REALTIME PLANE DETECTION FOR PROJECTION AUGMENTED REALITY IN AN UNKNOWN ENVIRONMENT

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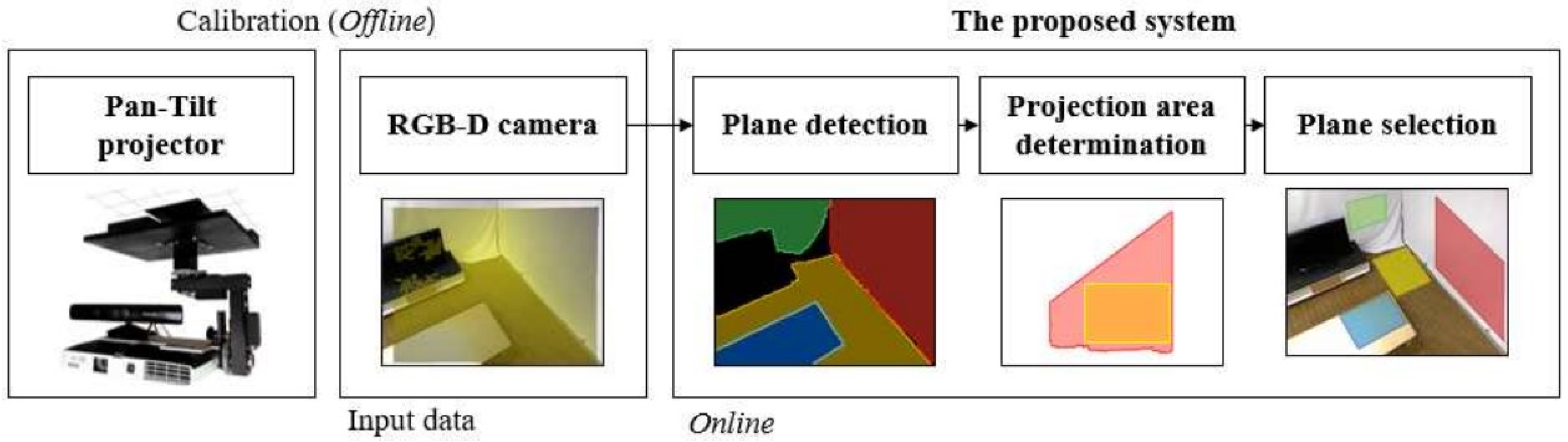
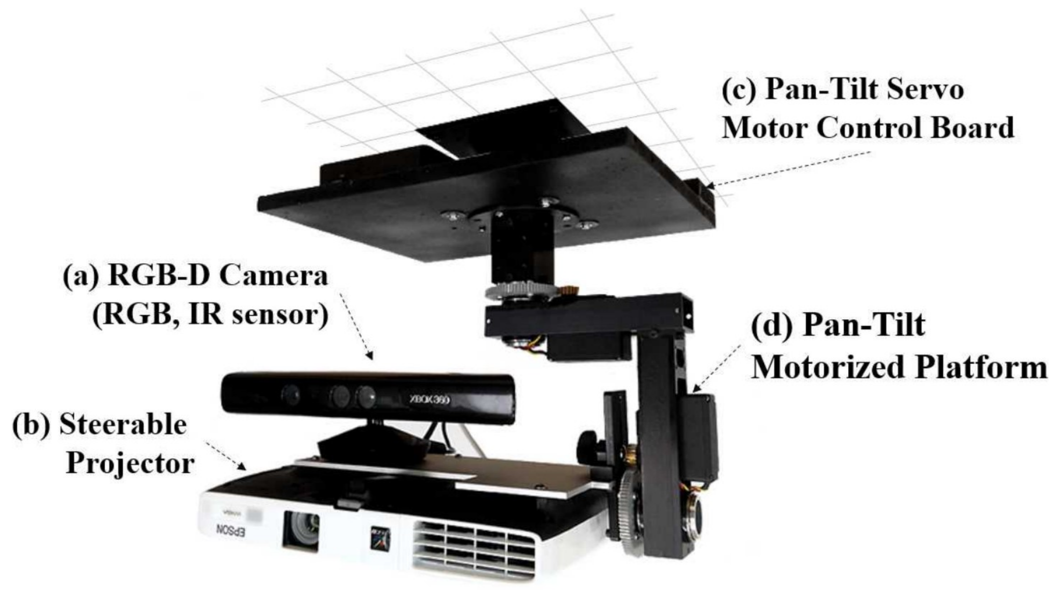


A **real-time plane detection method** for projection based Augmented Reality (AR) system in an unknown environment. The plane detection method automatically detects multiple planes based on the proposed constrained sampling strategy in **RAndom SAmpleing Concensus (RANSAC)**. In addition, when the multiple planes are detected, the importance for contents is measured by the score functions based on the properties of planes such as size, color, and position.

1 Projector-camera System Calibration

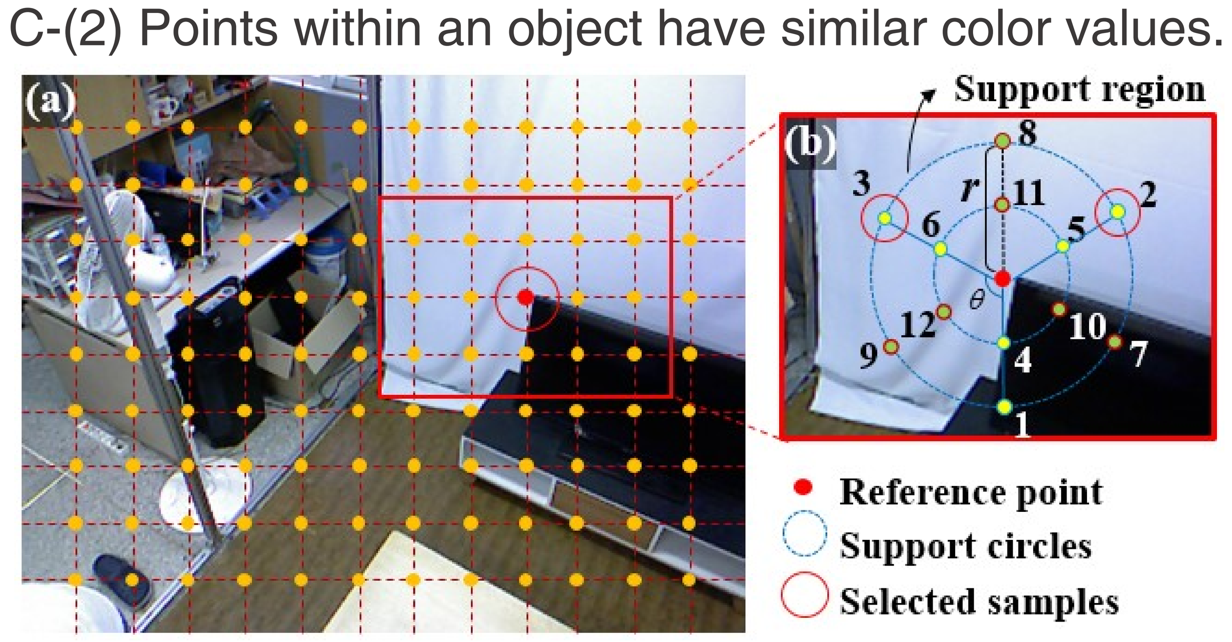


The 3D points in each device have different positions in each local coordinate system. Therefore, data from each sensor is **necessary to be transformed into a common coordinate system**. In our system, the relative position of the RGBD camera and projector is computed by using corner points on a checkerboard.

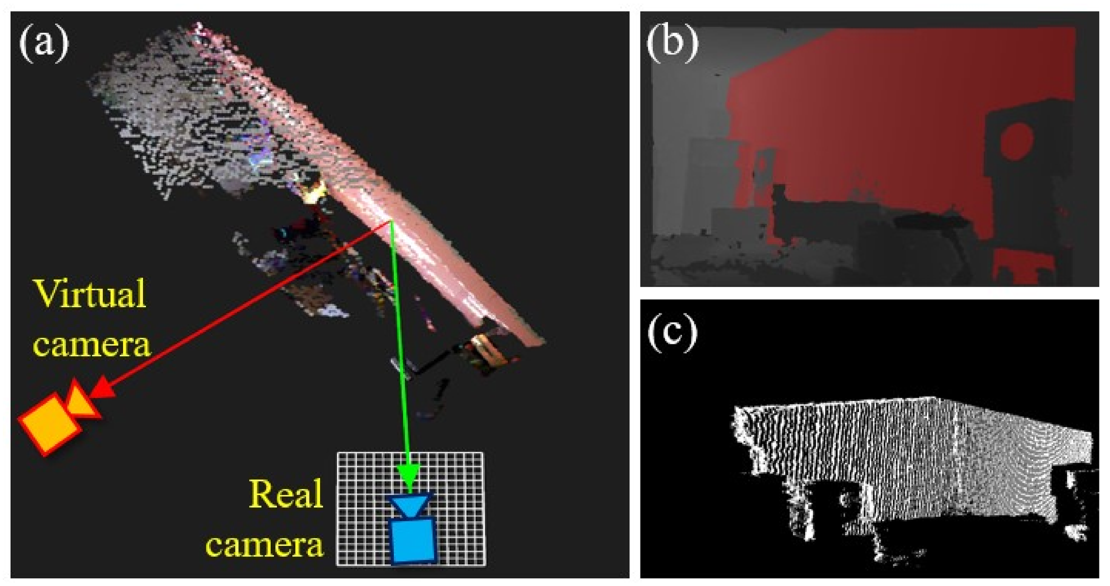
2 Multiple Plane Detection using Constrained RANSAC

We attempted to use the RANSAC for plane detection. However, its computation complexity was very high in order to obtain sufficient results as it has high probability of selecting points on a different plane. Thus, **we modify the sampling methods strategy of the RANSAC with two constraints based on the Gestalt grouping** as follows:

- C-(1) Points in local areas have a high possibility to be on the same plane.
- C-(2) Points within an object have similar color values.



3 Projection Area Selection



When the contents are projected on the planes directly, perspective distortion occurs from the viewpoint of the user. First, to correct this orientation difference, we first **place virtual cameras in front of Π** (a). Then, the point cloud of the plane is projected into the virtual camera. So, we can **obtain an image of the front view (c) from the depth map (b)**. A rectangular area of **maximum size is selected** from the front view image.

4 Proposed Projection Area Selection Method

When the multiple planes are detected, we consider the properties of planes such as width/height ratio, color, and area in a 3D space. We define **three different score functions** to consider each property, and the objective function is defined to select a plane from Π .

S_a, S_c, and S_r represent score values considering size, color and ratio of the projection area

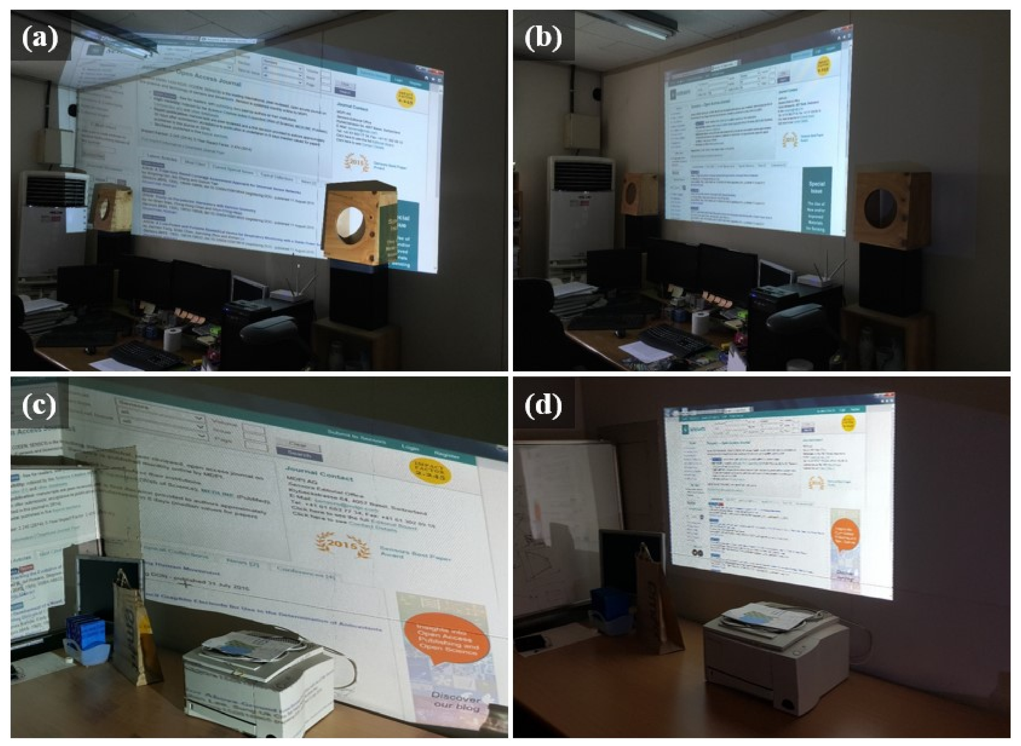
$$
\begin{aligned}
S^a(\pi) &= -\exp\left(-\frac{\pi^a}{\alpha}\right)+1, \\
S^c(\pi) &= \exp\left(-\beta\frac{\sum_{c\in\{r,g,b\},\pi\in\Pi}|\pi^c-255|}{255\times3}\right), \\
S^r(\pi) &= \max\left(-\gamma\left(\pi^r-\Psi^r\right)^2+1,0\right),
\end{aligned}
$$

π_a, π_c, and π_r are the area, mean color, and width/height ratio of a plane π. In addition, Ψ^r is the projection ratio of a projector. Larger score value represents a better plane for projection for all score functions.

Experiments

The experiments were conducted using a 2.40 GHz CPU, 8 GB memory. The image resolution was 640×480. To verify the proposed method, we compare the proposed method with the RANSAC method. Since no standard dataset is available that depth map and labels of planes at the same time, we manually generate ground truth data of 7 difference scenes to measure the quantitative precision.

Scene #	iteration count: RANSAC	iteration count: Proposed	Precision (%): RANSAC	Precision (%): Proposed	Processing Time (ms): RANSAC	Processing Time (ms): Proposed
1	9025.1	25.4	90.0	91.2	1545.7	7.7
2	1017.3	126.7	92.5	93.2	1785.7	7.6
3	26888.2	118.1	87.0	87.6	2622.5	25.9
4	41656.0	123.6	92.7	90.6	5975.1	25.8
5	30159.7	120.7	95.0	94.6	6638.3	33.5
6	79696.0	35.9	86.4	87.1	7070.0	7.3
7	12566.2	175.4	90.2	89.2	1073.6	36.0
Avg.	**28715.5**	**103.7**	**90.5**	**90.5**	**3815.8**	**20.5**



Conclusion

- Propose a **real-time plane detection and selection method** for a projector-camera AR system in an unknown environment.
- **Significant improvement in terms of speed (about 260 times faster than the RANSAC) while retaining precision (about 90.5%) similar to that of RANSAC**.
- Simple structure and is easy to install, making it easily applicable in practical life.