Proposal of architecture for ubiquitous direct drawing in 3D real space using monocular camera

Byongchol Pei*, Shun'ichi Tano*, Tomonori Hashiyama* Junko Ichino*and Mitsuru Iwata**

* Graduate School of Information Systems, University of Electro-Communications,
1-5-1 Chofugaoka, Chofu, Tokyo, 182-8585, Japan
E-mail: pei@media.is.uec.ac.jp, {tano,hashiyama,ichino}@is.uec.ac.jp

** Tokyo Metropolitan College of Industrial Technology
1-10-40 Higashi-Ooi, Shinagawa-ku, Tokyo, 140-0011, Japan
E-mail: miwata@s.metro-cit.ac.jp

Abstract—Recently, 3D measurement techniques have become widely used as personal computers and workstations develop further. Many pieces of 3D measurement equipment are on the market. The main pieces of 3D measurement equipment are electric wave type and magnetism type. However, those require large space and cost a lot. Therefore, a 3D measurement technique is needed that can be used anywhere and is inexpensive. Thus, architecture using a monocular camera has been developed for position estimation in 3D real space.

***Index Terms*— monocular camera, 3D location estimation, Vision-based.**

I. Introduction

A 3D measurement technique is very useful to find out positional relationships in real space. For example, if we know the positional relationship between our car and another car on a public thoroughfare, we can drive safely. The main pieces of 3D measurement equipment have become electric wave type, magnetism type, or optical type. All types of 3D measurement equipment have many restrictions. One of these is measurement place. A user can use 3D measurement equipment only in specific locations because it is difficult to set up. Thus, to carry out 3D measurement easily, a system is required that uses only well-understood devises and can conduct 3D measurements anywhere.[1]

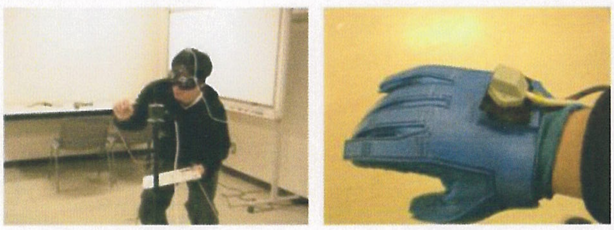

Fig. 1 3D measurement system

This work was supported by Hankook University Research Foundation Grant (HURF-2007-000-0000).

II. Purpose

In this paper, we propose architecture using only well-understood devises for position estimation in 3D real space.

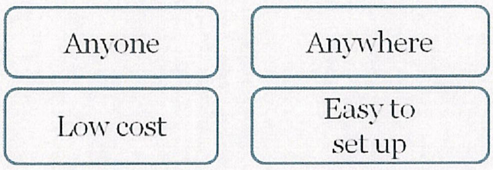

Fig. 2 Concept of this architecture

III. Approach

Our architecture uses a monocular camera as a sensor. When we understand objects' 3D location in real space, we use feature points from images obtained by our eyes. A feature point is a characteristic point in an image like a corner. Feature points can exist anywhere. We cannot understand 3D positional relationships without using them. Specifically, the temporal alteration changes arise to retinal image when someone moves his/her head when looking at the feature point. This is called motion parallax. The feature point becomes nearer if the motion parallax is larger, and become further away if it is small. This principle can enable us to perceive depth.

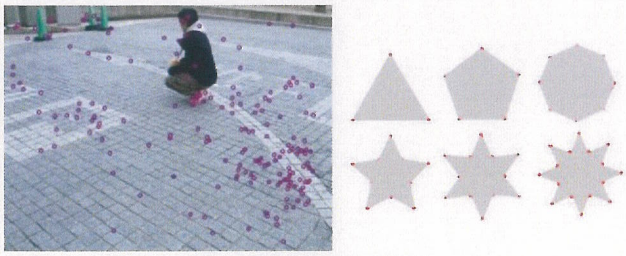

Fig. 3 Natural feature points

In this paper, we propose a 3D measurement method using disparity of feature points caused by moving a monocular camera. The approach of this architecture can be described in three points.

- Using natural feature points that exist universally in any image
- Conducting 3D measurement on the assumption of how the monocular camera will move.
- Utilizing information collected by each user

IV. ARCHITECTURE USING MONOCULAR CAMERA FOR UBIQUITOUS LOCATION ESTIMATION IN 3D REAL SPACE

We indicate schema of the system to create this architecture. This system is composed of the following three functions.

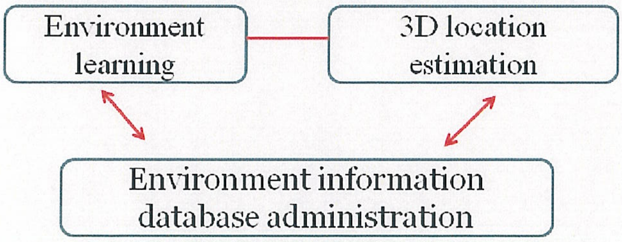

Fig. 4 Function of this system

・Environment leaning

To conduct a 3D measurement, this architecture uses feature points in images obtained by a monocular camera. Thus, all images taken by a monocular camera have feature point information. In addition, this system may not run correctly if the monocular camera is too near the object, because this system uses the monocular camera as a sensor. Thus, this system specifies the area that can be operated in and can keep the accuracy of measurements. Therefore, a user collects feature points from omnidirectional images in preparation for the 3D measurement. In particular, before the 3D measurement, the user turns and moves the monocular camera to all azimuths in order to collect feature points. Finally, this system becomes able to catch the feature point if the monocular camera turns to any angle and position. In addition, this system judges whether distribution and accuracy are sufficient for 3D measurement. If there are not enough feature points, the system feeds back insufficient information about the monocular camera's angle and position to the user.

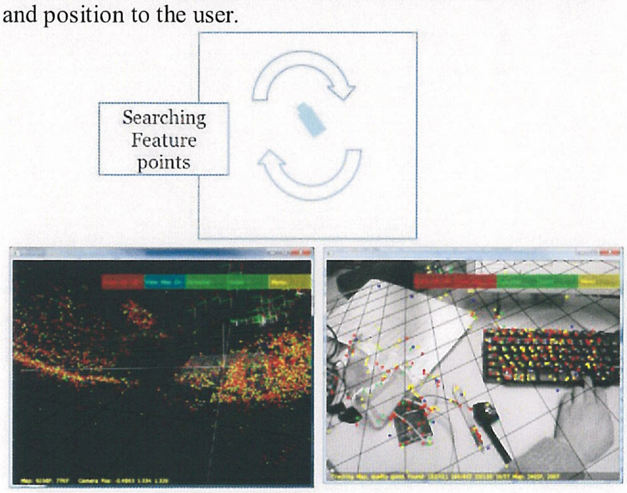

Fig. 5 Collecting feature points[2]

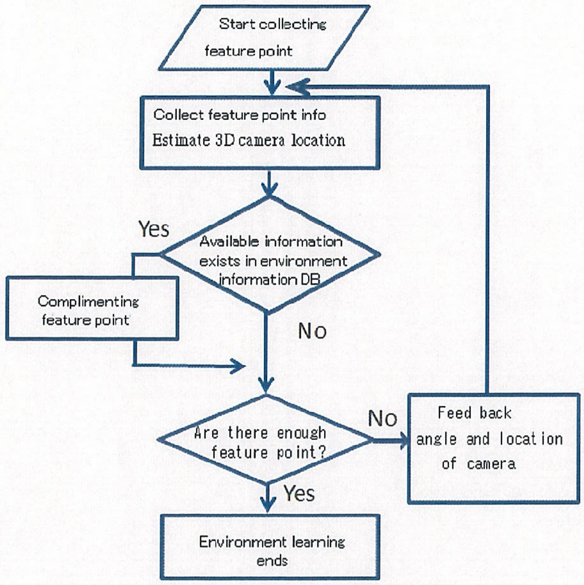

Fig. 6 Flow chart of environment learning

In addition, if feature point's information exists in an environment information database, this system can use that information to shorten processing time taken to collect feature points. In particular, usable information includes feature points collected at other times. Finally, feature point's information is complemented by an environment information database, which considerably reduces the environment learning process.

・3D location estimation

3D location of a monocular camera is estimated by calculating the feature point in an image using constructed in the previous process. However, if the monocular camera moves a long distance at once, it is difficult to estimate 3D location. Therefore, this system estimates 3D location following a flow chart (Fig. 6).

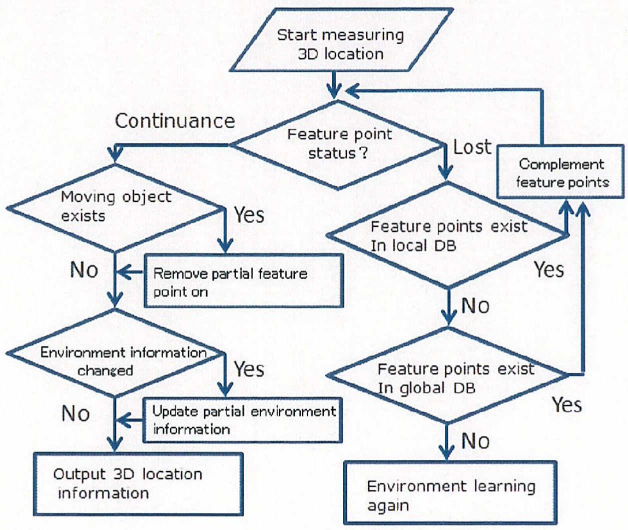

Fig. 7 Flow chart of 3D location estimation

We define two types of feature point status. The status in which feature points can be consecutively traced is "Continuance". The status in which feature points cannot by consecutively traced is "Lost". In the "Continuance" status, feature points can be traced successfully, so 3D location of the monocular camera is also estimated correctly. However, in this condition, if any dynamic body passes in front of the monocular camera, monocular camera cannot correctly estimate the 3D location. In this case, this system removes feature points located on blanked out objects. Next, if the conditions of measuring space change, this system updates feature point information.

In the "Lost" status, feature points cannot be traced successfully. In one of those cases, the monocular camera moves a long distance. When this happens, feature point information may exist inside information collected by the previous process, so this system searches for feature point information. In another case, the monocular camera moves too far, thus this system cannot search for information collected by the previous process. To estimate the 3D location, the system needs to search the environment information database. Finally, if this system finds feature point information in the environment information database, this system complements feature points. If feature points information is not found in the environment information database, system notifies the user that he/she has to do environment learning.

・Environment information database administration

It is complex for a user to construct a 3D measurement environment any time after all environment learning processes. To avoid this difficulty, when the user collects information of feature points system, he/she sends information to the environment information database. As a result, the user uses this information in any process. Thus, the user can start 3D measurement soon after the second time. In addition, this system becomes robust because it can correspond to various situations.

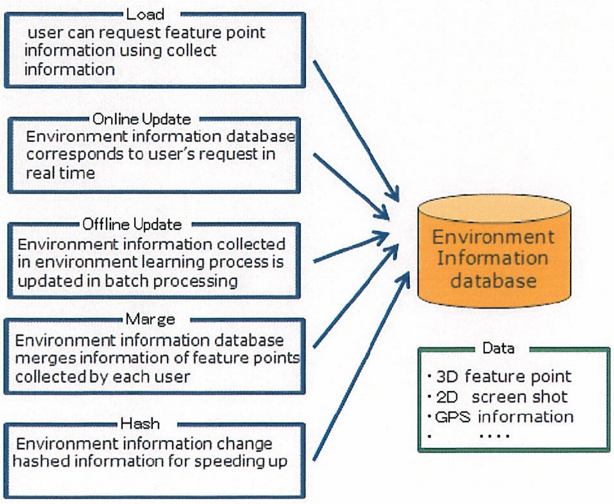

Fig. 8 Function of environment information database

・Online Update

The environment information database corresponds to the user's request in real time. This function is mainly used in the 3D location estimation process.

・Offline Update

Collected environment information in the environment learning process is updated in batch processing. This function is mainly used in the environment learning process.

・Load

In environment processes, the user collects feature point information for a few seconds and can request feature point information by using collected information. If user secondarily sends more information as a GPS data, search speed become fast because environment information database can confine searching area,

・Merge

The environment information database merges feature point information collected by each user.

・Hash

The environment information change hashed information for speeding up.

Finally, environment information database has a vast feature point information map because each user sends environment information.

V. PROBLEMS OF ARCHITECTURE

We developed architect for a system that achieves the concept by using only a monocular camera. However, our architecture has some problems.

- The system cannot calculate 3D camera location from feature points in images in real time
- We have no method for merging 3D feature points information
- We have no method for searching for 3D feature points information in the environment information database

VI. FUNDAMENTALS EXPERIMENT

We tested the fundamentals to prove the reliability of the architecture. First of all, we collected feature point information from all azimuths of the monocular camera one by one. Next, we calculated the 3D location of the monocular camera from collected feature points. Finally, we sketched in 3D real space using information of 3D camera location.

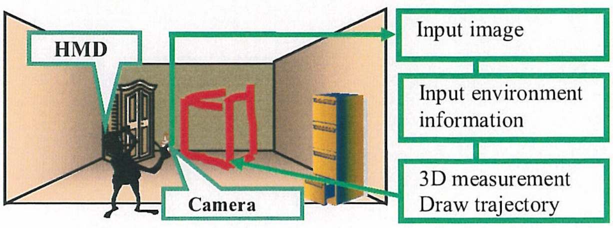

Fig. 9 Step of experiment

Table 1
Experimental circumstance

OS	Windows vista
CPU	Intel® Core™2 6700 2.67GHz
Video	NVIDIA Quadro FX 540
Camera	Ponit Grey FL2-03S2C
HMD	See-through HMD

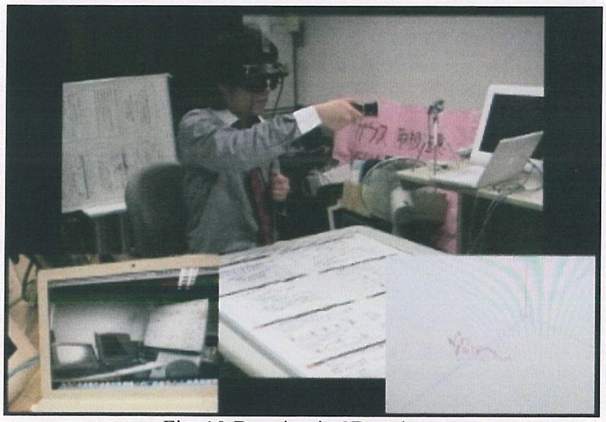

Fig. 10 Drawing in 3D real space

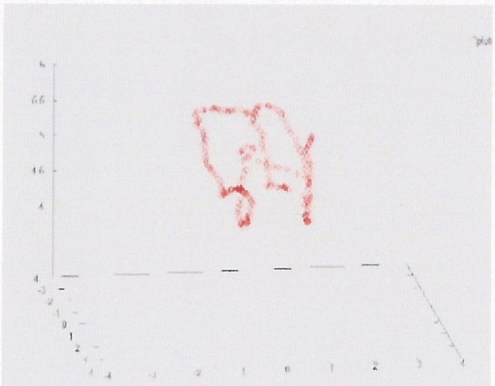

Fig. 11 Result of drawing in 3D space

VII. CONCLUSION

In this paper, we suggested new architecture for 3D location estimation using inexpensive equipment. In addition, to achieve the concept of this research, the feasibility of this architecture was revealed by testing fundamentals under an easy algorithm. We will make the research subjects clearer in future studies.

REFERENCES

[1] Emanual Sachs, Andrew Roberts, David Stoops: 3-Draw: A Tool for Designing 3D Shapes, IEEE Computer Graphics & Application, Vol.4, No.6, pp.18-26,(1991)

[2] Georg Klein and David Murray: Parallel Tracking and Mapping for Small AR Workspaces,In Proc. International Symposium on Mixed and Augmented Reality (ISMAR'07, Nara)