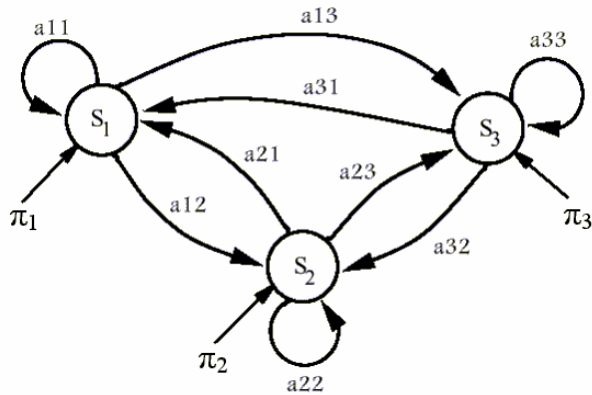


[1] ()



(N)

T

$$O = \{o_1 o_2 \dots o_t \dots o_T\}$$

N

t

D

o_t

(i)

π_i

t=1

$b_i(o_1)$

o_1

t < T

t = t + 1

j

a_{ij}

t

i

t-1

$b_j(o_t)$

o_t

j

t

:

Q

$$Q = \{q_1 q_2 \dots q_t \dots q_T\}$$

O

b()

A

π

λ

t

q_t

:

λ

$$P(O | \lambda) = \sum_{\text{all } q_1, q_2, \dots} \left[\pi_{q_1} b_{q_1}(o_1) \prod_{t=2}^T a_{q_{t-1} q_t} b_{q_t}(o_t) \right]$$

$$P(O | \lambda) = \sum_{\text{all } Q} P(O, Q | \lambda) = \sum_{\text{all } Q} P(O | Q, \lambda) \cdot P(Q | \lambda)$$

$b_i(o)$

i

:

$$b_i(o) = \sum_{m=1}^M c_{im} N(o, \mu_{im}, C_{im})$$

: C μ D $N(o, \mu, C)$

$$N(o, \mu, C) = \frac{1}{\sqrt{(2\pi)^D |\det(C)|}} \exp\left(-\frac{1}{2}(o - \mu)^T C^{-1}(o - \mu)\right)$$

. D×1 o_t

:

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

:

M

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

$b(\cdot), A, \pi$ λ

. C

$|\det(C)|$ C

C^{-1}

:

$$\lambda = (\pi, A, b(\cdot))$$

. (C_{im})

(μ_{im})

(c_{im})

$b(\cdot)$

BW

λ

λ

$b(\cdot), A, \pi$

λ

ML⁶

BW

EM

EM

BW

EM⁷

O

λ^*

BW

[2,3]

:

$$\lambda^* = \arg \text{Max}_{\lambda} P(O|\lambda)$$

BW

BW

[1]

⁶ Maximum Likelihood

⁷ Expectation Maximization

[4](ES¹²) [4](GA¹¹) (SA) [4](EP¹³)

[5] (CARLA)

[6,7] SA

EP ES GA

(SA) CARLA (GA) [8,9] CalTech

GA SA

(GA SA)

) SA GA (

SA (Performance Variance) GA

GA

SA GA

(EP) (ES)

(Step Size) EP ES

SA SA

SA SA [10]

SA [11]

[8,9] GA

SA

(SA)

⁸ Global Optimum
⁹ Global Search
¹⁰ Global Optimization
¹¹ Genetic Algorithms
¹² Evolutionary Strategies
¹³ Evolutionary Programming

(Temperature Schedule)

SA [8,9]

[12] (SA)

$g(x)$

$h(x)$

$E(x)$

(1/2)

SA

BA

SA

[8,9]

BA

SA

(x_1)

(T_1)

$x^* = x_1, k = 1$

x^*

x

$g(x)$

$$g(x, x^*) = (2\pi T_k)^{-D} \cdot \exp\left(-\frac{\|x - x^*\|^2}{2T_k}\right)$$

$E(x)$

x

(x^*)

$x^* = x$

)

$h(x)$

x

$$\Delta E = E(x) - E(x^*)$$

$$h(x) = \frac{1}{1 + \exp\left(\frac{\Delta E}{T_k}\right)}$$

$k = k + 1$

$$T_k = \frac{T_1}{\ln k}$$

x^*, x D

$\|x - x^*\|$

D

Barker

$h(x)$

SA

[13]

()

BA

BA

SA

()

¹⁴ Generating Function

¹⁵ Acceptance Function

$$E = -\text{Log } P(O|\lambda)$$

:

(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

$f(x,n)$, $[x_{\min}, r]$ $F(r,n)$, $z(n)$ $F(r,n)$

r

β $J(n)$ ()

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

J_{min}, J_{med} $[0,1]$ β
 $f(x, n)$ n $(R=500)$

:

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

r $H(x, r)$

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

() g_w, g_h

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

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

σ r () $N(x, r, \sigma)$

0.02, 0.3 [6,7] g_w, g_h

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

$f(x, n+1)$ α

$$g_w = 0.02, g_h = 0.3$$

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

CARLA

CARLA

CARLA SA

(ML)

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

: P

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

(Multiple Observation)

$$T=20$$

λ

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)

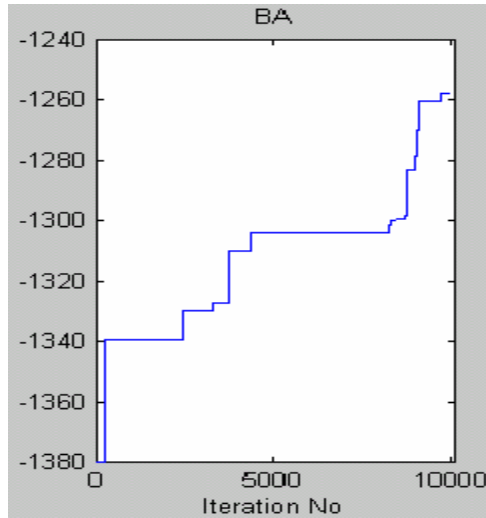
SA

SA

SA

()

SA



()SA

CARLA

CARLA

() CARLA

CARLA

()

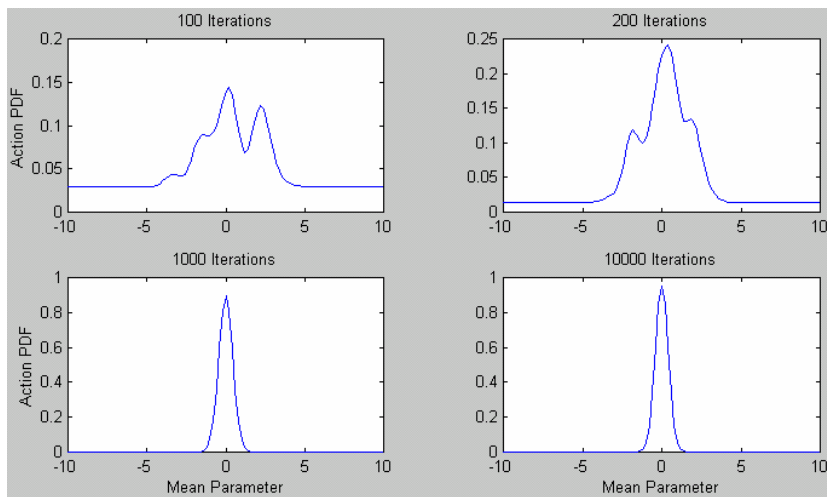
g_w CARLA

) g_w

([7]
CARLA

()

CARLA



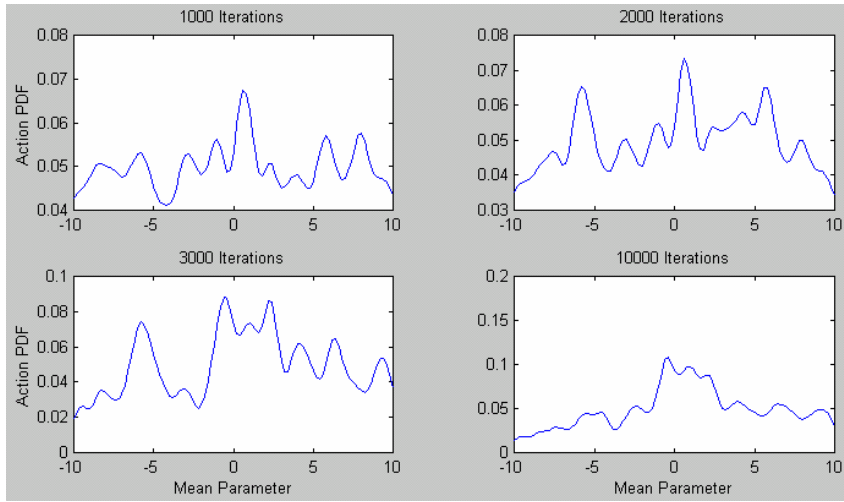
D=2 , M=3 , N=3

CARLA

()

57

SA BW



()

CARLA

[6,7]

()

[6,7]

β

$$g_w = 0.02 \quad g_h = 0.3$$

β

(

)

0.015

[7] g_w

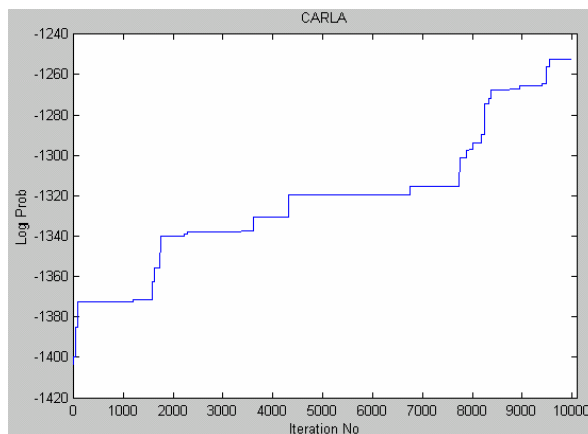
g_w

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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