Depth Perception Through the Use of Image Sensor Arrays

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Abstract - This paper presents the theoretical implementation of a short distance depth perception sensor, based on multiple axis stereopsis. The sensor is made up of 7 distinct sensing areas, arranged in a honeycomb pattern, each area meant to capture a separate perspective of the subject scene. Due to their arrangement, the sensing areas can be used as independent sources for a stereoptic system, or can be combined to form distinct sensing patterns that would then be used to determine the depth of the elements within the scene.

I. Introduction

Stereovision systems are based on the triangulation of 3-dimensional points from their projection on the 2-dimensional planes of images captured by distinct cameras, taking inspiration from the stereoptic mechanism of human vision. For such cases, the determining factor in most computations is the distance between the cameral, as it is directly linked to the maximum scene depth that can be perceived without noise perturbations. [1]–[3]

In other cases however, the baseline case is that of insect stereopsis, with multiple instances of the same scene being recorded as fractions of the same underling image. In such cases, the systems makes use of a micro lens array in order to focus light into specific points of the image sensor, leading to a small distance between the focal points of each image, thus losing accuracy for points that are deeper into the scene. [4]

This paper presents a variation on the latter, opting however to use different sensing areas in order to record the image data. The setup is based on the hemispherically curved image sensor CurvIS, in order to add a 3-dimensional component to the sensor pattern. In the end, the sensing areas can be combined into a larger sensor, depending on the resolution and accuracy needs of each application.

II. Implementation

Based on the multiple image stereopsis observed in insects, the proposed image sensor will consist of 7 hexagonal sensing areas, arranged in a honeycomb pattern. This arrangement will lead, in the base case, to 3 distinct opposite image pairs, on which disparity based depth perception algorithms can be applied. On top of this, the sensing areas can be combined in larger resolution sensors, with the amount of images captured changing based on the accuracy needs of the application.

2-dimensional sensor

In this particular case, the honeycomb pattern is flat, allowing for classical silicon-based image sensors to be used. The processing system will revolve around disparity map processing, using the center image as an anchor for the 3 pairs of disparity images resulted from opposite sided pairs, highlighted in (1):

The advantage of this system is that it can be rotated based such that the disparity axes match the configuration of any given scene. At the same time, the rotation can be done between two different shots, and superposed using the center section as an anchor between the images. For determining the depth data, an enhanced disparity map processing algorithm should be chosen, as the distance between the image projections is identical to the size of the viewport. For this, an adaptive thresholding algorithm, such as the one proposed by [2] can be used, skipping the

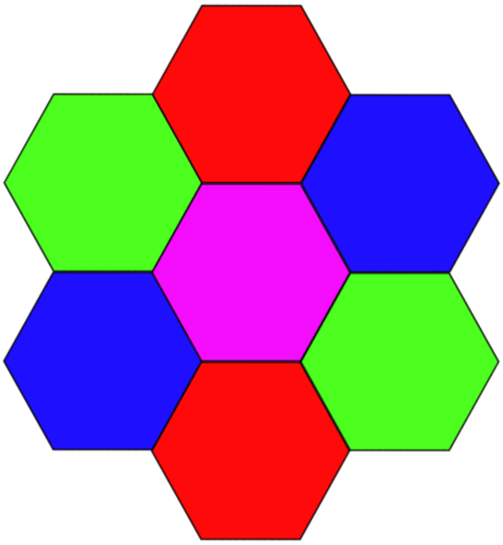

Figure 1: Proposed 2-dimensional model.

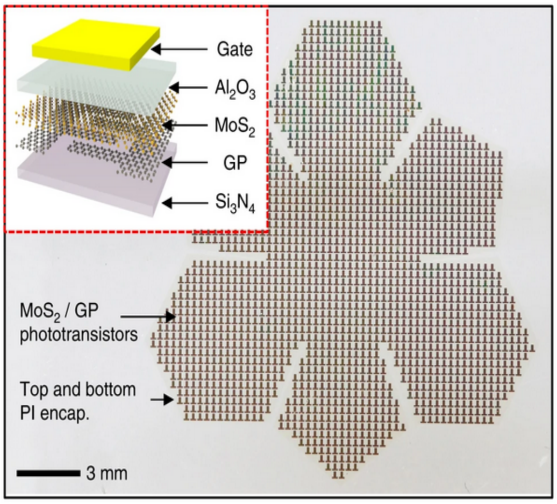

Figure 2: Phototransistor array. [5]

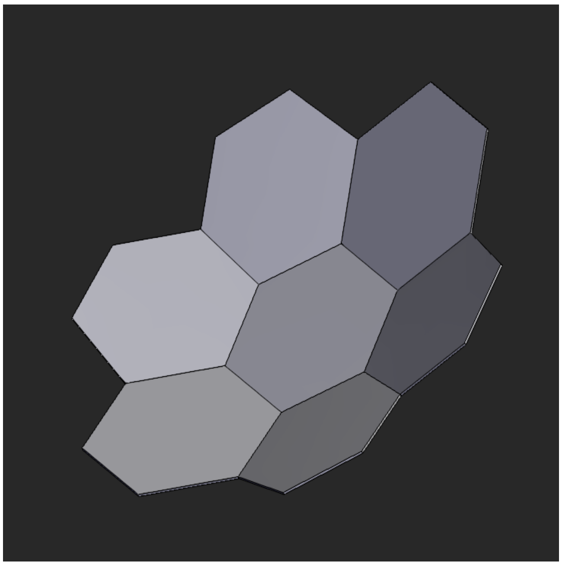

Figure 3: Proposed 3-dimensional model.

horizontal and vertical enhancement steps, as they can be compensated by the other disparity pairs.

3-dimensional concept

Inspired by the soft biometric device proposed by [5], this approach will also revolve around the use of a hemispherical image sensor, using the same MoS_2 and graphene combination in order to yeld significant photosensitive properties, while allowing for a structure that will not be damaged by the required bends.

As shown in (2), the sensor introduced by [5] represents 7 sides of a truncated icosahedron, as their application required for all the sides to come together in a seamless fashion, such that it could be used as a retinal implant. For the purposes of depth perception, each sensing area will record an image of the same target area, therefore seams will not present an issue in the sensor design. As such, the following honeycomb hemisphere pattern can be used:

In order to obtain the disparity data between each sensor pairs, the phase shift between the image planes needs to be accounted for. This shift allows for more significant disparity values, as well as increasing the field-of-view of the resulting image. As in the case of the 2-dimensional sensor, the center area is chosen as an anchor, with the 3-dimensional profiles being "stitched" on it, creating a panoramic effect. In this case, instead of opposite sections being compared for determining the disparity images, each area is instead compared against the center, considered the "frontal" view.

Area combination

In particular cases, the system can be configured such that more sensing areas are used in order

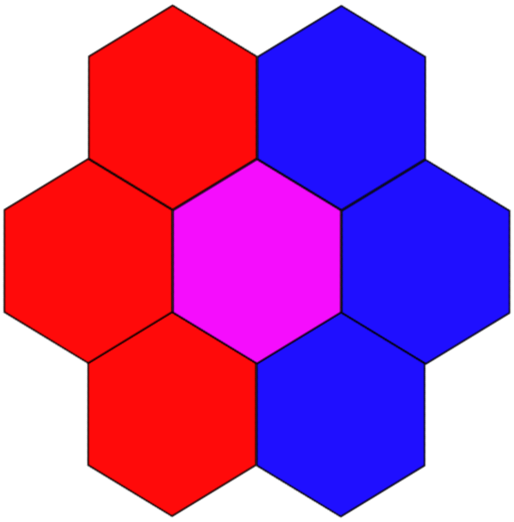

Figure 4: Classical stereopsis arrangement.

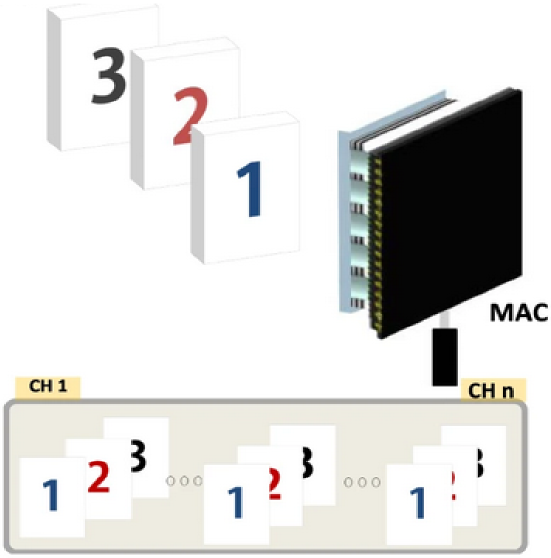

Figure 5: Visual disparity showcase. [4]

to record the same image. Best used for the 2-dimensional system, as the 3-dimensional one will be affected by the seams between the sensing areas, this procedure can create various patterns based on the scene requirements.

For example, showcased in (4) is the recreation of classical stereopsis, using the honeycomb pattern. The two halves act as individual cameras, with the center section being used in order to overlap the end result, after the disparities are computed. As mentioned previously, coupled with the ability to rotate the sensor around the center area, those arrangements lead to

III. Results

Based on the findings of [4], several performance and configuration aspects of the proposed sensor can be deduced. Those relate to both the feasibility of the proposed sensor in order to extract relevant information from the scene, as well as application areas for different configurations of the honeycomb pattern.

Firstly, as shown in (5), there is enough distinction between the images captured by each sensing areas, such that disparity-based can be utilized in order to extract 3-dimensional information. While the example only showcases horizontally spaced sensors, the hexagon-based proposal will have three main axes in which the scene will be assessed, further increasing the accuracy of the system.

Secondly, (6) presents the different use cases for multiple stereopsis systems. Due to the configurability of the proposed system, it could be adapted to function in different environments, with the most relevant environment being close-range imaging, due to the distance between image planes being equal to the size of the images themselves. As this is entirely dependent on the desired resolution and particular sensor configuration, use cases might range from surgery assistance to vehicle automation.

IV. Conclusion

This paper presents a depth measuring image sensor, designed for configurability and short distance accuracy. It is based on a honeycomb structure of phototransistor arrays, capable of being interlinked in order to capture the same scene on up to 7 distinct image planes, that are then compared in order to determine disparity images on up to 3 different planar axes. It also showcases a 3-dimensional configuration of the honeycomb pattern, used to generate greater differences between the image planes, as well as an increase field-of-view.

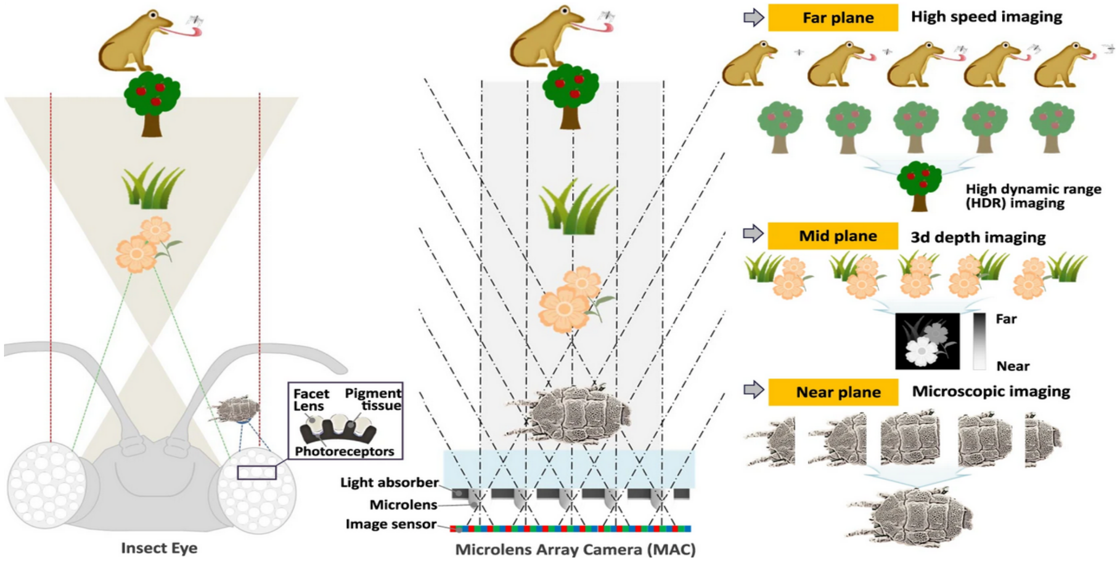

Figure 6: Multiple stereopsis example. [4]

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