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Work Step Indication with Grid-pattern Projection for Demented Senior People

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***Abstract*— This paper proposes a work step indication method for supporting daily work with a grid-pattern projection. To support an independent life of demented senior people, it is desirable that an instruction is easy to understand visually and not complicated. The proposed method in this paper uses a range image sensor and a camera in addition to a projector. A 3D geometry of a target scene is measured by the range image sensor, and the grid-pattern is projected onto the scene directly. Direct projection of the work step is easier to be associated with the target objects around the assisted person, and the grid-pattern is a solution to indicate the spatial instruction. A prototype has been implemented and has demonstrated that the proposed grid-pattern projection is easy to show the work step.**

I. INTRODUCTION

Several nations around the world, including Japan and Finland, are facing a problem with aging society structures. Growing number of elderly population needs more supports to maintain their quality of life (QoL) and the lack of supporting place is going to be serious problem. Home-based support for elderly people will play a large part in maintenance of the QoL.

The number of people suffering from dementia is increasing as the population ages. Sometimes it is difficult for the demented people to remember work steps of the daily operations, so providing the work steps to the people automatically is effective in efficiency. A Smart Kitchen concept [1] is an effective solution to improve daily life of demented senior people. The sensor-embedded kitchen senses a progress of work and provide an instruction which is appropriate to the current situation.

It is thought that the demented senior people have characteristics below:

- It may be difficult for the demented people to memorize complex instructions due to the deterioration of memory,
- The demented people may often forget to put the devices on,
- It may be difficult to associate a visual instruction on a monitor or a speech-based instruction with objects around the people.

It is expected that a projection-based work instruction addresses above problems, and several research works have contributed for sensing a scene and supporting the work using a projector. SixSense [2] is a natural input method using fingers of users. Interactive Dirt [3] is a concept to maintain good situational awareness about real world environments. The Interactive Dirt uses a projector and an infrared camera to display an image onto a real object in the environments. KinectFusion [4] enables to obtain dense 3D shape of a target scene with a range image sensor as Microsoft Kinect. Applications of the KinectFusion have demonstrated that the dense 3D scene is used for the augmented reality (AR)-based interaction method. LightBeam [5] is a concept to use everyday objects as projection surfaces and tangible interaction devices.

Nevertheless, when an indication system for demented senior people is constructed, it should be still considered how to indicate the instruction adjusted to their memory function and information technology literacy. In this paper, we propose a work step indication method with grid-pattern projection. A range image sensor, a camera and a projector are utilized for the proposed method. The instructions are directly projected onto target objects for a clear understanding of the instructions. We have proposed a method for supporting a kitchen work using a camera and a projector [6]. In this method, an indicator is directly overlaid onto a target object. In addition, we have proposed a method for an interaction with a projected image using a range image sensor [7]. The proposed method inherits the concept from the preceding methods. The proposed method in this paper utilizes a grid-pattern for work step indication to balance a variety and an understandability of the instruction. Firstly, relative positions between the devices are calibrated. Secondly, a target surface on which the grid-pattern is indicated is estimated from the range image. Lastly, the instruction based on the grid-pattern is directly indicated onto the target objects using the projector. A prototype has been implemented and demonstrated that the proposed grid-pattern indication is possible way to indicate the work step simply.

II. PROPOSED METHOD

Fig. 1 shows a concept of the proposed method. The proposed method uses a camera, a range image sensor and a projector. They are set downward from above at a workspace. The camera observes a scene including a target object and a target surface. The range image sensor is utilized for measuring a geometry of the target surface and the target object simultaneously under the situation that a geometry

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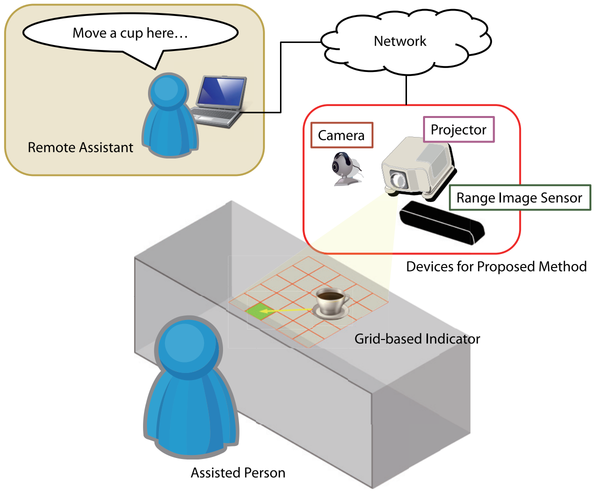


Fig. 1. Concept of the proposed method. A camera and a range image sensor sense a position and a color of the objects on a surface. A work step is indicated with a grid-pattern by a projector.

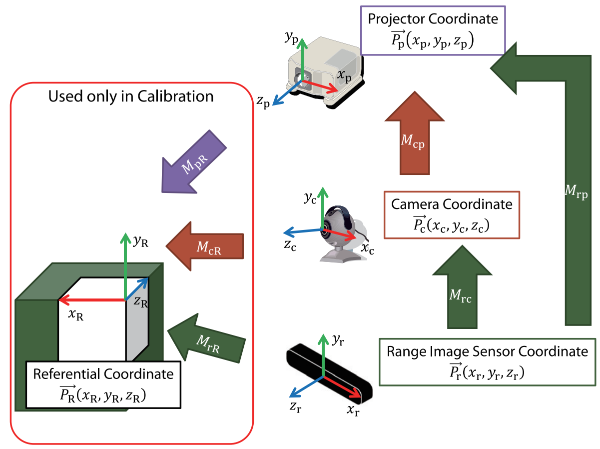


Fig. 2. Coordinate systems used in the proposed method. Firstly, a relative position and posture are estimated via a referential coordinate system $\vec{P}_R$. Transformation matrices M_{rc}, M_{rp} and M_{cp} are estimated before using the system, and the matrices are continuously used as long as the relative positions between the devices are maintained.

and an illumination of the scene are variable dynamically. It is assumed that there is a planar surface which has a solid color in a scene, such as a table surface. An instruction for assisted people is overlaid onto the target object and the target surface directly with the projector. To detect a position of the object and to project the instruction onto the scene properly, a relative position between the camera, the range image sensor and the projector should be calibrated. Note that intrinsic parameter of each device is calibrated in advance.

A. Indirect Calibration

Three device coordinate systems, a camera coordinate system $\vec{P}_c$, a range image sensor coordinate system $\vec{P}_r$ and a projector coordinate system $\vec{P}_p$ are used in the proposed method. To detect a color and a position of the target objects, and to indicate an instruction properly, transformation matrices between each coordinate system are estimated. We introduce additional coordinate system, a referential coordinate system $\vec{P}_R$, to calibrate between the coordinate systems mentioned above. Three orthogonal surfaces on a referential object are used for the calibration. Note that those four coordinate systems are all orthonormal. Fig. 2 shows coordinate systems used in the proposed method and the relationship between them.

Firstly, transformation matrix M_{rR} is estimated from the range image. The range image including the referential object is taken by the range image sensor as shown in Fig. 3. Parameters of surfaces on the referential object are estimated from the range image. Three normal vectors corresponding to the three estimated planes on the referential object are used as basis vectors of $\vec{P}_R$, and an intersection of the three estimated planes is used as an origin of $\vec{P}_R$ on $\vec{P}_r$.

Secondly, transformation matrices M_{cR} and M_{pR} are estimated with Gray code pattern projection based on a method proposed by Sato *et al* [8]. Fig. 4 shows an example

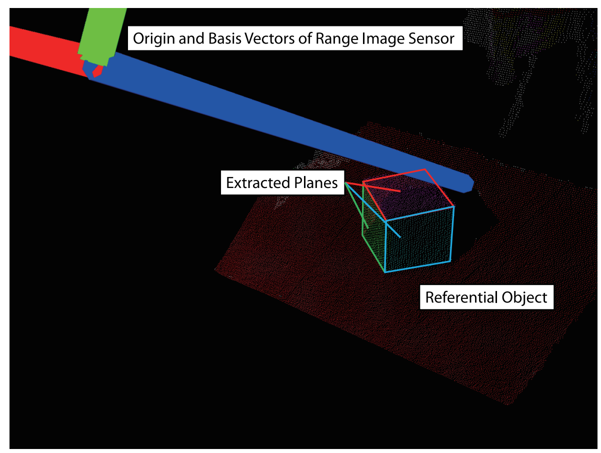


Fig. 3. A calibration between a range image sensor and a referential object. The range image sensor captures a scene including three surfaces of the referential object. Three orthogonal lines on left top corner describes basis vectors of a range image sensor coordinate.

of the Gray code pattern projection. Basis vectors of $\vec{P}_R$ and an origin of $\vec{P}_R$ on $\vec{P}_c$ are estimated from measured geometry of the scene including the referential object, as with an estimation of M_{rR}.

Lastly, transformation matrices between the three device coordinate systems M_{rc}, M_{rp} and M_{cp} are computed as a transformation via $\vec{P}_R$. For example, the transformation matrix M_{rc}, from $\vec{P}_r$ to $\vec{P}_c$, is computed by simply multiplying as $M_{rc} = M_{Rc}M_{rR}$, where $M_{Rc} = M_{cR}^{-1}$.

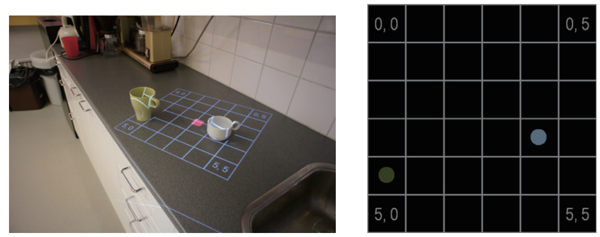
Only the relative positions between the devices should be maintained in use. *i.e.* A simultaneous movement of the devices is allowed. It indicates that the system can be moved freely if the devices are fixed in a housing.

B. Target Surface Estimation and Object Locating

Firstly, a parameter of the target planar surface is estimated to determine a position of a grid-pattern indicated by the

(a) (b)

Fig. 4. A calibration between a camera, a projector and a referential object. Conventional Gray code pattern projection is utilized to calibrate a relative position and a posture between the devices and the referential object. (a) Vertical Gray code pattern projection. (b) Horizontal Gray code pattern projection.



(a) (b)

Fig. 6. Object locating on grid map. (a) Target scene with a projected grid map. (b) Estimated position of objects on the grid map in target scene. Center of gravity of each object is projected onto a grid map on the target plane.

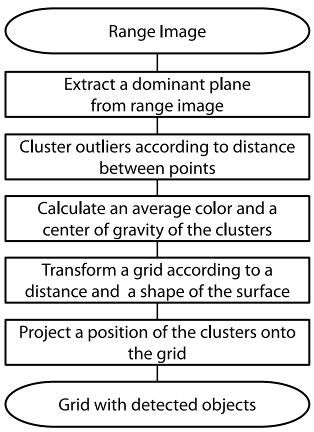


Fig. 5. Process flow of object locating.

projector. Secondly, a position and a color of the target objects on the grid-pattern are located. Fig. 5 shows a process flow of the surface estimation and the object locating.

First of all, a dominant plane which has a certain color is estimated from the range image. A color of each pixel in the range image is given from the converted camera image via M_{cr}, where $M_{\mathrm{cr}} = M_{\mathrm{rc}}^{-1}$. Secondly, the pixels other than the pixels extracted as the target planar surface are clustered according to a distance between the points each other. A cluster which has less than t_{c} points is removed. Lastly, center of gravity of the clusters is projected onto the grid-pattern coordinate system, and an average color and a position of the clusters is displayed. Fig. 6 shows an example of object locating. Fig. 6 (a) is a scene and (b) is a result of the locating with estimated colors.

C. Grid Pattern Indication

We assume that the instructions for the demented senior people are given by their remote assistant or the support system itself. There is a trade-off between a flexibility and an understandability of an instruction. For example, speech-based instruction is easy to catch. However, it is difficult to communicate *spatial* information on the speech-based instruction. On the other hand, a monitor-based instruction is good to *show* spatial information. Nevertheless there is still a problem remaining about applying a spatial information into the real target scene.

A direct grid-pattern projection is a solution to balance a flexibility and an understandability of the instruction for the demented senior people. And It is also expected that the grid-pattern indication is easy for the remote assistant and the autonomous system to give an instruction.

III. EXPERIMENTAL RESULTS

A prototype of the proposed method was implemented. Figure 7 is an overview of the prototype. A camera was Logitech C910, a width and a height of the camera image were 640 and 480 pixels, respectively. A range image sensor was Microsoft Kinect for Windows. An original width and a height of the range image were 80 and 65 pixels, respectively, and the captured range image was magnified to 320 and 240 pixels, respectively. A projector was Optoma EP1691i Digital Light Processing (DLP) Projector. A width and a height of the projected image were 1280 and 768 pixels, respectively. Point Cloud Library (PCL) 1.5.1 [9], OpenCV 2.4.0 [10] and Microsoft Kinect for Windows 1.5 [11] were used for the prototype. A RANSAC-based parameter estimation method on the PCL was utilized for the plane estimation.

Fig. 8 shows a referential object used for the calibration. Three orthogonal planar surfaces which have a square marker pattern are referred to calibrate. The square marker pattern was 0.16 meters on a side.

Fig. 9 shows an example of a work step indication by the prototype. In this case a work step was *move a pot to the designated position according to the arrow*, and the instruction was indicated on the target objects directly. The target plane was correctly estimated even if there were hands of the subject and the target objects between the range image sensor and the target surface.

IV. CONCLUSIONS

In this paper, we have proposed a method for indicating an instruction of a work step with grid-pattern projection for demented senior people. The proposed method utilizes a camera, a range image sensor to sense a target surface and target objects, and a projector to indicate the instruction of work step. *Indirect Calibration* is introduced to calibrate between the devices which are utilized in the proposed method. The geometry of the target surface is estimated in

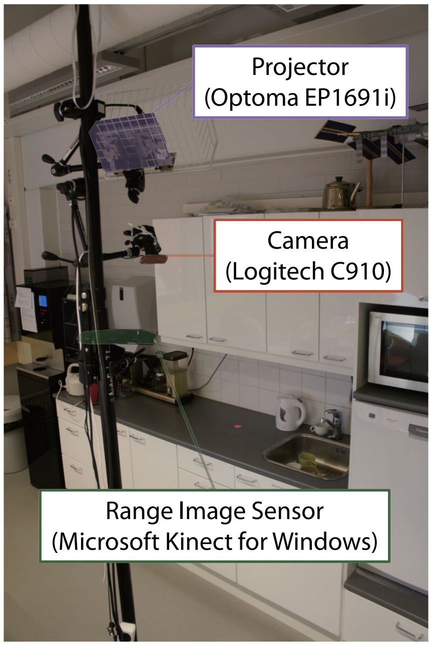


Fig. 7. A prototype of the proposed method. A range image sensor, a camera and a projector were attached to a pole downward. Relative positions between the devices were calibrated and the devices were not moved during the experiment.

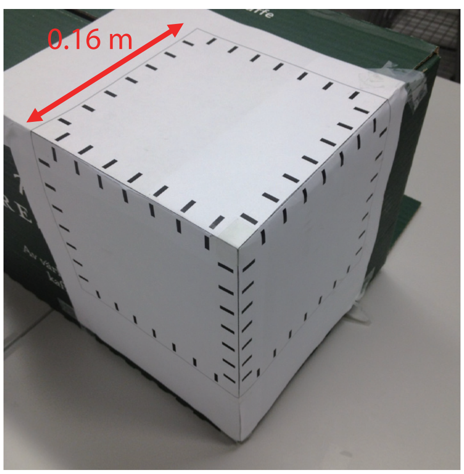


Fig. 8. A referential object for the calibration. The referential object has three diagonal planar surfaces, 0.16 meters on a side. Three surfaces should be visible from all of the devices.

real-time, and grid-based instruction is indicated onto the target surface and the objects directly. A prototype of the proposed method has been implemented and demonstrated that the target plane was correctly estimated even if there were hands of the subject and the target objects between the range image sensor and the target plane.

Future works will aim at improving a object recognition. It is desirable that the system recognizes not only a color but also a category of the target object. In addition, we are planning to develop an autonomous supporting system for senior people at a kitchen, based on the proposed method.

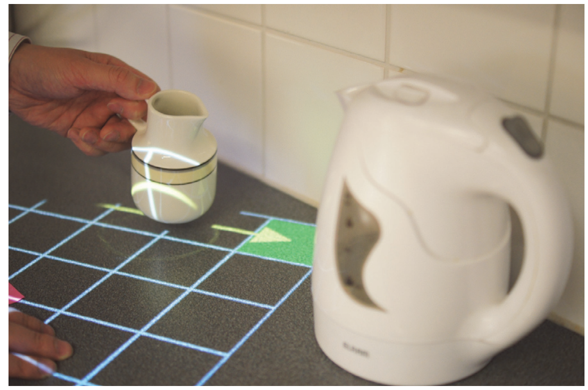


Fig. 9. A result of work step indication by the prototype. A work step — *move a pot to the designated position according to the arrow* was indicated on the target objects directly. The target plane was correctly estimated even if there were hands of the subject and the target objects between the range image sensor and the target plane.

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