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Study on Mold Monitoring System based on Improved Position Compensation Technique of Image Processing in Plastic Injection Industry

Yao Junfeng[1,*], *Huang Zhichao*[1], *Zhang Changming*[1], *Xie Xiaobiao*[1] *and Hung Chih-Cheng*[2]

[1] Center for Digital Media Computing, SoftwareSchool,Xiamen University,Xiamen,361005,China
[2] Department of Computer Science, Southern Polytechnic State University, Marietta, GA, 30060, U.S.A

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Abstract: In plastic injection industry, manual adjustment operation mode is applied for operational workers to prevent mold from sticking together by observing hand-touching approaches, which is characteristic of extremely low efficiency and high labor cost. In this paper we developed an automatic mold monitoring system which reduces the mold repairing cost and increases the mold life time. In plastic injection industries, due to the grate shock of injection molding equipment the Charged Coupled Device (CCD), used for acquiring the images, may shift from its original focused position. This in turn creates a bad pattern matching results and leads to a poor monitoring result. Therefore we developed an improved compensation algorithm based on similarity measurement techniques (SMT) to correct the tilted image automatically. The system has been applied in industry for 4 years since 2006. Based on the application data from the enterprise it is found that our developed automatic mold monitoring system is very promising and it can greatly improve production efficiency by decreasing the production cost.

Keywords: Position compensation, Image Segmentation, Image Edge Detection, Image Pattern Recognition, Mold Monitoring

1 Introduction

Image registration can be formally defined as the transformation of one image with respect to another so that the properties of any resolution element of the object being imaged is addressable by the same coordinate pair in either one of the images. By setting up the geometry parallelism among images to transform, compare and analyze images according to the same reference frame image [1]. In the process of multiple data-source images analysis, such as remote sensing, image fusion, computer graphics, computer vision, environment supervision [2], map drawing and medical imaging, the registration is one of the most important steps.

In plastic injection industry, mold monitoring system based on machine vision is related with computer technologies, optical technology, and image processing and pattern recognition. To reduce mold repairing cost and enhance its use rate, manufacturers apply manual alternation operation mode for operational workers with watching, head-motion or hand-touching approaches to prevent mold sticking together, which is characteristic of extremely low efficiency and intensive labor and needs substantial human and material resources. At least 2 or 3 employees are involved to serve for each molding machine. Damage from mold is also prone to occur when workers are with fatigue; even injury accident may happen caused by head-moving observation. On-site injection mold equipment is shown in Figure 1.

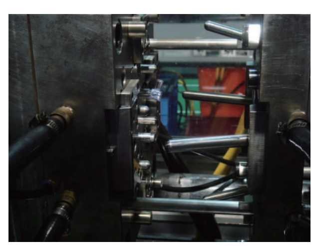


Fig. 1: Mold structure of Plastic Injection(Equipment)

* Corresponding author e-mail: yao0010@xmu.edu.cn

There is an urgent need to introduce mold warning system with automatic recognition in which CCD video images are acquired dynamically and digital images are processed by software technology. Judgment will be made about whether there is foreign matter by image segmentation method when the system works. If so, it will be analyzed whether it is a harmful foreign body according to the harmful limit set by users. Then the warning alarm with detailed messages will be activated automatically. It acts as warning function in advance, which can enhance efficiency and guarantee normal operation on molds.

Focusing on actual demand of plastic injection molding industry, in order to determine the abnormal cavity accurately and timely, we adopt digital video in real-time monitoring of mold products. The captured images are divided and saved in BMP format. Then by applying digital image processing technology, image recognition technology, combined with exception handling process together, an automatic mold monitoring identification system is established which can take photos of mold sampling, matching and error calculation automatically.

Research session are as follows: (1) Controlling modes of IO information in molding equipment, IO feedback information of image collection, application environment analysis of mold monitoring system, working principle of human judgments for a foreign object in mold cavity, designing an overall program suitable for mold monitoring system and image identification.(2) Image recognition method: combined with grayscale images, image enhancement, segmentation, position compensation and other processing techniques to study the structural characteristics of mold products, using template matching recognition technology to analyze images comparably. (3)Implementation: to design and develop mold monitoring system with DELPHI to achieve distinguishing foreign body in cavity and have alarm functions. (4) Applicationsto put the software and hardware into practice to check their effect.

2 Algorithm Study on Project Image Processing in Plastic Injection Mold Industry

Hiroaki Ishii made noise reduction and edge detection from the impulse noise and Gaussian noise by applying fuzzy reasoning method in the digital images in 2000 [1]. Jianlong Zhu presented a multi-scale plate image segmentation method based on wavelet transform in 2001 [2]. Polynomial kernal function was applied in facial recognition technique by KwangIn Kim [3]. S. Zhang proposed a filter based on nonlinear neural network for image smoothing and edge detection using hierarchical neural networks in 2002 [4]. In 2003, considering the digital image characteristics of engineering drawings, Xing Ruyi and others gave out concrete implementation steps of wavelet packet method to reduce digital image noise for engineering drawings, which could effectively eliminate the image noise [5]. In 1995, Kyong-Ho Kim divided the area and partition it with different threshold image,recognition ratio was improved to a greater extent [6]. Since snake model was presented by KassM [7]by which closed skeletal line could be formed, noise was decreased efficiently, image details could be kept better by the deformation pattern approach, which attracted more attention in image segmentation [8].Current research of image recognition algorithms mainly concentrate on numbers, text, fingerprints, face, car and etc., but little on mold video surveillance system in molding machine.

Under normal circumstances, it will cause degradation of image quality or blurred product due to a variety of factors during image generation, transmission and transformation process for various types of image systems. It is easy to get wrong conclusion because of less useful extracted information from image processing. Therefore it is necessary to improve image quality by technical means.

2.1 Mold Image Enhancement

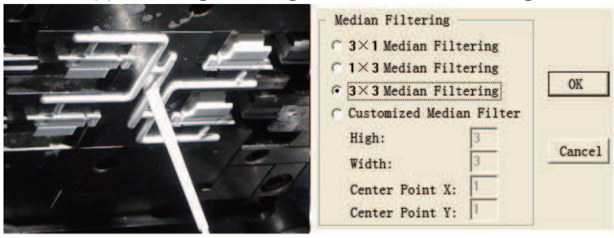
Image enhancement [9] is a kind of basic image pre-processing approach to enhance the useful information of images; however it may be a distortion process, in which the purpose is to enhance the visual effects. Images that are not clear will become clearer, certain interesting features will be emphasized; the uninteresting characteristics will be suppressed. This is a nice image processing method to improve image quality, enrich information amount and enhance image interpretation and identification. Appropriate wavelet filter method can be applied to sharpen image and enhance image edge information.

In this study, the median filtering method [10] is employed to process non-linear two-dimensional signal, in which the corresponding filter is non-linear median filter, which was first proposed in 1971 by JwJukey and applied in one-dimensional signal processing techniques (time series analysis), then it was applied in two-dimensional image signal processing [11]. In the two-dimensional case, the definition of output is shown as equation (1).

$$y_i = med\{x_{ij}\} = med\{x_{(i+r),(j+s)} \ldots (r,s) \in A, (i,j) \in I^2\} \tag{1}$$

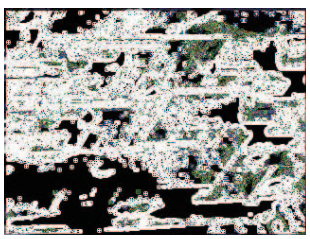
For the two-dimensional median filter, a 3*3 size window is applied; the effect is shown in Figure 2 after a 3 * 3 median filter is adopted.

(a). The original image before median filtering

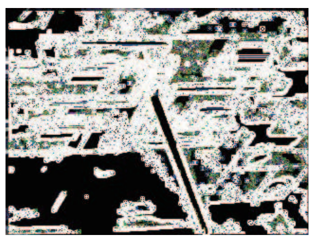


(b). The image after median filtering

Fig. 2: Effect of Median Filtering



a. Result 1



b. Result 2

Fig. 3: Results of Edge Detection

2.2 Edge Detection [12] of Mold Image

The image positioning needs to search the location information of mold products by captured video images. Canny edge detection algorithm [13] is adopted after analysis and selection, this algorithm is the first derivative of Gaussian, edge detection operator is measures based on the SNR (Signal Noise Ratio) and positioning multiplied value, finally the most optimal approximation operator is gotten [10,11]. Steps are as follows:

(1) Smooth the image with Gaussian filter.

(2) Calculate gradient magnitude and direction with first partial derivatives of finite difference.

(3) Suppress gradient magnitude for non-maxima.

(4) Detect and connect edges with dual-threshold value algorithm.

Two different edge detection results are gotten by adjusting different parameters, which are shown in Figure 3(a) and Figure 3(b).

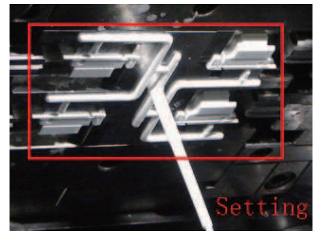


Fig. 4: Standard Sample Figure

2.3 Position Compensation of Mold Images

In plastic injection molding industry, images captured from video of molding equipment appear deviated easily caused by movement of CCD installed location, under tremendous impact for long-term mold opening and closing. So position compensation is very important before image processing, the follow-up image processing can be carried out only by correcting them according to pre-set standard images.

Correcting methods used commonly have their own advantages and disadvantages, but their common features are of great workload and time consumption when they are used to do different transformation calculation. Images, captured from surveillance video system by acquisition technology, include two kinds of regions, the first need to be monitored and the other one need not to be monitored. A rectangular frame set by operators is used as a dividing standard, as shown in Figure 4. The traditional Hough transform algorithm spends large time and space to correct images, which lead to be of slow speed. Here a rectangular frame is adopted as detection tag; the speed can be improved if matching algorithm and template matching accuracy are selected appropriately.

Associated with the actual needs of the system, image mismatch is due to differences among captured images. In order to correct the mismatch, zone-void method is applied to eliminate differences. Search space and the Similarity Measure Method are adopted to achieve image matching, obtain relevant calibration information, and as well as do appropriate position compensation, which can compensate analysis errors at the premise that the system is unable to predict the existence of mismatch among the collected images. Similarity Measure Method determines the relevant characteristics for each match testing; the similarity reflects the template matching degree. The closer the value obtained by the algorithm is to 1, the higher the similarity is. At last, the excursion position can be gotten according to the highest similarity value; the translation operation of images can be done. To Suppose the template T and the search map S, $S^{i,j}$ denotes the search map in the template, where i, j represent the position. Then its cross-correlation similarity measure is as follows:

$$R(i,j) = \frac{\sum_{m=1}^{M}\sum_{n=1}^{M} S^{i,j}(m,n) \times T(m,n)}{\sum_{m=1}^{M}\sum_{n=1}^{M} [S^{i,j}(m,n)]^2} \tag{2}$$

It can be normalized to be:

$$R(i,j) = \frac{\sum_{m=1}^{M}\sum_{n=1}^{M} S^{i,j}(m,n) \times T(m,n)}{\sqrt{\sum_{m=1}^{M}\sum_{n=1}^{M} [S^{i,j}(m,n)]^2}\sqrt{\sum_{m=1}^{M}\sum_{n=1}^{M} [T(m,n)]^2}} \tag{3}$$

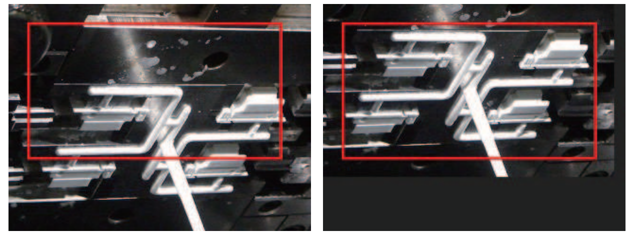
Figure 5(a) shows the real-time collected picture in monitoring process, from which we can find clearly the region excursion under user surveillance, which could easily lead to false forecasting of monitoring system. Therefore, template matching algorithm is needed to correct monitoring region and the offset X, Y can be gotten when the similarity is greatest. Translation can be come true according to correction geometry; the sudo code of realization is as follows:

for i $\leftarrow$ *xt to xb*
for j $\leftarrow$ *xl to xr*
for y $\leftarrow$ *A Range.Top to A Range.Bottom-1*
PS $\leftarrow$ *the X Scanning Pointer of the Original Image*
PT $\leftarrow$ *the X Scanning Pointer of the Offset Image*
for x $\leftarrow$ *A Range.Left to A Range.Right-1*
T $\leftarrow$ $\sum$*square of the gray value of the image with offset*
ST $\leftarrow$ $\sum$*gray value of the original image*gray value after the offset*
end for
$R \leftarrow \frac{ST}{\sqrt{S*T}}$
if $R > MaxR$ *then*
$R \leftarrow MaxR; cx \leftarrow j; cy \leftarrow i$
end if
end for
end for
end for
return MaxR

Through the program, we get matching and correction to Figure 5(a) according to Figure 4, the deviation is adjusted by the system: translation of 40 pixels along X-axis and 7 pixels along Y-axis, then the image location is changed in the rectangular by the translation algorithm, finally the correction image is obtained, as is showed in Figure 5(b) with black color to make up some empty parts.

2.4 Separation of Products from Mold Background

Differential shadow images provide information of differences among images, which can be used to guide the dynamic detection, moving-target detection and tracking, image background elimination and object recognition, etc. Generally, these methods can get clear and complete data of the object. Firstly, a background image S of a vacant hole is captured without forming any mold



a. Image before Being Corrected   b. Image after Being Corrected

Fig. 5: Comparison between before and after being corrected

Fig. 6: Effect Image of Differential Background

product, then a static image T with molding products, remaining in the mold, is captured and the difference between two pictures is calculated with formula(4). ST shadow image can be gotten which is shown in Figure 6.

$$ST = \sum_{m=1}^{M}\sum_{n=1}^{M} |T(i,j) - S(i,j)| \tag{4}$$

2.5 Matching of Mold Images

Earlier image matching technique [14] is mainly used for adjusting multi-band remote sensing images after geometric correction, by means of extremum of the cross-correlation function. They have been applied in identification, target tracking and many other fields including simple graphics (background, Automotive, plane, etc.) and complex images (character, fingerprints, human face, etc.).

Firstly error detection algorithm of image shadow [15] is employed to search the difference among images, then similarity is calculated with template matching algorithm, which helps to increase calculating speed and can be applied in practice. The specific algorithm works as follows:

Supposed template T translates in search graph, the search graph under template coverage is called sub-graph $S^{i,j}$, i and j are coordinates of upper-left corner point of the sub-graph in the diagram, called reference point. The value ranges of i and j are: $1 < i, j < N - M + 1$, shown in Figure 7.

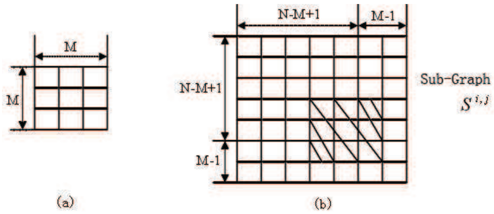


Fig. 7: Template (a) and Searching Graph (b)

Contents of T and $S^{i,j}$ are compared, if they are the same, the difference is zero between T and $S^{i,j}$ .We can measure the similarity for T and $S^{i,j}$, which is as shown in equation (5):

$$D(i,j)=\sum_{m=1}^{M}\sum_{n=1}^{M}\left[S^{i,j}(m,n)-T(m,n)\right]^2 \tag{5}$$

The expanded form of equation (5) is shown as equation (6):

$$D(i,j)=\sum_{m=1}^{M}\sum_{n=1}^{M}\left[S^{i,j}(m,n)\right]^2-2\sum_{m=1}^{M}\sum_{n=1}^{M}S^{i,j}(m,n)\times T(m,n) + \sum_{m=1}^{M}\sum_{n=1}^{M}[T(m,n)]^2 \tag{6}$$

The third right item of equation (6) expresses the total energy, which is an irrelative constant to (i, j). The first one is the energy of the sub-graph under the template coverage, which changes slowly with the change of (i, j). The second one is the cross-correlation coefficient between sub-graph and template, changing with (i, j), which will has the greatest value when T and $S^{i,j}$ matched. Therefore the correlation function is used as similarity measure, as is shown in equation (7) as follows:

$$R(i,j)=\frac{\sum_{m=1}^{M}\sum_{n=1}^{M}S^{i,j}(m,n)\times T(m,n)}{\sum_{m=1}^{M}\sum_{n=1}^{M}[S^{i,j}(m,n)]^2} \tag{7}$$

It can be showed according to the Schwartz inequality that, $0 < \mathrm{R(i,\ j)} < 1$ and R(i, j) is the maximum value (equal to 1) only when the ratio $\frac{S^{i,j}(m,n)}{T(m,n)}$ is a constant. Equation (7) can be written in a more concise form of inner product. Let $S_1(i,j)$ be the sub-graph, t expresses the template, and then there is equation (8):

$$R(i,j)=\frac{t^T S_1(i,j)}{\sqrt{(t^T t)}\sqrt{(S_1^T(i,j)S_1(i,j))}} \tag{8}$$

When the angle between vector t and S1 is zero, i.e. R(i, j) = 1 if $S_1(i,j)$ = kt (where k is a scalar constant); otherwise, R(i, j)<1.

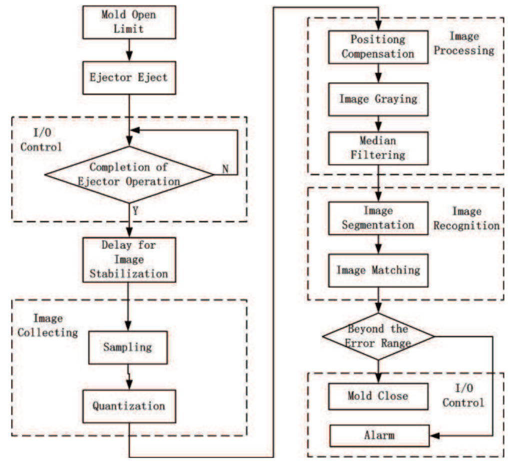


Fig. 8: Dynamic Analyzing Flow of System

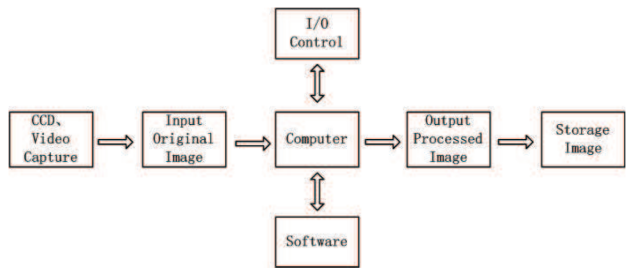


Fig. 9: Processing flow of Digital Image Processing of System

3 Design of Mold Monitoring System

Mold monitoring system is divided into two parts, software and hardware. Hardware is composed of electronic components and cooperated with the IO part of molding equipment to achieve data transmission among kinds of ports and alarm function. Software function is firstly to set the error threshold for users according to collected standard images. Then the system will process the real-time collected images in surveillance state. The system uses CMOS black and white high-definition camera (as products and molds themselves are black and white) to collect image data, and then the captured images are transmitted to a computer through the PCI video-capturing card, finally the aiming foreign body is analyzed by digital image processing and pattern matching, and etc. Such techniques are included as, video capture, position correction, segmentation, and image preprocessing and image enhancement technologies. The dynamic analysis flow and the overall digital image processing flow are shown respectively in Figure 8, 9.

The mold monitoring system is based on video capture, IO signal transmission, image preprocessing, image segmentation and image matching techniques. The specific software functions include programming control, system setting, alarm information processing and

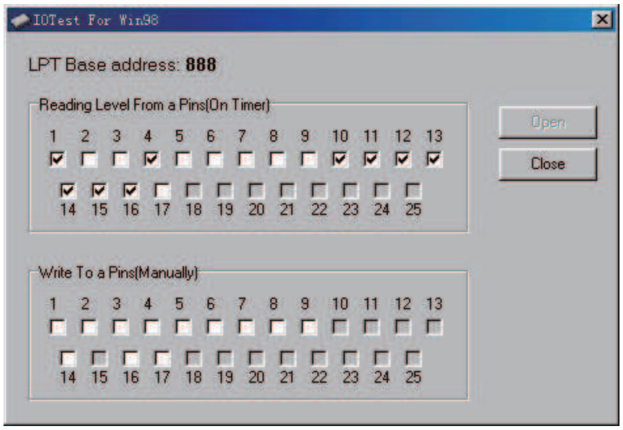


Fig. 10: Port Control Interface

Fig. 11: Mould Picture with Products

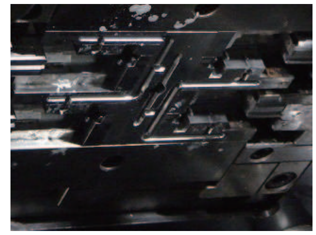


Fig. 12: Mould Picture without Products

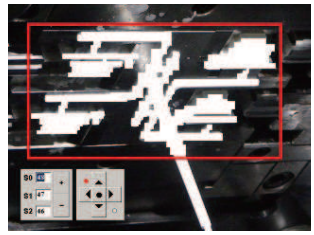


Fig. 13: Setting Effect Picture of Standard Sample

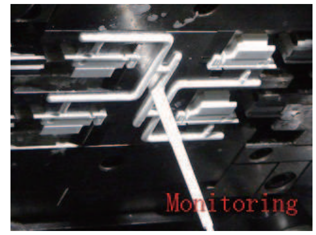


Fig. 14: Monitoring Picture of Mould Monitoring System

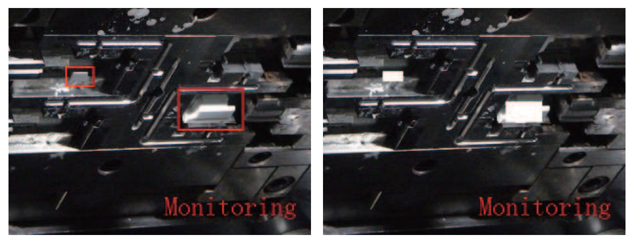


Fig. 15: Abnormal Tip Screen of Mould Monitoring

monitoring function. According to analysis of controlling hardware circuit, combined with the system development environment: DELPHI and WIN98, 378H (decimal 888) parallel data port in industrial control computer, embedded ideas are applied in designing.

Bit operation is applied in control module. For the parallel port data obtained from above-mentioned procedure, they need bitwise OR operation, which is also required in advance for the By-bit output data. Then the parallel port data is output and the interface of port control is shown in Figure 10.

4 Implementation of Mold Monitoring System

When Mold monitoring system is applied in industry, there is great demand in calculation speed requiring logic calculation of the entire system must be finished within 2 to 4 seconds. Otherwise good effect cannot be achieved. Video images collected in the system are of standard size: 320 * 240.

Standard image sample is captured via video capturing program, firstly one standard product image in cavity is collected in the molding machine, as is shown in Figure 11, and secondly one standard image without product in cavity is collected, as is shown in Figure 12. The two sample images are analyzed using image processing algorithms, requiring users to select the region to be monitored and set the error threshold of the surveillance system in the interface, the result is shown in Figure 13

Based on monitoring commands issued by users, the system goes into monitoring status automatically; the video shows ”Monitoring” on the screen, as is shown in Figure 14. For the surveillance region selected by the user during the monitoring process, the system will suspend at the video screen and hint the user the location of the foreign existence in black and white flickering screen if there is foreign matter which is beyond the error threshold set by users. Alarm lights on the machine are triggered by the control circuit to inform operators for transaction, as is shown in Figure 15.

Mold monitoring system has been put into practice since March 2006, elevating the qualified product rate from 90 percent to 99 percent, raising the plastic injection molding machine utilization rate from 75 percent to 96 percent, prolonging the mold use life span from 1.6 years to 2.7 years per set, compressing the maintenance and repair costs from 1.2 million RMB per year reduced to 400 thousand RMB per year, which enhance greatly the core competitiveness of the enterprise.

5 Conclusion

A practical mold monitoring system is developed with image analysis and system automatic processing technique to improve relatively low labor efficiency and avoid possible risk of misjudgment in current injection molding industry. The comparison method of mold foreign body identification based on molding working video can be applied fully to the plastic injection molding industry and meet their market demand in certain conditions. To ensure mold safety, reduce mold maintenance costs, improve machine cycle rate, enhance production efficiency of molding equipments and reduce indirect operating costs and so on, a new solution is brought forward.

The core mission of the entire system is product identification and error comparison. The whole process is equivalent to a closed-loop control process; namely, computers connect and communicate with peripheral equipment through the control circuit, then read real-time state parameter of molding equipment, and finally feedback the result to molding machine by video dynamic image analysis for continuous or interrupted use. Practice has proved that this system can satisfy the demand and can achieve good results.

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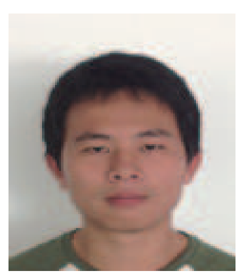
Yao Junfeng is a Professor at the Software School of Xiamen University, Fujian, China. He received his Ph.D. in Industrial simulation in 2001 from the Central South University China. His major research interest is Virtual Reality, Simulation and Optimization on Complex industry process.



Huang Zhichao, a Graduate Student at Software School of Xiamen University, Fujian, China. He received his B.S. in Digital Media Technology in 2011 from Shandong University, China. His major research interest is Virtual Reality and 3D Modeling.

Zhan Changming, Engineer in Xinhua Technology (Xiamen) Co., Ltd, Jimei, Xiamen, Fujian, China. He received his B.S. in 1997, Xi'an Jiaotong University, and he received his M.S. in Software Engineering in 2009, Xiamen University. His major research interest is Pattern Recognition and Image Processing.

Xie Xiaobiao, Postgraduated at the Software School of Xiamen University,China. He received his B.S. in EC from the Southwest JiaoTong University in 2008, M.S. in Software Engineering in 2011. His major researches relate to VirtualReality, Computer Simulation and Web projects.

Chih-Cheng Hung has been working on several different projects funded by U.S. ARMY MICOM, NASA, NASA/ASGC, NSF, DOE/University of Alabama, APL- John Hopkins University and State of Georgia. His research interests include image/video processing and analysis, pattern recognition, artificial intelligence, swarm intelligence, neural networks, genetic algorithms, fuzzy logic, information fusion, image/video retrieval, parallel processing, and software metrics.