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HMM¹

()

BW²

(SA⁴)

SA

CARLA

(CARLA⁵)

SA

CARLA

SA

BW

SA

(HMM)

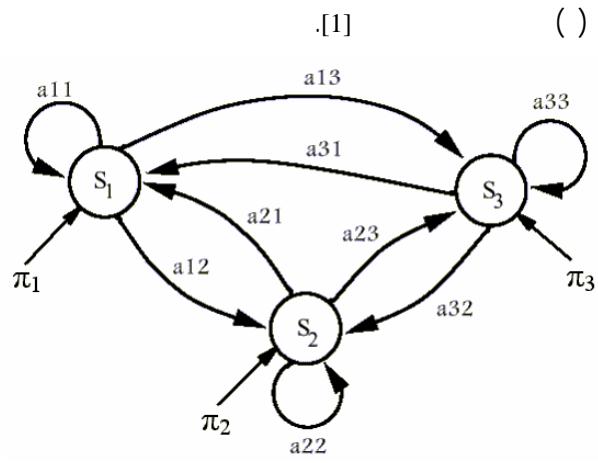
¹ Hidden Markov Model

² Baum-Welch

³ Local

⁴ Simulated Annealing

⁵ Continuous Action Reinforcement Learning Automata



$$\begin{aligned}
 O &= \{o_1 o_2 \dots o_t \dots o_T\} \\
 Q &= \{q_1 q_2 \dots q_t \dots q_T\} \\
 P(O | \lambda) &= \sum_{all \ q_1, q_2, \dots} \left[\pi_{q_1} b_{q_1}(o_1) \prod_{t=2}^T a_{q_{t-1} q_t} b_{q_t}(o_t) \right] \\
 P(O | \lambda) &= \sum_{all \ Q} P(O, Q | \lambda) = \sum_{all \ Q} P(O|Q, \lambda) \cdot P(Q|\lambda) \\
 &\quad b_i(o) \quad i \\
 &\quad \vdots \\
 &\quad \mathbf{P}
 \end{aligned}$$

(1) ()
 N D
 t o_t
 : t=1
 (i) π_i
 b_i(o₁) o₁
 : t < T
 j i
 a_{ij} t-1
 b_j(o_t) j
 : t
 : q_t
 O λ
 b() A
 π λ
 : t
 λ λ

$$\begin{aligned}
& b_i(o) = \sum_{m=1}^M c_{im} N(o, \mu_{im}, C_{im}) \\
& N(o, \mu, C) = \frac{1}{\sqrt{(2\pi)^D |\det(C)|}} \exp\left(-\frac{1}{2}(o - \mu)^T C^{-1}(o - \mu)\right) \\
& \sum_{m=1}^M c_{im} = 1 \\
& \sum_{i=1}^N \pi_i = 1 \quad \sum_{j=1}^N a_{ij} = 1 \\
& b(\cdot), A, \pi \quad \lambda \quad . \quad C \quad |\det(C)| \quad C \quad C^{-1} \\
& \lambda = (\pi, A, b(\cdot)) \\
& \quad \quad \quad (C_{im}) \quad (\mu_{im}) \quad (c_{im}) \quad b(\cdot) \\
& \quad \quad \quad \lambda \quad . \quad b(\cdot), A, \pi \quad \lambda \\
& \quad \quad \quad \text{ML}^6 \quad \quad \quad \text{BW} \quad \quad \quad \text{EM}^7 \\
& \quad \quad \quad \text{EM} \quad \quad \quad \text{BW} \quad \quad \quad \text{EM}^7 \\
& \quad \quad \quad \text{O} \quad \quad \quad \lambda^* \quad \quad \quad \text{BW} \quad \quad \quad .[2,3]
\end{aligned}$$

⁶ Maximum Likelihood

Expectation Maximization

[4](ES¹²) [4](GA¹¹) (SA)
 .[5] (CARLA) [4](EP¹³)
 .[6,7] SA
 EP ES GA
 CARLA
 (SA) (GA) [8,9] CalTech
 GA SA
 .(GA SA)
) SA GA ((SA)
 SA (PerformanceVariance) GA
 GA
 SA
 (EP) (ES)
 (Step Size) EP ES
 SA
 SA [10] SA [11]
 SA [8,9] GA
 SA
 (SA)

⁸ Global Optimum

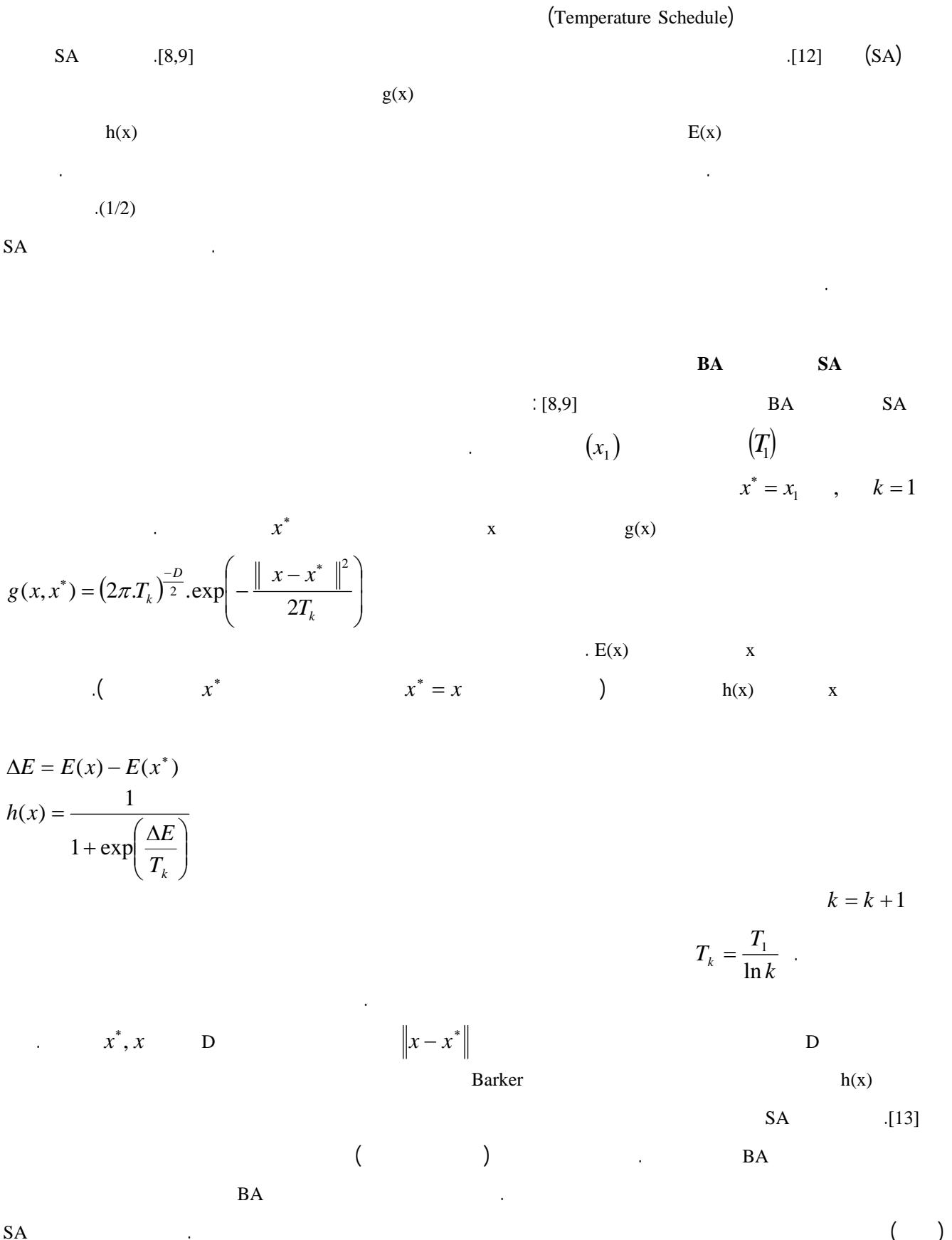
⁹ Global Search

¹⁰ Global Optimization

¹¹ Genetic Algorithms

¹² Evolutionary Strategies

¹³ Evolutionary Programming



¹⁴ Generating Function

¹⁵ Acceptance Function

$$E = -\log P(O|\lambda)$$

(CARLA)

[16] LA¹⁶

CARLA

CARLA [6,7]

CARLA

CARLA

CARLA

CARLA

r ()
()

$[x_{\min}, x_{\max}]$ x

$f(x,1) = \frac{1}{x_{\max} - x_{\min}}$
r f(x, n) n

$F(r,n) = \int_{x_{\min}}^r f(x,n) dx = z(n)$
r [0,1] z(n)

¹⁶ Learning Automata
¹⁷ Action

$$\beta(n) = \min\left(\max\left(0, \frac{J_{med} - J(n)}{J_{med} - J_{\min}}\right), 1\right)$$

$$f(x, n+1) = \begin{cases} \alpha[f(x, n) + \beta(n)H(x, r)] & \text{if } x \in [x_{\min}, x_{\max}] \\ 0 & \text{else} \end{cases}$$

$$H(x, r) = \frac{g_h}{(x_{\max} - x_{\min})} \cdot \exp\left(-\frac{1}{2} \cdot \frac{(x - r)^2}{(g_w(x_{\max} - x_{\min}))^2}\right)$$

$$H(x, r) = \sqrt{2\pi} \cdot g_h g_w N(x, r, \sigma)$$

$$\sigma = g_w(x_{\max} - x_{\min})$$

$$f(x, n+1) = \begin{cases} \alpha[f(x, n) + 0.015 \beta(n) N(x, r, \sigma)] & \text{if } x \in [x_{\min}, x_{\max}] \\ 0 & \text{else} \end{cases}$$

$$f(x, n+1) = f(x, n+1)$$

$$g_w = 0.02, g_h = 0.3$$

$$(\beta = 1) \quad f(x, n) \quad 0.015$$

CARLA

CARLA

CARLA SA

(ML)

$$P=N(1+N+M(2D+1))$$

$$D=2 \ , \ M=3 \ , \ N=3$$

$$T=20$$

$$(Multiple \ Observation)$$

$$\lambda$$

$$O$$

$$P(O|\lambda)$$

$$v_{ii} > 0$$

$$\sum_{m=1}^N c_{im}=1$$

$$\sum_{j=1}^N a_{ij}=1$$

$$HMM$$

$$i$$

$$v_{ii}$$

$$a_{ij} = \frac{\exp(a'_{ij})}{\sum_{j=1}^N \exp(a'_{ij})}$$

$$c_{im} = \frac{\exp(c'_{im})}{\sum_{m=1}^M \exp(c'_{im})}$$

$$v_{ii}=\exp(v'_{ii})$$

$$v'_{ii}, c'_{im}, a'_{ij}, \pi'_i$$

$$SA$$

$$(SA)$$

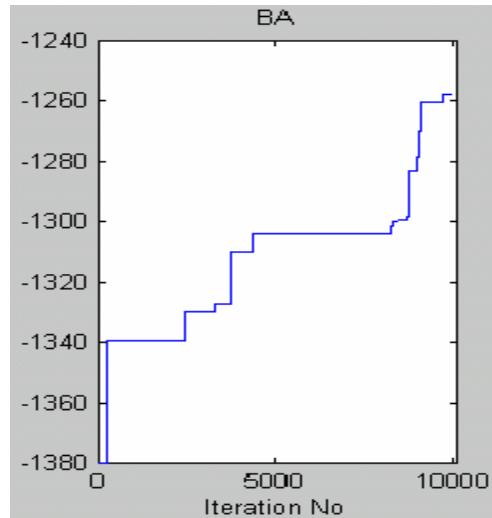
$$SA$$

$$SA$$

$$()$$

$$SA$$

$$\Lambda$$



() SA

CARLA

CARLA

() CARLA

CARLA

()

g_w CARLA

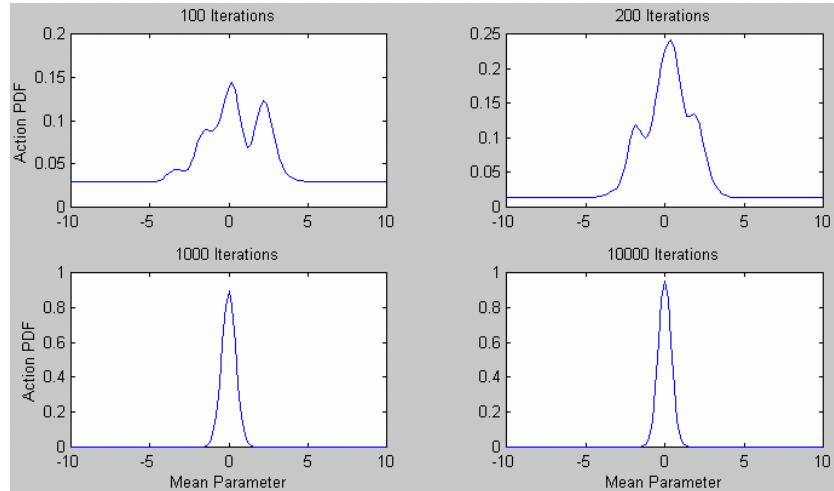
) g_w

.([7]

CARLA

()

CARLA



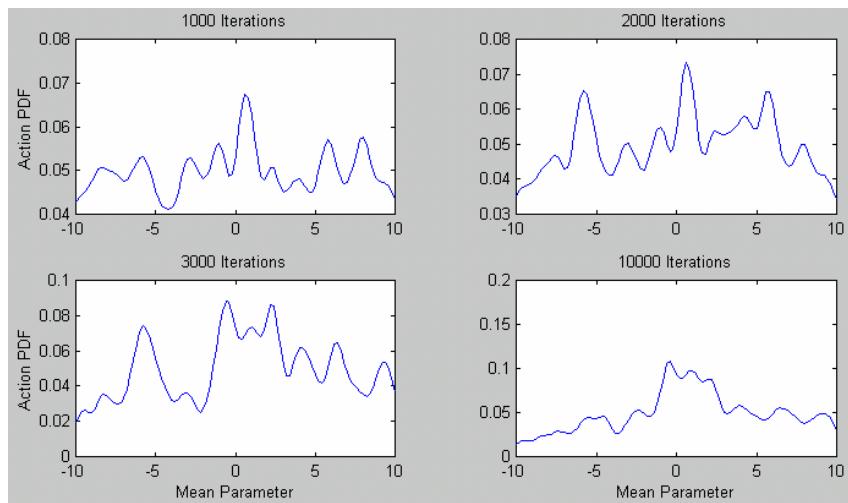
D=2 , M=3 , N=3

CARLA

()

57

SA BW



()

CARLA

[6,7]

β

() [6,7] β

$g_w = 0.02 \quad g_h = 0.3$

() 0.015

[7]

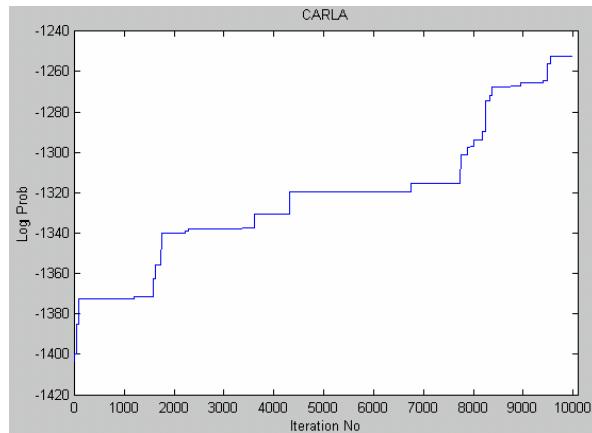
g_w

g_w

g_w

CARLA

()



CARLA

(Consistent)

(Seed)

() ()

CARLA SA

CARLA	SA
-1250.4	-1259.1

CARLA

CARLA

SA

SA

SA

()

SA

CARLA SA

SA

CARLA

SA

CARLA

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