Indoor spatial-environment measurement using ultra-wideband positioning system

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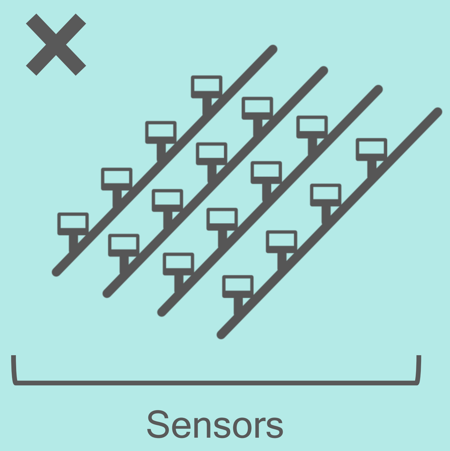
Introduction

Current Office Environment

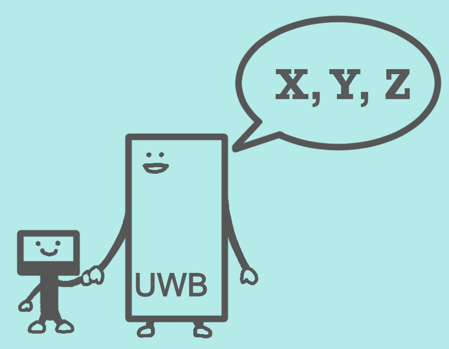
There has been an increased demand for improving work environments such as temperature and luminance. However, an active control of the environments consume the electricity. Therefore, The spatial optimization of light and temperature is required for reducing the power consumption and carbon footprint. Hence a spatial environment measurement have been attracting much attention.

3D Environment Measurement



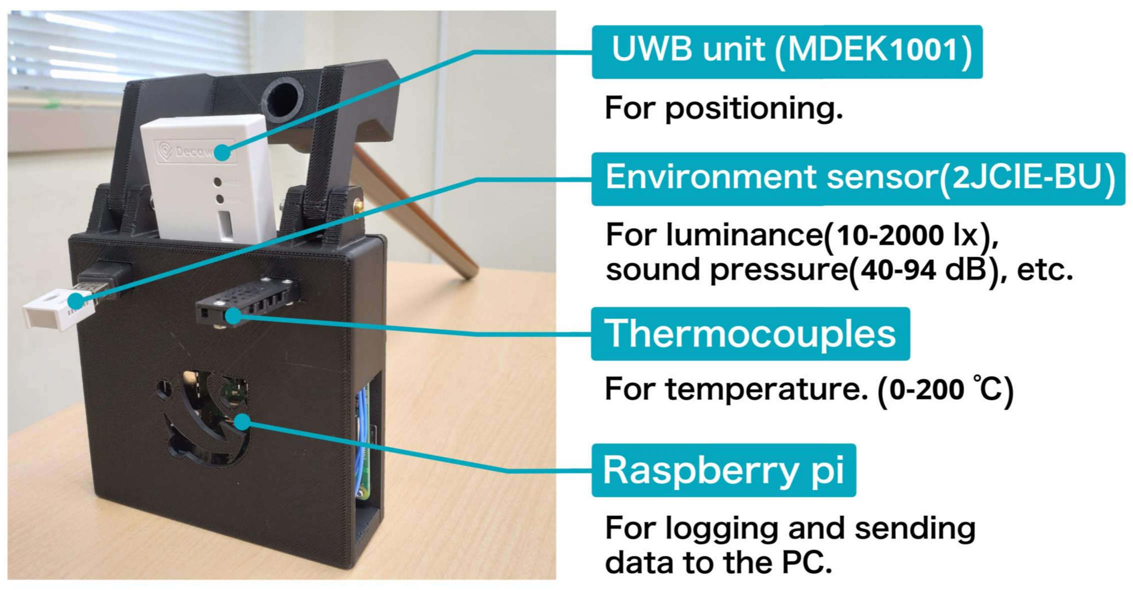
A spatial environment measurement is a key factor for the optimization. Typically, large arrays of spatially distributed sensors have been examined for this purpose. However, this method needs to install many sensors, which is expensive and time-consuming. Furthermore, the collected data for a given spatial range could be sparse and may require postprocessing to reduce gaps.

Solution: UWB + Environment Sensors

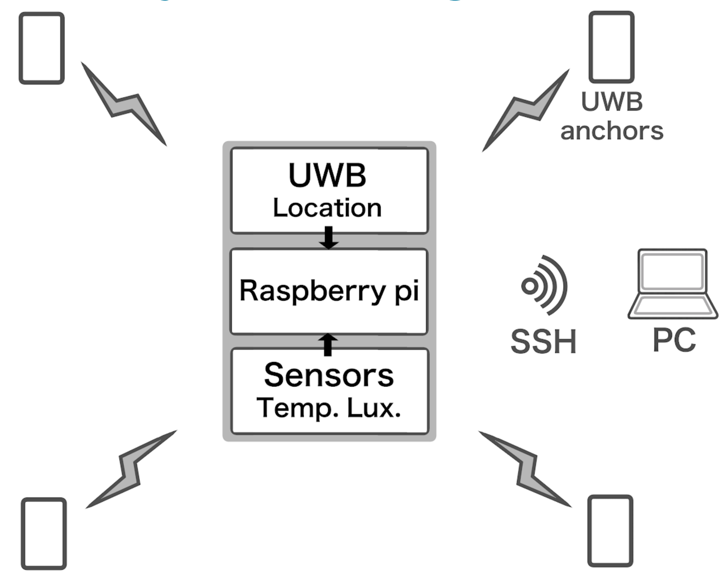


We propose a robust, reliable, and compact 3D environment visualization capability that integrates UWB indoor positioning system and ambient sensors. We prototyped this approach using a single-board computer with UWB units and environmental sensors. Illuminance and temperature are combined with the 3D position information that is processed on a handheld device. The utility is evaluated by field tests.

System

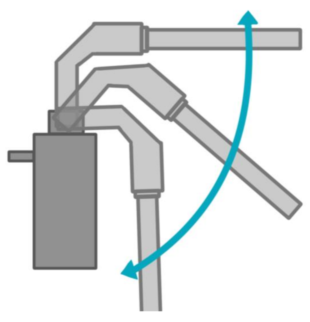


System Diagram



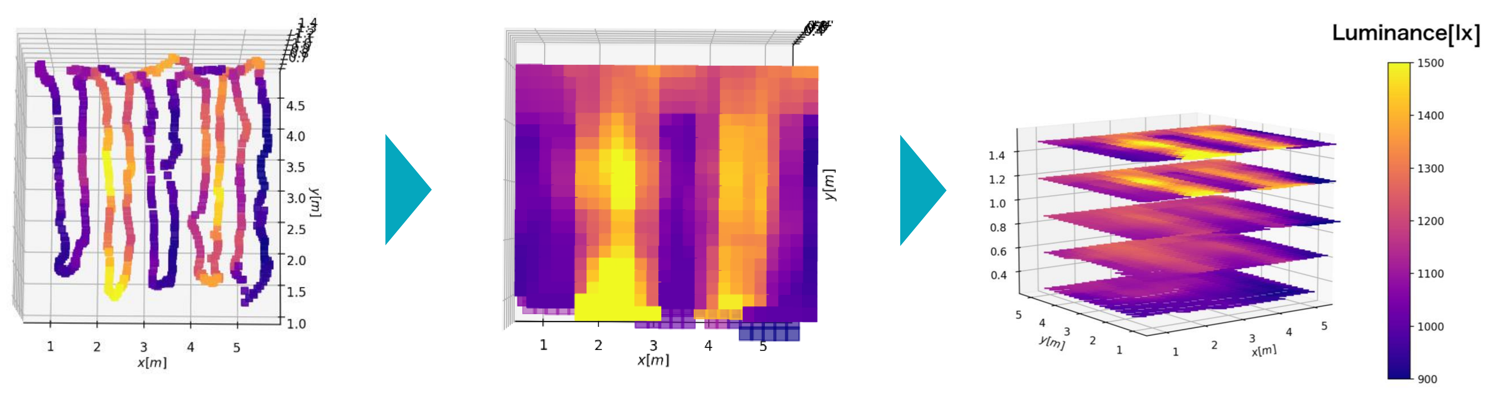
Our device can measure illumination, temperature, sound noise, and RSSI of Wifi in three dimensions.
A 2JCIE-BU compact universal serial bus environmental sensor was used to measure the luminance and sound pressure. An ultrafine K-type thermocouple was used to take the temperature measurements in milliseconds.
UWB anchors are put in the room's corner, and UWB tag's location is saved as x, y, and z coordinates.
The Data from these sensors were acquired once every 200 ms using the Raspberry Pi. The measured data were written into a comma-separated value file that is transmitted to a personal computer, where the data were processed and visualized.

Keep sensor horizontal



The sensor must always be oriented upward to measure the luminance distribution by ceiling lighting, Even if the angle of the handle changes, the sensor is designed to remain horizontal.

Visualization Procedure

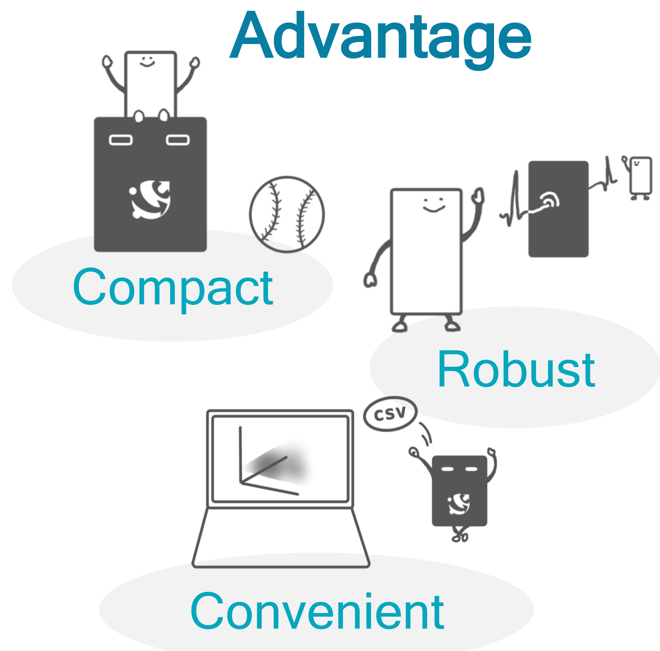


Raw data

Averaged every 0.2 m square

Plotted by height

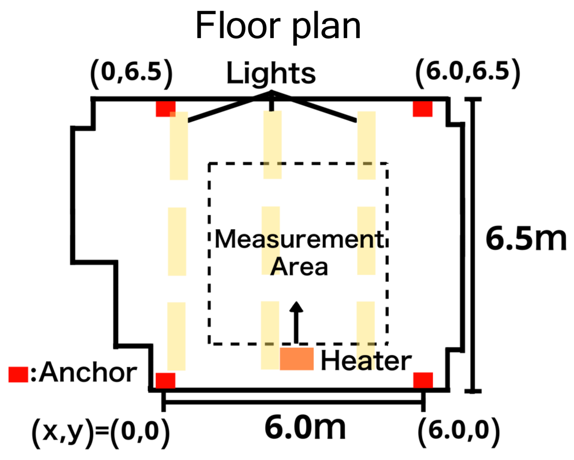
Advantage

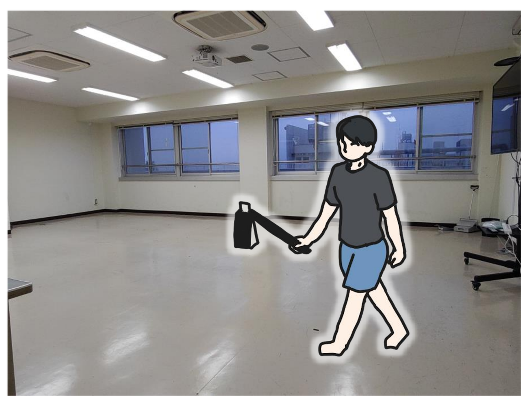


Experiments and Results

Measurement Environment

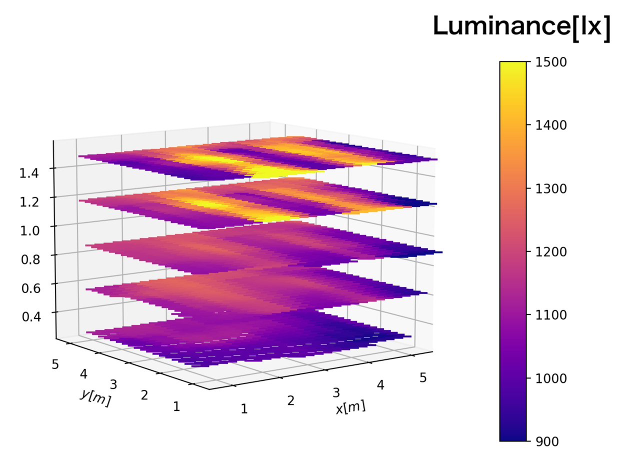
Floor plan





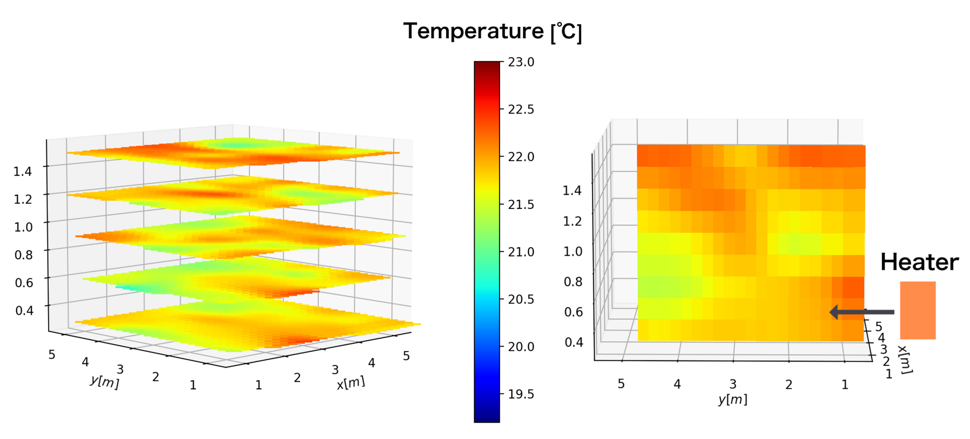
The spatial distribution of luminance and temperature were measured by installing the prototype device in a school classroom. The anchors were installed at the locations shown in the floor plan at a consistent height of 1.7 m. We measured the luminance distribution when all the lights in the room were turned on and the temperature distribution when electric heaters were running. During the experiment, the measurer carried the prototype device and moved around the room, and measurements were taken at five different heights separated by 0.3 m in the z direction.

Luminance result



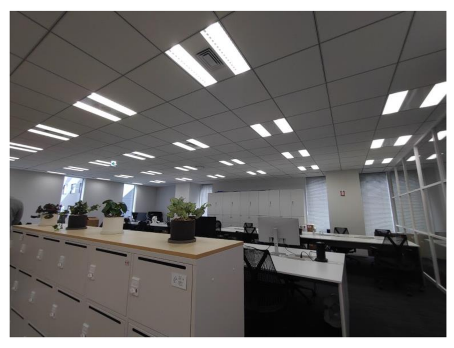
The measured space was illuminated by two lines of ceiling lights. The luminance distribution shows the influence of the lights.

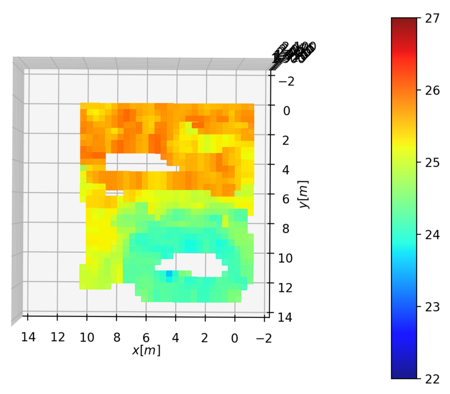
Temperature result



The air in front of the heater was heated, and raised up because of convection. The result reflects the temperature distribution by the heater and the convection.

Use Case





We tested the system in an actual office. Although there were many obstacles such as furniture and PC unlike the classroom, the temperature distribution was successfully measured.

Conclusion and Future work

we proposed a device that can perform indoor spatial-environment measurement using UWB. These results could be useful for improving the office environment and reducing power consumption In contrast, this system can be used in a variety of workspaces because it is low cost, compact, and convenient. Compared with conventional methods, this method has the advantage of robust position estimation with respect to the surrounding environment.
We intend to display it in conjunction with a 3D model of the measurement environment for easy-to-understand visualization because it is difficult to confirm correspondence with the actual environment with only a 3D scatter diagram.