?
φ
φ^{-1}
`PHI`
k
a_k
X
$N\times$
M
k
a_k
α_k

$\varphi_k(p) = \{\ \alpha_k[p] = 0 a_k[\alpha_k[p]-1], \forall p \in \{0, M-1\}$

$\varphi_k^{-1}(p) = \{\ \alpha_k[p] = M-1 a_k[\alpha_k[p]+1], \forall p \in \{0, M-1\}$

$\varphi_k(a_k[j]) = \{\ j = 0 a_k[j-1], \forall j \in \{0, M-1\}$

$\varphi_k^{-1}(a_k[j]) = \{\ j = M-1 a_k[j+1], \forall j \in \{0, M-1\}$

a_k
??

$a_6 = [14, 15, 0, 9, 10, 16, 8, 11, 12, 13, 18, 19, 1, 2, 3, 17, 4, 5, 6, 7]$

$\alpha_6 = [2, 12, 13, 14, 16, 17, 18, 19, 6, 3, 4, 7, 8, 9, 0, 1, 5, 15, 10, 11]$

$p =$
3

$\varphi(3) = a_6[\alpha_6[3]-1] = a_6[14-1] = a_6[13] = 2$

$\varphi^{-1}(3) = a_6[\alpha_6[3]+1] = a_6[14+1] = a_6[15] = 17$

$[i]. =$
p
$[i]. =$
l
p
a_i
q
$_k(x_p, x_q) \geq$
l
x_q
l
??
l
`RA-BV`
`LCE`
ν
`RA-BV`
$\mathcal{O}(\nu N)$
(1)
`LCE`
$\mathcal{O}(\nu \log(NM))$
(2)
φ
φ^{-1}
$\mathcal{O}(1)$
a_k
α_k
l
k, row, len
$haplos \leftarrow$
$[]$
$check_{down} \leftarrow$
$\top,\ check_{up} \leftarrow$
$\top$
$check_{down}$
$down_{row} \leftarrow$
$\varphi^{-1}(row, k)$
$(k, row, down_{row}, len)$
$push(haplos, down_{row})$
$row \leftarrow$
$down_{row}$
$check_{down} \leftarrow$
$\bot$
up_{down}
$up_{row} \leftarrow$
$\varphi(row, k)$
(k, row, up_{row}, len)
$push(haplos, up_{row})$
$row \leftarrow$
up_{row}
$check_{up} \leftarrow$
$\bot$
re-
turn
$haplos$
k
`PHI`
φ
φ^{-1}
φ
φ^{-1}
l
k
p
q
a_k
$a_k[i]$