SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (D3)
Novel Concepts and Technologies to Enable Future Building Blocks in Space Exploration and Development (3)

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A HIGH-ACCURACY 2D COLOR MARKER FOR DEXTEROUS MANIPULATION IN SPACE

Abstract

This paper describes the newly developed high-accuracy 2D color marker for on-orbit servicing. This marker has advantageous features of robust detection and identification in the dynamic lighting condition on orbit. A precise position and orientation between the robot end-effector and the target are necessary for the dexterous manipulation. Visual markers are known as an effective method for estimating position and orientation, and three-dimensional visual markers have been actually used in space proximity operations such as spacecraft rendezvous/docking and on-orbit servicing. The 3D structure, however, has limitation of the installation location in terms of safety and space limitation due to its protrusion shape. On the other hand, 2D markers such as AR marker which is widely used in terrestrial application has less restriction of the installation position than 3D marker, but its planar shape makes it hard to estimate the accurate orientation.

A novel 2D visual marker "ArrayMark" allows more accurate pose estimation than the conventional 2D markers. The marker utilizes moire pattern created by superimposing microlens array and dot patterns, and the orientation can be estimated precisely by measuring the moire pattern position which changes according to the visual-line direction. In our previous work, we have developed the space environmental tolerant visual marker for applying ArrayMark to space application by covering it with a special coating polycarbonate case for protecting from the material deterioration by the reactive cosmic material. It also has to be considered about the influence of the on-orbit lighting environment which makes it hard to detect visual markers in dynamic lighting condition caused by the rapid change of the relative position among the earth, the sun and the spacecraft.

For this issue, we newly developed a 2D color marker whose features are colored for robust detection and also for adding an identifier to each marker by using color information, while the previous marker has only black and white and no identifier. This newly developed marker can have 3,125 identifiers by assigning five different colors to each five circular feature, and the value of Hue in HSV color space is used for color identification. The colors are assigned at the equal interval of the Hue on the condition that the colors have the highest values of both Saturation and Value. In this paper, the detailed design of this new color marker will be described together with evaluation results of accuracy of the position and orientation estimation and identification.