'91 KACC 1991. 10. 22~24

ON A NEW LASER DIGITIZER SYSTEM

Ikumatsu Fujimoto and Daisuke Takahashi*

Developement Dpt. Wacom co,ltd.
4-23-4 Sakurada,Washinomiya-cho,Kitakatsushika-gun,Saitama 340-02,Japan
*Deparment of Applied Mathematics and Informatics,
Faculty of Science and Technology,Ryukoku University,Seta,Otsu,520-21,Shiga,Japan

ABSTRACT

A new system of a two dimensional large scale lazer digitizer with a cordless cursor is proposed.It provides an easiness of setting devices and a high accuracy of measurement.

1. INTRODUCTION

The large scale digitizer system is very useful in the area of manufacturing design.[1]
For example, about 2m*6m digitizer is used to design the car body and about 2m*3m one is used to design the glass product. High accuracy and easiness of manipulation are also required to such type of a digitizer.
The laser digitizer system with a cordless cursor may be one of the strongest candidates and is really used for the manufacturing design. Figure 1 shows a typical one of such system.
In the system, there are two optical units $U^{(1)}$ and $U^{(2)}$,each of which includes a laser,rotating mirror,a half mirror and a sensor. The cordless cursor has an all-directional reflecting mirror at the pointing position and can move in the coordinate area of the digitizer. As both rotating mirrors rotate at about 2400 rpm,the reflecting ray from the mirror scans the coordinate area. When the scanning ray enters the cursor, it is reflected,returns to the rotating mirror, is again reflected, and enters the sensor in a neglegible time. Then, the personal computer measures the time when the sensor senses the ray, and calculates the angle of the rotating mirrors of $U^{(j)}$ (j=1,2).The position of the cursor is calculated from both $\theta^{(j)}$ by the principle of triangle measurement as shown in Figure 2.[2]
Let suppose that the origin of the x-y coordinates stays at the center of the rotating mirror of $U^{(1)}$ and the distance between the centers of both rotating mirrors is L.
Then, the position (X,Y) of the cursor is calculatulated as follows.

$$X = \frac{L*\tan(\theta^{(2)})}{\tan(\theta^{(1)})+\tan(\theta^{(2)})} ,$$

$$Y = \frac{L*\tan(\theta^{(1)})*\tan(\theta^{(2)})}{\tan(\theta^{(1)})+\tan(\theta^{(2)})} .$$

The above process of measurement is a typical one of the laser digitizer system.However,there are following problems;
(i) The ray from the laser needs to enter exactly the center of rotating mirror.
(ii) The distance L between the centers of the rotating mirrors needs to be measured precisely
(iii) Both rays from the lasers needs to stay in the same line exactly.

Because of the above problems, it takes very long time to set up the system within a certain accuracy and it is very difficult to maintain the setting .
In order to solve the above problems,we developed a new system described in the Section 2.

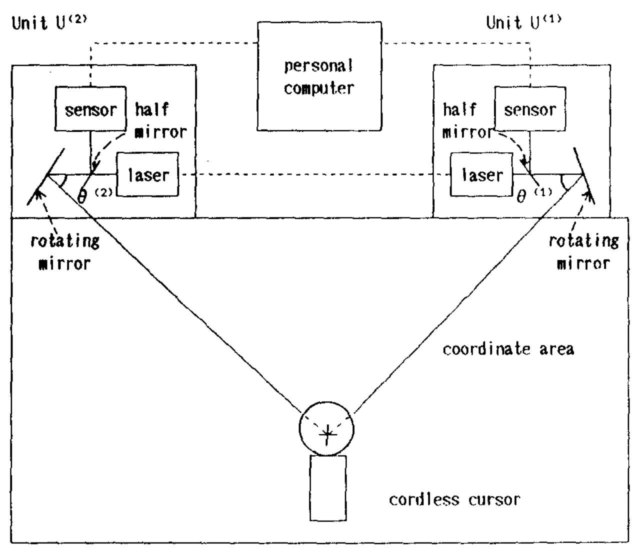

Figure 1:Typical laser digitizer system

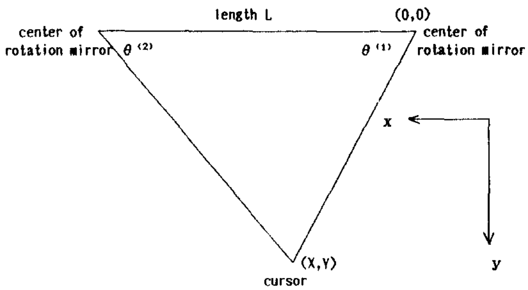

Figure2:Triangle measurement used in the system in fig.1

2. NEW LASER DIGITIZER SYSTEM

Figure 3 shows our new laser digitizer system with a cordless cursor. The devices which constructs the system are the same as those used in the system in Figure 1. However,both rays from the lasers do not need to enter the center of the rotating mirror.

Assume that $(x_c^{(j)},y_c^{(j)})$ denotes the center position of rotating mirror $U^{(j)}$ and the equation of the ray from the laser of $U^{(j)}$ is

$$y-y_c^{(j)}=a^{(j)}(x-x_c^{(j)})+b^{(j)}. \qquad (1)$$

The angle of the rotating mirror is set to 0 when the mirror is perpendicular to the ray entering from the laser. Assume that angle of the rotating mirror of $U^{(j)}$ is $\theta^{(j)}$ when the position of the cursor is (X,Y) and that the ray from the laser of $U^{(j)}$ enters the rotating mirror at $(x_I^{(j)},y_I^{(j)})$. Then, the following three equations are obtained for $U^{(1)}$;

$$y_I^{(1)}-y_c^{(1)}=\tan(\theta^{(1)}+\arctan(-1/a^{(1)}))(x_I^{(1)}-x_c^{(1)}),(2)$$

$$y_I^{(1)}-y_c^{(1)}=a^{(1)}(x_I^{(1)}-x_c^{(1)})+b^{(1)}, \qquad (3)$$

$$\arctan((Y-y_I^{(1)})/(X-x_I^{(1)}))+\pi-\arctan(a^{(1)})=2\theta^{(1)}. \qquad (4)$$

Canceling $x_I^{(1)}$ and $y_I^{(1)}$, eqs.(2)-(4) reduce to

$$(1-a^{(1)}\tan2\theta^{(1)})(Y-y_c^{(1)})-(a^{(1)}+\tan2\theta^{(1)})(X-x_c^{(1)})=b^{(1)}(1+\tan\theta^{(1)}\tan2\theta^{(1)}).(5)$$

Also,the following three equations are obtained for $U^{(2)}$;

$$y_I^{(2)}-y_c^{(2)}=\tan(\arctan(-1/a^{(2)})-\theta^{(2)})(x_I^{(2)}-x_c^{(2)}),(6)$$

$$y_I^{(2)}-y_c^{(2)}=a^{(2)}(x_I^{(2)}-x_c^{(2)})+b^{(2)}, \qquad (7)$$

$$\arctan((Y-y_I^{(2)})/(X-x_I^{(2)}))-\pi-\arctan(a^{(2)})=-2\theta^{(2)}. \qquad (8)$$

Canceling $x_I^{(2)}$ and $y_I^{(2)}$, eqs.(6)-(8) reduce to

$$(1+a^{(2)}\tan2\theta^{(2)})(Y-y_c^{(2)})-(\tan2\theta^{(2)}-a^{(2)})(X-x_c^{(2)})=b^{(2)}(1+\tan\theta^{(2)}\tan2\theta^{(2)}).(9)$$

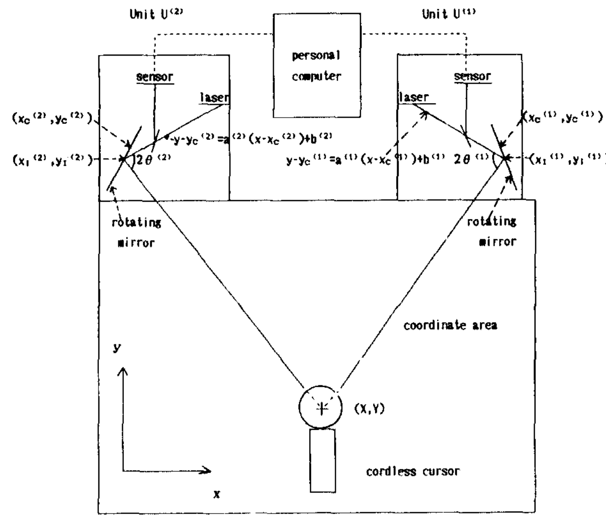

Figure 3:New laser digitizer system

If we measure $\theta^{(j)}$ for four individual cursor positions(X,Y) which are known beforehand, the unkown parameters $a^{(j)},b^{(j)},x_c^{(j)},y_c^{(j)}$ can be calculated using eqs.(5) and (9). Once those unknown parameters are calculated,any cursor position(X,Y) in the coordinate area can be calculated by measuring $\theta^{(j)}$ and by using eqs.(5),(9).

The advantages of our new system are as follows;

(i) As the positions of lasers and rotating mirror have a large arbitrariness, the setting of the system becomes easy.

(ii) As the mathematical model excludes the errors of the arrangement of lasers and mirrors,the accuracy may improve.Especially ,the shift of the reflecting position from the center of rotating mirror is one of large errors in the system described in section 1, but, it is incorporated into the model in our new system.

In order to estimate the accuracy of our system we made an experiment according to the following procedure;

(i) Plot two-dimensional grid points of which positions are known exactly, all over the coordinate area of the digitizer.

(ii) Determine the unknown parameters of eqs.(5) and (9) using the grid point in the four corners of the area.

(iii) Set the cursor on the other grid points and measure their coordinates according to our method.

(iv) Calculate the average ε of

$$\max(|X-X'|, |Y-Y'|)$$

for the grid points where (X,Y) is the coordinate measured by our method and (X',Y') is corresponding exact coordinate.

We estimate the accuracy with ε. In our experiment, ε was about 0.15mm for the 2m*6m digitizer. Note that only four grid ponits are neccessary for step (ii) in the above procedure, but, we choosed 7-10 appropriate grid points and adjusted the parameters $a^{(j)}, b^{(j)}, x_c^{(j)}, y_c^{(j)}$ with a simple statical technique. We made the same experiment to the system described in Section 1.Note that the step (ii) of the procedure of the experiment is unnecessary for that system. Though the accuracy depends on the precision of setting devices , ε could not be less than about 1mm in the best case.therefore we can conclude that the accuacy of our new system becomes about 6 or 7 times as high as that of the former system and the setting of devices becomes much easier simultaneously.

3. CONCLUDING REMARKS

The new laser digitizer system with a cordless cursor was proposed. It reduces difficulties in setting devices and improves the accuracy of measurement. The experimental results support those advantages.

The other probable cause of the measurement error is, for example,the jitter of the axis of the rotating mirror,the thickness of the mirror, and so on. Therefore, it may be the future subject to solve such errors without reducing the easiness of setting.

REFERENCES

1) Target;Industry studies on laser and cad/cam industries,Flint-Genesee Corp.,Ntis(1983)

2) N.Saito,T.Hirose,M.Abe,M.Suwama,I.Fujimoto S.Koizumi,R.Yamene and A.Murakami:Developement of super large size laser digitizer,Krean Automatic Control Conference (1990)