AN INTEGRATED ERGOMA SYSTEM FOR HUMAN MOTION ANALYSIS

Sosuke YOSHIDA, Hirofumi CHIKATSU
Tokyo Denki University, Japan
Department of Civil Engineering
{sosuke, chikatsu}@g.dendai.ac.jp

Working Group V/SIG

KEY WORDS: ERGOMA System, Auto Tracking, Feature Extraction, Sequential Images, Load on the waist, Workman

ABSTRACT

The authors have been developing an ERGOMA system using video image sequences, and visualization of human motion analysis using animation was demonstrated. However, there were some issues that needed to be resolved. These problems include automation of camera calibration, synchronization of stereo image and efficient stereo matching.
In order to resolve these problems, firstly this paper describes the integrated ERGOMA system utilizing image sequences taken by Hybrid Video Theodolite (HVT) which was developed by Chikatsu and et al.. Secondly, improvement of image acquisition, feature points and accurate extraction method for feature points are investigated in this paper. Finally, calculation of load on the waist and animation techniques are also investigated, and visualization of human motion analysis using animation are demonstrated.

1 INTRODUCTION

Recently, reduction of the construction cost and insufficiency of skilled hands are becoming serious problems on the construction plant from the point of view of the work efficiency. In these circumstances, an ERGOMA system has recently received more attention from the point of view of the improvement of working environment or evaluation of the work efficiency [Mikami, 1998]. An ERGOMA is a coined word by ergonomics and management. In order to develop an ERGOMA system, a video camera is expected to become useful tool since video image sequences often give important information to human motion analysis.
With this motive, the authors have been developing an ERGOMA system using sequential images for improvement of working environment or evaluation of the work efficiency on the construction plant [Yoshida and Chikatsu, 1999]. Fluorescence tapes were put on the head (helmet) and the waist of workman as a feature points in the ERGOMA system, and working image sequences was taken using two video cameras on the construction plant. The feature points were extracted automatically by image processing procedure from each stereo image sequences, and 3D coordinates of the head and the waist were obtained. It became possible to understand the position, the posture, the working area of workman, visualization of human motion analysis.
However, there were some issues that needed to be resolved. These problems include automation of camera calibration, synchronization of stereo image sequences and efficient stereo matching.
From the view point of multiple applications such as human motion analysis, auto-tracking, real-time positioning and so on, Hybrid Video Theodolite (HVT) system was developed by Chikatsu and et al. [Chikatsu and Anai, 2000]. HVT has some remarkable functions that are automated camera calibration, auto-tracking for moving object and synchronization of stereo image sequences.
In these circumstances, in order to resolve above problems, the integrated ERGOMA system utilizing the HVT is proposed in this paper. This paper also describes improvement of extraction method of feature points and efficient ERGOMA system utilizing image sequences taken by HVT. Furthermore, calculation of load on the waist and visualization of human motion using animated cartoons are investigated in order to perform more accurate calculation of load on the waist and more smoothly animation on ERGOMA system.

2 HYBRID VIDEO THEODOLITE (HVT) SYSTEM

The HVT was developed based on video theodolite system which have been developed by Chikatsu and et al., for multiple applications such as human motion analysis, auto-tracking, real-time positioning and so on. The HVT that is stereo image acquisition equipment consists of 2 CCD cameras, laser range finder, video signal synchronizer, time generator, two video recorders and a personal computer. The 2 CCD cameras and laser range finder mounted on motor driven pan head, and pan head mounted on tilt body. Figure1 shows the appearance and figure2 shows the system configuration. The remarkable features of this system are as follows:

+ Synchronization for stereo image is performed by the video signal synchronizer.
+ Synchronized stereo image sequences are taken by the CCD1 and 2 cameras.
+ Object distance above datum is measured by the laser range finder.
+ Pan and tilt rotation angles can be controlled from PC.
+ Rotation of the cameras are synchronous to the rotation for the pan head and tilt body.
+ HVT can take image sequences with tracking for moving object.
+ Time and H.V. angles are connected and thus recorded on real-time on PC.
+ Synchronized stereo image sequences and time are continuously superimposed on image frames and thus recorded on video recorder.

In this investigation, image sequences were taken using HVT. Thus, synchronized stereo image sequences can be taken with tracking for the workman.

Figure1 Appearance of HVT

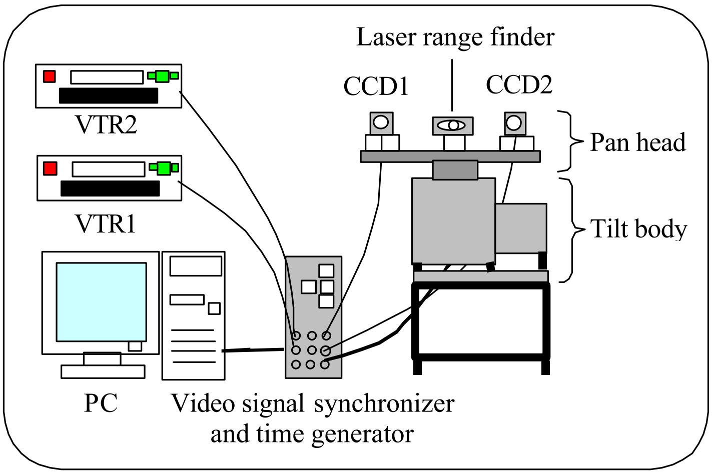


Figure2 Configuration of HVT

3 CAMERA CALIBRATION

In this paper, camera calibration was performed using 9 control points that were generated automatically on the image and in the space respectively from only one control point as same as video theodolite system [Chikatsu and Kakiuchi, 1999]. Furthermore, the remarkable points of HVT, automatic camera calibration can be easier than video theodolite system since the distance D from HVT to a control point could be measured without reflection sticker using laser range finder on HVT.

4 EXPERIMENTS

4.1 FEATURE POINTS

Accurate stereo matching for feature points was difficult in the old investigation since occlusion areas that is difficult to extract automatically by image processing procedure were sometimes occurred on the feature area of workman. In order to perform accurate stereo matching for feature points, investigation of feature points were needed. In this circumstance, improvement of feature point is performed in this paper in consideration that it won't be an obstacle to the workman motion or occlusion areas weren't occurred or automatic extraction by image processing procedure could be performed. As the results, the yellow and white loudly reflection stickers which was a regular square (7× 7(cm)) were selected as feature points. The two reflection stickers both yellow and white were respectively put on prepared vest(the waist) and helmet(the head) alternately that workman was worn(figure3). Further, white one was put on the top of helmet(the head) in this paper.

Figure3 The position of feature points

4.2 VIDEO IMAGE SEQUENCES

Video image sequences were taken by shutting the diaphragm(an aperture opening of 6.0) of two CCD cameras on HVT and throwing a video light from HVT to the object. Then, feature points recognition could be easier since brightness on the video image sequences became dark, and interference information(back ground, helmet, work clothes and etc.) for feature extraction by image processing were difficult to take into video image sequences. Further, when the workman moved extensively, two CCD cameras rotation was operated with PC and tracking for workman on real-time was performed. Thus, a video image sequences for extensively area was taken. Figure4 shows a video image sequences taken by utilizing HVT.

In order to develop an ERGOMA system on the construction plant, joining, welding and burnishing for horizontal steel pipes were performed respectively and a video image sequences for each work were taken using two video recorders in HVT. Working time for joining, welding and burnishing is 7, 12 and 5 minutes respectively. Generally, welding and burnishing on the construction plant are attached with strong radiation.

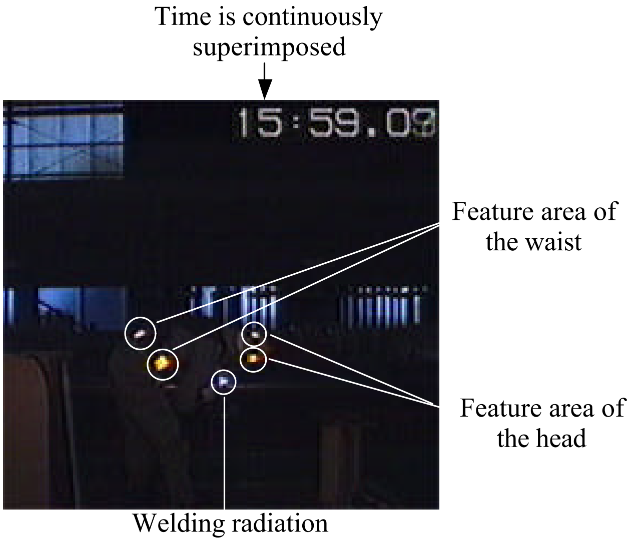


Figure4 Video image sequences in this system

5 ERGOMA SYSTEM

5.1 FEATURE EXTRACTION

In this system, video image sequences were taken by shutting the diaphragm(an aperture opening of 6.0) of two CCD cameras on HVT and throwing a video light from HVT to the object. Consequently, brightness of feature areas were much higher than back ground, helmet, work clothes and etc. Thus, the high brightness areas were extracted easier by SUSAN filter automatically [SMITH and BRADY, 1997]. SUSAN filter using circle as a structuring element can perform edge detection, corner detection and feature extraction. Figure5 shows an outline of SUSAN filter process. Fiture5 (a) shows an image of around reflection sticker as an extraction object. In figure5 (a), assume that a rectangle area is regarded as reflection sticker.

Reflection sticker has high brightness which shows more than (150,150,150) with RGB values in the video image sequences taken in this system. In this circumstances firstly, a base color using feature extraction is defined as RGB (175, 175, 175) ~ (255, 255, 255) respectively. Secondly, SUSAN filter scans in figure5 (a) and if the base color is detected at remarkable pixel(figure5 (b)), color comparison is performed between the remarkable pixel and all of pixels at circle within the radius of 7 pixels respectively. Color comparison means the difference of RGB values between remarkable pixel and another comparison pixel, and if an absolute value of the difference is less than 25, both remarkable pixel and another comparison pixel are considered as similarity pixel. Then the remarkable pixel and all of similarity pixel considered by color comparison is extracted respectively(figure5 (c)). Consequently, only reflection sticker is extracted(figure5 (d)).

In the old study, the authors have ascertained that opening in morphological image processinghas prominent ability to extract a feature area under insufficient image quality [Yamada and Chikatsu, 1999]. However, reflection stickers as a feature points in video

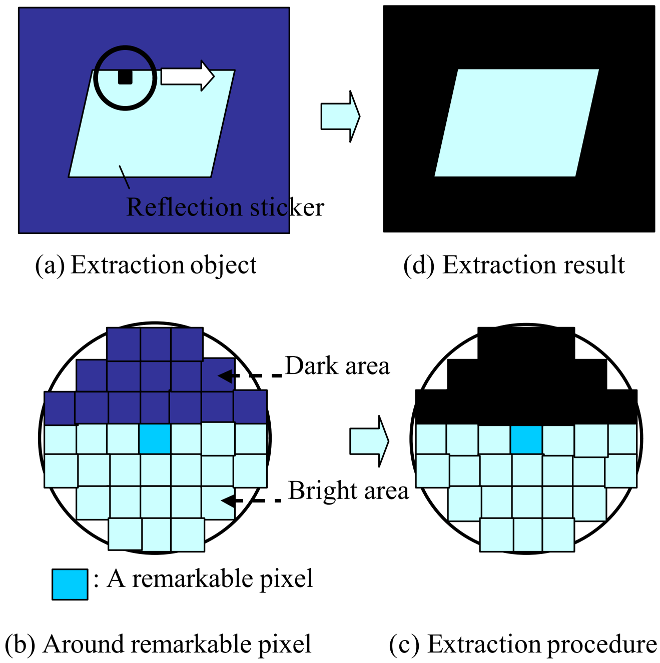


Figure5 Outline of SUSAN filter process

image sequences were taken clearly since improvement of video image acquisition and feature points were performed in this paper. Therefore, SUSAN filter that are difficult to occur swell and reduction is adopted as a feature extraction procedure in this system. Consequently, more accurate feature extraction can be performed using SUSAN filter.

5.2 AUTO-TRACKING

Figure 6 shows the system configuration that was used in this investigation. The LVR (Laser Videodisc Recorder) was used in this system has function for playing back and stop per a frame and connecting with another equipments such as PC or Video camera. Then, the original video images copied to the digital CRV disc (Component Recording Videodisc) for the LVR so that PC can continuously capture a scene of sequential images.
For human motion analysis, auto-tracking of the feature point and automatic stereo matching are performed as follows:

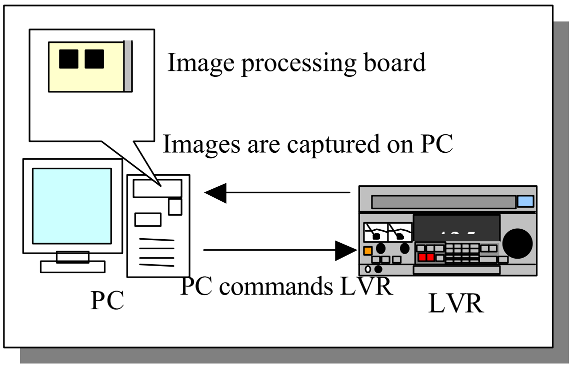


Figure6 Configuration of auto-tracking system

1) For differencing an image sequences, left and right image for the background are taken respectively.
2) As for both left and right image, window is previously cut out around the feature area in the first sequential images respectively.
3) As for both left and right image, differencing an image sequence procedure is performed between the background image and the first sequential image respectively.
4) As for both left and right image, extraction of feature areas are performed by SUSAN filter.
5) As for both left and right image, calculation of area, area gravity, height-width ratio and RGB values are performed for extracted feature area.

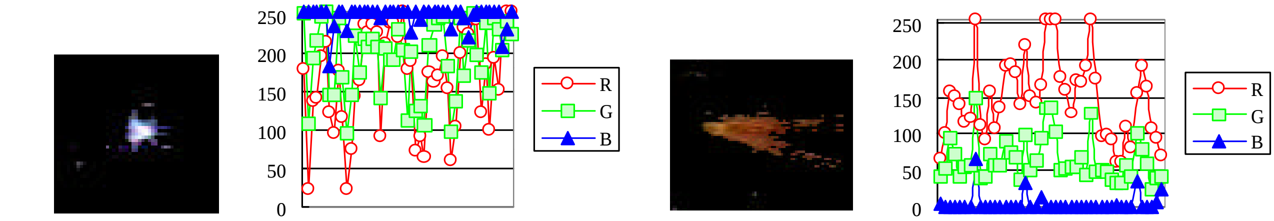
Further, as to the first frame of image sequences, 1 to 5 procedures are performed. Then, decision of the position for feature point and correspondence of feature point in left to right image are performed at the click of a mouse on PC monitor. Thus, 3D coordinates of the head and the waist are calculated.
As for the next frame, 1 to 10 procedures are repeated and auto-tracking for feature points are performed.

6) As for both left and right image, area, position, height-width ratio and RGB values of feature areas are compared between present frame and a before frame respectively, and most similar one is regarded as the feature point on present frame.
7) When the feature point cannot be extracted due to the feature area is hidden in steel pipe or due to insufficient image quality, "LOST" message is expressed on PC monitor, and extracting for feature area is performed around the lost position still the feature area appears again. When the feature area is found again, position of feature point are decided at the click of a mouse on PC monitor and auto-tracking is repeated again.
8) Feature points are circled for the purpose of certifying the position.
9) 3D coordinates of the head and the waist are calculated form corresponding position of feature point between left and right images.
10) These procedures are repeated automatically.

Auto extraction and Auto-tracking of 2 feature points can be performed for the head and the waist respectively in this system, and as to the head or the waist, when 2 feature areas are extracted, larger feature area between the two is regarded as a feature point.

5.3 WORK DISTINCTION

In this system, paying attention to features of radiation color for welding and burnishing, following two features with RGB values are found out.
+B is grater than R and G in welding.
+R is grater than G and B in burnishing.
Therefore, B-R ratio and B-G ratio are greatest in welding radiation color, similarly R-G ratio and R-B ratio are greatest in burnishing radiation color. Consequently, distinction between welding and burnishing could be achieved utilizing these ratios of RGB values. Figure 7 shows the features of radiation color for welding and burnishing.
Furthermore, these distinctions are expressed on the PC monitor such as "welding" or "burnishing" and the information are recorded as a part of database for ERGOMA system.



(a) Welding radiation (b) Future of welding radiation color (c) Burnishing radiation (d) Future of burnishing radiation color

Figure7 Work distinction

5.4 LOAD ON THE WAIST

Let assume that working load on the waist can be estimated using a force on the sacrum. Firstly, weight of human upper body as 240N, the arms and the head as 120N can be calculated using weight ratio(figure8) for human body parts and actual weight(600N) of workman [Kawano and et al., 1996]. Secondly, let assume that figure9 shows the human model with body bent forward θ °. In figure9, *F* is the pull force by the spine muscle. Generally, it is said that an angle of spine muscle is always 12 ° to the spine and the position takes 2/3 point on the spine from the sacrum. Then, a force on the sacrum *R* is regarded as working load on the waist in this paper, and these are calculated with the following equation.

$$F = 360 \times \sin\theta° / \sin 12° \quad [N] \qquad \cdots\cdots\cdots(1)$$

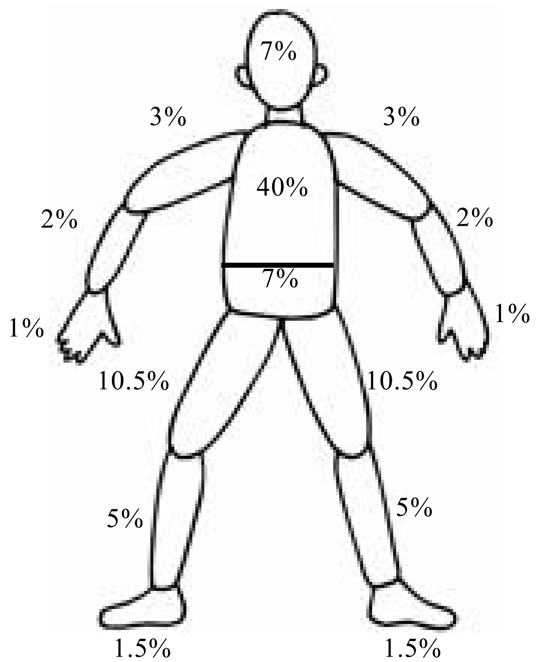
$$R = \sqrt{Rx^2 + Ry^2} \quad [N] \qquad \cdots\cdots\cdots(2)$$

$$* \; Rx = F \sin(\theta° + 12°)$$

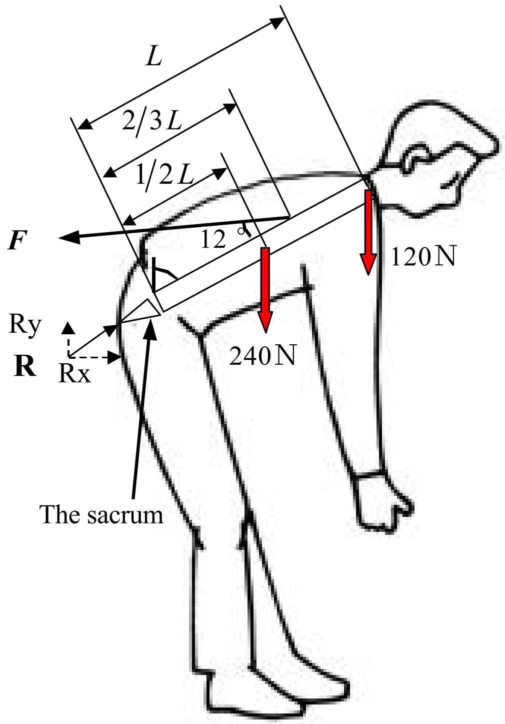
$$* \; Ry = F \cos(\theta° + 12°) + 360$$

1684N is calculated as the force on the waist at the body angle of 60 ° using upper equation (2). On the other hand, it is generally reported that 2.5 times weight of human is on the waist if a human bends his body forward 60 °, and 1500N are driven in this case.

Consequently, this assumption gives almost correctly values, therefore it is concluded that working load on the waist can be estimated using a force on the sacrum.



Fugure8 Weight ratio for human body



Fugure9 Load on the waist

5.5 VISUALIZATION OF HUMAN MOTION

Visualization of human motion is needed for objectively evaluation of working load or easy understanding of human motion. In these circumstances, this paper describes visualization of human motion and working load on the waist using animation. In order to analyze human motion using animation, detail animated cartoons should be prepared previously. Then, firstly 3D model of construction plant site and a human were reconstructed using 3D modeling software. Secondly, working postures or kind of works on the human 3D model was changed to variously assuming actual work on the construction plant. And these 3D models were located on reconstructed plant site. Finally, rendering for the 3D model of the construction plant site and the human model were performed, and 2240 kinds of detail animated cartoons corresponding to various human postures and radiation such as welding and burnishing were produced. Figure 10 shows the examples of detail animated cartoons.
Furthermore, a filename of these animated cartoons are regularly numbered, and these numbers correspond to the position and the working posture of workman and the kind of work. Thus, the position and the posture of workman and the kind of work can be understood from the filename. Consequently, these detail animated cartoons corresponding to various postures are animated automatically on PC monitor comparing the filename with 3D data of the head and the waist and kind of radiations. Figure 11 shows animated image.
On the other hand, in particular, visualization for estimation of working load on the waist that causes serious damages for human should be performed. With this motive, the color around the waist of human model is changed to red in the case of load on the waist is more than 1500N in this system. This value means that working load on the waist is equal about 2.5 times weight of workman, and these working situations should be improved.
The estimation value of working load on the waist, an angle of body bent and velocity of the head and the waist are displayed on PC monitor, and these are recorded as a data file in this system.

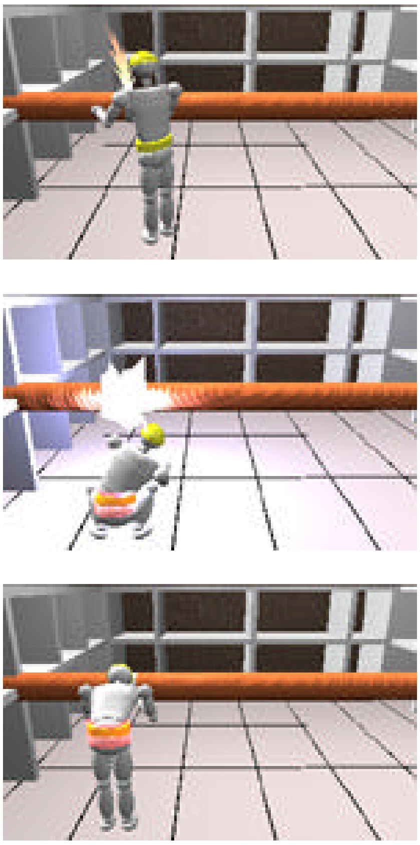


Figure10 Detail animated cartoons

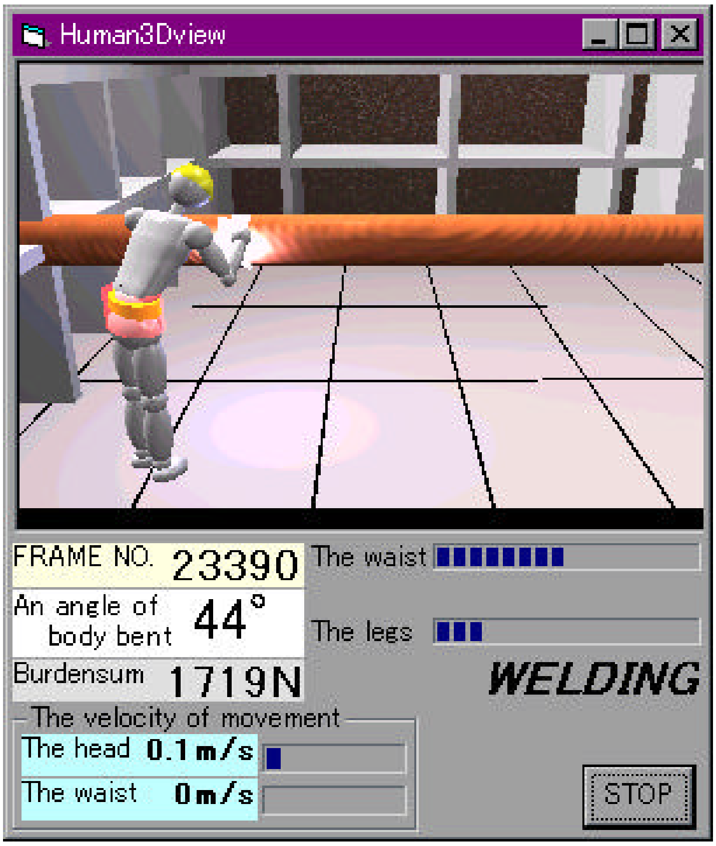


Figure11 Animation image

5.6 LOAD ANALYSIS

As several motion analyses can be performed using the data file from ERGOMA system, first of all working load on the waist was investigated in this paper. The roads on the waist were classified into three types such as a little(500~999N), medium(1000~1499N) and strong(1500~1999N) respectively. Figure 12 shows an example of load analysis on the waist for joining, welding and burnishing. As for the ratios more than 1500N, in the case of welding(75%) and

burnishing(56%) are much higher value than in the case of joining(13%). From figure 12, it can be said that welding and burnishing are more burdensome work than joining.
Figure 13 shows the results of posture analysis for joining, welding and burnishing. The postures are classified by height of the waist into three types such as standing(0.7~1.0m), half-sitting(0.3~0.7m) and sitting(0~0.3m) respectively. As for the standing ratios, in case of joining is much higher value than in case of welding and burnishing. As for the half-sitting ratios, in case of welding is much higher value than in case of joining and burnishing. As for the sitting ratios, in case of welding and burnishing are much higher values than in case of joining. In these circumstances, it can be understand that working posture of workman is different by kind of work respectively.

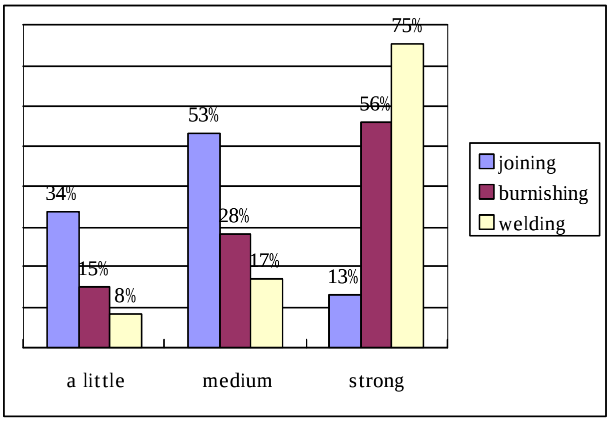


Figure12 Load analysis

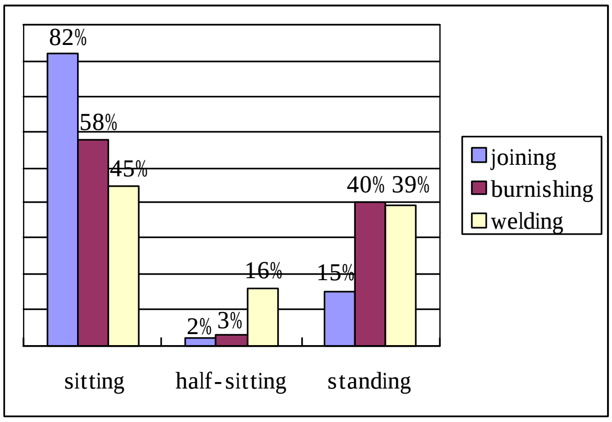


Figure13 Posture analysis

6 CONCLUSIONS

This paper describes the integrated ERGOMA system utilizing image sequences taken by HVT. Then, automatic camera calibration was performed and synchronized stereo image sequences tracking for moving object can be obtained. Thus, more efficient ERGOMA system was developed in this paper. Further, improvement of image acquisition, feature points and accurate extraction method for feature points are investigated, and the feature extraction and auto-tracking for feature points can be performed efficiently. Furthermore, more accurate calculation of load on the waist and more smoothly animation on ERGOMA system are also investigated, and visualization of human motion analysis using animation are demonstrated
However, it is concluded that objective evaluation and easy understanding of human motion while working can be possible using integrated ERGOMA system. Consequently, the integrated ERGOMA system is very efficient for improvement of working environment or evaluation of working load.

7 REFERENCES

・Mikami, K., 1998. An Approach to Work Redesign for Middle to Elderly Workers. Management systems : a journal of Japan Industrial Management Association, Vol.8, No.3, pp77-80.
・Yoshida, S. and Chikatsu, H., 1999. Visualization of Human Motion on The Construction Plant for ERGOMA System. International Workshop on Vision-Based Techniques in Visualization and Animation. Vol. XXXII-Part5-3W12, pp115-119.
・Chikatsu, H. and Anai, T., 2000. Development of Hybrid Video Theodolite and Application for 3D Modeling of Panoramic Objects. XIXth ISPRS Congress Amsterdam
・STEPHEN M. SMITH and J.MICHAEL BRADY, 1997. SUSAN-A New Approach to Low Level Image Processing. International Journal of Computer Vision 23(1), pp45-78.
・Yamada, N. and Chikatsu, H., 1999. Remapping of Historical Maps using Mathematical Morphology and Its Application. International Workshop on Mobile Mapping Technology, Bangkok, Vol.XXXII, P-2-6.
・Kawano, T and et al., 1996. Study of Computer Aided Consultation System for Working Postures Using Posture Input Puppet-Like-Device and Visualization of Joint Torque. Journal of the Japan Society for precision, Vol.62, No.5, pp712-716
・T. M. Khalil, E. M. Abdel-Moty, R. S. Rosomoff, H. L. Rosomoff, 1993. Ergonomics in Back Pain. Van Nostrand Reinhold.
・J.R.Potvin, 1997. Use of NIDSH equation inputs to calculate lumbosacral compression force. Ergonomics, Vol.40, No.7, PP691-707.