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Overview of 3D Underwater Optical Based Mapping Sensors

1. Introduction

Techniques used in terrestrial and aerial mapping fail to perfectly translate over in submerged environments. Underwater mapping solutions utilize novel techniques due to the complexities of the medium such as water refraction, turbidity, underwater currents, etc. [1]. This paper covers some of the optical based sensing modalities used in the industry and provides a comparison of each technology's features and limitations.

2. Overview of Optical Sensors

2.1 *Stereoscopic Vision*

Similar to the way human eyes work, stereoscopy requires placing two cameras a known distance away from each other to capture depth information from their intersecting field of views. It utilizes the triangular geometric property of the cameras' configuration to extract the depth image [1]. Implementing this system requires computationally intensive computer vision techniques such as Scale-Invariant Feature Transform (SIFT). SIFT finds similar features between two images and is used to solve the triangulation problem.

Stereoscopic Vision has an easy setup relative to all the other sensing paradigms. It requires two waterproof cameras such as GoPro Hero 5s which can cost anywhere from $199.99 - $399.99 per camera [2]. Cheaper products can be found but the form and build factors of GoPros make them notable candidates when minimizing volume and weight is of the essence.

2.2 *Light Detection and Ranging*

LiDAR is used in aerial and terrestrial mapping however solutions do exist for underwater environments. The current aerial LiDAR techniques can generate point clouds up to 30 meters under the water surface [1]. The range can be improved if the LiDAR module is submerged but not all the components can translate over. Underwater LiDAR requires using a 532 nm (green) laser instead of a 671 nm (red) laser and a robust housing to protect the internal equipment from the aqueous setting. However, both techniques use the same algorithms to generate point clouds.

Using time of flight information from laser emission to capturing the reflection, the system can generate a cloud of distances. Currently the company 3D at Depth provides leasing solutions for its underwater LiDAR module which is rated up to 1500 m. [3][4]. Unfortunately, no list price is available.

2.3 *Laser Line Scanning*

Similar to LiDAR, Laser Line Scanning uses a laser to fetch 3D surface maps. However, it uses a camera a fixed distance away from the laser emitter to produce 3D information. Rather than capturing the time of flight data, it observes the distortions in the laser emitter's pattern and applies a triangulation method using the onboard camera to extrapolate depth information [5]. Patterns don't necessarily have to be a single line but can also be variations of a combination of lines. Majority of the current applications of this technology is for generating 3D models of real objects. In manufacturing, this technique is used to find deformities in a product coming off an assembly line. In addition, there's a method similar to LiDAR that uses the camera to capture the laser reflection off a surface and time of flight measurements to get a surface map [1].

2GRobotics provides laser line scanning equipment at an undisclosed price point. However, developing a custom solution seems feasible by using underwater cameras, 532 nm lasers, and CV techniques such as SIFT to generate depth maps [6]. The cost of assembling is dependent on the power of the lasers and the resolution/build of the cameras.

3. Features & Limitations of Sensors

Stereoscopic Vision operates from a range of less than 3m [1] and provides a resolution of approximately 3mm at that height [2]. However, the resolution may significantly improve since newer GoPros have 4K resolution. However, there are more factors that limit stereoscopic vision such as water opaqueness and shadows. In addition, the cameras are rated for a depth of 10m without an underwater camera apparatus and may need an additional light source at lower depths.

The LiDAR solution from 3D at depth rating of 1500m, has a range of 2 - 45m, a 6mm resolution between 2-40m ranges and a sampling rate of 40 kHz. Communication with the device can be achieved through TCP/IP and the peak power consumption is 110 Watts at temperatures of -5 °C - 32 °C [4].

The Laser Line Scanning product (ULS-200) from 2GRobotics has a depth rating of 350m, with a range of 0.36m – 2.5m and a resolution of 0.6 mm at 2.5m. The sampling rate is approximately 4.75 kHz and the ULS-200 uses approximately 5 Watts at temperatures of -10 °C - 40 °C. The device uses triangulation to fetch depth information [7].

4. Conclusion

Choosing an optical sensor for mapping is non-trivial since each method has its benefits and flaws. For instance, line scanning may be good for mapping very small regions but it would be terrible at mapping larger swaths of space. For a general underwater mapping solution, using sensors from other domains, such as an IMU, in conjunction with an optical sensor may provide the best performance to cost.

References

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