Multi-lens Panoramic Network Camera

White Paper by Dahua Technology

Release 1.0

Table of contents

1 Preface

Currently there are two types of panoramic camera in the market, which are fisheye panoramic camera and multi-lens panoramic camera. Compared to the mainstream fisheye panoramic camera, the multi-lens panoramic camera is free from several problems such as pixel, big definition difference between image center and image edge, obvious image distortion and so on. The panorama function of this camera is realized by integrating several sensors with tailored lens, because regular rectangular image can be generated from each sensor and splice a panoramic image without de-warping, however, it needs a corresponding algorithm software to realize seamless image splicing; besides, the requirement of the whole program is quite high, meanwhile strict requirements are necessary for setting viewing angle and installation positioning.

There are several sensors installed inside the panoramic camera, which can splice each image to generate a panoramic picture. Currently the structure of the mainstream product is to encapsulate four 2MP sensors and short lens with 45 °or 90 ° view angle into one enclosure. The core technologies such as digital processing and compression etc. are integrated into the front-end firmware, splice four separate images into a HD panoramic picture of 180 °or 360 °according to the users' requirements, and then it is transmitted to back-end management platform via network. Compared to the mainstream fisheye panoramic camera, the advantage of the multi-lens is to get free from the restriction of focal length, which means seeing much further and clearer in the same condition. Meanwhile the multi-lens panoramic camera is equipped with the function of virtual PTZ, which can realize several functions such as edge clipping, center restoration, 180 ° unfolding and so on, which makes it convenient for users to adjust image according to monitoring requirements.

2 Overview

Dahua multi-lens panoramic network camera is a software and hardware all-in-one product with large field view HD imaging which is developed by Dahua Technology Co., Ltd. The product realizes two key indicators of monitoring camera which are HD and large field view, based on the technology of video splicing; it splices several channel HD video into panoramic video image with high resolution. The splicing algorithm is highly integrated in the front end and parallel real-time operation on the system, which is to make the multi-lens camera equivalent to a monitoring product which is HD, undistorted and equipped with ultra-wide angle, besides the horizontal field angle of the product is no less than 180 °, which has solved a series of problems such as small monitoring coverage, huge distortion and long delay etc.

3 Technical Background

The monitoring camera is required to own the field angle which is big enough in some big monitoring coverage scenes such as playground, square and airport etc. As for the traditional wide angle and fisheye camera, the resolution of unit field angle decreases because the field angle becomes bigger in the situation where the CMOS resolution is the same, which makes the target blurry. Besides, due to the imaging features of the fisheye camera, the straight line becomes warped when displaying image by using rectangular image, which generates image distortion. From another perspective, the imaging quality of one single HD camera can satisfy the monitoring requirements such as clear target, no distortion, but the only problem is that the filed view is not big enough, which makes the scheme of video splicing emerge at the right moment.

The video splicing algorithm can be divided into two parts which are splicing initialization module and splicing main module. As for splicing initialization module, it needs to go

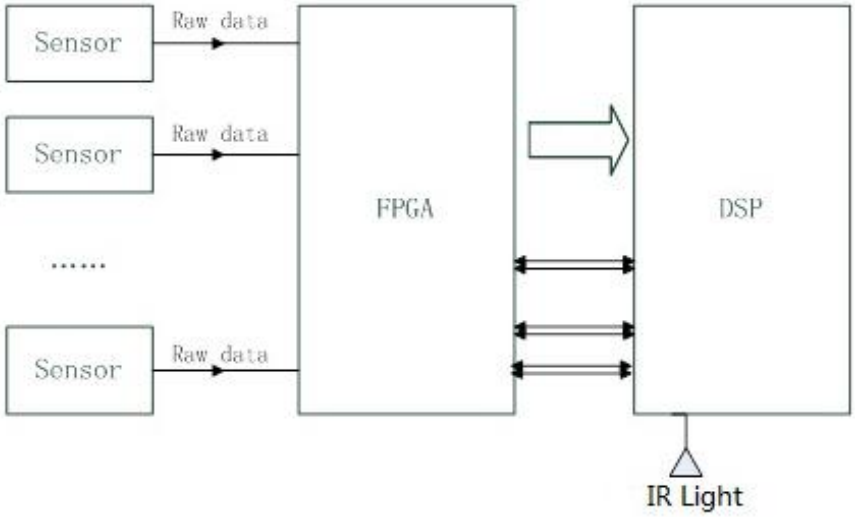
through a series of algorithm analysis to acquire the internal and external parameters of each camera in the system, and then it is to calculate the needed parameter sheet for splicing image which is mapped by each channel video; while the splicing main module just uses these parameter sheets and the current input image to complete the update of splicing image.

The calculation cost is huge because video splicing needs to deal with several channel HD video real time. In the past few years, it is generally to transmit front-end video back to back-end via high speed network in the industry, and then use customized high performance intelligent server platform to complete splicing. In a long period of time, it has solved the clients' requirements via video splicing solution based on the server, which has also contributed to the continuous improvement of splicing algorithm. However, it is the back-end that completes the splicing for the scheme, the back-end fails to make the splicing both real-time and synchronous because there is inevitable delay problem during the video transmission via network. It needs to establish the buffer pool to wait for the video of last channel if it has to guarantee that each video source of splicing image comes from the same moment; there will be delay for the total splicing video display when the video delay of some channel is quite big, real-time display will cause unsmoothness, frame skip and so on; it will fail to guarantee the synchronization among each video if it just simply splices the very first frame of the video line for each channel; it will make the moving object leap, lose and so on when there is moving object passing the splicing seam. Meanwhile, there will be big color difference among each channel video when some cameras are in backlight because the front-end camera separately make metering and gain control, which makes it impossible for back-end algorithm to restrain completely. Besides, the cost of the splicing scheme based on server is quite high, which has imposed restriction on the application range of video splicing scheme to some extent.

4 Key Technologies

Aiming at the problems above, Dahua has presented a scheme of multi-lens real-time splicing camera, which uses several CMOS image sensors and decompose, optimize the splicing algorithm main module to realize highly parallel integration in front-end via FPGA and hardware scheme realized by back-end digital processing chip.

The function diagram is shown as below:



Function module description:

Function module	Note
Sensor	Adopt CMOS as image acquisition sensor
FPGA	It is responsible for splicing function and part of image processing
DSP	It is responsible for encoding and part of image processing, IR control and so on.
IR light	It is responsible for IR function.

4.1 Feature Points Extraction and Matching

The key problem of splicing is to acquire the connection of adjacent images. In order to precisely establish the connection model without any manual interference, we adopt feature points as medium. The feature point is the most significant pixel location in the image, there are some common feature points such as SIFT, SURF and Harris etc. It is to extract feature points from the adjacent images respectively, first it is to use the nearest

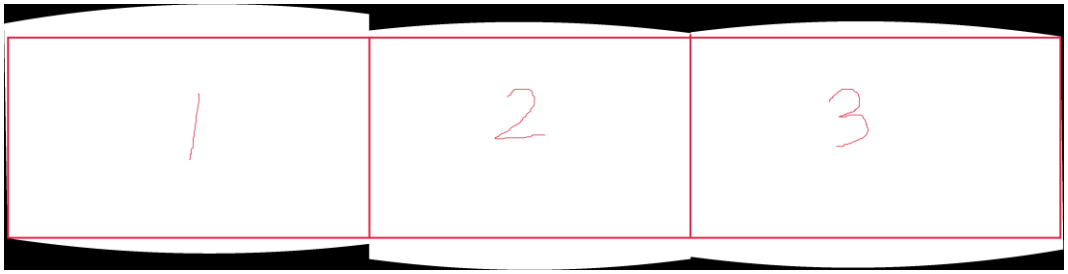
neighbor matching method, which is to use the Euclidean distance of feature vector as similarity measurement of key point for two pictures, then compare the minimum value of Euclidean distance to that of the second smallest value, it is to accept the matching point if it is smaller than the preset threshold value.

Example of matching result of feature points

4.2 Real-time Splicing Based on High Parallelization of FPGA

Project the image of each channel on the uniform spherical surface, and then unfold the spherical surface into a rectangular image, which is shown in Figure (c), the original rectangular image may be warped, the projected image area is shown by white, the lateral black edge is considered as invalid pixel.

（a）3-channel original input image



（b）valid area after black edge is cut out (inside the red line)

（c）output panoramic image（red vertical lines mark the splicing location）

As for the image from each channel, the task of splicing algorithm is to generate the red frame area shown in figure (b), or to say, it can complete mapping from figure (a) to figure (c) via confirming parameters in advance. It is recommended to use four-point interpolation method in order to guarantee image quality during mapping.

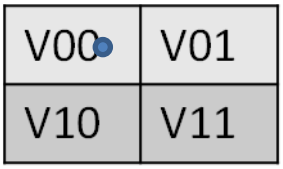


Figure 5 Four-point Interpolation Method

As it is shown in the figure above, for one dot in the splicing image, the location of projection dot in the returned original picture of projection function is floating point number, first it is to take its integral part, which is the upper left dot location in the four-point interpolation, the location of other three dots can be acquired by simply calculating upper left address and image width. Then it is to calculate the weight of the four dots in the process of interpolation according to the projection dot location and the difference value between horizontal and vertical coordinate of the four dots. Finally it is to read the data of four dots in the original picture which are v_00，v_01，v_10，v_11, and update the information of the dot in the panoramic image.

Every dot in the valid area of the panoramic image needs to be updated, therefore, it takes a lot to calculate, however, the update process of each dot is comparatively independent, which is featured with typical single instruction multiple data processing. We

decompose and optimize the splicing algorithm based on the features of FPGA, and implement the algorithm highly concurrently, which is to real-time generate panoramic image after splicing.

4.3 Multi-scene Adaptability Design

- Data Sync Acquisition

The sensor adopts SPI communication mode. The DSP port can only control one sensor, so FPGA will split SPI signal into four parts during writing operation, meanwhile it will write the signal into four sensors respectively; when DSP is reading the Sensor register, the Sensor needs to shield the signal line of the SPI and only leaves one Sensor for connection. Sensor is directly connected to FPGA, the splicing data of FPGA is from the data which is collected by Sensor; the sensor adopts slave mode, FPGA generates sync signal, which is to guarantee the data sync of each sensor.

- WDR

It can control the output mode of the sensor, which is to make it output WDR data and auto adjust ISP parameters according to the data; it is able to keep the clear details in the image when there is strong contrast between darkness and brightness in the scenario.

- 7*24

It adopts ICR technology which can control the B/W and color of the image and day/night ICR switch of the hardware according to the brightness of the current environment. Besides it can use Smart IR technology to control the brightness of IR light during black & white image, which is to make the image brightness normal.

The camera will auto switch to B&W image when it is located in the environment with low illuminance, and the illuminance value is as low as the IR-CUT trigger value (day/night: 0.78Lux); as the illuminance continuously decreases till the lowest range of the illuminometer ------ 0.01 Lux, the image is still clear enough to be recognized. Continue to

lower illuminance till noise appears (approx. 0.001 Lux), manually enable IR light (auto mode supported), at this moment the image is clear and recognizable within the view range.

- Structure Safety

Fully sealed design, IP67 compliance, which makes the camera normally operate in the harsh environment with dust and shower; the thick and solid aluminum enclosure design makes the device strong and secure with powerful tamper resistance capability; IK10 compliance makes the device operate outdoors.

- Color Uniformity

✓ It can control multi-lens to adjust exposure and gain according to the current environment, which is to output suitable brightness for the image after splicing and complete auto exposure.

✓ It can control the RGB proportion of multi ISP according to the current environment, which is to output normal color for the image after splicing and complete AWB.

5 Application Scenario

Multi-lens panoramic camera after splicing, the equivalent horizontal field angle is no less than 180 °, HD image, no distortion, no delay, which is suitable for most scenarios whose monitoring filed angle is 180 °, especially for middle and far distance scenes (more than 5m). The typical application scenarios include playground, square, station and airport etc. In consideration of its powerful synchronism and 7*24 imaging, it is particularly suitable for the scenario with moving object and continuous work around the clock, besides, the camera can show its advantages in outdoor environment due to waterproof and vandal proof functions of the camera structure.

It is important to point out that as a new generation of Dahua monitoring product, the

multi-lens panoramic camera is equally embedded with rich intelligent analysis algorithms, such as intrusion, tripwire, abandoned/missing, scene changing, audio abnormity detection, defocus detection, face detection and so on; what really counts is that the camera supports multiple alarm linkages and it can trigger rules to link actions, for example, it can realize smart track via matching a speed dome; it can optically zoom in the detected distance target even if it is applied in a big scenario such as road, meanwhile it can also provide panoramic and featured image which is capable of obtaining both panorama and details.

6 Summary

Multi-lens panoramic real-time splicing camera realizes panoramic 180 °ultra large field view monitoring without distortion, it supports starlight and 50m Smart IR 7*24 night vision imaging, provides multiple intelligent analysis and linkage actions, realizes smart track, object tracking and other intelligent functions; easy installation and convenient maintenance make it suitable for various outdoor large scene monitoring, which is a type of excellent panoramic monitoring product suitable for multi scenarios.

About Dahua Technology

Dahua Technology is a world-leading video surveillance solution provider. Our company enjoys the world's second largest market share according to the IMS 2015 report. We believe in investing and building strong R&D capabilities for new technology and innovation. The company invests more than 10% of sales revenue in R&D every year. Dahua technology has more than 5,000 professionals in R&D team, who are dedicated to provide cutting edge products and solutions for our valuable customers. The company has 770 patents in total till end of 2015 and advocates openess to share or license its technical know-how with global partners.

Dahua's product portfolio includes: Advanced Video Surveillance Products/Solutions and related Software, Access Control, VDP, Alarm, Intelligent Building Management Systems and Intelligent Traffic Management System etc.

Dahua's products are widely used in banking, public security, energy infrastructure, telecommunication, intelligent-building and intelligent-transportation etc. Many significant projects have been installed with Dahua's solutions including: The Sanxia Hydropower Plant, Six-Country Summit, Beijing Olympic Venues, APEC, Shanghai World Expo, UNESCO site in Italy and London Underground Subway as well as many others.