

S/c fica Ψ , BYY a Ψ a a b a ad Ψ a / d d c
 b b k^* a a a c c $J(k)$
 / (ME) [8]. H , / c a a c c a
 a c / a a c c d / a / a a a
 / c a a b d ff a k .
 I / a , / BYY a Ψ a a a c c
 BYY Ψ ME a a ad a Ψ a a
 a c d c ca b ad a a ca Ψ d / a a a
 da a a b a Ψ a , c d a d b Ψ a a d
 a / b a a d c c .

2 Gradient Harmony Learning Algorithm

A BYY Ψ d c b ac b a $x \in \mathcal{X} \subset R^n$ a d c / d
 / a $y \in \mathcal{Y} \subset R^m$ a Ψ Ba Ψ a d c /
 * d Ψ $p(x, y) = p(x)p(y|x)$ a d $q(x, y) = q(x|y)q(y)$, b ca d
 Ya ac a d Y ac , / c Ψ . G a da a x, a
 a a BYY Ψ / c Ψ a a / c $p(y|x), p(x), q(x|y), q(y)$
 a a Ψ a / c / / d b Ψ a a Ψ
 c a :

$$H(p||q) = \int p(y|x)p(x) \ln[q(x|y)q(y)] dx dy - \ln z_q, \tag{1}$$

z_q a a a . T d a a d [8]-[9].
 T BYY Ψ a d a Ψ a ca a b a / d / d
 a a a / $x \rightarrow y$ ba d a da a $\{x_t, y_t$

$$U(l | x_t, y_t) = P(l | x_t, y_t) \left(1 + \sum_{j=1}^k (\delta_{jl} - P(j | x_t, y_t)) \ln(q(y_t | x_t, j)q(x_t | j)\alpha_j) \right),$$

δ_{jl} K c c , a d η a a c a η a a
 c a .
 T ab ad BYY a η a a d d a
 d c . H , a bac η $\{x_t\}_{t=1}^N$ ($x_t = [x_{1t}, x_{2t}]^T$) a c c d
 a b a η a ac η b d b η c d a $[x_1, x_2]$.
 S η a $w_l^T x + b_l = 0, l = 1, \dots, k$ a η a a c a a
 a b d c d a . F ac η x, $w_l^T x + b_l = 0,$
 $L(x) = l$. T , a η b x a d y η d b η BYY
 η $y = w_{L(x)}^T x + b_{L(x)}$. F ac η $\{x_t\}_{t=1}^N$, η d
 b a (a d b d b η) a d a a η
 $y_t = 0$. W a ME d η d BYY η a η
 $\{x_t, y_t\}_{t=1}^N$ a ad BYY a η a a d ad
 a ac η fi a η fi a a $w_l^T x + b_l = 0$
 η η α_l η η η b η
 a $N, \dots,$ b a bac η a .
 A c c d c , ca $f_l(x, \theta_l) = (x - c_l)^T(x - c_l) - R_l^2, R_l = e^{bl}$
 ad $f_l = w_l x + b_l$ ab d a d d a η
 ac η ME d . H c , ad BYY a η a
 a d fi d b η η ac fi a a E (7)-(9)

$$\Delta c_l = -2 \frac{\eta}{N} \sum_{t=1}^N U(l | x_t, y_t) \frac{(y_t - (x_t - c_l)^T(x_t - c_l) + R_l^2)}{e^{2r_l}} (x_t - c_l), \quad (13)$$

$$\Delta b_l = -2 \frac{\eta}{N} \sum_{t=1}^N U(l | x_t, y_t) \frac{(y_t - (x_t - c_l)^T(x_t - c_l) + R_l^2)}{e^{2r_l}} e^{2b_l}, \quad (14)$$

$$\Delta r_l = \frac{\eta}{N} \sum_{t=1}^N U(l | x_t, y_t) \frac{(y_t - (x_t - c_l)^T(x_t - c_l) + R_l^2)^2 - e^{2r_l}}{e^{2r_l}}. \quad (15)$$

3 Experimental Results

I c , a η a ca d b a a d
 c c d c ad BYY a η a a . O
 a d, a a η d a a a
 ca d c a c c a a ca η . O a d,
 a η a η d c a d c a c .

3.1 Automated Detection on the Straight Lines and Circles

U k^* d b c a a ,
 η d ad a da a b a η a a a η

$k \geq k^*$ and $\eta = 0.1$. Here, k is the number of iterations, ME is the Mean Error, and M is the number of Monte Carlo samples. The error $|\Delta H| < 10^{-6}$. The BYY algorithm is used to estimate the parameters α_l and α_r . The results are shown in Table 1 and Table 2. The error α_l and α_r are estimated to be 0.001 , \dots . The error α_l and α_r are estimated to be 0.001 .

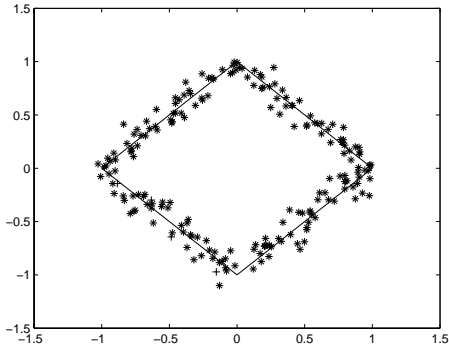
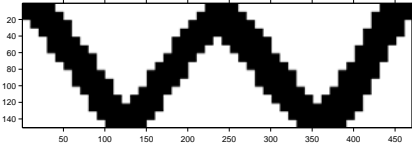
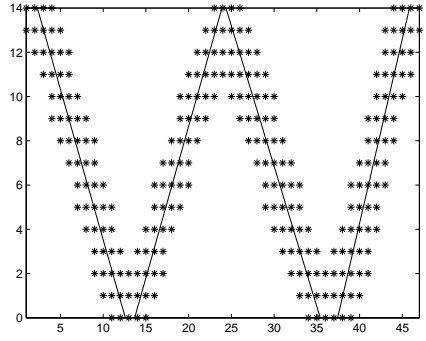


Table 1. The empirical result of the straight line detection on the data set from Figure 1(a), with $k=8$ and $k^*=4$

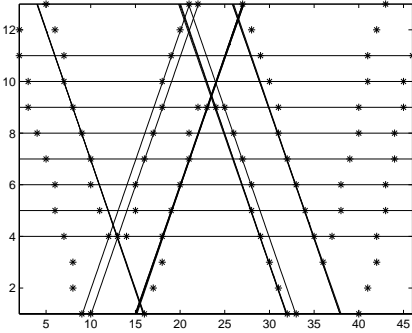
l	α_l	$w_{1l}x_1 + w_{2l}x_2 + b_l = 0$
1	0.0008	$1.2070x_1 - 0.7370x_2 - 0.2235 = 0$
2	0.0007	$-1.0329x_1 + 0.9660x_2 - 0.0455 = 0$
3	0.2319	$-0.9778x_1 - 1.0217x_2 - 0.9814 = 0$
4	0.0009	$-0.8693x_1 + 1.1155x_2 - 0.2002 = 0$
5	0.2369	$1.0181x_1 - 0.9816x_2 + 1.$



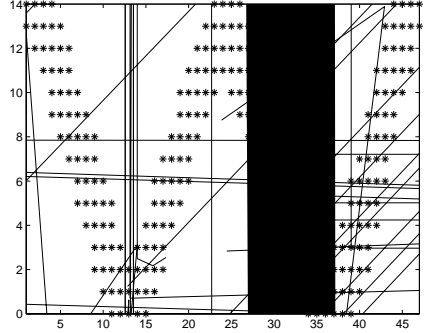
(a)

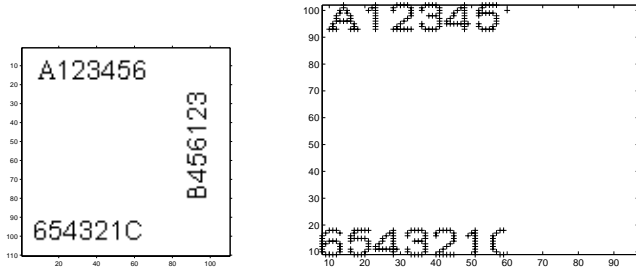


(b)



(c)





(a)