HIGH-PERFORMANCE FULL-VIEW VISION SYSTEM WITH GUIDANCE SUPPORT OF ACOUSTIC AND MICROWAVE ARRAYS

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ABSTRACT

This paper describes the concept of wide-angle coverage optical vision system integrated with guidance support of microwave or acoustical imaging arrays. The objective is to provide the capability of effective high-resolution full-view monitoring and sensing. The optical component, formed by a multi-camera array, is responsible for the main interface with human users. The acoustical and microwave arrays are integrated, allowing the system to function in the event-triggered modality for optimal efficiency. In this paper, the arrays discussed are in circular configurations. With minor modification, the system can also function with linear-array configurations.

KEY WORDS

Multiple-camera full-view vision system, acoustic or microwave arrays, event-trigger visual systems.

INTRODUCTION

Traditional vision systems, single or twin-camera systems, are designed and modeled based on the functionalities of the human visual system. The view perspective is normally limited, and the resolution is largely governed by the size of the lens and CCD array. For vision systems deployed for monitoring purposes, it typically involves the fixed-position modality. For wide-perspective applications, it requires one or two-dimensional mechanical movement for steering, which often creates undesired latency.

This project involves the use of a multiple-camera full-view visual system. A full-perspective high-resolution composite image sequence is constructed from the image frames from the camera system. Because each composite image frame contains full view, no rotational movement will be required. To enhance the capability of the visual system, an acoustic or microwave array is added and imaging algorithms are implemented onto the acoustic/microwave array for target profiling, such that the focusing of the camera visual system is guided by the acoustic/microwave system. This will significantly elevate the dynamic monitoring capability as well as the quality of interface with the users. As a result, this system has become an event-trigger visual system with dynamic focusing capability. With the addition of acoustic/microwave imaging capability, this visual system significantly elevates the performance of real-time tracking.

OPTICAL VISION SYSTEM

One of the key components of this imaging device is the optical vision system. Because of the perception capability of the human visual system, vision systems operating in the optical-frequency range offer the most effective interface. Yet, the main weakness of many vision systems is (a) the limited angular coverage, (b) requirement of focusing, and (c) resolution limit. An effective vision system needs to be capable of wide or full angular coverage with high-resolution and dynamic focusing capability.

To achieve wide or full viewing coverage, there exist two direct approaches. One is the utilization of a wide-angle camera system. Also, due to the wide-angular coverage, the resolution is compromised as a result. To achieve wide-angular coverage and high resolution simultaneously, we can perform the image reconstruction through composite imaging, if mobile platform is available. Composite image through moving platform is the optical equivalent of the synthetic-aperture imaging format, which results in resolution improvement.

Here, we provide a simple example of this wide-angle mobile composite imaging modality. The example is the scan of a wide-angle camera through a two-mile deep well of 9-inch diameter. Figure (1-a) shows a typical image frame from the vision system. Figure (1-b) is the unfolded version of Figure (1-a). The non-uniform resolution is visually noticeable.

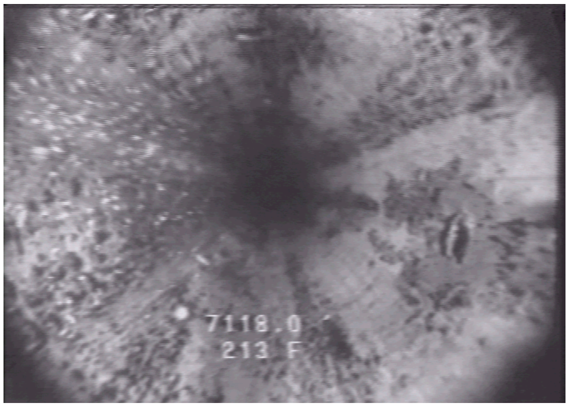

Figure (1-a): typical image frame from the wide-angle vision system.

Figure (1-b): Unfolded version of Figure (1-a).

As the system scans through the well, composite images of regions of interest can be formed. Figure (1-c) is the high-resolution composite version, combined from 70 frames from the video sequence.

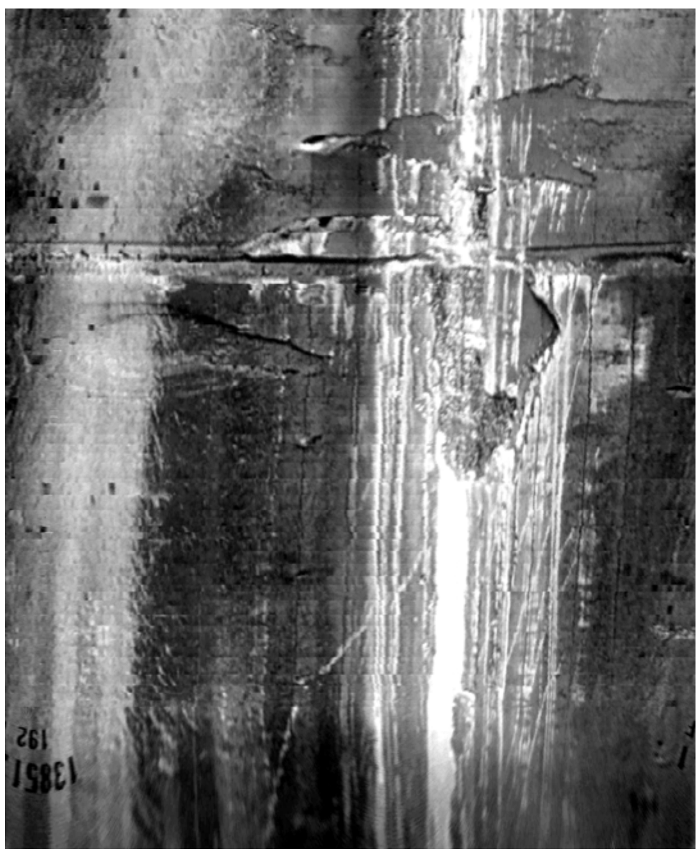

Figure (1-c): Composite image from 70 frames of the video sequence.

This system demonstrates impressive capability with one single wide-angle camera. Yet, the computation involved can be complex. This is because the formation of the composite images requires estimation of the displacement parameters, frame by frame. The procedure may often require the computationally extensive steps such as feature extraction, identification of matching correspondences, and image registration. As a result, it is not suitable to real-time applications.

MULT-CAMERA DEVICES

Another potential approach is the utilization of multi-camera devices. Because of the camera configuration is predetermined, estimation of displacement offset is no longer required and the image registration parameters can be computed and stored prior to data acquisition, such that the image registration for the formation of the composite images becomes straightforward. Figure (2-a) shows a typical multi-camera system for wide-angular coverage. Figure (2-b) shows the individual image frames from the camera system, and Figure (2-c) is the full-view composite image constructed from the image frames from all the cameras.

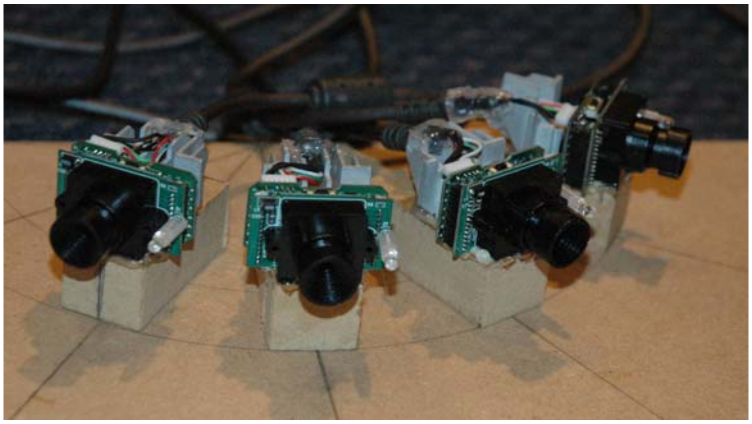

Figure (2-a): Multi-camera system for wide-angular coverage

Figure (2-b): Image frames from the camera system

Figure (2-c): Full-view composite image from the image frames

Although the discrepancy in terms of the flow of color and shading among the image frames is noticeable, these artifacts can be effectively removed or reduces through calibration.

EVENT-TRIGGER MONITORING

The high-resolution wide-angular coverage vision systems provide a large amount of visual information in real time. At high data rates, human perception capability can saturate within a short period of observation time, and it will become increasingly difficult for human observers to monitor and detect changes effectively. Therefore, our approach is to utilize microwave or acoustic systems to guide the vision component (1) to detect changes and events, and (2) to provide range information for dynamic focusing.

To be compatible to the configuration of the camera systems, the sensor array is also arranged in the circular format. Figure (3) shows the configuration of the standard 8-element microwave or acoustical arrays. Acoustic systems are suitable to underwater sensing applications and both microwave and acoustic systems are applicable to in-air modalities.

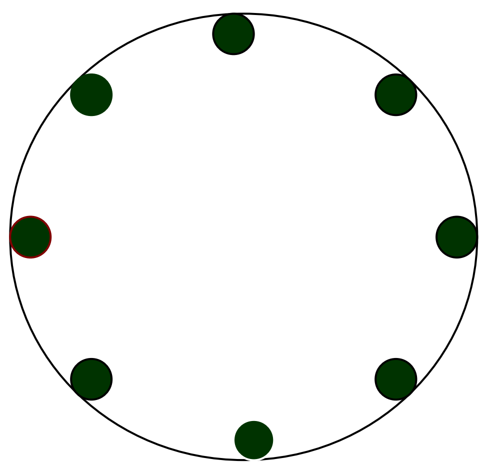

Figure (3): Configuration of the standard 8-element arrays.

The most common transceiver elements of a microwave array are antennas. The antenna type and beam pattern are designed according to the applications. For acoustic arrays, the elements are hydrophone transducers. The frequency range of the array elements is selected to achieve application objectives. Figure (4) shows the discone omni-directional antenna for the microwave arrays. The most effective frequency band for the discones for in-air applications is 1-2 GHz.

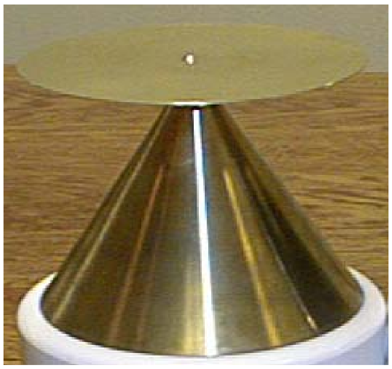

Figure (4): Discone omni-directional antenna for the microwave arrays.

MICROWAVE AND ACOUSTICAL IMAGING

The image reconstruction algorithm for the microwave and acoustic arrays is formulated based on the backward propagation method, operating in the circular-array format. The backward propagation method is known for the capability of high-resolution imaging with simple and scalable structure, which can be implemented in parallel form in both hardware and software for real-time processing. The circular configuration is designed to be compatible to the arrangement of the optical vision system. Eight antennas are selected to form the microwave imaging array, simply as an example. The number of transceiver elements can vary based on the specifications and requirements.

The signal-processing procedure for image formation can be implemented in spatial-frequency or time domain. For array systems with small number of array elements, time domain processing can be more effective in terms of computation complexity.

Because both the optical system and support microwave and acoustic arrays are in circular format, the backward propagation algorithm is selected to function in the polar coordinate system, for simplicity. The profile constructed by the image formation algorithm provides the range and bearing angle of the microwave or acoustical targets. The range information will be given to the optical system for dynamic focusing. The bearing information will be used to mark or high-light the angular index of the display from the vision system to serve as an active dynamic indicator to the human users. The resolution in range is governed by the bandwidth of the microwave or acoustic waveforms. And the angular resolution is defined largely by the radius of the circular array.

CONCLUSION

In this paper, we present a study of the concept of applications of dual-mode imaging systems. The main visual system remains in the optical range. Yet, it is supported by microwave or acoustical arrays for optimal effectiveness in imaging. The microwave/acoustic components of the devices can function in either passive or active modes. And the image formation algorithm is capable of operating in pulse-echo or step-FMCW signaling formats.

For simplicity and consistency, the presentation of this paper describes the optical vision system as the main visual interface and the microwave/acoustic arrays as the support systems to identify changes, such as events and motions, to provide the range for the focusing of the optical system as well as the bearing information as the marker/alert for the human users. With simple modifications, the roles of these components nay alter, and the microwave or acoustic systems can function as the main imaging component and the multi-camera device can assume the role of the support system for various new applications.

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