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Stereo vision development for high performance on stereo systems

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Abstract

Stereo vision applications and systems are being grown common and widespread, especially with technological advancement. These systems and applications are widely applied in multiple fields and areas including autonomous robots, navigation, movie producing industry three-dimensional measurements, 3D reconstruction, object tracking, security system and identification systems, and augmented reality applications, and etc. Recently, much attention has been paid to new algorithms and practical systems in parallel with advanced technologies. High competition has been realized among a wide range of scholars, developers, and researchers toward developing high efficient systems and techniques. In this paper, we mainly present significant literature on some existing stereo vision algorithm techniques and systems in stereo vision and image processing areas. Where for many decades until recent, remarkable works and researches have been performed to develop methods with high accuracy and fast time processing. These systems and methods can be easily integrated with several applications as newly created solutions for various stereo vision problems such as low acracy, mismatching algorithms, correspondence problems, and more. The authors abroad have introduced numerous methods to solve the previous issues with different structures and specified targets.

Keywords: Stereo vision, Algorithms development, Stereo vision applications, stereo, and image processing techniques

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1. Introduction

Stereo vision is currently one of the most search fields within computer vision. This topic is commonly attracting the huge attention of multiple researchers, developers, and scholars. Many approaches are generated every year which are directly related to stereo vision areas including sensing Visualization, transmission systems, 3D information, three-dimensional reconstruction toward advancing multiple applications in different fields such as medical, manufacturing, architecture, security, image and signal processing, multimedia, and more [5]. An up-to-date various of surveys and reviews of stereo vision techniques including stereo vision matching, stereo reconstruction, and correspondence algorithms have been contacted which are useful and beneficial for those who are already engaged in the stereo vision area, which provides them a significant overview of the advances accomplished, technologies applied, limitations and advantages as well as present for a quick introduction and brief summary to the state-of-the-art [6]. Stereo vision is specifically an imaging method that generally allows for reconstruction of point or multiple points of the coordinates in three-dimensional 3D space depending on images captured by two cameras from different positions. By detecting specific objects or targets in particularly corresponding frames, which are the three coordinates (x, y, z) which can be precisely obtained by applying the significant technique. Stereo vision principles are widely applied in numerous applications. However, in most of these applications, less time processing and high accuracy of stereo vision are crucial before any further processing stage. For instance, in biomedical applications and systems, the high accuracy in accruing and capturing objects is a critical point in order to investigate the kind of existing disease toward finding the right and specific medicine. Thus, a multiple stereo vision and filtering system have been proposed and developed [3].

On other hand, for today's complex technologies, new methods of stereo vision and three-dimensional 3D perception is have become an indispensable and state-of-art principle to deal with our real-world and surrounding environment. The visual image concept is commonly the wide appropriate technique for 3D data capturing and 3D information extracting from stereo images. Therefore, in order to build a complete stereo system from the software to the hardware part different and massive focus has been paid by numerous researchers in the computer vision field. On another hand, the stereo vision fundamentals are dramatically improving with the advance of stereo technology in order to fulfill the desired needs and meet all requirements for various applications particularly with reliability, high precision, accuracy robustness, effective cost, and modernity. Thus, different model systems, techniques, and devices are investigated and generated toward avoiding the previous disadvantages by considering multiple characteristics in different perspectives such as robustness, weight, size option, process requirement, resolution, effective cost, accuracy, and time processing, and reliability [13].

Some papers related to stereo vision and algorithms development have been selected to discuss and analyze, in [1] the author introduced a new method of stereo vision algorithms with an illumination control as a solution for absolute difference (AD) works in texture region. The author presents a three-dimensional aggregation technique stereo vision algorithms matching. The method was able to improve the accuracy of results by improving the performance near the area of the depth discontinuities. Tippetts has presented in [12] a method for resource-limited systems of stereo vision algorithms. It gives a perspective on the accuracy in terms of this trade-off. In [8], the authors presented an implementation and design of design automatic inspection system based on a stereo vision system which lead to an increase in the accuracy of shape classification. The authors have proposed a new constant time-weighted filter approach for stereo vision algorithms application. The method is considered a simple filtering technique that can be utilized in multiple stereo vision applications

based on stereo algorithms.

2. Literature Review

Stereo Vision is specifically a field of study in an area of machine vision principle which attempts to regenerate the human vision concept by applying multiple or two 2D images for the same view toward creating a 3D depth data or information of the targeted scene/ object. The excreted depth information or data is utilized as a part of many applications as mentioned previously. The common literature of selected Several of today's passive stereo vision systems are structured and implemented with specified stereo vision cameras that exactly combine two factory-calibrated cameras set at a fixed baseline. The benefits of utilizing a specified stereo camera are the low and effective price, the aim of high resolution, and the captured images are applicable for other applications. Figure 1 below presents the basic fundamentals and principles of the stereo vision system. The system is constructed from two parallel stereo cameras which are located in different places horizontally to capture right and left images for the same target or view, the captured images are then further processed in order to develop 3D scene model of the 2D images. The real challenge in stereo vision is to find a significant

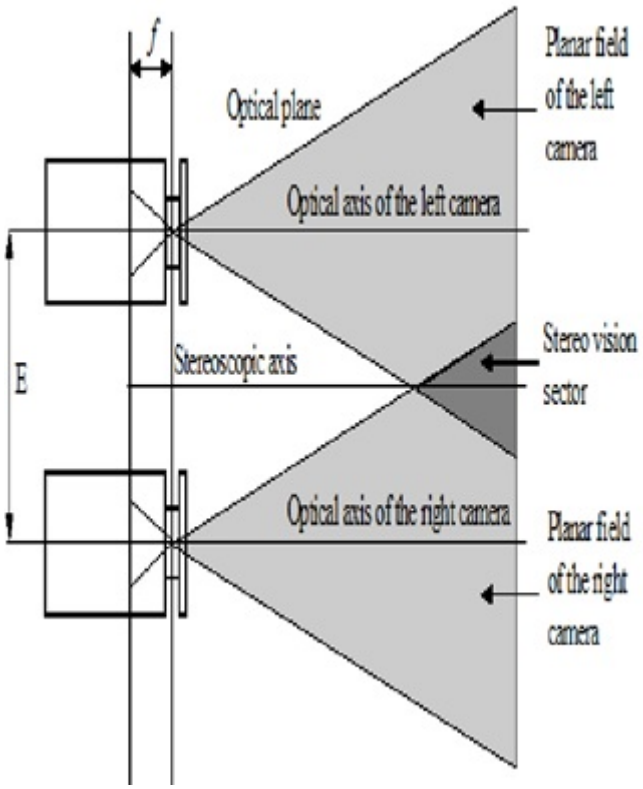

Figure 1: Stereo vision fundamental concept (Triangulation principle)

method in order to approximate the horizontal distance (differences) between the scene presented in the captured images toward the map (the correspondence of the target environment. The result's accuracy is commonly relying on the selection of the stereo camera to build an efficient system, it also depends on the robustness of the developed algorithms. This normally depends on the developer's target and type of stereo vision problem [2].

The nature of the stereo algorithm issues and challenges made this area receive a huge deal of attention until present days. The good results and their accuracy are affected by much missing

information and data including those are generated by slanted surfaces, occlusions, correspondence and other problems which are relating to extracting data and information as 3D from 2D images. Thus, numerous systems, techniques, and concepts have been implemented among the stereo vision areas [12]. These concepts and methods have been developed to contact a specific topic or challenge including stereo vision matching, stereo disparity mapping, stereo vision reconstruction, stereo correspondence, stereo algorithms filtering, and other more methods which have been established in the past few decades. Each of these systems, methods, and concepts have their own beneficial contributions, challenges, and limitations [1]. Figure 2 shows a simple representation for depth accuracy, where two cameras are used to generate left and right images and stereo algorithms are applied to further process these images toward gaining the depth information.

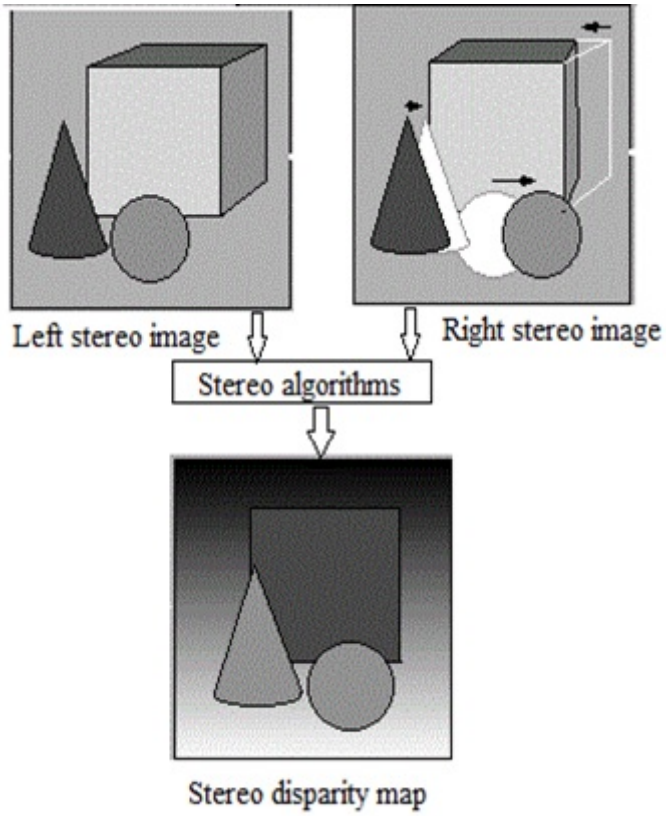

Figure 2: An example of stereo vision depth extraction

Multiple different types of structures and are investigated and proposed to measure the geometry and extract information from a specified captured scene. Early work and previous studies are focused on generating stereo algorithms which are mostly focused on the camera binocular configurations [11]. While the redundancy in some cases can lead to reliable depth and significant accuracy of estimations. Recently approaches, because of significant boost for available vision advanced systems with utilizing multiple cameras and computational power are becoming increasingly practical and functional. The move from binocular to multi-ocular advance systems leads to the advantage of possibly increasing the accuracy and the stability of depth information representation and calculations.

Modern stereo devices which are applied to obtain depth information are the structured light sensor and time-of-capture. These technologies are sort an active sensor, which differs from the classic stereo vision camera. The devices have the ability to gain stereo depth information with significant accuracy and increased interest for the applications of computer vision. The recent substantial focus

and development have been made in obtaining high accuracy of stereo vision results. Scharstein and Szeliski [14] in their review have provided infrastructure and techniques as quantitative evaluation to validate the accuracy of obtained dense stereo vision. In majority circumstances, finding a sufficient tradeoff between the accuracy and speed is based on the target objectives and desire applications [4, 7].

This manuscript paper is organized and structured as follows. In Section I, a brief introduction of stereo vision fundamentals and principles as part of the computer vision field has been presented. Section II contains a literature review of related work on stereo vision. In Section III the objectives of this paper are presented. In Section IV, the methodologies description is shown and discussed. Section V conducts a simple comparison of stereo vision techniques.

3. Target and Objectives

In this paper research, we aim to review comprehensive information of stereo vision development from different perspectives including fundamentals and principles, the structure of stereo vision, and technologies applied among their systems. The development of some stereo vision algorithm techniques use to extract information from stereo images will also be contacted. A basic comparison of some stereo vision methods will be presented.

4. Methodology

Numerous stereo vision methodologies as part of the computer vision area have been investigated, proposed, and developed. Each is conducting a specific challenge or topic of stereo vision including stereo vision calibration, dense 3D reconstruction, stereo matching, gesture recognition, depth extraction, disparity filtering and object detection, and others more.

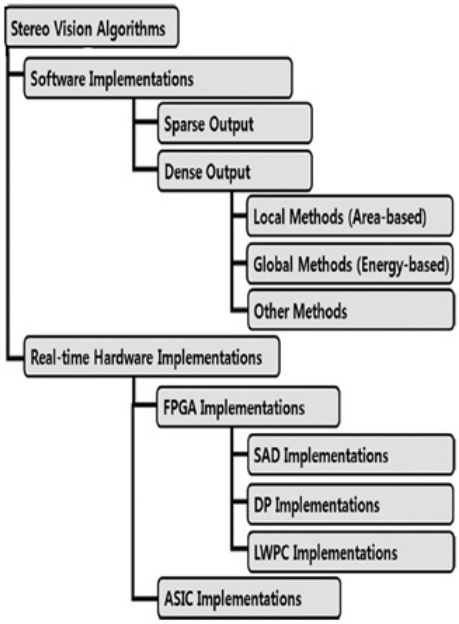

Figure 3: Stereo vision algorithms categorization

As our aim to go through stereo algorithms developments Figure 3 presents the stereo vision algorithms categorization. In the first category (stereo vision algorithms), the software part is divided into spare output and dense output parts. In particular, the dense algorithms utilize either global,

local, or other kinds of methods to perform the processes. While the other section deals with the hardware implementations.

The taxonomy by Scharstein and Szeliski [15] has summarized the general methodology structure for the development of the new algorithm. This methodology has shown the general structure and steps of stereo vision algorithms implementation as shown in Figure 4. The majority of newly developed stereo vision algorithms are following the taxonomy by Scharstein and Szeliski as a standard methodology with various structures in four specified steps in sequence, where the input images are captured by stereo vision cameras arranged horizontally to obtain corresponding images. These images are usually rectified, then these images will go for further process through all the steps based on researcher targets and goals.

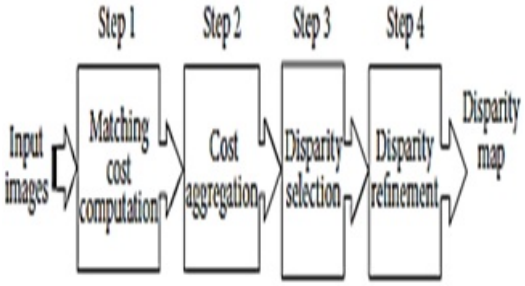

Figure 4: Stereo vision algorithm development framework

5. Comparison of Techniques

In the previous taxonomy by Scharstein and Szeliski, each step has been widely investigated, and numerous studies, concepts, methods have been proposed in order to achieve good results of the developed algorithms.

For step 1, in order to establish correspondence between pixels, several techniques have been developed to perform this part including absolute intensity differences (AD), the normalized cross-correlation (NCC), the squared intensity differences (SD), the sum of absolute differences (SAD), the sum of squared differences (SSD), each method has its own features and limitations [14, 9].

To achieve good performance of any newly developed algorithms, many generated methods have been suggested to perform step 2, step 3, and step 4 which mainly focused on increasing the accuracy of the obtained results with proposing diverse algorithms structures and processes which aim to go in two different directions, increasing the accuracy and maintaining fast algorithms performance.

In step 2 global methods of stereo vision, algorithms are most common, their goals are to perform smoothing toward increasing the accuracy such as global optimization, where these methods take into consideration the whole image to find perform for each pixel. These methods involve also segmentation input images based on colors. The other algorithm is the Dynamic programming method. This approach is a particularly fair trade-off between significant terms, the computations complexity, and the quality of the results achieved.

In addition, another developed and commonly applied methods which have been implemented as global strategies are those using a Graph Cut (GC). The Belief Propagation (BP), and more. Each of these techniques has a specific structure with advantages and disadvantages outcomes. For step 4, several different approaches have been suggested and published abroad. Most of these methods

are depending on some type of filters or smoothing strategies [10]. While, over the last few years, advanced and significant stereo vision filters techniques have been achieved, especially among the area of image and signal processing such as guided filters, mean filters, Gaussian filters, median filters, LOG filter and more other filters which have been part of stereo vision algorithms smoothing approaches.

Table 1: Comparison of some stereo vision algorithms

Method	Features	Limitations
NCC	Obtained accurate result	Complex algorithms Effect with illumination
SAD	Less complicated Perform speedily	Low accurate Effect with illumination
SSD	Easy algorithms Fast	Low accurate
AD	Less complex Perform speedily	Low accurate Sensitive to outliers
SD	Fast Applied for gray image	Low accurate Sensitive to outliers
DP	Smoothing generated results Occlusion handling A bit handling illumination	Generate horizontal line on result Time consuming
GC	Sufficient for color segmentation Occlusion handling	Complex algorithms Time consuming
BP	High accurate Occlusion handling Symmetrical cost functions	High computational(complex) Time consuming

6. Discussion

Generally, stereo vision implementation, concepts and principles can be presented by using numerous ways and perspectives. This field continues to grow and extend with the advancement of information and technologies. In this review, a detailed summary of some works of stereo vision algorithms has been conducted based on several specified steps of stereo algorithm development.

Each work has its own algorithm structure and conducts a crucial challenge or problem with stereo vision areas such as stereo vision limitations, correspondence issues, matching problems, occlusion issues, and more. The outcomes of the selected works have various contributions and limitations. However, all these approaches have a common target which to obtain better performance and accurate results toward applying the outcome with actual applications in different fields.

7. Conclusion

This paper mainly represented a review and comparison regarding stereo vision based on some selected published related papers. This review shows the great role of stereo vision as a high attracted area in technology advancement and computer vision application development. The paper reviewed and compare some stereo vision works relying on their algorithms developed, their common targets and challenges. The detail among the selected works has clearly illustrated the major common interest of developing stereo vision with high performance and better speed to be part of stereo modern applications. The researchers attempt to find satisfied solutions to multiple challenges and different problems toward gaining good results.

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