Intelligent Target-scoring System based on image processing

(This is only a brief technical report, for more information, be free to contact me)

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1 Introduction

This technical paper is devoted to the development of automatic target-scoring system for military shooting exercises. Taking the 50*50cm Chest silhouette as our research target, we review traditional techniques and achievements in target image processing and point out the defects of the Distortion Rectification method in image preprocessing, the limitations of Image Subtraction method in bullet hole recognition. Furthermore, we extend the working domain from Lab to military shooting environment.

To begin with, we select corners on the target panel manually to determine the borderline of the target for simplicity of implementation and computational speed, especially under complex outdoor environment.

For the defects of traditional Distortion Rectification method, also considering the reliability, real-time processing ability and the efficiency of reading target in outdoor military shooting environment, we put forward a real-time approach to locate the target center and Circular-orbit Neighborhood Searching algorithm to produce a quick orientation of the target rings. For nonuniform illumination conditions in outdoor military shooting environment, we introduce the method of *Light-dark Self-adaption Image Subtraction* to recognize the bullet holes with relatively high precision rate. To cope with the tremor of target when hit by bullet, we design an algorithm named *Tremor-removing Image Subtraction* to eliminate suspected bullet holes resulting from tremulous effect.

2 System Design

2.1 Hardware Design

We choose Intel Atom Z510P(512M on board memory, 1.1GHz speed) as our central processor and connect peripheral devices as shown in figure 2-1:

- IP Camera, HKVISION(2.0mpeg), connected to the LAN port of the Intel Atom Platform; We use it to capture pictures and transmit image data via cable.
- DVI-D screen(Hyundai), mouse and keyboard for the interaction between the embedded system and operators.
- 60 G hard disk for the storage of Windows XP operating system and programs.
- Speaker, automatically reads shooting scores of our users.

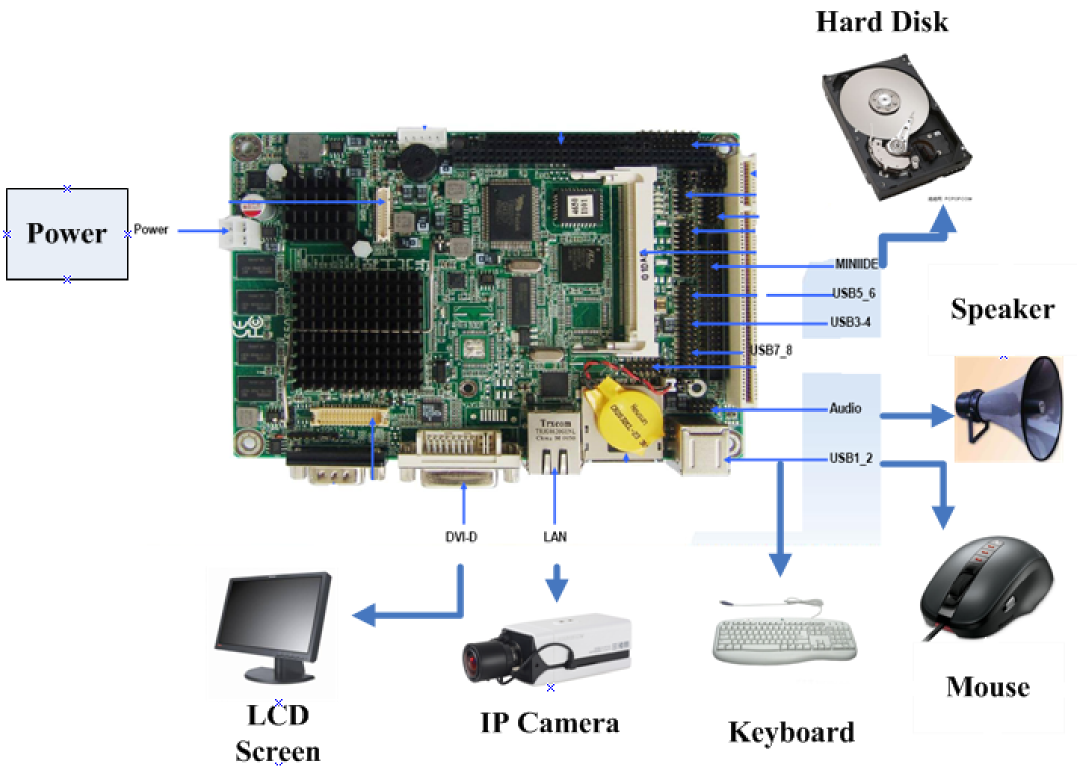


Figure 2-1 hardware design of the Single Station mode

2.2 Software Design

Depending on Intel Atom Platform, we construct our software system under Visual Studio 2005 with the aid of the C# language. Because of its intuitive properties, simplicity, network security, object oriented quality and computational efficiency , C# makes it convenient for us to integrate single stations with each other in order to form a muti-station mode system that we will discuss later in system outlook section. Figure 2-2 illustrates how we achieve the goal of bullet holes recognition and target-scoring step by step, locating target center, target rings and bullet holes are three key steps marked with a red circle. We will discuss further about the detailed algorithms to implement them in the next section.

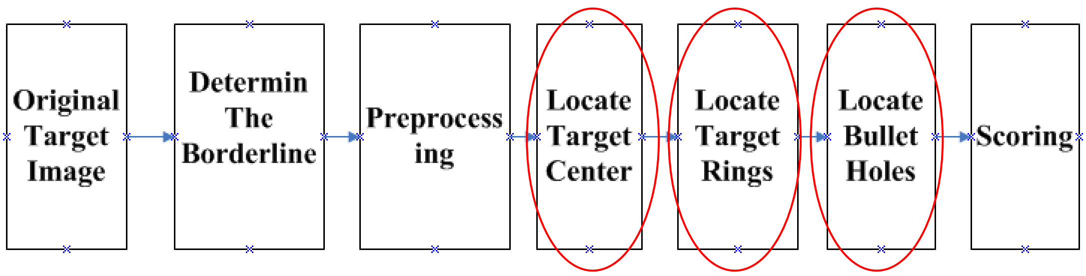


Figure 2-2 software design

3 Key Algorithms

3.1 An approach to locate target center

Step1: Calibrate original image, adaptive median filter, Ostu threshold

Step2： Erode Ostu binary image in Step 1;

Step3： Edge image=Ostu binary image—Eroded image;

Step4： Program TraceBoundary() function to trace edge pixels on Edge image;

Step5： Record coordinates of all the edge pixels; Describe all the closed-borderlines and objects using Bounding Box Model（External rectangle， Width*Height）;

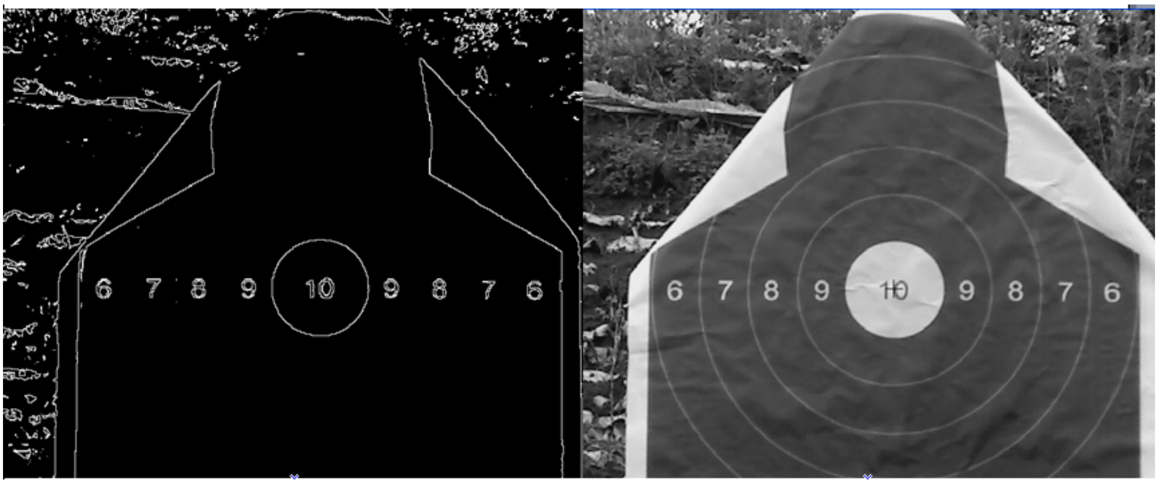
Step6： Discard the objects that are smaller than 5*5 in area, calculate

$$Compactness = \frac{Area}{Width * Height};$$

Step7： Locate centeral 10-ring region based on Compactness values and geometrical features of Bounding Boxes; Store the coordinates of pixels on the 10-ring borderline in a structure named tenBorderLine;

Step8： Calculate the mass center and the average radius of 10-ring borderline.

$$x_c = \frac{\sum_N x_i}{N} \qquad y_c = \frac{\sum_N y_i}{N} \qquad radius = \frac{\sum_N \sqrt{(x_i - x_c)^2 + (y_i - y_c)^2}}{N}$$



(a) Boundary Image (b) mark target center with cross

Figure 3-1 Results of running our algorithm

Locate target center in outdoor conditions, Target Center（463,332）

3.2 Circular-Orbit Neighborhood Searching algorithm to locate target rings

In this algorithm, we take full advantage of geometric features of the 50*50cm Chest silhouette. All target rings (N-Ring, N=6,7,8,9,10) are concentric circles with the same center at O and radius equal to (11-N)×R_0, if we define O as the target center and R_0 as the radius of 10-Ring circle. Given the fact that target image will get distorted when captured and it is complicated to reconstruct original image according to certain effective mathematical model, we open up a new approach to cope with distortion problems. If we can extract all the coordinates of borderline pixels on the target rings, it might become less necessary to reconstruct original target images. Acting on this hypothesis, we conceive the Circular-orbit Neighborhood Searching algorithm to locate target rings on distorted target images around predefined concentric circles(standard circles)with radius equal to (11-N)×R_0, thus increasing the computational speed of our system.

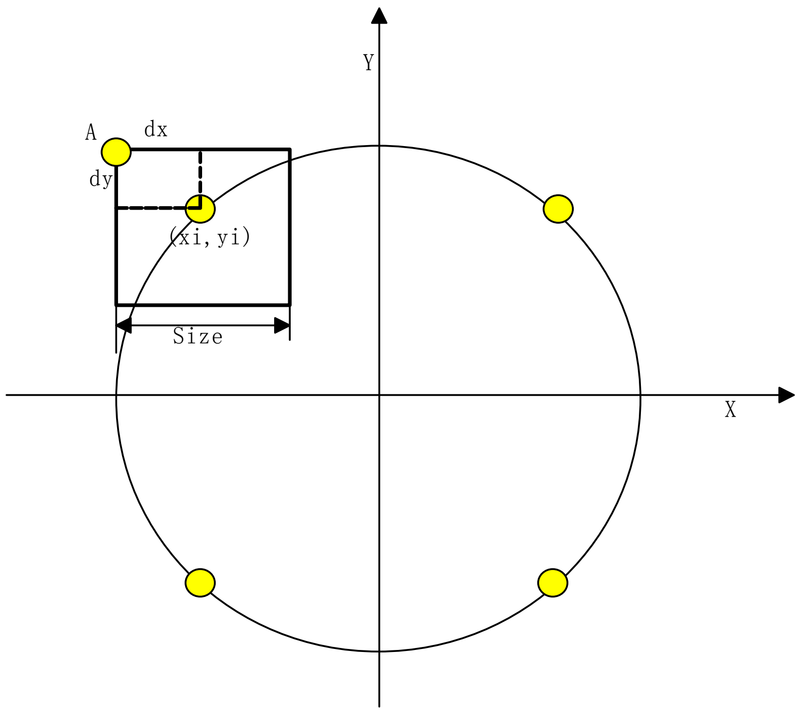


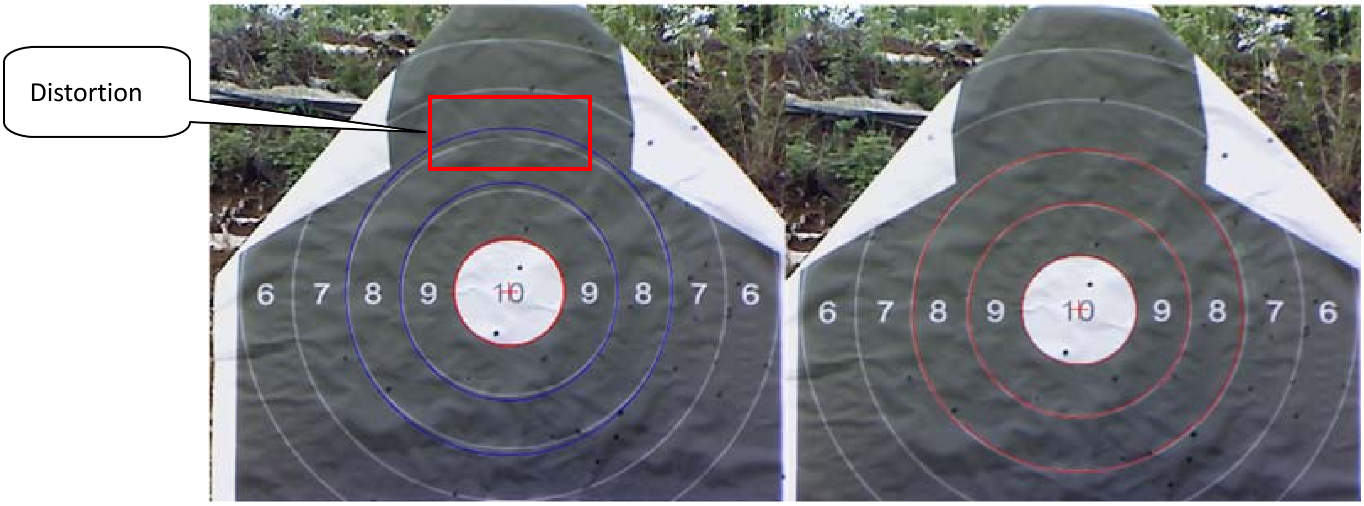
Figure 3-2-1 Circular-orbit Neighborhood Searching Algorithm

Step1： Scan every pixel on the N-Ring standard circle with predefined radius equal to (11-N)×R0;

Step2： For every pixel（xi，yi）visited in Step1,construct a square neighborhood with *Size* pixels on a side，the offset of upper left vertex A against point（xi，yi）is defined as（dx，dy）;

Step3： Ostu thresholding within the square neighborhood defined in Step2;

Step4： Find out all the pixels with intensity values equal to 255(the candidate pixels on target rings); Calculate the mass center (X_m, Y_m)of these pixels to replace point （xi，yi）; Mass centers of different square neighborhood constitute the real borderline on a distorted target image.



(a) Predefined(Standard) Target Rings (b) Modified Target Rings

Figure 3-2-2 Results of Circular-orbit Searching algorithm

3.3 Locate bullet holes

Based on hundreds of times of indoor and outdoor tests, we finally define the mathematical model of bullet holes in terms of the following aspects:

a) Bullet holes are darker compared to surrounding pixels;

b) The absolute threshold and relative threshold (difference) of bullet holes;

c) The area of bullet hole regions;

d) The geometrical shape of bullet holes.

According to above features of bullet holes, we introduce two algorithms to recognize and locate them:

1） Light-dark Self-adaption Image Subtraction Method

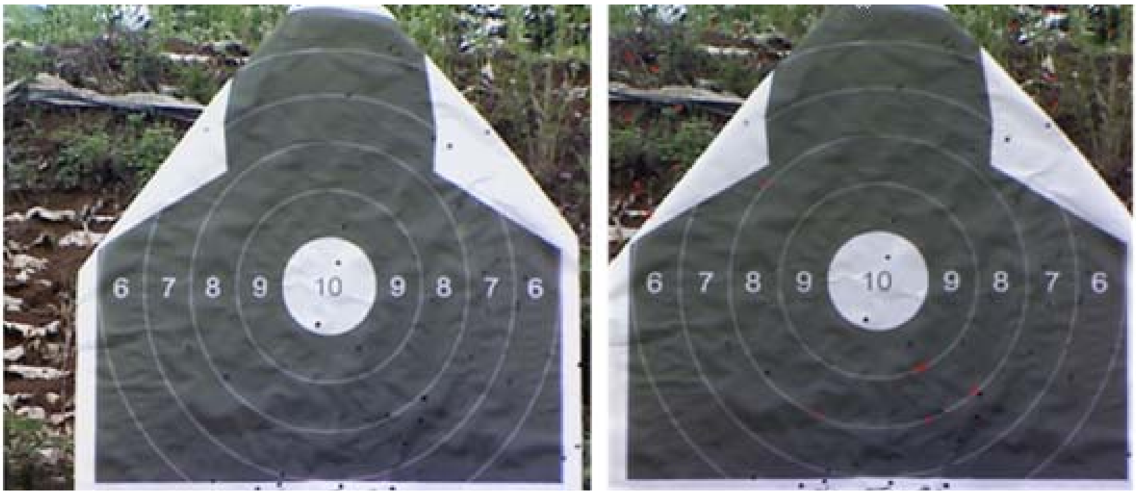
- Gray values compensation on overall scale.

  Formula: gray_compensate = templateAveGray – matchAveGray

- Two criterions (absolute & diff bullet hole gray values) for 8-bit gray image after gray compensation:

  Absolute Gray Value < Thr1; Diff Gray Value > Thr2;

Figure 3-3-1 illustrates the effect of illumination on the recognition of bullet holes.



(a) Brighter (b) Darker

Figure 3-3-1 Two pictures taken within 1 second outdoor

2） Tremor-removing Image Subtraction technique

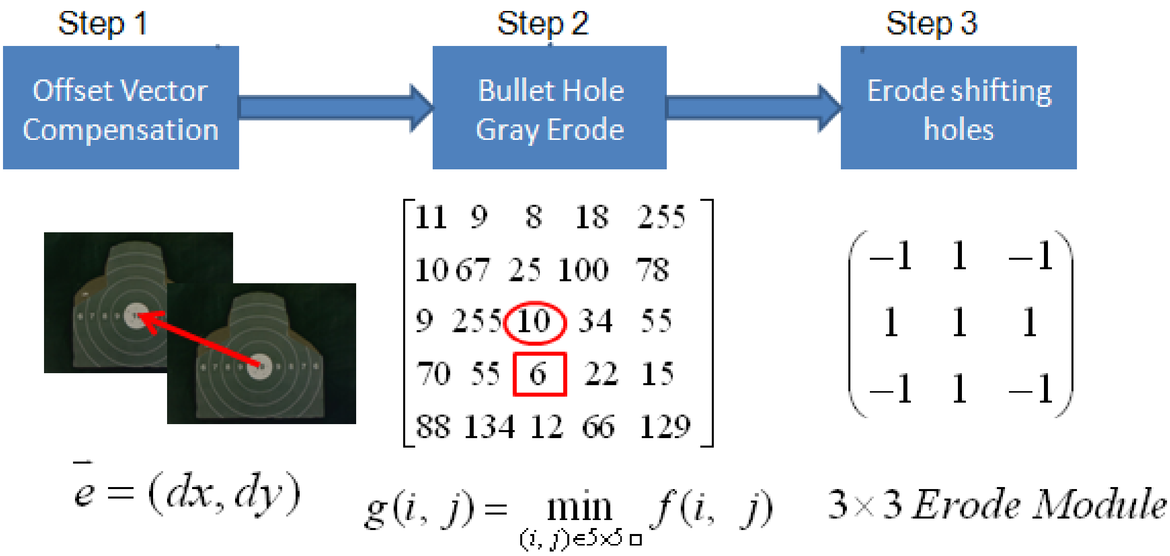


Figure 3-3-2 Procedures of Tremor-removing algorithm

4 System Function and Test

Our intelligent target-scoring system enjoys the following functions justified by tests:

- Accurate location of target center and quick location of target rings;
- Even under the conditions of non-uniform illumination and slight tremor of target, our system can also recognize the bullet hole exactly in decimals;
- Phonetic target-scoring, Multi-ID log-in, real-time calculation and analysis of scores, convenient query of scores and rank;

- ➢ dynamic reconstruction of the shooting conditions of trainers in real time on mimic target.

We use a toy gun to shoot through target sheet pasted on a cystosepiment. The following test is completed in the lab.

First shot: lies in 10-ring region

First shot

Figure 4-1 First shot, 10-ring region

Shooting scores appear on the mimic target.

Figure 4-2 First shot, current score: 10.4, total score: 10.4

Second shot: on the inner side of 8-ring circle

On the inner side of 8-ring circle

Figure 4-3 Second shot, on the inner side of 8-ring circle

Shooting scores appear on the mimic target.

Figure 4-4 Second shot, current score: 8

Third shot: off the target

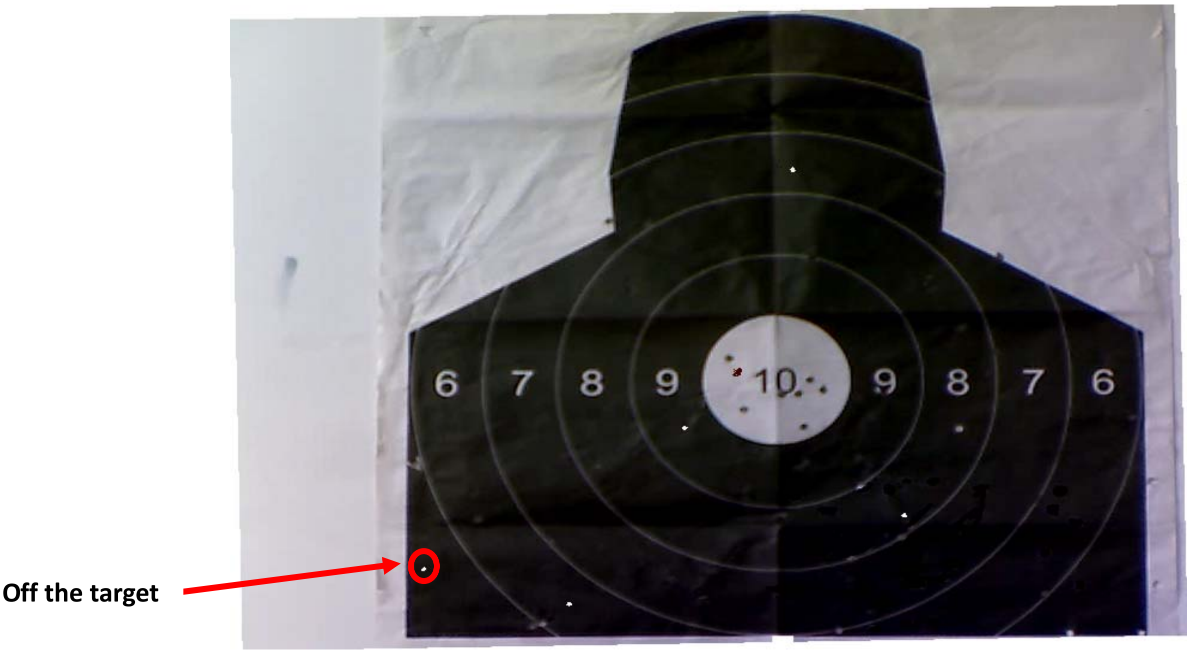


Figure 4-5 Third shot, off the target

Shooting scores appear on the mimic target.

Figure 4-6 Third shot, current score:0, off the target

5 System Outlook

A Multi-station Mode System:

In the future, we will expand the scale of our system from single-station mode to multi-station mode, provided with a much more powerful processor, which integrates end to end IP-Camera stations together. Each IP-Camera station can provide users with a separate firing room and is connected to the same central processor, which transmits timely shooting situations of our users to a supervisory computer.

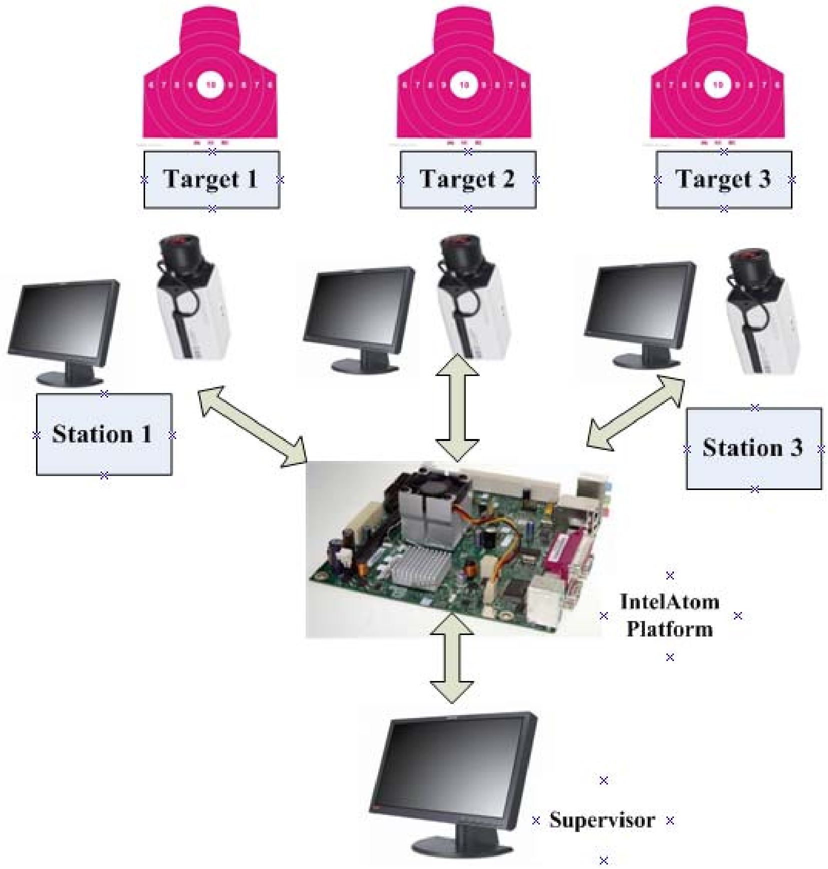


Figure 5-1 Multi-station Mode

Some aspects to be improved in the future

- Our system will become more intelligent if it is possible to get the characteristic points to identify the outer boundary of the target automatically not manually against more complicated background, such as trees and flowers.
- How to improve recognition precision rate when the target is moved fiercely.
- The premise that the target can return to the original position is founded on the elasticity of the pole supporting the target.

Prospective Solutions

- Construct mathematical models to describe more complicated background under outdoor environment;
- Use sensors to measure the rotation angle, the vector $\vec{e} = (x_{ci} - x_o,\ y_{ci} - y_o,\ \Delta\theta)$

can then be calculated to compensate the effects of rotation and tremor.

- Flow control method, we can trace the target center of every frame and select the most ideal image for further processing, which has the least deviation from calibrated target center.

6. References

[1] 张红民,何健鹰. 用改进的广义 Hough 变换获取靶纸图像子像素级圆心坐标[J].计算机与现代化，2003 (10):43-50.

[2] 袁莉茹. 基于图像处理的军用自动报靶系统弹孔识别[D].重庆：重庆大学

[3] 宿业勇. 基于图像处理技术的军用自动报靶系统研究[D].哈尔滨:哈尔滨工业大学，2007

[4] 陈海峰. 基于图像处理技术的自动报靶系统研究[D].南京:南京航空航天大学，2005

[5] 张军，颜树华. 自动报靶系统的研究进展[J].激光与红外，2006(12):1152-1164

[6] 钱学成. 基于图像处理技术的自动报靶系统设计[J].技术研发，2009 (4)：52

[7] 李柏年. 基于图像处理技术的自动报系统的设计与实现[D].兰州：兰州大学，2007

[8] P.V. Hough, Machine analysis of bubble chamber pictures.International Conference on High Energy Accelerators and Instrumentation, CERN, 1959.

[9] P. V. C. Hough, Method and means for recognizing complex patterns. U.S. Patent 3,069,654, Dec. 18, 1962.

[10] Richard O. Duda, Peter E. Hart. Use of the Hough transformation to detect lines and curves in pictures. Graphics and Image Processing, vol.15, pp.11-15, 1972.

[11] 张铮，王艳平.数字图像处理与机器视觉[M].北京：人民邮电出版社，2010

[12] 谭浩强.C++程序设计[M].北京:清华大学出版社，2004.

[13] Liberty,J.张晨,王丽译.C#3.0 学习指南[M].北京:人民邮电出版社,2010.

[14] 范盛荣.Visual C# 2008 控件使用范例详解[M].北京:清华大学出版社，2009.