Design of Automatic Tiny Grain Color Sorting System

LI Mingwei#, Xie Xiaofei ,Meng Hua and Liu Peng
1 School of Control Science and Engineering, Dalian University of Technology, LingGong road NO.2, DaLian, LiaoNing, China
Li Mingwei / E-mail:dzxiexiaofei@foxmail.com TEL: +86-13889406260 FAX: +XX-XX-XXX-XXXX

KEYWORDS : dynamic distribution particle; tiny grain purification; linear CCD sensor; dynamic distribution particle; critical path

Color sorting technology that distinguishes tiny grain according to the different gray of tiny grain in material is an important technology of material impurity screening. As small characteristics of impurities grain and different gray in material, the automatic tiny grain color sorting system is designed to purify tiny grain based on the linear CCD sensor.In this paper, an optimal purification path of dynamic distribution particle is proposed through modeling and analysis the color sorting system. According to the constraint condition of the real system, a dynamic AOE knot network topological graph is established using improved critical path algorithm through weight binarization and impurity path normalization, and eventually we find an optimal purification path of dynamic distribution particle with improved critical path algorithm, obtain the objective function by which servo controlling system can traverse the most particles in a limited time. The result through the system running proves that the system design and path algorithm are both reasonable.

Manuscript received: January XX, 2011 / Accepted: January XX, 2011

1.Introduction

Color sorting method is a new technology. It has a wide range of applications in tiny grain material impurity, such as purification of industrial raw materials, purification of milled rice, materials sorting technology and so on. Use linear CCD to obtain the gray image of the raw materials, and then set the reasonable binarization threshold, identify the specific location in the image, drive the impurity removal device to pick out the impurities, achieve to the aim of the purification of materials. The impurity removal device is divided into one dimension system and two dimension system. One dimension system can follow the particle only in the one direction, so it’s easy and cheap to make. Two dimension systems can follow the particle in its running direction and in its upright running direction, so it’s more difficult than the one dimension system to make and its algorithm is very complicated.

How to find an optimal route which could improve the impurity rate is the emphases and hard point of the system. There are many algorithms of the route choose problems, but many algorithms we have done are limited that just find a shortest route as their object function, such as A* route identify algorithm, Dijkastra shortest rout algorithm, improved D algorithm, TSP model algorithm and dynamic random network K expected shortest route algorithm, and so on. These algorithms are based on the static image and the random parameters of the network, and then get a shortest route from the start to the end. The number of nodes in the route is not considered. In this paper, we analyze the distribution of the dynamic particles and give a optimal route search algorithm. A dynamic distribution particles route is get through setting the model and solving. This algorithm improves the purity rate.

2.Purification model

In this paper, the purification of industrial quartz sand is as the background, model and solve the system. Figure 1 is the impurity purification system. First through the feeder quartz sand tiles into the uniform motion of the conveyor belt, transmit the material through the CCD sensor system, and get the moving image. The special location of impurities is calculated after the image process, and drive the executive system to pick out the impurities by precision time control, and the left materials is send to the recycle equipment. The executive system can only move in the y direction, can’t move in the x direction from the belt, so impurity system can only pick out one impurity when there are many impurities in the y direction at the same time. The left impurities can only be picked out by the second impurity system. Therefore, the system is one-dimensional impurity.

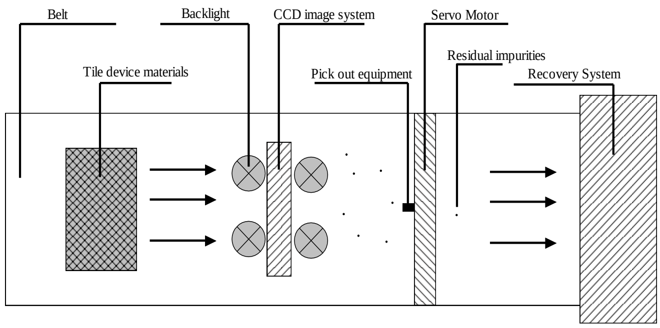


Fig.1 Impurity purification system structure

After the materials pass the CCD image system at the same speed, the impurities gray image is obtained. When we set binarization threshold D, if the gray of this pixel is large or equal to D, we use 1 to express it; if the gray of this pixel is small to D, we use 0 to express it. If the speed of the belt is 0.1m/s, a dynamic distribution uniform motion picture is get because the pure quartz sand is white and the impurities are gray or black, such as figure 2.

V=0.1m/s

0	1	0	0	0	0	0	1	0	0
0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1
1	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0
0	0	1	0	0	1	0	0	1	0
1	0	0	1	1	1	0	0	0	0
1	0	0	0	0	0	0	0	0	1

Fig.2 Dynamic distribution of impurity particles

By the system model and system indicators system can be known conditions, system objectives and constraints are as follows:

(1) Known conditions

① the distance between the CCD image system from actuator is L1;

② the speed of the belt is V1;

③ the horizontal speed of the actuator is V2(V1<<V2);

④ the time of processing a frame image is Ta;

(2) Constraints conditions

①the maxima transverse velocity of the actuator is 0.1m/s;

②the speed of the belt is more than 0.1m/s;

③the time from sending commands to doing for the actuator is 16ms at least;

④impurity system can only pick out one particle at the same time in the y direction;

(3) Objective function

The impurity system can possibly pick out the most impurities in the quartz sand and improve the purity rate Pr.

3.Solving the system model

In the figure 3, CCD image system detects the impurity at the t0 time, and then controller begins to do things at the t1 time, and the actuator move to the intended location with the impurity removal equipment at the t2 time, and impurity action once, and the impurity is picked out.

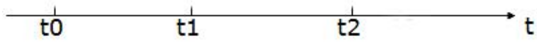


Fig.3 System controlling signal sending time

In the figure 4, the actuator horizontal distance between now position and the next impurity position is Sc, the time interval between the two positions is t, so there must be enough time left for actuator to get the impurity position.

$$Sc/t<V2 \tag{1}$$

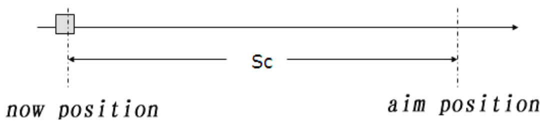


Fig.4 Severo motor reaching judgement

If n1 is the now position and n2 is the next position and Sc is discrete, there must has this relationship as the second formula.

$$Sc=|n1-n2| \tag{2}$$

The time interval between the twice acquisition time is Ta, there must has the third formula.

$$Smax=Ta*V2 \tag{3}$$

So the Smax and Sc must have the relationship.

$$Smax>Sc \tag{4}$$

The actuator can move Xmm per pulse, the actuator drive frequency is f, a and-gate is used to control the pulse outputting. The actuator move a pixel distance per N0 pulses, the distance is r, so the number of output pulses for motor from the n1 position to n2 position is shown as fifth formula.

$$|n1-n2|*N0 \tag{5}$$

The needed time to output these pulse is shown as sixth formula.

$$|n1-n2|*N0/f=t2-t1 \tag{6}$$

We can introduce the following operator relations:

① t2-t0=L1/V1, it's a stable value.

② if t0 is the acquisition time, t2=L1/V1+t0.

③ t2=L1/V1+t0.

④ t1=L1/V1+t0-|n1-n2|*N0/f.

4.The optimal route algorithm of dynamic distributed particles

First, build the model mathematical description, suppose $G=(N,A,S,D)$ is the network of the image, $N=\{1,2,\cdots,n\}$ is the impure particles in the image, $A=\{1,2,\cdots m\}$ is the edge collection, $S=\{s_{ij}\mid(i,j)\in A\}$ is the edge length collection, $D=\{d_{ij}(t)\mid(i,j)\in A\}$ is the time constrained functions of each edge, $B=\{i\mid i\in N\}$ is the point collection in the motor running route. Because the actuator in the system move at the fastest speed, D is a stable value which means the longest distance that motor move between the two frames in the system. So the following conditions should be meted in this model.

$$S\le D \tag{7}$$

$$B \subseteq A \tag{8}$$

The algorithm description is shown as follows: firstly, make binarization processing for the A collection according to (8) formula, and retain the edges that meet the (7) formula, and set the edge length between the two points in the S collection to 1, else set it to 0. Find a beginning point i, and find any edge in the A collection that the beginning point is i, and the end point is j, and then add j point to the B collection, delete the j point from the N collection, next from j point do the previous operation, and stop if the j point is the end point. Finally the points in the B collection are the route of the motor. Because every edge length is 1 in the route of the actuator, if the number of the particles that the actuator picks out in the stable time is Num, the number of the edges that the actuator passes by is (Num-1), because the value of each edge is stable, when the pure rate is highest, the route L that the actuator moves is the longest route, and the object function is shown as (9) formula.

$$L = \sum_{i}^{j} s(x_i, x_{i+1}) \tag{9}$$

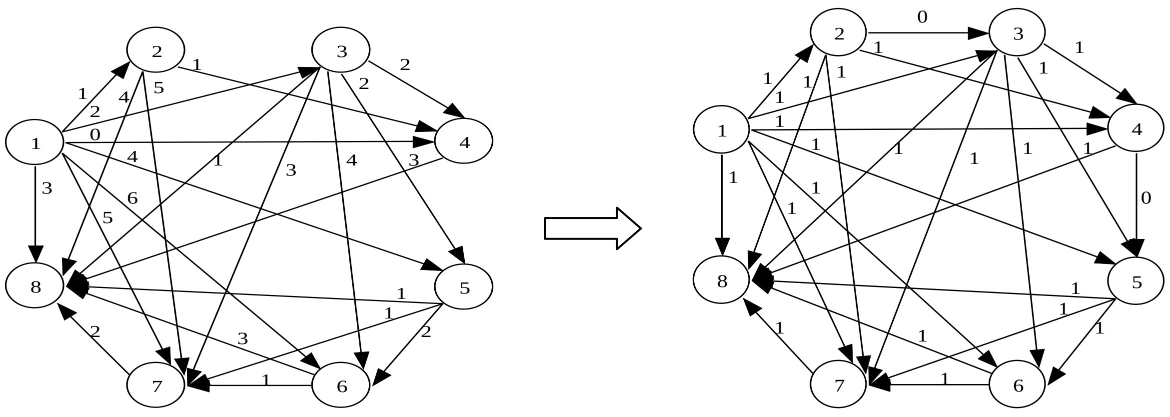
In the (9) formula, the beginning point is i, and the object point is j, $s(x_i, x_{i+1})$ is the weight between x_i and x_{i+1}.

As it's shown in figure 5, firstly build a impurities gray picture, non zero points are the impurities in the picture, and the actuator should find a suitable route that includes the most particles.

0	1	0	0	0	0	0	0	0	0
0	0	2	3	0	0	0	0	0	0
0	4	0	0	0	5	0	0	0	0
0	0	0	0	0	0	0	6	0	0
0	0	0	0	0	0	7	0	0	0
0	0	0	0	8	0	0	0	0	0

Fig.5 Optimal path search algorithm for dynamic path analysis diagram

According to the distributed impurities image shown in the figure 5, build the topology map as it's shown in the 6(a) figure. In the picture, the weight is the distance between the two points, and the topology map is the one-way map. When two points are in a same row, the actuator can't arrive at these two points at the same time. We use advanced critical path algorithm to implement it. If the two particles meet the constrained conditions, set the distance value between them to 1. As it's shown in the figure 6(b), build a AOE network, and using advanced critical path algorithm can implement the optimal route search.



(a) (b)

Fig.6 Impurity point topology transformation graph

The definition in this algorithm is shown as follows:

e(i) :the earliest start time of the point i particle;

$l(i)$: the latest start time of the point I particle;

$ve(j)$:the earliest start time of the edge v_j;

$vl(j)$:the latest start time of the edge v_j;

$s(i,j)$:the distance between i and j;

so there has these relationships:

$$\begin{cases} vl(n) = ve(n) \\ vl(j) = \min\{vl(k) - s(i,j)\} \end{cases} \tag{10}$$

$$l(i)=vl(k)-s(<j,k>) \tag{11}$$

Algorithm thought is as follows：

(1) solve the earliest start time point $ve(j)$ of the point j:

$$\begin{cases} ve(1) = 0 \\ ve(j) = \max\{ve(i) + s(i,j)\} \end{cases} \tag{12}$$

In the process of solving topological sort，use a auxiliart array structure $ve(1..n)$ {the number of the vertexes is n }：

① Initial vaule $ve[j]=0$ $1 \le j \le n$;

② when output a vertex j without previous vertexs, change all vertexes before the vertex j，and then all next vertex k have the relationship $ve[k]$: $ve[k]=\max\{ve[k], ve[j]+s(j,k)\}$;

(2) solve the latest time $vl(i)$ for the number i particle:

$$\begin{cases} vl(n) = ve(n) \\ vl(j) = \min\{vl(k) - s(i,j)\} \end{cases} \tag{13}$$

Calculate one by one in reverse order sort：

(1) Initial $vl(n)$;

(2) Calculate $vl(i)$ time from front to back one by one;

(3) Calculate the optimal path of servo control system, the condition is $vl(i)=ve(i)$;

(4) There may be more than one path after the third step,

Use C++ language to implement the algorithm, and simulate it. Firstly use random function to generate a random tab, set the threshold reasonably according to the actual conditions that the pure rate of the raw materials is up 99%, and secondly binarize the table to get a table like the table 2, and thirdly figure out the number of the impurities, the purity of raw materials, actuator system path, purification rate and purity after one filter. The simulation result is shown as figure 7, the table is 10*10. The simulation path meet the requirements, it's really a optimal path, but the system automatically chooses one path.

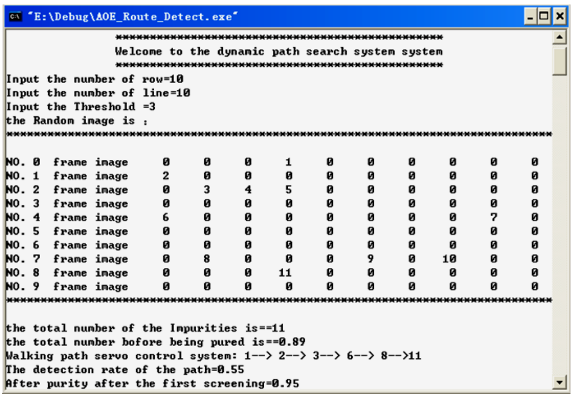


Fig.7 Algorithm simulation result

According to the experimental statistics, when the detect system is one-dimension system , and the map size is 300*300, and adjust the speed ratio of the V2/V1 that V2 is the actuator speed and V1 is the belt speed in order to adjust the D value. When the pure rate of the raw materials P_0 =90%, the rate Pr curve after a purification is shown as figure 8.

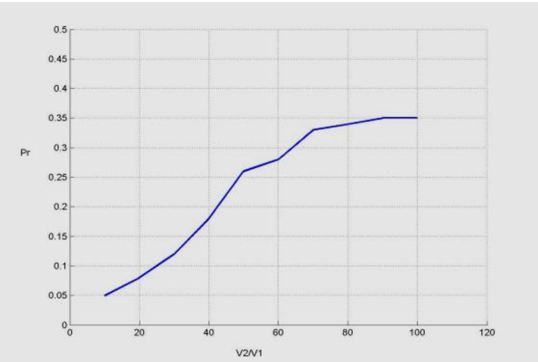


Fig.8 The first purification rate curve

The curve shows that Pr will become a maximum with the increase of D value, because one-dimension system can only move at one direction and pick out one particle when there are many particles in the same row at the same time. The maxim pure rate for this system is 35%. If the pure rate of the raw materials is P_0 , the pure rate after many purified times can be calculated by the formula 14.

$$P_n = 1-(1-P_{n-1}) * P_{rn}; \quad n \geq 1 \tag{14}$$

The P_{rn} is the purification rate of the NO. n purification. As the rate will be increased after every purification and impurities will be decreased, when the D value is stable, P_{rn} will become higher with the increased n, for the quartz sands purification, when P_0 is equal to 90%, after four purified times, the rate of quartz sands can be up to 99% which meets the requirements of the industry.

5.Conclusions

In this paper, we build a mathematical model based on the actual problems and give a optimal algorithm of dynamic distributed tiny grain problem. In the actual test, Xilinx Company's FPGA XC3S200 and high-speed linear array CCD sensor TCD1209 are used as color sorting technology, servo motor and air rifle are used as impurity removed system. Base on the actual constrained conditions, use industrial quartz sand as experimental object, the first purification rate is 35% while the usual algorithms are about 20%, so advanced AOE algorithm is more effective than the usual algorithms, and achieve the desire goals.

REFERENCES

1. Liao K,Paulsen M R,Reid J F. "Real-time Detection of color and surface defects of maize kernels using machine vision" Journal of Agricultural Engineering Research,1994, 59(1): 263-271.

2. He Fangguo, Qi Huan. "Model and algorithm of random shortest path problem with constraints". WuHan university of technology transaction.2008,6(32):1125-1128.

3. Tan Guozhen. "Studies on optimal path algorithms and its applications in time-varying and stochastic networks".DaLian:DaLian university of technology，2002.

4. Zou Liang, Xu Jianmin, Zhu Lingxiang. "Application of A* algorithm in dynamic route guidance system based on electronic map". WuHan university of technology transaction,2006,5(30):885-888.

5. Yan Bo. "dynamic path planning in vehicle autonomous navigation system". BeiJing:Tinghua university,2004.

6. Wastlund J. "Random assignment and shortest path problems". Fourth Colloquiumon Mathematicsand Computer Science, 2006: 31-38.