3. Hardware

The 2D map measuring device that we use is LMS200 laser scanner and two IEEE-1394 cameras. Two cameras are set up like Fig. 2 in order to get wide view of texture. The LMS200 has 10mm accuracy with 180° scanning range and can measure up to 8m range. The IEEE-1394 Dragonfly camera with 2mm lens has a viewing angle of 96° for horizontal direction and 80° for vertical direction. With two cameras we can obtain wider viewing angle of texture. Camera has been calibrated before obtaining data using a calibration cube pattern. It is assumed that the camera and laser scanner is set up in parallel to ground plane.

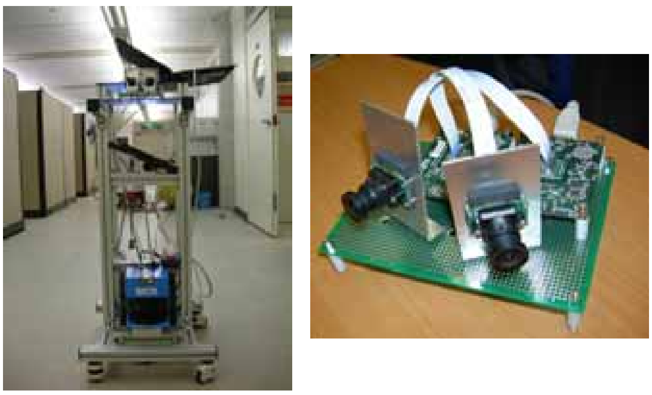


Fig. 2. Hardware. Laser scanner and IEEE-1394 dragonfly camera pair are set up in moving kart.

4. Calibration

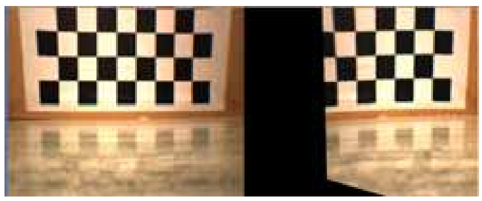
Camera calibration process consists of two steps. First calibration is for getting radial distortion parameter and the last one is for obtaining external parameter between two cameras. Since we use 2mm lens for obtaining textures, we need to remove lens distortion first. To get radial distortion factor, we calibrate camera by using typical camera calibration method (We use Zhang method [3]). After we get the radial distortion parameter, we acquire image that has square pattern which is used for calibrating camera information. Fig. 3 shows radial distortion removed image. Now we would like to know camera external parameter between two cameras.

Here we use homography method. Two square pattern images are taken from two camera respect and from 4 correlation points gives us the relation between two cameras. In Fig. 3, one camera(left) is set up as orthogonal to pattern plane and from the homography matrix we can warp the image of other camera to left one. After right image is warped to right image, the overlapped region is blended in simply average with two pixel value in following equation.

$$Color = \frac{\alpha \cdot R + \beta \cdot L}{\alpha + \beta}$$

Calibration pattern and camera distance is 70cm so that if the object is located far or near than 70cm image that we acquire may be not shaped because of incorrect homography matrix value.

(a)



(b)

Fig. 3. radial distortion removed image. (a) two camera images that has pattern (b) right camera image is warped to left camera by homography matrix

The entire system of vertical axis are set up as in one vertical line as Fig. 2. In our indoor environment, there is a 0.6m square size tile on the floor. We use these tiles for localizing the camera position as known position. We use the tile for localizing kart position but the kart has indoor localization device called as StarLITE[5] which is developed in ETRI. So we can easily obtain local position in real time by using this localization device.

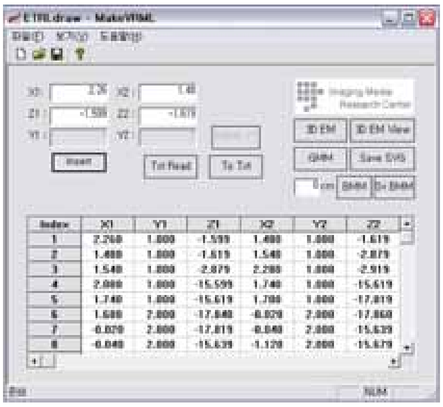
5. Building 2D Model

A 2D map is the basis of our algorithm because an accurate 2D map could build an accurate 3D model. Typical approach of 2D map building method using laser scanner is scan matching[4]. To use scan matching method, the system needs to have moving vehicle with odometry equipment like robot. Robot platform with laser scanner equipment can solve the problem of pose and position but it is quite complicate. In our case, we use metric map which is generated by laser scanner with known orientation. If we use the 2D map data from 2D flat drawing, we just need to process that kind of data to line-based presentation data which represent the basic wall plane. We use user interface program is shown in Fig. 4(a) and the graphical 2D map is shown in Fig. 4(b).

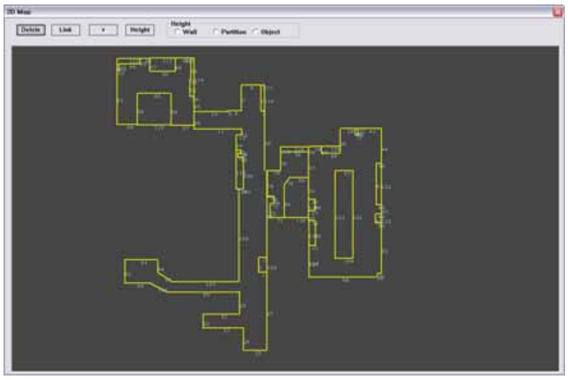
Here, we define line-based 2D map as shown in Fig. 4(a). We use two points coordinate for specifying one line and each line is connected for 2D map model. Because each line is specified with table format, so we call it as TMM (Table Metric Map). Fig. 4(b) shows a graphic version of TMM, so we call it as GMM (Graphic Metric Map).

The laser scanner is positioned in the same center point of camera which is already known location. And then we can determine the laser scanner pose by doing that set the laser scanner orthogonal to wall. Now we know the laser orientation information so that we can generate 2D metric map data from laser scanner. We gather two metric data from 1 location by rotating the laser scanner to scan the opposite side. We can finally generate total 2D metric map by gathering these metric data. Since we use a line (wall plane) - based raw data format, we can extend the 2D map data to various standard file format like SVG.

A SVG based 2D model is generated from TMM automatically. SVG file can be rendered with internet explorer browser. We also implement SVG browser for cellular phone application with MIDP emulator. Fig. 5 shows the rendering of 2D map model with Cellular phone emulator.



(a)



(b)

Fig. 4. 2D metric map. (a) Tabled metric map (TMM) data and user interface (b) Graphical metric map (GMM) data (2D map)

Here is a basic idea of building a 3D model. We assume that wall plane is orthogonal to floor plane. This assumption is quite very adequate for indoor environment because a wall is basically orthogonal to a floor in most case of building. The geometry of the 3D model consists of two parts: the floor and the walls. The floor is modeled by a single plane. The walls are the main model of the 3D model.

Since we use the 2D metric map data, we just need to show the wall and floor plane in 3D model. More accurate 2D map data enables to build a 3D model so

Fig. 5. SVG player for 2D map model

that accurate 2D map measuring is very important process in our method. This generation is a full of automatic step. This method gives us various advantages. First of all, it is very simple so that we don't need to setup expensive equipment like laser scanner and moving platform. Instead of that kind of devices, we just need a 2D flat drawing and this is available practically these days. Secondly, since we focus on the presentation of the wall in our modeling, we do not want the temporarily changing objects and linear features, which do not correspond to walls. We do not need to consider if doors might open or not and if there is an object in front of walls. A 2D map and 3D model depends on only measuring exactitude so our method has good advantage in terms of simplification.

Our 3D model is generated in VRML format. Since we use a raw data which is line-based table metric map data from 2D metric map, we can render the 3D model in other 3D renderer such as OpenGL.

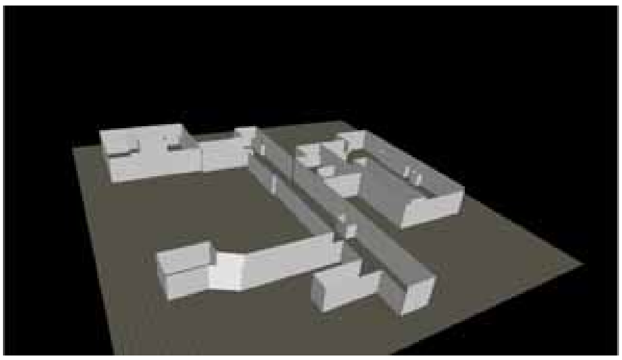


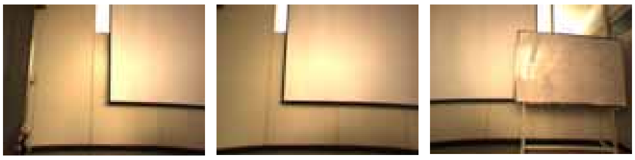
Fig. 6. 3D VRML model

6. Texture Generation

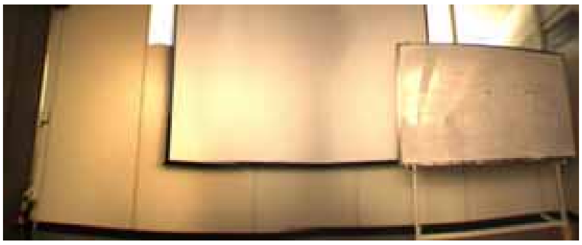
In this paper, the texture generation is focused on the walls. First, the images which are gathered from walls are stitched in one image automatically. And then, we process the image by cutting to represent different depth part. Finally, we acquire textures for the 3D model to match especially for walls.

The calibrated camera, moving the kart that has camera at known point manually, and the assumption that camera pose does not change when moving camera allows for a simple basic acquisition of textures for walls. Both floor and walls are given by known planes in 3D: the floor is simply the ground plane, and a wall's plane is given by assigning the respective wall of the 2D map. Instead of using moving platform like robot, we use the known point of texture acquisition device and pose of device that is very still when it moves to other point. By calibrating radial distortion, we can get removed radial distortion images. Using small focal length value makes it is possible to get wide range of wall texture but its resolution is limited and the size of removed distortion image is also limited. The stitching process is processed semi-automatically. We basically find the correspondence points between two input images but if it is not found, we directly designate the correspondence points. So after we take images for all walls, we can get stitched images for both walls respectively. Finally we cut stitched images for fitting to the 3D model. If the wall plane of indoor environment is one plane and there is no disparity, we do not need to make a 3D model in different depth or cut stitched images for texture generation. However, there are several doors in our wall plane and we already build a 2D map considering the depth. So, we process images taking depth into account to produce individual texture for the 3D model each other.

Actually we concentrate on the wall plane and wall texture, the floor texture is generated by one pictured image which is tile. Fig. 7 shows the processed image in each step.



(a)



(b)

Fig. 7. Processed image of wall texture. (a) Distortion free image (b) stitched image.

7. Result and Conclusion

Fig. 8 shows the presented method for building 2D and 3D model for virtual indoor environment. A data set of 83 images and 2D metric map data was recorded at ETRI 7th building 1st floor, covering parts of a region of about 25 × 25 meters. The 2D map was shown in Fig. 4 and a screen shot of the final textured 3D model is shown in Fig. 9. The 2D map data that we use are 112 wall planes. This model is generated as VRML model and it can be viewed in a web browser with a VRML plug-in. We see our technique as a successful easy and simple method to generate 3D model. The big advantage of our method is in vivid described model that is texture of model is very realistic. In order to communicate with robot and human through virtual model like the 3D model in our paper, it needs to be very accurate and realistic. We are confident to build a 3D model simply and easily in human's wants that is enough to realistic.

We built 2D and 3D model for virtual indoor environment with known location. We will develop our algorithm in terms of automatic processing of 2D map generation and texture matching.

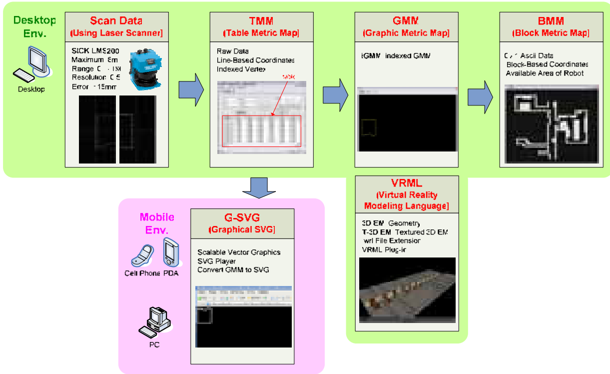


Fig. 8. Building 2D and 3D model for indoor environment

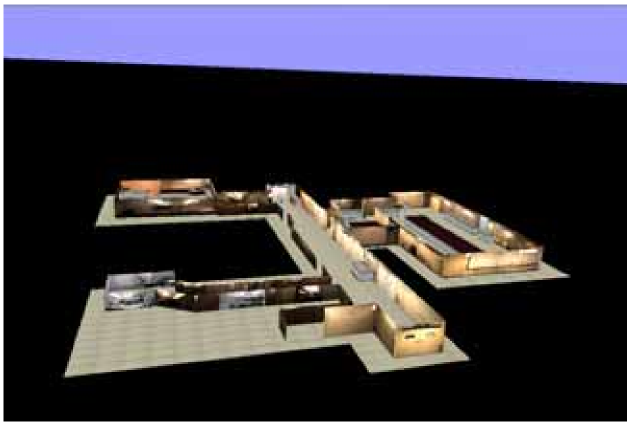


Fig. 9. A view of the VRML 3D model.

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