A Panorama Parking Assist Solution for Embedded Systems

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Abstract

This paper presents a panorama parking assist solution for embedded systems. The panorama parking assist system is a representative automotive advanced driver assistance system technology that assists the driver in parking the vehicle safely by allowing drivers to see objective aerial view image of the vehicle. The system consists of four wide angle cameras, video decoder and embedded processors[1]. In order to get the real-time image information of the vehicle 360°, we designed a solution for the system, we mounted four wide angle cameras around the vehicle and each one faces a different direction. Next video signal would be translated into digital signal through four-channel video decoder. Then run lens distortion and transform the perspective view image to top view image. Finally run the image mosaics algorithms on the embedded processors and an aerial view image of the vehicle could be displayed on the screen. Experimental results show that this solution has a ideal imaging effect.

Keywords

Panorama parking assist, Embedded systems, Vehicle safely, Aerial view image of the vehicle.

1. Introduction

With the growth of international economy, the total number of cars is increasing rapidly. The urban traffic pressure increases gradually, parking is becoming more and more difficult for drivers especially for new drivers. Because of the blind area around of the car, the inaccuracy of the distance estimation and the narrow parking space, it becomes more and more difficult if the drivers want to park their vehicle safely, which caused more and more accident[2]. A panorama parking assist system can make drivers understand the environment behind them more clearly, and help drivers finish parking easily.

The panorama parking assist system used multiple cameras mounted around the car to collect the image data, four-channel video decoder could translate video signal into digital signal. A series of image processing algorithms would be run on the embedded processors such as DSP, ARM and FPGA. Lens distortion, perspective conversion and image mosaics algorithms would be explained in this papers[3].

Figure 1 shows the flow chart of function implementation, The hardware design of system includes camera detection, A video decode A/D conversion, the central processing unit CPU part, software algorithm mainly includes wide angle image distortion correction algorithm, perspective transformation and image stitching algorithm.

Software and hardware design of system would focus on the selection of the types of the CPU. From hardware point of view, this system would be applied in the car which a specific scene, so the system adopts the core chip level must be a car level. At the same time, panorama parking assist system may only be a part of vehicle terminal in the future. We need to consider the CPU on a chip resources to meet the demands of system upgrades in the future. From the point of view of software design, the CPU bear the four-way camera data collected ,the three algorithms are running on the CPU at the same time, This have higher demand for the bandwidth of the CPU and running speed.

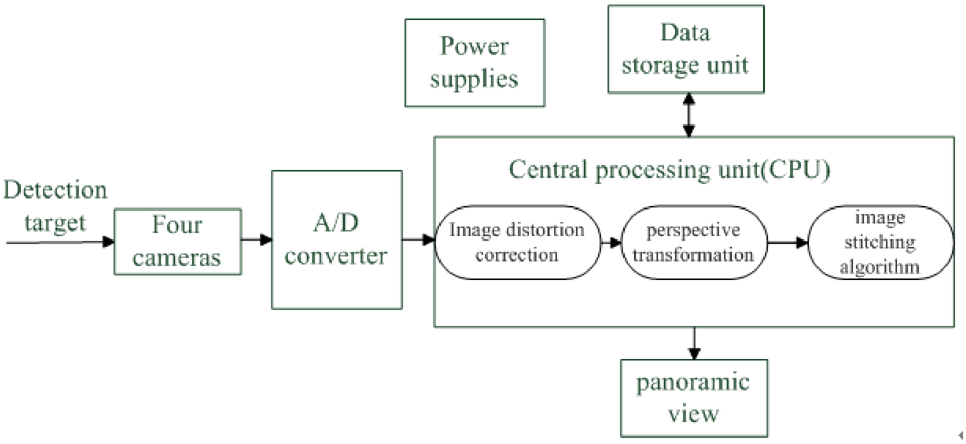

Fig. 1 Flow chart of function implementation

2. Hardware Architecture

ARM, DSP and FPGA is the mainstream of three kinds of embedded processor, three processors are designed for a certain purpose and have their own characteristics and advantages, and the architecture of panorama parking assist system has the following three kinds of typical solutions.

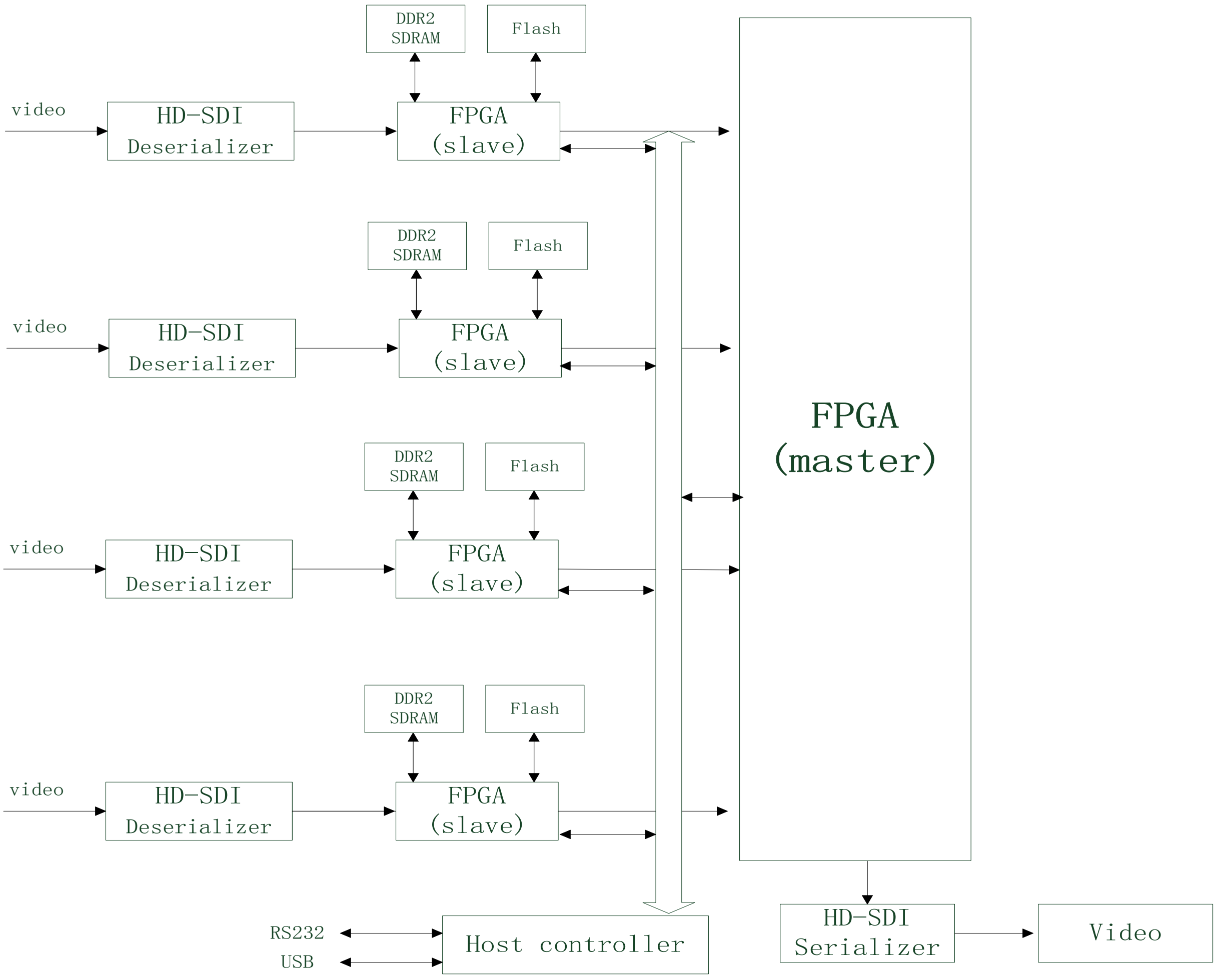

Fig. 2 Block diagram of full HD AVM board

2.1 The solution based on FPGA

For the purpose of solving the low-resolution of majority parking imaging system (AVM), the system resolution has reached 1920*1080 based on five slices of FPGA and six slices of DDR2 SDRAM [4]. Figure 2 show the architecture of the system, the string editor of HD-SDI editor HD camera acquisition of the high speed serial signal parallel signal, four Slave FPGA to effective pixels after filtering, arrangement and duplicate transferred to Mater the FPGA. A look-up table (LUT) was calculated beforehand the SPI Flash memory write every piece of FPGA and upon initial DDR2 SDRAM are imported, the main controller is used to control and monitor every piece of FPGA.

2.2 The solution based on DSP

As shown in figure 3, block diagram of panorama parking assist system based on DSP[5].There are two pieces of the same C66x DSP that is the core of the video data acquisition and algorithm processing. The first one collects four camera data based on simultaneous multi-threading and then put these in SDRAM, it costs 5 seconds to run a geometric correction algorithm after power on at the same time. Look-up table would be put in the second piece of DSP after adjusting the generated images, which the operation of image fusion algorithms on the purpose of decreasing camera data packet loss. After correction of piece-wise transfer image into several blocks in the second piece of DSP on the DMA mode. This system has realized the four-way cameras seamless splicing, real-time synthesis of toy cars have a bird's eye view of video format for D1, frames for 30 frames.

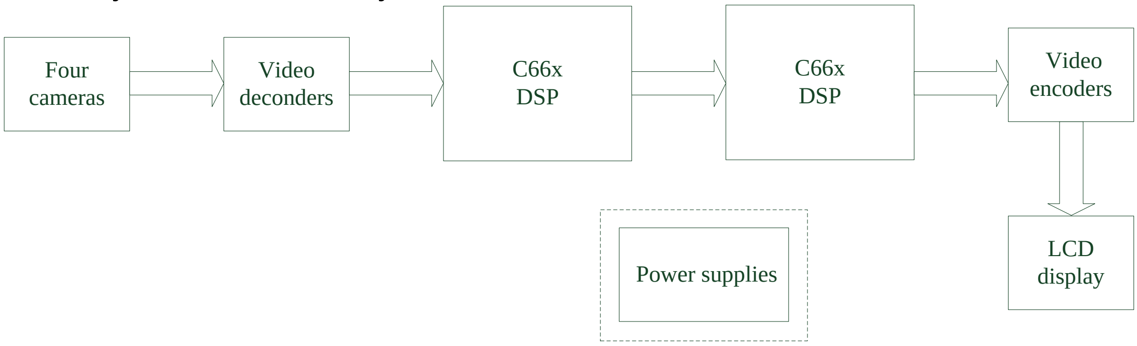

Fig. 3 Block diagram of panorama parking assist system based on DSP

2.3 The solution based on heterogeneous CMP

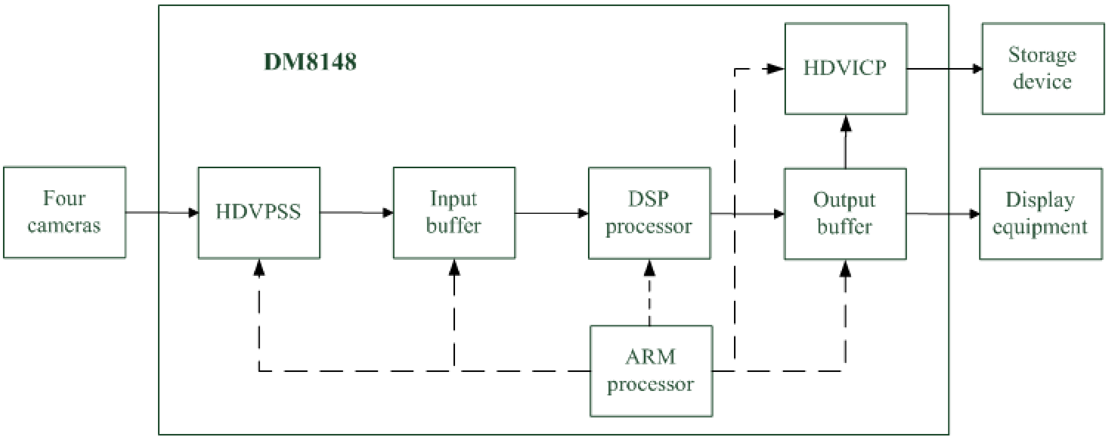

Fig. 4 Block diagram of panorama parking assist system based on DM8148

Figure 4 shows block diagram of panorama parking assist system based on heterogeneous CMP, The main control chip of the system based on DaVinci technology with dual-core processor DM8148. It is an advantage of high floating point arithmetic to run a serial of processing algorithms. Video image collected by C674x DSP processors and ARM processor is responsible for the operation of the whole system. The development of software architecture based on OpenMax framework, which could achieve call the h. 264 video compression encoding library and store video on the local storage[6].

2.4 The solution based on i.MX6

There are three solutions based on different processor, but they all development difficulty and complex surrounding construction. Figure 5 is the block diagram of panorama parking assist system based on i.MX6. The system collecting primitive data relied on four cameras which through the TW6865 that produced by Intersil company video decoding chip of image data transmission. After decoding, video would be sent to i.MX6 through PCIe interface. Image processing algorithms would be transplanted in i.MX6 embedded platform. Finally the system would give the driver presents a objective aerial view image of the vehicle that could show a panoramic scope of vision for safety driving.

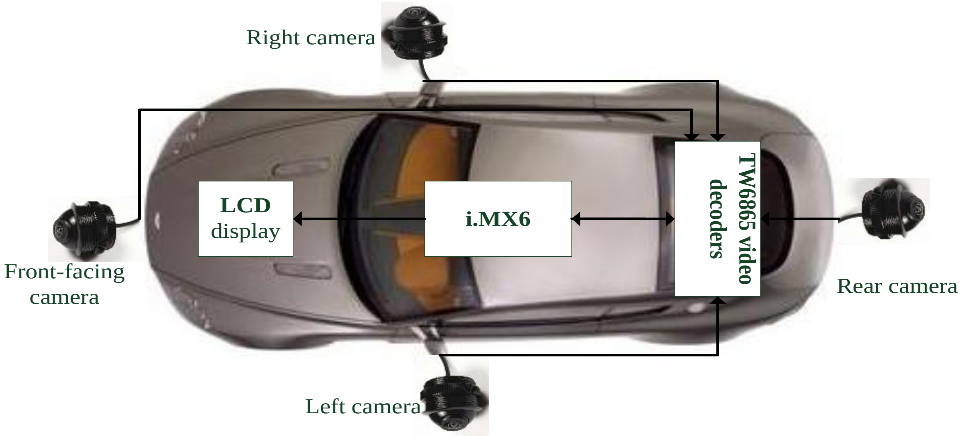

Fig. 5 Block diagram of panorama parking assist system based on i.MX6

There are some signal analysis for the platform. Four channel video decoders that internal integration in TW6865 decoding four-way analog signals into digital YCbCr signal, and use high performance adaptive 4H comb filters to separate luminance and chrominance. The TW6865 contains a high-performance dedicated DMA controller, Optimizes fully PCIex1 bandwidth utilization, and enable it to maintain at a high throughput. Based on V4L2 drivers use DMA can grab the video directly, because of the four channel video at the same time, the video researched to megabytes-per-second, PCIe interface can fully meet the requirements. Then the application processor of i.MX6 uses the IPU to catch the interlaced camera image solution mixed get to saw-tooth smooth after the image processing, and run on processors of image processing algorithms. Four ARM architecture A9 kernel and three GPU embedded in the i.MX6 that have the ability of parallel processing programmable pipeline processing, which could guarantee the smooth implementation of the algorithms.

3. Algorithms of the System

Algorithm process of panorama parking assist system as shown in figure 6, there are three steps to finish to finish all, including lens distortion, transform the perspective view image to top view image and image mosaics algorithms.

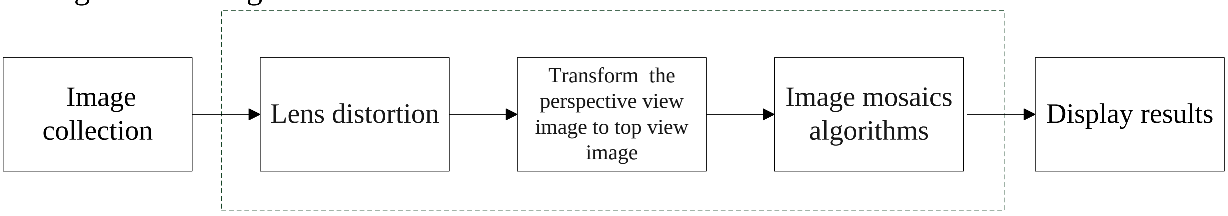

Fig. 6 Algorithm process of the system

3.1 Lens distortion

The physical world the coordinates of the point $Q(X_i, Y_i, Z_i)$ was mapped to the view plane $q(x_i, y_i)$, imaging process of linear camera model could be expressed by the formula (1):

$$q = MQ \quad q = \begin{bmatrix} x \\ y \\ w \end{bmatrix}, M = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}, Q = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \tag{1}$$

M is camera parameter matrix, and choose to define the model of a physical plane it $Z = 0$, assume That camera without distortion, setting $H = [h_1 \quad h_2 \quad h_3]$, $R = [r_1 \quad r_2 \quad r_3]$ deduce the formula (2):

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = sM\begin{bmatrix} r_1 & r_2 & r_3 & t \end{bmatrix}\begin{bmatrix} X \\ Y \\ 0 \\ 1 \end{bmatrix} = sM\begin{bmatrix} r_1 & r_2 & t \end{bmatrix}\begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} \quad H = sM\begin{bmatrix} r_1 & r_2 & t \end{bmatrix} \tag{2}$$

Resolved formula (2) to deduce $\begin{bmatrix} r_1 & r_2 & t \end{bmatrix} = \begin{bmatrix} \lambda M^{-1}h_1 & \lambda M^{-1}h_2 & \lambda M^{-1}h_3 \end{bmatrix}$, Because of tectonic rotation vector is orthogonal, while the rotation vector dot product is zero, and equal length, $r_1^T r_2 = 0$ And $r_1^T r_1 = r_2^T r_2$,for any vector a,b , $(ab)^T = b^T a^T$, use r_1, r_2 replace a,b , $h_1^T M^{-T} M^{-1} h_2 = 0$. For $r_1^T r_1 = r_2^T r_2$ and $h_1^T M^{-T} M^{-1} h_1 = h_2^T M^{-T} M^{-1} h_2$. It is assumed that

$$A = M^{-T} M^{-1} = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \tag{3}$$

The general form of solution of matrix A is

$$A = \begin{bmatrix} \frac{1}{f_x^2} & 0 & \frac{-c_x}{f_x^2} \\ 0 & \frac{1}{f_y^2} & \frac{-c_y}{f_y^2} \\ \frac{-c_x}{f_x^2} & \frac{-c_y}{f_y^2} & \frac{c_x^2}{f_x^2} + \frac{c_y^2}{f_y^2} + 1 \end{bmatrix} \tag{4}$$

Simultaneous the type(2)(3)(4)of the parameter matrix

$$\begin{cases} f_x = \sqrt{\lambda / A_{11}} \\ f_y = \sqrt{\lambda A_{11} / (A_{11}A_{22} - A_{12}^2)} \\ c_x = -A_{13} f_x^2 / \lambda \\ c_y = (A_{12}A_{13} - A_{11}A_{23}) / (A_{11}A_{22} - A_{12}^2) \end{cases} \tag{5}$$

According to the radial distortion and tangential distortion equation, get orthopedic calibration results:

$$\begin{bmatrix} x_p \\ y_p \end{bmatrix} = \left(1 + k_1 r^2 + k_2 r^4 + k_3 r^6\right)\begin{bmatrix} x_d \\ y_d \end{bmatrix} + \begin{bmatrix} 2p_1 x_d y_d + p_2(r^2 + 2x_d^2) \\ p_1(r^2 + 2y_d^2) + 2p_2 x_d y_d \end{bmatrix} \tag{6}$$

Through the above derivation, we could solve the matrix M, distortion parameters $\begin{bmatrix} k_1 & k_2 & k_3 \end{bmatrix}, \begin{bmatrix} p_1 & p_2 \end{bmatrix}$, external parameters of rotation matrix *R* and translation vector *t*. According to the camera model, the rectified image was available [7, 8].

3.2 Transform the perspective view image to top view image

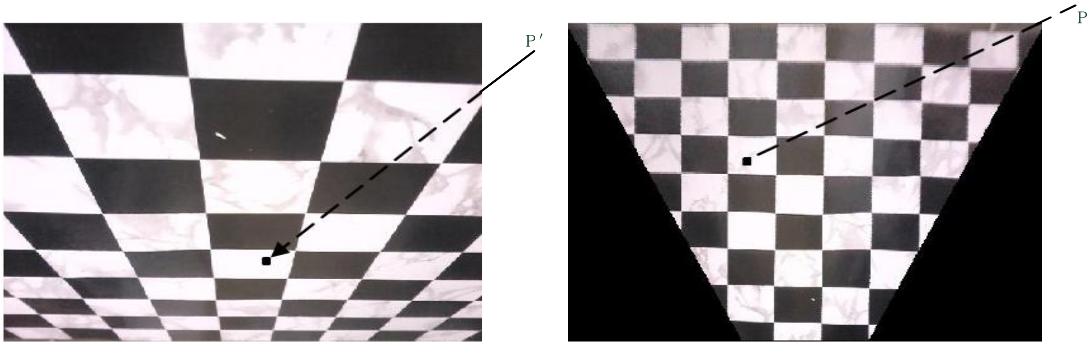

Fig. 7 The schematic of perspective transformation

Figure 7 shows the schematic perspective of transformation of image, we set target $P(p_x, p_y, p_z)$ in the image coordinates of a pixel in the world coordinate system; after image correction for pixel coordinates the target change to $P'(p'_x, p'_y)$, based on the relationship between world coordinate and image coordinate system, triangle transform and formula derivation, we calculated :

$$\begin{cases} p'_x = \dfrac{p_x W}{2\tan\dfrac{\partial}{2}\sqrt{h^2 + p_y^2}} \\ p'_y = \dfrac{H(p_y - h\tan\gamma)}{2p_y\tan\gamma\tan\dfrac{\beta}{2} + 2h\tan\dfrac{\beta}{2}} \end{cases} \tag{7}$$

The results of first two steps algorithms transforms as shown figure 8.

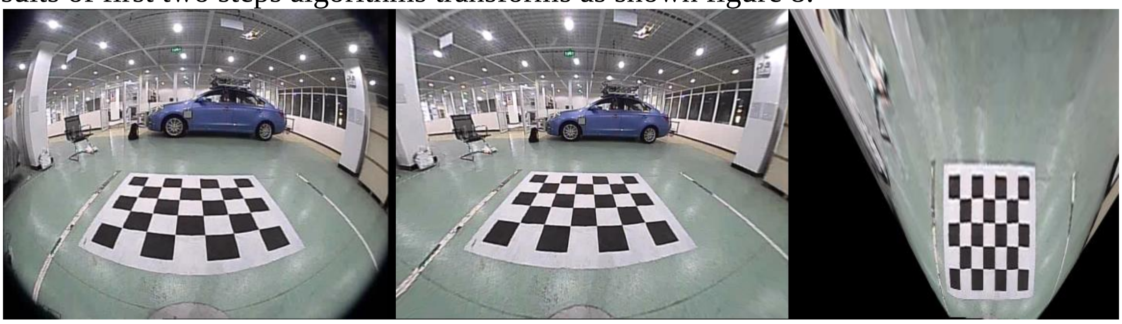

Fig.8 the results of first two steps algorithms transforms

3.3 Image mosaics algorithms

After first two steps algorithms, the video images data has been transformed to virtual vertical view without optical distortion[9]. We need to do the last one for the purpose of getting four correction image stitching around the vehicle. There is a schematic of image mosaics as shown in figure 9 would be set up, according to the experimental vehicle conductor *L1* and body width *W1*, set wide panoramic aerial view *W2* and *L2*. Set effective area, that is, the dimensions of the four trapezoidal, effective area relative to their respective correction chart of displacement, intercepting trapezoidal area effectively.

Trapezoidal intercept figure at panoramic aerial view coordinate system *(X, Y, O)* in configuration, according to from top to bottom, from left to right scan, the coordinates of the four ladder diagram are

$(0, 0)$, $(0, 0)$, $(W2, 0)$, $\left(\dfrac{W2-L1}{2}, \dfrac{L2+W1}{2}\right)$

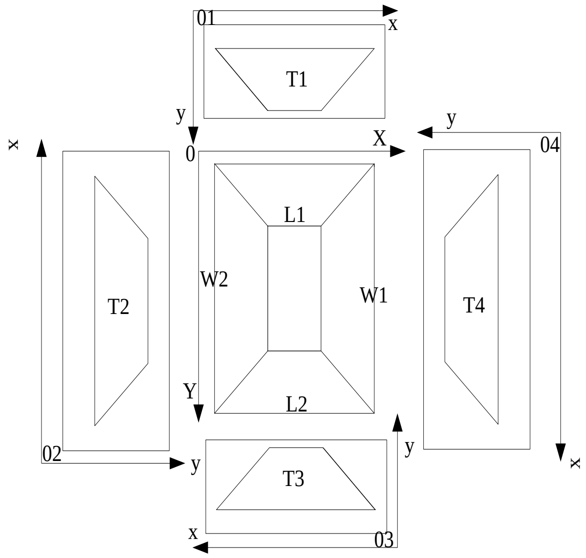

Fig.9 The schematic of image mosaics

After image mosaics algorithms, we could the get image information of the vehicle 360°, that it also be called objective aerial view image of the vehicle.

4. Experimental tests

From lens distortion we worked out the intrinsic parameters and distortion parameters of wide angle cameras (for the camera we deem that k3=0), see Table 1.

Table 1. Parameters of wide angle cameras

Intrinsic parameters		Distortion parameters	
f_x	249.305	*k1*	-0.0295
f_y	358.935	*k2*	-0.0248
c_x	254.410	*p1*	0.0769
c_y	282.429	*p2*	-0.0543

From transform the perspective view images step, according to the experimental data in Table 2, we set up the experimental environment.

Table 2. Parameters of perspective view

α	170 °
β	110 °
γ	35 °
h	0.6m
W	1080
H	600

In experimental scenario, we simulated car size to build the platform, the experimental platform is 1.1 meters long, 0.5 meters wide. The height is 0.6 meters of four cameras. In order to verify the validity of the algorithm, we choose the ground level off, have obvious logo white line on the ground and surrounded by striking feature objects as experimental scene.

Figure 10 shows four original image, after three algorithms we get objective aerial view image of the vehicle. Figure 11 is the objective aerial view image of the vehicle.

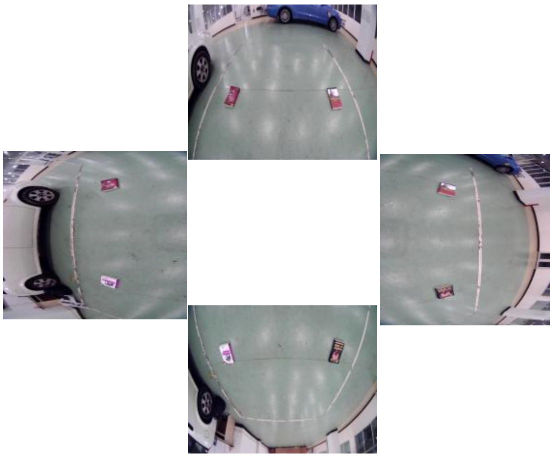

Fig 10. Four original image

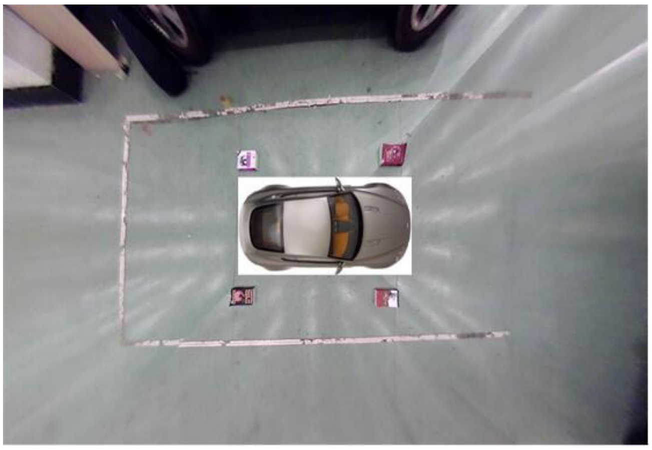

Fig 11. Objective aerial view image of the vehicle

5. Conclusion

This paper presents a panorama parking assist systems based on i.MX6 for helping drivers finish parking easily. This solution uses a single processor to replace heterogeneous CMP or more processors which made its hardware frame simpler. We also put forward lens distortion, transform the perspective view image to top view image and image mosaics algorithms. For these algorithms we did a lot of research and derivation. And the experimental results show that this solution has a ideal imaging effect that assists the driver in parking the vehicle safely.

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