

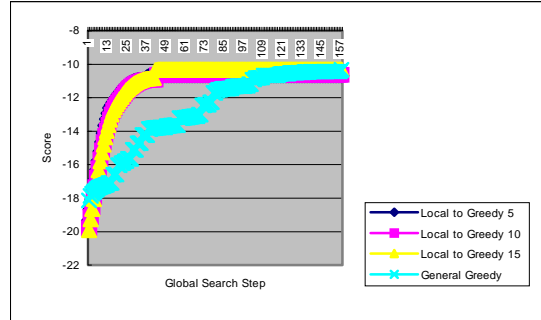
Structural Learning Algorithm for Large-Scale Bayesian Networks

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: 가 가 [4], [5] n $n!$
 가 $\times 2^{n(n-1)/2}$ NP-hard greedy search가
 가 [6].
 : (Bayesian network) 가 [3]
 (random variable) 가
 (conditional independence) 가
 (joint probability distribution) greedy search $O(n^2)$ 가
 [1]. greedy search 가
 (causal relationship) 가 [7] candidate” “sparse
 greedy search
 (bioinformatics) 가
 [2] (microarray) network (genetic) **Markov Blanket:** X_i
 Markov blanket
 가 X_i Markov blanket, $BL(X_i)$
 가 $P(X_i | BL(X_i)) = P(X_i | \mathbf{X} - \{X_i\})$
 Markov blanket 가 X_i
 divide-and-conquer Markov blanket 가 $BL(X_i)$ $BL(X_i)$
 : 가 Markov blanket
 (mutual information), χ^2 test [3] D 1 B_0
 가 가 MDL BD 가
 가 MDL **Local Search Step** 가
 (minimum description length) Dirichlet, BD (Bayesian) **Global Search Step** Markov blanket **Local Search Step**
 가 가 가 B_{n-1} B_{n-1}
 가 가 Markov blanket CB_i^n B_{n-1}
 Markov blanket Markov blanket D

information) CB_i^n (conditional mutual information)
 CB_i^n local greedy search
 Markov blanket
 Markov blanket
 H_n H_n cycle
Global Search Step
 가
 B_n global greedy search H_n
 가

microarray data
 38 -477.92
 가
 greedy algorithm -710.18



Input:
 - A data set D .
 - An initial Bayesian network structure B_0 .
 - A decomposable scoring metric,
 $Score(B, D) = \sum_i Score(X_i | Pa^B(X_i), D)$.
Output: A Bayesian network structure B .
Loop for $n = 1, 2, \dots$, until convergence.
-Local Search Step:
 *Based on D and B_{n-1} , select for each variable X_i , a set $CB_i^n (|CB_i^n| \leq k)$ of candidate Markov blanket of X_i .
 *For each set $\{X_i, CB_i^n\}$, learn its local structure and determine the Markov blanket of $X_i, BL^n(X_i)$, from this local structure.
 *Merge all the local network structures $G(\{X_i, BL^n(X_i)\}, E_i)$ into a global network structure H_n (usually cyclic).
-Global Search Step:
 *Find the Bayesian network structure $B_n \subset H_n$, which maximizes $Score(B_n, D)$ and retains all non-cyclic edges in H_n .

1. greedy search

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greedy search

가

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 ALARM network
 ALARM network 37 46
 가 . ALARM network 10,000
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 greedy search algorithm
 x global greedy search step
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 greedy algorithm
 가
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[1] Friedman, N., Geiger, D., and Goldszmidt, M., Bayesian network classifiers, *Machine Learning*, **29**(2):131-164, 1997.
 [2] Friedman, N, Linial, M., Nachman, I., and Peer, D., Using Bayesian networks to analyze expression data, In *Proceedings of RECOMB '00*, 2000.
 [3] Margaritis, D. and Thrun, S., Bayesian network induction via local neighborhoods, In *Proceedings of NIPS '99*, 1999.
 [4] Friedman, N. and Goldszmidt, M., Learning Bayesian networks with local structure, *Learning in Graphical Models*, pp. 421-459, 1998.
 [5] Chickering, D.M., Heckerman, D., and Meek, C., A Bayesian approach to learning Bayesian networks with local structure, In *Proceedings of UAI '97*.
 [6] Chickering, D.M., Learning Bayesian networks is NP-hard, In *AI & STAT V*, 1996.
 [7] Friedman, N., Nachman, I., and Peer, D., Learning Bayesian network structure from massive datasets: the "sparse candidate" algorithm, In *Proceedings of UAI '97*.